Perugia, Italy July 2-13, 2007

IASPEI

INTERNATIONAL ASSOCIATION OF SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

ASSOCIATION SYMPOSIA AND WORKSHOPS

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Compiled by Lucio Ubertini, Piergiorgio Manciola, Stefano Casadei, Salvatore Grimaldi

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Perugia, Italy **July 2-13, 2007**

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EARTH: OUR CHANGING PLANET

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Abbreviations

IAG	International Association of Geodesy
IAGA	International Association of Geomagnetism and Aeronomy
IAHS	International Association of Hydrological Sciences
IAMAS	International Association of Meteorology and Atmospheric Sciences
IAPSO	International Association for the Physical Sciences of the Oceans
IASPEI	International Association of Seismology and Physics of the Earth's Interior
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
CliC	Climate and Cryosphere
Ev-K2-CNR	Everest-K2 CNR Committee
GEWEX	Global Energy and Water Experiment
HKH-FRIEND	Hindu Kush-Himalayan Flow Regimes from International Experimental and Network Data
IABO	International Association for Biological Oceanography
IACS	International Association of Cryospheric Sciences
ICACGP	International Commission on Atmospheric Chemistry and Global Pollution
ICASVR	International Commission on Atmosphere-Soil-Vegetation Relations
ICCE	International Commission on Continental Erosion
ICCL	International Commission on Climate
ICCLAS	International Commission on the Coupled Land-Atmosphere System
ICCP	International Commission on Clouds and Precipitation
ICDM	International Commission on Dynamic Meteorology
ICGW	International Commission on Groundwater
ICIMOD	International Center for Integrated Mountain Development
ICMA	International Commission on the Middle Atmosphere
ICRS	International Celestial Reference System
ICSIH	International Commission on Snow and Ice Hydrology
ICSW	International Commission on Surface Water
ICT	International Commission on Trac
ICWQ	International Commission on Water Quality
ICWRS	International Commission on Water Resources Systems
IGAC	International Global Atmospheric Chemistry
IGS	International Glaciological Society
ILP	International Lithosphere Program
INQUA	International Union for Quaternary Research
ION	International Ocean Network

IRC	International Radiation Commission
PUB	Prediction in Ungauged Basins
SCAR	Scientific Committee on Antartic Research
SEDI	Study of the Earth's Deep Interior
SPARC	Stratospheric Processes and their Role in Climate
UCCS	Union Commission for the Cryospheric Sciences
UNESCO	United Nation Educational, Scienti. c and Cultural Organization
UNITAR	United Nations Institute for Training and Research
WMO	World Meteorological Organization

Session code naming

The first letter of the session codes indicates whether the session is a Union, a Joint Interassociation or a single Association sponsored event, the second letter indicates the type of event: Symposium (S) or Workshop (W). For Joint events, the second letter indicates the Lead Association (with the abbreviations listed below) and the third indicates whether a session is a Symposium (S) or a Workshop (W). In some cases (namely IAGA, IAHS) Association session codes have an extra codi. cation referring to a speci. c Theme or Division.

U	UNION
J	JOINT
G	IAG
A	IAGA
H	IAHS
M	IAMAS
P	IAPSO
S	IASPEI
V	IAVCEI

Some examples:

US002

is a **U**nion **S**ymposium; **JGW**001 is a **J**oint IA**G** **W**orkshop with IAG as the Lead Association;

MS003

is an Association (IA**M**AS) **S**ymposium. **AS III** 020 is an Association (IAG**A**) **S**ymposium sponsored by its **III** Division.

SS001 Symposium (6110 - 6248)

Convener : Dr. Dmitry Storchak
Co-Convener : Dr. Winfried Hanka, Dr. James Dewey, Prof. Haruo Sato, Dr. Roger Musson

Seismic Observations And Interpretation

SS002 Symposium (6249 - 6319)

Convener : Prof. Zhongliang Wu, Dr. Fabio Romanelli

Earthquake Hazard, Risk, and Strong Ground Motion

SS003 Symposium (6320 - 6359)

Convener : Dr. Pierre-Yves Bard
Co-Convener : Prof. Takashi Furumura, Dr. Donat Fh

Earthquake Hazard, Risk, and Strong Ground Motion - Site effects (and their dependence on source and propagation-path)

SS004 Symposium (6360 - 6388)

Convener :
Co-Convener : Dr. John Douglas

Earthquake Hazard, Risk, and Strong Ground Motion - Estimation of strong ground motion

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SS005 Symposium (6389 - 6468)

Convener : Prof. Mitsuhiro Matsuura
Co-Convener : Prof. Alexey Zavyalov

Earthquake Sources - Modelling and Prediction

SS006 Symposium (6469 - 6481)

Convener : Dr. John Taber
Co-Convener : Dr. Kiyoshi Suyehiro

Education and Outreach

SW001 **Workshop** **(6482 - 6496)**

Convener : Dr. Paola Albini

Earthquake data in archaeological and historical studies

SW002 **Workshop** **(6497 - 6535)**

Convener : Prof. Massimiliano R. Barchi
Co-Convener : Dr. Thomas Pratt

Geophysical studies of active faults

SW003 **Workshop** **(6536 - 6548)**

Convener : Dr. Kiyoshi Suyehiro
Co-Convener : Dr. Kuo-Fong Ma

Seismogenic zones: emergence of in situ fault zone observations to the understanding of earthquake physics

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SW004 **Workshop** **(6549 - 6579)**

Convener : Dr. Johannes Schweitzer
Co-Convener : Dr. Dmitry Storchak, Dr. James Dewey

Modernizing ISC procedures: model evaluation and magnitudes

SW005 **Workshop** **(6580 - 6594)**

Co-Convener :

Reference Events for Improved Locations

SW006 **Workshop** **(6595 - 6624)**

Convener : Prof. Stanislaw Lasocki
Co-Convener : Dr. Aderson Do Nascimento, Dr. Rajender Chadha, Prof. Hans-Joachim Kuempel

Induced seismicity

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SS001 **6110 - 6248**

Symposium
Seismic Observations And Interpretation

Convener : Dr. Dmitry Storchak
Co-Convener : Dr. Winfried Hanka, Dr. James Dewey, Prof. Haruo Sato, Dr. Roger Musson

The essence of seismology lies in the observation and interpretation of earthquakes and earthquake-generated ground motions, together with effective data distribution and analysis. There is a continuing need to improve mechanisms for the archiving, dissemination and analysis of these data. The real Earth structure varies in three-dimensions, can show variation with time and is anisotropic and anelastic in part. Thus methods for seismogram interpretation need to take account of the complexities, which are revealed in the currently available high quality data. Papers are invited for the topics: 1.Developments in seismic instrumentation, networks and data centers, early warning systems, large-scale portable networks, international data exchange and management of massive data sets. 2.Comprehensive seismogram analysis at single stations, seismic networks and arrays - requirements, potentials and future developments. 3.Rapid and routine determination of earthquake parameters, particularly in the context of natural disasters as well as the verification and detection associated with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). 4.The role of international data centers in improving and modernizing the global catalogs of earthquakes. 5.Advances in wave propagation in heterogeneous media, including synthetic seismograms and waveform modeling in realistic Earth structures, theory and observations of scattering, attenuation and anisotropy. 6.Developments in seismological interpretation, including development of inversion techniques, seismic tomography and whole-Earth analysis methods. 7.Earthquake location and relocation. 8. Preserving and cataloging the seismological records of past earthquakes. 9.Re-interpretation and calibration of early 20th century earthquakes from seismological archive data.

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SS001 **Oral Presentation** **6110**

Some characteristics of aftershocks sequences of major earthquakes from 1994 to 2002 in the Kivu Province, Western Rift Valley of Africa

Mr. Mavonga Tuluka
Geophysics Centre de Recherches en Sciences Naturelles IASPEI

The temporal and spatial distribution of the aftershock sequences of the Ruwenzori (Feb.5, 1994, Mb5.8), Masisi (Apr.29, 1995, Mb5.1) and Kalehe (Oct.24, 2002, Mb5.9) earthquakes have been studied. It has been found that most of aftershocks of the Ruwenzori earthquake are located on the eastern flank of the main escarpment and those of the Masisi earthquake are confined to the northwest of Lake Kivu margin where earthquake occurrence of swarm-type was normally observed. .The Kalehe earthquake occurred in the central part of Lake Kivu and it was the largest earthquake observed in the Lake Kivu basin since 1900. The rate of decrease in aftershock activity with the time has shown that the p-value for Ruwenzori and Masisi earthquake equals to 0.6, somehow smaller than that found in other geotectonic zones where p is close to one .The p-value of the Kalehe earthquake is a normal value equal to 1. From area delimited by spatial distribution of aftershocks, the linear dimension of the fault was estima-ted. The fault area determined in this study correlates well with those of previous studies which occurred in the Western Rift Valley of Africa including the Tanganyika and Upemba Rift.

Keywords: aftershocks, kivuprovince, western rift valley of africa

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SS001 **Oral Presentation** **6111**

Tracking the North Korea nuclear explosion on October 9, 2006 using the Hi-Net array and FORMOSAT-2 observation satellite

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Institute of Earth Science Academia Sinica IASPEI

Accurate location of the 2006 North Korea nuclear explosion has been imaged by a back-projecting regional Pn waves recorded by the Japanese Hi-net array. Based on determined location, the nuclear explosion site can be identified from geo-referenced FORMOSAT-2 satellite imagery. The seismically determined epicenter was shifted about 2.5 km in northeastern direction from its absolute location. Results indicated that a remote suspect event has been unambiguously detected and accurately located by a dense array in regional distance. Employed ground-truth correction, the satellite imagery can be referred to shift the array determined epicenter to its absolute position. This event after correction can be treated as reference event to accurately locate future nuclear explosions. Furthermore, our example implies public information from dense seismic networks and commercial observation satellites are ready to accurately monitoring the Comprehensive Nuclear-Test-Ban Treaty, and the same as a remote disaster earthquake and a hazarded tsunami in near real-time.

Keywords: north korea nuclear explosion, formosat 2, hi net

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SS001 **Oral Presentation** **6112**

New methods to estimate the contribution of intrinsic absorption and scattering to total S-wave coda attenuation

Dr. Arantza Ugalde
IASPEI

Eduard Carcol

We propose two new methods for practical estimations of the contribution of intrinsic absorption and scattering to total S-wave coda attenuation: the envelope fitting method and the envelope ratio procedure. For both methods, the formulation used is based on an accurate approximate analytical solution of the Boltzmann (or radiative transfer) equation for modelling coda waves envelopes which only involves the computation of an algebraic expression. This allows the direct computation of the attenuation parameters much faster than the methods used up to the present. As compared with the Multiple Lapse Time Window Analysis (MLTWA), the new methods proposed allow computing the attenuation parameters without using time integrals of the energy density. This means that they take into account in more detail the temporal and spatial evolution of the coda envelopes. The envelope fitting method has the additional advantage of giving estimations of the attenuation parameters for every hypocenter-station path.

Keywords: coda waves, scattering, intrinsic absorption

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SS001 **Oral Presentation** **6113**

Synthesis of wave envelopes in 3-D random media characterized by a non-isotropic Gaussian ACF based on the Markov approximation

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Geophysics, Science Tohoku University IASPEI

The apparent duration of seismograms are broadened with travel distance increasing and become much longer than the earthquake source duration time. Broadening of seismogram envelopes can be interpreted as caused by scattering due to velocity inhomogeneities randomly spreading over the lithosphere. When the wavelength is shorter than the correlation distance of random media, the Markov approximation is known as a powerful tool for the direct synthesis of wave envelopes. It is a stochastic extension of the phase screen method. In the case of impulsive radiation from a source, this approximation statistically derives the mean square envelope of waves at a given travel distance from the source. The peak delay from the onset and the envelope width are characterized by a few number of statistical parameters which describe the ensemble of random media. In the real Earth, randomness is generally non-isotropic as revealed from log data of deep wells and precise velocity tomography surveys; however, most of the previous works are founded on the isotropic assumption for randomness and there have been few studies on wave envelopes especially in non-isotropic random media in 3-D. On the basis of the Markov approximation, here, we propose a synthesis of wave envelopes in 3-D random media which are characterized by a non-isotropic Gaussian autocorrelation function. In the case that the global ray direction is along one of the three principal axes of the non-isotropic autocorrelation function, we are able to solve analytically the stochastic master equation for the two-frequency mutual coherence function of wave fields, of which the Fourier transform gives the mean square wave envelope at a given travel distance. The peak delay and the envelope width increase in proportion to the square of travel distance. They depend not only on the non-isotropic statistical parameters but also on the global ray direction, where the mean square fractional velocity fluctuation, the correlation distance in the propagation direction and the ratios of non-isotropic correlation distances are key parameters. Especially in the case that the non-isotropic autocorrelation function has rotational symmetry around the global ray direction, mean square envelopes in time domain are analytically written by using the elliptic Theta function. The synthesis of scalar waves is extendable to the synthesis of vector waves. When the correlation distances in the horizontal direction are larger than that in the vertical direction as typically seen in the crustal inhomogeneity, the envelope broadening of horizontally propagating waves is more prominent than that of vertically propagating waves. It suggests that we have to pay attention to seismic ray angles from a vertical line for the analysis of envelope broadening. In parallel it is necessary to study coda excitation in non-isotropic random media.

Keywords: scattering, inhomogeneity, envelope

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SS001 **Oral Presentation** **6114**

Seismicity and tectonics of China Continent and surrounding regions

Dr. Ruomei Sun
Institute of Geology & Geophysics, Chinese Academy Division of Qinghai Tibet plateau IASPEI

E. R. Engdahl, You Tian, E. A. Bergman, Jiwen Teng

The study area (15-58N,60-135E) contains the Chinese continent, the collision zone of the India plate and the Eurasia plate and the Philippine subduction zone to the Eurisia. With the development of geophysical surveys our understanding of the tectonics in this area has progressed rapidly. However, synthesis of the data from these surveys with earthquake data is complicated because of large location errors for many events, particularly in depth. We begin to address this problem by assembling a data set of more than 18000 well-constrained earthquakes in this region during the period of 1967-2004 with more accurate focal depths estimated using the EHB* method with careful review. Hypocenter determination, especially focal depth, is improved by combining the arrival times of local, regional and teleseismic P and S phases, PKiKP, PKPdf, and teleseismic depth phases in the relocation procedure. These systematically determined and improved hypocenters provide better definition of seismicity features. Intermediate-depth events are mainly distributed in the two syntaxises of Himalaya and the Okinawa trough. 1) The foci distribution in the Burma Range shows an inclined Benioff zone up to 150-170 km. 2) The Pamir-Hindukush region is characterized by high concentrations of intermediate-depth earthquakes. Under the western and central parts of the Hindukush the seismicity zone dips 60-90 to the northwest at depths of 100-300km. In contrast, under the Pamir the seismicity zone dips 45-70 southwards and mostly is at shallower depths of 80-200km. 3). The penetration depth of the northwestwards inclined seismicity zone dipping 50 is 298km in the south Ryukyu, decreases to 157km dipping 40 in the north Ryukyu. 4) In China continent seismic activity in the western part is much higher than in the eastern part. Only in Tibet around 92E, 27N, 87 E, 28N, 90E,30N, and 75.5E,36N are there events with depths > 70 km. Most shallow earthquakes in China are distributed belt-like patterns. The study is supported by the Chinese National Science Foundation (40434009 and 40234042) *E.R. Engdahl, Van der Hilst, R.D., and Buland, R.P., 1998, Global teleseismic earthquake relocation with improved travel times and procedures for depth determination: Bulletin of the Seismological Society of America, v. 88, p. 3295-3314. 1. SS001 2. Seismic Observations And Interpretation 3. EHB relocation, Seismicity, China continent 4. sunrm, SUN Ruomei, Institute of Geology & Geophysics, Chinese Academy of Sciences, Beituchengxilu No. 19, 100029 Beijing- CHINA Tel. +86 10 62007425, Fax. +86 10 62010846 e-mail: sunrm0@yahoo.com.cn or sunrm@mail.iggcas.ac.cn 5. B 6. PC 7. NO 8 Yes Ruomei SUN

Keywords: ehb relocation, seismicity, china

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SS001 **Oral Presentation** **6115**

Preliminary study of seismically active structures in the Drake Passage and Bransfield Strait, Antarctica

Dr. Hyun Jae Yoo
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Minkyu Park, Robert P. Dziak, Delwayne Bohnenstiehl, Haruyoshi Matsumoto, Won Sang Lee, Sukyoung Yun

The South Shetland Island-Bransfield Strait region exhibits a globally unique tectonic setting, with slowing of subduction, cessation of island arc volcanism, as well as the apparent onset of back-arc rifting occurring within the last four million years.. Although the South Shetland Trench has a morphology similar to that of active trenches, global seismic catalogs show low levels of seismicity and no evidence of the shallow thrust faulting earthquakes that occur in most subduction zones. Moreover there is longstanding controversy about whether Bransfield back-arc extension occurs along discrete rift zones, or is more diffuse geographically. Because of these uncertainties, a detailed study of local seismicity, a regional focal mechanism study, and a study on the crust and upper mantle structure are required to understand better the regional tectonics. In November 2005, seven Autonomous Underwater Hydrophones were deployed within the Bransfield Strait and Drake Passage with the goal of recording low magnitude earthquakes from throughout this region. In addition, we will utilize all other seismic data available in and around the Bransfield Strait, such as stations from the IRIS-GSN, CTBTO (PLCA), SEPA temporary network, and the KSJ instrument operated by KOPRI. We plan to use these datasets to examine the temporal and spatial characteristics of seismic activity in this little studied region.

Keywords: seismic activity, autonomousunderwaterhydrophon, antarctica

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SS001 **Oral Presentation** **6116**

Acoustic and Elastic Radiative Transfer Theory and its Application to Earthquake Data

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The energy transfer theory describes the transport of wave energy. Phase information of waves is neglected. This makes it possible to describe the intensities or energy densities of waves by particles, and to solve the transport equations by a Monte-Carlo method. With this method we are able to model complete seismogram envelopes in random heterogeneous media from the P-wave onset until the late S-coda where multiple scattering dominates. Data of an earthquake at distances below 100 km in Scandinavian crust are compared to the acoustic and the elastic theory. The results show, that a simple random medium apparently does not suffice to explain the data. A random medium which consists of the superposition of media with different internal scales can explain the data better. Data of deep earthquakes recorded on a volcanic structure are compared with the elastic radiative transfer theory. A fit of the complete envelopes is successful at frequencies of 1 - 4 Hz here. At higher frequencies only the main maxima of envelopes and the S-Coda can be explained with this theory. P-Coda at higher frequencies indicates that the used models are still too simple to describe the behavior of the complete envelopes.

Keywords: scattering, radiative transfer

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SS001 **Oral Presentation** **6117**

A new model that forms both strong and weak coupling asperity in a shallow inter-plate region

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Tatsuo Matsuda, Takumi Matsumoto

We made a new model that forms both strong and weak coupling asperity in a shallow inter-plate region. The difference of these strength, it depend on a serpentinization of harzburgite layer under the oceanic crust. We (NIED F-net) have established the earthquake mechanism database in and around Japan region. The database is composed by earthquake mechanisms that were calculated from F-net broadband seismic time series data and JMA epicenters, since 1997. From this database, we made distribution of earthquakes of a thrust type along the north part of Japan Trench. Two parallel lines along Japan Trench were recognized by this distribution. And some branches that connected the two parallel lines were recognized, too. We did comparison with this distribution and conventional large earthquake asperity of this region (Yamanaka and Kikuchi, 2003). As a result, the conventional large earthquake asperity does not overlap with this distribution. Furthermore, we made distribution of normal type earthquakes of east offing of Japan Trench (outer-rise earthquakes). And we did comparison with this distribution and the conventional data. As a result, we found that some large slip areas of the asperity map are located in the outer-rise earthquakes west-northwest. This direction is the same as the direction that Pacific plate moves. Therefore, it is supposed that these large slip areas are related with the outer-rise earthquakes. It is expected that the large slip areas in asperity region are easy to slip than other areas. We will call it weak coupling asperity in contrast to strong coupling asperity. And we made a model that the weak coupling asperity was formed as follows. First, the outer-rise earthquake faults cut oceanic crust of Pacific plate. And then, harzburgite layer came in contact with seawater and caused serpentinization. Second, Pacific plate subducted under land crust and sediment layer on oceanic crust was changed into illite. The illite usually lets land crust and oceanic crust couple to each other and forms strong coupling asperity. However serpentinized hurzburgite is very easy to slip. This is the reason why to form the weak coupling asperity in a shallow inter-plate region. How does this weak coupling asperity hold and become large earthquake asperity? In our model, this weak coupling asperity was enclosed by strong coupling asperity. The slip of large earthquake will start at the strong coupling asperity region.

Keywords: asperity, harzburgite layer, outer rise earthquake

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SS001 **Oral Presentation** **6118**

Analysis of 4+ Years of Aftershock Data of the 2002 M7.9 Denali Fault, Alaska, Earthquake

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Roger Hansen

The Denali fault is the longest intra-continental strike-slip fault system in North America. A section of this fault ruptured in two large earthquakes in late 2002. The earthquake sequence began with the magnitude Mw 6.7 Nenana Mountain event on October 23, 2002.Ten days later on November 3, the magnitude Mw 7.9 Denali Fault earthquake ruptured nearly 340 km of the combined fault length with the maximum vertical and horizontal surface offsets of 2.8 m and 8.8 m, respectively. Inversions of the seismic, geodetic, InSAR data and combined datasets indicate variable subsurface slip, mainly restricted to the shallow depths with three main patches of highest slip. The Denali fault aftershocks were registered by the permanent Alaska regional seismic network and by an array of temporary seismic stations. Over 40,000 aftershocks were located through the end of 2006, with an overall magnitude of completeness of about 1.5. We examined various spatial and temporal characteristics of the aftershock sequence, including b-value distribution, aftershock locations, focal mechanisms, and stress orientations. The inferred parameters vary widely both in space and time. The aftershock distribution varies along the ruptured fault with the paches of persistent acitvity interchanging with virtually aseismic segments. The overall b-value of the aftershock sequence is 0.7, but varies widely between 0.6 and 1.4, with the highest b-values in the epicentral region. Likewise, the aftershock faulting parameters vary both in time and space. The inferred stress regime reflects an interchanging thrusting and strike-slip faulting along the ruptured fault. The thrust faulting is concentrated in the epicentral region of the Mw 7.9 event and along the rupture segments showing the largest surface offsets. We will present the aftershock catalog, illustrating the multiple challanges in the data processing, and the spatial and temporal variations in parameters of the aftershock sequence. We estimate that it will take 14 years for the seismicity rate to drop to the background level.

Keywords: seismology, aftershocks, alaska

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SS001 **Oral Presentation** **6119**

The Rayleigh-Wave ZH ratio Inversion

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Tomoko Yano, Luis Rivera

As seismic arrays with three-component seismographs proliferate in the world, there are new opportunities to study the interior structure of the Earth. There can be many new approaches for various seismic phases, but surface waves remain a good source of information for studying the crust and upper mantle. We developed an approach which uses amplitude ratios between vertical and horizontal amplitudes, measured as a function of frequency, and we term it here as the ZH ratio. Use of this quantity has been around a long time, at least from Boore and Toksoz (1969), and has been successful for geotechnical engineering for recovering shallow seismic structure from its applications in high-frequency range. We have examined the use of this approach for lower-frequency range. Specifically we examined the measurement of the analysis of this parameter, the ZH ratio, for frequencies within the microseismic frequency band (0.1-0.2 Hz) and within long-period seismic frequency bands (0.004-0.05 Hz) and their combined use for the inversion. Depth sensitivity kernels can be computed quite rapidly by numerical differentiations and they demonstrate that the ZH ratio data are far more sensitive to shallower structure than phase/group velocity data for the same frequency band. These kernels are used to invert the ZH ratio data in nonlinear iterative inversion. We have tested this technique by applying it to most of GEOSCOPE stations. The analysis clearly indicates that we must know the depths of Moho in order to retrieve reliable velocity variations, but in case we know the Moho depth, we get new constraints for the 1D structure under each station. Some stations near hotspots clearly show signatures for low velocity anomalies and the technique allows us to constrain its depth range. Since GEOSCOPE has stations near many hotspots, we may be able to compare the size of low velocity anomalies through this technique. In other tectonic regions, the technique identified low velocity anomalies in the lower crust and also under the Moho which clearly have tectonic implications. We will report on the summary of these results and our evaluation of this surface-wave technique.

Keywords: surface wave, structure, inversion

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SS001 **Oral Presentation** **6120**

Spatial Distribution of Random Inhomogeneities in the Southwestern Japan - Relation to the Quaternary Volcanoes and S-wave Reflector -

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Seismic envelopes in high-frequency range (>1Hz) are broadened with travel distance increasing due to medium inhomogeneities in the vicinity of the ray-path. The studies of envelope broadening in the northeastern Japan revealed the spatial variation of random inhomogeneities related to the volcanic front (Obara and Sato, 1995) and the Quaternary volcano distribution (Takahashi et al., 2007). This study examines the path-dependence of envelope broadening, and investigates the spatial distribution of random inhomogeneities in the southwestern Japan. The waveform data of 291 microearthquakes recorded at 508 Hi-net (NIED) stations and 37 ocean bottom seismograph (OBS) stations are used in this study. The magnitude and focal depth ranges are 1.1-5.4 and 35-200km, respectively. The total number of ray-paths is approximately 16000. We composed the root mean square (RMS) envelope of velocity seismograms from the horizontal components in 2-4Hz, 4-8Hz, 8-16Hz and 16-32Hz bands. We measured the peak delay time which is defined as the time lag from the S-wave onset to the maximum amplitude arrival of S-wave envelope. This peak delay time is the best measure to quantify accumulated scattering effect due to random inhomogeneities. Examining the path-dependence of RMS envelopes and their peak delay times, we found the following remarkable characteristics; (1) envelopes propagating beneath the Quaternary volcanoes (Hida Mts., Izu-Peninsula and Yufu ~ Aso area) are strongly broadened in higher frequencies (2) The region from Osaka-plain to Biwa-lake also indicates strong broadening in higher frequency even though there is no Quaternary volcanoes. We apply the inversion analysis of the peak delay time assuming the spatially non-uniform isotropic random media with impulsive seismic sources (Takahashi et al., 2005, IASPEI general assembly). The power spectral density function of random media is assumed to be von Karman type. We divide the whole space to small blocks having two unknown parameters. These parameters represent the spectral decay in short-wavelength component and the spectral level in long wavelength component. The strongly inhomogeneous regions are estimated in the following regions; (1) beneath the Quaternary volcanoes on rift zone (Yufu ~ Aso) at the depth of 0-20km, (2) Izu-peninsula at 40-60km depth, and (3) from Osaka-plain to Biwa-lake (20-40km in depth). The strong inhomogeneities beneath the Quaternary volcanoes are similar to the characteristics in northeastern Japan. However, strong inhomogeneities in region-(1) are located in shallower part, meanwhile the northeastern Japan and Izu-peninsula show stronger inhomogeneities in deeper part. The strong inhomogeneity in region-(3) is also imaged by the Coda-wave analysis (Nishigami, 2006). In this region, an S-wave reflector is detected (Katao, 1993) and can be considered as an origin of strong coda excitation. Even though it seems to be difficult to determine the thickness of inhomogeneities from these two studies, our result implies the inhomogeneous layer in this region must be thick enough to generate broadened direct waves.

Keywords: scattering, inhomogeneities, reflector

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SS001 **Oral Presentation** **6121**

Particle motion of coda waves in terms of energy partitioning

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In terms of the applicability of the coda wave interferometry, renewed attention is paid to the nature of coda waves. It is an important issue whether single scattering or multiple scattering is dominant in S coda part. Shapiro et al. (2000) focused on the stabilization of S-to-P energy ratio in the multiple scattering regime for tackling the issue. Here, we study particle motions of S coda, which may also be useful. In this study, practical data analysis is done for local earthquakes using Japanese KiK-net data, at each station of which strong-motion seismometers are deployed at the top and the bottom of a borehole. Two stations of IWTH13 and IWTH17 are chosen, which show small variation of seismic velocity with depth in well-log data. As a quantitative measure of particle motion, energy partitioning ratio (EPR) to three orthogonal directions of motion is calculated for the mean squared velocity envelopes in a 2-16 Hz band and in a S-coda time window with lapse time of 40-80sec. The EPR first reflects the source radiation pattern at the direct S-wave part, but tends to fluctuate around an average value after about 1.5 times of S-wave travel time. The EPR averaged in the time window and over events shows that equal partitioning of energy, EPR of about one third, is realized at subsurface receivers of the stations. On the other hand, the EPR at the surface receivers is different from that at the subsurface receivers. A theoretical calculation following Hennino et al. (2001) is performed to explain the results at the surface receivers. Under an assumption that P, SV, and SH plane waves with the stabilized S-to-P energy ratio of 10.4 are isotropically incident on the free surface in a homogeneous half space, the EPR becomes 0.41 for two horizontal components and 0.18 for vertical component. Contribution from surface waves is not incorporated in the calculation. These values show a good agreement with our observation. This shows that two stations used in this study can be modeled by a homogeneous half space, and that contribution from surface waves is negligible in the frequency range of 2-16Hz. And this agreement also implies that the assumption on the S-to-P energy ratio is reasonable. Generally speaking, the EPR can be affected by subsurface velocity structures. Therefore, the EPR may be a measure for the shallow velocity structure if contamination by surface waves can be neglected. Acknowledgments Seismograms registered by the KiK-net, NIED Japan, and an integrated event catalogue by the Japan Meteorological Agency and the Ministry of Education, Culture, Sports, Science and Technology in Japan were used.

Keywords: coda, energy partitioning, particle motion

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SS001 **Oral Presentation** **6122**

Calibration of the IRIS global seismographic network

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Improvements in computer processor speed and the declining cost of data storage now enable systematic study of data sets far larger than was possible a short time ago. We analyzed over ten years of data from the IRIS Global Seismographic Network (GSN) to test the accuracy of response information published for both the principal and auxiliary seismic sensors deployed at GSN sites. To maximize the scientific return from GSN data, the equipment at each GSN station is subjected to a series of stringent tests before field deployment. These tests include careful calibration of the data acquisition system. The Earth's tides provide an independent check of the instrument response determined in the laboratory. Using the current generation of tidal models that effectively incorporate ocean loading as well as the solid earth tide, one may now compute a tidal series accurate to 1% in many regions. This accuracy is sufficient to verify calibration information routinely distributed with GSN data. Time series lasting greater than 45-180 days were used to test the published instrument response for many GSN station-calibration epochs. For each time series recorded on a vertical broadband seismometer, a synthetic tidal series for the exact same time period and spatial coordinates was computed. The relative amplitude and phase of the two series were compared to check the published response. Tests confirm that local crustal tilting exerts too strong an influence on the data for horizontal seismometers also to be calibrated in this fashion. The results for tidal frequencies computed in this study are compared to those from a similar study that utilized GSN recordings of the mode 0S0 excited by the 2004 Sumatra-Andaman Islands earthquake. Additionally, we examined the relative calibration of multiple sensors in cases where two or more seismometers were co-located within several meters. These measurements support findings from the tidal signals.

Keywords: seismometry, tides, calibration

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SS001 **Oral Presentation** **6123**

Determination of broadband body-wave magnitudes mB and mBc using an automatic near real-time procedure and comparison with interactive measurements and Mw data

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Bormann and Wylegally (2005) proposed the determination of cumulative amplitude broadband body-wave magnitudes mBc as a fast procedure for non-saturating magnitude estimates of big earthquakes with Mw = 8 and larger. For smaller events they showed that already single amplitude mB yields satisfactory fast magnitude estimates. One of us (J.S.) has now developed an automatic real-time procedure for mB and mBc determination. By comparing for identical events the interactively (i) and automatically (a) determined mB and mBc values we proved that this procedure reproduces sufficiently well the measurements of an experienced seismogram analyst. Interactively we analyzed the records of only one station (for some 50% of the data) up to a maximum of 7 stations per event. In contrast, the automatic procedure permitted to quickly calculate mB and mBc from the digital data of 24 up to 207 world-wide distributed stations per event. This allowed to analyze the robustness of mB and mBc estimates if only a limited number of station records are available for real time processing. For events with Mw between 6 to 9 we got the following average differences (with SD = standard deviation): - mB(i)- mB(a) (for identical stations) = + 0.03 (SD = 0.13 m.u., N = 138); - mBc(i) mBc(a) (for identical stations) = + 0.04 (SD = 0.20 m.u., N = 42); - mB(i)(single station) mB(a)(global network) = - 0.02 (SD = 0.24 m.u., N = 26); - mB(i)(2-7 stations) mB(a)(global network) = + 0.06 (SD = 0.10 m.u., N = 29); - mBc(i)(single station) mBc(a)(global network) = +0.07 (SD = 0.23 m.u, N = 27).; - mBc(i) (2-7 stations) mBc(a)(global network) = + 0.02 (SD = 0.14 m.u., N = 24). Since the differences between interactive measurements and automatic ones are on average smaller than 0.1 m.u. with standard deviations ranging only between 0.1 and 0.24 m.u. we can confirm that the developed automatic real-time procedure for the new IASPEI standard magnitude mB as well as for the cumulative amplitude mBc reproduces very well the readings of an experience seismogram analyst but being at the same time more objective and fully reproducible. Also, we can prove the high robustness and reliability of broadband body-wave estimates, which yield with the readings of only a few stations results comparable to those of a large global network. This finding is highly relevant for near real-time magnitude estimations in disaster situations when many nearby stations may fail. Finally, we will present diagrams comparing automatically calculated mB and mBc values for global network data with Mw(HRV) in the magnitude range 5.9 < Mw(HRV) < 9.1. The data scatter will be explained in terms of differences in seismic energy and moment release depending on regional stress-drop conditions and prevailing source mechanisms.

Keywords: magnitude, real time, broad band

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SS001 **Oral Presentation** **6124**

On the use of background noise to calibrate seismographs

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Ramon Ortiz

In this work we present a methodology to obtain an indication of the full response of a seismograph system, based on the analysis of background seismic noise. The stability of the very base levels of noise in the microseismic band (0.04 Hz - 0.3 Hz) for quite large areas, makes the use of that part of the spectrum suitable to get a good indication of the absolute magnification of a seismograph system. By scanning a long term span of data in continuous mode values of magnification may be obtained with enough accuracy to perform some of the classical earthquake analysis. The method we present allows to obtain this information with a minimum knowledge of the electronic system and without the need of any known transitory source to be used as a reference. Only the behaviour of the noise, even at far stations or in different periods of time is needed. The methodology has provided very good results in its test in several stations when comparing results for a given site with respect to others obtained during different years or in different sites.

Keywords: background noise, calibration, microseism

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SS001 **Oral Presentation** **6125**

Source phenomenology explosion experiments in Israel

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We studied empirical features of seismic energy generation for different explosion seismic sources, and partitioning of this energy between regional phases, in specific geological conditions and tectonic settings of the Middle East. The goal of the research was to provide data for improvement of nuclear test monitoring within the framework of the CTBT. Experimental explosions with near-spherical charges at different depths were conducted at Oron phosphate quarry in Northern Negev. A special complicated technology was applied for creation of large cavities (up to 3.5 m size) at different depths for accommodation of ANFO explosives. A series of decoupled and fully coupled (reference) explosions in the cavities with charges 1240 kg were conducted on July 17, 2006. Extensive observations in near-source zone and remote area demonstrated peculiar signal features and energy generation related to these specific decoupled seismic sources. Decoupling factors were estimated at local distances, that correspond roughly to theoretical values. On January 2, 2007, after long preparations and many efforts the unique Depth-of-Burial (DOB) experiment with original design and configuration was successfully conducted. The explosion series of three charges of 4200 kg ANFO each one were detonated at different depths: 26 m, 45 m and 59 m. The design and configuration of the explosions were different and preferable compared to previous similar experiments (Balapan DOB experiment in 1997): near-spherical charges, homogeneity of accommodated media (all charges were placed in the same consolidated sediments marls), full containment and small separation (~200 m) of explosions. Numerous good recordings of signals from all shots were obtained at portable near-source accelerometers and close-in 3C seismic stations, permanent local Israel SP and BB stations, and IMS stations EIL and MMAI (240 km). A clear expected magnitude/energy reduction with depth was observed at regional distances, complemented by near-source observations of higher frequencies (and larger amplitude/ energy) for deeper charges. Obtained data will contribute to the ability of parameter estimation of nuclear explosions. The research was sponsored by the AFRL of the US Department of Defense.

Keywords: decoupling depth of burial

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SS001 **Oral Presentation** **6126**

Attenuation Structure of P Wave in the Aftershock Area of the 2005 West-off Fukuoka Prefecture Earthquake (M7.0)

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We have developed a method of estimating seismic attenuation (1/Q) in a seismic active region such as aftershock area. To estimate attenuation factor between the adjacent two hypocenters, we employed two seismograms taken at a station, and calculated a ratio between two power spectra of direct waves normalized by those in coda for the two events. The coda normalization for the spectrum and the ratio between two events minimized possible effects of source, site, instruments, and attenuation from station to the hypocentral area. 1/Q value could be estimated from variation of collected ratios of event pairs in many stations at different travel time difference. We applied this method to the aftershock area of the 2005 West-off Fukuoka Prefecture Earthquake (M7.0). Using the spectra of seismograms of 1780 events recorded by the dense seismic network deployed around the aftershock area, we obtained spatial variation of 1/Q value in the area. The 1/Q distribution thus obtained suggests that there is a high attenuation area around the edge of the main shock fault.

Keywords: attenuation, heterogeneity, seismic wave

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SS001 **Oral Presentation** **6127**

Sudan seismicty and the Sudan seismic network

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Abd Alhadi Ibrahim Alhassan, Amani Elkhidir Belail, Hatim Siddig Hag Elbashir, Indira Abdel Rahman Mohamed, Mustafa Bashir Mohammed and Nada Bushra Eltahir, Geological Research Authority of Sudan (GRAS), Khartoum , Sudan. Jens Havskov, Department of Earth Science, University of Bergen, Norway Sudan seismicty and the Sudan seismic network Though Sudan is characterized by low seismic activity, several big earthquakes have been recorded, which resulted in loss of life and damage to properties. The largest of these was probably the largest earthquake in Africa in the 20th century. It occurred on 20 may 1990 (Ms=7.1-7.4) near Juba in the southern part of Sudan. Other earthquakes whose effects caused major damage and even deaths, include the Suakin graben earthquakes (Ms= 5.8) of 12 May 1938, located in the Western margin of the Red Sea, the Jebel Dumpier event located in Central Kordofan (Ms=5.6), which occurred on 9th October 1966, and the Khartoum event (Ms=5.5) of August 1993. In 2001, the Sudan Geological Research Authority (GRAS) established a three station seismic network to monitor earthquake activity in the region. The network is, for practical reasons, distributed around Khartoum and local, regional and distant earthquakes are recorded. Most of the local events are found to be correlated with the fault NW of Khartoum, which is thought to be the epicenter of the Khartoum earthquakes of August 1993. The SSN, is also able to detect and locate events from large distances. The network is well calibrated, has low noise stations and seems to give very accurate Ms and Mb. SSN has started to report all readings to the International Seismological Centre (ISC) and should be able to make a significant contribution considering the scarcity of stations in the area and the accuracy of its observations.

Keywords: sudanseismicnetwork

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SS001 **Oral Presentation** **6128**

Deep very low-frequency earthquakes coincident with non-volcanic deep low-frequency tremors and slow slip events

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Takuto Maeda, Kazushige Obara

Non-volcanic deep low-frequency tremors and slow slip events occur simultaneously in the transition zone from the locked slip to the aseismic slip along the Nankai subduction zone in southwest Japan [Obara 2002; Obara et al., 2004]. To understand the stress relaxation process in the transition zone of the deep portion of the subducting plate interface, it is important to identify all seismic and geodetic phenomena. Recently, we have detected another slow earthquake with the predominant frequency of 20 s. Here, we report the deep very-low-frequency earthquakes (dVLF) that occur on the subducting plate interface along the Nankai subduction zone. Using a bandpass filter of 0.02 to 0.05 Hz, we succeeded to detect anomalous distinct VLF signals at several broadband seismic stations. In particularly, these wave trains were best identified on the radial and vertical components during high activities of the non-volcanic deep low-frequency tremor. Two peaks of 0.5 and 20 s were identified on velocity amplitude spectra: One of 0.5 s was radiated from the sources of tremors; the other was probably radiated from other sources. We also investigated velocity amplitude spectra of some other time windows when tremor activity was only observed without arrivals of distinct VLF signals. The peak of 0.5 s was only observed on the velocity amplitude spectra. These results suggest that seismic sources radiating signals of 20 s were difference with those of non-volcanic deep tremors. Considering the sources of the VLF signals as VLF earthquakes, we calculated their centroid location and moment tensor solutions. To detect VLF seism signals and estimate their hypocenters systematically, we adopted the grid moment tensor inversion (GMTI) approach, in which we assume that the target earthquake always occurs at a grid point that is arranged with respect to both space and time. Using this approach and continuous seismograms obtained from four broadband seismometers close to each grid point, we calculated the point source moment tensor solution at 0.1 horizontal, 3km depth, and 1s interval grid-point spacing. First we removed time periods that are potentially contaminated with seismic waves from teleseismic and ordinary regional earthquakes from the GMTI solutions. Next, using more than 12 broadband stations, we applied the centroid moment tensor inversion approachin which hypocenters and fault mechanisms of the target earthquakes are calculated simultaneouslyto the remaining CMTI solutions. The dVLF events with seismic moment magnitudes of 3.1 to 3.5 were located on the belt-like distribution of deep low-frequency tremors along the strike of the subducting Philippine Sea plate. The focal depths of VLF earthquakes were distributed across a slightly wide range of 35 to 40 km. The dip angles of the nodal planes that dip landward were consistent with the slope of the Philippine Sea plate. The fault strikes of these nodal planes were generally subparallel to the depth contours of the plate interface. These results show that VLF earthquakes may occur on the subducting plate interface. The seismicity of dVLF events accompanied and migrated with the activity of non-volcanic deep low-frequency tremors and slow slip events. The migration pattern of dVLF events was very consistent with both the deep low-frequency tremor activity and the observation of the geodetic deformations. This observation indicates a close relationship between the activity of both dVLF events and deep low-frequency tremors, and slow slip events, reflecting the stress accumulation and relaxation process on the transition zone at the deep portion of the subduction zone.

Keywords: very low frequency earthquake, deep low frequency tremor, slow slip event

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SS001 **Oral Presentation** **6129**

Monitoring temporal variations of seismic velocity associated with the Mw = 6.6 Mid-Niigata earthquake, Japan, using Passive Image Interferometry and Hi-Net data

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Passive Image Interferometry is a new technique to continuously monitor small temporal changes of seismic velocity in the Earth's crust with a temporal resolution of one day. We retrieve the high frequency source-receiver co-located elastic wave Green's function from the auto-correlation function of seismic noise recorded during one day. Applying interferometric methods to the Green's functions from different days we analyze the temporal evolution of the subsurface medium. In an application of the technique to Japanese Hi-net seismometer stations we analyse the source region of the Mw = 6.6 Mid-Niigata earthquake, Japan. We observe a sudden decrease of relative seismic velocity in the Earth's crust of some 0.1 per cent that coincides with the occurrence of the earthquake.

Keywords: noise correlation, hi net, monitoring changes

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SS001 **Oral Presentation** **6130**

Super-wide angle one-way wave propagator for seismic modeling and imaging

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Conventional one-way propagator has propagation angle limitation to 90 degree, and may have large errors in for steep angle propagation in strong contrast media. The other more fundamental limitation of the one-way methods is the difficulty in handling turning waves. To overcome the angle limitation of regular one-way wave propagation methods, we develop and extend the capability of one-way propagators by a wavefront reconstruction method which combines and interpolates two orthogonally propagated one-way wavefields. The proposed method has accurate super-wide angle (greater than 90) propagation and can model turning waves. The method has the potential to be used in imaging steep subsurface reflectors and overhanging structures using turning waves. Numerical tests demonstrated the validity of the method.

Keywords: seismic modeling, scattering, wave imaging

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SS001 **Oral Presentation** **6131**

Three-component envelope synthesis in randomly heterogeneous media based on the Monte Carlo Simulation

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The scattering theory of seismic wave for the synthesis of coda waves (e.g., Sato, 1984; Yoshimoto et al., 1997) reveals the relation between the non-isotropic scattering patterns and stochastic feature of random inhomogeneity of the medium under the assumption of the weak-inhomogeneity. However, their envelope model is valid only for short lapse time because their models are based on the single scattering approximation. On the other hand, recent developments of radiative transfer theory enable us to synthesize multiply-scattered waves. Although it is difficult to solve the radiative transfer equation analytically, Monte Carlo simulations which synthesize coda envelopes by using the stochastic behavior of many particles has been done incorporating non-isotropic scattering pattern derived from wave scattering theory (Margerin et al., 2000; Przybilla et al., 2006). Here we report the synthesis of three-component MS envelope incorporating the non-isotropic scattering expected from Born scattering theory based on the Direct Simulation Monte Carlo (DSMC) method (Yoshimoto, 2000). Non-isotropic scattering pattern of S waves in a randomly inhomogeneous medium is characterized by the scattering coefficient based on the Born approximation (e.g., Sato and Fehler, 1998). Normalizing the scattering coefficient by its solid-angle integration, we define the distribution function of the scattering direction for the statistical treatment in the DSMC simulation. We can simulate the variables which obeys the distribution function by inverse function method. However, we can not represent the inverse function of distribution function of S-wave scattering analytically. So, we pre-calculate the distribution function at every 0.5 degree grid as an alternative to the inverse function. In addition, we need to trace the polarization angle information to trace scattered S-wave particle in the DSMC simulation. An angle between polarization direction of S waves and SV wave direction is defined as a characteristic parameter of the polarization direction. Contributions to each of three components of one energy particle can be calculated from the polarization direction. We perform the DSMC simulation for isotropic SH source in randomly inhomogeneous medium. The exponential-type auto correlation function having the characteristic scale a of ak=0.1 is assumed, where k is wavenumber of S waves. We use 15 million energy packets for the simulation. At each time step, three-component MS envelopes are calculated by counting the number of particle in the spatial mesh. At a lapse time of mean free time, direct wave amplitude on the horizontal plane has strong anisotropy among components: x-component MS envelope is strong along y-axis direction and vice versa. This is because SH waves polarize in transverse direction. Although this anisotropy is expected even in a homogeneous medium, we observe weak vertical component coda waves that are generated by the scattering from SH to SV waves. We found that the difference of MS amplitude of x and y components rapidly decreases as lapse time increases due to the scattering. Polarization directions of S waves are randomized and MS envelopes of three components are equalized at large lapse time.

Keywords: coda wave envelope, elastic wave scattering, random media

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SS001 **Oral Presentation** **6132**

The Capability for Seismic Monitoring of the North Korean Test Site

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On 9 October 2006 the Democratic Peoples Republic of Korea (DPRK) conducted an underground nuclear explosion at a test site near Kimchaek. The explosion was detected by several seismic stations in the International Monitoring System (IMS), and the event magnitude as reported in the REB was 4.1. In this paper we analyze the recorded waveforms in order to investigate the capability of the IMS to monitor the DPRK test site for possible future explosions. Our analysis is based upon the so-called Site-Specific Threshold Monitoring (SSTM) approach. Using actual seismic data recorded by a given network, SSTM calculates a continuous threshold trace, which provides, at any instance in time, an upper magnitude bound on any seismic event that could have occurred at the target site at that time. We find that the IMS primary network has a typical threshold monitoring capability of between mb 2.3 and 2.5 for the DPRK test site. Not unexpectedly, it turns out that the Korean array (KSRS) is of essential importance in obtaining such low thresholds. We have also experimentally investigated how the capability could be improved by adding non-IMS stations to the network. We find that by adding the nearby station MDJ in , the threshold monitoring capability is improved to between magnitude 2.1 and 2.3. A different perspective is to investigate the actual network detection capability for events at the test site, requiring at least 3 IMS stations to detect the event. This is the traditional way of looking at network capability, and the resulting threshold will always be considerably higher than that obtained by the SSTM approach. A global capability map, which is published by the IDC for each hour, shows that at the time of the event, the IMS 3-station detection capability was approximately 3.5. This is an order of magnitude higher than the threshold obtained by SSTM. We conclude that the SSTM approach allows the analyst to identify times when there is a possibility of occurrence of events too small to be detected by the usual 3-primary station requirement, and to subject such occasions to extensive analysis in order to determine whether an event in fact occurred. Thus, the SSTM approach constitutes a valuable supplement to the traditional network processing carried out at the IDC.

Keywords: nuclear explosions, threshold monitoring, north korea

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SS001 **Oral Presentation** **6133**

Calculation of effective seismic properties of untextured crystal aggregates and application to inner core crystallisation

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The top of Earth's inner core behaves as a strongly scattering, statistically isotropic body. This is evidenced simultaneously by the existence of a prominent backscattered coda of the reflected core phases, and by the isotropic behaviour and strong attenutation of P waves that bottom at shallow depth in the inner core. To interpret these observations, we propose to model the superficial part of the solid core as an untextured aggregate of iron "patches", each patch being characterized by the anisotropic properties of individual ironcrystals. To calculate the seismic response of such a body we have developed a formalism based on the Dyson equation, that takes into account all the physics of the problem: arbitrary anisotropy of individual grains, mode conversions, multiple scattering. The solutions of the Dyson equation yield effective velocities and scattering attenuation lengths for both P and S waves. We use our theory to test existing models of elastic properties of iron at core conditions obtained from ab-initio calculations or laboratory experiments. We show that models with similar effective velocities can have more than one order of magnitude difference in attenuation. By comparing observed P wave attenuations with our theoretical predictions, we put constraints on the possible stable phases of iron at core thermodynamical conditions as well as on the typical size of individual patches. Our most probable models favour a typical scale length of 200 meters, but larger correlation lengths are also possible, but less likely. For crystals with cubic symmetry invariant elastic constants describing the material anisotropy show a bimodal distribution. For hexagonal symmetry, it is slightly more probable to have crystals with a slow symmetry axis as suggested by Steinle-Neumann (2001). Our model predicts a shear wave quality factor at 1 Hz ranging between 30 and 80, close to the PREM model.

Keywords: multiple scattering, anisotropy, inner core

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SS001 **Oral Presentation** **6134**

A new perspective for MEDNET

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MedNet (Mediterranean Network) is a network of very broadband seismic stations installed in Countries surrounding the Mediterranean Sea.Its main objectives were mapping the structure of the Mediterranean region, studying the seismic source properties of intermediate and large events, and applying this knowledge to measures for hazard mitigation and civil protection. Although general goals still hold, the network has now a different valence in the Euro-Mediterranean seismological landscape. National Networks are now equipped with similar high quality instrumentation, real time transmission is adopted everywhere for seismic monitoring and infrastructures can support high rate data exchange among networks. MedNet objectives have then shifted toward contributing to real time monitoring of the Euro-Med region.The network presently comprises 22 operating seismic stations installed and maintained in cooperation with 13 geophysical institutions in Italy and in most of the Euro-Mediterranean countries. All the stations are equipped with 24-bit digitizers and very broadband sensors (Streckeisen STS2, with a few STS1).Its Data Center (MNDC) exchanges data in real time with many seismological observatories, as well as with over-national organization, such as ORFEUS DC and IRIS DMS. MedNet thus rely on an extended network of 40-50.The station coverage and the data quality allow for the implementation of real-time regional moment tensor (MT) estimation procedures as proposed by Dreger and Romanowicz (1994). The automatic MT algorithm is triggered for events with magnitude greater than Ml 3.5 by an alert with preliminary epicentral and origin time information from different recognized agencies. Recorded waveforms are filtered in different frequency bands: 0.02-0.1Hz for Ml between 3.5 and 3.8 while 0.02-0.05 Hz for Ml greater than 3.8. This procedure gives a first unmanned solution, a successive solution revised by a seismologist is published on the web site. In the framework of IOC initiative on North East Atlantic Tsunami Warning System (NEAMTWS), INGV is developing a Regional Center for a tsunami watch in the Mediterranean. In this regard, two different algorithms (LocSat and NonLinLoc) and different network configurations are under test at MedNet to check the capability of the extended network for locating large earthquakes. Preliminary results will be presented and discussed.

Keywords: monitoring

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SS001 **Oral Presentation** **6135**

The 2006 Kythira, Southern Greece, aftershock sequence

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A strong (Mw=6.7) intermediate depth earthquake occurred on January 8, 2006 (11:34 UTC) in Southwestern Greece causing serious damage to structures on the islands of Kythira and Antikythira, as well as in western Crete.The epicentral area belongs to the SW segment of the Hellenic Arc, which is capable to generate large shallow and intermediate depth earthquakes, mainly due to the subduction of the Eastern Mediterranean oceanic lithosphere under the Aegean plate.In this work the main shock is relocated and the aftershock sequence from 8 to 31 January 2006 is analyzed aiming to contribute to the better knowledge of the seismotectonics of this high seismic hazard region.The main volume of data is provided by the 9 short period 3 components seismic stations of the digital telemetry network of the Geophysical & Seismological Laboratory (GSL) of the Technological Educational Institute of Crete. These data were enhanced by the recordings of the permanent seismological stations of the GEOFON network, the National Observatory of Athens and the Seismological Network of Geophysics Department, Aristotle University of Thessaloniki.For the location we use the HYPOINVERSE algorithm (Klein, 2000) and a velocity model computed for the area. For depths greater than 30 km we use the values of the velocity structure proposed by Papazachos & Nolet (1997). In order to improve the initial locations we calculate the mean residuals at each seismological station and use them afterwards as station corrections following an iterative process of relocations.The final spatial distribution of the 48 best relocated aftershocks with vertical (ERZ) and horizontal (ERH) hypocenter uncertainties less than 10 km and 8 km respectively and root mean square residual (RMS) less than 0.8 s delineates a NE-SW trending seismic zone. This result is in agreement with the one nodal plane of the CMT solution determined by Harvard (strike=66, dip=55, slip=119). The focal mechanism indicates dextral strike slip faulting at a depth of 74 km, within the descending slab. T axis is oriented parallel to the slab downdip. Additionally, a focal mechanism computed using the first onsets of the P waves of the recordings gives similar results (strike=70, dip=75, slip=165).Furthermore, the computed cross-sections, one parallel to the seismic zone and the other perpendicular to it show that the aftershocks range in depth from about 55 to 75 km forming a rectangular with length equal to 21 km and width equal to 22 km, which reflects an approximate dimension of the ruptured area.

Keywords: hellenic subduction zone

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SS001 **Oral Presentation** **6136**

A relation between Japanese local magnitude Mjma and seismic moment determined from dense broad band seismograph network for shallow crustal events

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Relation between local magnitude and seismic moment Mo is very important issue on modeling of source characteristics as well as estimation of strong ground motion. However, existing relations are determined statistically from limited records. In Japan, a local magnitude Mjma is announced systematically by Japan Meteorological Agency. Takemura et al. (1990, 1998) determined empirical relations between Mjma and Mo for crustal earthquakes, and Fukushima (1998) derived a semi-empirical relation based on available data up to their publication. Strong motion is strongly depending on source modeling, nevertheless, Mo for specific magnitude is still derived with those relations. Nowadays in Japan, high density broad band seismograph network is already installed by National Research Institute for Earth Science and Disaster Prevention (NIED), and moment tensor solutions are systematically announced through their web site. We determined an empirical relation between Mjma and Mo with data announced by the both organizations. Data are selected from March 1997 up to last December and Mjma less than 4 are omitted. This region is locating on a confusing tectonic regime, and different strong motion characteristics can be expected for individual source types such as crustal, inter plate and slab events. In this study, we focus on shallow crustal events, since extremely strong motion is estimated at close distance from source of crustal events. Total of 368 data from crustal events were selected, and a regression analysis was performed. A determined relation is log10 Mo=1.37Mjma +16.42 This result was compared with several other relations of Takemura (1990, 1998), Fukushima (1998), and Sato(1997) of a classical equation. Takemura's relations are also focusing on crustal events, so our result are well corresponding to them particularly above Mjma greater than 7, although this range is not enough constrained by the observed data. To the contrary, our result agrees well with Fukushima (1998) from 5.5 to 6.0 of Mjam maybe due to reliability of the data in this range. Determined equation between the local magnitude and Mo in this study is based on the newest and numerous data, and agree well with former relations. With this equation, conversion from Mjma to Mo can be facilitated. It is quite obvious that Mo is more physical parameter than the local magnitude for the estimation of strong ground motion. The converted Mo from Mjma will be able to apply on source modeling of crustal events, and used for predictions of strong ground motion with empirical attenuation relations of Mw as a parameter. Furthermore, historical seismic catalogues are independent in individual regions with local magnitude, therefore, continuity among catalogues is always trouble. Actually in Japan, we are using Mjma, therefore discontinuity of magnitude is blocking universal use, although quantitative and qualitative data are observed. With this result, we wish that Japanese local data will be available for world wide application.

Keywords: jma magnitude, seismic moment, shallow crustal earthquakes

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SS001 **Oral Presentation** **6137**

Crustal heterogeneity and deep structure of active faults in the Kinki region, southwest Japan: Inversion analysis of coda envelopes

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In the Kinki region, southwest Japan, there are several active fault zones near large cities such as Osaka and Kyoto, and the evaluation of realistic strong ground motion is an important subject. For these purposes, we have been carrying out a research project to understand the detailed crustal structure and earthquake generating properties in the Kinki region. In this presentation we show some results of estimating the crustal heterogeneities and the deep structure of active fault zones. We estimated a 3-D distribution of relative scattering coefficients in the Kinki region, also in the vicinity of each active fault zone, by inversion of coda envelopes from local earthquakes. We analyzed 758 seismograms from 52 events which occurred in 2003, recorded at 50 stations of Kyoto Univ., Hi-net, and JMA. The result shows the existence of a remarkable scattering zone at a depth from 20 to 30 km, just below the high micro-seismicity area. The strong scattering zone is well correlated with the location of S-wave reflectors estimated by previous studies (Katao, 1993), and also suggests the existence of some fluid probably related to the high micro-seismicity. The result of scattering analysis also shows that active fault zones can be imaged as higher scattering than the surroundings. Based on previous studies of scattering properties in the crust, we consider that the relatively weaker scattering (namely more homogeneous) part on the fault plane may act as an asperity during future large earthquakes, and also that the part with relatively stronger scattering (namely more heterogeneous part) may become an initiation point of ruptures. We also estimated the detailed distribution of microearthquakes, b-values, and velocity anomalies along the active fault zones. Combining these results, we estimated a possible fault model, which is related to the earthquake rupture process, for each of the active fault zones in the Kinki region.

Keywords: seismic scattering, crustal heterogeneity, active fault

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SS001 **Oral Presentation** **6138**

Study of 1999 Xiuyan, NE China, earthquake sequence from near-source seismic observation data

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The Institute of Geophysics, China Earthquake Administration (IGCEA) and the Southern Methodist University (SMU) have been collaboratively deployed a broadband seismic network in Xiuyan area, an area about 65 km to the SE of the epicenter of the 1975 Haicheng earthquake of MS7.3. The Xiuyan area is a seismic active area. On November 29, 1999, an earthquake of MS5.4 occurred in this area. Up to February 17, 2000, the 1999 Xiuyan earthquake was followed by approximately 89 aftershocks with ML equal to and greater than 3.0 and the largest aftershock of MS5.1 which occurred on January 12, 2000. The current operating Xiuyan seismic network, started operation since August 2004, includes 13 stations with station-spacing of 12 km to 18 km. This network has well recorded the up-to-date continuing aftershock activity of the Xiuyan earthquake sequence in near-source distance and provides unique opportunity to refine earthquake locations and to better understand natures of seismic source in the Xiuyan area. These aftershocks were well located with average location RMS of 0.001s, the uncertainty of the epicentral location of 0.08 km to 0.16 km and the uncertainty of the focal depth of 0.25 km. We used these well-located aftershocks as ground-true event to calibrate the 1999 Xiuyan aftershock sequence recorded by the regional seismic networks operated by the Liaoning Province Administration. The relocated hypocenters of the 1999 Xiuyan earthquake sequence delineate a distinct NW-SE trending aftershock zone extending up to 12 km depth, which suggests the NW-SE trending nodal plane of the 1999 Xiuyan earthquake focal mechanism is the fault plane, and the Wangjiapuzi fault is the causative fault of the 1999 Xiuyan earthquake. The 1999 Xiuyan earthquake is a dominate right-lateral strike-slip movement with a minor normal-slip component on a NE-dipping plane, which agrees with the causative nodal plane of the 1975 MS7.3 Haicheng earthquake.

Keywords: relocation, ground true, xiuyan

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SS001 **Oral Presentation** **6139**

Seismic networks in Iran

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Earthquake monitoring in Iran has been started in 1960's by Institute of Geophysics,University of Tehran (IGUT) using four World Wide Standard Seismograph Network (WWSSN) stations. IGUT added another few analog stations allover country. Also, in 1976 an array with seven borehole stations has been established in south-western of Tehran. The occurred seismic events were located and reported only using data from these stations. But, Iranforms one part of the Alpine-Himalayan Belt which shows a high level of seismicity and has experienced destructive earthquake several times in the past. Therefore, it is particularly important to be able to monitor any seismic activity quickly and efficiently. We can achieve this goal by installing modern seismic networks with good coverage all over the country. This allows seismologists to monitor any ongoing seismic activity. After the Rodbar destructive earthquake Mw=7.7, on 21 Jun 1990, the government funded the IGUT to establish digital seismic network allover country. The first digital telemetric seismic network operated in lat 1996 in Tehran region with 12 stations. The next network established in Tabriz region with 8 stations. By growing the number of seismic network, a center established as Iranian Seismological Center (IRSC) which activate as a part of IGUT. Now the IRSC is running eleven sub-networks with 60 stations, 4 individual analog stations (S-13 sensors) and 3 active borehole stations (M38600 sensors). Each sub-network consists of locally designed station recording continuously. The seismic signals in each station which is equipped with 3 short-period SS-1 seismometers is digitized by 24-bit digitizer then is transferredcontinuously to the centre of related sub-network using telemetric system. The data are transmitted from sub-networks to the data center in Tehran (IRSC) by VPN and Satellite. In addition above networks, 14 seismic stations (CMG-3T) are running by International Institute of Earthquake Engineering and Seismology (IIEES). We are planning to use more data especially for events occurred in border of Iran by changing data with other International or National Agencies.This presentation describes the network configuration, data acquisition and waveform processing. The presentation will describe efforts to address procurement of Iranian Seismological Center (IRSC) instrumentation and also the results of analysis the collected data.

Keywords: seismological, network, iran

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SS001 **Oral Presentation** **6140**

3-D scattering image of Mt. Vesuvius

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Somma Vesuvius complex is a composite central volcano located near the city of Naples, southern . It is formed by an ancient caldera (Mt. Somma) and a younger cone (Mt. Vesuvius). It is one of the world's most dangerous volcanoes, and a constant threat to hundreds of thousands of people who live in its shadow. Since 1944 the complex has been in a quiescent stage but it attracts scientific interest because of its plinian and subpliniam eruption history. Recently, a high resolution P-velocity tomography experiment (Scarpa et al., 2002) found evidence for a shallow high-velocity zone beneath and south of the crater. In almost the same area, an attenuation tomography analysis (Del Pezzo et al., 2006) found high total Q values. We seek to investigate the relationship between velocity, attenuation and elastic heterogeneity within the volcano to help us better interpret the relationship between structure and volcanic processes. This is accomplished by conducting an inversion of coda envelopes of the local VT earthquakes to determine the spatial distribution of scattering coefficient, which is a quantity that is related to the spatial heterogeneity. We use earthquakes that are located beneath Mt. Vesuvius and recorded by the local seismic network during the period 1996-2000. Data consist of 2260 waveforms recorded at 16 short-period high-dynamic range seismic stations. We use Nishigamis (1991) approach (single scattering approximation), modified to take into account the 3-D velocity distribution found using velocity tomography. Ray tracing is carried out in the velocity model. The analysis is performed using a multiscale approach, reaching the optimal resolution in the crustal layer located below the crater. Comparing the scattering image with the velocity and attenuation tomography we find an approximately coincidence among high velocity, high total Q and high scattering Q zones, 1 km below the Vesuvian crater. This area is surrounded by a low scattering Q, low velocity and low total Q zone. This may be interpreted as due to the presence of a residual solidified magma body left in place after the last effusive 1944 eruption surrounded by an highly fractured zone (the aquifer).

Keywords: scattering, attenuation, vesuvius

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SS001 **Oral Presentation** **6141**

The INGV integrated seismic monitoring system in Italy

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Italy is a high seismicity region where even moderate earthquakes can produce extensive damage. The need of responding quickly after an earthquake, as well as having high quality seismic and GPS data for earthquake research, motivated an extraordinary effort of a large part of INGV researchers and technicians, also in cooperation with other Italian institutions.In the past 5 years the Italian monitoring system, managed by INGV, has been strongly improved, thanks to support from the National Department of Civil Protection (DPC). Basic goals of the network are the rapid evaluation of earthquake parameters and the acquisition of high quality data for seismological research on earthquake source and deep structure. Particular emphasis has been given to real-time data transmission, network robustness and redundancy, multisensor remote stations. Presently, data from more than 250 stations are received in real-time at the INGV acquisition system in Rome, mostly through satellite links (about 100) and terrestrial digital lines (about 100), while other data are received through radio links and Internet. Our stations are equipped with either commercial (mostly Nanometrics) or INGV-produced digitizers (GAIA2). MedNet data in and EuroMed regions are also used for real time monitoring. MedNet data are shared in real-time with ORFEUS and IRIS, while data from the National Seismic network are presently distributed for triggered events a few minutes after an earthquake.Data latencies are mostly in the range 0-10 s, with the upper limit (constrained by satellite channel sharing) presently being reduced down to 3 s. Most of the stations are equipped with either Trillium 40s, 120s or 240s, or STS2 seismometers, coupled with Episensor accelerometers. In about 100 sites, continuous GPSs send stream data in real time to the INGV centres, at 1s or 30s sampling rate. Data from GPS receivers are available at http://ring.gm.ingv.it for a subset of the network. A few dense dial-up local networks in central contribute to the monitoring system.Beside a centralized acquisition in Rome, data from wide regions covered by the network are transmitted in real time to other INGV centres (Grottaminarda, Catania) to guarantee redundancy and disaster recovery. In volcanic areas, such as Etna and Vesuvio, dense multiparametric networks are operated in real time from INGV centres in Napoli and Catania. Original tools for seismogram analysis, earthquake locations, magnitude estimation, interactive mapping were also developed to better respond to the Civil Protection requests. Data from the last two years show the first important improvements, both in the number of located earthquakes (more than doubled compared to previous years), in location accuracy, and in the capability of computing rapidly earthquake source parameters.Current targets of the national network, which is still under development, include off-shore monitoring through OBS development and connection, integration with the strong motion national network, Shake Maps rapid computation (http://earthquake.rm.ingv.it/shakemap/shake/), early warning for targeted areas. With the high quality data now available, a wide variety of studies on earthquake source, crust and mante structure, and active tectonics have just started. In the next years they will allow to gain a much more detailed view of the evolution and present deformation of the central Mediterranean region.

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SS001 **Oral Presentation** **6142**

Imaging of seismic sources by Time-Reversal and application to recent large Earthquakes

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Jean-Paul Montagner, Carene Larmat, Mathias Fink, Yann Capdeville, Arnaud Tourin

The occurrence of the disastrous Sumatra-Andaman earthquake on dec. 26, 2004 makes it necessary to develop innovative techniques for studying the complex spatio-temporal characteristics of rupture. The concept of time-reversal (hereafter referred to as TR) was previously successfully applied for acoustic waves in many fields such as medical imaging, underwater acoustics and non destructive testing. The increasing power of computers and numerical methods (such as spectral element methods) enables one to simulate more and more accurately the propagation of seismic waves in heterogeneous media and to develop new applications, in particular time reversal in the three-dimensional Earth. We present here the first applications at the global scale of TR with associated reverse movies of seismic waves propagation by sending back time--reversed seismograms. We show that seismic wave energy is refocused at the right location and the right time of the earthquake. When TR is applied to the Sumatra-Andaman earthquake (26 dec. 2004), the migration of the rupture from the south towards the north is retrieved. All corresponding movies can be downloaded at the following webpage: http://www.ipgp.jussieu.fr/~larmat Other applications to recent smaller earthquakes will be also shown. Therefore, the technique of TR is potentially interesting for automatically locating earthquakes in space and time and for constraining the spatio-temporal history of complex earthquakes .

Keywords: time reversal, earthquake, imaging

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SS001 **Oral Presentation** **6143**

Instrumental noise of the STS-2 using 3-channel correlation analysis

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At low frequencies (e.g < 100 mHz) in the seismic spectrum the instrumental noise (or self-noise) of seismic recording systems increases like in any other active electronic component and may dominate the seismic signal. It is therefore important to have knowledge about the instrumental noise level, in particular at low frequencies, and to identify under which conditions the interpretation of the recorded data may be biased by the recording system. For example in studies towards the seismic low noise level or in seismic normal modes studies. Correlation analysis of 3 recordings from a common, coherent input signal is a new method to estimate the self-noise of the 3 recording systems, as well as to determine the relative transfer functions between the systems. The method does not require a priori information about the transfer function of the recording system, as is required in the conventional 2-channel correlation technique. This presentation will give the outline of the new correlation method and shows results from experiments using STS-2 sensors and Quanterra Q330 dataloggers.

Keywords: self noise, sts 2, 3 channel correlation

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SS001 **Oral Presentation** **6144**

Seismic Wave Gradiometry: Quantification of Dynamic Strain and Rotation

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Chuntao Liang

Dense seismic arrays, seismic strain meters, and seismic rotation meters can be utilized to investigate the variation in phase and amplitude of observed wave fields through seismic wave gradiometry. The spatial gradient of the seismic wave field can be parameterized using simple models of seismic wave propagation to obtain 2D images of wave slowness, azimuth, geometrical spreading, and radiation pattern variations. These images may be used in empirical studies of structure throughout a gradiometer array, source studies, and further modeling studies to determine earth structure. Gradiometer cells may consist of small arrays of matched seismographs to determine the wave spatial gradient through finite differences or a single 3 component seismograph in conjunction with a strain or rotation meter. Gradiometry techniques may be used at all wavelength scales from small scale seismic refraction and reflection experiments to continental scale broadband networks and arrays. Gradiometry essentially incorporates dynamic strain and rotation as an additional seismic observable in studies of source and earth structure and utilizes local measurements of the entire seismic wave field.

Keywords: array seismology, gradiometry, strain

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SS001 **Oral Presentation** **6145**

S-wave Tomography of the Crust and Uppermost Mantle in China

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We use 260,000 local and regional arrival times from 12,215 local earthquakes recorded by 220 seismic stations to determine a detailed three-dimensional (3-D) S-wave velocity structure of the crust and uppermost mantle under and surrounding regions. We use a travel-time tomography code that accommodates a layered crust and varying Moho depth. The grid for tomographic inversion is 11 in latitude and longitude and 10 km thick layers. Our results show that large velocity variations of more than 6% exist in the crust and upper mantle in the region. The velocity image of the upper crust correlates with surface geological features. The crustal heterogeneity is clearly observed. Velocity changes are visible across some of the large fault zones, and the faults and some large crustal earthquakes seem to occur at the boundary areas between slow and fast velocity anomalies. Some of the faults, such as the Red River fault, may have cut through the crust and reached up to the upper mantle. Low velocity zones beneath volcanic sites and the rifts are clearly observed in our tomographic results. Under the Tengchong volcanic area, strong low-velocity zones are visible down to 100 km depth, with a lateral extent of about 100 km, suggesting the existence of magma chambers under the volcano. Low velocity zones beneath other volcanic sites and the rifts are clearly observed in our tomographic results.

Keywords: lithosphere, seismic, tomography

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SS001 **Oral Presentation** **6146**

The western mediterranean seismic network: a joint effort at Ibero-Maghrebian Region.

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The Royal Naval Observatory in San Fernando (ROA), together with the Universidad Complutenseof Madrid (UCM), and in collaboration with the GeoForschungsZentrum of Potsdam (GFZ), have deployed a broad band seismic network around the Alboran sea, in southern Spain and northern Africa. This network named WM (Western Mediterranean) started to operate in 1996 with the installation of the SFUC station, near the San Fernando Observatory.Since then, seven stations have been deployed by ROA/UCM in this area with the objetive of having a broad-band network able to monitor the seismic activity at the Ibero-Maghrebian region. New partners ahve also jointedthe network:the Geophysical Centre of theEvora University incorporating EVO station on June 2006, and the Institute Scientifique of Rabaton July 2006, whenthe AVE station was installed. Two new stations are planned along 2007, at Ifrane (Morocco) and Oran (Algeria) the last one in collaboration with the Oran University. Actually, the WM network is composed by 9 stations with a common instrumentation: Streckeisen STS-2 sensor, a high resolution acquisition system Quanterra or an EarthData digitizer, and a process system Seiscomp, based on an embedded PC with Linux operating system (Heinloo, 2004). The WM stations, except AVE, CEU and PVLZ, are linked in near-real time with ROA data center via modem (ppp protocol) or internet. CEU station is powered by batteries and solar panels and, in order to decrease the power consumption, the Seiscomp PC are being placed about 1 km away from the digitizer (where electric power is available), linked by a serial Bluetooth. On other hand, AVE station is placed 18 km away of the place where internet connection is provided, at Berrechid (near Casablanca, Morocco), and a wireless internet link is being developed at ROA. The WM is a distribute network with several data collect centres, presently at ROA, Evora and the Institute Scientifique of Rabat. A data center will also be installed at the Oran University when ORAN station be installed. Each data collect centre takes charge to maintain and upgrade the data (data latency oscillates between 2 and 15 minutes) from their stations, acting ROA as main data centre.In this work the present status and the future of the broad band WM network are shown.

Keywords: western mediterranean, seismic network

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SS001 **Oral Presentation** **6147**

Focal Depth Determination of Local and Regional Earthquakes from P and S Coda Waves: A Time-Reversed Acoustics Approach

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In this paper we introduce a method to determine the focal depth of shallow earthquakes using an adaptation of the Time Reversed Acoustics (TRA) methodology. The basic concept used in TRA is that if the recorded waves from a source are reversed in time and pumped back into the medium the acoustic energy will propagate back to, and focus at, the original source point. In fact, when the medium is highly scattering, like the crust of the earth, the convergence to the source is greatly enhanced. This property of TRA is the main idea for back propagating the P and/or S waves with codas to the source location in order to obtain the source depth. The back propagation step in highly heterogeneous media reduces to an autocorrelation, meaning that detailed knowledge of the velocity field is not needed. The autocorrelation of the Greens function for the highly scattering medium is an approximate delta function. Thus the autocorrelation of the P wave, including its coda, gives two side peaks at delay times. Stacking autocorrelograms of several stations enhances the signal to noise ratio and provides a clear indicator of source depth from the time lag of the secondary peak, which is related to the pP depth phase arrival. The use of TRA for focal depth determination is tested with numerical models (synthetic seismograms) and with records from a number of shallow earthquakes and a quarry blast. The tests show that the method is highly effective, and practical to implement, for focal depth determination of shallow events from seismograms recorded at regional distances. Using both P and S waves and their respective codas further enhances the method. The use of shear waves (after filtering out surface wave phases) provides a means of validation of the method and the event depth estimates. This will separate depth effects from source asperity effects. Source asperities will result in the P and S wave analyses giving the same time lag, while depth phases (pP, sS) will give different time lags.

Keywords: p and s coda waves, tra methodology, back propagation

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SS001 **Oral Presentation** **6148**

Implementation of the Sabana's broadband seismic array in Colombia

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The adequate understanding of the seismic hazard is an imminent necessity for a country in permanent development as Colombia. Earthquakes that took place during the 20th century like Tumaco (1906), Bogota (1917), Quindio (1938), Quindio (1961), Caldas (1962), Quindio (1973), Valle (1976, 1979), Tumaco (1979), Popayan (1983), Murindo (1992), Paez (1994), Tauramena (1995), Pereira (1995) and Armenia (1999) show that the seismic phenomenon is one of the most important natural hazards for Colombia including serious social and economic repercussions. In spite of big efforts implemented by different institutions in order to reduce the seismic vulnerability in Colombia, the understanding of the nature of the seismic phenomena and its spatial and temporal distribution and evolution is insufficient. In order to estimate the seismic hazard it is necessary to know the geological conditions of those regions where the cities are developing, it is necessary to study their structure, dynamics and behavior, looking for information which allows understand the processes which generate the seismic events and to obtain an adequate model of ruptures of the system. In this paper we show the implementation of an instrumental seismological network for the Colombia's capital city: Bogota. The global project consists on fifteen seismological three components, broadband stations, located near the coordinates: 4.5 N latitude and 73.5 W longitude. This array is expected to be a complementary, high sensitive addition to the National Seismological Network of Colombia, which at present has only short period sensors. This array has to bring the possibility of improving the understanding of the seismic hazard in the Bogota's region, considering the better understanding of the spatial and temporal microseismic activity in this region, where live more than 15 millions people (30 % of Colombia's population), and more than 40% of the GIP is concentrated. Based on the obtained information it will be possible to incorporate structural elements to the adequate development of this region considering the seismic hazard and supply the guidelines to designs and constructions.

Keywords: seismic array, microseismicity, seismic hazard

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SS001 **Poster presentation** **6149**

Seismic activity in Khorasan province, north east Iran, obtained by the locally recorded earthquakes

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Dr. Mohammad Reza Gheitanchi

In this study the Khorasan province is referred to the region limited from 30 to 40 degrees north latitude and from 52 to 62 degrees east longitude. The major tectonic regimes of this region are the Kopeh Dagh folded belt, the eastern Alborz and the central and eastern Iran. This region has experienced many destructive earthquakes, including major historical earthquakes during the past eight centuries and the teleseismicly located large earthquakes. We use seismic data collected by the local seismological network that was deployed in Khorasan province in 1996. About 1436 earthquakes were processed by Khorasan seismic network occurring during the period 19962006. The distribution of epicenters suggests two main active areas in north and southern parts of Khorasan. Several fault plane solutions suggest the presence of thrust and strike-slip faulting. The majority of events were shallow and most of the large shocks were accompanied by surface ruptures. It is concluded that the seismic activity in this region is taking place in upper crust and the seismogenic layer has a thickness of about 20 km. Our study suggests that there is a NE-SW shortening within Iranian plateau which is mainly due to the northeast compressional stress between Arabia and Turanian Plateau.

Keywords: khorasan, seismicity, tectonic

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SS001 **Poster presentation** **6150**

Study on the time-varying aharacter of kinematic parameters about small earthquake sequence in seismic window

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Most earthquakes of low focus are the macro phenomena that rocks large-scale crack occurred under the tectonic ambient shear stress. The tectonic ambient shear stress field is the important parameter that control the earthquake occurred. The state of stress field can be described quantificationally by this parameter. Apparent stress and average stress level that lead earthquake slide can be contracted by earthquake wave radiant efficiency. Averaging the average stress level that lead earthquake slide in some area can be regarded as indirect estimate to the absolute stress level. In this paper, velocity peak value and acceleration peak value can be calculated by using earthquake wave that recorded by digital earthquake station net. Then the ambient shear stress can be obtained. The earthquake radiant energy and earthquake moment can be measured independently. The medium parameter near the focus area was inversed by earthquake wave data. Based on this, the apparent stress can be obtained. In this paper, the tectonic ambient shear stress and apparent stress varying character of the small earthquake sequence in seismic window of huoshan was detailed studied by using the digital earthquake data in anhui province and its region. The results indicate the value of tectonic ambient shear stress and apparent stress not only reflect strong or weak stress background in earthquake source region but information of stress background around earthquake generating area in special tectonic position namely the small earthquake in seismic window of seismic activity point apart from future strong earthquake epicenter . The difference about the stress state is distinct before and after mid-strong earthquake in east china.

Keywords: seismic window, tectonic, apparent

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SS001 **Poster presentation** **6151**

The abnormal tremor detected by gravimeteratiltmeter and broadband seismometer

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China owns many observation stations within high-precision instruments, such as broadband seismometerAtiltmeterAstrainmeterAgravimeter and so on. Theoretically, the signals detected by all these instruments together contain the periods from few seconds to several hours. What other geophysical signals we can observe except the earthquake wave and the earth tide? So we develop observation experiment for the signal by the digital broadband seismometer; gravimeter and pendulum tiltmeter. All these instruments are installed in the observation station of Huazhong University of Science and Technology (HUST) in Wuhan of China. This paper reports the observation results and the preliminary analysis on abnormal tremor in recent two years. The main contents are: Since the end of 2004, we have observed some dozens of tremors. They can be synchronous detected by broadband seismometerAgravimeter and tiltmeter clear, but weaker than earthquake wave and the earth tide. The most of tremor continuance time about two to five days. The preliminary analysis indicate that these tremors have no obvious correlation with the observation environment and the change of temperature and air pressure, but have strong relationship to occurrence of strong earthquakes and the typhoon in Chinese Mainland coast. And they were different spectrum structure between the tremor caused by typhoon and earthquake, The tremor is different from the gslow earthquakeh and gsilent earthquakeh. The present analysis showed that: it contains many signals from several ten seconds to one hour period.

Keywords: tremor, gravimeter, seismometer

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SS001 **Poster presentation** **6152**

Analyses of astronomical background of largest earthquakes in the world

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The National Earthquake Informational Center of the United States of America published a list of 14 largest earthquakes in the world on the web site http://wwwneic.cr.usgs.gov in 2005. The magnitudes of the largest earthquakes are greater than or equal to 8.5. This paper analyzes the astronomical background of the 14 largest earthquakes. The results show that there are 4 main characteristics in the astronomical background. (1) According to our analyzing for the earthquakes of magnitude greater than or equal to 7.0 in the world in the 20th centur, the major earthquakes of the principal seismic belts or regions obviously are affected by the lunar node tide. Only the phases of the belts or regions with respect to the lunar node tide are different one another. 11 of the 14 largest earthquakes have occurred in the seismic belts or regions which is being corresponding the seismic active period with the lunar node tide. (2) 11 of the 14 largest earthquakes occurred in the falling period of solar activity, which is seventy nine per cent of the total and much concenteated. (3) 10 of the 14 largest earthquakes occurred in the accelerating period of the earth rotation or near turning points of the earth rotation curve. This is as for the variation of long period of astronomical factors. (4) For the variation of short period of astronomical factors, whether for local time or local sidereal time and lunar phase there is phenomenon of occurrence of concentrating in certain time interval for the earthquakes. These are practically the effect of the lunar and solar tide for the lunar phase and local time. For the short variation of earth rotation this phenomenon is clearer; either the earthquakes occur in the most fast or in the lowest of the earth rotation. The above mentioned results indicate that the earthquake occurrence is affected by astronomical factors. The astronomical factors are one of motive force causing earthquake from outside the earth. The astronomical factors with long period may act as modulation for the earthquake pregnant process, and the astronomical factors with short period will causeing huge fluctuations of the system and an earthquake occurs when it acts on seismic structure away from the balance state. In other words, the astronomical factors with long period, such as lunar node tide, solar activity and long variation of the earth rotation participate in the accumulation of energy of the largest earthquakess and one with short period provid the outside condition of the occurrence of the largest earthquakes. Therefore, as for extenal astronomical factors, the occurrence of the largest earthquakes is absolutely no without reason or cause, and has centain asteonomical background.

Keywords: largest earthquake, astronomical background

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SS001 **Poster presentation** **6153**

Investigation of precursory seismicity in Iran with special attention to background gaps and preparation gaps

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The Iranian plateau is a relatively wide zone of compressional deformation along the Alpine-Himalayan active mountain belt that is entrapped between two stable platforms, The Arabian plate and the Turan platform (Eurasia) in the northeast. Its deformation is related to continuing convergent movement between the Arabian plate to the southeast and the Turan platform, by the north-northeastward drift of Afro-Arabia against Eurasia. Iran is on one of the seismic areas of the world and is frequently affected by destructive earthquakes, imposing heavy losses in human lives and widespread damages. Seismic gaps are the most important precursory patterns in spatial distribution of earthquakes. There are two kinds of precursory seismic gaps, called background gaps and preparation gaps respectively. A background gap is surrounded by relatively large earthquakes in a larger area with the longer duration. Forming a background gap means that the stress field in the gap region and its vicinity is intensifying; while a preparation gap is surrounded by smaller earthquakes in a smaller area and with shorter duration before the impending major earthquake. Preparation gaps are generally situated inside the background gaps. The characteristics of the seismicity patterns mainly observed in China have shown certain ability of prediction. In this study, we plotted more than 6000 earthquakes in Iran, and obtained more than fifteen background gaps and preparation gaps in five major seismotectonic provinces. Some of these gaps are related to the earthquakes happened before, such as Rudbar earthquake on June.20.1990, Bam earthquake on December.26.2003 and Dorud earthquake on March.31.2006; and some of them are preparation gaps which are formed in Bushehr in Zagros seismotectonic province and Dasht-e-Bayaz in Centeral-East of Iran. Seismotectonic provinces are examples of candidate places for occurrence of future earthquakes.

Keywords: seismic gaps, intermediate term prediction, seismic precursory

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SS001 **Poster presentation** **6154**

Seismicity investigation of Iran (2004/07/01 to 2006/12/30) by using Iranian National Broadband Seismic Network (INSN)

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Gholam Javan Doloei

Iranian plateau has been registered as one of the most active areas of the world that always experiences destructive and catastrophic earthquakes. Considering the great importance of seismological studies in Iran, Iranian National Broadband Seismic Network (INSN) has been designed in early 1990s. The site selection, construction and installation of seismic equipment have been started since 1995. INSN established to study the seismotectonic of Iran, earthquake location, rapid announcement to rescue teams, mitigation of seismic hazards, deriving crust and upper mantle structure beneath Iranian plateau. At the present, INSN has been equipped with fourteen 3-components broadband seismic station across the country in which the continuous real time data are transferring to center of network at the main building of IIEES through VSAT. Reliable and fast earthquake location and informing responsible persons via SMS, electronic mail (E-mail) and IIEES web site is one of the main successive achievements of IIEES. The validity of our earthquake location in comparison with other local and regional agencies have been showed fairly good agreement of our results with damaged area, while other agencies have an uncertainty of location about 40 Km. The main goal of this article is to locate and to analyze the Iranian earthquakes since commencement of INSN stations with new instruments, which were recorded at least in three stations. Our study is limited to seismicity of Iran from 2004/07/01 to 2006/12/30. At this period INSN recorded and located more than 2800 events with magnitude range between $2<M<7$. Two-year seismicity map is in fair agreement with active faults of Iran. The local magnitude (ML) is determined for events in Richter scale.

Keywords: broadbandstation, insn, seismicity

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SS001 **Poster presentation** **6155**

Three-dimensional spatial distribution of scatterers in the Canary Islands

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A three-dimensional spatial distribution of relative scattering coefficients is estimated in the lithosphere of the Canary Islands volcanic complex by means of inversion analysis of coda wave envelopes. The inversion analysis is performed by means of the Filtered Back-Projection method (FBP) which is a fast non-iterative algorithm that has proved by the authors to provide very accurate reconstructions. Data used consist of selected 400 vertical-component, short period recordings of microearthquake codas from shallow earthquakes with magnitudes ranging from 2 to 4 and epicentral distances up to 100 km recorded by 12 stations of the Canarian seismograph network. The degree of heterogeneity at the scale length of the studied frequency bands is discussed. Then, a correlation of the observed distribution of scatterers with the presence of a NE-SW reverse fault between the islands of Tenerife and Gran Canaria as well as with the results of other geophysical studies performed in the archipelago is suggested.

Keywords: coda waves, scattering, canary islands

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SS001 **Poster presentation** **6156**

Seismicity of Bosnia&Herzegovina in the period 19962005

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During the 19952005 periods, seismic activity of Bosnia&Herzegovina was confined to the previously identified seismically active areas. All together 293 earthquakes were located. Seismically the most active was the southern part of Bosnia&Herzegovina, especially in Trebinje, Ljubuski and Nevesinje epicentral areas, with magnitudes 5.2, 5.1 and 5.1, respectively. These tree events were the strongest ones recorded in Bosnia&Herzegovina during the studied period.

Keywords: seismicity, bosniaherzegovina

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SS001 **Poster presentation** **6157**

Hypocenter relocation in south of Jiangsu Province and adjacent area, China, by using DD and GA jointly

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We use Double-Differnce(DD) technique and Genetic Algorithm(GA) jointly to relocate hypocenters in south of Jiangsu province and adjacent area(29-34N, 117.5-122.5E) which located on the East China. The location accuracy is basically same for above two methods. The result of DD-relocated events can be expected to give precise relative location for neighboring events, but the apart distance of events pairs are not far due to crustal heterogeneity. 58% original events can be used to DD, 42% events were located by GA using same crustal model as DD. We found the directions of some important faults agree with earthquake distribution line, for example, Chenjabao-Xiaohai Fault, Taizhou Fault, Subai-Binhai Fault, Hongze-Goudun Fault, Chuhe Fault, Huzhou-Suzhou Fault, Taichang-Fengxian Fault, Maoshan Fault, Wuxi-Chongming Fault and so on. The deep geometry of Maoshan Fault on which occurred M6 earthquake in 1979 was analyzed, the result shows that the fault trend is SE, dip is 60-65,the end of fault can reach 23km, the distance between epicenter of M6 event and emergency on ground is about 8-9km, focal depth is 12km. The deep geometry of Taicang-Fengxian Fault on which occurred M5.1 earthquake in 1990 shows that the fault trend is SW, dip is 60-65,the end of fault can reach 18km, the distance between epicenter of M5.1 event and emergency on ground is about 3-6km, focal depth is 14km. The deep geometries of other major fault and swarms were estimated.

Keywords: relocation, dd and ga, tectonics

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SS001 **Poster presentation** **6158**

Focal Mechanisms of Small and Moderate Size Earthquakes Recorded by the Egyptian National Seismic Network (ENSN), Egypt

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Seismic activity in Egypt, while generally moderate constitutes a significant hazard as was demonstrated by the aftermath of the moderate-sized 1992 Cairo earthquake. In this study the digital records of the new installed Egyptian National Seismic Network (ENSN) from 1997 to 2003 is used to evaluate the focal mechanisms with high reliability. The analysis is based on P, SV and SH polarities and their amplitude ratios. The solutions of fifty events are used to examine the mode of tectonic deformation and the present day stress field acting along different tectonic provinces of Egypt. The results exhibit mainly normal faulting generally trending parallel to the Gulf of Suez-Northern Red Sea rifts and tend to lie WNW-ESE to E-W on land inside the Egyptian territory. Some mechanisms reflect small component of shear especially for the events located close to the intersection points of two fault trends. A dominant tension stress prevailed at the NE corner of Africa directed NE-SW to ENE-WSW along the Northern Red Sea- Gulf of Suez-Gulf of Aqaba rifts while trends NNE-SSW on the Egyptian land. Four mechanisms on the northern Red Sea closer to the intersection point of the Northern Red Sea-Gulf of Suez-Gulf of Aqaba faults show strike slip faults with minor normal component with unexpected NW-SE tension stress that reflects a heterogeneous stress at that point or slipping along pre-existence NE-SW fault. Three mechanisms around the Naser's Lake give mainly strike slip faults with minor normal components. The solution of a moderate sized event along the Mediterranean coast show reverse mechanism trends NNW-SSE with P-axis directed ENE-WSW similar to that prevailed at the most eastern side of the Hellenic arc and the western side of the Cyprean arc. The changes from a dominant tension on land to a dominant compression towards the Mediterranean Sea have occurred along the transition zone between the continental-oceanic crusts. This change indicates an extension of the back thrusting effect and/or positive inversion of the pre-existence passive margin due to the sunduction and collision of the African plate with the Eurasian plate.

Keywords: focal mechanism, seismotectonics of egypt, seismicity of egypt

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SS001 **Poster presentation** **6159**

Control Experience of Tavshut Dam on Dynamic Influences

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In Armenia many earthen dams which are maintained more than 30th years and because the country is in one of the seismic active regions of the world at strong seismic events the probability of their destruction strongly grows. On this the control of their behavior at seismic and other dynamic influences gets paramount importance. For the decision of this task, we created special system of the seismometric equipment with which help it is possible to observe the various dynamic processes occurring both on a dam, and on ground, being the base of a dam. For the first time in Armenia such system was established on Tavshut dam. The seismometric equipment system contains more than 30 seismic receivers for registration of speeds of displacement and accelerations, the switchboard with the analog-digital converter, a computer and the special power unit intended for emergencies, at disconnect of a feed of network. Seismic receivers are established in five points on a dam and in three points on a ground. The circuit of seismic receivers installation is picked up so that at seismic influences first three forms of fluctuation of a construction have turned out. During the operation of this system, for the present it was not possible to fix seismic events, but were registered set of events of local character. As a result of the analysis of these events anomalies of speeds and acceleration displacement in the certain site of a dam were revealed. Careful visual survey of a body of a dam has confirmed presence of a dangerous site as residual deformations.

Keywords: seismicobservation

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SS001 **Poster presentation** **6160**

Source Parameters of Small Earthquakes in the South of Sakhalin (Russia)

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Frequency-depended attenuation factor of Southern Sakhalin is obtained from seismic coda of local earthquakes assuming a single backscattering wave model. Seismic moment, source dimension and stress drop of 162 small earthquakes (1.3 ≤ ML ≤ 3.5) occurred in the south of Sakhalin are computed. Digital waveforms obtained by the local network of seismic stations located over the southern part of Sakhalin Island are used in the calculations. Dynamic source parameters of shocks are determined using SH-wave spectra after attenuation and geometrical spreading corrections assuming Brune source model. The log-linear relationship log10 M0 = 1.25 ML + 9.01 between seismic moment M0 (N m) and local magnitude ML is obtained. Average relations of source parameters poorly differ from the world-average data in the main magnitude range, although differences have taken place and discussed in this study.

Keywords: source parameters, seismic moment, attenuation factor

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SS001 **Poster presentation** **6161**

Seismic activity in Khorasan province, north east Iran, obtained by the locally recorded earthquakes

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In this study the Khorasan province is referred to the region limited from 30 to 40 degrees north latitude and from 52 to 62 degrees east longitude. The major tectonic regimes of this region are the Kopeh Dagh folded belt, the eastern Alborz and the central and eastern Iran. This region has experienced many destructive earthquakes, including major historical earthquakes during the past eight centuries and the teleseismicly located large earthquakes. We use seismic data collected by the local seismological network that was deployed in Khorasan province in 1996. About 1436 earthquakes were processed by Khorasan seismic network occurring during the period 19962006. The distribution of epicenters suggests two main active areas in north and southern parts of Khorasan. Several fault plane solutions suggest the presence of thrust and strike-slip faulting. The majority of events were shallow and most of the large shocks were accompanied by surface ruptures. It is concluded that the seismic activity in this region is taking place in upper crust and the seismogenic layer has a thickness of about 20 km. Our study suggests that there is a NE-SW shortening within Iranian plateau which is mainly due to the northeast compressional stress between Arabia and Turanian Plateau.

Keywords: khorasan, seismicity, tectonic

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SS001 **Poster presentation** **6162**

The crustal structure beneath the Iranian plateau from joint inversion of receiver functions and surface waves dispersion

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Surface wave group velocity dispersion and P-wave receiver function inversion techniques provide complementary information regarding crustal and upper mantle structure. Previous studies show that receiver function method is an efficient tool for determining Moho depth [Ammon et al., 1990; Sheehan, 1995], and crustal velocity models [Cassidy, 1995]. However, receiver functions are mostly sensitive to sharp velocity contrasts, and relatively insensitive to the average velocity and to smooth velocity gradients. Group velocity dispersion is sensitive to average shear velocity over a broad range of depths between two seismic stations. While extremely useful for determining the general velocity profile with depth, dispersion techniques are largely insensitive to velocity discontinuities. Combining these complimentary tools in a single inversion allows for more unique analyses of crustal and upper mantle structure and increases the uniqueness of the solution over separate inversions and also facilitates explicit parameterization of layer thickness in the model space. More than one year of teleseismic waveforms recorded by 11 broad band stations of Iranian National Seismic Network (INSN) were used to study structure and thickness of the crust in different parts of Iran by joint inversion of receiver functions and regional surface wave group velocities. Information about the group velocity dispersion comes from tomographic images between 15 and 60 s period produced by a study of regional fundamental mode Rayleigh waves propagating across Iran and surrounding regions (Rham et al., 2005). The preliminary results indicate an average crustal thickness of 45-50 km beneath most of the INSN stations. A Moho depth of 35 (+/-2) km beneath the Mako station located in NW of Iran, consistent with gravity studies (Dehghani and Makris, 1984) and previous results (Tatar, 2001), indicates on existing of a thin crust in Northern west part of Iran.

Keywords: joint inversion, receiver functions, surface waves dispersion

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SS001 **Poster presentation** **6163**

Anomalies of shear wave attenuation field in the regions of Semipalatinsk, Nevada and Lop Nor test sites

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We have been studying characteristics of shear wave attenuation field in the regions of Semipalatinsk (STS), Nevada (NTS) and Lop Nor (LTS) test sites. Recordings of underground nuclear explosions (UNEs), chemical explosions and earthquakes, obtained by digital and analog seismic stations, were analyzed. We have been considering spatio-temporal variations of an amplitude ratio of Lg and Pg waves and also that of S and Lg coda envelopes. The data obtained show, that at the end of 1980-s in comparison with the beginning of 1970-s attenuation increased strongly in the earths crust and, as a whole, diminished in the uppermost mantle in the region of the STS. At the same time, local areas of high attenuation exist at the depth interval of ~20-120 km under large deep fault zones at the Balapan site of the STS. Since 1992, a territory of the NTS was characterized by higher attenuation in the earths crust and weaker attenuation in the uppermost mantle relative to surrounding areas. It has been shown, that in 1996-2002 attenuation was relatively low in the earths crust and high in the uppermost mantle of the LTS. These data can be explained by active juvenile fluid migration (at the beginning a concentration in the upper mantle and a following ascent into the earths crust) as a result of protracted intensive technogenic influence. This process was the most active at the NTS, where the crust has a highest permeability, and the least active at the LTS, where comparatively small quantity of UNEs have been produced.

Keywords: nuclear, explosion, attenuation

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SS001 **Poster presentation** **6164**

T-Wave excitation: multiple anisotropic scattering on and below the seafloor with examples from Bransfield Strait, Antartica

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Oceanic T-waves generated by either marine-seismic sources or earthquakes can travel great distances within the ocean-sound (SOFAR) channel with little loss in signal strength. Although they were first identified almost fifty years ago, their excitation mechanism has not been clearly resolved. In this study, we address the effect of multiple anisotropic scattering on and below the seafloor in an attempt to explain quantitatively the generation of T-waves. We first apply a Monte Carlo simulation method based on the radiative transfer theory to deal with anisotropic multiple scattering on the seafloor and in the lithosphere since the scattering pattern is never isotropic even in the case of ak << 1, where a and k are correlation distance and wavenumber, respectively. We then systematically compute the excitation of propagating acoustic modes using modal scattering from a rough seafloor having non-planar bathymetry and random boundary roughness defined by the Gaussian autocorrelation function. We also show that anisotropic scattering as well as a rough seafloor in the epicentral region could significantly contribute to the excitation of T-waves. Lastly, we will compare synthetic T-waves with those observed from data collected by seven Autonomous Underwater Hydrophones (AUHs) moored in the Bransfield Strait, Antarctica from November 2005 to November 2006.

Keywords: t wave, scattering, auh

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SS001 **Poster presentation** **6165**

Aftershock sequence and main shock investigations of 2005 Dahuieh (Zarand) eartquake in kerman province, South-East Iran

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Mohammad Reza Geitanchi

Locally recorded aftershock sequence of the 2005 Feb. 22 dahuieh (Zarand) earthquake (Mw=6.4 given by USGS) was analyzed. Aftershock processing has done by using the records of 24 permanent (in Iran) and 5 temporary short period (PDAS) seismic stations. A W-E trend near vertical faulting with an extension of about 15-20 km could be suggested by the distribution of aftershocks and source dimension calculation. The fault rupture causing the Dahuieh large and destructive earthquake apparently initiated in the modified epicentric area and propagated unilaterally to the west. The cross-section of aftershocks along the fault suggests that the aftershocks had a depth range of 20 km, indicating that the seismic activity was taking place within the upper crust and the seismogenic layer had a thickness not greater than 20 km in this region. The distribution of aftershocks and right-lateral motion of Kuh-Bannan (one of active faults in South-East) fault suggested that the earthquake related fault must be reverse and northern block acted as hanging wall during the source process of the main shock. One distinguished gap, was formed by the epicenter distribution of aftershocks, and s minus p calculation show that the gap suggested as modified main shock location(the epicenter of main shock was modified as 30.80N and 56.84E, having a depth of 9 km witch has good corresponding with wave form modeling(Talebian et. al. 2005)). The extent of aftershocks activities and calculations indicated a range of 15-20 km source dimension, and was in agreement with the observed surface rapture (Talebian et.al. 2005). Considering the epicenter of main shock as the initial break, comparing of two near accelerographs in the West and the East of the rupture, and the distribution of locally recorded aftershocks comparing epicenter of main shock, indicate that the rupture be initiated in the East and extended to the West in a unilateral manner. The time-frequency pattern of aftershocks decay followed stretched exponential descending function of n (t) = 17.04exp (-0.032t). Paying attention to main shock depth, 9 Km, and grater seismogenic zone thickness, about 20 Km, in this area it is concluded that the Zarand region has siesmicity potential grater than 6.4 magnitudes.

Keywords: aftershock, seismology, south east iran

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SS001 **Poster presentation** **6166**

The aftershocks of the 1970 Tonghai and the 1976 Tangshan Great Earthquakes: Difference and Interpretation

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Gui-Ling Diao

Comparison of the 1970 Tonghai and the 1976 Tangshan Earthquakes sequences indicates that there are obvious differences between these two Earthquake sequences. We observe differences in time, space and magnitude. The aftershock decrement of Tangshan earthquake is slower than that of the Tonghai earthquake, the aftershocks of Tangshan earthquake sequence are more and stronger than those of the Tonghai sequence and the epicentre area of aftershocks of the Tangshan earthquakes is wider than that of the Tonghai earthquake. These differences possibly reflect the different adjustment processes of the media exposed to the dislocation effects of the main shocks. Let a be the major axis of the area of aftershocks and b be the minor axis of that area. For faults with a similar dip, a larger a/b ratio would imply that the stresses are released on or close to the rupture fault plane whereas a small a/b ration may suggest that the aftershock occurred in a volume. The adjustment process over a plane are expected to be simpler; i.e., associated with a quicker decrease in the number of aftershocks and with less number of strong aftershocks as compared to a situation where the adjustment process takes place in a ruptured volume. The a/b ratio associated with the Tangshan aftershocks (a/b = 1.3) is less than that of Tonghai where a/b = 2.2. Following the assumption made above, the aftershocks of the Tangshan earthquake occur in a volume while those of the Tonghai earthquake tend to occur over a plane. This will also explain the observed differences between the aftershock sequences of the two earthquakes.

Keywords: tangshan earthquake, tonghai earthquake, aftershock sequence

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SS001 **Poster presentation** **6167**

Differentiated tomography in comparision with standard LSQR technique and double-difference tomography

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We give cruxes of new theory to solution of linear inversion problem in seismic tomography. The developed differentiated approach (DA) to the over-determined sparse system is different from the standard least-square method by means of the selection of observations are having the maximal low probability of error. We demonstrate the DA tomography images are produced using aftershocks data of the fault zone in Western Nagano (Japan), which include more than 8000 events and 30 registered stations. The DA relocation results are compared with the outcome of LSQR technique. This shows the better ability of DA to simplify the complex fault patterns and to reveal hypocenters with maximal amplitude of the location error. The comparison of DA with Double-Difference (DD) tomography is illustrated for different cross-sections (XOY, XOZ, YOZ). We conclude that DA retrieves the very thin main fault plane in the well-defined velocity structure. Thus the obtained DA images are in very good agreement with geological studies. This had not been achieved by the DD method.

Keywords: seismictomography, inversiontechnique

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SS001 **Poster presentation** **6168**

Statistical evaluation of the parameter of repetition of the earthquakes and its change in space and time

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Nahapetyan Hasmik

In this work was done an attempt to give a statistical evaluation of the parameter b of angular coefficient of inclination of the graph of repetition of earthquakes in the space and time: 1) 1900-1961, 2) 1962-2001 in Armenia and contiguous regions of Turkey and Iran by two methods: the method of the least squares and the method of maximal liklehood. The events of the catalogue are located in two-dimensional histogram in dependence from the year (1962-2007) and energetic class (K), and magnitude (M) . The quantitative distribution of the earthquakes in space allowed to pick out seismogenic zones and subzones. For the territory of Armenia and contiguous regions for the picked out seismogenic zones we built graphs of repetition by above mentioned periods. Grouping by magnitude were carried out by the step M=0.25 and for energetic class K=0.5. The average value of the parameter b=0.49 0.02. For revealing of the change of the parameter (b) in time and in the periods which are preceding the strong earthquakes weve evaluated the parameters of the repetition of covering of three year, five year, ten year period of observations. When we study a big interval of time, it is a constant value for each separate seismogenic zone. For instance for Zangezur and contiguous regions Turkey and Iran b=0.5; the statistical evaluation of the angular coefficient of inclination of the graph of repetition while studying of the seismic regime for a short period of time, before the strong earthquake is observed a fluctuation of the value b. For obvious presentation of the change of the angular coefficient we built a map breaking the territory into cells with the step (0.2 0.2) and calculating the values b1,b2,...,bn in each cell. From the map of the angular coefficient b, it is obvious that its value on the territory is ambiguous. The value of b is varying in the range of 0.5 0.9. Before the Spitak earthquake of 1988 was observed a depression of the value b up to 0.35 (for the given zone b=0.49). The coefficient of the inclination of the graph of repetition is a parameter for prediction. Before the strong earthquakes observes a reduction of the value of b in space and time.

Keywords: graph of repetition, prediction, earthquake

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SS001 **Poster presentation** **6169**

Tuning Antelope configuration for best earthquake location

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Damiano Pesaresi, Adriano Snidarcig

The large amount of digital data recorded by permanent and temporary seismic networks makes automatic analysis of seismograms and automatic wave onset time picking schemes of great importance for timely and accurate earthquake locations. Since 2002 the Centro di Ricerche Sismologiche (CRS, Seismological Research Center, http://www.crs.inogs.it/) of the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS, Italian National Institute for Oceanography and Experimental Geophysics) is involved in the EU Interreg IIIA project Trans-national seismological networks in the South-Eastern Alps together with other four institutions: the Earth Science Department of the Trieste University in Italy, the Civil Protection Department of the Friuli-Venezia Giulia Autonomous Region (DPCFVG) in Italy, the Environmental Agency of the Republic of Slovenia (ARSO), and the Austrian Central Institute for Meteorology and Geodynamics (ZAMG). The Antelope software suite has been chosen as the common basis for real-time data exchange, rapid location of earthquakes and alerting. Each institution has an instance of Antelope running at its data center and acquires data in real-time from its seismic stations and those of the other partners. Antelope detects events by STA/LTA algorithm and the association is based on location by grid search. The actual set up for fast location capabilities uses only P arrivals. The location is performed by grid search over 87x81 nodes for an extension of 7x6.4 degrees (corresponding to cells of 8.9 km in longitude and 8.7 km in latitude) centered in Lat=46.26o, Lon=13.28o with depth steps at 0, 2, 4, 6, 8, 10, 12, 14, 16, 20 and 24 km, using the 1D uniform velocity model IASPEI91. Recently the CRS acquired a new SUN cluster hardware: consequently a new set up of the Antelope software suite has been tested to improve location accuracy using a denser grid and also S-phases arrivals. The results of the performances of the new configuration will be shown; in particular, we compute the variance of the differences between the location data sets of the two different configurations, inferring the precision of each data set by comparing them with the reference OGS bulletin database. We adopt the recall, precision and accuracy estimators to appraise objectively the results and compare them with those of the other datasets.

Keywords: earthquakes, location, picking

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SS001 **Poster presentation** **6170**

Seismotectonics along the northeastern margin of Amurian plate in Sakhalin, Far Eastern Russia, and Hokkaido, northern Japan, inferred from the 2004 Rumoi Earthquake (M6.1) and the 2006 Gomozavodskoe Earthquake (M5.9)

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1. 2004 Rumoi Earthquake (M6.1) On December 14, 2004, an M6.1 earthquake occurred in the northwestern part of Hokkaido, Japan, where suggesting plate boundary between Amurian and Okhotsk plates. We installed nine temporal seismic stations around the source area immediate after the occurrence and had continued the observation for about two months. We determined a mainshock mechanism solution by P initial polarities, 823 aftershock hypocenters with high precisions, and then, estimated one dimensional P-wave velocity structure model. Aftershocks are clearly distributed on an eastward dipping plane with a dip angle of about 25 degree, which well agrees with one of the nodal planes of the focal mechanism. We also estimated three-dimensional P-wave velocity structure based on the temporary travel time data. This indicated that aftershocks are mainly distributed on the velocity boundary. 2.2006 Gomozavodskoe Earthquake (M5.9) On August 17, 2006, an M5.9 earthquake on occurred in the southwestern part of Sakhalin, far eastern Russia. We have operated nine offline seismic stations in the focal area since 2000. Therefore, we could determine 174 aftershock hypocenters with high accuracy, and estimate one dimensional P-wave velocity structure model. Aftershocks are clearly distributed on a southwestward dipping plane with a dip angle of about 45 degree. This plane well aggress with a nodal plane by global CMT solution. 3.Seismotectonics along the northeastern margin of Amurian plate These two earthquakes are located along the northeastern margin of Amurian plate boundary, where ~1cm/yr east-west convergence relative to Okhotsk plate is estimated from GPS observation. Focal mechanisms of these two events indicate east-west compressional pure reverse faulting. This fact agrees with relative plate motion in this region. Therefore, these events are due to plate convergence in these regions. Rumoi earthquake is one of the tectonic events which uplifting marine terrace along the northwestern Hokkaido coast with 150km long. Gomozavodskoe earthquake is also re-activation of an echelon fault which was formed associated with the Japan Sea opening until 15Ma. These seismic events clearly indicate active plate convergence progress. Deeper aftershock of the Gomozavodskoe events (16-26km) also agree with low heat flow and may suggest thick crust structure comparing near Pacific subduction zone area. These events are probably resulted from fold and thrust compaction of upper crust which is observed in geomorphological and geologic features in this region.

Keywords: seismotectonics, hokkaido, sakhalin

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SS001 **Poster presentation** **6171**

Hypocenter determination in complicated cases using network beamfroming technique

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The problem of reliable and accurate seismic event location is a key issue in the earthquake monitoring systems of different scales and in the early warning systems. This issue is determined by how we manage to fight various detrimental factors such as sporadic seismic noise, poor network configuration, heterogeneity of Earth, wrong phase association or multiple event manifestation. For this purpose we have development a robust sparse network location technique, based on small array beamforming principles: Network Beamforming (NB), which processes bulletin phase arrival time data via the use of complex exponents in a grid-search for the maximum semblance in hypocenter space. The use of the robust semblance statistic provides reliable and fast phase association and location results for 1D and 3D Earth in local, regional and teleseismic distance ranges, effectively separates double events and associates depth phases. The method is working in combination with several automatic picking approaches and effectively resists to false readings.

Keywords: event location, network beamforming, early warning systems

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SS001 **Poster presentation** **6172**

Correlation study of ambient seismic noise using broad-band network recordings in Israel

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Shapiro and Campillo (2004) have shown recently that broadband surface waves can be extracted from ambient seismic noise recorded at pairs of seismic stations and their dispersion characteristics can be measured in a broad range of periods. This non-trivial result is based on the theoretical finding (Snieder, 2004; Wapenaar, 2004) that the cross-correlation process applied to diffused noise recordings at a pair of stations accumulates over time the coherent deterministic components which coincide with an accuracy of frequency dependent scaling factor with a Green function of the trace between stations. Because noise data are easily available and are not earthquake dependable, we are witnesses nowadays of the headily emerging new field of seismological research. The new method was tested and verified on half-year time-series of the broad-band seismic permanent network installed in Israel and Cyprus taking for analysis firstly only days without energetic earthquakes which are the undesirable source of a noise contributing decreasing the SNR. Testing of different kinds of clipping of single-station data have shown that the best resolving capacity of the cross-correlation analysis gives the so-called temporal and spectral normalizations suggested by Bensen et al. (2006) which essentially reduce the influence on the cross-correlations of earthquakes, instrument irregularities and so on. Moreover, temporal and spectral normalizations are data-adaptive procedures allowing automating data processing without using a catalog and data visualization. The goal of our investigation is to improve the calibration of surface wave propagation in Israel. We computed vertical and transverse components of broad-band cross-correlations to produce Rayleigh and Love wave Greens functions for all available station to station paths within the network using one- and two-year time-series. The resulted cross-correlations are partially asymmetric and this asymmetry depends on the frequency band that supports an idea about acting here different kinds of directional noise sources. Application of the multiple-filter analysis to the waveforms extracted from the ambient seismic noise gives us a set of broad band surface-waves dispersion curves which are a database for generating of 1D Vs profiles and 2D group velocity maps of the crust and shallow mantle in the study area.

Keywords: cross correlation, surface waves, dispersion

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SS001 **Poster presentation** **6173**

Detailed investigation of the intermediate depth seismicity of the Vrancea region (Romania) during the last decade

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Taking advantage of the compilation of a homogeneous earthquake catalog for the Vrancea region (Romania), the present work aims to perform a detailed study of several parameters characterizing the intermediate depth seismicity. The earthquake catalogue is homogeneous from the point of view of magnitude estimate and it is obtained using recent, accurate structural models. The catalogue is based on the records provided by 2 permanent seismic networks (the telemetered network consisting of 14 short period stations, and the K2 digital accelerometer network composed of 44 instruments), and the large tomographic experiment CALIXTO99 (a temporary network of 120 receivers, 25 broadband instruments, in operation from May to November 1999). The Vrancea region is located in a particularly complex environment, in a zone of continental convergence characterized by at least three tectonic units in contact: the East European plate, and the Intra-Alpine and Moesian subplates. The seismogenic volume with a rather well confined epicentral area expands in depth from 60 to about 200 km. The earthquake recurrence, the coefficient b, the seismic energy released are analyzed in detail, for various depth ranges of the subcrustal source zone, and a series of peculiarities of the seismicity during the last decade are pointed out.

Keywords: parameters, energy, records

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SS001 **Poster presentation** **6174**

International Seismological Centre

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The International Seismological Centre is a non-governmental, non-profit making organization, charged with the final collection, analysis and publication of earthquake source information from all over the world. Earthquake data is received from more than 100 seismological agencies representing every part of the globe. This data comprises readings from more than 4,000 seismograph stations. The Centre's main tasks are to re-determine earthquake locations and magnitudes, making use of all available information and to search for new earthquakes, previously unidentified by individual agencies and to distribute this information to the global seismological community. The International Seismological Centre, ISC, is widely recognized as the source of the most comprehensive reliable listing of global seismic data. This information is made available by the ISC through CD-ROMs and on-line Bulletins and Catalogues from the ISC website. The ISC international team, of only 9 people, is integrating the efforts of seismologists who run stations and networks around the world and provide readings of phase arrivals and amplitudes. The ISC builds on those efforts to locate tens of thousands of earthquakes each year. With the current tendency of almost all local agencies to focus their efforts on rapid dissemination of earthquake information, it is the ISC that becomes the source for the most complete earthquake information. We wait more than one year for all possible earthquake data to be collected before we begin analysis and editing to produce the ISC Bulletin. The time required to complete the data collection is determined by the many agencies that send the data. As soon as the data are parsed and inserted into the database, contributed hypocentres are grouped and phase readings are associated with automatically selected primary hypocentres. This automatic process is repeated every few days and this raw information is available, on-line, from the ISC website. Many of these events will be relocated by ISC seismologists who manually review every event that complies with one of the following conditions: the reported magnitude is higher than 3.5 the event was reported by at least 2 agencies the event was recorded at a distance greater than ~1000 km An ISC solution is normally provided when there are more than 4 phase readings (P or S) from more than one network and when the solution converges successfully. On average, about 3500 events with more than 150,000 associated readings are reviewed each month. Other services of ISC involve maintenance of the International Registry of seismic stations (jointly with USGS/NEIC), links to web-sites with additional seismological information, information about seismologists and seismological institutions (national points of contact), bibliographic lists, reports and documentation of ISC's software. On-line new services are being added. These include Information about magnitude determinations, reference events to improve location, basic seismicity parameters and seismological standards. Visit www.isc.ac.uk for more details.

Keywords: isc, global seismicity

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SS001 **Poster presentation** **6175**

Small array observation just on the active region of the deep non-volcanic tremor in the Tokai subduction zone

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During February 4-10, 2007 a strong activity of the deep non-volcanic tremor in the Tokai subduction zone occurred. Obara (2002) reported that the deep non-volcanic tremor was generated in the subduction zone of the Philippine Sea plate beneath the Japan plate. The nearly same tremor was observed in the Cascadia subduction zone (e.g., La Rocca et al., 2005). To understand the generation mechanism of the tremor, we installed a temporary small array just on the active region in Aichi prefecture of the Tokai subduction zone. We report a seismological result especially by seismic wave analysis of the observed tremor. The array is shaped as a regular triangle with the side lengths of about 27-28m. We put four high sensitive and three-component 2Hz seismometers on its three vertexes and center. The seismic waves were recorded in continuous mode at 200 Hz sampling by using two digital loggers and a high capacity HDD. We recorded the tremor during its activity except the period from 8 am on February 5 to 12 am on February 8 (Local Time). The tremor signals are veryweak and complex as so difficult to identify the initial P- and S-wave onsets (e.g. Obara 2003). We calculated coefficients of cross-correlation in one minute length between tremor signals observed by four seismometers. And we obtained about 0.6 of the coefficients in each component and 10 msec of the maximum time lag.

Keywords: non volcanic tremor, array, subduction

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SS001 **Poster presentation** **6176**

Can the standard broadband body-wave magnitude mB substitute Mwp, which is commonly used in tsunami early warning systems?

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Tsuboi et al. (1995; 1999) developed the moment magnitude Mwp, based on broadband P wave-forms. It scales well with Mw(HVR) for earthquakes in the magnitude range 5 < Mw < 8.3 and is considered by these authors as a simple and robust technique for a rapid evaluation of the tsunami potential of a large earthquake. However, Mwp determination is not as simple. It is based on model assumptions about the source-time function and had to be upgraded during recent years by empirical corrections, dependent on magnitude and apparent P-wave velocity, to obtain better results. Despite these improvements, it has failed to reliably estimate Mw for some of the largest recent events, amongst them the Mw9.3 Sumatra December 26, 2004, tsunamigenic earthquake. We propose as an alternative to use the classical broadband body-wave magnitude mB based on the empirical teleseismic Q(D,h)PV calibration function by Gutenberg and Richter (1956). It is free of any further hypothesis and uses, according to the IASPEI 2005 recommendations for new magnitude standard procedures, only the maximum amplitude in the total P-wave train. This amplitude is directly measured on unfiltered velocity broadband records. For very large earthquakes with Mw > 7.8 a cumulative amplitude mB, called mBc, yields even non-saturating magnitude estimates. Depending on source distance and rupture duration, mB values can be made available with a fully automatic procedure within 4 to 18 min after rupture initiation and can serve as a reliable proxy for Mwp. We have analyzed two data set. In the first one we compared for 109 events the Mwp values published by Tsuboi et al. (1999) for earthquake in the range 5.2 < Mw < 8.3 with interactively determined mB event magnitudes determined from digital broadband recordings of the German Regional Seismograph Network (GRSN). In the second data set we compared for some 60 earthquakes in the Mw range 6 to 9 between 1992 and 2007 the mB and mBc values, determined with a fully automatic near real-time procedure with the respective Mwp values calculated at the Pacific Tsunami Warning Center (PTWC). For tsunamigenic relevant moment magnitudes between 7 and 8 the average difference mB(GRSN)-Mwp was always < 0.2 m.u., and for individual events < 0.5 m.u.. For stronger earthquakes, mBc is in better agreement with Mw(HRV) of Harvard than Mwp. Considering only our measured mB values in the range 6.0 to 8.3, then the average difference mB-Mw(HRV) = -0.02 with a standard deviation SD = 0.31 magnitude units. Thus mB and mBc yield at least comparably good quick alarm estimates for Mw(HRV) as Mwp.

Keywords: moment, magnitude, broad band

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SS001 **Poster presentation** **6177**

Coda Q estimates in the Andaman Region using Local Earthquakes

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The attenuation properties of seismic wave energy have been estimated using the single back-scattering model around the Andaman seismogenic region analyzing local earthquakes. As the region is not very well understood in terms of seismic attenuation, the December 26, 2004 great Sumatra earthquake has generated considerable interest amongst the scientists to understand the earth medium in terms of heterogeneities, scattering and attenuation properties of the lithosphere for better study of seismic hazard. A total of 32 local earthquakes of magnitude range 2.7- 4.2 have been used from four stations namely TGP, RGT, HVL and PBL to calculate frequency dependent Coda Q (Qc) applying the time domain coda-decay method at central frequencies 1.5, 3.0, 6.0, 9.0, 12.0 and 18.0 Hz. Eight lapse time windows from 25 to 60 s have been selected for analysis starting at double the time of the primary S wave from the origin time. The average quality factor for Andaman region is estimated as,Qc=129f**0.85, while the average values vary from 18026 at 1.5 Hz to 1548186 at 18 Hz central frequencies. The variation of the quality factor has also been estimated at different lapse times to observe its effect with depth and they vary from 101f**0.91 to 143f**0.84 at 25 to 60 s lapse time window length respectively. For 25 s lapse time window, the average Qc value of the region varies from 13714 at 1.5 Hz to 1296132 at 18 Hz, while for 60 s lapse time window its variation is from 20539 at 1.5 Hz to 1639238 at 18 Hz of central frequency. The variation of Qc with frequency and lapse time reflects that the upper crust is seismically more active compared to the lower lithosphere. It has also been observed that Qc value is increasing from northern station (TGT) to the southern station (PBL) which shows the spatial variation in Coda even for a smaller region like Andaman.

Keywords: codawave, attenuation, andaman

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SS001 **Poster presentation** **6178**

Seismological analysis of Zarand earthquake, February 22, 2005 and its aftershocks based on a dense local seismic network.

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Following destructive ML=6.4 Zarand earthquake on February 22, 2005, we arranged a local and intense seismic network for recording aftershocks. The IIEES network was contained 15 three-component mid-band (CMG-6TD) seismic stations plus 2 strong motion (SSA-2) stations around damaged area. The network recorded more than 3000 small quakes and aftershocks during 40 days continuously. In order to locate aftershocks, we used the data of local stations and 3 broad-band stations of Iranian National Broad-Band Seismic Network: Kerman, Naeen, and Zahedan. In this study, using first motion polarity of P-wave method, we determined precise location of aftershocks and source mechanism of major aftershocks (N=50, with ML>3.0). During this study, we found different focal mechanisms for aftershocks, which most of them are in good agreement with focal mechanism of the main shock (i.e. reverse). Our results show that two branches of Kohbanan fault are responsible for producing February 22, 2005 main shock (ML=6.4) and its aftershocks.

Keywords: aftershocks, source mechanism, first motion

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SS001 **Poster presentation** **6179**

Linear seismic tomography without ray-tracing: constructing the velocity models of an earth crust by the times of the first arrivals of seismic waves.

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Investigation and analysis of structures of the epicentral zones of large earthquakes are the actual basic problem of seismology. The waveforms of the aftershockes of large earthquakes, registered by network of seismic stations in the epicentral area, contain in themselves the unique information about deep structure of the medium in source area. By the times of the first arrivals of seismic waves it is possible to construct the velocity models of an earth crust and the upper mantle. Problems of reliability assessment for obtained results and reduction of calculations amount for data inversion are actual to present day. The paper presents one of probable effective methods for the solution of a linear seismic tomography problem on passing waves (for example, a problem of crossborehole tomography). Specificity of the considered problem in real scales is extremely large dimension, therefore the usual approach to the calculation (a method of ray tracing) requires huge amount of RAM to provide storage of a matrix. Therefore for the numerical solution of a problem it is offered to use iterative algorithm LSQR (Algorithm for sparse linear equations and sparse least squares problems. Iterative method, more stable than symmetric conjugate-gradient method on normal equations). The algorithm has the important advantages: 1. It does not require attraction of powerful computing resources for storage of a matrix 2. In our concrete case, it does not require calculation of elements of a matrix. Its realization is come to serial action of direct and conjugate operators of linear tomography on the each iteration. Actions of direct and conjugate operators of linear tomography are calculated on each step by the solution of the linear differential equations of the first order. For numerical experiments synthetic models of two types have been chosen: 1. The objects of various forms with various velocities of propagation of waves placed in a homogeneous medium. 2. The set of subhorizontal layers with various velocities of wave propagation. The received results of numerical experiments are presented and commented. Modeling has shown, that algorithm LSQR well recommends itself in application to the considered tests, receiving results of high accuracy. The algorithm LSQR has proved itself to be effective in practice for the linear seismic tomography on passing waves. Next steps in development of this research are: 1. Carrying out of similar calculations with real data, 2. Application of LSQR method for nonlinear problems of a seismic tomography, 3. Application of LSQR method for a linear 3-D seismic tomography.

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SS001 **Poster presentation** **6180**

The dynamic strain derives the impotant seismological information, in the case of the 2004 off the Kii peninsula earthquakes

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On September 5, 2004, large earthquakes occurred at southeast off the Kii peninsula. We observed the dynamic strain variations with these earthquakes by the borehole strainmeters which were installed at 1020m depth, 200km away from epicenters. These records simultaneously include a "strain-step" which is often observed in a traditional geodetical observation record. At first, in order to research the growth process of the "strain-step", we applied time-series analysis to these strain seismograms which had been recorded with fast sampling. Comparing the seismic phase arrivals with the amplitude variations of "strain-step" that estimated from the filtered records, we clarified the growth process of "strain-step". Transmitting the various strain phases with large amplitude through the crust, a "strain step" grows gradually and its amplitude enlarges until the amount of static deformation which can compute from a dislocation model of earthquake. Secondly, in order to clarify the relation between the dynamic strain and the velocity of the ground motion, we analyzed the waveform of those. Because our borehole instruments were equipped with the various sensors, such as seismographs, tiltmeters, magnetometers and thermometer, we can research this analysis. By this analysis, we clarified that dynamic principal strain corresponds to radial component of the velocity. And that its coefficient factor is determined by the transmit velocity of the crust. Thus, important information is included in the dynamic strain records, and we think that more new discoveries are acquired, if these records are fully analyzed.

Keywords: dynamic strain, strain step, broadband seismogram

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SS001 **Poster presentation** **6181**

The frequency dependent attenuation of P and S waves in Northeast of Iran

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Abstract: Attenuation is an important crustal constrain and the study of attenuation in high frequency seismic waves is useful for both the seismologist and the earthquake engineers as it is an essential parameter in predicting the earthquake ground motion in seismic hazard analysis. The most commonly used measures of attenuation found in the literature are the dimensionless quality factor Q and its inverse Q-1, sometimes called the internal friction or dissipation factor. As an intrinsic property of rock, Q is a ratio of stored energy to dissipated energy. The values of Qp-1 and Qs-1 in northeast of Iran are not yet known. In this study we have analyzed Qp-1 and Qs-1 by the extended coda normalization method based on hundreds of local events recorded by the twenty stations of the temporary seismic network in northeast of Iran. Estimates of Qp-1 and Qs-1 in Northeast of Iran is frequency dependent that decrease from (0.014542 0.006002) and (0.009440 0.007726) at 1.5 Hz to (0.001271 0.000548) and (0.000547 0.000348) at 24.0 Hz respectively. The best frequency dependence of Qp-1(f) and Qs-1(f) in northeast of Iran are 0.0164 f -0.8687 and 0.0118 f -1.0193 respectively.

Keywords: attenuation, quality factor, northeast of iran

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SS001 **Poster presentation** **6182**

Estimation of small-scale inhomogeneity from travel-time residuals of cross-well tomography

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We propose a combined method of deterministic and stochastic approaches for estimating subsurface velocity structure, and apply the method to a data set of crosswell seismic experiment. First, we image a large-scale structure deterministically by a conventional travel-time tomography and make a wavefield simulation to obtain residuals between observed and calculated travel-times. Then, we calculate a spatial correlation of the travel-time residuals. To explain the spatial correlation, we suppose the inhomogeneity is composed of the tomographic model and small-scale stochastic inhomogeneity. Numerical simulations indicate that the variance of the travel-time residual increases with increasing the intensity of the small-scale inhomogeneity e^2 , and the spatial-variation scale of the travel-time residual increases with increasing the correlation distance of the inhomogeneity a. Comparing the spatial correlation between the observation and the numerical simulations, we estimated the small-scale inhomogeneity at the borehole site as e= 2-4 % and a < 40m.

Keywords: tomography, residual, stochastic approach

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SS001 **Poster presentation** **6183**

Observational seismology in the Scotia Sea region. Fifteen years(1992-2007) of continued operation and growth of the ASAIN network.

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Milton Percy Plasencia Linares

The Antarctic Seismographic Argentinean Italian Network (ASAIN) was born fifteen years ago when OGS and IAA researchers installed a temporary station at Esperanza base (Antarctic Peninsula). It has been the first broadband seismograph operated in the whole Scotia Sea area. Since then, the ASAIN started a steady growth, financed by the Italian PNRA and the Argentinean IAA, and today consists of four broadband stations distributed along the Antarctic Peninsula and the South Scotia Ridge islands, and of two stations in Tierra del Fuego. Immediately following the installation of the ESPZ station, changed to a permanent seismological observatory at the beginning of 1995, a plan for the deployment of an effective network in the Scotia Sea and the neighbouring area was prepared by the OGS and its realization has been attained with a strong cooperation between Italian institutions and Argentinean ones. Building the network and choosing the appropriate station sites, we took always in mind the SCAR recommendations and the contemporary deployment of some broad band stations in the same area by the IRIS Consortium. During its fifteen years life the increasing availability of efficient solutions for remote data recovery and network operation control provided powerful tools to optimize ASAINs efficiency. Since 2005 two Antarctic stations (ESPZ, Esperanza and ORCD, Orcadas) provide their recordings to the ORFEUS Data Center (ODC) using real time data links while a third station, installed at the Argentinean San Martin Base (68 07 S, 67 06. W) during the 2006-2007 Antarctic campaign, is already sending real-time data to the OGS and IAA and is going to be added to those providing their recordings to the ODC. The huge amount of data recorded by the network already allowed the scientific community to add new information to the knowledge of the structural and geodynamic characteristics of the Scotia Sea region. At the moment, we are planning to install a new ASAIN station in the Southernmost Argentinean base Belgrano II (77 52' S, 34 37' W) which is located on a rocky outcrop (Nunatak Bertrab) on the Filchner barrier. An increased event detection capability of the Tierra del Fuego network branch also represents an high priority objective for the institutions involved in the ASAIN project.

Keywords: antarctica, asain, broadband

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SS001 **Poster presentation** **6184**

Temporal changes in site responses at borehole sites before and after strong motions as revealed from coda wave analyses

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Strong ground motion often decreases shear modulus and increases attenuation coefficient of the ground; however, there have been few reports about their recovery process. We present temporal changes in site responses at borehole sites which experienced strong motions. Here, we propose to apply two methods, coda wave spectral ratio and coda wave interferometry to seismograms of local earthquakes registered by seismometers installed on the ground surface and at the bottom of a borehole. These methods offer stable measurement of site responses since coda waves are composed of incoherently scattered S-waves with omni-directional propagation directions. Two stations TTRH02 (borehole depth 100m) and SMNH01 (100m) of KiK-net of NIED experienced 1109 and 844 gal excited by the 2000 Western Tottori Earthquake (Mw6.7), respectively, and station IBUH03 (150m) experienced 377 gal excited by the 2003 Tokachi-Oki Earthquake (MW8.3). Stations TTRH02 and IBUH03 are located at weathered rock sites and station SMNH01 is located on a hard rock site. We collected seismograms of over 100 earthquakes occurred in six periods (before each mainshock, 0 to 280 s, 0 to 10 days, 10 to 100 days, 100 to 1000 days, and 1000 to 2000 days after the mainshock), then averaged coda spectral ratios in each period. Before each mainshock, the peak frequencies of the spectral ratios were about 7.5 Hz, 6.4 Hz, and 1.2 Hz at stations TTRH02, SMNH01, and IBUH03, respectively. A few minutes after the strong ground motions, the peak frequency decreased 10 to 20 % lower than before at SMNH01 and IBUH03, while 30 to 60 % lower than before at TTRH02. After that, the peak frequencies continued to recover for more than 3 years roughly in proportion to the logarithm of lapse time. On the other hand, the peak levels of the spectral ratios dropped just after the strong motions, and they recovered within a few days. We further calculated the cross correlation functions of coda waves. The averaged cross-correlation function in each of the six periods clearly shows a delayed peak corresponding to an up-going SH-wavelet, which enables us to measure the average S-wave velocity between the borehole bottom and the ground surface. Before each mainshock strong motion, the average S-wave velocities were about 500 m/s, 1100 m/s, and 210 m/s at stations TTRH02, SMNH01, and IBUH03, respectively. A few minutes after the strong ground motions, the average S-wave velocity decreased 10 to 20 % lower than before at each station. After that, the average S-wave velocities continued to recover for more than 3 years roughly in proportion to the logarithm of lapse time. The delays of S-wave travel time amount to 10 to 85 ms, which might affect S-wave travel time for the earthquake hypocenter location. These complementary analyses, coda wave spectral ratio and coda wave interferometry applied to vertical array data, are found to be very useful to measure the temporal change in site response.

Keywords: coda spectral ratio, coda wave interferometry, recovery of site responses

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SS001 **Poster presentation** **6185**

High Seismic Attenuation in the Reflective Layers of the Philippine Sea Subduction Zone, Japan

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Intrinsic seismic attenuation gives additional constraints on the physical properties of the deep medium. However, in many cases attenuation is masked by scattering loss. In this work, the high-frequency Q-value, i.e. parameter of seismic attenuation, was studied in the Kii Peninsula segment of the Philippine Sea subduction zone of Japan. The geometrical spreading factor, which is necessary to exclude before inversion of the Q-value, is calculated numerically using a realistic 3-D velocity model and ray approximation. Generally, estimated "total" Q-values agree well with results of other studies and with common expectations based on tectonic structure, except for one striking result: Q-values for the lower crust and the subducting oceanic crust become extremely low, Qtotal ~ 20-30f ^0.9. In order to interpret this result we compiled attenuation related phenomena that were observed in the studied region: (1) the seismogenic upper crust; (2) aseismic lower crust; (3) reflective lower crust (RLC); (4) belt-like zone of the deep low-frequency tremor generation (LFT), that is parallel to the slab; (5) low-frequency earthquakes (LFE); and (6) reflective subducting oceanic crust (SOC). Analysis of ray coverage reveals that anomalously low Q-value in RLC and SOC can be explained mostly by high scattering attenuation (i.e., low Qsc value) in the reflective layers.

Keywords: attenuation tomography, reflective layers, subduction

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SS001 **Poster presentation** **6186**

Seismic activity features of Vietnam territory

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The structure of the Earth's Crust, the activation of faulting system and seismic regime in the territory of Vietnam are the objects in this paper. The obtained results have shown that: 1. Within the present geology structural plan, SE Asia is a SE part of the Eurasian lithosphere plate, surrounded by a subduction zone (first order fault) extending from Myanmar through Nicobar, Java, Timor, to East Philippines. The second order faults: Red River, Three Pagodas and Hainam - Natuna divided the SA Asia into three micro plates. 2. In general, the fundament surface varies quite complicatedly from exposal on the surface to the depth of 7 9 km.: in Northwest Vietnam-Pha Long region can reach the depth of 7 8 km; Northeast Vietnam region has weak variation of crystallized fundament (2 6 km); Crystallized fundament surface of Truong Son region varies from exposal on the surface to depth of 5 6 km.; The Kon Tum, Da Lat and South Vietnam have the feature of crystallized fundament surface varying quite complicatedly, from exposal on the surface to depth of 4 5 km. 3. Transitional crust region of East Sea margin has quite big thickness of Cenozoic sediments, varying in the limit from 2 3 km to 13 14 km. Making up this sediment crust are basins with big depth, which have the biggest prospect on oil in the territory of Vietnam. Broken quaternary sedimentary coverage in the area of new oceanic crust region has thickness of less than 1 km. 4. In general, the depth to the M-discontinuity is about 14 38 km. This discontinuity has tendency to increase its depth northwestward and in central part of Mesozoic folded regions and in ancient geological blocks or platform, and decreases in the Cenozoic folded zones, such as Vietnam East Sea plate, rifting depressions and basins. 5. Most of the second and third order faults were in active during Late Cenozoic and continually developed at the same grade during Early Cenozoic, but in some cases they have completely reverse movement directions, especially their strike-slip movements. The generation of the basins, uplifts as well as magma intrusions, folding and branch faults in whole territory depend absolutely on the displacement along the boundaries of the micro plates. 6. The Dien Bien 1935-M=6.8 and Tuan Giao 1983-M=6.7 earthquakes are the two largest ones that happened in Vietnam main land territory in the 20th century. These events caused heavy losses to the Dien Bien and Son La provinces. 7. Upon the standpoint of seismicity, the largest observed maximum earthquake occurrences of the following geological structures: Song Da - Son La (MS=6.0-6.9), Thanh Nghe Tinh zone (MS=6.0-6.9), Bac Hoang Sa (MS=6.0-6.9). 8. 28 seismogenic zones could be determined in the territory of Vietnam and surround areas. Among that, the high rank of the earthquake activity are: Muong Te (7.1), Xiao Jiang (MS=6.8), Song Da - Son La (MS=6.7), Sam Nua - Thai Hoa (MS=6.8), Song Ca - Rao Nay (MS=6.8), Lingshan - Ha Long (MS=7.5), Huyen Nhai - Van Ninh (MS=7.5), Guangzhou (MS=7.3), and Bac Hoang Sa (MS=6.8).

Keywords: seismotectonic

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SS001 **Poster presentation** **6187**

A waveform inversion method in the frequency domain for simultaneous determinations of focal mechanism and source-time function and its application to broadband seismic data in Indonesia

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We develop a method to estimate source location, focal mechanism, and source-time function based on a waveform inversion carried out in the frequency domain. In the waveform inversion, the source mechanism is estimated by solving the normal equation d=Gm, where d is the vector representing the observed data and m is the vector representing the parameters for a source mechanism and source-time function. G is the matrix representing the Green functions, of which the size is (number of data)x(number of parameters). If we solve the equation in the time domain, the size of G is (Nt Ns)x(Nm Np), where Nt, Ns, Nm, and Np are the number of data traces, the number of samples in each trace, the number of source-mechanism components, and the number of parameters to represent temporal variations of the source-time function. If we solve the equation in the frequency domain, on the other hand, the normal equation can be solved for each frequency separately. In this case, the size of G becomes as small as (Nt)x(Nm). Solving the small matrices Nf times is much faster than solving the single large matrix in the time domain, in which Nf is the number of frequency components used for the inversion. In this approach, there is no need to care about elementary source-time functions. Accordingly, this method can be applied even for tsunami earthquakes without a priori information about source-time function. In the inversion method described above, the frequency components of the estimated source-time function mf(t) are limited to those used for the solution of the inversion. Therefore, the frequency components not included in the inversion or the observations, as a DC component of a ramp-function like source-time function, can't be recovered. We develop a method to recover the original source-time function as follows. First, we assume the original source-time function m(t) is represented by a convolution of an elementary function s(t) (e.g. a ramp function) with a function a(t) (m(t)=a(t)*s(t)). Second, we apply the filter used for the inversion to s(t), and we represent the filtered function as sf(t). Then, we estimate a(t) by fitting a(t)*sf(t) to mf(t), in which we apply the non-negative constraint on a(t) because m(t) represents a fault slip, and obtain m(t). We apply the method to observed waveform data from JISNET. The analysis relies on seismograms obtained from a few stations since JISNET station distribution is not dense. In this analysis, we assume slip on a fault represented by a pure double couple as the source mechanism. Grid searches with respect to strike, dip, and rake angles are performed to estimate fault orientation. We also carried out a spatial grid search to find the best fit source location. This approach is an extension of the method proposed by Nakano and Kumagai (2005; GRL) for source mechanism analysis of volcano-seismic signals. Examples of the applications are given below. The event on July 17, 2006 (South of Java; Mw 7.8): This earthquake is characterized by a long rupture duration over 100 s, which implies a tsunami earthquake (e.g. Ammon et al., 2006: GRL). We investigate this earthquake by using observed waveforms bandpassed between 50 and 200 s. The centroid is located at 9.8S, 107.4E and a depth of 10 km. A reverse-type fault mechanism with moment magnitude (Mw) of 7.5 is estimated. We obtain the rupture duration of about 120 s. These results are consistent with the results by Ammon et al. (2006), USGS, and Harvard CMT. The event on January 21, 2007 (Northeast of Sulawesi; Mw 7.5): We investigate this earthquake by using the period band between 50-100 s. The source is located at 1.0N, 126.2E and a depth of 25 km. We obtain the magnitude of Mw 7.5, reverse-type fault mechanism, and

rupture duration of about 15 s. The source location and focal mechanism are consistent with the results by USGS and Harvard CMT. The obtained rupture duration is consistent with the typical value of this size of earthquakes. As such, our method has been successfully applied to JINET data. This method can be automated to routinely estimate the source parameters including source-time functions.

Keywords: waveform inversion, focal mechanism, jisnet

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SS001 **Poster presentation** **6188**

Theoretical amplitude response of Tehran seismic network

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After the catastrophic Rudbar earthquake of 1990, the World Bank provided a loan to the Institute of Geophysics, the University of Tehran to buy and install some seismic networks in Iran. Later the Iranian Seismic Telemetry Network was founded in 1995 and has gradually installed some short period seismic networks around the country. Because of the earthquake vulnerability of Tehran one of these networks has been installed around this city. The Network comprises of 12 seismic stations equipped with short period seismometers with eigenfrequency of 1 Hz, VHF antenna, transmitters, 24-bit digitizers, and power supply set charged by solar energy. The Tehran central station has been equipped with VHF antenna and receivers, central computer system to process and deliver the results, GPS and power supply. The 50 Hz continuous data are sent from remote stations, recorded and processed in the real time by the system software to make necessary corrections. Then data is transmitted to a ring buffer that may keep them for some days. But the system is working on a triggering mode, so that, when at least four stations detect an event, the triggering system will be activated and records it. The triggering system is based on an STA/LTA. One of the key concepts for the later studies on the data provided by this system is its response to the different kinds of the ground motion. As there has been no calibration test on this network we have calculated its theoretical response based on the system components technical data, to help to standardize data processing for the determination of the ground motion amplitudes from digital seismograms in terms of displacement, velocity and acceleration frequency response curves.

Keywords: amplitude response, ground motion amplitude, tehran seismic network

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SS001 **Poster presentation** **6189**

A proposal for an early warning system around Tehran, Iran

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Providing a reliable earthquake early warning system (EWS) even on an order of a few seconds to a minute before hazardous earthquakes might significantly reduce human being live lost and injuries as well as properties lost. Although a few seconds seems short, it may be enough for airports and railroad stations to manage their traffic, students to go under their benches, electric and gas providers to shut down their systems and so on. In Iran there are many essential facilities which are vulnerable to earthquakes that it is practically impossible to retrofit all of them before the next great earthquake. So an early warning system that can alarm even a few seconds before the arrival of the PGA could save a lot of lives. On the other hand there are many programs for identifying and retrofitting seismically vulnerable essential facilities in Tehran. Considering the costs, it seems also, really impossible to reinforce or reconstruct all vulnerable structures before the next great event. EWS systems are benefiting from the difference between the speed of the seismic waves (about 3-8 km/s) and the speed of radio waves (about 300,000 km/s). After detecting an earthquake it is possible to transmit an alert to the vulnerable vicinities, so they will be informed much earlier than the real seismic waves arrive. As the time lag between the arrival of the seismic and radio waves are larger for farther areas, they will have much more time to react. This proposal is suggesting to installing a network of strong-motion instruments specially near the suspected active seismic sources around Tehran, a set of wireless communication networks to send the alert signal to the central control station, the event identification and quantification system and the radio transmitter to send the alarms to the list of the subscribers based on a pre-defined database. It is necessary to reduce the false alarms caused by electronic problems, local noises etc Meanwhile it is necessary to train subscribers so that they know how to react during an alarm.

Keywords: early warning system, wireless communication network, identification and quantificat

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SS001 **Poster presentation** **6190**

Crustal Model and Seismotectonics of Tehran Region, Iran

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The Tehran region is situated in the central Alborz range in northern Iran. The Alborz is an active tectonic region along the southern side of theCaspian Sea. Several local permanent short-period seismic networks belonging to theUniversityofTehranhave been monitoring the region for the last 11 years. In this study, we merged seismic data of 717 events recorded by all these networks during the period 1996-2004 and relocated the events using an initial assumed velocity model. To have a uniform accuracy for phase readings, we repeated all phase picking. We calculated new 1-D P and S seismic velocity models using a simultaneous inversion for velocity, hypocenters and station corrections. Only 213 events with good azimutal coverage (gap≤180) were participated in the inversion process. We have obtained a nine-layer model with an average Moho interface of about 45 km. To assess the stability of the final 1D velocity model, various tests with randomly selected and randomly shifted hypocenters were performed. No significant changes in velocity and hypocenter locations are observed and all events are relocated close to their original position. The improvements in the earthquake locations allowed us to use local seismicity to better describe activity on local known active faults. The majority of focal depths are above 20 km depth, with some extending to 30 km, suggesting that seismicity for the most part is limited to the upper crust. This shallow seismicity may be consistent with the high-angle reverse faults of central Alborz. The most active faults are Garmsar, Eyvaneky, and the eastern part of Mosha and Tehran faults. No seismicity on the central and western parts of the North Tehran fault is observed. This fault is the nearest fault to the megacity of Tehran.

Keywords: velocity model, seismotectonics, iran

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SS001 **Poster presentation** **6191**

Stress triggering by March 31, 2006 Silakhour, Iran earthquake (Mw 6.1) from aftershock observation

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The 6.1 Mw (USGS) Silakhor earthquake happened at 1:17 UTC on March 31, 2006 in Lorestan province in western Iran. USGS reported its epicenter at 33.50N and 48.78E and its depth at 7 km. The event was preceded by two relatively large foreshocks of 4.8 mb (at 16:17 UTC on March 30) and 5.2 mb (at 19:36 UTC on March 30) and followed by two relatively large aftershocks of 5 and 5.3 mb at 01:31 and 11:54 UTC on March 31, respectively. The event occurred along the direction of the right-lateral strike-slip Main Recent Zagros (MRZ) fault. In this study we have merged all seismic data recorded by Iranian seismic networks, and relocated the events using a simultaneous inversion for velocity, hypocenters and station corrections. The relocated epicenter cloud lies to the north of both the main event and the MRZ fault, and spreads parallel to the MRZ fault over a distance of about 50 km. The epicenter cloud is segmented where the fault steps towards north close to Boroujerd, the most affected city by the Silakhour event. The two large aftershocks are within the northern part of the aftershock cloud and close to the Boroujerd. From empirical relationships for fault length and magnitude, the fault length for the Silakhour event is estimated to be not larger than 15 km. Since the accuracy of location of epicenters of the Silakhour events is better than 5 km, we can be sure that the two large aftershocks did not occur along the fault which caused the Silakhour event. This suggests that the Silakhour event triggered the two rather large aftershocks. It is interesting to know that a large event of magnitude of 4.9 Mn occurred close to the epicenter of the large aftershocks in 2005/05/03. This implies that the area where the MRZ fault steps towards the north was somehow ready to be triggered by a nearby event.

Keywords: earthquake, triggering, iran

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SS001 **Poster presentation** **6192**

General space-time characterization of the source of Mw=7.6, 20 April 2006, Olutorskoe earthquake (NE Russia): polynomial moments from teleseismic P-waves using empirical Greens function technique

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The destructive Olutorskoe earthquake occurred in the Koryakia region in North-Eastern Russia. It is a crustal event, assumedly associated with the boundary between the hypothetic Beringia miniplate and North American plate. The general space-time structure of its source is analyzed using polynomial moments of 1st and 2nd degrees. The latter are determined from teleseismic broadband records of P-waves at GDSN stations and Japanese F-net. To obtain apparent source time function (ASTF) for a certain ray, the method of empirical Greens functions is used. The deconvolution is performed in time domain using non-negative least squares. Then, polynomial moments of 1st and 2nd degrees of ASTFs are determined. Linear equations relate these moments with polynomial moments of the source (of corresponding degree). These equations are solved, to result in estimates of source moments, accompanied by accurate error bounds. The obtained set of source polynomial moments is interpreted in frames of the Haskell-type source model with asymmetric bilateral rupture propagation, constant rupture velocity. Additionally, the location of the rupture termination point is found by inversion of duration of apparent source time functions. The following parameters of a Haskell-type source are obtained: the distance from the epicenter to centroid: 13-25 km (to SW); the length of the source: 1138 km; strike 2228; rupture velocity equals 3.00.3 km/s; the lengths of arms of the bilateral source larger (SW) arm: about 725 km, smaller (NE) arm: 415 km; total source duration: 243 seconds. These estimates agree well to CMT nodal plane solution, aftershock zone orientation and surface breaks from field geology; however, the NE extremity of the aftershock zone is somewhat farther from the epicenter (80 km) than our estimate (41 km).

Keywords: space time structure, earthquake rupture, higher moments

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SS001 **Poster presentation** **6193**

An envelope inversion method for improved location of deep low frequency tremor

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Non-volcanic deep low-frequency tremors in southwest Japan occurs at a depth of 30 km on the plate boundary on the forearc side along the Philippine Sea Plate with a predominant frequency of 1-10Hz (Obara, 2002). On some occasions, impulsive onset appears on the wavetrains of the tremor. The Japan Meteorological Agency (JMA) measures this onset as S wave arrivals of Low Frequency Earthquake (LFE), and determines their epicenter by normal hypocenter location procedure. By referring the LFE locations, more fine-scale distribution of LFEs relocated by using cross-correlation of tremor waveforms has been discussed (Shelly et al. 2006; Maeda et al. 2006). However, it is impossible to pick every tremor arrivals since continuous tremor waveforms are too complicated. Envelope Correlation Method (ECM) enables us to locate tremor epicenters without arrival time picks (Obara, 2002). However, Obara and Hirose (2003) reports that ECM can not locate tremors precisely on the most active stage of tremor activity associated with the short-term slow slip event. To understand the mechanisms of tremors and related slow-slip event, it is important to determine the location and radiated energy of continuous tremors more precisely. Here, we propose a new method for estimating the location and radiated energy of tremor by using envelope amplitude of deep tremor. From continuous wave trace of tremors, we found that the tremor amplitude decays in proportion to the reciprocal of the source-receiver distance even if the phases of the tremor are very complicated. So, we model the observed mean square (MS) envelope amplitude by time-dependent energy radiation with geometrical spreading factor in proportion to the distance to the power of -2. In the model, we do not have origin time of the tremor since we assume that the source of the tremor continuously radiates the energy. To incorporate the migration of tremor with time, we locate the source of the tremor every 1 minute. Travel-time differences between stations estimated by the ECM technique also give important information for locating the tremor. Therefore, we locate the tremor epicenter and radiated energy by minimizing weighted summation of the squared residuals of the MS amplitude and travel-time difference. ECM method is applied to root mean square (RMS) envelope. Initial source location and energy is estimated by the amplitude grid search method (Obara and Hirose, 2003). We adopted 0.1 degree grid width lateral direction for initial source estimation. The depth of initial source is fixed to 35km. We use three-component 1-hour Hi-net velocity continuous waveform for the inversion. After applying the pass-band filter of 2-10 Hz, we make MS and RMS envelopes. For reducing computational cost, envelope traces are decimated to 10 Hz and to 1 Hz samplings for RMS and MS envelopes, respectively. The source location and energy are estimated by applying least square inversion to the 1-min window iteratively. Location by ECM generally has low resolution since we can only use relative travel time of S waves. We expect to have more fine-scale resolution of the tremor by mixing different MS amplitude information for estimating the source location in the present method. Additionally, we can estimate the source energy of tremor in the method. Recent reports show that the reduced amplitude of the tremor obeys the exponential-type distribution (Rokosky et al. 2006; Watanabe et al. 2006). Direct estimation of tremor energy may give more accurate information on size distribution of deep tremor.

Keywords: deep low frequency tremor, subdunction zone, event location

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SS001 **Poster presentation** **6194**

Spatio-temporal change in Coulomb stress in the subducted Pacific slab in the Hokkaido region, northern Japan revealed from the inversion of seismicity rate change

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Ongoing seismic activities in the Hokkaido region of northern Japan is manifested by frequently occurring strong to great earthquakes from time to time. In this region seismic activity is pervasive up to a depth of more than 600km where the intermediate to deep focused earthquakes are bound onto the subducted Pacific slab. In this paper we studied the seismicity rate change within the subducted Pacific slab in the Hokkaido region of northern Japan and estimated the evolution history of the coulomb stress with respect to stressing events. We considered an earthquake with magnitude >=6.0 as a stressing event. To avoid tectonic complexities we confine our study within a rectangular area of width ~270km that strikes 315o (perpendicular direction of the Kurile trench) and extends up to 800km from the Kurile trench. The bottom right corner of this rectangular area is located at a 40.75oN latitude and 144.25oE longitude such that the rectangle incorporates the subducted portion of the Pacific slab in Hokkaido and its vicinity. We used a method devised by Dieterich et al. (2000) to invert the Coulomb stress change from the observed rate of seismicity in an interval of 1 year. For both temporal and spatial estimation of stress we assumed a constant stressing rate of 0.8bar/year (observing an interseismic period of ~50 years and stress drop of 4.0Mpa during the great earthquake of 2003 in this region). We used earthquake data from the Institute of Seismology and Volcanology of Hokkaido University between the period of 1994 and 2006. We relocated the earthquake hypocenters using a method of Zhao et al. (1992) and selected the earthquakes that occurred within the slab. Since the seismic network of the ISV was modified in 1997 with deployment of numerous broadband instruments, to compensate the trade off in magnitude due to this modification we selected events with magnitude >=2.5 in this study. To map the detailed stress state, we divided the study area into more than 8000 square cells each of dimension 5kmX5km. A cylinder of radius 19.8km (~5 neighboring cells) is set at the center of each cell to collect enough earthquakes for the stress history estimation. In this study we assume a minimum number of five events per year per cell to be used in the inversion. Our analysis reveals three main stages of stress evolution in the study area. The first stage is characterized by three successive stressing events in the year 1997. Occurrence of a stressing event in 1994 near the easternmost boundary of the study area induced stress anomaly in a local scale. In the following years (1995 and 1996) stress became pervasive in the area and finally stress was relieved in most of the region due to the 1997 events.In the following years from 1998 to 2002 stress is increased locally in the southern part of the study area. The second stage is characterized by 6 stressing events in 2003. The great earthquake of magnitude 8 of 26 September 2003; and its aftershocks increased the stress in the shallower part of the slab whereas the deeper part is not affected significantly. The third stage of the stress evolution follows the second stage immediately by the occurrence of off Nemuro Peninsula earthquake and its aftershocks. The stress is then decreased in the years 2005 and 2006.

Keywords: seismicity rate change, stressing event, coulomb stress

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SS001 **Poster presentation** **6195**

Interplate slip distribution in the northeastern Japan subduction zone inferred from small repeating earthquakes, GPS, and combined data

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We developed the technique to estimate slip distributions by using small repeating earthquake data, GPS data and combined their data, and applied to estimate the coupling condition of the subducting Pacific plate boundary of the off Miyagi prefecture and Ibaraki prefecture in the northeastern Japan.Slip estimation by using small repeating earthquakes is based on a scaling law by Nadeau and Johnson (1998). We estimated slip rates at their location by assuming constant and quasi-static slip within inter-seismic period to satisfy slip amount of next small repeating earthquake. Then, we considered that small repeating earthquake groups which occurred at the almost same location show the slip of the same area and averaged their slip rate. Slip distribution based on GPS data were inverted by assuming back slip model. We used only horizontal displacement data and assumed nnr-nuvel1 model as plate velocity in this analysis. The technique combined both data is the same style as GPS data inversion. We divided the average slip rate from small repeating earthquakes at suitable time interval, and handled as the individual data. And then, we input the values which subtracted them from plate velocity. Slip direction of earthquakes fixed to the direction of plate motion in this analysis.As the results, slip rates estimated from small repeating earthquake analysis are equal to or lower than the relative velocity of plate motion within wide area from deeper limit of the plate coupling area to around trench. On the other hand, slip velocity distribution from GPS data inversion is resolved very well in off Miyagi prefecture and we can find pre-seismic coupling, coseismic slip and after slip of the 2005 off Miyagi earthquake (M7.2). However, we could not resolve in off Ibaraki because GPS station is far from the region and tectonics in this area is very complex. GPS data inversion is an advantage to estimate slip velocity at temporal continuously, and small repeating earthquakes are to estimate slipped region at plate boundary which is far from the land area at high spatial resolution. The result of each analysis was able to compare pattern of slip distribution of them, although spatial and temporal resolution of estimated slip information is very different. Next, we estimated coupling condition by using combined data and compared them with individual results. The distributions were well constrained the subducting velocity of Pacific plate in off Ibaraki prefecture. On the other hand, In off Miyagi prefecture, they were almost the same as GPS results for great weight of GPS data. To estimate spatio-temporal change of interplate coupling in the subducting plate boundary beneath the Japan Islands with very high spatio-temporal resolution is important to use combined results of small repeating earthquake data and GPS data with optimized weight.

Keywords: small repeating earthquake, slip distribution, subduction zone

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SS001 **Poster presentation** **6196**

The Foreshock Sequence of the 2002 Eastern Tottori Earthquake and Its Effect on Mainshock

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In order to understand the earthquake nucleation process, it is important to know how foreshocks occur. Dodge et al. (1996) pointed out that foreshock sequences are not compatible with the cascade model in which the foreshocks all occur on a single fault plane and trigger the mainshock by static stress transfer. Instead, they noted that foreshocks seem to concentrate near structural discontinuities in the fault and may be a product of an aseismic nucleation process. In this study, we investigated the foreshock sequence of the 2002 Mj 5.5 Eastern Tottori Earthquake. This event was about 40 km west of the 2000 Mj 7.3 Western Tottori Earthquake and the focal mechanism was a strike-slip fault with a nearly horizontal P axis striking NW-SE. The mainshock was preceded by about 30 foreshocks with similar waveforms and the largest foreshock occurred 11 days before the mainshock.We estimated relative locations of the mainshock, similar foreshocks and aftershsocks with cross correlation analysis and HYPO71 (Lee and Valdes, 1985). We found that foreshocks were concentrated 0.5 km SSW and 1.5 km shallower from the mainshock. The aftershock distribution suggested that the fault plane of the mainshock was along N105W, but the foreshocks row was aligned in the direction of N125W. This suggests that the foreshocks might not be related to aseismic nucleation process. Next we estimated the relative source time functions (RSTFs) of the mainshock with an empirical Greens function (EGF) method and projected Landweber deconvolution (Bertero et al, 1997). The largest foreshock (Mj 2.5) was chosen as an EGF and we found two clear peaks in RSTFs of stations west of the mainshock. This suggests that the mainshock rupture might to move to the west.

Keywords: foreshock, corss correlation, relative source time function

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SS001 **Poster presentation** **6197**

Application of array-based waveform correlation techniques to event detection and relocation for the 2003 Lefkada Island, Greece, aftershock sequence focusing on the very small aperture trisar array

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A strong earthquake (Mw=6.2), followed by a vast number of aftershocks, occurred close to the NW shores of Lefkada Island, Ionian Sea, Greece, on August 14, 2003. The first 2 days of this seismic sequence were recorded by the small-aperture 4-element Tripoli Seismic Array (TRISAR), which was installed by the Seismological Laboratory of the University of Athens in central Peloponnese, Southern Greece. TRISAR recorded more than 250 events associated with this sequence. The aftershocks are distributed almost linearly along the western shore of Lefkada Island, all the way to the northernmost part of Kefalonia Island to the South and to the shores of Greek mainland to the North (Karakostas et al., 2004). Mean epicentral distances from TRISAR are of the order of 200 km. Array-based waveform correlation techniques were applied to available TRISAR data to investigate for the existence of spatio-temporal clustering of the events and the applicability of full-waveform matching techniques to detect seismicity distributed over a large area. The TRISAR waveforms for the mainshock do not correlate sufficiently well with any of the recorded signals for a template from this event to be used as an effective aftershock detector. However, highly similar waveforms are observed for many of the aftershocks with correlating events falling into distinct clusters. Array-processing of the cross-correlation functions allows for a confident association of events with less than optimal waveform semblance. The clustering of events from the correlation analysis at TRISAR facilitates accurate double-difference relocations for many aftershocks additionally using signals from 3-component single stations at regional distances operated by the National Observatory of Athens. Results obtained are expected to contribute to the better understanding of the mechanisms controlling the evolution of the initial stages of the Lefkada aftershock sequence.

Keywords: aftershock sequence, waveform correlation, array

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SS001 **Poster presentation** **6198**

Radiated energy, static stress drop, seismic moment and radiation efficiency of intermediate-depth earthquakes in the Pacific slab beneath Japan

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Although the studies of source parameters relationships for shallow earthquakes have been investigated (e.g. Kanamori et al [1993]), those for intermediate-depth earthquakes are much fewer. Our interests are whether the relations of source parameters depend on the depth and the earthquake size.In this study, we investigated the intermediate-depth earthquakes (Depth:70km-150km, MJ:4.0-6.0) in the Pacific slab beneathalong with attenuation properties such as Q-values. We estimated the radiation efficiency (ηR), which is considered an index to express the rupture dynamics. This parameter can be calculated from the radiated energy (ER) and the fracture energy (EG). Furthermore, we investigated the relations between the static stress drop (σS) and the seismic moment (MO).Our results indicate that the radiation efficiency does not depend on the depth and the earthquake size. The ratios of the radiation energy to the seismic moment are similar to the studies for the shallow events reported (e.g. Abercrombie [1995] and Kanamori et al [1993]). Our results suggest that the mechanism of the earthquakes does not depend on the depth and its size.

Keywords: static stessdrop, radiated energy, radiation efficiency

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SS001 **Poster presentation** **6199**

Regional and teleseismic event detection capability of the small-aperture Tripoli seismic array, Greece

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The Tripoli Seismic Array (TRISAR) is an experimental, very small-aperture installation operated by the Seismological Laboratory of the University of Athens, and was designed to monitor and locate the local and regional seismicity in the area of Greece. It was installed in the vicinity of the town of Tripoli, central Peloponnese, Greece, on July 16th, 2003 and consists of short period sensors forming a triangle of 250 m side length and a broadband sensor in the middle of this deployment. In this study, its detection capabilities are discussed for far-regional and teleseismic events. A reference event list is compiled, consisting of events of mb larger than 5.0 for regional and teleseismic distances (epicentral distance larger than 6.0 degrees), according to the ISC On-line Bulletin. TRISAR exhibited detectability levels comparable to that of sensitive single stations in Central Europe over the entire investigated distance range. Taking into consideration the rather small gain achieved by a 4-element array due to beamforming, TRISAR detection capabilities are expected to be significantly influenced by background noise. Indeed, detectability varies with time of day, suggesting that the main component of background noise in the vicinity of the array is anthropogenic. Regarding the observed seismic events, their geographic distribution is fully consistent with major Earth structure features. Although TRISAR slowness vector residuals are rather large, as expected for an array of such small aperture, the benefits resulting from the use of such a system for reporting regional and teleseismic activity is obvious.

Keywords: array, detection capability, global seismicity

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SS001 **Poster presentation** **6200**

Crustal structure in the northwestern Iran as derived from Pn and Pg phases

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Crustal structure in northwestern is shaped as a result of the continent-continent collision of the Arabian and the Eurasian plates. In this study, we determine crustal thickness, average Pn and Pg velocities and the dip of the Moho boundary in northwestern , an area bounded by 44 to 53 east longitudes and 36 to 40 north latitudes. We use seismic data collected during the period 1995-2006 by the Iranian short-period seismic networks operated by the University of Tehran , as well as IIEES broadband network. The original short period data had been poorly located in the areas outside the local networks. In order to improve the accuracy of epicentral locations, we combined all waveforms from all shortperiod networks, and repeated the location process. This resulted in repacked Pg and Pn arrival times. We selected 727 of the relocated events with azimuthal gaps of less than 250 degrees to carry out this study. The new seismicity map of the region that resulted from this relocation effort has a much better correlation with the active fault distribution of the region.We constructed traveltime curves of Pg and Pn for all of the 34 stations in the region. All Pn arrivals picked before 200 km distance and all Pg arrivals picked between 160 and 180 km were excluded from the data. The average Pn and Pg velocities and Moho depth for each of the stations were calculated. The average Pn velocity in Alborz region in the north, northeastern of Zagros, and the region in northwest are 7.97, 8.07, and 8.08 km/s, respectively. Corresponding Pg velocities are 6.14, 6.3, and 6.3 km/s, respectively. The crustal thicknesses in the three sub-regions are 43 5, 455 and 45 4 km, respectively.The dip of Moho and the Pn velocity were estimated on two profiles. Profile 1 in the NW-SE direction included stations of and Tehran (in central Alborz) networks. Each event on the profile is recorded by at least three distant stations (more than 200 km) with azimuthal differences of less than 4 degrees. Profile 2 runs N-S along the western boundaries if . For both profiles the reciprocal shot method was applied. The averages Pn velocity for the profiles are, 8.0 and 8.03 km/s, respectively, and the dip of the Moho is not significant.

Keywords: moho deoth, average pn velocity, average pg velocity

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SS001 **Poster presentation** **6201**

The crustal velocity structure in North-East Iran

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In this research, we studied the crust in the North-East of , by earthquake data inverting method. In order to study the crust in this region, the earthquakes which were recorded by Iranian seismic network were processed. By establishing profiles, each profile included two stations and one event (the event has the same azimuth with the stations); we read arrival time of P-waves in the certain stations. An initial model having 3 layers was obtained, and then by using Zelt tomography program, we refined depth and velocity parameters of each layer. The refined results were used to draw contour maps of depth and velocity variations. By analysis the contour maps, velocity discontinuities or unexpected depth variation of layers interfaces were related to faults in the region. Our results are in agreement with the results of other studies and the existing geological faults in the region.

Keywords: north east iran, zelt, tomography

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SS001 **Poster presentation** **6202**

Assessİng the capabİlİtİes of turkİsh statİons to monİtor the seİsmİcİty İn the aegean

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The Aegean Sea and its surrounding territories are the most seismically active areas in the Euro-Mediterranean region and the proximity to the foci of seismic activity is of great concern to the population residing in that region. The seismic activity in the Aegean region is monitored by a number of local agencies that also contribute their data to the International Seismological Centre (ISC). In this study we focused on the performance of the seismic network that is operated by the Kandilli Observatory and Earthquake Engineering Research Institute (KOERI). We have compared bulletins of the Kandilli Observatory and Earthquake Research Institute (KOERI) and the ISC, for the period 1976-2003 that comprises the most complete data sets for both KOERI and ISC. The selected study area is the East Aegean Sea and West Turkey, bounded by latitude 350N to 410N and by longitude 240E to 290E. The total number of events known to occur in this area, during 1976-2003 is about 41,638. 72% of those earthquakes were located by ISC and 75% were located by KOERI. As expected, epicentre location discrepancy between ISC and KOERI solutions are larger as we move away from the KOERI seismic network. Out of the 22,066 earthquakes located by both ISC and KOERI, only 4% show a difference of 50 km or more. About 140 earthquakes however, show a discrepancy of more than 100 km. Focal Depth determinations differ mainly in the subduction zone along the Hellenic arc. Less than 2% of the events differ in their focal depth by more than 25 km. Yet, the location solutions of about 30 events differ by more than 100 km. As a first approximation, we can quantify the detection capabilities of the Turkish stations, in terms of magnitude thresholds deduced from the frequency magnitude relationships. The most complete set of earthquake magnitude data refers to earthquakes that were assigned the local duration magnitude Md. This data set suggests a threshold magnitude of Md=2.7 which most likely reflects the capability of the network to detect and locate earthquakes in west . The correlation between the ISC magnitudes and the KOERI magnitudes show a relatively high scatter. This study reveals, in quantitative terms, some of the basic limitations of the current Turkish network in monitoring the Aegean region. It is apparent that KOERI, like other agencies in the region, will greatly benefit from a much improved regional cooperation. It also demonstrates the usefulness of ISC Bulletin serving as a reference that facilitates an empirical quantification of the performance of a seismic network.

Keywords: detectibility, koeri isc, aegean region

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SS001 **Poster presentation** **6203**

Aftershock distribution of the 2005 off Miyagi Earthquake (M7.2) by ocean bottom seismographic data

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Interplate earthquakes (M~7.5) have occurred repeatedly at about 40 years intervals along the subduction plate boundary of the Miyagi-Oki region, middle part of the Japan Trench area. About 30 years have already passed from the occurrence of the latest large earthquake, the 1978 Miyagi-Oki earthquake, and next large earthquake in the Miyagi-Oki region will occur with high probability in the near future. In 2005, an interplate earthquake (M7.2) occurred in this area, considered to be re-rupturing of one of the asperities of the 1978 earthquake (M7.4) (Okada et al., 2005; Yaginuma et al., 2007). It is important to estimate the progress of stress redistribution and of aseismic slip along the plate boundary around the 2005 rupture area to predict the character of the next Miyagi-Oki earthquake; how the unbroken asperities would rupture, whether the neighboring asperity ruptured in 1981 would also rupture at once. We have monitored the seismic activity around the region by deploying pop-up type Ocean Bottom Seismographs (OBSs) repeatedly since 2002. The 2005 Miyagi-Oki earthquake and its aftershocks occurred just beneath the OBS network and their hypocenters were precisely determined. In this paper, we will report the spatio-temporal distribution of the aftershocks, paying attention to their focal mechanisms. The size and location of the most active aftershock seismicity defined by our epicenter distribution did not remarkably expand. The active seismicity is observed only in the vicinity of the rupture area of the mainshock with large coseismic slip was estimated (Yaginuma et al., 2007), except for the northeast of the rupture area of the 1981 earthquake, where two large earthquakes (M6.3) occurred within two weeks after the main shock occurrence, 16 Aug. 2005. The aftershock activity is generally low to the east of the focal area of the 2005 earthquake, but we see a north-south trending zone of moderate seismicity along the western margin of the rupture zones of the 1981 Miyagi-Oki and the 2003 Fukushima-Oki earthquakes (M 6.8). The location of this seismicity seems to match to the eastern limit of the postseismic slip distribution of the 2005 earthquake (Miura et al., 2007). In this zone, there are many earthquakes having the focal mechanisms different from that of the mainshock (thrust fault type), as in the eastern edge of the rupture area of the 2005 mainshock. Therefore, we think that the distribution of the earthquakes having focal mechanisms dissimilar to the mainshock, probably occurred within the plates, may be indicative of spatial extent of the coseismic slip of the mainshock and that of the postseismic slip.

Keywords: focal mechanism, subduction zone, asperity

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SS001 **Poster presentation** **6204**

Advantage of moment tensor inversion to small local earthquakes in the Indochina Peninsula

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The purpose of the application of moment tensor inversion method is to determine source mechanisms of recent small earthquakes (ML4.5 or less), which are very common in the Indochina Peninsula. Earthquakes of this type have a widespread geographic occurrence, and in some cases provide the great clue to know the active tectonics of a region. Therefore, it is necessary to study the focal mechanism of small earthquakes using the moment tensor inversion. This paper presents results of focal mechanism solutions of small events with magnitude ranged from M4.0 to M4.7 occurred on the Lai Chau - Dien Bien Neotectonic fault zone by using moment tensor inversion method (TDMT_INV). This neotectonic fault zone lies in the Northeastern Laos-Northwestern Vietnam. It has very strong activities although it located on the Indochina Peninsula where is not in high seismicity zone. The focal mechanism solutions of these earthquakes showed that: they are the left strike-slip faults in the direction of NE-SW. These earthquakes were caused by the near horizontal compression in the near longitude direction that reflects general tectonic characteristics of this region in the Indochina Peninsula. This paper also presents the comparison results used by a single station and multiple stations at local networks. It shows that provided the study areas are not large as the Indochina Peninsula, the application of moment tensor inversion using a single station is of much benefit to determine source parameters because it saves the time-consuming efforts without harming results.

Keywords: momenttensorinversion, greensfunction, momentmagnitude

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SS001 **Poster presentation** **6205**

Aftershock observation of the intra-plate earthquakes under the NANKAI trough axis in Japan using ocean bottom seismometers

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The 2004 off the Kii Peninsula earthquake occurred around Japan islands on September 5, 2004. Knowing the precise aftershock distribution is important for understanding the mechanism of this earthquake. However, the hypocenter of the main shock was located more than 100 km offshore from the nearest station of the land observation network. In the three days after the main shock, we started ocean bottom seismometer (OBS) observation in order to determine the precise distribution of the aftershocks. And after the six days, we deployed 25 OBSs in cooperation with three universities and JAMSTEC. We assumed a seismic velocity structure for the hypocenter calculation, based on the results of previous seismic refraction study. The station corrections were incorporated to locate the hypocenter precisely. The hypocenters located within an area covered by 25 OBSs show relatively small errors. It is found that the OBS-located hypocenters are located about 5.5 km east-southeast from those by Japan Meteorological Agency and the depth range of the aftershocks is about 5-25 km just beneath the Nankai trough axis. The aftershock hypocenters can be grouped into two clusters at different depths of about 10 km and about 20 km. The shallower group is located within the oceanic crust of the bending and subducting Philippine Sea plate (PSP). The deeper group is located within the upper mantle of the PSP. Although we cannot assign the actual fault plane of the main shock form our observation results, it is clarified that intra-plate earthquakes occurred near the trench region. Our OBS result supports that the main shock was the earthquake not at the plate boundary but within the bending PSP near the trough axis.

Keywords: intra plateearthquake, obs, troughaxis

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SS001 **Poster presentation** **6206**

Correlations of magnitude and felt-area for earthquakes in the Fennoscandian Shield/East European Platform

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Magnitudes of historic, pre-instrumental earthquakes are estimated from observed intensities and felt areas. For a start, a basic requirement is access to macroseismic and instrumental observations for establishing meaningful correlations between modern digital magnitudes and felt areas for various intensity levels. Commonly a log-linear relation is established between instrumental magnitudes and size of felt area for intensity level 3. Our preference is for intensity 4 felt area as the macroseismic parameter, since this gives less ambiguities. Recently we have established an interactive graphic procedure for estimating sizes of felt areas. In fact, the center of a reasonable enclosing ellipse may be used constructively as the macroseismic epicentre. This procedure has been extensively tested on recent earthquake observations in Scandinavia with satisfactory results. The set of data points has just been extended, so that judgement becomes better for larger magnitudes. New important key points in the correlation between modern digitally-determined magnitudes and felt areas have become available from the Kaliningrad earthquakes in 2004. They can be used together with smaller events to scale old earthquakes. This gives improved judgement of the larger-than-usual earthquakes like the Oslo earthquake 1904, which is very similar to the largest Kaliningrad earthquake 2004 of Lg-wave magnitude 5.3.

Keywords: earthquakemagnitude, earthquakefeltarea, fennoscandianshieldeasteurope

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SS001 **Poster presentation** **6207**

Relocation of the 31 March 2006 Lorestan (Iran) earthquake sequence using the double-difference technique

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Analyzing tectonic processes and microseismic activity inside the hypocentral volume of an earthquake require accurate knowledge of precise spatial offset between the aftershocks hypocenters. The relocated epicenters can define seismicity zones that activated during this event. In this way, the HypoDD relocation technique is very efficient approach to take help. This technique has been extensively used with data from permanent and temporary networks around the world, where it has demonstrated an ability to improve the image of seismicity in every case studied. In order to obtain the reliable parameters in this procedure, we weighed p-wave first arrivals due to residual variance as a function of distance, as well as applying the systematic errors of station to reweigh data. The data bank of this research is consisted of aftershocks of Lorestan shock within two months after the mainshock occurrence. Routine catalog P-phase and S-phase data from the permanent stations of the Iranian National Telemetry Network are used to relocate aftershocks of this event. As a consequence of this research, we show that weighing and reweighing the data set give a good estimation of accurate hypocentral parameters for better understanding of the seismotectonics of active fault zone.

Keywords: systematicerrors, aftershocks

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SS001 **Poster presentation** **6208**

Equipartition of seismic waves in the long and short period seismic coda: observation and theory

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We report the observation of equipartition of seismic waves in the long and short period band of seismograms. Equipartition is a first principle in multiple scattering which stipulates that in a small frequency band, all the modes are excited to equal energy. As a consequence, any energy ratio such as kinetic to potential, shear to compressional, vertical kinetic to horizontal kinetic should become independent of time. Such stabilization is observed over a wide range of frequencies in seismic data, but the equipartition time varies from a few seconds around 3 Hz to more than twenty thousand seconds at 10 mHz. Roughly stated, the scattering strength decreases by five orders of magnitude over three orders of magnitude in frequencies. In the short period band, we calculate theoretically the energy ratios at equipartition using an exact spectral decomposition of the elastic operator in stratified elastic media which combines a discrete and a continuous spectrum. Excellent agreement is found between theory and observation. We find that the frequency dependence of energy ratios gives information on the local velocity structure. At long period, equipartition ratios can be calculated using a classical normal mode decomposition of the elastic operator. Agreement between theory and observation is fair. We ascribe the discrepancy to the effect of absorption which tends to suppress preferentially toroidal modes. Numerical models of multiple scattering in scattering and absorbing media are currently under development.

Keywords: coda, multiple scattering, equipartition

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SS001 **Poster presentation** **6209**

Seismo-acoustic study of the dynamic processes in the system "Solid Earth – Atmosphere" at Mikhnevo array.

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We present the analysis of seismo-acoustic data obtained at geophysical observatory Mikhnevo in the Moscow Region, Russia. Large about of pulses with duration 1-2 s are observed in seismic records. Spectral properties (frequency range 3-40 Hz) and time-spectral characteristics of the pulses do not allow to attribute them neither to earthquakes nor to explosions or other events of technical origin. More than 600 events of pulse type from January, April, June, September and December 2006 were selected for detailed study of seasonal variations. The smallest number of events was recorded in January (48), this number increases in April (120); the peak number is reached in June (216). Analysis of correlation of seismic and acoustic records with weather conditions, such as wind, rain or snow, and thunderstorms was carried out. Seismic pulses were separated into several groups according to the waveforms. Events of the first group were observed during the end of April and in June, and were not observed in January. Detailed analysis allows to relate this group of pulses to the propagation of thunderstorm convective cells above the site of the seismic array Mikhnevo. Another group of pulses reaches its maximum on the day following the thunderstorm. No correlation between the pulses number and the precipitation level was found. Observed effect can be accounted for by the changes in stress-strain state of the uppermost crust, caused by interactions on the boundary "atmosphere – solid earth". It is supposed that the process of relaxation of the crust after the influence of thunderstorms results in impulse seismic energy emission.

Keywords: seismic, acoustic, array

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SS001 **Poster presentation** **6210**

Seismic observations at Russian Platform

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During the last decade considerable attention has been attracted to the study of the seismicity of the platforms, the East European (Russian) Platform (EEP) in particular. Recording of events with small magnitudes became possible after the extension of the seismological network with the installation of new seismic stations on the Voronezh crystalline massif, in the north-west of Russia – in Arkhangelsk region, and in the central part of Russia – in the Moscow region, where the small aperture array Mikhnevo is operating since 2004. Beginning with 2000 more than 10 tectonic earthquakes with magnitudes over 3 were recorded with epicenters in the conjunction zones of the EEP and other tectonic plates, such as Skif and Tymano-Pechora, as well as within the ancient Baltic and Ukrainian schields and other tectonic zones. More than two thousand events of different origin are recorded by the seismic array Mikhnevo in the central part of the Russian platform. Analysis of spectral characteristics of most of these events, time of the day distribution, frequency and location of epicenters allow to consider most of these events as industrial explosions. Nevertheless some of these events can be regarded as tectonic earthquakes. Recording of a large number of quarry blasts gives the basis for the construction of the detailed velocity model of the region. Addition of temporary observation sites will help to build a detailed three dimensional model necessary for the accurate event location.

Keywords: seismicity, platform, earthquake

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SS001 **Poster presentation** **6211**

Recent developments of the seismological station network and seismic mapping of earthquake activities in Turkey

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Turkey is one of the most seismically active countries in the continents of the world. The observed earthquakes in the country are generated as a result of the collision of the Arabian and African plates with Eurasia. In order to meet the requirements of monitoring, real time reporting and prediction for large earthquakes and to provide information for engineering construction and scientific research work, at present, The Kandilli Observatory and Earthquake Research Institute and ERI & National Earthquake Monitoring Center (NEMC) has been monitoring the seismic activity countrywide since 1926. At the beginning of 1990s year there were only 22 seismic stations in operation in Turkey. Particularly, after the 1999 catastrophic East Marmara Earthquakes (Golck, Mw=7.4; Dzce Mw=7.2) remarkable development has been occurred in Turkey seismology in the last 8 years. During and since this period the number of seismic stations have been raised from 65 to 120. The satellite based data transmission system has been set up in 2004 and 56 broadband stations have been installed in Turkey so far. Events are recorded at the center both in analog and digital forms obtained from telemetred, broad-band and on-line seismic stations. In the Center, the seismological data from all 120 stations are manually interpreted (P and S arrivals, identification, first onsets, signal duration) and processed by computer for the focal parameters determination an adaptation of the software HYPO71 and the four layers regional velocity model are used. The center determines as rapidly and accurate as possible, location and size of all earthquakes magnitude larger than 2.5 that occur in the country. NEMC provides twenty-four hour information service to government agencies,to government public information centers and to news media for the initation of effective emergency response, search and rescue operations. The center has been supplying mainly 3 kind of seismological data; event based data files, waveforms and catalogue to the earth scientists in Turkey and over the world through internet facilities. The data are also disseminated to the relevant international seismological centers such as NEIC,ISC and CSEM by e-fax,SMS and internet. The data centre NEMC offers free access to its seismological waveform archive to all scientific users . The waveform archive can be found on the web pages of the NEMC. After modernization, NEMC became a high standarted network providing, high quality real-time seismic monitoring and reliable rapid earthquake information to both authorities in Turkey and international seismological centers in the world.

Keywords: seismicobservation, seismicity, network

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SS001 **Poster presentation** **6212**

Characteristics of double bottom simulating reflectors by amplitude verses offset modeling

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Occurrence of Bottom Simulating Reflector (BSR) in the Multi Channel Seismic (MCS) data infers the possible presence of gas hydrates in the region of study. The identification of Double Bottom Simulating Reflector (DBSR) in the seismic data necessitates different approaches for the processing and interpretation. Such attempts provide opportunities to built new concepts for the formation and the genesis of hydrates. We have modeled for the formation of DBSR considering isotropic and anisotropic medium. We find that DBSR can occur either because of the upward migration of gas through discrete layers or presence of a low velocity layer with in the gas hydrate zone. We interpret the presence of DBSR in terms of the distribution of methane hydrate source. In presence of seismic anisotropy, frequency depending amplitude verses offset (AVO) and amplitude verses angle (AVA) analysis reveal the characteristics of DBSR. The AVO within pre-resonant frequency (tuning effect) range of the DBSR model differs considerable from that in the resonant frequency.

Keywords: gas hydrates seismic anisotro, double bottom simulating refl, amplitude verses offset frequ

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SS001 **Poster presentation** **6213**

Aftershock distribution of the 2003 Tokachi-oki Earthquake derived from temporal network of ocean bottom seismographs

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The 2003 Tokachi-oki earthquake (M8.0) occurred in the area off the southeastern coast of Hokkaido in northern Japan at 19:50 UTC, 25 September 2003. To obtain a detailed aftershock distribution, we constructed a dense seismic array using pop-up type ocean bottom seismometers (OBSs) five days after the main shock. The observation in total 47 OBSs at 38 sites lasted one and half months. The observation array covered a 150 km x 100 km area, where a high aftershock activity was estimated from a land seismic network. For accurate determination of aftershock distributions, we deployed OBSs with a spacing of 15 km near the trench in contrast to 20 km in the landward region. Hypocenters were determined by using a three-dimensional velocity structure based on the seismic refraction study. From an epicentral distribution, aftershocks occurred within the small slip region of the mainshock rather than the large slip region. In addition, the epicentral distribution of aftershocks except near the large slip region, is similar to that of the earthquakes occurring before the mainshock. The hypocentral distribution forms a dipping plane toward the land and we infer that this plane shows the upper boundary of the Pacific Plate.

Keywords: subduction, obs, tokachi oki

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SS001 **Poster presentation** **6214**

Update of the European-Mediterranean Regional Centroid Moment Tensor (RCMT) Catalog

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The European-Mediterranean Regional Centroid Moment Tensor (RCMT) Catalog collects solutions routinely computed since 1997 for earthquakes with moderate magnitude (4.5 < M < 5.5) in the Mediterranean region. The database represents an extension to smaller magnitudes of the Global CMT catalog, based on analysis of seismograms recorded at regional distance, and on modeling of intermediate-period surface waves. The Catalog is regularly updated until a few months behind real time, and published on Phys. Earth Planet. Int. and on the internet. Quick solutions, based on data available in quasi-real time, are generally published on the web one or a few hours after event occurrence. We further extended the catalog back in time for the Italian region, as far as availability of digital data allows since 1977 with the same analysis and inversion method used for current seismicity. The new dataset includes events in many seismic zones where moderate seismicity had previously been scarcely documented, e.g. the Po Plain and the Adriatic Sea. Seismicity in the Central Adriatic Sea holds special interest, as the region had often been depicted as aseismic.

Keywords: focal mechanism, mediterranean, catalog

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SS001 **Poster presentation** **6215**

The fault zone of Mw=7.6 Olyutorskoe earthquake (Apr. 20, 2006, Koryakia, NE Russia) reconstructed from GPS, geological and seismological data: the first emerged segment of North-American - Beringia plate boundary

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The large Mw=7.6 Olutorskoe earthquake occurred in a territory of very low historical seismicity located in Koryakia District in North-Eastern Russia. To analyze the source of this rare event, we combine original geodetic and field geology data, with seismological evidence on aftershocks, and earthquake source structure determined from teleseismic P waves . Two permanent GPS stations TIL and KAM, located in the vicinity of the fault, showed clear coseismic displacements, of 10 and 2 cm, respectively. The surface rupture was oriented SW-NE, roughly along the coast of Bering Sea. Fault branches were traced along about 120 km length of a segmented fault that crossed snow-covered tundra, largely with permafrost. The sense and amplitude of slip could be accurately recovered only in a few locations, each of 0.5-1.0 km length. The amount of slip (up to 4 m) and its orientation varied significantly. In one extreme case, strike-slip motion with normal component was observed. However, the general picture agrees reasonably well with Harvard CMT tensor orientation that predicts reverse dip-slip with slight right shear. Among two nodal planes, one dipping SE seemingly agrees better with field geology, suggesting the uplift of the coastal block. The size and position of the seismogenic fault was determined from three independent sources: aftershock data, and spatial part of two reconstructions of the source obtained by two independent inversions of teleseismic P waves, that used broad-band amplitudes and high-frequency energy. With assumed fault position, size and dip, GPS displacements were inverted for slip orientation and seismic moment, resulting in a good fit with Harvard CMT parameters. As an alternative, the auxiliary nodal plane was tried as a possible real one, with definitely worse fit. Previously, the boundary between the North-American (NA) plate and hypothetic Beringia (BE) miniplate was assumed to be situated in the study area. The earthquake fault zone of April 20, 2006 event accurately fits this prediction, and can be considered as an emerged segment of the named boundary. However, with lack of significant mountain-building and relatively small observed strike-slip, the style of overall motion along this boundary remains vague.

Keywords: earthquake source structure, surface rupture, plate boundary

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SS001 **Poster presentation** **6216**

Constraints to source properties of the October 9, 2006 underground nuclear explosion in North Korea from regional observation

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Various issues remain puzzling with the recent underground nuclear explosion (UNE) test of North Korea on October 9, 2006. One of outstanding questions is how big the event was. Another question is why Lg wave, which is typically the most prominent regional phase even for UNEs, is not observed well in regional observations at South Korea. This Lg phase used to be importantly analyzed for constraints to the size of detonation. We observe that the regional seismic waves recorded at stations in South Korea are significantly affected by the variation in crustal thickness along the great-circle ray-paths that cross over the continental margin of East Sea (Sea of Japan). This ray-path effect is confirmed from additional analyses of three natural earthquakes occurred in North Korea. We find that the Lg from the nuclear explosion was significantly dissipated by energy leakage into the Moho due to Moho undulation. A part of the leaked energy appears in a form of mantle-lid waves, which causes an energy addition to the Sn portion. The observed feature is supported by a numerical modeling of waveform. The Lg body-wave magnitude, mb(Lg), of the UNE is estimated to be 4.00.2 from records with pure continental paths.

Keywords: underground nuclear explosion, north korea, regional observation

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SS001 **Poster presentation** **6217**

Free oscillations of the Earth observed by closed borehole wells

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We have made observations of pore pressure under undrained conditions by an airtight borehole penetrating an artesian, or confined aquifer in the Atotsu tunnel, excavated in the Kamioka Mine in central Japan. We confirmed that the relation between pore pressure change and stress change is a zero-order system for a wide range of frequencies. That stress change, strictly speaking strain change, is induced within the rock mass shared by the skeletal framework of rock and pore fluid. The 26 December 2004 Mw = 9.1 Sumatra-Andaman Islands earthquake (epicentral distance Δ = 51) enabled us to investigate how a closed borehole responds to free oscillations of the Earth. We carried out Fourier analyses of the hydroseismogram, or pore pressure record, produced by the Sumatra-Andaman Islands earthquake. We examined (1) whether the closed borehole has sufficient sensitivity to identify free oscillations, and (2) how the closed borehole responds to spheroidal and toroidal modes. The poroelastic theory predicts that pore pressure should respond only to spheroidal modes since pore pressure change is proportional to volumetric strain change. No pore pressure response is expected from shear strain that is produced by toroidal modes. However, it is controversial whether pore pressure responds to shear strain, since phases corresponding S- and Love waves have been detected on hydroseismograms. We calculated the spectrum for 24 hour time windows (86400 points) shifted by 1 hour, from 24 hours before the origin time of the event to 24 hours after. The spectral peaks corresponding to fundamental spheroidal modes were clearly observed. The Q of each mode is calculated by fitting the decay of the amplitude of each peak. The peaks whose eigenfrequencies are less than 1 mHz (0S0, 0S22, 0S3, 0S4, and 0S5) clearly appear 5 hours after the event. On the other hand, no spectrum peak corresponding toroidal modes was observed. These results confirm that the poroelastic theory correctly predicts the pore pressure response.

Keywords: pore pressure, free oscillation, sumatra andaman

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SS001 **Poster presentation** **6218**

Poroelastic observations of seismic phenomena using closed borehole wells

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We developed a new technique to precisely measure pore pressure changes with a closed borehole well. The new measurements improve the frequency response of pore pressure observation compared to conventional techniques, which use water level measurements in open wells, by greatly reducing the water flow between the well and surrounding rocks. From 2002 to the present, we monitored pore pressure changes of the host rock using two closed borehole wells drilled in the Atotsu tunnel in the Kamioka mine, central Japan. The distance between two boreholes is 40 m. We analyzed the response of the pore pressure produced by loading and unloading of barometric pressure (at frequencies of 10-6 - 10-5 Hz). We also analyzed the response of the pore pressure to crustal deformation associated with earth tides (at frequencies of 10-5 Hz). The hydroseismograms (pore pressure oscillations associated with passage of seismic waves at frequencies of 0.1 - 1 Hz) that were recorded for the large earthquakes (including the 2004 Kii-Hanto-Oki, 2004 Chuetsu, the 2004 Sumatra-Andaman Islands, 2005 Fukuoka-Seiho-Oki, 2005 northern Sumatra, 2006 and 2007 Kuril earthquakes) revealed that the radial component of ground velocity is proportional to pore pressure. One borehole (K1) has a flat frequency response in this wide (barometric, tidal and seismic) range of frequencies. The other borehole (K2) shows a seismic response comparable to K1, but negligible barometric and tidal response. The difference of barometric and tidal response between two boreholes implies that the hydraulic diffusivity of the volumes probed by the two boreholes is different and the degree of confinement has a frequency dependence that is controlled by the hydraulic diffusivity. The water volume associated with K1 is confined for barometric, tidal and seismic frequencies, while the water volume associated with K2 is only confined for the seismic frequency range. The pore water around K2 drains into a water table for the barometric and tidal frequency range. Based on these observations, we confirm that the pore pressure and deformation changes, in response to elastic stresses, are well described in terms of the theory of linear poroelasticity throughout a wide range of frequencies with consideration of the variation of hydraulic diffusivity.

Keywords: pore pressure, hydroseismogram, poroelastisity

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SS001 **Poster presentation** **6219**

Shallow seismic fault zone beneath the Taipei Basin in Northern Taiwan

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The Taipei basin, an area of historically low seismicity, is located in northern. A dense broadband seismic array has been deployed in the basin since June 2004 to monitor seismic activity. During the period of operation, three felt earthquakes occurred near the eastern Taipei basin, about 3 km to the south of Taipei 101. Well-located earthquakes recorded by the broadband array and collected over the last 34 years show a clear pattern of southeast-dipping distribution for hypocenters beneath the Taipei basin. The seismicity pattern and focal mechanisms suggest that the felt earthquakes with normal faulting are most likely associated with an unknown fault along the river channel in the middle of the basin. This fault may be the result of the lower reach of the Tahan River changing its flow dramatically from northward to northeastward to cut across the northwestward flow of the Hsintien River in the Taipei basin.

Keywords: taipei basin, fault zone, river channel change

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SS001 **Poster presentation** **6220**

Relocation of Earthquakes in Northwest Region of Iran using HDC Method

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Earthquake Location and having reliable data sets is the most important aspect for any geophysical research or analysis and has been the most important task of the seismologists to do so. There have been so many methods being used to minimize the error in location and improve the results of the geophysical researches. The best methods for location have been proved to be the relative location using inverse problems. In this study we used the HDC method (Hypocentroidal Decomposition) which is a new method for relocation. We divided the region of interest into four sections and relocated 130 teleseismic earthquakes from 1930. The results show that in section one we had a maximum shift of 13Km at an azimuth of 71deg for March 30th 1993 earthquake with the magnitude of 4.5 at Tasodj, in section two we had a maximum shift of 10Km at an azimuth of 251deg for April 2nd 1983 earthquake at Iran-Azerbaijan border (south-west of Caspian sea) with the magnitude of 4.7, in section three we had a maximum shift of 14Km at an azimuth of 258deg for July 25th 1988 earthquake at Baneh with the magnitude of 4.7 and in section four we had a maximum shift of 14Km at an azimuth of 127deg for June 20th 1990 earthquake with the magnitude of 6.2 at Rudbar region. The average depth in the region is almost 17 km and all the relocated earthquakes are in agreement with the regions faults trends.

Keywords: hdc, relative location, northwest iran

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SS001 **Poster presentation** **6221**

New data to assess seismic hazard of Kazakhstan

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According to current maps of general seismic zoning, south and south-east of Kazakhstan was considered as seismic active zones over decades. Earthquake catalogues were used as basis for seismological base of seismic zoning maps. The catalogs were compiled for Kazakhstan territory over long period using the results of SEME RK seismic stations network operation. Essentially, these stations are installed at areas that traditionally considered as seismic. Processing of these data and inclusion of processed events into catalogues was subjective, i.e. the compiled catalogues were limited by the regions of high seismicity Northern Tien Shan and Dzhungaria. In recent years, new digital network of seismic stations of National Nuclear Center of RK was created and operates. The main task of the stations network is monitoring of nuclear explosions within CTBT. At the present time the network includes 6 threecomponent stations, 8 seismic arrays and 3 infrasound stations. NNC RK stations have the best conditions for seismic signals registration among all Kazakhstan stations that detect low level of seismic noises in location area. Stations are located along the perimeter of Kazakhstan. In recent years, staff of Data Center of IGR NNC RK has analyzed retrospective historical data and new data of digital stations. Availability of large amount of historical seismograms since 1960 in the Republic allowed to determine parameters of series of historical earthquakes from different areas of Kazakhstan. Opinion of Kazakhstan seismicity has changed significantly. Several source zones were revealed in regions that traditionally were considered as aseismic or of low activity. Tectonic events with magnitudes mb>4.5 (with intensity up to 6) were localized in Central Kazakhstan and in North-East of Kazakhstan near Semipalatinsk Test Site. Many earthquakes with magnitudes mb>3 occurred in the north of Kazakhstan, in the north of Balkhash region and in the west of Kazakhstan. In addition, using data of IGR seismic bulletins, seismic activity in the east and south of Kazakhstan was calculated and as a result higher values of this parameter were received. New data about seismicity should significantly influence on the assessment of seismic hazard in Kazakhstan and should be taken into account during plotting of the new map of general seismic zoning.

Keywords: seismic hazard of kazakhstan

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SS001 **Poster presentation** **6222**

Nature and characteristics of seismic noise at periods near 1.6 second according to data of stations located in northern Tien Shan

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At the present time there are many digital and analog seismic stations in Northern Tien Shan region. Records of these stations are used to compile earthquake catalogues, study of Earthstructure and geodynamical processes in this region. Stations are located near such mountain ridges as Zailiysky Alatau, Terskey Alatau, Ketmen, Kyrgyz ridge. Instruments are installed on bedding rock. Most of the stations have noise level close to low-level model of Peterson, i.e. these stations are very efficient for seismic monitoring. However, appearance of strong noises was noticed in seismic records during storms at Issyk Kul Lake. Issyk Kul is a high-mountain deep lake, 182 km length and 58 km wide, average depth is 280 m, maximum depth is 702 m (in the middle of the lake, closer to south coast). Therefore, study of short period microseism on the basis of spectral and spatial-time analysis of wave fields registered by Northern Tien Shan stations is of much interest. Detailed analysis of dynamical characteristics of seismic noise during storm days in Issyk Kul in comparison with quite days was conducted for 17 broadband seismic stations installed on the territory of Kyrgyzstan and Kazakhstan in 1997-2000 within Tien Shan Project. Noise characteristics in the day time and night time were analyzed separately. Stations are located at different azimuths from the lake at the distance range 5-250 km. Sharp increase of spectral density of seismic noise in frequency range from 1.5 to 2 s was detected for all stations during storms in comparison with quite days. Augmentation of noise spectral density level reaches 30 dB for the closest stations (ANA, KAR, KDJ) and decreases log. linear law with distance. Thus, for the most distant Khantayu station this difference is only 3 dB. Polarization analysis of microseism was made and seasonal variations of storm microseism were considered for the closest stations to Issyk Kul. Essential influence of storms in Issyk Kul on stations effectiveness located in the region of Northern Tien Shan is shown. Recommendations concerning frequency filters to decrease influence of noises were given.

Keywords: seismic noise, northern tien shan

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SS001 **Poster presentation** **6223**

Seismic monitoring of the northern Caucasuss central part in Russia.

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Starovoit Oleg

Geophysical Survey Russian Academy of Sciences is responsible for seismic monitoring in Northern Caucasus the most seismically active regions of European part of Russia.After 2000 improvement of a network of Northern Caucasian seismic stations is connected with two factors: installing the modern digital equipment on existing seismic stations and creation new stations in seismoactive zones of this region. Five new seismic stations were installed in central part of Northern Caucasus at last year:- in Kabardino-Balkaria Republic Nalchik and Kuba-Taba; - in Karachaevo-Cherkesskaia Republic Arkhys and Dombay in Near Elbrus mountains area;- in Stavropol region - Nevinnomyssk.Short-period seismometers SM3-KV and digital equipment SDAS produced in GSRAS (Obninsk) has been established at these stations. These observations take part in production of the regional seismological bulletin in common with other eighteen stations worked in this area earlier. A possibility of local network is increased in central and western parts of region. About a thousand earthquakes with magnitudes more than M=1-1.5 are registered in this zones of Northern Caucasus every year.There is a local data collection and processing center in Kislovodsk, Caucasian Mineral Water region, which worked in Alert and Current regimes and send information in central Data Processing Center GSRAS (Obninsk). WSG (Windows SeismoGrapher) software package is used for standard processing of seismic records and analysis of seismic data. Software has Russian language interface and can be operated in widely used operation systems MS Windows 9X/NT/2000/XP.This software contains the module of mathematical processing of signals and a set of utilities for using different data formats.The procedure of the regional seismic bulletin includes location with using local velocity model and calculation of three magnitude estimations: energy class K, regional body wave magnitude MPSP and local magnitude ML.

Keywords: northern, caucasus, observations

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SS001 **Poster presentation** **6224**

Development of Multiscale Slip Inversion Method and Its Application to the 2004 Mid-Niigata Prefecture Earthquake

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We present a multiscale slip inversion method for earthquakes as a first attempt to analyze an initial rupture process on a small scale and a whole one on a large scale. A multiscale source model is constructed by renormalizing slip rate distributions on different scales. A multiscale observation equation includes a renormalized kernel matrix. Using the new method and employing theoretical and empirical Greens functions with two small events (Mw 2.3 and 3.3), we analyze the 2004 mid-Niigata prefecture earthquake (Mw 6.6). Following a preliminary deconvolution analysis suggesting a complexity of the initial phase, the multiscale analysis reveals details of the initial stage of the rupture process (the first 1 s) successfully. In the multiscale model, the estimated source process is consistent for all scales, while independent slip inversion analyses on three scales (monoscale analysis) result in inconsistent slip distributions with large errors. The maximum slip rate is about 1.0 m/s and the rupture velocity is 2.53.0 km/s in the initial rupture process. Four stages of rupture growth with different rupture directivities are found: the first 0.4 s with northeastward directivity; from 0.6 s to 1.0 s with southward directivity; until 2.0 s with northeastward directivity again; and after 2.0 s with southwestward directivity. These stages may represent cascading ruptures, evolving into a large earthquake. The image of the whole rupture process implies self-similarity of the dynamic rupture process and is a breakthrough in the complete realization of earthquake source scaling.

Keywords: multiscale analysis, slip inversion analysis, mid niigata earthquake

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SS001 **Poster presentation** **6225**

Testing coda methods in high resolution seismic imaging of active volcanoes: application to Campi Flegrei and Mt. Vesuvius.

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The three-dimensional S waves attenuation images at Mt. Vesuvius and Campi Flegrei havebeen obtained by multiple measurements of coda-normalized S-wave spectra.For Mt. Vesuvius we used 2203 waveforms, relative to 826 volcano-tectonic earthquakes,located close to the crater axis in a depth range between 1 and 4 km (below the sea level),recorded at 7 3-component digital seismic stations. For Campi Flegrei area we applied ourmethod to 853 waveforms, relative to 224 earthquakes, recorded at 15 different seismic stations.We adopt a two-point approximate ray tracing (Thurber modified) traced in the high reso-lution 3-D velocity model which was previously obtained by velocity tomography. The coda-normalization method was already applied to a limited data set to image the S-wave seismicattenuation structure in the same area; the new database is now able to image a bigger partof the area, with a resolution comparable with that of the velocity tomography. We also ap-plied the ordinary spectral-slope method to both P- and S-waves. This method is based onthe assumption that the differences between the theoretical and the experimental high fre-quency spectral-slope are only due to attenuation effects. The total attenuation factor hasbeen estimated assuming that the theoretical high frequency spectral source decay equals theexperimentally evaluated average spectral decay. We applied this method to test the goodnessof the coda-normalization method as well as to complement the S attenuation image with theP attenuation image. The images were obtained applying multiple least square inversion of thespectral data in order to increase the space resolution. The minimum resolution cell dimensionresults to be of 300 m.Results for Mt. Vesuvius are particularly intriguing, showing the coincidence of an high-Qzone exactly located below the crater between 0 and 1 km depth, with the high velocity zone atthe same depth, inferred by the velocity tomography. A low-Q zone is located at the N-W sideof the high Q zone, and may be associated with the low rigidity volcanic materials constitutingthe aquifer.

Keywords: coda normalization, spectral slope, quality factor

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SS001 **Poster presentation** **6226**

Microtremor Observations in Taipei Basin

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Bor-Shouh Huang, Kou-Chen Cheng

In 2004, Institute of Earth Sciences (IES) was contracted by Central Geological Survey (CGS) to deploy a seismic network to investigate, evaluate and monitor of the seismicity for the active faults in metropolitan Taipei. The network is to install to provide continuously monitor seismic activity and its low frequency tremor. At the end of 2006, more than twenty free-field stations were deployed in Taipei Basin and its surrounding area. Each station in the network consists of a triaxial force-balanced velocity (Model KS-2000). Their outputs are digitized at each station with 24-bit resolution at 100 samples per second (Model DL-24). Besides, two broadband downhole seismic stations with depths of 100 meters and 150 meters, respectively, were also built up in Taipei Basin. The free-surface and downhole seismic stations will be integrated to form a 3-D seismic network and to attain a high probability of recording seismic activitiesin this area. In this study, the microtremors will be investigated by using of frequency-wavenumber analysis. Our goal is to realize the origin and characteristics of microtremors in the metropolitan Taipei area. One of the major considerations in the future study is try to realize the effects for a site in response to weak and strong motions from different sources in Taipei and to improve our understanding of the urban seismic hazard in Taipei.

Keywords: microtremor, frequency wavenumber

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SS001 **Poster presentation** **6227**

An updated unified catalogue of earthquakes in Central, Northern and Northwestern Europe

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Homogeneous high-quality earthquake data covering large territories and long historical time spans are lacking for many parts of Europe. Domestic catalogues cover small areas, and international data centres such as the ISC, NEIC and EMSC cover short time periods, at least what concerns but the largest events. These sources as well as the Krnk (1996) European catalogue (1800-1990) with high strength thresholds do not meet the full needs of seismicity and seismic hazard studies in this area of low activity. To remedy this deficiency, Grnthal and Wahlstrm (2003) presented a catalogue for Europe north of the Mediterranean region (north of lat. 44N), based on data from many local catalogues and special studies, and with homogenized Mw magnitude. This catalogue, which includes events with Mw >= 3.50 north of lat. 44N, is frequently visited at our web page http://seismohazard.gfz-potsdam.de/projects/EEC_CNNW.html. It has now been upgraded from several continued and new sources, and extended to the years 1000-2004 (previously 1300-1993). The new catalogue contains some 7,000 events, i.e., about 2,000 more than the previous version. It is based on a databank of about 175,000 entries compiled from all the considered local data sources. The reduction and selection of the final data set include identification and removal of non-tectonic and different types of fake events, specification of size criteria, and selection algorithms with respect to local catalogues (duplicate elimination) and strength types. A variety of relations derived in this study, by Grnthal and Wahlstrm (2003) or locally available are used for the Mw calculations. An innovation with the new catalogue is an analysis of the degree of harmonization of Mw obtained from different data sources.

Keywords: earthquake catalogue, mw homogenization

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SS001 **Poster presentation** **6228**

Geometry and seismogenic layers of the young Philippine Sea slab beneath Southwest Japan as estimated from hypocenter distribution and seismogram interpretation

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The geometry of the upper surface of the young Philippine Sea (PHS) slab beneath southwest Japan was inferred based on the intraslab seismicity, which was examined by the JMAs hypocenter database, and the identification of seismogenic layers, oceanic crust or mantle, which was made by phase interpretation on NIEDs Hi-net seismograms. We focus on the region from Ise Bay to the Kii Peninsula. We investigated seismograms of intraslab earthquakes (> magnitude 3.5) during the period from October, 2000 to May, 2005. They turned out to be classified into two groups, events with weak initial phases and ones without them, in the azimuth of gentle dip of the slab. Based on the existence of weak P and S initial phases, their apparent velocities, and numerical simulation by Sekiguchis (1992) Gaussian beam method, we revealed that the events with weak initial phases had occurred within the oceanic crust. The weak initial phases are interpreted as refracted waves through the oceanic mantle, which are accompanied by direct waves as later phases. As for the events without weak initial phases, we consider that they occurred within the oceanic mantle, and that the initial phases are direct waves. We also investigated the distribution of well-determined hypocenters and estimated the geometry of the upper surface of the PHS slab assuming that it roughly coincides with the upper limit of crustal seismicity. The estimated slab geometry and remarkable features are as follows: (1) From Ise Bay to Lake Biwa, the slab is subducting northwestward with gentle dip, on the other hand, the slab is subducting steeply beneath the Kii Peninsula. (2) A double seismic zone can be seen clearly though the PHS slab is young. The events of upper plane with weak initial phases are considered to occur within the oceanic crust and the events of lower plane without weak initial phases, within the oceanic mantle. (3) Beneath the middle part of the Kii Peninsula, dip angles and depths of the intraslab seismicity show difference between the northeastern and southwestern parts. Some lineaments along the SSE-NNW direction can be seen in the slab seismicity in the southern part of the Peninsula. Together with remarkable lineaments of aftershocks of the 2004 Off-the-Kii-Peninsula earthquakes in the SE-NW direction and highly fractured oceanic crust off the Peninsula revealed by seismic survey, we infer that the slab is fractured in the SE-NW direction beneath the wide region from the Nankai trough to the Kii Peninsula. This slab fracture zone may be formed by the difference of convergence modes, buoyant subduction to the east and normal subduction to the west, and seems important for tectonics in this region.

Keywords: phase interpretation, seismogenic layer, intraslab earthquake

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SS001 **Poster presentation** **6229**

30 years ongoing development of the German Regional Seismological Network and the GRF-array

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The Seismological Central Observatory Graefenberg (SZGRF), a part of the Federal Institute of Geosciences and Resources (BGR), is the data centre for the German permanent digital broadband stations. The core of this station set is the Grfenberg-Array (GRF) and the German Regional Seismological Network (GRSN). GRF and GRSN are the two major broadband station systems within . The 13 stations of the GRF array are in operation since 1976 and the GRSN project started in 1991. Currently a total number of 42 stations is contributing to the continuous waveform archive of the SZGRF. The size of the data archive is about 1 TByte, all data are automatically accessible using Raid-Systems and DVD- and CD-Jukeboxes. The data are available via AutoDRM and Internet (www.szgrf.bgr.de) with a delay between a few minutes and one day. All detected local, regional and teleseismic seismic events are manually analysed on a daily basis. For regional events at the border and outside of , waveform data of GEOFON, and are used for routine data analysis. Those data which are not available on Seedlink connections are copied via AutoDRM within a few minutes. Analysed source parameters are stored in a database and distributed to national and international data centres (EMSC, NEIC, ISC). The homepage of the SZGRF (www.szgrf.bgr.de) allows interactive requests to this database.

Keywords: grsn, grf array, germany

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SS001 **Poster presentation** **6230**

Modernization of the Slovenian National Seismic Network

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The Environmental Agency of the Republic of Slovenia, The Seismology and Geology Office is responsible for the fast and reliable information about earthquakes, originating in the area of and nearby. The project Modernization of the Slovenian National Seismic Network started in the year 2000 and was completed in the year 2006. The purpose of a modernized seismic network is to enable fast and accurate automatic location of earthquakes, to determine earthquake parameters and to collect data of local, regional and global earthquakes. In view of the required sensitivity, precision and geological conditions, a network of 25 seismic stations were chosen. The decision was mainly influenced by the geological conditions and locations of the existing seismic stations. It is desirable that seismic stations be located on the hardest rock possible, which has favourable geo-technical characteristics and high seismic impedance. Since the seismometer must be in contact with non-decayed rock, it is set into a several-metre deep shaft or, where the layer of weathered rock is too thick, into a borehole. The analysis of seismogeological conditions comprised the analysis of basic and thematic geological maps. Laboratory analyses were followed by a geological inspection of the terrain, where additional data were collected, including the use of the ground, ownership, possible sources of seismic noise and the possibility of communication and power lines. By geological inspection the thickness of the weathered soil layer was also determined and seismic refraction measurements were carried out. High-quality farmland and forests were avoided, because wind-induced movement of trees transmitted to the ground represents a strong source of seismic noise. The level of seismic noise was determined by measurements on selected locations. The seismic network covers the entire Slovenian territory, involving an area of 20,256 km2. The network is planned in the way that more seismic stations are placed around bigger urban centres and in regions with greater vulnerability (Krsko basin where the Krsko nuclear power plant is placed, Upper Soca Territory where the last strongest earthquakes occurred , area around capital town Ljubljana). A typical seismic station consists of the seismic shaft with the sensor and the data acquisition system Quanterra Q730 and, the service shaft with communication equipment (modem, router) and power supply with a battery box, which provides energy in case of mains failure. The data acquisition systems are recording continuous time-series sampled at 200 sps, 20 sps and 1sps.The remote broadband stations subsystems include 21 surface broadband seismometers (CMG-40T, STS2 and CMG 3ESPC), 5 seismic stations are additional equipped with strong motion accelerographs EpiSensor and 4 system consist with borehole broadband seismometers CMG-40T BH. All seismic stations transmit data to UNIX-based computers running Antelope software. The data is transmitted in real time using TCP/IP protocol over the Government Wide Area Network. Real-time data are processed automatic, earthquake parameters are calculated and web pages are generated and presented on WWW in minutes after earthquake occurred. Data are also exchanged with seismic networks of the neighbour countries, where the data is collected from the seismic stations, close to the Slovenian border. The detection and location capabilities of the network are being improved even better than it was expected.

Keywords: network, seismic, instrumentation

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SS001 **Poster presentation** **6231**

Observation of coda signals from regional and local earthquakes recorded from a downhole-uphole couple of broad-band sensors at Mt Etna.

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Seismic coda of regional and local earthquakes recorded at a couple of broad band seismometers located at the bottom of a 125 m deep borehole and up-hole at surface show interesting spectral features. We observe strong similarity between the waveforms recorded from up- and down-hole sensors at low frequency (0.1 -3 Hz) and measurable differences in the higher frequency limit. We interpret this observation assuming that at high frequency the up-hole coda is produced by body-to-surface wave scattering in the near surface. We compare the experimental results with numerical simulations done using the Monte Carlo scheme of Yoshimoto et al. (2000) carried out in the assumption of velocity and scattering coefficient which smoothly vary with depth, with the addition of a body-to-surface wave conversion for the energy particles which reach the surface. The comparison of the experimental coda envelopes with those obtained through numerical simulation allow for a quantification of the turbidity parameter at surface.

Keywords: borehole seismology, coda, seismic scattering

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SS001 **Poster presentation** **6232**

An efficient method to locate the micro-earthquakes generated by small geophysical objects

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Small geophysical objects like glaciers, rockfalls or landslides are known to generate their own seismicity. The micro-earthquakes are the signature of highly-stress zones in the volume, of fluid transport, of stick-slip displacement, etc. Given the rough nature of the local topography of such objects, it can however be hard to get to such sites to install seismic stations. Regrouping seismometers in arrays can therefore improve the seismic instrumentation. To this effect, we developed a method using small aperture seismic arrays in order to locate and characterize the micro-seismicity generated by small geophysical objects. This method is well suited for such sites since it does not require any particular geometry in the seismometers layout. Our method is divided in three steps. The first one is dedicated to the computation of time delays between each possible pairs of sensors belonging to the considered array. They are computed using a time domain cross-correlation method. Initially, the time shifts are multiples of the sampling period. Then a quadratic interpolation is performed close to the maximum of the cross-correlation function, thus yielding the final value of the time lag whose precision is below the sampling rate. Pairs showing a correlation level exceeding a user-defined threshold are kept. The second step consists in tracing rays from every point of a given Data Elevation Model to each sensor of the array and for different velocity models in order to compute theoretical travel times. To this effect, we use an enhanced Podvin-Lecomte algorithm. These theoretical travel times are used to calculate theoretical time-delays. Finally, the theoretical time-delays are compared to the measured time-delays in the third step of our method. We compute the probability density function (PDF) of the entire set of events plus velocity parameters, to find the velocity model and the positions that best match the time delays. It is therefore possible to extract marginal distributions for hypocenters position. The standard deviation of each marginal PDF yields the location errors. We present examples of successfull application of this method with different data set corresponding to Alpine, seismicity-generating objects.

Keywords: array, seismology, location

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SS001 **Poster presentation** **6233**

Very Low Frequency Earthquake: Seismicity And Its Interpretation

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Recently the varieties of seismic and geodetic sources are recognized. The recognition depends on high dense seismic and geodetic observation network. Nowadays rapid developing of high performance network brings us better condition to research for new phenomena. Slow slip and deep low frequency tremor in depth of some tens kilometer around subducting slab are detected by GPS, tiltmeter and short period seismic networks. Moreover very low frequency seismic event that apparently excites longer period seismic wave is detected around trough zone by broadband seismic network. Using dense broadband seismic network in , we analyzed seismicity of very low frequency earthquake and characteristics of its source. The very low frequency earthquake shows similar wave envelope to deep low frequency tremor in high frequency range. It implies that apparent different characteristics seismic events have same source mechanism. The shallow depth source excites surface wave efficiently, so that apparent dominant frequency is shifted to lower. Deep low frequency tremor may be higher frequency band signal originated by deep small very low frequency earthquake. The seismicity pattern has two types that are aftershock type and background type. Aftershock type is that very low frequency earthquakes occur with aftershock of major earthquake. In the cases of 2002 Tokachi-oki and 2003 Kii-oki earthquakes, very low frequency earthquakes occurred at surrounding rupture zone of main event and occurred some days to some months later from main earthquake. Another type activity is independent of ordinary earthquake. The seismicity shows that its frequency is higher level every some months and temporal variation is similar to earthquake swarm. These hypocenters are also located to relative narrow area. The later type is called independent swarm type. We propose that very low frequency earthquake is higher frequency side signal of slow slip along subducting plate. Aftershock type event is related to after slip following major ordinary earthquake. The temporal and spatial distributions support it. Independent swarm type is related with aseismic slow slip. These events are distributed in classical aseismic zone. The detection of slow slip around trench and trough is very difficult by geodetic measurement. The monitoring of very low frequency earthquake is good tool for detection of aseismic slow slip indirectly.

Keywords: low frequency earthquake, slow slip

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SS001 **Poster presentation** **6234**

GEOFON and the Indian Ocean Tsunami Warning System

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After the Mw=9.3 Sumatra earthquake of December 26, 2004, which generated a tsunami that effected the entire Indian Ocean region and caused approximately 230,000 fatalities, the German government funded the so-called German Indian Ocean Tsunami Early Warning System (GITEWS) Project. The GEOFON group of GFZ Potsdam was selected to develop and implement its seismological component. In this presentation we describe the concept of the Earthquake Monitoring System and report on its present status.The major challenge for a Earthquake Monitoring System (EMS) within a tsunami warning system is to deliver information about location, size, source parameters and possibly rupture process as early as possible before the potential tsunami hits the neighboring coastal areas. Tsunamigenic earthquakes are expected to occur in subduction zones close to coast lines. This is particularly true for the Sunda trench off-shore Indonesia, but also in the Macran subduction zone off-shore Iran. Key for an Indian Ocean monitoring system with short warning times is therefore a dense real-time seismic network in Indonesia, supplemented by a substantial number of stations in other countries and territories within and around the Indian Ocean. Up to 40 new broadband and strong motion stations will be installed until 2010 with real-time data collection using a private VSAT communication system.The GITEWS EMS Control Center in Jakarta will be based on an enhanced version of the widely used SeisComP software and the GEOFON earthquake information system prototype presently operated at the GFZ-Potsdam (http://geofon.gfz-potsdam.de/db/eqinfo.php). However, the Control Center software under development (SeisComP3) will be more reliable, faster and automatic but with operator supervison. It will use sophisticated visualisation tools, offer the posibility for manual correction and re-calculation, flexible configuration and support for distributed processing. Its large redundancy for algorithms, moduls and hardware assures easy integration into larger multi-sensor, multi-hazard control centers and decision support systems. A first prototype of the EMS Control Center software is already operational.

Keywords: tsunami warning, earthquake monitoring

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SS001 **Poster presentation** **6235**

Determination of local magnitude for large earthquakes by using recorded accelerograms.

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One of the possible methods to determine local magnitude (ML) of large earthquakes is reconstructing standard seismogram of Wood-Anderson seismometer by using recorded accelerograms. Considering acceleration curve as input of Wood-Anderson system the response is calculated. The ML can be calculated by using synthetic seismograms and empirical relation that is defined by Richter. In this research the accelerograms for 6 catastrophic earthquakes, which recently occurred in Iran were used. The determined average ML values in this research have a good correlation with those announced by International Seismological Centers such as USGS and ISC.

Keywords: large earthquakes, local magnitude, accelerogram

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SS001 **Poster presentation** **6236**

Summary of the ISC bulletin of events of 2004

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The ISC Bulletin for the year 2004 is now available on the Internet and the ISC CD Volume 15. In our presentation, we give an overview of the data published in the Bulletin. We describe the major sources of parametric data contributed to the ISC and compare the data sets from other global data centres with that of the ISC. We evaluate the importance of re-analysis on a global scale from the distribution of events for which the ISC associates independently reported phase readings or hypocentres. We discuss the overall and regional completeness of the Bulletin as well as completeness in the oceanic and continental areas. We exhibit and give explanation for the differences between locations and magnitudes computed by the ISC, IDC and NEIC. We also give a summary of "new" events discovered by the ISC from previously unassociated phase readings, and other events of special interest in the Bulletin. We discuss the magnitude threshold policy, which was applied to select events for manual review at the ISC and show the difference between the Collected, Published and Comprehensive ISC bulletins available on-line.

Keywords: isc, seismicity, bulletin

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SS001 **Poster presentation** **6237**

THE GEOSCOPE Program: state of the art in 2007

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The GEOSCOPE program was launched in 1982 by the National Institute of Sciences of Universe (INSU), a department of the French National Center of Scientific Research (CNRS), following the initiative of the Institute of Physics of the Earth of Paris (IPGP). The purpose was the installation of about 25 stations well distributed worldwide (in particular in the southern hemisphere), in the standard configuration defined by the FDSN (very broad-band 24 bit, continuous recording at 20sps). At present, the GEOSCOPE program is operating 28 digital 3-component very- broadband stations. In terms of site locations, the aim of the GEOSCOPE program is almost fulfilled. Our purpose is to maintain the stations at original sites (Indian Ocean, Africa) and to fill some geographical gaps at high latitudes in the southern and northern hemisphere. In particular, at high latitudes in Russia, we plan to install a new station VOR (Vorkuta) and to move the station SEY (Seimchan) to a new location in northern Kamchatka. We are also working on improving data quality and transmission. Historically, GEOSCOPE did not operate real-time data. Continuous data from most of stations arrive with significant delays and records from large events are teletransmitted from some stations (by phone RTC line or through internet) and are made available within one day. To improve this situation, we are replacing the old Streckeisen digitizers with new Quanterra data loggers, essentially Q330-HR ones. Presently data from 13 stations are made available at the IPGP Geoscope Data Center in near real-time, with a delay depending on the station:1- ATD (Arta, Djibouti), a joint CTBTO/CERD/G station2- CAN (Canberra, Australia), a joint ANU/G station3- DZM (Dzumac, New Caledonia, a joint DASE/CTBTO/G station4- ECH (Echery, France)5- FDF (Fort de France, French West Indies)6- KIP (Kipapa, Hawa), a joint USGS/IRIS/GEOSCOPE station7- RER (Rivire de lEst , La Runion)8- SSB (Saint Sauveur-Badole, France)9- SPB (Sao Paulo, Brazil)10- PAF (Port aux Franais, Kerguelen Island)11- TAM (Tamanrasset, Algeria)12- TAOE Marquesas Islands, a joint DASE/GEOSCOPE station 13- TRIS Tristan Da Cunha, a joint USGS/IRIS/GEOSCOPE station.Our challenge is to link the maximum number of stations to our Data Center for getting data in real time. To reach this objective in a few years, we plan to upgrade 3-4 stations every year, our priority in 2007 is the upgrade of stations PEL and COYC in Chile.For the last ten years we have been progressively installing en environmental sensors (microbaromtres, thermometers), transforming all our stations in multiparameter observatories. We are participating to the European projects as NERIES (Network of Research Infrastructures for European Seismology); at the European level, IPGP will be one of the four nodes of the EIDA structure (European Integrated Waveform Data Archive) with ORFEUS, GFZ (Potsdam) and INGV (Roma). We also are participating to the national efforts for the creation of a Tsunami Warning Center at La Runion Island in the frame of the CNATOI project (Centre National dAlerte aux Tsunamis dans lOcan Indien). That project includes the installation of two new stations in 2007, one at Citronelle (CIT station, Rodrigues Island / Mauritius) and one at Fort-Dauphin (NAM station, Madagascar).Daily automatic procedures allow to compute the noise level plots of each component, for each station in near real-time, in order to detect any anomalous behaviour of the station and to follow the station status.

Keywords: broad band seismology, multiparameter networks, tsunami warning

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SS001 **Poster presentation** **6238**

Source Dynamics of the 2006 Silakhor (Lorestan), western Iran, earthquake sequence

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On 31 March 2006, at 01:17:01 GMT and 04:47:01 local time, a moderate but considerable destructive earthquake occurred at the northwest Zagros suture zone in Lorestan province in western . The epicentral region was located in Silakhor plain between Drood and Brujerd cities in western . The epicenter of mainshock was computed as 33.581N-48.794E by NEIC. The magnitude of the mainshock, given by NEIC, was 6.1 and the focal depth determination indicated a shallow depth of 7 kilometers. The mainshock was followed by several strong aftershocks that caused additional damages in the affected areas. The recorded aftershock activity was extended to a length of about 40 km and a depth of about 30 km. The majority of aftershocks took place at a depth range 10-20 km and was scattered indicating a complex mode of faulting. Field investigation and the distribution of aftershocks suggest a NW-SE trend faulting with a right-lateral strike slip mechanism. In this paper, we retrieved teleseismic P waves data recorded at IRIS-DMC stations in order to provide better constraints on the source parameters of the 2006 Silakhor earthquake. We obtain the source time function and the image of temporal and spatial variation of slip on the fault plane. The result of waveform inversion indicated that the mainshock followed mainly strike slip mechanism and the source process incuded two major fault slip. The total seismic moment was calculated to be M0= 3.11025 dyne cm. The calculated maximum dislocation is about 50 cm and the obtained moment magnitude in this analysis is Mw = 6.2. The average stress drop was estimated to be 25 bar and the average dislocation was 25 cm. The Silakhor earthquake is one of the rare events that has occurred in Zagros suture zone with magnitude greater than 6. Therefore, the ground-motion characteristics during the mainshock should be considered for the high safety design of structures in the damaged area.

Keywords: source model

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SS001 **Poster presentation** **6239**

Source process of the 26th December 2003 Bam destructive earthquake in southeast Iran, revealed from field observation and inversion of far field data

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Sourceprocess of the 2003 Bam destructive earthquake is obtained by the field observation and inverting far field waveform data. The information from field investigation and locally recorded aftershocks are considered as supplementary data to constrain the source parameters. The sourceprocess of mainshock is explained in terms of at least three major asperities. Rupture initiated in epicentral area and mainly extended towards the north in a unilateral manner. Displacement initiated in the deeper part and propagated upwords but did not reach the surface. The major slip took place during the first 5 seconds and it is concluded that the directivity played main role for producing extensive destruction in the damaged area. The source mechanism is given as: (strike, dip, slip) = (173, 63, 159.6), the total seismic moment is calculated to be M0= 6.81018 Nm. The source duration is 10 seconds and the fault length is about 30 km. The calculated maximum dislocation is about 1.2 m and the moment magnitude is Mw = 6.5, while the estimated maximum stress drop is 6.1 MPa. Macroseismic evidence and recorded accelerograms in Bam city indicate that the ground strong motion was intense during the mainshock. Although the area had been seismicly active in historical times there was no evidence that earthquakes as severe as this one had occurred in the vicinity of Bam region during at least the past 2200 years. From the engineering point of view, the Bam earthquake, which provided ground-motion characteristics of a rare large event in the affected area, was the controlling event for the design of structures with high safety requirements.

Keywords: source process

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SS001 **Poster presentation** **6240**

Source parameters of the significant earthquakes in Iranian Plateau, during 2005-2006, revealed by Local Seismic Networks

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Since 1996, the Geophysics Institute of Tehran University has deployed several telemetric seismic networks in the seismically active areas of the Iranian Plateau. The main purpose of these networks is the acquisition of seismic data originated in a set of about fifty remote seismological stations, and investigation of the origin of processes that cause earthquakes in this region. The data is transmitted from each remote station through telemetric link to a central station located at the major cities where all the information are processed. The new seismological networks have been aimed at forecasting and warning capabilities concerning earthquakes, to study the spatial and temporal seismic distribution to identify seismogenic sources, their mechanism and geometry; and to create public awareness about the causes, effects and mitigation of natural hazards. Thus, the operation of the new seismological networks, brought new stages in gathering of knowledge and studies of seismic processes related to active tectonics in . In this study, the source parameters of the locally recorded significant earthquakes during the years 2005-2006, in Iranian Plateau, are analyzed and discussed with the other geological and seismologicals features. The Zagros suture zone has been the most seismically active region in , during 2005-2006. The mechanisms by which the seismic activity is accomplished probably involve ductile creep at deeper levels and folding, faulting and fracturing at shallower levels.

Keywords: seismicity iran

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SS001 **Poster presentation** **6241**

The June 22nd 2002 Changoureh-Avaj Earthquake

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The Changoureh-Avaj earthquake of June 22nd 2002 is the largest shock since the occurrence of the 1962 Buyin-Zahra earthquake in Qazvin province. The source time function indicates that rupture, during the source process, was initiated with main shock and was followed by a small aftershock. Therefore, the major amount of seismic energy was released during the first 10 seconds. Considering the field observation and the distribution of aftershocks, an average source dimension of about 20-30 km, a NW-SE strike and a SW dipping fault plane could be estimated. This result is in good agreement with the result of waveform analysis. The mechanism for the total source is obtained as (strike, dip, rake) = (267, 53, 71). The total seismic moment is calculated to be M0= 5.351025 dyne cm and the obtained moment magnitude in this analysis is Mw = 6.4. The average stress drop is about 40 bar. The static displacement is calculated to be about 35 cm. The Changoureh-Avaj earthquake is in some respects comparable with the 1962 Buyin-Zahra earthquake: they have similar mechanisms and occurred in similar fault systems. Changoureh-Avaj earthquake is one of the rare events with magnitude greater than 6 that has occurred in the vicinity of large densely populated cities. Therefore, the ground-motion characteristics during the main shock should be considered for the high safety design of structures in the region.

Keywords: source model

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SS001 **Poster presentation** **6242**

A reevaluation of the North Panama deformed belt seismicity through the use of historical seismograms

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The North Panama Deformed Belt (NPDB) extends along the Caribbean margin of Panama, from the Gulf of Uraba, Colombia up to Limon, Costa Rica. Here the Caribbean plate subducts below the Panama Microplate, and in its Eastern segment earthquakes are recorded up to depths of 70 km or more. In this zone originated the September 7th, 1882 San Blas Earthquake (Ms7.9), which caused extensive damage in Central Panama and destroyed most of the initial works of the French Canal, directed by Ferdinand de Lesseps. This earthquake also originated a tsunami which killed more than 100 persons in the San Blas Archipelago in northeastern .In Central Panama lives more than 60% of the population of Panama in the cities of Panama and Colon and it is also traversed by the Panama Canal, an earthquake like the one in 1882 will have devastating effects on the economy of and perhaps the world, so it is crucial to understand the seismotectonics of the NPDB and characterize its seismicity.This region of moderate seismicity has been shaken by few major earthquakes so it is important to study events prior to the WWSSN. In the present project we have gathered new macro seismic information, to create an isoseismal map of the main events in the Caribbean region of as the September 7th, 1882 San Blas earthquake. The other major earthquakes of the Caribbean region of are being reevaluated, through the analysis of historical seismograms. One of these events occurred on November 30th, 1935 (Ms6.2) and caused some damage in Central Panama .We have been collecting and digitizing historical seismograms from the and Europe to redetermine its magnitude, estimate its moment tensor and CMT.The present status of this research project on the earthquakes of the Caribbean of and further developments are presented here.

Keywords: nord panama deformed belt, historical seismograms, seismic source parameters

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SS001 **Poster presentation** **6243**

Maximum intensity map for northeastern Brazil

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Carlos Da Silva Vilar, Jose Antonio De Morais Moreira, Francisco Hilario Rego Bezerra, Marcelo Assumpcao

Northeastern Brazil is a populated area and the most active seismic zone in the country. Despite the maximum observed magnitude of 5.2 mb, in many cases the seismic sequences occur as swarms which are continuously felt by the local population for many years. Since the 1980's macroseismic and instrumental surveys have been carried out in this region and they are an important data archive which allows the composition of a reliable catalogue of seismic activity for this region. Macroseismic data were obtained from books, local newspapers and interviews with the local population so that, for many events, it was possible to estimate the intensity in the MM scale. Here, we present a maximum seismic intensity map for NE Brazil. In order to compose this map, we have used the macroseismic data available in which an attenuation model could also be estimated. The modelled intensities were then superimposed so that the maximum intensity for each point of the region could be found. According to our results, the maximum intensity in NE Brazil is VII MM. This map can be used as a first approach to seismic risk/hazard of this region.

Keywords: seismology, intraplate seismicity, maximum intensity map

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SS001 **Poster presentation** **6244**

The Plate Boundary Observatory Borehole Seismic Network

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PBO UNAVCO IAG

Michael Hasting, Jennifer Eakins, Greg Anderson, Kathleen Hodgkinson, Wade Johnson, Mike Jackson

As part of the NSF-funded EarthScope Plate Boundary Observatory, UNAVCO will install and operate 103 borehole seismic stations throughout the western United States. These stations continuously record three-component seismic data at 100 samples per second, using Geo-Space HS-1-LT 2-HZ geophones in a sonde developed by SONDI and Consultants (Duke University). Each seismic package is connected to an uphole Quanterra Q330 data logger and Marmot external buffer, from which UNAVCO retrieves data in real time. UNAVCO uses the Antelope software suite from Boulder Real-Time Technologies (BRTT) for all data collection and transfer, metadata generation and distribution, and monitoring of the network.The first stations were installed in summer 2005, with 28 stations installed by December 2006, and a total of 35 stations expected by May 2007. In a prime example of cooperation between the PBO and USArray components of EarthScope, the USArray Array Network Facility (ANF), operated by UC San Diego, handled data flow and network monitoring for the PBO seismic stations in the initial stages of network operations. Data flow in real time from the remote stations to the UNAVCO Boulder Network Operations Center, from which UNAVCO provides station command and control; verification and distribution of metadata; and basic quality control for all data. From Boulder, data flow in real time to the IRIS DMC for final quality checks, archiving, and distribution. Historic data are available from June 2005 to the present, and are updated in real time with typical latencies of less than ten seconds. As of 1 September 2006, the PBO seismic network had returned 60 GB of raw data. Please visit http://pboweb.unavco.org for additional information on the PBO seismic network.

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SS001 **Poster presentation** **6245**

Recent developments within ORFEUS and EMSC

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Remy Bossu, Stephanie Godey, Orfeus Participants, Emsc Members

ORFEUS and EMSC are currently going through some rapid developments largely due to the NERIES project.ORFEUS (www.orfeus-eu.org) is rapidly expanding the Virtual European Broadband Seismic Network (VEBSN) and creating a. European Integrated waveform Data Archive (EIDA). The VEBSN is a joint effort of the seismological observatories in and around Europe and has resulted in a significantly improved availability of high-quality waveform data for research purposes. The core of EIDA is created in collaboration between the KNMI in The Netherlands, GFZ in Germany, INGV in Italyand IPGP in France. The techniqueused for creating this distributed waveform data archive is based on ArcLink, developed by GFZ and an extension of the SeedLink protocol used in the VEBSN. The web tools to access waveform data are currently being rapidly developed making use of the implemented General Data Interface developed at the Orfeus Data Center (ODC) The EMSC (www.emsc-csem.org) is rapidly improving its services to provide rapid earthquake information and to offer new products and services. All these services and products being based on data made available by tens of network operators, real-time and robust exchange mechanisms are being tested. Even more challenging is the necessity to define a policy on public earthquake information among the Euro-Med network operators to ensure the coherency of the information in the region. For example, the possibility to establish a Euro-Med Shakemap service operated by a few network operators and coordinated in real time is currently being explored.ORFEUS and EMSC coordinate their efforts where possible. Besides the successful NERIES EC-infrastructure project it has also been active to promote coordination of European efforts with surrounding countries, among others in the EERWEM project in which data exchange between countries in and around the Western Mediterranean area is being improved.In this presentation we will provide a short overview of some recent developments and its impact on the services provided by the two organisations

Keywords: europe, orfeus, emsc

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SS001 **Poster presentation** **6246**

Network of Research Institutes for European Seismology (NERIES):An EC Research Infrastructure project. [http://neries.knmi.nl]

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The EC project NERIES (contract 026130) is one of the approximately 30 projects supported by the EC projects funded within the so-called Research Infrastructures theme, part of the EC political initiative to build the European Research Area. Jointly initiated by ORFEUS (Observatories and Research Facilities for European Seismology) and EMSC (European Mediterranean Seismological Centre), the project consortium comprises 25 European partners from 13 countries.NERIES consists of 18 projects which will be coordinated into one European research data infrastructure for seismology with access guided through one web portal. The individual projects aim, among others, at expanding the Virtual European Broadband Seismic Network (VEBSN), implementing the European Integrated waveform Data Archive (EIDA) and the Distributed Archive of Historical Data. Further we improve dissemination of European acceleration data and launch a number of experimental Ocean Bottom Seismometers in the Mediterranean and the Atlantic Ocean .Five research projects aim at a European seismological reference model, new approaches to earthquake hazard assessment and forecasting, shake-maps and loss estimation capability and new techniques for geotechnical site characterization and data mining.NERIES also offers grants to access five research facilities: Swiss Seismological Service Network, the verification and detection centre at CEA/DASA in France, the old seismogram scanning facility SISMOS at INGV, the seismic arrays at NORSAR and the underground observatory facility CONRAD in Austria.In this presentation we will provide a short overview of the project, illustrate its progress with some recent developments and emphasize initiatives that involve coordination with other European and global developments.

Keywords: neries, orfeus, emsc

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SS001 **Poster presentation** **6247**

Investigating the effective parameters on designing seismograph using Laplace transform simulink

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Continuous vibration resulting from an earthquake can be considered as a sequence of impulses (spikes). If oscillator system of a seismograph isnt damped, it will oscillate a few time for each impulse (spike), therefore the seismogram is not useful because a sequence of impulses (spikes) exists and oscillations of each impulse (spike) interfere with each other. Then oscillator system of a seismogram must be damped for indicating this point that output of a seismograph shows earths vibration approximately, in a way which there is an output oscillation for every input impulse (spike). Interaction of earths vibration and a seismograph as a system can be presented mathematically by convolution mathematic operator which is equivalent with multiplication operator in Laplace domain. In this study those parameters which affect on seismograph output by optional inputs (or vibrations) were investigated in Laplace domain by using Simulink software and the role of each of these parameters was studied and presented here. Obtained collection of this study can be used in order to predict the output of a seismograph in media with different seismic noise for selecting the most appropriate value for controller Parameters of the output of a seismograph.

Keywords: spike seismograph, laplace transform simulink, convolution mathematic

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SS001 **Poster presentation** **6248**

Application of the dynamic calibration's method of IMS stations for the Central Asian Region

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Method of Dynamic Calibration (MDC) of seismic stations, based on natural seismicity data, initially presented in the works [O.K. Kedrov, E.O.Kedrov 2001; Kedrov and others, 2001; O.K. Kedrov, E.O.Kedrov, 2003], was applied for calibration of the International Monitoring System (IMS) stations for the Central Asian region. The algorithm of the MDC of diagnostic parameters (DP), characterizing a seismic source for the examined source-station traces and the appropriate experimental software were worked out. Calibration of stations in the explored region (ER) by MDC is executed by selection of attenuation constants for DP, adapting them for the conditions of the base region (BR). This method takes the stable region of Eurasia as a base region, including Nuclear Test Sites in and . Digital data samples of earthquakes from the International Data Center (IDC) archive for five IMS stations – MKAR, BVAR, EIL, ASF and CMAR for the region of Central Asia were applied for calibration. The present work utilizes DP in a spectral and time domain of mode, independent of magnitude and epicentral distance, worked out in [Kedrov and others, 1990; Kedrov, Luke, 1999] DX = Xi – am mb – bD lg Δ. MDC assumes that calibration factor am doesn't depend on the region, and factor bD depends only on geologic-tectonic medium properties irrespective of a source type. Consequently, it is acceptable to assess factor bD only by earthquakes sampling in ER and to adapt parameters D(Xi) in ER to BR. Algorithm is designed in such a way, that estimated values of calibration factors bD are using for calculation of the corrected DX values and then for screening of natural events in the ER. Experimental estimations of screening efficiency depending on a station vary within the range of 95–100%. The independent MDC testing was performed using the records of explosions in India on 11.05.1998 and in Pakistan on 28.05.1998 received at BRVK and MAKZ stations of IRIS network, analogous by their location and recording equipment characteristics to IMS stations BVAR and MKAR. This testing provided correct results of identification of the source type and directly confirmed the relevance of the proposed method of calibration of stations according to natural seismicity data. It's showed that calibration factors bD for source-station traces, similar by the conditions of signals propagation (as for traces from to the stations EIL and ASF), prove to be comparable practically for all diagnostic parameters. The conclusion is being drawn that the method of dynamic calibration of stations based on natural seismicity data in the region, where the explosions didn't take place, could prove to be significant for rapid and low-cost calibration of IMS stations. MDC can also be applied, for example, for identification of industrial chemical explosions, which sometimes wrong classified in regional catalogues as natural earthquakes.

Keywords: calibration, diagnostic parameters, attenuation

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SS002 **6249 - 6319**

Symposium
Earthquake Hazard, Risk, and Strong Ground Motion

Convener : Prof. Zhongliang Wu, Dr. Fabio Romanelli

Since recent years, the rapid development of theoretical and numerical tools has led to new understandings of source complexity, seismic wave field, effect of site geology, and seismic destructions. Interaction between seismologists and earthquake engineers has obtained fruitful results. New scientific problems have been emerging from the needs of the development of large/critical engineering works and big cities. Many earthquakes have occurred since recently, with plenty of strong motion data recorded by densely deployed high-quality strong motion networks. The analysis of such a huge database is to much extent behind schedule. Even handling the data itself becomes one of the difficult issues under discussion. In comparison, in most of the developing countries/regions with high seismic activity and intense earthquake disasters, there is still lack of enough strong motion recordings. Observation and study of earthquake hazard in these countries/regions are urgently needed for the safety of society with the threatening of earthquake disasters. Meeting these dual challenges is one of the tasks of seismological and engineering communities within the next four years. To reflect the up-to-date advancements in earthquake hazard assessment, risk management, and strong ground motion seismology, and to foster inter-disciplinary international exchange and cooperation in these fields, this session will be focusing on, but not limited to, the following topics: 1) Strong motion seismology: observation, interpretation, and modeling; 2) Earthquake hazard assessment: probabilistic and deterministic approaches; 3) Long-term and intermediate-term medium-range earthquake forecasting, and analysis of the complexity of seismicity: statistical and physical approaches; 4) Interaction among seismological community, engineering community, policy makers, and the public in the perspective of the preparedness and management of earthquake disasters.

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SS002 **Oral Presentation** **6249**

Characteristics of Spectral Intensity Revealed from Strong Motion Data in Southwestern Taiwan

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In earthquake engineering, the spectral intensity has been considered as one of effective parameters for correlating with the seismic damage in order to develop an optimal structural design response spectrum. However, many research efforts indicated that the observed response spectra represent significant diversities both in the value and the shape even within close regions. Some of factors, as we know, including magnitude(source mechanism), epicentral distance, path, and site condition, need to be analyzed to clarify the effects on the complexity of spectrum. Several hundreds of digital strong motion records collected in the dense seismic array deployed in southwestern Taiwan from some near moderate earthquakes, including major aftershocks of the 1999 Chi-Chi earthquake, were analyzed in this study. Before the calculations of spectral intensities defined by the integration of spectral acceleration or velocity, the shape of response spectra was surveyed for characterizing the effects of soil conditions from foothill to alluvial site within this area. Three period ranges for calculating spectral intensities in short-, medium-, and long-period of structural response, respectively, were determined based on the pattern of spectrum resulted from various site conditions. In addition, the common obvious prolonged duration of strong ground motion, caused by the short-period surface waves which are frequently generated from shallow earthquakes, was also taken into account to assess its effect on the response spectrum. We finally will propose an attenuation curve for the spectral intensity with the correcting factors in specific site condition and source parameters. This work possesses a very important part in constructing the seismic hazard map of the southwestern Taiwan where was always focused on the high potential of the recurrence of big earthquakes in the past decades.

Keywords: spectral intensity, attenuation

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SS002 **Oral Presentation** **6250**

Microzonation Studies of some Indian Cities

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Manoranjan Mohanty

The occurrence of great (M>=8) earthquake in Himalaya, North East India and Rann of Kuchch during 1819, 1897, 1905,1950 & 2001 has attracted the attention of geoscientists more towards Himalayas in view of the rather long quiescence phase in the region after 1950. This is because the destructive earthquake in Himalaya not only causes local impact but affects its neighbouring areas, especially, which lie in alluvium along the river beds, mainly due to rapid increase in urban population. The seismic microzonation basically involves mapping of geology related hazards, which is depended on seismic and geological data structure in general and earthquake source, deep underground and site specific conditions in particular. One of the major components of seismic microzonation study is the estimation of Peak Ground Acceleration (PGA) on the surface due to a possible future scenario earthquake, which will help the builders/designers/architects to design earthquake resistant structures. Keeping in view the importance of the study, Department of Science & Technology initiated a multidisciplinary & multi-institutional experiment on Seismic Microzonation study of Jabalpur Urban agglomerate. The above pilot study was aimed at i) establishing a model for seismic microzonation with Indian perspective and ii) evolving strategies for hazard & risk prognosis for pre-disaster mitigation planning. In pursuance of the above focused objectives, a model for seismic microzonation has been evolved. Based on the model developed for Jabalpur, Seismic Microzonation studies were initiated for Delhi, Guwahati & Bangalore city. A first order Microzonation map at 1:50, 000 scale has now been prepared for NCT of Delhi by Earthquake Risk Evaluation Centre (EREC). Necessary efforts are being made to further refine the microzonation maps of Delhi at large scale (1: 10,000) incorporating PGA values at the surface. Similarly, 1st order microzonation maps for Guwahati city have been prepared taking into account the seismological, geological, geomophological and site response studies data. The microzonation study for Bangalore city is under progress. In another study, microzonation of the Sikkim has been completed utilizing the strong motion data recorded for the earthquakes occurred in that region during the last few years. Though the microzonation studies initiated by DST has established standard methodologies for such studies, it needs further improvement, especially in developing response spectra to be used by engineering community for designing specific structures and estimation of PGA at bedrock and surface as well.

Keywords: earthquake, hazard, zoning

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SS002 **Oral Presentation** **6251**

Development of shakemap methodology based on Fourier amplitude spectra and its application for the case of Vrancea (Romania) earthquakes

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Shakemaps are generated within a few minutes on a routine basis for Southern California (Wald et al., 1999) by extrapolation ground motion parameters such as PGA, PGV, response spectra (RS), and computed intensity (CI) from observational sites equipped with accelerometers with distances in the range of kilometers to tens of kilometers between them. Extrapolation is based on empirical hard-rock attenuation relations, geological classification of the sites, and on empirical relations of ground motion amplification for a given geological class. The Californian approach cannot be copied for many cases due to a lacking empirical strong motion data base and due to missing understanding of the relations between geological near-surface structure and ground motion amplification for PGA, PGV or CI. We suggest the following approach based on Fourier amplitude spectrum (FAS) that can be used in most cases and that allows obtaining site-dependent assessment in terms of various ground motion parameters using a single model. First, source scaling and attenuation models for FAS are evaluated using recordings obtained on rock stations. Second, the site effect at non-rock stations is analyzed as ratios between the spectra of observed records and the obtained spectral models. Third, the generalized site amplification functions are constructed for typical soil conditions. Fourth, so-called phantom sites are introduced to cover areas with a lack of strong-motion stations. The site amplification functions are assigned to these sites regarding the typical site classification or results of modeling based on available geotechnical data. The site amplification factors may be evaluated for PGA, PGV, and RS as values, which are dependent on magnitude and distance (i.e. frequency content and intensity), using stochastic simulation. Also, the site-dependent attenuation relations may be constructed to be used directly in Shakemap generation. The CI amplification factors or intensity attenuation models are evaluated using the proposed relationship between intensity and FAS. The developed ground-motion database will also provide a basis for early-warning system and for site-dependent deterministic and probabilistic seismic hazard assessment both in regional and urban scale. The technique is applied for the case of intermediate-depth (70-140 km) earthquakes of the Vrancea (Romania) source zone, which produce the most significant seismic hazard to Romania, including the city of Bucharest, and its neighboring countries. We modeled ground motion parameters distribution for four major Vrancea earthquakes occurred during the last century, namely: November 10, 1940 (M = 7.7); March 4, 1977 (M = 7.4); August 30, 1986 (M = 7.2); and May 30, 1990 (M = 6.9). The theoretical data were compared with available macroseismic observations and instrumental data

Keywords: shakemap, ground motion

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SS002 **Oral Presentation** **6252**

Three decades of seismic hazard and risk analyses: a review on probabilistic seismic hazard analysis

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Although probabilistic seismic hazard analysis (PSHA) has been widely used to assess seismic hazard and risk for various aspects of public and financial policy, from residential building code, insurance rate, to nuclear power plant, it contains a mathematical error: treating ground-motion uncertainty as an independent random variable. Ground-motion uncertainty, as it is modeled in modern ground-motion attenuation relationships, depends on the uncertainty in the source, path, and site effects. In other words, ground-motion uncertainty is an implicit or explicit dependence of earthquake magnitude or site-to-source distance, or both. This incorrect treatment of ground-motion uncertainty results in extrapolation of the return period for ground motion from the recurrence interval of earthquakes and ground- motion uncertainty, or the so-called ergodic assumption, treats spatial uncertainty of ground motions as an uncertainty over time at a single point. PSHA mixes temporal measurement (occurrence of earthquake and its consequence [ground motion] at a site) with spatial measurement (ground-motion uncertainty due to the source, path, and site effects). Temporal and spatial measurements are two intrinsic and independent characteristics of an earthquake and its consequence (ground motion) at a site, and must be treated separately. This incorrect treatment of ground-motion uncertainty in PSHA also results in uncertainty in earthquake magnitude and site-to-source distance being counted twice in hazard calculation. The mathematical error has caused confusion and difficulty in understanding and applying PSHA. More importantly, use of PSHA may not provide an appropriate seismic hazard or risk estimate for policy consideration.

Keywords: ground motion, seismichazard, seismicrisk

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SS002 **Oral Presentation** **6253**

First Order Seismic Microzonation of Haldia, Bengal Basin (India) using GIS

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The seismic microzonation of the Bengal Basin, Haldia region, India is carried out using the Analytical Hierarchy Process (AHP) on Geographic Information System (GIS). Haldia is of strategic importance in terms of massive Industrialization and port facilities. Three themes are used for the seismic microzonation namely Peak Ground Acceleration (PGA), predominant frequency and elevation map. Earthquake catalogues are prepared from various sources viz., India Meteorological Department (IMD), United States Geological Survey (USGS), International Seismological Centre (ISC), Harvard Seismology and the historical earthquake catalogue gathered by Bapat et al. The complete catalogue was prepared for the period June 1897 to November 11, 2006. An analysis on the b-value of the G-R relationship surrounding Haldia region is carried out. Based on the tectonic set-up and seismicity of the region, five seismic zones were delineated, which can pose a threat to Haldia in the event of an earthquake. They are broadly classified as Zone 1: Arakan-Yoma Zone, Zone 2: Himalayan Zone, Zone 3: Shillong Plateau Zone, Zone 4: Bay of Bengal Zone and Zone 5: Shield Zone. The maximum magnitude and the return period predicted for Zone 1, 2, 3, 4 and 5 are 8.60 0.18, 8.80 0.23. 8.70 0.60, 6.30 0.21 and 6.80 0.07 respectively. PGA of Haldia is determined following some of the well-established attenuation relationship. The Source Zone 3 gives the highest PGA as compared to the other Source Zones. A maximum PGA of 0.265g is observed towards the northeastern part of Haldia and decreases to 0.21g towards the southwestern part. The predominant frequency of Haldia is also calculated using the H/V ratio with a frequency ranging from 0.2 3 Hz. The elevation map of Haldia is also generated using the Shuttle Radar Topography Mission (STRM) data. A first order seismic microzonation map of Haldia is prepared by the integration of the three thematic maps viz., PGA, predominant frequency and elevation. Four zones of vulnerability have been broadly classified for Haldia as very high seismic hazard zone, high seismic hazard zone, moderate seismic hazard zone and less seismic hazard zone. The very high seismic hazard zone occurs towards the eastern side of Haldia and the vulnerability decreases gradually towards the western part.

Keywords: source zones, peak ground acceleration, predominant frequency

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SS002 **Oral Presentation** **6254**

Site specific seismic hazard assessment for construction sites in Israel

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Israel is small and its population centers are in close proximity to the seismically active Dead Sea Fault system which is capable of generating earthquakes with magnitude as high as 7.5. Consequently, more than 90% of the population is vulnerable to earthquakes. Furthermore, the majority of the population lives either on soft sediments or on hilly terrain where topographical and geological effects will probably amplify seismic ground motions and significantly increase the hazard. Consequently, site specific seismic hazard assessments became a very important issue especially when considering the construction of new densely populated structures, lifelines, industrial plant etc. The Seismology Division of the Geophysical Institute of Israel took the lead in site specific seismic hazard assessments in Israel. This presentation is an interim summary of the work done during the last decade. Lacking sufficient number of locally recorded strong ground motions, site specific hazard estimations were based on stochastic simulations. We applied the SEEH procedure (Stochastic Estimation of the Earthquake Hazard) developed by Shapira and van Eck (1993). This procedure produces a number of synthetic earthquake catalogues that represent the possible future seismic activity within 150 km of the investigated site. For each of the earthquake in a catalogue, SEEH implements the stochastic simulation method (see e.g. Boore 1983) to generate synthetic ground motions (accelerograms) expected to occur on the free surface of the studies site. The assembly of these synthetic accelerograms is used to predict spectral accelerations and the unified probability response spectra -10% exceedance in 50 years for structures with 5% damping. The SEEH procedure uses a soil column model of the subsurface to compute the convolved effect of the specific site. In recent years, more than 80 building site have been investigated in Israel. The subsurface models for those sites were derived by integrating available geological, geophysical and borehole information relevant to the site and by conducting seismological surveys where we applied reference and non-reference techniques and made use of different sources of excitation local and regional earthquakes, near-by explosions and ambient noise. Our studies suggested that in the frequency range 0.5 10.0 Hz we can expect amplification of ground motions reaching a factor of 8. We compared the requirements presented in the Israeli building code 413 with the site specific seismic hazard assessments. This comparison suggests that for many sites the building code requirements are underestimates.

Keywords: earthquake hazard

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SS002 **Oral Presentation** **6255**

Strong ground motion simulation based on a dynamic fault rupture model and empirical Greens tensor derivatives

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We developed a new methodology for the broadband strong ground motion simulation by combining a spontaneous dynamic fault rupture simulation as source model and empirical Greens tensor derivatives (EGTD) to accurately account for wave propagation in a complex media. Ground motion from a finite fault at a given station is calculated as the summation of seismograms obtained by the convolution of dynamic slip velocity functions and EGTD for every subfault across the fault plane. The methodology is applied for the strong motion simulation of the 2000 Tottori-ken Seibu earthquake. Five components of EGTD (assuming no volumetric changes) are calculated at every station by a frequency domain inversion of a set of linearized equations using recordings from a cluster of events with known moment tensor solution (Plicka and Zahradnik 1998). The EGTD method is able to retrieve accurate propagation and site effects characteristics between the cluster and the station, for frequencies up to around 10Hz. We estimated EGTD for two aftershocks clusters zones, located close to the asperity areas of the Tottori earthquake, at five Hi-net stations around the clusters. For the inversion we used a total of 28 events with magnitudes between 2.5 and 3.7 relocated by the Double-Differences method (Okada et. al. 2004, Fukuyama et. al. 2003). Moment tensor solutions of the events were obtained from Hi-net as well as F-Net data (Ito 2005, Fukuyama et. al. 2003). The EGTD are then interpolated at every square km within the fault plane of the Tottori earthquake, for every station and component. The spontaneous dynamic model is implemented by adding a dynamic rupture capability to a 3D-Staggered grid finite difference code by modelling the fault zone using a Staggered-grid Split Node model (SGSN, [Dalguer and Day 2007]). The SGSN is an adaptation of the traction-at-split-node method (DFM) (Dalguer and Day 2006) to a velocity-stress staggered-grid finite difference scheme, introducing velocity as well as stress discontinuities via split nodes. Using the SGSN method we calculated the spontaneous dynamic process of the Tottori earthquake, using a grid spacing of 0.1km and a time step of 0.0065s. Friction law parameters of the dynamic model are constrained by the stress histories and final slip obtained from a kinematic model (Iwata et al. 2002). We calculated a representative slip velocity function for every subfault (1km x 1km), by adding all slip velocities functions obtained from the dynamic model, to account for therupture propagation effectwithin the subfault, and made the convolution with the corresponding EGTD to get the ground motion from every subfault at a specific station. Total ground motion is obtained by adding the contribution from all subfaults. Our methodology has the capability to introduce a physically based source rupture process as well as accurate propagation and site effects to the strong motion simulation in a broad frequency band.

Keywords: strong motion, dynamic model, empirical greens tensor

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SS002 **Oral Presentation** **6256**

Remote sensing satellite and GPS data for seismic hazard assessment in Vrancea area

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Understanding the earthquake cycle and assessing earthquake hazards is a very important topic for seismic active areas, as is Vrancea zone in Romania. In frame of an integrated earthquake observing system, satellites and GPS networks offer powerful new tools to observe tectonic deformation for improving knowledge of fault system behaviour and earthquake hazards. The coupling of complex numerical models allow a more systematic approach to prioritizing the retrofitting of vulnerable structures, relocating populations at risk, protecting lifelines, preparing for disasters, and educating the public. As one of the most seismically active area in Europe, Vrancea region has a relatively high potential of seismic hazard mainly due to the subcrustal earthquakes located at the sharp bend of the Southeast Carpathians. Is assumed to be placed at conjunction of four tectonic blocks which lie on the edge of the Eurasian plate. Integration of satellite (SAR, ASTER, LANDSAT), GPS and field data of Vrancea area provides a better monitoring of different geophysical parameters and long-term deformation in relation with earthquake activity. Seismic risk in areas of large earthquakes can be assessed by estimating fault model parameters from satellite and GPS deformation data. These parameters include fault location and depth, fault geometry as well as variations in slip magnitude and direction on the fault plane. ASTER data provides a new alternative for geologic mapping at medium to large scales and for generating digital elevation model (DEM) from the along-track stereo data. Digital Elevation Models are very useful for terrain parameters assessment in order to interpret the satellite remote sensing data. Over 1975-2006 period , multispectral and multitemporal satellite images have been analyzed for recognizing the continuity and regional relationships of active and potential active faults as well as for geologic and seismic hazard mapping. Associated GPS data provided by GPS Romanian network stations revealed a displacement of about 5 or 6 millimeters per year in horizontal direction relative motion, and a few millimeters per year in vertical direction. As Vrancea area is characterized by a significant regional tectonic activity, evidenced by neotectonic deformation and seismicity, future use of long-term InSAR data will be a useful tool in active tectonic investigation for this region. The joint analysis of geodetic, seismological and geological information on the spatial distribution of crustal deformations is revealing new insights in the understanding of the kinematics and dynamics of the complex plate boundary system present in the Eastern Carpathians- Vrancea area.

Keywords: vrancea, satellite, gps

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SS002 **Oral Presentation** **6257**

Can Apparent Stress Be Used to the Estimation of Time-Dependent Seismic Hazard?

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This report reviews the approach taken in China since recent years to use apparent stress to time-dependent seismic hazard assessment and/or earthquake forecast. Since the year 2001 case studies of earthquake sequences have been being accumulated, observing that apparent stress changed before and after some earthquakes. Apparent stress was also used to estimate the tendency of aftershock activity following strong earthquakes. This approach is directly related to the development of digital/broadband seismological networks. Such development has made it possible to have independent estimate of radiated energy and seismic moment before this development both radiated energy and seismic moment can only be calculated from magnitude/s. At present time, controversies still exist on the reliability of the apparent stress estimation and the statistical significance of the apparent change of apparent stress before and after earthquakes. Problems associated with such reliability are related to the estimation of broadband radiated energy, one of the complicated and controversial measurements in seismological observation and interpretation. Another problem lies in the physical interpretation of apparent stress as well as its temporal change, and, directly related to such temporal change, the scaling of apparent stress with the size of earthquakes. Nevertheless, this approach, no matter whether successful or not, has provided seismic hazard analysis with new earthquake catalogues of more degrees-of-freedom and in turn a new perspective looking at earthquake sequences.

Keywords: time dependent, seismic hazard, apparent stress

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SS002 **Oral Presentation** **6258**

Ground Motion at bedrock Level in Delhi City from Himalayan earthquake scenarios

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Delhi the capital of India - is prone to a severe seismic hazard threat not only from local events but also from the Himalayan earthquakes at 250-300 km distance. In this study, we simulate the earthquake ground motion, at bedrock level, in Delhi city, by the modeling of the source of Mw=8.0, located in the central seismic gap of Himalayas, at about 300 km of epicentral distance from Delhi city. We simulate the time histories using both point source and extended source models. The seismic waves due to an extended source are obtained by approximating it with a rectangular plane surface, corresponding to the fault plane on which the main rupture process is assumed to occur. Effects of directivity and of the energy release on the fault can be easily modeled, simulating the wide-band radiation process from a finite earthquake source/fault. The source is represented as a grid of point subsources, and their seismic moment rate functions are generated considering each of them as realizations (sample functions) of a non-stationary random process. Specifying in a realistic way the source length and width, as well as the rupture velocity, one can obtain realistic source time functions, valid in the far-field approximation. Finally, to calculate the ground motion at a site, Green functions are computed with the highly efficient and accurate modal summation technique, for each subsource-site pair, and then convolved with the subsource time functions and at last summed over all subsources. Furthermore, assuming a realistic kinematic description of the rupture process, the stochastic structure of the accelerograms can be reproduced, including the general envelope shape and peak factors. The extended seismic source model allows us to generate a spectrum (amplitude and phase) of the source time function that takes into account both the rupture process and directivity effects. In such a way it is possible to perform a speditive parametric study to investigate the dependence of the ground motion (in the time and frequency domain) on source parameters (geometry, energy release etc.). In the central seismic gap of Himalayas, we consider earthquake sources at an epicentral distance of about 300 km from Delhi city with Mw=8.0, depth=10, 15 and 20 km, dip=10 deg, rake=95 deg, length of fault=178 km and width of fault=45 km. The maximum amplitude of ground motion is searched as a function of the strike-receiver angle. The peak values - displacement of 9.1 cm (vertical comp.), velocity of 3.9 cm/sec (vertical comp.) and acceleration of 8.1 cm/sec**2 (NS comp.) - are obtained for the source depth 10 km. Similarly, keeping all other parameters fixed, we estimated the ground motion when the source is at depths of 15 and 20 km and the dip is 20 deg. A similar study will be performed for sources at a regional and local distances, to analyze and to assess likely earthquake scenarios driving the seismic hazard in Delhi city.

Keywords: strong ground motion, delhi, extended source

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SS002 **Oral Presentation** **6259**

Neo-deterministic definition of seismic input and its application to seismic isolation of residential building

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The neo-deterministic, physically sound, method for the definition of seismic input is based on the computation of synthetic seismograms at different level of detail, depending on the degree of geological, geophysical, seismological and seismotectonical knowledge. Both 1D and 2D structural models are considered, at national and local scale, respectively. The seismic waves due to an extended source are obtained by approximating it with a rectangular plane surface, corresponding to the fault plane on which the main rupture process is assumed to occur, discretized with a grid of point-sources whose seismic moment rate functions are generated considering each of them as realizations (sample functions) of a non-stationary random process. Effects of directivity and of the energy release on the fault are modeled. To calculate the ground motion at a site, Green functions are computed with the highly efficient and accurate modal summation technique, for each point-source site pair, and then convolved with the point-source time functions and at last summed over all point-sources. The practical case of Nimis (UD), is illustrated; the town, located in a seismically active area along the Alps-Dinarides junction, was hardly hit by the 1976 Friuli earthquake. Modelling has demonstrated that the high level of seismicity of the zone makes the construction of a residential building by traditional antiseismic techniques very difficult, while the use of advanced techniques, like seismic isolation, is particularly advantageous.

Keywords: seismic hazard, synthetic seismograms, seismic isolation

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SS002 **Oral Presentation** **6260**

Critical aspects of ground motion simulations for seismic hazard assessment

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The use of deterministic ground motion simulations in seismic hazard assessment is currently a rapidly growing field of research. The advantage of such methodologies is that much more detailed information about the spatial distribution and frequency dependant variation of strong ground motion can be obtained because they are based on earthquake scenarios which make use of the available knowledge on fault behaviour and rupture characteristics. However, to a large extent, the success of such simulations depends upon the reliability of the knowledge about the active faults and their rupture properties in the studied region. A method for calculating the broadband frequency ground motion due to a scenario earthquake will be presented. In our hybrid model we combine the deterministic simulation of the low frequencies (0.1-1.0 Hz) with a semi-stochastic simulation of the high frequencies (1.0-10.0 Hz) using empirical Greens functions. We apply a high-frequency radiation model which uses a smooth transition between non-spherical to spherical radiation pattern as the frequency increases. Computation in each frequency range is performed separately and the total ground motion is combined in the time domain. Examples from two case studies will be used to illustrate the various aspects of the method. Results will be presented for simulations performed for an expected future earthquake in the Marmara Sea, NW Turkey, and for the Dec 26, 2004 Sumatra earthquake. Furthermore, the effects of varying the input source and attenuation parameters on the simulated ground motion will be discussed. One limitation of the deterministic methodologies is that the hazard assessment is usually conducted due to a single scenario earthquake. Several scenarios need to be applied to take into account the uncertainties associated with the parameter variability. This is usually adequate, as long as the earthquake hazard is controlled by a single fault close to the site of interest. In many regions, however, the seismic hazard is combined from the threat of several active faults for which several scenario earthquakes can be defined with different probabilities of occurrence. Future plans towards the implementation of deterministic earthquake scenarios in probabilistic seismic hazard calculations will be discussed.

Keywords: ground motion simulation, hybrid method, seismic hazard

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SS002 **Oral Presentation** **6261**

Geoinformation analysis of earthquake hazard in North India

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The presentation addresses the results on development of geoinformation technology oriented to seismotectonic problem domain and application of the technology to spatial analysis of seismicity in North India region. The following initial data were used for geoinformation analysis: historical and instrumental earthquake catalogue of Wadia Institute of Himalayan Geology from 1552 till 30.01.2005, digital elevation model in grid 30″x30″, linear tectonic structures (active thrusts, non-active thrusts and faults), and astronomical data (right ascension and declination of moon). Geoinformation modeling tools were presented by Web-GIS GeoProcessor 1.5 and GIS SeismoTide. Web-GIS GeoProcessor 1.5 (http://www.iitp.ru/projects/geo) is implemented as Java 1.5 applet. The applet can be used for decision support in environmental zonation, natural hazard and risk assessment, and exploration of natural resources. GIS SeismoTide operates in the Matlab environment. It was designed specially for calculating tidal force characteristics, assessing the measure of correlation between seismicity and tidal force, and composing the maps of prevailing seismic activity. The following three main results of data exploration will be discussed: (1) spatial patterns of main seismic parameters (sensitivity of North India Seismic Network, spatial model of b-value, spatial model of seismic activity), a statistically significant relationship between seismicity and one of the components of tidal forth, and spatial analysis of relationship between strong earthquakes with m≥6 and digital elevation model. The analysis was done for the seismic data of Janurary 1999 to January 2005 with the improved quality of the catalogue for this period. The grid-based spatial analysis of seismicity shows that the region around Delhi has lowest value (2.0) of the minimal representative magnitudes, while its value is highest (2.6) in the region of Punjab and SW of Garhwal-Kumaon region. The seismic activity of earthquakes with m=3 is highest to the SW of Garhwal-Kumaon region and lowest in the Delhi-Haridwar region. The b-value is around 0.5 for Kangra-Chamba region and less than 0.5 for the Garhwal-Kumaon region. Comparison of the Lunar component of tidal force with the seismic activity of the region detects the area which is seismically active to the daily variation of tidal force. The statistic significance in selected area is high enough to testify for essential distinction between frequencies of earthquakes for two compared phases. This result shows that the area is in the condition of primary vertical tectonic compression. The standard deviation of the Earth surface elevations (consequences of geotectonic deformation) with RMS value of more than 500 m is positively correlated with the strong earthquakes m>=6. This work was carried out under ILTP cooperation program. It was supported in part by ILTP, by the Russian Foundation for Basic Research, project no. 06-07-89139 and by Basic research program of Presidium of RAS No 15, section "Electronic Earth".

Keywords: earthquake, hazard, gis

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SS002 **Oral Presentation** **6262**

Sustainable Geophysical Observatory Networks

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Geophysical networks are defined not only by their technical specifications, but also by the characteristics and needs of the communities that use them. Growing populations supported by more elaborate urban infrastructure with its fine-grained socio-economic interdependencies and relying on global and regional connections for sustainability make new demands for natural hazard risk management. Taking advantage of advances in the underlying science to provide society with accurate risk assessments often requires higher fidelity measurements, entirely new types of observations, and an evolutionary sense of data products and information management. Engineering a high-tech system to address stakeholder needs is difficult, and designing for unpredictable developments requires an emphasis on adaptation. Thus, it is essential to promote formation of organizations or communities that can support evolution of a technological system, imagine new uses, and develop the societal relationships that sustain operations and provide capital for improvement. The owners must have a deep understanding of why the system works in particular ways and how to manage data products for the benefits of stakeholders. To be effective, community promotion must be sustained over a longer period of time than required to build a network and should be aimed at integrating the community into worldwide partnerships. Practices that can promote community formation if they are sustained include repeated training and scientific exchange workshops, extended visits by experts and staff at all levels to and from countries where networks are installed, mechanisms that make timely upgrades realistically possible, and routine exchange and wide dissemination of data in all directions. The combination of international research and educational collaborations, supported by open data exchange, with regionalized and specific assessments of local stakeholder needs and concerns, provides a sustainable model for geophysical observation.

Keywords: sustainability, hazard, monitoring

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SS002 **Oral Presentation** **6263**

Integrated Neodeterministic Scenarios for Reliable Earthquake Hazard Assessment

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Problem and its Significance. The input for the seismic risk analysis can be expressed with a description of groundshaking scenarios, or with probabilistic maps of perhaps relevant parameters. The probabilistic approach, unavoidably based upon rough assumptions and models (e.g. recurrence and attenuation laws), can be misleading, as it cannot take into account, with satisfactory accuracy, some of the most important aspects like rupture process, directivity and site effects. This is evidenced by the comparison of recent recordings with the values predicted by the probabilistic methods. Proposed Approach. We propose to integrate a) the intermediate-term medium-range earthquake predictions with b) the procedures developed for the recognition of strong earthquake prone areas and c) for the Neo-deterministic assessment of seismic hazard. This permits to associate the alarms declared by the prediction algorithms to a set of possible seismic ground motion scenarios: the seismological and morphostructural analysis permit to define the Scenario Earthquakes, i.e. the strong events that could affect a selected area, that can be used by a neo-deterministic analysis, able to model the seismic input at a given site. For the relevant sites, where the synthetic seismograms can be successfully compared with the recorded signals or with the macroseismic data, the theoretical estimates allow to draw a microzonation scheme, given a set of possibile scenario earthquakes. Results and Application. We supply examples of scenarios corresponding to possible events with M?6.5, that turn out to be the closest to several cities in Italy. A practical advantage of the described procedure is the time information given by the intermediate-term earthquake prediction that is very useful to plan preparedness and rescue actions and to define priority criteria for the more detailed studies required by seismic microzonation. Furthermore, the skill of seismology to estimate realistic ground motions at a particular site should be fully exploited by seismic engineers. In fact, even if recently strong motion records in near-fault, soft soil, or basin conditions have been obtained, their number is still very limited to be statistically significant for seismic engineering applications.

Keywords: seismic hazard, earthquake scenarios

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SS002 **Oral Presentation** **6264**

Seismic Hazard Disaggregation Maps for the Italian Peninsula

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The rates of exceedance calculated in a PSHA reflect the combined contribution of all the magnitudes, M, source-to-site distances, D, and number, ε, of (logarithmic) standard deviations by which the (logarithmic) ground motion deviates from the median value predicted by an attenuation equation for a given M=m and R=r pair. In some cases, it is useful to define what values of M, D, and ε control these rates. Seismic hazard disaggregation (e.g., McGuire, 1995; Bazzurro and Cornell, 1999) provides insights into the earthquake scenarios driving the hazard at a given ground motion level. The proposed work presents the disaggregation at each grid point of the Italian probabilistic seismic hazard map, which was defined by Gruppo di Lavoro MPS (2004). Note that the hazard values considered here correspond to the 50th percentile of the hazard distribution obtained by using a specific logic tree (Gruppo di Lavoro MPS, 2004). The Italian seismic hazard map, indeed, was not developed in terms of the mean hazard values but in terms of the median hazard. Thus, the disaggregation is performed using the inputs along the logic tree path that provided hazard values closest to the reference 50th percentile hazard (path 921, Montaldo and Meletti, personal communication). Both peak ground horizontal acceleration (PGA) and spectral acceleration values corresponding to different mean return periods are disaggregated by M, D, and ε bins (3-dimensional disaggregation). Mean and modal values of M, D, and ε are provided based on two different binning schemes. The former is based on equal spacing of the magnitude and distance bins, while the latter is based on finer bins at short distances and broader bins at larger distances. Note that the mode corresponds to the M-D-ε group that gives the largest contribution to the hazard and, consequently, corresponds to a realistic source. The main disadvantage of using modal values is that they are sensitive to the bin size (e.g., Abrahamson, 2006). The mean, on the other hand, does not always represent the most likely M-D-ε group but is independent of the binning scheme adopted. Maps of M, D, and ε for both the mean and the mode of the joint M-D-ε distributions are presented for the first time for the Italian area. The complete joint M-D-ε distributions are also presented for some sites. The results show that higher spectral periods are generally controlled by larger earthquakes at larger distances while smaller events at smaller distances dominate the PGA hazard. This confirms results from McGuire (1995) showing that high and low frequency ground motion hazards can be dominated by different scenario earthquakes. Moreover, for a given site the longer the mean return period, the larger the contribution of stronger earthquakes at smaller distances. The maps presented here can be helpful to private and public users as a guide for selecting ground motion records for design and/or numerical ground response analyses. Note that these maps, by design, identify M-R-ε values for the mean and the modal peaks only. The joint M-D-ε distributions in some cases can have multiple peaks, some of which contribute about the same amount than the mode to the hazard. Therefore, the complete joint M-D-ε distributions should always be evaluated for a site-specific analysis.

Keywords: disaggregation, psha

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SS002 **Oral Presentation** **6265**

Unified Scaling Law for Earthquakes: Implications for seismic hazard and risk assessment

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The evident fractal nature of seismic distribution calls for generalizing the fundamental Gutenberg-Richter relation in the following form of the Unified Scaling Law for Earthquakes (USLE): log10N(M, L) = A + B (5 M) + C log10L, where N(M, L) is the average annual number of earthquakes of magnitude M within a seismic locus of liner size L. The coefficients characterize the level of seismic activity (A), the balance between magnitude ranges (B), and the fractal dimension of seismic locus (C). The global, regional, and local distributions of reliable local estimations of the A, B, and C coefficients show practically overall agreement of the data with USLE. An estimate of earthquake recurrence rate depends on the size of the territory that is used for averaging and may differ dramatically from traditional rescaling to the area of interest. The implications regarding the recurrence of catastrophic earthquakes, estimation of seismic hazard and risk, as well as earthquake prediction could be crucial in specific cases. Therefore, USLE should eventually substitute the Gutenberg-Richter relationship in a contemporary hazard assessment allowing for multi-scale analysis of seismic evidence at a given site.

Keywords: scaling, fractals, recurrence

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SS002 **Oral Presentation** **6266**

Application of the intermediate-term earthquake prediction algorithm CN to the Adriatic region

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The properties of seismicity in the Adriatic region and its surrounding are investigated with the aim to set up a system for the monitoring of the seismic flow, by the application of intermediate-term middle-range earthquake prediction algorithm CN. The formally defined and globally tested algorithm CN allows for a diagnosis of the periods of time (TIP: Time of Increased Probability for the occurrence of a strong earthquake) when a strong event is likely to occur inside a given region. The application of the algorithm requires the use of a homogeneous, sufficiently complete and timely updated earthquake catalogue. Hence, a new unified catalogue has been compiled for the Adriatic area and surrounding territory. The catalogue is the result of the merging of two national earthquake data sets covering, respectively, the Italian area and the Croatian territory and its vicinity, with the global seismic catalogue NEIC (National Earthquake Information Centre, USGS, USA). CN algorithm is applied, since 1998, for the routine monitoring of earthquakes occurrence in the Italian territory, considering a regionalization defined strictly based on the seismotectonic zoning and taking into account the main geodynamic features of the area. The successful results obtained for the Italian territory, including the real-time prediction test for earthquakes with magnitude larger than 5.4, indicate that the seismotectonic model may provide a useful guide in the selection of the fault systems involved in the preparation of strong earthquakes, leading to a general reduction of the space-time uncertainty of predictions. With these results acquired a new region for the Adriatic area, complementary to the Italian regionalization along its western boundary, has been defined on the basis of the seismotectonic model. Several stability tests have been satisfactorily performed with respect to the selection of the boundaries of the region, as well as of the interval of time considered for the setting of the algorithm parameters. The retrospective prediction results for earthquakes with magnitude larger than 5.4 are stable with respect to the control tests.

Keywords: adriatic region, cn algorithm

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SS002 **Oral Presentation** **6267**

Seismic hazard definition for performance-based design

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Earthquake engineering recently proposes a new generation of methods that can be used to predict the probable earthquake performance of individual buildings.The Performance-based Seismic Design consists of different types of seismic performance assessment and they provide estimates of the probable human losses, direct economic losses and downtime.Each type of performance assessment requires a somewhat different way of characterizing ground shaking. For intensity-based assessment, a response spectrum, representing the intensity for which the performance is to be assessed, and a suite of ground motions, scaled to this spectrum, are required. Scaling must be performed in an appropriate manner to capture the natural uncertainty associated with ground motion of a particular intensity. A scenario-based performance assessment is an estimate of the probable losses, given that a building is subjected to a specific earthquake, normally defined as a specified magnitude and distance from the site. When a scenario, consisting of a specific magnitude(M) earthquake at a specific distance(R) from the building site, occurs, there is some uncertainty as to how intense the ground shaking at the building site may be. In order to perform a scenario-based assessment, it is necessary to obtain a hazard curve for the building site. The hazard curve used in scenario assessments must indicate the conditional probability of exceedance of ground shaking intensities, given that the scenario event occurs(M,R). A time-based assessment should be an estimate of the probable consequences, considering all potential earthquakes that may occur in a given period of time, and the probability of each one. The hazard curve, in this case indicates the probability of experiencing ground motions of different intensities, in a specified period of time. In the described methods the evaluation of the losses and demands are calculated through a probabilistic evaluation of a large number of dynamic non linear responses. In this paper the criteria for the hazard definition are discussed within the Performance-based Seismic Design methodology.

Keywords: earthquake, hazard, performance based design

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SS002 **Oral Presentation** **6268**

A new probabilistic seismic hazard map for Portugal

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The probabilistic seismic hazard of Portugal is analyzed with a logic tree approach. Instrumental magnitudes and isoseismal areaswere converted to M through empirical relations, to produce a catalogue with a uniform magnitude scale. Three published attenuation relations were used in the logic tree, with relative weights based on tectonic considerations and on the comparison with macroseismic data converted to horizontal peak ground acceleration (PGA). The Ambraseys et al. (1996) attenuation model, used by most previous hazard studies of the region, seems to underestimate considerably the ground motion for mainland Portugal. A total of 96 hazard curves were calculated with SEISRISK III for each point of a 0.05 by 0.05 grid. The resulting mean hazard map for 10% exceedance probability in 50 years displays PGA values that range from 0.05g to 0.20g. These mean values are slightly higher than in previous PGA studies. The hazard patterns obtained display a maximum related to intraplate onshore seismicity, whereas previous studies using intensities highlighted the SW offshore contribution. Further work on ground motion attenuation in western Iberia is necessary to improve the seismic hazard assessment.

Keywords: psha, portugal, mean hazard map

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SS002 **Poster presentation** **6269**

Study on causative mechanism of unusual geological incidents occurred during 2001 in Kerala, India

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In order to understand causative factors responsible for triggering various unusual geological incidents in Kerala during 2001, field investigations were carried out and macroseismic data pertaining to various unusual geological incidents were collected and a database was generated listing 512 such incidents during the period. A total of 14 different types of incidents grouped under four categories as: seismicity, land deformations, fluctuation in well water and other unusual incidents have occurred in two active phases i.e. February-March, and June to November 2001. The spatio-temporal patterns of the incidents show that these incidents may be considered earthquake precursors under macroscopic category. These incidents might have been triggered by the internal geological processes leading to uplift and tilt of the ground affecting existing geological equilibrium condition giving rise to these phenomenal. Detailed observations and analysis of active fault zones, intersection points of lineaments and reported several unusual geological incidents can be of great help in delineating the probable epicentral tract of impending earthquake. The results of these investigations and the database on the incidents are presented in this paper.

Keywords: ground fissures, unusual geological incidents, quiescence

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SS002 **Poster presentation** **6270**

Precursory swarm is a real diagnostic parameter as seismic precursor before major shocks a case study

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Studies in earthquake prediction report many evidences that long-range correlation between the earthquakes is relected in some phenomena precursory to strong earthquakes. Most of the major earthquakes show prior seismic activity that in hindsight seems anomalous. The features include changes in regional activity rate and changes in the pattern of small earthquakes, including alignments on unmapped linear features near the (future) mainshock. It has long been suggested that large earthquakes are preceded by observable variations in regional seismicity. Studies on seismic precursors preceding large to great earthquakes with M ≥ 7.5 were carried out in northeast India region bounded by the area 200 320 N and 820 1000 E considering earthquake database from 1853 to 1985. It is observed that all the earthquakes of M ≥7.5, including both the great earthquakes of 1897 and 1950 in the region, are preceded and followed by abnormal low seismicity phases some 11 to 27 years prior to occurrence of mainshocks which are considered seismic precursor for the mainshocks. Based on precursory swarm observed during 1964-1965 in Arakan Yoma fold belt, an earthquake of M 7.5 was predicted to occur during 1986 to 1990 in the delineated zone. It is noteworthy to mention here that an earthquake of M 7.5 had occurred in the delineated zone on 06 August 1988. The pattern of anomalous seismicity preceding major earthquakes in northeast India region can be regarded as one of the potential seismic precursors. Database constraints have been the main hindrance to search this precursor prior to smaller earthquakes, which, otherwise, certainly would have provided additional information on its existence. The entire exercise shows that anomalous seismicity preceding major shocks is a real seismic pattern for the northeast India region and can be employed for long-range earthquake prediction when better quality seismological datasets covering a wide range of magnitudes are available.

Keywords: precursory swarm, predictive parameter, precursory time

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SS002 **Poster presentation** **6271**

Seismic hazard zoning of Southern Part of Khorasan Province_Iran (Gazik_Qayen_Nehbandan_Birjand) and designing a fortran program to estimate the seismicity parameters on base of numbers and magnitude of earthquakes

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In this study we select the birjand city for our site and effect of earthquake on it was investigate and studied. At the first stage by use of geological map and surfer software we digited the exist fault of region.then with emprical relationships for each type of fault, the length of them calculated and after that by use of available refferences, historical and instrumental earthquakes of region digit and located on above mentioned map.after this with deterministic and ultimately probabilistic seismic hazard zoning the factors such as seismicity parameters,suitable attenuation relation ship,maximum acceleration of strong ground motion on selected site,reccurance interval of earthquakes was studied and calculated.ultimately we could design a fortran program to estimate the seismicity parameters on base of numbers and magnitude of earthquakes with fortran environmental programming. This study show that the obtained numbers and relationships have good comparity with fact and can use the results of this study for probable disaster prevention and we can relaiy to its results.

Keywords: seismichazardzoning iran

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SS002 **Poster presentation** **6272**

Comparison ofearth quake response spectera of earth (soil) and concreat dams behaviour indiffferent regions of Iran with a new geotechnical analysis method

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Iran plate has complex and saphisticate seismicity pattern characteristic and every 5 year we have and can see a destructive earthquake in our country.so that for obtaining the seismicity of a region 3 major data such as paleoseimology, historical and instrumental must be used and noticed. Before the desining and seismic evaluating structures it is necessary that parameters such as seismotectonic of performance region, selection of earthquake for different levels of desining accurate siesmicity parameters, estimation and selection of them must take an account. In this study at the first we select some of earth(soil) and concreat dams in different regions of iran.then by use of seismotectonic and tectonic studies and after it with a new combined method the earthquake response of dams was investigated. This study show that this new applied method can reply to many questions about the dam behaviours.

Keywords: earthquakeresponse

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SS002 **Poster presentation** **6273**

Probabilistic earthquake hazard analysis in western Algeria

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Northern Algeria belongs to the African-Eurasian tectonic plates boundary. Therefore, seismic hazard constitutes a permanent threat for peoples and their properties. Indeed, during the last two decades two majors and several moderates destructive earthquakes has been occurred. In this work, we aim to present results of seismic hazard study performed in the Mascara region, western Algeria, by using a probabilistic approach with emphasis on the seismic potential of geological structures. For this purposes four steps has been followed, (i) identification of potential geological structures, (ii) assessment of their geometrical and seismotectonic parameters, (iii) choice of attenuation laws and finally, (iv) compute of seismic hazard in terms of peak ground accelerations in hard rock.

Keywords: seismichazard probabilistic

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SS002 **Poster presentation** **6274**

Geological structure of Sri Lanka and its influence on micro seismic activities

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Geologically there are three different lithological units can be identified in Sri Lanka. They are Highland Series (HS), Wanni Complex (WC) and Vijayan Complx (VC) (Cordani and Cooray, 1989) which is entirely classified based on their metamorphic grades. Many geological structural features like lineaments, micro faults, shear zones, doubly plunging antiforms and synforms, etc can be observed within these geological units. After interpretation of satellite images and aerial photographs, it was found that there are several hundreds of lineaments, fractures and joints exist within Sri Lanka and its surrounding (after W. Kehelpannala, 1987). Of these lineaments, there are three sets of mega lineaments which are trending NE-SW, N-S and NW-SE are significant. Mahaweli shear zone-I between Highland Series and Vijayan Series boundary, Mahaweli shear zone -II near Minneriya and Giritale and Mahaweli shear zone-III with major gravity low between Mahiyangane and Polonnaruwa, and Mahaweli shear zone IV runs from Nuwaraeliya Kegalle Kurunagala are few known mega lineaments in Sri Lanka (after P. W. Vitanage). Few major reservoirs and dams like Victoria, Randenigala, Kotmale, Samanalawewa, ..etc are located very close to some these lineaments which can be micro seismically very active regions in Sri Lanka. There werent any major earthquakes recorded in Sri Lanka in the past. However, occasionally there were few tremors had recorded in Sri Lanka very recent past. Also it is noted that recording micro seismic activities in and around Sri Lanka has been increasing within last ten years. It is clearly identified that most of these micro seismic events were took place very closer to lineaments and major joints. Therefore, it is obvious that these events were structurally controlled. With the activate of these lineaments due to micro seismic activities, there is a serious threatened for dams and reservoirs located closer to these weak zones in future.

Keywords: tremors, geological structure

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SS002 **Poster presentation** **6275**

Identification of basement Rock Beneath Kanto Plain by normalized input-output minimization (NIOM) method and conventional receiver function using strong motion accelerograms

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Kanto-Tokai region is among the complicated underground structures in Japan having been located in a triple junction of Philippine, Pacific and Eurasian plates. Large part of Kanto region is covered by quaternary sediments starting from seaside in the east and the remaining area consists of hills and mountains. Receiver function technique nowadays has been one of the tools of seismologist to infer crust and upper mantle. In this study, we applied the Normalized Input-Output Minimization (NIOM) method (Haddadi, H. and Kawakami, H., 1998) and conventional receiver function (Langston, 1979) to identify the basement-sediment interface beneath Kanto plain using strong motion accelerograms. Taking advantage of the availability of borehole data from KiK-net stations that basement-sediment interface is visible, synthetic receiver functionsare created using Haskell method (Haskell, 1962) and found that from different layers of substructure in borehole data, the basement-sediment interface is the one that dominantly generates P to S conversion. Comparing the resultof synthetic receiver function to both NIOM and conventional receiver functions showed the same Ps arrival time. Shallow earthquakes and earthquakes ranging from epicentral distances of 30 to 300 km are chosen in the analysis. Horizontal components are rotated to radial and tangential to clearly identify the SV and SH type of waves and the primary (P) wave part is extracted from the whole earthquake record by applying cosine taper. By deconvolution procedures of NIOM and conventional receiver function, the direct arrival of P wave is retained in radial and tangential components and followed by conversion and reverberations of P to S type of wave. We also conducted receiver function analyses at the bottom record of KiK-net to have the finest result of basement depths. The depth of basement-sediment interface beneath an individual station is determined using time delay of P-SV phase from the results of NIOM and conventional receiver functions. Result shows the 3D basement basin structure beneath Kanto plain that has been identified by covering 80 stationsof KiK-Net and K-NET strong motion accelerographs. In this study the deepest basement is located in CHBH12- FUTTSU station with a depth of 4.1 km from zero elevation. The result has a good agreement with geological data and other studies of Kanto area.

Keywords: receiver, function

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SS002 **Poster presentation** **6276**

Complex analytical and monitoring the method of the long-term and short-term earthquakes forecasting

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The modern earthquakes forecasting is based on statistics of seismic events have occurred, monitoring of the current lithosphere condition and probability to an estimation of time of earthquakes' occurrence. Expected time of earthquake is defined in a range from a month to about one year and more. The basic problem of the probabilistic approach of forecasting is uncertainty of distribution law of seismic processes and events. For last centuries of seismological supervision the huge volume of the statistical information is saved up, however mathematical methods of statistical processing of databases on earthquakes still do not allow to reveal law of earthquakes' occurrence. Scientific and prognostic value of this information is obvious and great, but new technologies are necessary for such analysis. Recently two directions in perfection of the long-term and short-term forecasting of large earthquakes were defined is account of solar-terrestrial relationship and monitoring meteorological and biological "harbingers". Researches have shown, that high solar activity not always accompanies strong earthquakes, and presence of "harbingers" or their attributes not always means preparation of earthquake and can be connected completely to other natural processes. At the same time, from analysis of conditions of occurrence of strong earthquakes follows, that they have taken place on extremums of transients change of solar activity, fluctuations and shift of terrestrial axis and at characteristic phases of the Moon. Basis of the new complex analytical and monitoring method of the long-term and short-term forecasting of time and a place of earthquakes makes: - the account of transients change of solar and geophysical factors or any other parameters describing any influence or change of a lithosphere energy condition; - definition of global and local statistical spectral-temporal laws of earthquakes activization after extreme values of transients change of solar and geophysical parameters; - monitoring of "sensitivity" - the response of a controllable local or regional geographical zone to extreme changes of transients and the coordination of changing local geophysical parameters or "harbingers" with an calculated time of earthquakes activization. In the given method are realized integration of interdisciplinary approaches: statistical (information databases), physical (mathematical models of seismic processes) and instrumental (monitoring of solar and geophysical parameters). For reception of numerical values of the forecasting time of earthquakes activization is used the mathematical device of the catastrophes theory and properties of systems complexity.

Keywords: forecasting

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SS002 **Poster presentation** **6277**

Probabilistic seismic hazard assessment for Romania considering intermediate-depth (vrancea) and shallow (crustal) seismicity

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The earthquake risk on Romania is one of the highest in Europe, and seismic hazard for almost half of the territory of Romania is determined by the Vrancea seismic region, which is situated beneath the southern Carpathian Arc. The region is characterized by a high rate of occurrence of large earthquakes in a narrow focal volume at depth from 70 km to 160 km. Besides the Vrancea area, several zones of shallow seismicity located within and outside territory of Romania are considered as seismically dangerous. We present results of probabilistic seismic hazard analysis, which has been performed using so-called stochastic event technique and which considers both intermediate-depth and crustal seismicity. The 1706 stochastic events are generated from 24 seismic sources using a probabilistic approach and seismic hazard in terms of macroseismic intensities, peak ground acceleration, and response spectra is evaluated for each event with computed rate of occurrence or probability. For the Vrancea area, the region-dependent attenuation relationships were used (Sokolov et al., 2007). These attenuation relationships are based on Fourier Amplitude Spectrum (FAS) source scaling and attenuation models, and generalized site amplification functions. For the crustal events, due to lacking of strong motion data, the attenuation relationships developed for Europe by Ambraseys et al. (1996) are used. The probabilistic hazard assessment performed at commune level is used in disaster risk management model developed for Romania.

Keywords: seismicity, hazard, earthquakes

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SS002 **Poster presentation** **6278**

Seismic hazard assessment of the Ilam Region in Western Iran

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This paper presents a probabilistic hazard assessment of Ilam region in Zagros mountain, western Iran. Zagros is one of the most seismically active parts of Alpine-Himalayan seismic belt. We got a catalogue containing historical and instrumental, complete for magnitudes greater 4. To account for seismicity of regions near Ilam, area under study was extended and fault map then seismotectonic map was obtained. Considering seismic pattern in area, potential seismic sources were detected and modeled as volume sources. Because of inaccuracy in depth of events, depth of sources fixed to 10 km in consistent with seismogenic zone depth in Zagros. Using probabilistic method and choosing Cornell (1979) attenuation relationship, we obtained peak ground acceleration on bedrock in sites for exceedance probability 10% and life time 50 years. Considering four relatively hazard level, we zoned Ilam to four zones as high danger part, relatively high danger, intermediate and low seismic hazard level.

Keywords: hazard, zoning, ilam

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SS002 **Poster presentation** **6279**

Short-Term M4+ Earthquake Probability Forecasts for California and Western Nevada

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Short-term earthquake forecasts have an advantage over long-term forecasts in that one does not need to wait a long time to evaluate the success or failure of a short-term forecast. When earthquake forecasts are expressed as the probabilities of occurrences of future events, they are easiest to evaluate if they are issued frequently enough that their performance can be assessed statistically after a few years. We plan to start issuing three different short-term (5-day) forecast probabilities of M>=4.0 mainshocks for California and western Nevada after every M>=4.0 mainshock in this region. The first forecast model will be based on observations of excess short-term clustering of mainshocks throughout the region relative to a Poisson process as determined from the M>=4.0 mainshock seismicity of California and western Nevada from 1932 to 2006 (declustered of foreshocks, aftershocks and triggered earthquakes). The forecast probabilities for each earthquake will be adjusted somewhat depending on the location of the event that triggers a forecast and the time of year that the event occurs. A second forecast model is based on a Hidden Markov Model (HMM) of the seismicity, where the HMM is used to compute the probabilities of different states of the seismicity based on the past seismic activity. In this model also, the forecast probability following each event is a function of the location and time of the event. The third forecast model is based on a purely Poissonian model of the temporal behavior of the seismicity, and the forecast probabilities are independent of the times and locations of all earthquakes. The study area is split into two regions, an eastern region and a western region, divided by a line that runs from the central San Joaquin Valley southeast to the Imperial Valley. Separate forecast probabilities will be issued for each region. We expect to issue about 17 earthquake probability forecasts each year, and about 5 years of forecasts should yield sufficient data to test the relative reliability of each of these forecast methods.

Keywords: forecasting, seismicity, california

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SS002 **Poster presentation** **6280**

Probabilistic seismic hazard evaluation of Albania

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Cornell-McGuire methodology, using computer code of Risk Engineering Inc. CO, USA, has been applied in for probabilistic hazard analysis.Albania, characterized by shallow crustal seismicity, is one of the most seismically active countries in Europe. Most strong earthquakes occur in 3 well-defined seismic belts: a) The Ionian-Adriatic coastal earthquake belt at the eastern margin of the Adria microplate, which trends northwest-southeast; b) The Peshkopi-Kora earthquake belt, which trends north-south, and c) The Elbasani-Dibra earthquake belt, which trends north-easterly. The revised catalogue of Albanian earthquakes used in this analysis contains 552 events with M ≥ 4.5 from the 58 A.D. up to 2005, occurred in the region within coordinates 39.0o-43.0o N and 18.5o-21.5o E. The 9 seismic source zones are delineated in based on two fundamental tools: a seismicity profile and the present-day tectonic regime of the region under consideration. Based on the differences in ground motions for crustal earthquakes generated by normal, thrust or strike-slip faulting, we have selected for Albania to use the following attenuation relations of ground motions: For seismic source zones in extensional regime, located in eastern Albania, the attenuation relation of Spudich et al., 1999 is used for the evaluation of ground shaking, while the attenuation relation of Sadigh et al., 1997 is used for seismic source zones in compressional regime, located in western Albania. The main parameters of seismic hazard of : Peak Ground Accelerations (PGA) and Spectral Accelerations (SA) damping 5 % are calculated using the EZ-FRISK 7.12 computer code for rock type conditions, and in accordance with Eurocode 8 for two levels of probability: 10 % in 50 years (475 years return period) and 10 % in 10 years (95 years return period). The ground motion values are calculated for firm rock sites that correspond to a shear-wave velocity of 760 m/s in the top 30 m. For evaluation of ground motion shaking, the attenuation relations of Spudich et al., 1999 and Sadigh et al., 1997 are used. The seismic hazard maps of PGA and SA (0.2, 0.5, 1.0 and 2.0 sec.) for two levels of probability are compiled. Some results presented on Map of PGA seismic hazard on rock sites for a probability of 10 % / 50 years are given below. The PGA values, rock site condition, for a probability of 10 % / 50 years or 475 years return period, are the largest ones along the Adriatic-Ionian coastal earthquake belt going from 0.24 g in Southern Albania to 0.25-0.30 g from Vlora to Lezha towns, and up to 0.40 g NW of Shkodra town, along the Dalmatian coast; while in Eastern Albania the PGA values are 0.20-0.22 g from Ohrid Lake to Leskoviku town, and from Kukesi to Peshkopia districts; the highest values of PGA 0.20-0-30 g in Eastern Albania are along the Elbasani-Dibra-Tetova and Shkodra-Tropoja transversals. The lowest values of PGA 0.12-0.15 g are in Moker, Mat-Mirdite and Has-Gjakove areas, and 0.07-0.15 g in northern extremity of the country from Vermoshi to Dukagjini areas. In Table 1 are given values of seismic hazard (PGA and SA for 0.2, 0.5, 1.0, 2.0 sec.(g)) for 370 municipalities and communes of . In Table 2 are given full spectral values (SA g) for 36 towns of , based on which are compiled the uniform hazard spectra for each town.

Keywords: seismic hazard, estimation, albania

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SS002 **Poster presentation** **6281**

Q-models for deterministic seismic hazard assessment in Romania

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The territory of Romania is exposed to a high seismic risk, due mainly to the seismogenic source of strong earthquakes located at the bending of the Eastern Carpathians (the Vrancea region). The destructive earthquakes of Vrancea are rare events, and consequently the deterministic methods - based on the numerical reconstruction of the ground motion - are of highest interest for the assessment of the seismic hazard on the Romanian territory. As a key element in the deterministic approach is the availability of detailed, appropriate models for the Earth structure, we aim to study a less known structural parameter, the quality factor of the medium Q. The algorithm we propose is based on the modelling of the high frequency wavetrains; the records of low magnitude local events which may be approximated by instantaneous point sources are compared in frequency domain with synthetic seismograms, generated as response of the local structure to elementary seismic sources. Observational data are short period velocity records of small crustal and subcrustal earthquakes, collected by the digital seismic networks in operation in Romania. Theoretical signals are computed using the multimodal summation method in layered anelastic media. The optimal 1-D models for Q-factor along the investigated ray paths are estimated down to about 200 km depth, by fitting the normalised amplitude spectra of the selected records with those of the synthetic waveforms.

Keywords: vrancea seismic region, seismic wave attenuation, 1d models for q factor

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SS002 **Poster presentation** **6282**

Dams rating in seismic risk classes in Banat Region - Romania

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The main goal of this paper is rating all dams from Banat region - western part of Romania into seismic risk classes. Dam owners and regulators must ensure that dams are safely operated and present no risk to the public in case of an earthquake. While most old or new dams in recognized seismic regions have been evaluated and analyzed for seismic loads, dams located in areas of moderate or infrequent seismicity have been given less systematic attention. In such cases, owners of many dams or officials in charge of dam safety programs may consider comparative assessment of the seismic risk associated with their dams and establish priorities, as needed. Risk classes can be used to establish the necessity of detailed assessment of seismic safety of the dams and to establish the priorities of these evaluations. Methodology which is used in this paper offers an easy way to evaluate the most vulnerable hydrotechnical facilities among the multitude of the Western part of Romanian dams, that are affected by crustal-depth earthquakes from Banat and Danubian regions. The risk is expressed as a product between hazard and vulnerability. In particular, seismic risk in the case of hydrotechnical arrangements is computed as a product between seismic hazard (corresponding to the location of the respective hydrotechnical arrangement) and the seismic vulnerability of the respective arrangement. Various risk factors and weighting points can be used to approximately quantify the Total Risk Factor (TRF) of any dam [Bureau and Ballentine, 2002]. The TRF depends on the dam type, age, size, the downstream risk potential, and the dam vulnerability, which depends on the seismic hazard of the site. The dam structure influence is represented by the sum of capacity, height, and age risk factors. The downstream hazard factor is based on population and property at risk. The vulnerability rating is a function of the site-dependent seismic hazard and observed performance of similar dams, as defined by a predicted damage factor. This procedure can be used to quickly asses the potentially most vulnerable facilities in a large dam inventory. The risk classification based on the TRF, provides guidance to dam safety officials to select appropriate evaluation procedure and to assign priorities for seismic safety evaluation of the most critical dams.

Keywords: risk classes, crustal earthquakes, hazard assessment

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SS002 **Poster presentation** **6283**

Determination of Ground Motion Attenuation law in Tehran Region

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Estimation of ground motion attenuation law in the Tehran region is a very important parameter for calculation of more precise Hazard map of Tehran, the political capital and the megacity of Iran. Fortunately, three short period networks have been operating by Institute of Geophysics, Tehran University during the last 10 years in the Tehran region and collecting a pile of seismic data. In this study, for the first time we use the data to calculate the shape of ground motion attenuation law for the Tehran region defined as region bounded between 34.1-36.6 N and 49.5-54E. A collection of 47 events of Magnitude 3.2-3.8 in the Tehran region are relocated using 19 stations. The stations are equipped with 3-components short period Kinematrics SS-1 seismometer (i.e., 1-Hz corner frequency) and 24 bit digitizer. All records of the well relocated events having a signal to noise ratio of greater than 4 are included in our study. Empirical studies of the attenuation ground motion amplitude are based on linear regression of data to an equation of the following form, log(A(f,i))=a-b*log(R(i))-c(f)*R(i) where A(f,i) is the observed spectral amplitude of earthquake for i th seismogram. a is a dummy variable which includes the source effect; because of the narrow width of magnitude range we assumed the source effect as a constant. b is the geometric spreading coefficient. c(f) is the coefficient of anelastic attenuation. The geometric spreading includes three distinct sections, hinged trilinear form (Atkinson, G., and R. Mereu, BSSA, 1992, 82, 20142031). Solving the above equation, we calculated attenuation parameters for 480 records with a good spatial distribution. To find the distances at which b changes significantly, we used a local regression smoothing methods called Robust Lowess. We found that the hinges of the trilinear (Atkinson, G., and R. Mereu,1992) are at about 106 and 191 km. Using a trilinear regression analysis, we checked all combinations of parameters for the above equation and found that b1=1.1, b2=-0.4, b3=0.5 minimizes the average absolute value of the residuals at frequency 4 Hz. Assuming geometric spreading coefficients are the same for all frequencies, we removed the effect of geometric attenuation from the amplitudes in other frequencies and calculated the remaining attenuation in each frequency. The remaining attenuation is connected to anelastic attenuation. Using the anelastic attenuation at different frequencies, the Quality factor is calculated as Q=121*f^0.67 .

Keywords: ground motion attenuation, anelasticity, geometric spreading

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SS002 **Poster presentation** **6284**

Deterministic Seismic Hazard Assessment of North-East IRAN "NEYSHABOUR Region"

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NEYSHABOUR is located in a highly seismically active region. This city has been completely destroyed with several large historical events: Ms=7.6, 1209 AD; Ms=7.1, 1270 AD; Ms=7.6, 1389 AD and Ms=7.6, 1405 AD. Deterministic seismic hazard analysis is conducted to estimate future earthquake ground motions. Because, earthquake timings are unpredictable within our current understanding, the best method is time-invariant deterministic seismic hazard analysis (DHSA) to assess effects from the largest single earthquake called Maximum Credible Earthquake (MCEs) expected from seismogenic faults. This method has been performed in North-East IRAN, including NEYSHABOUR and adjacent regions. A uniform catalog of earthquakes in the region, including historical and instrumental earthquakes is provided. A total of 8 potential seismic source zones in the region are delineated as area sources for seismic hazard assessment based on geological, seismological and geophysical information. After determination of seismic sources and maximum magnitude for each source, attenuation relationships have been applied to estimate Peak Horizontal Acceleration (PHA) for each source at NEYSHABOUR. At the research site, the highest value of PHA is as high as 0.86g Caused by an earthquake of Ms=8 due to activity of north NEYSHABOUR reverse fault positioning almost at 15km from the city.

Keywords: deterministic seismic hazard, maximum credible earthquake, peak horizontal acceleration

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SS002 **Poster presentation** **6285**

Is It Possible an Integrated Use of Microzonation Studies and City Disaster Plan ? Sisli (Istanbul) Example

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Main purpose of this study is to discuss the combined use of microzonation studies and disaster plan in the context of integrated disaster management. Earthquake occurrences on the Turkey being usually characteristic and well documented in history, a time dependent model can be reasonably used for the probabilistic assessment of the seismic hazard in Istanbul. For the study area, the probabilistic seismic hazard analysis were determined by using Poisson and Gumbel probabilistic approaches. By using deterministic seismic hazard analysis, the magnitudes were estimated by the four rapture (with four different fault length, 108 km, 119 km and 37 km and 174 km) model in the part of North Anatolian Fault Zone in Marmara Region. By using both analysis (deterministic and probabilistic seismic hazard analysis), magnitude of design earthquake were taken as 7.6. From these design earthquake, accelerations were estimated for several distances (from 15 km to 50 km) by several attenuation relations. In the other phase of the study, soil amplification factors and site characteristic periods were determined and estimated by seismic measurements and SPT test data for the area of Sisli where is important part of Istanbul city. Soil amplification values estimated by empirical relationships by shear wave velocities. In the second part of the study, microzonation data and city disaster plan were merged in integrated form. Disaster management of a city, in coherent, stable and true manner, were realized by understanding and organizing of the disaster plan. When we consider the scientific data and we take a base the current legal structure of our country, the aim of the disaster plan is to provide the fist and emergency aid for the citizens when the destructive earthquake were occurred and effected the general life. This disaster plan includes base of the coordination and helping each other of the activity which all institution and organizations will do during possible disaster. The aims of making of plan is to provide the cooperation and collaboration between before the disaster and to act urgently during the disaster, and to provide the following necessary activity. This necessary activity as main headlines are; the providing of communication and transportation; regulation of traffic; rescue; emergency medical aid, to transportation patient and injured people to the hospitals; to put out fire; to provide security and public order; eating, dressing, heating and lighting studies; to provide temporary housing; the burial of dead citizens; to remove wreckage; to repair and to re-provide the electrical, water and canalization construction. Microzonation studies focus on the studies before the natural hazards occurred, and are evaluated in the phase of mitigation. For this reason, microzonation studies are one of the most important inputs for city disaster plan. The microzonation studies and disaster plane must be coordinate each other. But we didnt say that this connection have not yet constructed in true manner. In this study, it will mainly be presented the integrated use of seismic microzonation studies and city disaster plan for Sisli (Istanbul) case.

Keywords: microzonation, disaster, management

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SS002 **Poster presentation** **6286**

Seismicity and seismic energy release in Central Alborz, Northern Iran

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The region in this study is bounded to long. 49E-54E and lat. 35N-38N and includes major well known active faults. Thus, the region is seismically active and there is high possibility of occurrence of destructive earthquakes. In this study an update version of the earthquake catalogues are provided by using available references which concern the acquisition data in Iran and specially the local seismographic network. Based on this study Seismicity and seismic energy released in this region accords with the major well known and active faults in central alborz. An update version of the earthquakes catalogue is provided by using available references which concerns the acquisition data in Iran and specially the local seismographic network. This region has experienced destructive earthquakes in a historical scale and also in the recent century. Thus, the region is seismically active and there is a high possibility of the occurrence of destructive earthquakes. The results from this study indicate that the seismic activity in this region is not uniformed and follows a cluster pattern model. The epicenters of local earthquakes are in good agreement with the location of major faults as well as the regional tectonic settings. Regarding the recorded local earthquakes in Tehran seismic network, several seismically active areas could be understood. There are seismic gaps in the region that which should be studied in details. The maximum horizontal peak ground accelerations at grid points for percentages probability are estimated and calculated. The results have been illustrated as relevant tables and figures. The maximum acceleration counters maps indicate that in north and northeast and some parts in the center, the rate of seismic activity is high. The analysis of seismic energy released indicates that during 1960-1990, west and southwest parts were more active. Also, in this century, the rate of energy released in east and north east were significant. Most of the recorded earthquakes have shallow depths indicating that the seismic activity is mainly taking place in upper crust and the seismogenic layer has a thickness of about 20km. Taking into account the historical background and the present situation, the occurrence of a major earthquake in Alborz in the vicinity of Tehran is not far from expectation.

Keywords: energy, earthquake, seismicity

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SS002 **Poster presentation** **6287**

Spatio-temporal changes of b-value in Alborz

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The GutenbergRichter relation is one of the well known empirical relations in Geophysics which represent the frequency of occurrence of earthquakes as a function of magnitude: log10 (N) = a − bM. N is the cumulative number of earthquakes with magnitude larger than M and a-value and value-b are constants. The first constant, a-value, is related to seismic activity and so to the time and the volume window considered. The second constant, b-value, is a measure for the relative abundance of strong to weak earthquakes. The b-value is considered to be related to the tectonic regime of the area. The b-value value anomalies may be considered to be an indication of anomalies caused by low or high stress levels, anomaly in thermal gradient or heterogeneity. On the other hand there are some studies discussing about spatio-temporal variations of b-value before large earthquakes and its spatial variation in aftershock studies. In this paper it has been tried to discuss the spatio-temporal changes of b-value in the Alborz Mountain Ranges and the neighboring regions. The data has been extracted from the Tehran Seismic Network (TSN) from 1996 to 2006. First the explosions have been removed from the constructed database and later the remained events have been relocated. Then by assuming that location errors are random and do not depend on magnitude, the spatial and the temporal changes of the b-value has been calculated using different assumptions on the input events such as different spatial, temporal windows etc that help to compare and to produce more reliable results.

Keywords: frequency magnitude distribut, b value, a value

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SS002 **Poster presentation** **6288**

The 2007 UK national seismic hazard map

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Since the UK is a country of only low to moderate seismicity, in the past not much importance has been placed on national maps of seismic hazard. Although a map of sorts was published as long ago as 1976 for Great Britain, it was not until the mid 1990s that probabilistic seismic hazard maps were officially commissioned for the land area of the UK; these were published in 1997. In the years since then, although the UK was, of course, included in the maps resulting from the GSHAP and SESAME projects, the only update within the UK was the publication of a single EMS intensity hazard map in the BGS Atlas Britain beneath our feet. However, the introduction of Eurocode 8 requires the production of a National Annexe covering the intended application of Eurocode 8 to the UK. This in turn requires an updated hazard map that can be used as the basis for seismic zoning. Accordingly, a new hazard map for the UK, giving PGA values with a 90% probability of not being exceeded in 50 years, has been prepared by BGS with financial support from the Institute of Civil Engineers Research Support Fund, ABS Consulting, and the British Standards Institute. The source zone model is an update on the model used in 2004 for the BGS Atlas, incorporating a greater reliance on seismotectonics viewed as a kinematic process. This project also marks the first use of NGA (Next Generation Attenuation) ground motion models in the UK. The results confirm what might be expected, that the whole of the UK is a low-hazard area.

Keywords: earthquake hazard, risk, strong ground motion

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SS002 **Poster presentation** **6289**

Statistical distribution of elapsed times and distances of seismic events: the case of the Alborz in northern IRAN

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In this study, we apply nonlinear analyzes of the sequences of magnitude and performed inter event time intervals and investigate differences in the temporal distribution of small earthquakes before and after large events, obtain statistical models to describe the elapsed times and distances between earthquakes occurred in northern Iran and these results will be compared with those derived from several seismic crises occurred in the same area. We investigated several empiric cumulative distributions of elapsed times and distances between seismic events occurred in the northernfrom 1996 to 2006 by data recorded from network deployed by national Geophysics Research Institute of Tehran University (IGTU). First, the set of elapsed times, δT, and distances, δD, between consecutive seismic events of the whole catalogue, have been analyzed for four different magnitudes of 2.5, 3.0, 3.5 and 4.0. Then, the elapsed times and distances between six seismic crises, without distinguishing magnitudes, are investigated. Additionally, the series of distances and elapsed times from the main event to every aftershock are also analyzed for the six seismic crises. This analysis shows that the power law reasonably explains the empirical distribution of distances and elapsed times when the magnitude varies but the Weibull distribution and logarithmic law have been also successful in some cases. The analysis of the six seismic crises shows a more complex behavior and suggests the breakdown of the fractal behavior for all cases where a power law is not sufficient to perform empiric data. Finally, the results concerning functions used to modeling the elapsed time and distances between seismic events have to be considered. It could be especially useful for the analysis of the whole seismic activity ofNorthern Iran.

Keywords: elapsed times, nonlinear analyzes, statistical earthquake

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SS002 **Poster presentation** **6290**

Aftershock activity of the 28th May 2004 (Ms=6.4) Baladeh kojour earthquake in Iran

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The Baladeh Kojour Earthquake (ML = 4.9, Mw = 6.3) of 28th May 2004 occurred in Baladeh area at a distance about 70 km in northern Tehran . We investigate the spatial and temporal seismicity parameters and the related probable aftershock hazard for the aftershock sequence of the Balade-Kojour earthquake. Aftershocks of this earthquake were recorded by two networks: The acceleration network deployed by Building and Housing Research Center (BHRC), and a close combined network deployed by national Geophysics Research institutes of Tehran University (IGIC). This paper describes the aftershock activity in the first 50 hr following the mainshock by relocated 210 aftershocks, and 150 early aftershocks using the Tehran network data during 1-12th Jun 2004 were relocated. Then, 250 late aftershocks were also relocated using the data from several seismographs and accelographs during June to December 2004. The aftershock area expanded about 1800 km2 at the end of the 30 May 2004. The distribution of aftershocks suggests two clustered activities and it strongly confirms that the mainshock is a multiple source. The aftershock zone, a region of 40 km length and 45 km width, extends between the Alborz fault to the north and kojour fault towards the south. The extent of aftershock activity indicated an average source dimension of about 40 km and hypocenters were distributed in a depth range of 30 km with the high concentration around the depth of 10-15 km. The released strain of aftershocks within two periods of 12 days and 6 months after the main shock shows the effect of the landslide in the faulting area. The strain during these two periods of time demonstrated their concentration in south and south east, taking into account that these activities decrease in north and north west . This result is consistent with the lowered state of the stress in the area after the major shock. Aftershocks decay was studied and it was obtained that the energy released greatly at first. Then it sharply decreased which indicates that the area is seismically active and both ends of the main fault may be activated by coming earthquakes. Thus, the occurrence of a significant earthquake in this area is not out of expectation.

Keywords: aftershock activity, earthquake, distribution

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SS002 **Poster presentation** **6291**

Can't groundwater level be induced by shear waves?

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Water level fluctuations of many open wells are observed due to the passage of teleseismic earthquake waves. These oscillations of water level resemble seismograms and were referred to be hydroseismograms. The first published observations of hydroseismograms were by Blanchard and Byerly [1935]. They referred to the apparatus that recorded the hydroseismogram as a phreatic seismograph and recognized the phase arrivals of P, S and Rayleigh waves on their hydroseismograms with absence of Love waves. They suggested a simple model by assuming that the aquifer was an open cavity and that a volumetric change of the cavity induced a change in the well level. They attributed the phase that corresponded to the arrival of the S wave to the mode conversion of a shear wave to a compressional wave at the free surface, and explained the absence of love waves on the basis of the theoretical prediction that there is no dilatation of the cavity due to Love waves. Many later reports supported this view (Eaton and Takasaki, 1959; Cooper, 1965; Liu, 1989; Kano and Yanagidani, 2006). While Rexin et al. (1962) used the same apparatus and observed P, PP, PPP, S, SKS, PS, PPS, SS, LR as well as LQ (Love) waves in the Nunn-Bush well in Milwaukee. They explained this as a result of passage of the Love wave train effectively changing the local vertical and therefore affecting the relative elevation of water level within the reservoir at most points. In this research, we used a 16bit recorder system to line with hydraulic sensor and digitally sampled water level in 50Hz at a near 3000 meter deep Zhouzhi well and recorded the 2004 greatSumatra earthquake. We exactly compared the Hydroseismogram with seismograms recorded in Xian CDSN station which is 68km away from the deep well. We captured the body waves and surface waves completely and we can not deny the Love waves of the water level record. We try to suggest a shear-compaction/dilatation conceptual model to explain the observation results

Keywords: groundwater level, shear waves, the 2004 sumatra earthquake

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SS002 **Poster presentation** **6292**

Seismic hazard analysis in Kerman Region, Iran

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Kerman in South East Iran is one of the seismically active regions in. In recent years, several destructive earthquakes have occurred and caused extensive destructions and much human loss in the region. In this study, probabilistic seismic hazard assessment has been performed in Kerman region (55˚-61˚E, 28˚-32˚N) and seismic zoning map of region has been performed. A total of 41 potential seismic zones in the region delineated as area sources for seismic hazard assessment based on geological seismological and geophysical information. Because of insufficient earthquake data in some of the potential sources, concept of spatial distribution function has been used for evaluation of seismicity parameters in each potential seismic source. Using the Campbell (1997) attenuation relationship, dividing the region to grids into 0.1 distances (longitude and latitude) and the SeisRiskIII computer program seismic hazard assessment carried out for a grid of points considering the concept of background seismicity. Horizontal peak ground acceleration for 10% probability of exceedance in 50 years (475 years return period) and for 63% probability of exceedance in 50 years (50 years return period) are estimated for the grid points and seismic zoning maps of region have been prepared.

Keywords: kerman, seismic hazard assessment, south east iran

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SS002 **Poster presentation** **6293**

Estimation of b-value and fractal dimension in the Andaman-Sumatra Region

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A great earthquake of magnitude 9.0 (Mw)(USGS) struck off the West Coast of northern Sumatra (Indonatia) at 00:58:53 hours (GMT) leading to generation of devastating tsunami. The epicentre of the mainshock was located at 3.244N and 95.825E (USGS) and the depth is 10 km (USGS). It had rupture up to 1300 km. It was followed by huge number of aftershocks. The b-value, a-value and fractal dimension of spatial distribution of 7673 earthquakes have been estimated for the entire data set (1973 to Jan 30, 2006), 2765 events prior to the main shock (1973 to Dec 26, 2004) and 4908 aftershocks (Dec 26, 2004 to Jan 30, 2006) dividing the area into four blocks. The b-value was estimated by least-square fit using Guttenberg- Richter relation, however, fractal dimension was estimated by correlation integral method. The b-values range between 0.40 to 1.72. These estimates are also compared with the estimates obtained from the analysis of the earthquake data for the same region during February 16, 1973 to just before the occurrence of mainshock. In general, b-value and fractal dimension for spatial dimension of earthquakes are comparable for both data sets for respective blocks. Sumatra region has lowest b-value (0.89, 0.84 and 0.75 for entire data set, prior to main event and aftershocks, respectively), indicating high stress in general. However, Andaman region block has b-value as 1.17, 1.11 and 1.14 for entire, pre and post events of mainshock, respectively. Nicobar region has the b-value 1.24, 1.21 and 1.25 and a-value 8.78, 8.25 and 8.67 for entire data set, prior to main shock and aftershocks, respectively. Highest fractal dimension is estimated for Nicobar region as 1.885 and 1.871 for entire data set and aftershocks, respectively. In general, the fractal dimension ranges between 1.825 to 1.484 for entire data set and 1.871 to 1.102 for aftershocks. Fractal dimension is very close to each other for the blocks except northern part of Andaman region, which has 1.484 and 1.102 for entire data set and aftershocks, respectively. The b-value, a-value and fractal dimension of spatial distribution of earthquakes was also estimated for a 1x1 having 50% overlapping grid to map the entire region for both of the data sets. The result shows that b-value and fractal dimension have good correlation.

Keywords: andaman sumatraregion, b values, fractal dimensions

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SS002 **Poster presentation** **6294**

Deaggregation of seismic hazard for selected canadian cities

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The Geological Survey of Canada's new seismic hazard model for Canada forms the basis for the seismic design provisions of the 2005 National Building Code of Canada (NBCC) http://earthquakescanada.nrcan.gc.ca/hazard/zoning/haz_e.php. We deaggregate the seismic hazard results for selected cities to help understand the relative contributions of the earthquake sources in terms of distance and magnitude. Deaggregation for a range of probabilities and spectral accelerations (Sa) from 0.2 to 2.0 seconds is performed to examine in detail the hazard for two of Canada's largest urban centres at high risk, Vancouver in the west and Montreal in the east. Additional plots and a summary table of deaggregated seismic hazard are provided for other selected Canadian cities, for Sa(0.2), Sa(1.0) and peak ground acceleration (PGA) at a probability of exceedence of 2%/50 years. In most cases, as the probability decreases, the hazard sources closer to the site dominate. Larger, more distant earthquakes contribute more significantly to hazard for longer periods than shorter periods. Deaggregation plots can provide useful information on the distance and magnitude of predominant sources, which can be used to generate scenario earthquakes and select corresponding time histories for seismic design.

Keywords: seismic hazard, canada, deaggregation

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SS002 **Poster presentation** **6295**

Parallel implementation of a displacement finite difference method for computation of the seismic response of geologic models

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In this work an optimized parallel implementation of a finite difference method is presented. This implementation is developed for problems in 2D and 3D dimensions. The finite difference method shown here is based in an explicit displacement scheme using second order of approximation in both space and time. The free surface of the model and the interaction among different materials are treated in this implementation. The method discretizes the studied model by a regular and rectangular grid. This parallel implementation allows distribute the elements of the grid at different nodes of the supercomputer, in any dimension of problem. An efficiency analysis of the different parallel distributions is presented. In function of the number of available computers is possible distribute the model to achieve the highest efficiency. This implementation is tested with several canonical models in order to check its validity. At last it is employed to model the seismic response of a real problem.

Keywords: finite difference, parallel implementation

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SS002 **Poster presentation** **6296**

An advanced method to generate damage scenarios employing an index of vulnerability of buildings for seismic risk assessment in urban zones. Application to Motril city (Spain).

Prof. Prez Ruiz Juan Alfonso
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Antonio M. Posadas Chinchilla, Nieves Lantada Zarzosa, Lluis G. Pujades Beneit, Antonio Garca Jerez

A method of ultimate generation for the expected evaluation of seismic risk in single buildings and larger countries is presented. This method, called method of index of vulnerability, defines the seismic action in terms of macroseismic intensity and it characterizes the vulnerability of the buildings in function of an index. To estimate the expected damage for a defined intensity and an index of vulnerability given, semiempiric functions based in observed data of damage in the past earthquakes are employed. With this method is easy to incorporate complementary information of similar buildings, it does this methodology very efficient for the characterization of the vulnerability in countries. In the present work, details about possible earthquakes, building and damage function definition are employed in order to apply this new method to Motril city (). At least, two catastrophic earthquakes occurred in Motril (January 13, 1804 and December 24, 1884) in the past; moreover, the city is located in the border of Granada basin, the region with higher level of seismicity in . A preliminary data base of this city has been obtained, containing parameters as the situation, the geometry, the structural and constructive features of the buildings and so on. With this method, two different seismic scenarios in function of macroseismic intensity are analyzed correspond to two probabilistic scenarios with return periods of 50 years and 500 years. The obtained damage scenarios are consistent and they show the validity and robustness of this technique.

Keywords: damage scenarios, vulnerability

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SS002 **Poster presentation** **6297**

An advanced method to generate damage scenarios using capacity spectrum of buildings for seismic risk assessment in urban zones. Application to Motril city (Spain).

Prof. Prez Ruiz Juan Alfonso
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Antonio M. Posadas Chinchilla, Nieves Lantada Zarzosa, Lluis G. Pujades Beneit, Antonio Garca Jerez

A method of ultimate generation which allows evaluating the expected seismic risk in single buildings and larger countries is presented. This method, called method of Capacity Spectrum, it is a theoretical method. With this method we start from capacity spectrum of the building obtained through to structural analysis, and it spectrum leads to fragility curves. Later, the seismic action is defined by the demand spectrum. This spectrum is crossed with the fragility curves in order to obtain the probability of occurrence of the different damage states. That way, first, the theoretical framework of the studies of seismic risk is presented, giving details about earthquake, building and damage function definition. Later, the application to Motril city () is presented. At this region it is possible to remember two catastrophic earthquakes (January 13, 1804 and December 24, 1884), these earthquakes correspond to two probabilistic scenarios with return periods of 50 years and 500 years; moreover, the city is located in the border of Granada basin, the region with higher level of seismicity in . A preliminary data base of this city has been obtained, containing the principal parameters of situation, geometric, structural and constructive of the buildings necessary for this method. The two different seismic probabilistic scenarios are analyzed. The obtained scenarios of damage are consistent and they manifest the validity and robustness of this method.

Keywords: damage scenarios, capacity spectrum

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SS002 **Poster presentation** **6298**

Analysis of strong ground motion of February 22, 2005 Zarand earthquake

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On February 22, 2005 at 02:25:26 (GMT) a strong earthquake with estimated magnitude MW 6.5 occurred east of Zarand city in Kerman province, SE Iran. The epicenter and the damaged area of Zarand earthquake are located at 30.76 N, 56.81 E in the Kuhbanan Fault zone. The earthquake ruptured an intramountain reverse fault, striking E-W and dipping north at ~60 to a depth of about 10 km. Strong ground motion data have been analyzed to extract the characteristics of strong ground motion at 27 set of SSA-2 digital accelerographs, provided by Building and Housing Research Center (BHRC). Among the accelerograms produced by this earthquake the biggest amplitude corresponds to Shirinrood Dam accelerograph (510.09 gals) located east of the epicenter. The observed peak ground acceleration has been estimated using the world wide attenuation relationships and then compared with observed P.G.A. Then we have compared the characteristics of this earthquake with the 2003 Bam earthquake, which occurred at a distance of ~200 km in the southeast of this earthquake.

Keywords: zarandearthquake, stronggroundmotion

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SS002 **Poster presentation** **6299**

Source model of the 2005 Miyagi-Oki, Japan, earthquake from broadband strong motion simulation by the empirical Greens function method

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On August 16th, 2005, an M7.2 earthquake occurred in the off-shore of Miyagi Prefecture (Miyagi-Oki region), northeast Japan. Miyagi-Oki region has repeatedly experienced M7.5-class earthquakes at average interval of 37 years and the last one occurred in 1978. In order to understand the source process of this interplate earthquake related to broadband strong motions and consider the relationship to the 1978 event, we estimate the source model which consists of strong motion generation area (SMGA, Miyake et al., 2003) using the empirical Greens function (EGF) method proposed by Irikura (1986). SMGA represents a large slip-velocity area within the total rupture area and has successfully explained the observed broadband waveforms (e.g. Kamae and Irikura, 1998). Because two major S-wave pulses were observed in strong motion records, we assume two SMGAs (SMGA1 and SMGA2). In the P-wave portion, the small first motion preceded the main phase, which means that the rupture of SMGA1 started not from the hypocenter. At first, the rupture starting point and the rupture time of the SMGA1 are determined from the time difference between the first P-wave motion and the main P-wave phase onset following Takenaka et al. (2006). Then, we estimate the size, rise time, rupture propagation direction of SMGAs, and the rupture starting point of SMGA2 by fitting the synthetic waveforms into observed ones for S-wave portion over wide frequency range. This is achieved by minimizing the sum of the normalized misfits of the velocity waveforms (0.2-1 Hz) and the acceleration envelopes (0.2-10 Hz) using the genetic algorithm. Lower frequency limit is decided from the S/N ratio of EGF, the record of an M4.1 aftershock. SMGA1 and SMGA2 are located to the landward side from the hypocenter, and SMGA2 is nearer to the coastline. SMGAs coincide with the two major large slip area inferred from the waveform inversion using strong motions and teleseismic data by Wu and Koketsu (2005). The broadband strong motions of this earthquake are mainly radiated from the large slip regions. Rupture velocity is estimated to be 3.15 km/s, 70% of the shear wave velocity. Obtained stress drop of the shallower SMGA1 is 17.6 MPa while that of the deeper SMGA2 is 34.1 MPa. Comparing the distribution of SMGAs of the 1978 Miyagi-Oki earthquake estimated from a similar source modeling by Kamae et al. (2002), two SMGAs of the 2005 event do not overlap two landward SMGAs of the 1978 event. We have examined the scaling relationship of the size of SMGAs for interplate earthquakes in the northeast Japan. It tells that these interplate earthquakes have the smaller SMGA size than crustal earthquakes of the same seismic moment. The 2005 Miyagi-Oki earthquake also shows the same characteristics. These characteristics indicate that interplate earthquakes in this region have larger stress drop on SMGAs than crustal earthquakes.

Keywords: egf, broadband frequency, source model

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SS002 **Poster presentation** **6300**

Simulation of peak ground acceleration

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Seismic Q is a dimensionless quantity which measures the amount of energy dissipated per radian as seismic waves propagate. Seismic Q varies with the composition of the material and its physical condition. The amount of seismic energy received in building strictly depends on the anelasticity of the media that the seismic wave traveling through. Therefore, the seismic attenuation factor of the subsurface material is the parameters for estimating the displacement near the ground. In this study, we use the new high-quality data recorded by CWBSN and TSMIP to inverse the detailed Q-structures in Taiwan area. The theoretic maximum amplitudes of the ground acceleration in Taiwan area for 30 events have been calculated by using the attenuation equation and the Q-structures. The deviation between these estimated amplitude and the maximum amplitudes of these events observed at stations of CWBSN are obtained. The results show that most of the deviation is small than 30%. It indicates that we can predict the maximum amplitude of ground acceleration for any events occurred in Taiwan area under the accuracy of 70 %(probability).

Keywords: q structure, ground acceleration

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SS002 **Poster presentation** **6301**

Analysis of global damage and functioning of highway systems in earthquake conditions

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The strong earthquakes that occurred in the past undoubtedly pointed out the important role of the road network in elimination of the consequences of occurred earthquakes and normalization of the living conditions. The damages to the road network components (bridges, tunnels, retaining walls etc.) can induce disruption of the traffic flow and disturbance of the road functioning in the most critical moments immediately after an earthquake. From these reasons, the investigations in the field of earthquake engineering are directed toward (1) investigation of damage to road systems, (2) analysis of disturbance of functions and (3) methods for mitigation of the consequences based on exploring the nature and the reasons for occurrence of earthquakes as well as the structural elements of the road systems. The purpose of this is improvement of the functioning of the road network composed of a number of facilities affecting the performances of the entire system. The objective of this paper is to draw general conclusions on the behaviour of the road systems, i.e., define the global damage, the seismic performances and the functioning of these systems in earthquake conditions based on investigations related to analysis of seismic hazard and risk, vulnerability of structures and their importance. To that effect, certain models from the theory of probability and seismic scenarios have been used to simulate the earthquake effect. Due to the pronounced spatial character of the road systems in the analysis of the global damage and functioning of the road system, the GIS technology has been used. The results from these investigations are presented through a concrete case of the road network in a country with a relatively frequent seismic activity.

Keywords: damages, highway, seismic hazard

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SS002 **Poster presentation** **6302**

Characterstics of destuctive earthquake in Turkey

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has frequently suffered from major damaging earthquakes that they are particularly concentrated in the segment boundaries of the main active faults in the last century. For example, the 900 kilometer North Anatolian fault has produced seven large (MS $\geq$ 7.0) earthquakes in the period from 1939 through 1999. These earthquakes have ruptured the fault progressively from east to west. In this study the fault plan solution of strong earthquakes that have occurred in during 1964-1999 were re-examined. In order to understand the characteristics of their sources, the waveforms of two destructive earthquakes of 17 August and 12 November 1999 have been inverted to their sources to investigate their source complexity. The results of analysis suggest that the first earthquake is a single event and the second earthquake is a multiple source consists of at least two main sub events. The mechanism of earthquakes is mainly strike slip and in some cases they show dip-slip components. Earthquakes on the North Anatolian fault are caused by the northwards motion of the Arabian plate against the Eurasian plate, squeezing the small Turkish microplate westwards. Compression in this region is due to northwards motion of the African plate producing subduction at the and Hellenic arcs.

Keywords: turkey, earthquakes, fault plan

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SS002 **Poster presentation** **6303**

Investigation of seisimicity and seismic energy release in Middle East

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To investigate the seisimicity of Middle East , The Source parameters of earthquakes recorded by global seismic stations during the last 40 years were analyzed. The time- frequency, magnitude- frequency and time- magnitude diagrams were provided. The region of study was divided into sub squares of each 0.50.5 degree. The energy released for each earthquake was evaluated from energy- magnitude relation and the energy of earthquakes in each square for each time interval was sum up and the maps of seismic energy released in 4 time intervals of 10 years between 1965 and 2005 and 1 time interval for the past 40 years were provided and over lapped on the fault map. The graph of accumulated energy released in 5 years intervals from 1965 to 2005 for Hindu Kush, and were calculated. The result indicated that seismic energy released in Hindu Kush is higher than in and . The comparison of seismic energy maps indicates that the seismic gaps in early intervals were filled up by the seismic activities during the following time intervals. Distributions of epicenters indicate high seismic activities in region. Epicenters of small earthquakes are scattered, having depth less than 50 kilometer. In different parts, earthquakes have shallow depths.

Keywords: middle east, earthquakes, seismic energy

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SS002 **Poster presentation** **6304**

Charactristic of Hindu Kush Earthquakes

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In this study, focal-mechanism solutions have been evaluated for major earthquakes occurring in Hindukush region using p-wave first motion direction observed from short and long period records. In general, these solutions have indicated a thrust type faulting. The trend of nodal planes in these solutions was found to vary between northeast and southeast directions. The dip rarely exceeds 25. The distribution of earthquakes in Hindukush region and their focal mechanism solutions show the existance of a compression force in the region. The depth of subduction zone extends down to 300km. Major earthquakes happened in a depth range of 70-300 km. As expected, the majority of earthquakes indicate significant reverse component of source mechanism. Compared with the dimensions of faulting in oceanic subduction zones, the faulting in this region has limited extensions. Therefore the big earthquakes as large as in the subduction zone is not expected in Hindukush.

Keywords: hindu kush, focal mechanism solution, subduction zone

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SS002 **Poster presentation** **6305**

Investigation of seismotectonic on the basis of aeromagnetic and earthquake data in East Azarbaijan Province

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The region in this study is situated in the north west of Iran and the east Azarbaijan province. This region is one of the seismically active regions in Iran . The activity is mainly due to active tectonic in the region applied by the convergence of Arabian Plate. Data used in this study is Aeromagnetic data obtained with flight line spacing 7.5Km, barometric elevation 2500m and the other data obtained from atomic energy organization with flight line spacing 500m and elevation 120m.The another data that is used in this study, is the source parameters of local earthquakes with magnitudes up to 4.9 and depthsup to 40Km from the Tabriz seismic network during years 1995-2005. In this study, the lineaments have been extracted from aeromagnetic data. By comparison with geological faults, the results show that there are close relationships between final structural layers and the earthquake epicenters in most cases. The depth of lineaments is determined by Euler deconvolution method and was compared with the reported depth of earthquakes in the region.

Keywords: seismotectonic, aeromagnetic, lineament

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SS002 **Poster presentation** **6306**

Improvement of the experimental system in Turkey automatically estimating seismic source, ground motion, and damage

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We report improvement of the network system for strong motion observation in to mitigate seismic risk, in 1997 the Research Center for Earthquake Disaster Prevention of ERD (Earthquake Research Department) installed a strong motion network in and around the central part of North Anatolian fault (the project area). The development of the network system was supported by JICA (Japan International Corporation Agency). The network has 10 stations with a broadband velocity-type seismograph and linked from the stations to the main center in Ankara by the packet-exchange communication (X.25) using TURPAK. The system had been designed so as not only to gather strong ground motion records into the main center but also to present seismic information. But it could not provide any useful seismic parameters, e.g. hypocenter and magnitude, of the 1999 Kocaeli (Mw7.5, about 170,000 death toll) and the 1999 Duzce earthquakes, in spite of well recording of strong motion data, because their epicenters were out of the covered area. This urged us upgrading the software part of the system. By using a sub-system, Kagawa et al. (2003) developed software parts to estimate source parameters and distribution map of ground motions all over the country and to send them by e-mail automatically. By using these software parts and changing the systems OS from Sun-UNIX to PC-Linux including hardware, ERD improved the main system by the follow-up project of JICA during from 2005 to 2006 as the followings. At first step, the system detects P and S arrivals with high accuracy by newly developed technique and estimates hypocenter parameters using travel time table for earthquakes occurring in Turkey. Next it estimates moment magnitude using high-quality and long-period velocity records and using Q structure. Then, fault strike, length and width of the target earthquake are calculated using (1) estimated source parameters, (2) spatial database of fault strike directions in and (3) scaling law between fault area and seismic moment. And maps of PGA (peak ground acceleration) and seismic MM intensity distribution are presented using attenuation relation vs. distance to the fault. ERD also changed the database software in the system from Oracle to MySQL. By using estimated PGA distribution, we are trying to estimate dead and injured persons in each town and villages, however not enough the database is. The system has been prepared with computer terminals for linking with outside system. By combining with the nationwide network, the system will provide more accurate hypocenters and moment magnitudes, and damage estimation for all of large and medium earthquakes occurring not only in the project area but also in the whole of Turkey in near future.

Keywords: strong motion, network system, damage estimation

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SS002 **Poster presentation** **6307**

Australian Earthquake Ground Motion Model Development

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The intraplate environment of Australia has experienced few large earthquakes that were instrumentally recorded. For events large enough to potentially cause damage, only a handful of records exist which can usefully constrain parameters for earthquake ground motion prediction equations. An increase in routine ground motion monitoring following the 1989 Newcastle, New South Wales earthquake, has led to the gradual accumulation of both strong and weakground motion recordings for small-to-moderate magnitude earthquakes (MW 2.0-4.7), particularly in southeastern Australia. Additional temporary seismograph deployments have also produced local earthquake data suitable for developing ground motion prediction equations. These data have been assembled into an Australian Earthquake Ground Motion Database, which has been used to develop empirical ground motion models for these small-to-moderate events. Stochastic finite-fault simulations have subsequently been applied to develop ground motion prediction equations for larger damaging earthquakes. To date the most well-developed model is that for southeastern Australia. This region appears to demonstrate high near-surface attenuation (kappa) relative to other stable continental regions, but otherwise crustal attenuation and ground motion predictions are similar to recent models developed for eastern North America (e.g. Atkinson and Boore, 2006; Allen and Atkinson, in press). Ground motion models are also being developed for South Australia and Western Australia. In this presentation, we discuss results of our ground motion model development, the challenges we face in improving these models, and the implications our models have for earthquake hazard in Australia.

Keywords: earthquake, strong motion, hazard

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SS002 **Poster presentation** **6308**

Dynamic seismic hazard prediction and pipeline earthquake impacts

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During global industrial development of oil and gas fields in any seismoactive region designing of thethe main oil and gas pipeline is particularly important for the assessment seismic hazards in these regions. This is one of the important tasks during antiseismic construction and for environmental protection. It is possible to prevent and minimize possible losses by means of normative maps of seismic zonation designated for the Caspian basin and for oil and gas pipeline routes. At present these maps significantly underestimate the regions hazard and current construction works are being performed without the proper assessment of this regions seismicity. It is possible to solve problems on assessment of seismicity on new conceptual base by methods of dynamic earthquake prediction. Such a long-time dynamic earthquake prediction for the Caspian Sea-Eastern Turkey-Iran region was based on systemic seismogeodynamic approach to investigation of earthquake focal zones and on block model of seismokinematics of this region. The resulting map of dynamic regionalisation of the degree of seismic hazards up to year 2006 predicted not only place and strength of potential zones of the strongest earthquakes, but also the periods of increased probability of their occurrence within the source volume of the future mainshock. An early warning system of automatic telemetry have to be set up along with local and regional monitoring networks to predict short and medium term seismic hazard zonation the international earthquake monitoring and forecasting network.. Economically, continuous operation of large pipelines is extremely important because of the huge energy content of the oil flow. The earthquake detection system presented here consists of accelerometers, which measure the immediate effects of the earthquake, and pipeline deformation sensors, which detect secondary impacts to the pipeline.

Keywords: pipelines

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SS002 **Poster presentation** **6309**

ShakeMap analysis for Vrancea (Romania) intermediate-depth earthquakes and implications on disaster management strategy

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The ShakeMap is a ground shaking representation obtained within minutes after the occurrence of a large earthquake. Such maps, released via Internet, provide valuable information for a diverse audience composed of emergency response agencies, scientists, businesses, media, and the general public. Ideally, ShakeMaps should uniquely integrate all the information available before and after a main shock. Therefore, previously compiled databases on soil conditions and regional attenuation, information on the rupture mechanism and magnitude of an event, as well as the actual strong ground motion recordings from the event, transmitted in real-time are required.The earthquakes generated beneath SE Carpathians, in the Vrancea area (Romania), are characterized by very peculiar features which differentiate this seismic area from all other seismic areas in the World. In particular, the concentration of seismicity in a narrow focal volume and the persistence of seismic activity in time (with an average of 3 shocks above magnitude 7 per century) allow us to set in advance the approximate epicenter position of the next large event and roughly the expected time interval. Moreover, the predominance of the reverse faulting mechanism with relatively well-defined fault plane geometry, reduce the number of the possible scenarios we can expect for these earthquakes. Specific shakemaps are computed on the basis of Vrancea earthquakes scenarios. To account for the site amplification factors, we introduced a generalized geological classification for different subdivisions of the territory at regional scale, based on geology, geomorphology, and geotechnical characteristics and thickness of sedimentary layers. At the same time, features related to deep crust and upper mantle structure (mainly lateral variation in seismic wave attenuation) are included in the computation. On the basis of an existing earthquake database, we test how accurately the scenarios computations are matching the observations. Finally the implications on seismic hazard and seismic risk in are analyzed and the proper earthquake disaster management implementation is discussed.

Keywords: shakemap, vrancea, scenarios

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SS002 **Poster presentation** **6310**

Time-dependent seismic hazard assessment on the basis of monitoring seismicity behaviour in Vrancea region, Romania

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The seismic activity in the Vrancea region, located at the SE Carpathians arc bend,in Romania, consists of a strong cluster of earthquakes at intermediate depths (60 180 km). The atypical geometrical configuration of the hypocenters, elongated along NE-SW direction and close to a planar distribution, the persistence of the earthquake generation in time (around 15 events/month with M > 3 and around 3 events/century with M > 7), the predominance of the focal mechanism, raise a lot of questions and debates in connection with this interesting seismic area. The seismic network on Romanian territory was designed firstly to monitor the Vrancea area. Therefore, the detection and location of these events are of high accuracy and allow detailed and complex analyses related to seismicity evolution in time and space.The purpose of this paper is to study the variation of the seismic activity in space and time, frequency-magnitude distribution, fractal dimension, deformation accumulation curve (Benioffs curve), on different time and space windows and to test any possible earthquake precursor. We use a high-quality catalog of Vrancea intermediate-depth events recorded by the seismic network of National Institute for Earth Physics between 1994 and 2006 and a routine catalog for a 70-year time interval. The refined catalog (based on JHD technique, used for hypocenters determination) is complete for duration magnitudes above 3 and contains only small and moderate earthquakes (Mw 5.8 was the largest observed magnitude). The study area, situated between 60 and 180 km depth, is divided in two active segments, one centered around 90 km depth, other centered around 140 km depth. The particular configuration of the foci along NE-SW direction allows a 2D approach. The largest events are the most infrequent, but the most important to understand, since they control the evolution of the system and are the most destructive events. Our detailed pattern analysis suggests that recognizable patterns of smaller, more frequent events can be used to detect the generation of the next major event and that reliable forecasting of the largest events may be possible. We identify the characteristics of the preparation process of the strong subcrustal events originating in Vrancea region and analyze how they can be incorporated in a time-dependent seismic hazard assessment.The evolution of seismic activity shows alternative accelerating and decelerating deformation release in the upper segment and lower segment, respectively, of the subducting lithosphere. The different seismicity behaviour in the two segments of the seismic active volume and the apparent interconnection between them can be speculated to predict the most probable future particular seismic hazard pattern. Our results are of highest interest if they are correct, since the focal depth parameter of the next major shock plays an essential role in the way the strong ground motion will be distributed geographically and implicitly in the pattern of the areas with strong damage. Implications of our approach for earthquake disaster management are discussed as well.

Keywords: hazard, seismicity, vrancea

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SS002 **Poster presentation** **6311**

Reevaluated macroseismic map of March 4, 1977 major Vrancea (Romania) earthquake.

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In the past time the macroseismic intensity was an important parameter for the quatification of the Romanian territory seismic activity.The strongest and the best known, from the point of view of the macroseismic effects, is the March 4, 1977 earthquake (MGR = 7.2 and Imax = IX), occurred in Vrancea seismogenic zone. The earthquake was a multiple event, consisting of a foreshock and at least 3 main shocks.The third main shock which was the strongest one of the earthquake, occurred 19 sec after and at a horizontal distance of 62 km from the foreshock. The main purpose of reevaluation of the macroseismic effects of the March 4, 1977 major earthquake, is, on the one hand, to eliminate the existing suspicions regarding the veracity of evaluating the macroseismic effects by the romanian seismologists at that time, and, on the other hand, to take out some of the uncertainties that have appeared during the process of evaluation, processing and interpretation of the macroseismic data.

Keywords: major earthquake, vrancea region, macroseismic intensity

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SS002 **Poster presentation** **6312**

Long-period ground motion simulation on the Ishikari and Yufutsu plain, Hokkaido, Japan

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During the 2003 Tokachi-oki earthquake (M8.0), strong long-period ground motions occurred on the Ishikari and Yufutsu plain and damaged oil storage tanks. We develop a 3D seismic velocity model of the Ishikari and Yufutsu plain and simulate long-period ground motions from the mainshock and aftershocks. The velocity model is developed using geologic mapping, reflective surveys and oil boreholes. An velocity model is constructed by using seismic velocities from boreholes and SPAC microtremor surveys. This model is further refined through coda R/V spectra of weak motions from small local events.We simulate 3D wave propagation in the velocity structure model with 3D finite-difference method for the mainshock and aftershocks (M6.0-6.5) of the 2003 Tokachi-oki earthquake. The synthetic is bandpass filtered from 0.02 to 0.4 Hz. Results of the simulation reproduce distribution of the peak and response amplitude and duration of most of the events recorded in the plains. The simulation suggests that the amplification of long-period waves (periods longer than 5 s) in the plain is mostly affected by the deep basin structure and is also sensitive to the incident wave field.

Keywords: long period ground motion, simulation, ishiari and yufutsu plain

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SS002 **Poster presentation** **6313**

New generation of probabilistic seismic hazard assessment for Germany considering uncertainties as an integral part

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Probabilistic Seismic Hazard Assessment is a key element in seismic risk calculation and thus an important tool in the mitigation of the effects from future earthquakes. Its results require updates when new data and improved scientific insights become available. Although Germany has only low to moderate seismicity, the combined effect of the high degree of industrialization, the infrastructure and the high population make the seismic risk considerable. The population density is especially high in several of the most earthquake prone areas. Innovations in the present study include an extended and improved Mw based earthquake catalogue for Germany and the surrounding regions. Declustering and completeness algorithms for the catalogue entries are specified. A set of area typical ground motion models, a new large-scale and three neotectonically constrained small-scale seismic source zone models, and sets of maximum expected magnitude models are used as epistemic uncertainties. Different distance metrics of ground motion models, different rates of faulting styles in the seismic source zones and uncertainties in the parameters of the source zones are fully considered. Aleatory and epistemic uncertainties in the input elements are introduced in the calculations. The resulting hazard is expressed in terms of fractiles for the probability of exceeding various ground motion values. Maps of expected spectral accelerations and intensities are produced. Although the general patterns resemble those of previous maps, there are obvious changes.

Keywords: seismic hazard, germany, uncertainties

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SS002 **Poster presentation** **6314**

Designing new strategic facilities: ground motion evaluation for two bridges in the Veneto-Friuli Plain (NE Italy)

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In order to design new strategic facilities, as bridges, the assessment of the expected ground motion is needed. Two new bridges are planned in the Veneto-Friuli Plain (NE Italy) and, consequently, the expected seismic acceleration in the two locations has been computed. The two sites are both very interesting from the seismological point of view, as one is placed near to potentially seismogenetic faults, while the other is far from the deformation belt and was interested only by moderate historical earthquakes. For the two sites, a standard PSHA evaluation, for several return periods, has been performed using the logic tree approach, taking into account the effects of the local amplification. The variability of the attenuation model has been taken into account considering the standard deviation in the hazard computation. Moreover, the maximum possible and the design events for the two sites have been individuated. Finally, the uniform hazard response spectrum for the two sites has been computed together with synthetic accelerometric time histories compatible with the computed response spectrum.

Keywords: response spectrum, ne italy, psha

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SS002 **Poster presentation** **6315**

New approach to the characterization of the tail of the distribution of earthquake magnitudes and instability inherent to the widely used Mmax estimates

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We develop a new method for the statistical estimation of the tail of the distribution of earthquake sizes recorded in the Harvard catalog of seismic moments converted to mW-magnitudes (1977-2004 and 1977-2006). For this, we suggest a new parametric model for the distribution of main shock magnitudes, which is composed of two branches, the pure Gutenberg-Richter distribution up to an upper magnitude threshold m1, followed by another branch with a maximum upper magnitude bound Mmax, which we refer to as the two-branch model. We find that the number of main events in the catalog (N = 3975 for 1977-2004 and N=4193 for 1977-2006) is insufficient for a direct estimation of the parameters of this model, due to the inherent instability of the estimation problem. This problem is likely to be the same for any other two-branch model. This inherent limitation can be explained by the fact that only a small fraction of the empirical data populates the second branch. We then show that using the set of maximum magnitudes (the set of T-maxima) in windows of duration T days provides a significant improvement, in particular by minimizing the negative impact of time-clustering of foreshock-main shock-aftershock sequences in the estimation of the tail of magnitude distribution. We propose a method for the determination of the optimal choice of the T-value minimizing the Mean Square Error of the estimation of the form parameter of the GEV distribution approximating the sample distribution of T-maxima, which yields Toptimal=500 days. We have estimated the following quantiles of the distribution of T-maxima for the whole period 1977-2006: Q16%(Mmax)= 9.3, Q50%(Mmax)= 9.7 and Q84%(Mmax) = 10.3. We have show significant instability inherent to Mmax evaluation. Finally, we suggest two more stable statistical characteristics of the tail of the distribution of earthquake magnitudes: the quantile QT(q) of a high probability level q for the T-maxima, and the probability of exceedence of a high threshold magnitude r T(m*) = P{ mk >m*}. This way we have obtained, for example, the following sample estimates for the global Harvard catalog QT(q=0.98) = 8.6 0.2 and r T(8) = 0.13-0.20. The comparison between our estimates for the two periods 1977-2004 and 1977-2006, where the later period included the great Sumatra earthquake 24.12.2004, mW=9.0 confirms the instability of the estimation of the parameter Mmax and the stability of QT(q) and r T(m*) = P{ mk >m*}. The revealed significant instability in Mmax estimates should be taken into account in practice of seismic risk assessment.

Keywords: seismic risk assessment, mmax value instability, heavy tail

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SS002 **Poster presentation** **6316**

Sensitivity Analysis in Probabilistic Seismic Hazard Analysis (PSHA): a Case of Study in Northern Tuscany (Italy)

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Many studies emphasize the importance of acknowledging and documenting sensitivities and uncertainties in Probabilistic Seismic Hazard Analysis (PSHA) (e.g., Kulkarni et al., 1984; McGuire and Shedlock, 1991; Senior Seismic Hazards Analysis Committee - SSHAC, 1997; Barani et al., 2007). The knowledge of the parameters that drive the hazard and contribute the most to the epistemic uncertainty in the hazard is useful to scientists in seeking further information to reduce the uncertainties in the models and in the parameter values of each model used in PSHA, and to public or private users for better understanding and using a particular seismic hazard estimate. The use of logic trees in PSHA allows the analyst to consider the epistemic uncertainties in assumptions, models, and parameters. Therefore, the logic tree formalism allows one to quantify the uncertainty in the probability of exceeding a given ground motion (or alternatively, in the ground motion that is exceeded with a certain probability). In this work the authors present a sensitivity analysis to identify the models and the parameters that have the largest influence on the Northern Tuscany (Northern Italy) seismic hazard. This area is characterized by moderate to strong seismicity. The historical seismicity shows that large earthquakes have occurred in the past. The strongest one occurred in September 7, 1920 with epicentral intensity equals to the IX-X MCS (Mercalli-Cancani-Sieberg). This earthquake would have been caused by the Garfagnana North fault that is interpreted as a moderately blind normal fault (DISS Working Group, 2006). Other strong earthquakes occurred in February 14, 1834 and April 11, 1837 with epicentral intensity of VIII-IX MCS and XI-X MCS respectively. The sensitivity analysis is conducted for different sites following the multi-parameter approach developed by Rabinowitz and Steinberg (1991) and accounts for both mean hazard values and hazard values corresponding to different percentiles (e.g., 16%-ile and 84%-ile). In particular, the focus is on the sensitivity of the hazard caused by changes in earthquake sources. The influence of fault sources, areal sources, and spatially smoothed seismicity is considered. The effect of alternative frequency-magnitude parameter values, maximum earthquake magnitude values and attenuation relationships is also presented. As a result, the sensitivity analysis has allowed us to identify the models and parameters with higher influence on the hazard and its uncertainty. Equally important, this study has allowed the identification of the assumptions with little or no effect. These parameters can be excluded from subsequent logic-tree-based seismic hazard analyses of this area while those with the largest influence should be subjected to careful discussion or further research in order to reduce the uncertainty in the hazard.

Keywords: sensitivity, uncertainties, psha

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SS002 **Poster presentation** **6317**

Limited constraints on probabilistic seismic hazard estimates

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The amount of probabilistic hazard studies has been increasing in the last years, due to the requirements by new regulations that hazard be estimated in probabilistic terms. The present study aims at defining the possibilities and limits for a comparison test between predictions and observations. Comparison tests directly on the ground-motion occurrences are favored, rather than on the earthquake occurrences. Based on the properties of Poisson processes, the minimum time windows insuring reliable rate estimates at a site are evaluated. For example, for a ground-motion with a 475-yrs return period at a site, a minimum 12,000 years observation time window is required for estimating the rate with a 30% uncertainty (coefficient of variation). These values are not dependent on the seismicity level of the regions under study. An analysis of the recorded ground-motions at the stations of the permanent French accelerometer network shows that at best, the occurrence rates can be estimated with an accuracy of 20% for very low acceleration levels (0.0001-0.001g for the station STET). Because the acceleration levels of interest in earthquake engineering are much higher, a comparison test led at very low acceleration levels would need to be generalized for higher levels, which is not obvious and would need further studies to be validated.

Keywords: probabilistic, hazard, strong motion

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SS002 **Poster presentation** **6318**

A Study on the Recent Recorded Strong Motion in Bandar Abass region in Zagros, Southern Iran

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Bandar Abass region in Hormozgan province is located along south- east extension of Zagros Mountain belt and is one of the most active seismic regions in . During 1975-2006 many earthquakes has been recorded by near field strong motion instruments operated by Building and Housing Research Center .In this study, first we reviewed the geological and seismological background of the region. We provide the detail of active fault in this region and overlap the epicenter of the significant earthquake in the past years. Then we selected the earthquake that was recorded by the strong motion stations in the region. One of them is the earthquake of Bandar Abas that happened in 04/03/1999 with magnitude of Ms=6.5, (ml=6.2). The epicenter of this earthquake is located at 57.19 E and 28.34 N. All accelerometric information and data of this and other important earthquakes are collected based on strong motion records obtained during the main shocks. In order to assess the data, at first we analyze the data based on the ratio of signal to noise and then with consideration about the characters of maximum acceleration and frequency content (based on the Fourier spectrum of source acceleration), the attenuation of strong motion in this earthquake has been studied. The Mw of the earthquake is calculated using the data with the best quality. The result of our study is in general agreement with the studies performed on the Zagros belt in view point of strong motions.

Keywords: bandarabasearthquake, ratio of signal to noise, attenuationrelation

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SS002 **Poster presentation** **6319**

Seismic attenuation in SW Iberia: constraints from the M6.1 Feb 12, 2007 Cape St Vincent Earthquake

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The ground motion database of Mainland Portugal is composed of small magnitude events (M2.7 - 4.0) at short to medium distances (10 - 200km), moderate magnitude events (M5.0 5.3) at medium to large distances (80 - 450km), and one large event (M7.8) at a large distance (332km). The latter record was obtained at a cable anchorage of the Tagus Bridge in Lisbon, and therefore does not represent the free field. The moderate to large magnitude events that affected the region occurred prior to the instrumental period, and its effects are characterized in terms of intensity. The absence of peak ground acceleration or spectral density ground motion models derived or validated for this region is a hindrance to accurate seismic hazard assessment and disaggregation. Lopez Casado et al. (2000) analyzed mean isoseismal radii of historical earthquakes felt in Iberia, and concluded that the westernmost region of the Peninsula has very low attenuation. Imported attenuation relations may therefore lead to an underestimate of the ground motion when applied in this region.In this context, the M6.1 Cape St Vincent earthquake of Feb 12, 2007provided unprecedented amounts ofinstrumental data to constrain seismic attenuation. Although accelerometric records do not cover the first 200 Km and the recorded levels of ground motion are low, the new data can be expected to through some light on the attenuation characteristics of the crust. In this paper, we present theaccelerometric data recorded bythe strong motion network operated by IST, and compare the results with the main attenuation models that have been used in the region.

Keywords: iberia, attenuation, ground motion

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SS003 **6320 - 6359**

Symposium
Earthquake Hazard, Risk, and Strong Ground Motion - Site effects (and their dependence on source and propagation-path)

Convener : Dr. Pierre-Yves Bard
Co-Convener : Prof. Takashi Furumura, Dr. Donat Fh

The importance of site response and site effects in the resulting damage has been demonstrated in numerous examples of both recent and past earthquakes. These topics have therefore attracted considerable attention over the past decades; though, a number of issues are still unsatisfactorily solved, and, as usual, latest data, often raise new questions. This session will welcome all papers bringing improvements in the sceintific understanding of site effects and their sensitivity to the incoming wavefield, and their quantitative prediction for future events. All approaches (instrumental, numerical, empirical, theoretical), and all viewpoints (from scientific understanding to engineering applications in earthquake regulations) are welcome. Contributions on several specific topics are especially encouraged : Coupling between source, crustal propagation and site effects Advances in numerical modeling Evidence of site effects within seismological networks that might bias estimates on source parameters (long period effects, weathered rock, ...) Surface topography effects non-linear response of soils : observations, characterization (lab and in-situ tests), modeling site characterization techniques and results advanced processing techniques for different kinds of instrumental data (surface, borehole, dense arrays) Dealing with uncertainties: estimating their level and accounting for them for hazard estimates and design levels

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SS003 **Oral Presentation** **6320**

Estimating earthquake ground motions at Nuweiba City

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Adel M.E. Mohamed, A. Deif

Nuweiba City lies on the Gulf of Aqaba. The Gulf of Aqaba represents the southern part of the Gulf of Aqaba-Dead Sea transform system that separates between the Arabian plate and Sinai subplate. Nuweiba is affected by a destructive earthquake occurred on November 22nd, 1995 with a moment magnitude 7.2. This was the largest instrumentally recorded earthquake in Egypt. The current study is concentrating on two main topics: (1) detailed mapping of site response functions using microtremors recordings and (2) estimate the seismic hazard in terms of peak ground acceleration and response spectra applying the stochastic technique of Boore (2003).The Nakamura technique was used to empirically estimate the site response functions. 113 sites with 500-m spacing in Nuweiba were instrumented for varying length of time. The site response of the selected sites exhibits peaks of amplification factors ranging from 2.5 to 7.0 in the frequency range 0.5 to 6.8 Hz. These findings suggest that there are significant differences in the uppermost sedimentary cover. The stochastic simulation method was used to calculate the acceleration of ground motion at the 113 sites distributed in the studied area. The maximum peak ground acceleration produced by the Gulf of Aqaba seismic source reaches 223 cm/sec2 in Nuweiba. Ground motion amplification factors control the sites of high values of peak ground acceleration. The response spectrum, which reflects the characteristics of earthquake and the nature of the recording sites, was calculated also at various damping values.

Keywords: site, effect, spectra

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SS003 **Oral Presentation** **6321**

Toward bedrock elevation mapping of Istanbul: Comparison of analytical and experimental analyses

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Local S-wave velocity (Vs)-depth profiles and bedrock depth distributions are key factors in the assessment of seismic hazard and earthquake ground motion characteristics since they allow determination of amplification potential of sedimentary cover overlying bedrock. In this study, estimation of the bedrock depth distribution in the Istanbul region was carried out by comparing transfer functions obtained from microtremor analyses and one-dimensional (1D) S-wave velocity profiles at sites where shallow velocity structure is known. For this purpose, the correlation between the resonance frequencies and the sediment thickness was investigated at the sites where geotechnical data consisting of standard penetration test (SPT) blow counts and standard soil descriptions from borings at adjacent areas to the strong motion sites are available. The bedrock depth of each site was determined by computing analytical transfer functions so as to fit to the resonance frequency and the shape of experimental transfer functions Based on those results, a relationship between the resonance frequency and thickness of sediment layers was derived. Finally, the bedrock distribution beneath populated areas of Istanbul was obtained by applying the derived relationship to all the strong-motion sites, where the resonance frequency is known.

Keywords: bedrock depth, istanbul

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SS003 **Oral Presentation** **6322**

Robust estimation of site response in the Kachchh seismic zone, Gujarat, India, from strong motion data using generalized inversion technique (reference site)

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Dr. Utpal Dutta, Dr. R.K. Chadha

To study the spatial variation of site response in the Kachchh seismic zone, Gujarat, India, we used the generalized inversion technique (reference site) to estimate the site response (SR) using the horizontal components of S-waves from 36 aftershocks (Mw 3.5-5.6) recorded at 5-16 three-component digital strong motion accelerograph sites. The SR values thus obtained were averaged (logarithmically) for two frequency bands, namely, a low frequency band (0-4 Hz, LFB), and a high frequency band (4-8 Hz, HFB), respectively. In LFB, SR shows larger values (> 2.0) in the regions southwest (e.g. at Satapar and Newdudhai stations) and immediate northeast quadrant of the location of the 2001 Mw7.7 Bhuj earthquake, however, it reduces to 1.5-1.8 in the regions south and southeast of the mainshock (e.g. Bhachau, Vondh, Sikara and Kumbardi stations). In the east, SR in LFB further reduces to 1 at Sivalaka (reference site). The areas with SR > 2.0 were associated with extensive ground failure during the Bhuj earthquake (Mw=7.6) of 2001. In HFB, SR suggests larger values (> 2.5) at Satapar station in the southwest and Kakarvad station in the region northeast of the mainshock. In the near vicinity of the mainshock, SR in HFB shows a value ranging from 1.1-1.7, whereas, it increases to 2.0-2.2 in the regions south and southeast of the mainshock. It is inferred that larger SR (>2) values at 0.5-0.8 Hz could be indicating the probable presence of soil class C (360 < Vs 760 m/s) and D (180 < Vs 360 m/s) in the Kachchh basin (according to 1997 NEHRP provisions). This abstract deals with a very important topic in seismology, which is related to the short-term forecasting of the rare, unique intraplate earthquakes. Like all large (M > 7.5) continental midplate earthquakes, both the 1819 Kachchh and the 2001 Bhuj earthquakes also took place within an old rift that has been tectonically reactivated in compression. This intracontinental rift zone has a retur

Keywords: site response, generalised inversion method, strong motion data

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SS003 **Oral Presentation** **6323**

S-Wave spectral analysis for estimation of source, site and path effects.

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Hossien Hamzehloo

S Wave spectral analysis is applied to 100 velocimetric records to obtain the source parameters of 10 aftershocks (4<Mw<5.9) of the March 31, 2006, Mw 6.1, Silakhor (SW Iran) earthquake. We derive attenuation models, site response functions, and source parameters from small-magnitude events recorded at a regional scale. Our data set consists of 10 Silakhor events with magnitude 4 to 6.1, for which more than 100 displacement spectra could be computed. We assume that the far-field displacement spectrum is the product of source, propagation, and site effects. S-wave displacement spectra are computed for velocimetric records using fast Fourier transform by integration in the frequency domain for 0.0110 Hz. Owing to the velocimeter response. A Brune-type source is assumed. Attenuation is decomposed into a frequency-dependent term (anelastic attenuation) and a nonfrequency-dependent term (geometric attenuation). Adapting a process proposed by Scherbaum and Wyss (1990), we invert the data with a two-step regression. The first step recovers the geometric attenuation, the seismic moment, and a frequency independent scaling factor. The second step gives the corner frequency, the anelastic attenuation, and a frequency-dependent site effect. Our results show that the propagation term includes a slightly superspheric geometric attenuation that varies as 1/r1.2 and an anelastic attenuation that cannot be safely resolved with a linear approach. Computed moment magnitudes are generally 0.5 to 1 unit smaller than local magnitudes. Corner frequencies decrease linearly with magnitude, and the stress drops obtained appear to be nearly constant whatever the magnitude. Finally, robust site responses are computed that are compatible with those derived with other methods.

Keywords: attenuation models, site response functions, source parameters

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SS003 **Oral Presentation** **6324**

Investigations of geological and topographical site effects using two felt earthquakes recorded at Israel seismic network

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The phenomenon of seismic wave amplification due to sedimentary deposits and topographical conditions constitutes a major factor in damage and loss caused by strong earthquakes. In the present study we concentrate on evaluation of site effects at the sites where two local earthquakes that occurred on 11.2.2004 and on 7.7.2004 along the Dead Sea transform that triggered strong motion accelerometers and were recorded by three-component short and broad band seismic stations operated as part of the Israel Seismic Network. In addition we use microtremor recorded by temporary seismic stations alongside the accelerometers. The horizontal-to-vertical (H/V) spectral ratio of earthquake shear wave (receiver function estimates) is used to approximate the fundamental resonance frequencies of the subsurface and their associated amplitude. The spectral ratios of six stations located directly on the outcropping rocks of limestone, well-cemented conglomerates, chalk and basalt have flat H/V ratio shape in the frequency range 0.4-10 Hz and amplitudes are close to unity. Amplification effects of factor 4-6 are observed at various frequencies in the 0.8-4.0 Hz at fourteen stations by near-surface geological conditions. Through the analysis it becomes evident that H/V ratio from ambient noise recorded at the same site provides estimation of the resonance frequency and its associated amplification level, which is similar to those obtained from H/V spectral ratio of accelerograms. Finally, we use empirical observation, geophysical data and geological information to validate H/V ratio with 1-D model. In seismic stations located on the high plateau near top escarpment and on small mountains and hills we observe amplified motion in the frequency range 0.6-3.0 Hz with a factor of up to 5. At these sites there are differences in the shapes of H/V spectral ratios between two horizontal components. These earthquakes add significantly to our knowledge about the influence of the effects of local geology and topographic prominences on the amplitude of seismic waves.

Keywords: site effect, earthquake

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SS003 **Oral Presentation** **6325**

Seismic microzonation and subsurface modeling across urban areas in Israel using H/V specttral ratios from ambient noise and seismic events

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Many Israeli towns are relatively close to active faults and are vulnerable to strong earthquakes. Local variations of soil conditions did and will increase ground motions generated by earthquake and will increase the consequential damage. Seismic Microzonation and subsurface modelling are thus important in realizing the earthquake hazard across the populated areas. Since 2000 we have carried out more than 3000 microtremor measurements in 13 towns situated in the different part of Israel. The measurement sites were designed to be on a grid with a spacing of 500 m to assure a good coverage of the area. Different surface sedimentary deposits, thickness of sediments and the shear wave velocity contrast between sediments and bedrock were also considered in that design stage. At instances where high variation have been observed, we increase the spatial density of measurements reaching a grid spacing of 250 m and in some locations 150m. We mainly measured ambient noise but occasionally recorded earthquakes and explosions from quarries and computed the H/V spectral ratios. Ensemble of carefully selected windows of ambient noise provided average H/V ratios similar to those obtained from seismic events. The soil sites exhibit H/V peak amplitudes ranging from 2 to 8 in the frequency range 0.3 Hz to 14 Hz. For many sites, the H/V spectra show two peaks at frequencies related to resonating waves from deep and shallow surfaces of different rock types. Special attention was given when measuring ambient noise near boreholes and refraction surveys where we could confirm a good agreement between H/V spectral ratios and analytical transfer functions using 1-D multi layer models. The geology of the subsurface often limited to the layers close to the surface was consequently used to build a 3D picture of the subsurface which is consistent with the spatial distribution of the main features of the H/V spectra, i.e., fundamental frequency and its associated H/V amplitude. The obtained 3D model for the study area was used to compute site response functions (assuming linear behavior of the soils) and map the spatial distribution of the expected amplifications and their associated resonance frequencies. In turn, we divided the study areas into zones of characteristic response functions (i.e., soil column models) to be used for design purposes as well as for prediction of ground motions from earthquakes. The obtained seismic zonation maps are thus closely tied to actually measured site effects, and therefore may lead to realistic site specific seismic hazard assessments in these towns.

Keywords: microtremor, microzonation

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H/V site-effect interpretation using microtremor measurements and Linear Dynamic System constrains

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Usual approach to estimate site-effect from microtremor measurements is to compute spectral ratio of horizontal-to-vertical components H/V (Nakamuras technique). The main problem of this method is a large scatter of H/V ratio maximum amplitudes and a somewhat less scatter of corresponding frequencies. This instability of the estimates is related apparently to non-stationarity of the microtremor sources randomly distributed in time and space. We interpret the H/V ratio in terms of the transfer function of a linear dynamic system (LDS) with input V and output H observed with non-stationary and correlated noise. Consequently the problem of accurate site effect estimation is determined by selection of the sequence of time windows with relatively large input and output Signal-to-Noise ratio. However, we have no means to compute SNR from observations but it is possible to judge about it indirectly. For this purpose we estimate maximal amplitudes and corresponding frequencies of H/V ratio in a sequence of time windows and then collect time windows were the data is clustering around certain frequencies and amplitudes. Then we continue sorting the data fitting best to the assumption of the 1D LDS model described by a vector of parameters. The outliers in the new parameter space are automatically removed by a sort of clusterization procedure based on the statistical robust Maximum-likelihood approach (M-estimtes), thus providing relatively more stable maximum amplitude and frequency estimations. Such approaches make it possible to assist the routine analyst processing but doesnt exclude intelligent interpretation using apriory knowledge about geological and velocity undersurface structure. The interactive and automatic procedures, using this principal have been designed and verified on a number of simulated and real data, showing good performance.

Keywords: site effect, hv ratio, m

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Single-station microtremor estimates of Vs30

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Eurocode 8, which constitutes the standard for seismic design in Europe, has its roots in the U.S. National Earthquake Reduction Program site classification procedure. The latter adopts as a key quantitative parameter the average speed of the S waves in the first 100 feet of depth, chosen for its approximate correlation with local amplification and for its wide availability in the seismic regions of the western US. This parameter, which the translation in the decimal metric system has renamed Vs30, is not generally available in European seismic countries, where it may also have a less positive correlation with site amplification due to a different soil geology. We attempt to solve the practical difficulty encountered by the land use planners, who are requested to provide a parameter at the same time laborious to measure and of comparatively modest efficiency. We propose a quick procedure to estimate the Vs30 on the basis of single station measurements of seismic tremor. In fact, provided that the stratigraphic column is known to some extent from direct analysis (drilling or penetration test) at least at one point, the tremor measurements can be tuned for absolute depth. Tremor measurements can then be inverted to estimate Vs30 at all sites with similar surface geology. This procedure has been applied to a variety of geological settings where independent Vs30 estimates were available through established active or passive prospection methods like Down-Hole, Cross-Hole, MASW, ESAC and REMI. Analysing all the cases that are practically encountered in Italy, with bedrock and bedrock-like stratifications above or below 30 meters, we find that a site classification capability coherent with that attained by the classical prospection techniques can be achieved at a small fraction of the cost by using 20 single-station tremor recordings.

Keywords: vs30, ambient noise, single station

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Seismic microzonation of Damascus City using H/V spectral ratio for ground_shaking site effects

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The most effective measures to mitigate seismic risk in any urban area are to introduce statutory seismic design requirements for new constructions and to retrofit existing structures that are vulnerable to expected earthquake ground motions. It is imperative to carry out comprehensive seismic hazard assessment for big cities in order to reduce the potential damage from earthquakes Seismic hazard assessment of big cities is imperative to mitigate the potential damage and loss of life due to earthquakes. One of the fundamental steps in seismic hazard assessment is microzonation of cities, which provides a basis for site-specific hazard analysis. The comprehensive seismic hazard assessment involves: a) identifying the regional seismic sources and defining attenuation model for the area b) identifying local site effects and microzonation of cities and c) vulnerability analysis of structures. Throughout the history, Damascus city was affected by strong earthquakes. One of the best-documented and most recent destructive earthquakes (M = 7.4) occurred on October 30, 1759 and caused the destruction of a great part of Damascus city reaching the seismic intensity of XI on the MSK scale ((Ambraseys, 1998). Such a high intensity from a relatively distant earthquake of magnitude 7.4 is probably the result of the local site effects of the sedimentary layers that significantly enhance earthquake ground motions and thus the seismic intensities. An accurate evaluation of the site responses across Damascus to seismic ground motion, is of prime importance for urban developments, safer design of buildings and to the mitigation of the earthquake risk. This study is focused on microzonation of Damascus city, using microtremor observations which involve the following three steps: (1) detailed mapping of site response functions using microtremors recordings, (2) Use geotechnical borehole Data, geophysical, geological, hydrological, seismological and geomorphological information to derive soils ground motion parameters like soil amplification factor, shear wave velocity, peak surface acceleration as well as PSV, PSD for different sites across the study area and (3) estimate the seismic hazard of Damascus city in terms of Uniform Hazard Site-Specific Acceleration Spectra. The Nakamura technique is used to empirically estimate the site response functions. Approximately 300 sites in Damascus city were instrumented for varying length of time. The predominant period of the ground at all the sites is determined from the horizontal to vertical (H/V) spectral ratios of microtremors and a microzonation map is developed for Damascus on the basis of the variation of the predominant period of the ground. Identifying the variation of site amplification factor and other important parameters for the seismic design of buildings and structures within Damascus city were estimated. The site response of soil sites exhibit peaks of amplification factors ranging from 4 to 8 in the frequency range 0.5 to 2.5 Hz. These findings suggest that there are significant differences in the uppermost sedimentary layers. The work utilized not only the microtremor analysis results but also an extensive database of basic soil properties and soil profiles in the area. Microzonation of big cities can assist in the mitigation of earthquake damage. Microtremor observations can be used to determine the dynamic properties of a site (the predominant period of vibration) and, hence, can be used for microzonation. The area can then be classified according to the predominant period of the ground. The conventional means for determining the dynamic characteristics of soil is the Borehole method. However, this method is costly, time consuming and is generally not suitable for microzonation work. Methods based on analysis of strong motion data are more straightforward for determining site effects. Nevertheless, the availability of ground motion records is limited to very few countries only.

Keywords: microzonation, site effect, ground motion

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SS003 **Oral Presentation** **6329**

Different approaches to evaluate site effects: application to Gemona del Friuli (NE Italy) alluvial fan area.

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The urban area of Gemona (NE Italy) is mainly built on alluvial fan sediments that contributed to the destruction of the city during the Friuli earthquake, May-September 1976. Three accelerometric stations of the Friuli Venezia Giulia Accelerometric Network, run by the Department of Earth Sciences, University of Trieste, in collaboration with the Civil Defence of FVG, are set in Gemona for site effects estimation purposes. Using weak motion recordings of these stations, we are able to derive the H/V spectral ratio and also to apply the reference site technique. The result of these elaborations shows different resonant frequencies in the two sites (one on the fan, one on the sedimentary basin), when excited by the same event, and also different resonance frequencies at the same site when excited by different events. This can be explained with 2D or 3D site effects modelling, that requires, however, the characterization of the local subsoil structures, in particular the sediment-bedrock contact. We use gravimetric data to characterize a model with a homogeneous sedimentary layer of variable thickness along five selected profiles. The models are elaborated using the residual Bouguer anomaly and, as a constraint, three boreholes that reach the bedrock together with geological outcrops and intersection points on the profiles. We derive the mean thickness along all the profiles and the bedrock undulations. To investigate the 2D or 3D character of the alluvial fan we also use approaches based on noise measurements. We acquired seismic noise data along the same profiles. These data were analysed first to calculate the fundamental frequency of soft soil using Nakamuras techniques. Then we use for the same data the angular analysis technique to allow us to test if the 2D effect is visible or not. This angular analysis is able to show the direction of polarization of the incident wave using noise data. This is very useful to evaluate site effects in areas of low or medium seismicity such as Gemona.

Keywords: noise measuremens, alluvial fan

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SS003 **Oral Presentation** **6330**

Earthquake Strong Ground Motion Scenarios at the 2008 Olympic Games Site, Beijing Based on Historic Records

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Historic earthquake record indicates mediate to strong earthquakes have been frequently hit greaterBeijing metropolitan area where is going to host the 2008 summer Olympic Games. During the last 500 years (the Ming and Qing Dynasties) there are at least 12 earthquake events with the maximum intensity of VI or greater occurred within 100 km radius from the city center. Numerical simulation of the seismic wave propagation and strong ground motion has been carried out to study the strong ground motion scenarios based onfour particular historic earthquake events: One is the Great 1679 Sanhe-Pinggu Earthquake (M~8, Maximum Intensity XI at the epicenter and Intensity VIII in city center)) whose epicenter is about 60 km ENE of the city center. The second one is the 1730 Haidian Earthquake (M~6.5, Maximum Intensity IX at the epicenter and Intensity VIII in city center) with the epicentral distance less than 20 km away from the city center in NW. The third one is the 1665 M~6.5 Tongzhou earthquake about 20 km east of the city center onthe NW oriented Nankou-Sunhe fault. The last one is the 1586 M~5 event with an epicenter possibly directly beneath the city center on a NE oriented strike slip fault. The exist of the thick Tertiary-Quaternary sediments (maximum thickness ~ 2 km) in Beijing area plays a critical role on estimating the surface ground motion at the Olympic Games sites. Newly acquired engineering geological and seismological data providedmore constraints to better estimate the near-surface site effects on the potential seismic hazard caused by strong ground motion at the site.

Keywords: earthquake scenarios, ground motion, numerical simulation

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SS003 **Oral Presentation** **6331**

Experimets on the stability of SPAC, 2sSPAC and lienar array methods

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In recent years for estimation of shear wave velocity structure microtremors array observations were in use. One of the known method is conventional spatial autocorrelation method (SPAC), which requires at least 4 simultaneously recorded datasets. The modified SPAC methods such as 2sSPAC and linear array methods allow to estimate shear wave structure by using only two sensors, but in these cases the instability problem of the spatial autocorrelation coefficient could arise in frequency range higher than 1Hz. We carried out observations in Tsukuba city, Japan, with arrays size 900m, 500m, 200m, 150m, 100m, 50m and four 25m. Results obtained from four 25m triangular arrays with four sensors, as well as from four 25m linear arrays with two sensors, showed good stability of SPAC coefficient for 2-5Hz frequency range. For 500m array the shear wave velocity structure was obtained by using 2sSPAC method and compared the results with those obtained by SPAC method for 520m from 900m array.The imaginary part of the SPAC coefficients was also observed, as an indicator of the quality of data, however it is difficult to say definitely that the imaginary part of SPAC coefficients can show the stability.

Keywords: spac, stability, pattern

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SS003 **Oral Presentation** **6332**

Characteristics of Soil Response in Near-Fault Zones during the 1999 Chi-Chi, Taiwan, Earthquake

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The distribution of parameters characterizing soil response during the 1999 Chi-Chi,earthquake (Mw=7.6) around the fault plane is studied. The results of the performed stochastic finite-fault simulations and constructed models of soil behavior at 31 soil stations were used to estimate amplification of seismic waves by the soil layers, average stresses, strains, shear moduli reduction in the soil layers (in the upper 30 m or 80 m), and nonlinear components of the soil response.The obtained estimates show that the amplification coefficients increase in proportion with the distance from the fault plane, whereas average stresses and strains, shear moduli reduction in the soil layers, and nonlinear components of the soil response decreasein inverse proportion to distance. The area of strong nonlinearity, where the soil behavior is substantially nonlinear (the content of nonlinear components in the soil response is ~50% of the intensity of the response and higher), and spectra of oscillations on the surface take the smoothed form close to E(f) ~ f -n, islocated around the fault plane at distances up to ~20-25 km from the fault (~1/5-1/4 of the length of the fault). Nonlinearity decreases with increasing distance from the fault: at ~40-50 km, the content of nonlinear components in the soil response does not exceed ~10-20% of the intensity of the response. Comparing the soil behavior in near-fault zones during the 1999 Chi-Chi earthquake, 1995 Kobe earthquake (Mw=6.8), and 2000 Tottori (Japan) (Mw=6.7) earthquake, we note similarity in the behavior of similar soils and predominance of the hard type of soil behavior. At soil stations, resonant oscillations are induced in soil layers by the strong motion, however, during the Chi-Chi earthquake they involved deeper soil layers (down to depths of ~40-60 m), whereas, during less-magnitude Kobe and Tottori earthquakes, they were concentrated in the upper 10-15 m.

Keywords: nonlinear soil behavior, stress strain relations, the 1999 chi chi earthquake

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SS003 **Oral Presentation** **6333**

Soil seismic hazard estimates for the Friuli Venezia Giulia region (N.E. Italy)

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Although national seismic hazard maps refer to rock or to a very stiff soil, soil hazard estimates are very important in urban planning and become to be considered in seismic zonation as well. Without entering into the details of a complete microzonation study, soil hazard can be assessed on the basis of a good geological information of the study region. The OGS has recently developed a study aimed at defining the soil hazard for general purposes: revision of the seismic zonation and future urban planning. A probabilistic approach for seismic hazard assessment was considered according to the Cornell (1968) approach in the Bender and Perkins (1987) formulation. The PGA hazard estimates refer to a 475-year return period, corresponding to the 10% exceedence probability in 50 years, standard reference in seismic design. The variability of the attenuation model has been taken into account considering the standard deviation in the hazard computation. The study area is the Friuli Venezia Giulia region in N.E. Italy. A detailed geological map is available for this region and several geophysical measurements were done to define the litho-stratigraphic characteristics of six test sites, roughly representative of all the situations in the study region. Rock seismic hazard was assessed according to the most updated methodologies (logic tree approach) and data (tectonic and earthquake data). The logic tree consists of 3 seismogenic zonations, 3 methods for the seismic rate computation, 3 approaches for the maximum magnitude determination, and 2 attenuation models. An additional attenuation relation was used for stiff soil. Consequently, the number of branches is 54 for rock and soft soil, and 81 for stiff soil. A total of 189 runs of the Seisrisk III code (Bender and Perkins, 1987) have been processed in order to compute the hazard results for each of the 3 soil types. All branches were evenly weighted. With the aim to represent seismic hazard taking into account the effects of the local amplification, a soil map of the Friuli Venezia Giulia (Department of Geological, Enviromental and Marine Sciences, University of Trieste) according to the different soil tipologies of the NEHRP classification (BSSC, 2001) was used. This map offers an indication of the three soil tipologies considered by the Eurocode EC8 (rock, stiff soil and soft soil), on which also different attenuation relations are calibrated. More precisely, the NEHRP A and B classes were assimilated to the EC8 rock, C class to stiff soil, and D and E classes to soft soil. Taking into account the soil typologies identified in the study region, the adequate 475-year return period PGA value has been associated to the different area units using the potentialities of a GIS and the final soil hazard maps have been constructed. The importance of the pertinent soil type is pointed out by all maps. In fact, the hazard is notably higher in the plain and along the Alpine valleys than in the mountain sectors. At the same time, the site amplification for the six test sites was computed by 1D and 2D modeling. 1D modeling (Pshake; T.San and A.Pugliese, 1991) was used in case of simple situations of one or more plan-parallel layers with the seismic motion coming perpendicular to the free surface. In situations such as center areas of extended alluvial valleys, the main cause of the ground motion amplification is the stiffness contrast between different soil layers. 2D modeling was used when stratigraphy has a variable geometry in depth: examples are given by marginal areas of alluvial valleys, where edge effects connected to the site geometry are observed. The Besoil code (T.San, 1996) is based on the contour elements method and does not need to represent the whole stratigraphy, but only that of the terrain surface and the contours of the zones with uniform mechanical properties, allowing a remarkable computational saving. Modeling results have been applied to the rock hazard map according

to the actual local litho-stratigraphic situations. The final soil hazard map shows clearly the areas where the stronger ground motions are expected and offers a precise view of what can be observed in the case of the occurrence of a violent earthquake.

Keywords: amplification factors, psha, ne italy

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SS003 **Oral Presentation** **6334**

Soil amplification in Ottawa, Canada, from Urban Strong Ground Motion records

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A strong motion network established in Ottawa in the winter of 2002 was expanded with additional ETNA and IA (Internet Accelerometer) instruments in 2004-5. It has now recorded weak motions from three earthquakes: M5.0 (Au Sable Forks, 20020429) at 180 km, M4.7 (Charlevoix, 20050306) at 525 km and M4.0 (Thurso, 20060225) at 32-56 km distance. The records have been analysed using site-to-reference spectral ratio and H/V spectral ratio methods and show significant amplification and sharp resonance peaks at the thick soil sites. Although strong ground motion records are of the greatest value, these weak motion records help to calibrate engineering models in the linear range of soil behaviour.

Keywords: site effects, h v ratio, amplification

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SS003 **Oral Presentation** **6335**

Conjoint use of H/V spectral ratio, f-k and SPAC methods to assess 2D effects over the Tamar Valley, Tasmania, Australia

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Pr. Michael W. Asten

Tamar rift valley runs through the city of Launceston, in northwest Tasmania. Although Launceston is not located in the proximity of an active seismic zone, damage has occurred to buildings in the city due to earthquake activity on faults associated with the Bass Strait. Previous microtremor and gravity surveys have identify the presence of soft sediments of varying thickness over short distance. These sediments are thought to induce a 2D resonance pattern, amplifying the surface motion over parts of the valley. The soft Tertiary sediments have a measured shear velocity between 400 and 800 m/s, and lay on top of hard Jurassic dolerite bedrock, with a shear velocity estimated of 1800 m/s. In this study, we conjointly use H/V spectral ratio, f-k and SPAC methods of study of microtremors to identify and characterize 2D effects in the Tamar valley. Each method gives complementary information about the geological settings over Tamar valley at Launceston. Used on a profile across the valley, H/V spectral ratio measurements give information about the frequency and pattern of resonance. H/V data being recorded with a single sensor, it allows a rapid and effective semi-quantitative estimation of the valleys properties. Previous studies have proven the usefulness of H/V to identify 2D pattern of resonance over an ancient valley. In addition to H/V data, we have set up arrays of sensors above assumed layered geology and in the valley to study f-k and SPAC methods in 2D environment. We match with precision a layered earth model to SPAC data at WindMill Hill Reserve (WHR), confirming the assumption of a 1D geology at WHR. Precision is significantly degraded over Kings Park (KPK) and the Rugby Ground (RGB) stations when comparing field azimuthally-averaged coherencies with model coherencies computed for a 1D earth. These latter two stations are located in the Tamar valley, where 2D effects are expected, which we hypothesize is the cause of degraded precision in the comparison. We test this hypothesis using a combination of SPAC methods and f-k methods to compare azimuthal variations in estimated velocities on the field data, with variations on data modeled with a full-wave 2D modeling code.

Keywords: microtremors, 2d resonance, azimuthal spac

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SS003 **Oral Presentation** **6336**

Numerical predictions of ground motion in 3D basins: learnings from the Grenoble (France) comparison

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The validation of numerical methods for seismic wave generation on complex sources and their propagation in complex media is an absolutely necessary step before using them for ground motion estimates. As a contribution to that effort, a ground motion prediction test has been proposed during the 2006 ESG meeting held in Grenoble. The benchmark consisted in computing the seismic response of the Y-shaped Grenoble valley to (i) two local earthquakes (M<=3) for which recordings were avalaible; and (ii) two local hypothetical events (M=6) with finite fault size and prescribed kinematics. Amongst a total of 18 contributions from 14 different groups, 7 used 3D methods, while the other predictions are based upon 1D (2 contributions), 2D (4 contributions) and empirical Greens function (EGF) (3 contributions) methods. Although the performance and frequency range of predictions do vary significantly form one method to the other (for instance, from [0.1 - 2.5 Hz] for 3D computations to [0.8 40 Hz] for EGF calculations, a summary comparison of the different predictions was attempted through raw indicators (e.g. peak values of ground velocity and acceleration, Fourier spectra, site over reference spectral ratios, ...) as well as sophisticated misfit criteria based upon previous works. While initial, "blind", computations significantly differed from one another, it turns out that after one iteration, four 3D predictions (out of 7) exhibit a remarkable fit and allow to identify a 3D reference solution to the problem. Further discussions wil briefly address the importance of 3D effects, non-linear rheology and surrounding surface topography on the estimation of ground motion in Grenoble valley.

Keywords: numerical simulation, 3d effects

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SS003 **Oral Presentation** **6337**

Effects of love waves on microtremor H/V ratio amplitude

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Khler Andreas, Cornou Ccile, Wathelet Marc, Cotton Fabrice, Bard Pierre-Yves

The H/V method has the potential to significantly contribute to site effects evaluation, in particular in urban areas. Within the SESAME European project (Site EffectS assessment using AMbient Excitations) we investigate the nature of ambient seismic noise in order to assess the reliability of this method. Through 1D seismic noise modeling, we simulate the ambient noise for a set of various horizontally stratified structures. We perform array analysis (f-k) for both vertical and horizontal synthetics and estimate the contribution of different seismic waves (body/surface waves, Rayleigh/Love waves) at the H/V peak frequency. We show that the very common assumption according which almost all the noise energy would be carried by fundamental mode Rayleigh waves is not justified. The proportion of different waves is dependent on site conditions, especially the impedance contrast. However, for the 1D horizontally layered media presented here and whatever the H/V peak origin (Rayleigh waves ellipticity, Love waves Airy phase, or the S-wave resonance), the H/V peak frequency always provides a good estimate of the fundamental resonance frequency; while the H/V peak amplitude is controlled by the relative proportion of Love waves in the horizontal ambient noise wavefield.

Keywords: microtremor, site effects, amplification factor

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SS003 **Oral Presentation** **6338**

Site effect evaluation in Mt.Vesuvius area: comparison of results obtained by classical empirical techniques and wavelet transform method.

Dr. Danilo Galluzzo

Mario La Rocca, Edoardo Del Pezzo, Rosalba Maresca, Mario Castellano

The present study aims to analyze site amplification effects in Mt. Vesuvius volcanic area by using empirical methods applied to local earthquakes and seismic noise recordings. Data set is composed by 35 local seismic events (1.5 < Md < 3.6) recorded at 11 digital seismic stations equipped with three period short period sensors in the period 1996-1999. Site amplifications are evaluated for the S-wave windows of seismic records using classical (direct) spectral ratios (DSR), the generalized inversion method (GI), the coda inversion technique (CI), H/V spectral ratios (HVs) and for seismic noise by using Nakamura method (HVn). The first method is based on the ratio between the spectrum of the site of interest and the spectrum at a reference site, which is a nearby hard rock site. Here, the lack of a hard rock site led us to consider the average spectrum between all of the investigated sites as the reference spectrum. A similar assumption is made for the methods based on the inversion procedure: the average spectra evaluated at all of the stations is constrained at unity (GI and CI techniques). In addition to these conventional method, we use wavelet transform method (WTM) to evaluate site effect both in frequency and time domain for all the investigated site and compare the WTM results with those obtained with previous methods.The results obtained with the methods based on S-wave windows (DSR, GI, CI and WTM methods) show a good agreement within the estimated uncertainties for each method. HVs and HVn methods show the same results in terms of frequency range of amplification for the sites located in lower part of volcanic area. The method based on the Coda wave inversion (CI) shows amplification values higher respect to the other methods. This is probably due to the trapped waves located in the volcanic edifice and to the the strong surface topographical heterogeneities. The Wavelet transform method shows the same results in frequency domain of conventional methods based on the S-wave windows and gives further and useful informations in time domain about the duration of ground motion. Site amplification function in frequency domain and time duration of records at different sites can be considered as crucial parameters for the estimation of ground motion parameters in the investigated area.

Keywords: site effects, wavelet

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SS003 **Oral Presentation** **6339**

Geophysical Studies for Seismic Hazard Assessment at Jabalpur, India. T. Seshunarayana

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The earthquake hazard assessment studies are important in areas of seismically active regions, in order to prevent/minimize the loss of life and damage to infrastructure and property in the event of a major earthquake. It is well known that the local ground conditions are one of the major risk factors that cause the havoc to human beings and not earthquake as such. Therefore, it is imperative to study the ground conditions which are termed as site characteristics. The objective of this work is to estimate the shear wave velocity, depth to bed rock and spectral ratio (H/V) which in turn paves the way for earthquake hazard assessment in Jabalpur. Geologically, Jabalpur city is complex coupled with the fact that the area is seismically active in shield region. Relatively recent method Multichannel Analysis of Surface Waves (MASW) was used for estimating the shear wave velocity at 116 locations. The P-Wave velocity (VP) data obtained from seismic refraction survey covering all rock units provided valuable information on the nature of subsurface layers in terms of velocities and corresponding thickness. The spectral study of ground roll helped to estimate the response of the ground i.e., the frequency at which the signal is getting excited at each location. The low frequency short duration data was acquired with a low natural frequency (1Hz) using a 3-component geophone. The short duration data (16 sec) was used for estimating the site amplification based on different computational techniques, which enabled to evaluate the comparative merits and demerits. it is found that the spectral ratio of H/V and reference site techniques yield reliable results even with short duration (16 sec) data. Based on the combined study of MASW, seismic refraction and spectral ratio, the entire study area of Jabalpur is divided into six zones following NEHRP guidelines and using the following three criteria namely, 1) harmonic mean shear wave velocity up to top 30 m (VS30), 2) depth to bed rock and 3) spectral response of the ground at low frequency.

Keywords: hazard, spectral, jabalpur

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SS003 **Oral Presentation** **6340**

Seismic microzonation of Damascus City using H/V spectral ration for ground_shaking site effects

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The most effective measures to mitigate seismic risk in any urban area are to introduce statutory seismic design requirements for new constructions and to retrofit existing structures that are vulnerable to expected earthquake ground motions. It is imperative to carry out comprehensive seismic hazard assessment for big cities in order to reduce the potential damage from earthquakes Seismic hazard assessment of big cities is imperative to mitigate the potential damage and loss of life due to earthquakes. One of the fundamental steps in seismic hazard assessment is microzonation of cities, which provides a basis for site-specific hazard analysis. The comprehensive seismic hazard assessment involves: a) identifying the regional seismic sources and defining attenuation model for the area b) identifying local site effects and microzonation of cities and c) vulnerability analysis of structures. Throughout the history, Damascus city was affected by strong earthquakes. One of the best-documented and most recent destructive earthquakes (M = 7.4) occurred on October 30, 1759 and caused the destruction of a great part of Damascus city reaching the seismic intensity of XI on the MSK scale ((Ambraseys, 1998). Such a high intensity from a relatively distant earthquake of magnitude 7.4 is probably the result of the local site effects of the sedimentary layers that significantly enhance earthquake ground motions and thus the seismic intensities. An accurate evaluation of the site responses across Damascus to seismic ground motion, is of prime importance for urban developments, safer design of buildings and to the mitigation of the earthquake risk. This study is focused on microzonation of Damascus city, using microtremor observations which involve the following three steps: (1) detailed mapping of site response functions using microtremors recordings, (2) Use geotechnical borehole Data, geophysical, geological, hydrological, seismological and geomorphological information to derive soils ground motion parameters like soil amplification factor, shear wave velocity, peak surface acceleration as well as PSV, PSD for different sites across the study area and (3) estimate the seismic hazard of Damascus city in terms of Uniform Hazard Site-Specific Acceleration Spectra. The Nakamura technique is used to empirically estimate the site response functions. Approximately 300 sites in Damascus city were instrumented for varying length of time. The predominant period of the ground at all the sites is determined from the horizontal to vertical (H/V) spectral ratios of microtremors and a microzonation map is developed for Damascus on the basis of the variation of the predominant period of the ground. Identifying the variation of site amplification factor and other important parameters for the seismic design of buildings and structures within Damascus city were estimated. The site response of soil sites exhibit peaks of amplification factors ranging from 4 to 8 in the frequency range 0.5 to 2.5 Hz. These findings suggest that there are significant differences in the uppermost sedimentary layers. The work utilized not only the microtremor analysis results but also an extensive database of basic soil properties and soil profiles in the area. Microzonation of big cities can assist in the mitigation of earthquake damage. Microtremor observations can be used to determine the dynamic properties of a site (the predominant period of vibration) and, hence, can be used for microzonation. The area can then be classified according to the predominant period of the ground. The conventional means for determining the dynamic characteristics of soil is the Borehole method. However, this method is costly, time consuming and is generally not suitable for microzonation work. Methods based on analysis of strong motion data are more straightforward for determining site effects. Nevertheless, the availability of ground motion records is limited to very few countries only.

Keywords: site effect, ground motion, microzonation

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SS003 **Oral Presentation** **6341**

The Umbria-Marche sequence: digital recordings at ENEA stations.

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The Nerina valley, where Borgo Cerreto is located, is surrounded by the Apennine mount chain at the top of which lies the historical centre of Cerreto di Spoleto (Fig.1). The study is part of a research project aiming at analysing natural disasters and their impact on the Italian cultural heritage. Within the framework of this research project, local seismic records was analysed for both the carbonate ridge and the bordering alluvial valley. The choice of Cerreto di Spoleto as a test site derives from the analysis of Italian seismic hazard maps, obtained in terms of peak ground velocity and taking into account regional geology (Romeo et al., 2000). The maps highlight the considerable seismic hazard which characterises the Apennine belt and its possible increase due to the effect of alluvial deposits. In particular, the choice of the Cerreto di Spoleto municipality for investigating local seismic response is justified by its geological setting, as well as by its geomorphological features. The village has predisposing factors for seismic wave amplification, such as the shape of its carbonate ridge, the significant variations in the jointing conditions of its exposed limestones, the occurrence of travertine deposits accommodating wide flats, the occurrence of extensive debris slopes and of alluvial deposits filling the Nera River valley. To this aim, ENEA installed in the 80s an accelerometric array. The array originally composed of 8 instruments (all digital), installed at 5 recording stations, was modified in such a way that only 4 instruments were surviving when the 26 September events struck the Umbria-Marche region. The instruments were CODISMA(Contraves Digital Strong Motion Accelerograph) with 12 bits acquisition system and PCB triaxial accelerometers. The 4 accelerographs were installed at 3 different sites, two on the valley: (Campo Sportivo alluvium site, and Borgo Cerreto Torre rock site) and one at the top of the ridge (Cerreto di Spoleto Municipio). During the days following the main shock the permanent array was extended installing a CODISMA in Preci (Gli Scacchi Hotel) a site north-west of Cerreto di Spoleto and an accelerometric station in Foligno at the basement of the towerbell of the Santa Maria Infraportas church. The station was composed of a FBA-23 kinemetrics triaxial force-balance accelerometer connected to a MARS-88/fd Lennartz acquisition system. In table 1 Accelerometric records available to be processed and interpreted for the reported seismic events are listed. Starting from January 2000, ETNA 18 bits accelerographs, in all stations of the Cerreto di Spoleto permanent array, were deployed and CODISMA removed. Finally from May 2000, a temporary array of 3 K2 (12 accelerometric sensors each) was set up to perform a seismic instrumentation of the CEDRAV (Centre for Anthropological Documentation and Research of Nerina Valley) building of Cerreto di Spoleto, up to September 2001. The accelerometric data base ENEA decided to collect all recordings obtained at the Cerreto di Spoleto permanent array stations and surrounding temporary stations developing a data base management system dealing with parameters almost matching the ones inserted into the CD-ROM related to the CEE project Dissemination of European strong motion data. The data base engine was FILE MAKER PRO V.8. The results could be queried by a run-time application. All recordings have been validated and elaborated un order to obtain: uncorrected version of the acceleration; corrected acceleration, velocity and displacement time-histories and response spectra. All data are available as files and plots. Querying the data base, the time-histories will be selected on the base of comparisons between seismological parameters (magnitude, epicentral coordinates, etc.) and strong ground motion features. Fig. 2 shows an example of time-histories and response spectra selection. The final version of ENEA accelerometric data base will contain about 300 recordings related to the 1997 Umbria-Marche crisis, collecting records

from the main shock and after-shocks up to year 2006. Characteristics of Ground Shaking. Records from seismic events with magnitude ranging between 3 to 6, obtained during the Umbria - Marche seismic crisis were processed to recover uncorrected accelerograms time-histories and corrected versions of the ground acceleration, velocity and displacement in time and frequency domain. Some PGAs in the range 0.1-0.4 g were recorded ; particularly high were the values at the station on rock soil (Cerreto Torre) and the record 7098 obtained at Preci (>0.2 g on the NS component for a Md of 4.4) very close to the fault rupture (s-p of 0.8 seconds). Although such readings are not unexpected, and do not directly translate to either building damage levels or appropriate design criteria, PGAs this high (particularly over the nominal code value and any ground motion prediction) generated by seismic events of magnitude less then 6, serve to focus attention to the validity to represent the seismic input selecting some best favorite strong motion parameters. Records from the 26 September 1997 events Time domain analysis The record obtained at Borgo Cerreto Torre (BCT) during the fore shock of the 26 September at 00: 33 show a larger PGA (but shorter duration) if compared with the record obtained at same station during the main shock of the 26 September at 09: 40. This is connected to the fault ropture propagation indicated in the NE-SW direction for the main shock and opposite for the fore shock. Records at Municipio Soffitta of Cerreto di Spoleto (CMS) shows a clear influence of the building. In fact both, frequency and time domain analysis, show a resonant frequency where the seismic wave is amplified. If comparison is made between the Fourier Amplitude Spectrum (FAS) of the acceleration obtained at BCT station and the FAS of the acceleration obtained at the station CMS (e.g. WE component) they are almost equal up to 2 Hz. Then there is a departure on the FAS recorded at CMS, showing much more energy then the FAS in BCT, up to 10 Hz. Unfortunately the station at Municipio Base did not record the events. So we did not be able to de-aggregate the contribution to the FAS of the acceleration obtained in CMS due to the building amplification of the ground motion at the basement from some other contribution (i.e. topographic effect). Records from main after-shocks Records at rock sites show evidence of high frequency content(see figs. records 7042 -7043 - 7044 - 7045 - 7046 - 7047 obtained at Cerreto Torre, 7095 and 7098 obtained at Preci). The seismic event of the 14 October at 15:23 Ml=5.4 produced 2 recordings: Cerreto Torre 7047 and Foligno S. Maria Infraportas 7217. It is interesting to note that records 7047 obtained at Cerreto Torre and 7217 obtained at Foligno have comparable s-p (so the hypocentral distance should be similar) but PGA values are mutch smaller in the second one. Finally the analysis of records obtained in the remaining two stations, Preci and Cerreto Campo Sportivo is very interesting. In fact even if the two stations did not record during the principal events, the records obtained at Preci were important because near to the seismic source (see on figs. records 7095 and 7098 with s-p of 0.8 and 1.2 seconds and max-PGA of 116 and 229 gals and magnitude Md, 3.9 and 4.4 respectively: the Cerreto di Spoleto array, the Norcia SMA-1s as well as the instrument of the ENEL permanent network did not produce any records for those events) and the records obtained at Cerreto Campo Sportivo were important to have an experimental evidence of the seismic waves amplification because of the narrow, geometrically complex, alluvial valley where the instrument was installed (see fig. record 7062 and 7063). The last statement will be more evident in the frequency domain analysis of these records. The 14 October event, was recorded as well at the CMS station. This is important to check the features observed comparing the FAS of acceleration at CMS and BCT during the 26 September events. Frequency domain analysis The analysis of the FAS of acceleration at the site of Cerreto Torre confirms the very high spectral content on records obtained at this station (see e.g. figs. for the WE components of record 7042 and 7043). Spectral values are still important at frequencies larger then 30 Hz. The analysis of the FAS of records obtained at the Cerreto Torre and Foligno stations, during the seismic event of the 14 October, seems to confirm the seismic wave propagation patthern evidenced on the time-histories, probably connected to the fault ropture propagation. There is some more on the spectra comparison(see figs.). The spectral values in Foligno (record 7217) are scaled of a factor, more or less costant in the observed frequency intervall, respect to the spectral values of the record 7047 obtained at Cerreto Torre: it is than possible to state that seismic waves propagate from the hypocenter in such a way that its energy content at Foligno is reduced respect to the energy content of waves at Cerreto Torre of a constant factor at any frequency of interest, even if the hypocentral distance was the same. As previously stated (see time domain analysis) the FAS of the acceleration of records 7062 and 7063 obtained at Cerreto Campo Sportivo show spectral peaks on horizontal components at low frequencies, not evidenced on the vertical component, indicating amplification due to the layers of the alluvial valley (Nerina valley). This amplification refers to frequencies not always in the spectrum showing a dependence from the seismic event. Spectral ratios

The calculation of spectral ratios has been the most applied technique used to estimate site response (Borcherdt, 1970; Rogers et al., 1984; Borcherdt, 1994). In this approch, the spectrum of the ground motion recorded at a site of interest is divided by the spectrum recorded for the same source at a nearby hard-rock site. This method assume that hard-rock site has no amplification on seismic waves. The analysis of recordings obtained during the Umbria-Marche earthquake sequence, at the station of Cerreto campo sportivo show the complexity of the site response to seismic waves excitation. All records shows several peaks both on the FAS of acceleration and on the spectral ratios. Spectral ratios of records 7062, 7063 and 7064 shows common peaks in the frequency interval 4-8 Hz; particular evident the peak at 6 Hz. Comparison between the FAS of horizontal components of the acceleration and the vertical component confirm that, particularly for record 7062, the spectrum in the vertical direction at this frequencies is flat and very low in amplitude. Several other peaks on the spectra (as well on the spectral ratios) are evidenced on the above mentionned records (i.e.,2, 2.2 , 4.6 and 7on the 7062 2, 4, and 9 on the 7063, and several at frequencies less then 2 Hz, 4 , 4.6 and several at frequencies greater then 8 Hz on record 7064) but is clearly cumbersome try to model the site response. Moreover the spectral ratios ant the FFT of record 7061 show evidence of peaks at frequencies somewhat not similar with the others (even if the peak at 6 Hz seems to be confirmed as well as the trend of the spectrum on the vertical direction).

Keywords: accelerometric data base, ground shaking, spectral ratios

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SS003 **Poster presentation** **6342**

Sedimentary basin depth estimated by receiver function and VSP methods in the Chiba Area, Japan

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Synthetic strong ground-motion has been impressively progressed in the last few decades, and its bandwidth resolution has been approaching to three seconds or even shorter. A lack of near-surface velocity-structures, however, unlikely makes the simulation high resolving capability. Overviewing conventional methods of investigation for underground velocity-structures, the vertical seismic profile (VSP) is extremely valuable but too expensive to be widely used. In this study, an attempt was made to extend the VSP results by means of the Ts-Tp travel times obtained by an all-pass receiver functions (APRF) from dense earthquake observations. The APRF function, which was de-convolved from minimum-phase-shift function, can improve the identifiability of original receiver function. We developed the analysis procedure to detect the P-to-S phase and therefore to calculate sedimentary depth down to pre-Neogene bedrock. Over 2000 records at 110 stations around the Chiba area, Japan, were used to calculate APRF. Then, the APRF profiles were constructed along with 5x6 mesh lines. By sum up these profiles, a Ts-Tp imaging of 3-Dimensional travel times were built up around this area. On the other hand, we broke down the existing VSP data down to bedrock layers at 600 to 2000 meters in depth, and created the relationship between a Ts-Tp travel-time and a sedimentary depth. Furthermore, the regression functions of a sedimentary depth versus a Ts-Tp travel time were obtained at the VSP locations. Excellent coincidence of the Ts-Tp travel times between APRF and VSP methods made the study much convincible. Using the APRF functions and the regression functions by VSP, the sedimentary depth contours down to the pre-Neogene bedrock with S-wave velocity over 2.5km/sec have been calculated over the north Chiba area, Japan. The results have been also proved by oil prospecting information.

Keywords: receiver function, vertical seismic profile, sedimentary basin depth

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SS003 **Poster presentation** **6343**

Basement rock in Metro Manila, Philippines inferred using receiver function analyses of strong motion accelerograms

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High rise buildings are progressively constructed in Metro Manila in order to accommodate the increasing number of population having an estimated of 10 million people in year 2000 census. In order to develop a suitable design located in seismically active and industrialized area like Metro Manila, a good investigation of underground structure is of vital importance. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) maintained ten (10) strong-motion accelerographs that were installed in different geological sites in Metro Manila. The Normalized Input-Output Minimization for receiver function (NIOM-RF) has been formulated and applied in this study to identify the basement rock in Metro Manila. The theory of NIOM (Haddadi, H. and Kawakami, H., 1998) was based on the random vibration process considering the statistical correlation of earthquake motion. In frequency domain the input (vertical component) and output (horizontal component) can be related by means of transfer function $H(\omega)$. This transfer function can be obtained by the deconvolution of the vertical component to the horizontal component in frequency domain (Phinney,1964). Since the actual record contains noise, the squared Fourier amplitude spectra of the ground motion of the vertical and horizontal are minimized and weighted using the method of Lagrange multipliers subjected to constraint. The filtered response of radial component is called NIOM receiver function (NIOM-RF). This method is comparable to the deconvolution procedure of Langston, C.A. (1979) for conventional receiver function, in which by conventional one the filtering procedures were made by applying a Gaussian low pass filter to limit the final frequency band and water level method to suppress the holes in the spectrum. The time delays of Ps phase from NIOM-RF and conventional receiver functions were used to estimate the depth of the basement rock in Metro Manila. In this study, the theoretical receiver function based on Haskell method (Haskell, 1962) was also applied to find the appropriate model in comparison with the results of NIOM-RF and conventional receiver functions. In determining the depth of basement-sediment interface, the values of Vp that were used are based on the seismic refraction study of Hirano, et.al (2000) and for Vs are from the microtremor array studies of Masaki, K., et.al, (2000) and Yamanaka, H. et.al, (2000). The basement rock in Metro Manila was identified by covering eight stations equipped with strong motion accelerograph. The basement rock beneath PHV station in Quezon City has an estimated depth of 1.2 km. This result is acceptable and the value is close to seismic refraction study of Hirano, et.al, (2000) having a basement depth of 1.4 km near PHV site.

Keywords: receiver, functions

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SS003 **Poster presentation** **6344**

Basin and crustal velocity structure model for strong ground motion prediction in Kinki area, SW of Japan

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We construct a basin and crustal velocity syructure model in Kinki area, South-West of Japan, for strong ground motion prediction. The headquaters of earthquake research promotion reported that a long-term evaluation of occurrence potentials of the next Nanaki and Tonankai earthquakes are more than 50% within 30 years from 2006. Quantitative evaluation of long-periond ground motions in the large basin is quite important issue for earthquake disaster reduction. We collected reflection profiles, seismic tomography results in this area for constructing crustal velocity structure model. The basin velocity structure model of Osaka, Kyoto, Nara, and Ohmi area are put into this crustal velocity sytructure model To examine the applicability of the velocity structure model to long period ground motion prediction, waveform simulations for intermediate-size event occurred in this area are conducted. Predominant periods of observed ground motions are well recovered by this simulation.

Keywords: strong motion prediction, basin velocity structure

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SS003 **Poster presentation** **6345**

Ground motion characteristics using ambient noise in Bangalore, India

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Noise measurements have been carried out in Bangalore city, India at about 60 different locations. The resonance frequency for each site has been estimated from the main peak in the spectral ratio of the horizontal and vertical component, obtained from Nakamura technique. These dominant frequencies range between 2 to 11 Hz in the Bangalore region. The soil cover thickness obtained from borehole data at different locations in Bangalore ranges between 2 m to about 30 m. Also, we have estimated the cover thickness from the frequency of the main peak in the H/V spectrum using simple formula and compared with the soil thickness obtained from bore hole investigations. The frequency of the main peak in the spectral ratios correlates with the soil thickness for the given site. From this study one of the salient results is, sites conspicuous with lower resonant frequencies correlate with the lake beds having thicker soil cover.

Keywords: ambient noise, bangalore, nakamura technique

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SS003 **Poster presentation** **6346**

Site effect in central Iran, Yazd city.

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Studying site effect is a necessary stage in seismic hazard assessment. It plays an important role in damages and reducing damages produced by earthquakes, particularly in places with strong earthquakes, such as intraplate environments. Central Iran as a part of Iran plateau, has intraplate seismic behavior, and beside, has important and populous cities. In our study we tried to determine site effect in Yazd city located in central Iran. Eight holes caved in different parts in city and geotechnical data produced. Using these data and what was accessible from holes caved before and considering geological data, amplification factor and frequency of amplification were determined in different points. Finally isoamlification factor and is isoamlification frequency maps of Yazd city were produced.

Keywords: site effect, geotechnical data, yazd city

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SS003 **Poster presentation** **6347**

Determination of predominant periods of Meridas City soils, from ambient vibrations measurements

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As part of the studies of seismic microzonation which are carried out in different cities of Venezuela by the Venezuelan Foundation for Seismological Research with the collaboration of the different universities of the country, arose the necessity of doing this project where the fundamental periods was determined for soft-sedimentary (soil) deposits of the city of Merida, starting from mensurations of ambient vibrations and with the application of the Nakamura Technique. We have to remember that Venezuelan Andes represents a high seismic hazard region due to the presence of right-lateral strike-slip Bocono fault, with more than 400 Km. of extension, that affects tomain cities of mountain range. For this reason, it is very important to know and to evaluate the behavior of soils during the influence of a seismic event, in order to work in the creation of control and evaluation mechanisms of the different structures that are built, specifically in the city of Mrida-Venezuela.To reach this objective, the Nakamura Technique was applied to 170 mensurations made out in different parts of the city with an approximate spacing of 500 meters among each station. For the processing and interpretation of the acquired data was used the LabView andJSesame softwares.With the results obtained when was found the H/V spectral ratio, we elaborated a periods distribution map of the city, where it is pointed out the areas of high seismic risk in correlation with the sites geology. In this sense, we found Proterozoic and Paleozoic associations, Carboniferous-Permian, Jurassic and Tertiary formations and sediments belonging to the Pleistocene alluvial terrace of Merida.On the other hand, it was defined a proportional relationship between the period and the thickness of fans sediments, where the highest ranges in periods correspond with the biggest thickness in the terrace, in agreement with the medium velocity and possible acoustics impedance contrasts. The values of thickness were obtained of the geophysical modelling project of Merida metropolitan area underlying basement from the processing and interpretation of gravimetric data.The ranges of periods that were determined for the city of Merida oscillate between 0,09 and 1 seconds.

Keywords: ambient vibration, predominant period, seismic microzonation

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SS003 **Poster presentation** **6348**

Numerical simulation of long-period strong ground motions in Tomakomai, Hokkaido during the 2003 TokachI-Oki, Japan, earthquake

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We successfully reproduced important features of the long-period (7 to 8 s) large-amplitude (about 0.4 m/s) ground motions observed within the Yufustu sedimentary basin, Hokkaido, during the Mw 8.0 2003 Tokachi-oki, Japan, earthquake through numerical simulation of seismic-wave propagation. These long-period strong ground motions excited sloshing of liquid in large oil storage tanks in the city of Tomakomai within the basin and caused severe damage such as fire and sinking of floating roofs to the several tanks. The most important feature of the observation was the recording of the strongest long-period shaking around the Tomakomai west port, where the oil storage tanks were severely damaged. To better characterize the underground structure of the Yufutsu basin, we carried out 2-D and 3-D numerical simulations of seismic-wave propagation using the available underground structure data and the finite difference method, and tried to reproduce the observed spatial variation of the long-period shaking within the basin. As a result, we found two factors that brought the strongest long-period shaking around the Tomakomai west port. One is the near-surface soft deposit around the port. Our calculated waveforms from the 2-D simulations match the observations, explaining the significant spatial variation of the long-period shaking within the basin. The characteristics of the basin model assumed in these simulations are as follows: (1) The depth of bedrock with an S-wave velocity over 3 km/s is about 4 km beneath the port area, while its depth is about 6 km in the east of the port area, where the long-period shaking was weaker compared with the port area; (2) The near-surface low-S-wave-velocity (less than 0.8 km/s) sediments are the thickest (about 1 km) beneath the port area. We therefore consider that the thickness of the near-surface soft sediments rather than the bedrock depth governed the spatial variation of amplitudes of the long-period (7 to 8 s) shaking within the basin. These findings suggest the need for understanding the detailed structures of near-surface soft sediments as well as the deep basin structure such as bedrock depth for predicting long-period strong ground motions in deep sedimentary basins. The other factor is the boundary between the basin and the surrounding mountains. The Tomakomai west port is located near the western edge of the Yufutsu basin. Our 3-D wave propagation simulations demonstrated that the western boundary of the basin laterally refracts surface waves coming from the southeast and the consequent constructive interference between the refracted waves and the incident waves increases the amplitude of the long-period shaking near the port area. We so presume that the strongest long-period shaking around the port was partly related to the planar shape of the western basin boundary and the position of the port area to the western basin boundary, although the major factor is the near-surface thick soft sediments beneath the port area. These findings suggest that the effects of basin edge should be also carefully considered for accurate prediction of long-period strong ground motions at sites near basin edges.

Keywords: long period ground motion, 2003 tokachi oki earthquake, wave propagation simulation

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SS003 **Poster presentation** **6349**

Estimation of site resonance frequency using microtremor records

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Microtremor measurements were carried out in the sarcheshmeh copper mine (southern iran) area at about 12 sites and the resonance frequency at each site was estimated considering the main peak in the spectral ratio between the horizontal and the vertical component, the method so called NAKAMURA technique (H/V). Many experimental and theoretical studies have been shown the reliability of microtremor measurements in site predominant frequency estimation. At each site traces have been collected 3 or 4 times and for all of them natural frequency based on sesame project group standards have been analyzed. Then on the basis of natural frequency, site soil types have been determined and average Shear wave velocity for each site has been predicted. All Results compared with available field observations.

Keywords: microtremor, nakamura technique, natural frequency

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SS003 **Poster presentation** **6350**

Influence of soil conditions on building seismic response application to Angra do Herosmo

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Within the framework of the project COMICO (Contribution to Seismic Risk Mitigation for Ponta Delgada, Angra do Herosmo and Horta Towns), a study on the seismic response of the Angra do Herosmo building stock was developed, in order to estimate the coupling between its vulnerability and the underlying soil conditions. The basic principle is very simple and well-know: if the building and soil natural frequencies coincide, in the occurrence of a seismic event, the building can undergo "double" resonance and, consequently, suffer more severe damage than similar buildings lying on rock or other soil conditions. Our main contribution has been to try and quantify such a damage increase, through a methodology based on the following procedures: (1) definition of ground representative soil columns, through the analysis of ambient vibrations and geologic cartography; (2) determination of the seismic response of the soil columns, using real and synthetic accelerograms for different epicentral distances and magnitudes; (3) analysis of the displacements suffered for an oscillator with 1 degree of freedom and elastic-plastic behavior, when submitted to the accelerograms obtained in point (2); (4) derivation of a damage estimate from the comparison of these displacement values and the yield and ultimate displacements associated with building typology (on the basis on RISK-UE capacity curves). This methodology is applied for different building typologies of Angra do Herosmo town.Finally these results are interpreted in terms of increase on macroseismic EMS98 intensity, in order to be integrated in seismic scenarios.

Keywords: site ffects, vulnerability, soil conditions

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SS003 **Poster presentation** **6351**

Seismic vertical array analysis: Phase decomposition for S and surface waves

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It is important for interpretation of the seismic responses of a sedimentary basin to distinguish S and surface waves on strong-motion seismograms. A vertical array analysis method that decomposes S and surface waves from a set of surface and borehole seismic records (horizontal components) are proposed. We assume that one of horizontal components consist of S wave and only one kind of surface (Love or Rayleigh) wave. This assumption may be reasonable for a 2-D sedimentary basin. The Fourier transform of each phase at the borehole is expressed as the product of the Fourier transform of that phase at the surface and the transfer function of that phase. The transfer functions are obtained by the Haskells matrix method assuming a 1-D velocity structure. Array data vectors consist of the Fourier transformed set of vertical array records and elements of the condition matrix consist of the transfer functions at each frequency. Wave model vectors that consist of the Fourier transforms of S and surface waves for the surface records can be estimated by solving normal equations for a given frequency. A decomposed waveform of each phase is obtained by the inverse Fourier transform of each element of the estimated wave model vectors. We apply this method to the vertical array records observed at the northwestern part of Sapporo, Japan. This vertical array is located on the thick (> 2km) sediment and at 3.5 km northeast from the basin edge. Three observed array records of nearby intermediate-depth earthquakes are analysed assuming that Rayleigh waves are on the edge-normal component and Love waves are on the edge-parallel component. The array analysis results for ground motion with frequencies of about bout 0.5 - 1 Hz show short duration of the direct S wave and long duration, late arrival surface waves. The estimated records are good agreement with synthetic seismograms calculated by a 2-D finite difference method for a sedimentary basin model assuming vertical incident plain SH and SV waves. The simulation indicates that the basin-induced surface waves are generated at the southwestern basin edge and arrive at the array in the expected times.

Keywords: vertical seismic array, ishikari plain, surface wave

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SS003 **Poster presentation** **6352**

Confirmations of 3D basin structure models by long-period ground motion simulation - in case of Osaka basin, western Japan -

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Tomotaka Iwata

Osaka area, western Japan, is located inside a sedimentary basin (about 60km x 40km) surrounded by mountains and has bedrock depth of about 3km at the deepest. Because of this underground structure, long-period ground motions with large amplitude are observed during a large earthquake. During the 2004 Off Kii Peninsula earthquake sequence that occurred near the source region of the hypothetical Tonankai earthquake, we have recognized site dependent characteristics in predominant period and polarization of ground motions at many stations inside the basin. In order to study these long-period ground motion characteristics inside the basin, it is critically important to assess basin velocity structure models for long-period ground motion simulations. Osaka area is full of geological and geophysical underground information and several researcher groups have constructed 3D basin velocity structure models. In this study, we conducted long-period ground motion simulations based on two kinds of basin structure models (Kagawa et al., 2004 and Horikawa et al., 2003), aiming to reproduce the observed long-period ground motion characteristics at each station and examine the appropriateness of each basin structure model for long-period ground motion simulation. The basin structure model by Kagawa et al. (2004) consists three sedimentary layers whose depths are proportional to the bedrock depth that is expressed with smooth B-spline function. The seismic velocities and the density are homogenous throughout each layer. On the other hand, the basin structure model by Horikawa et al. (2003) is constructed by adding geological structure information containing thrust faults. The velocities and the density in the sediment change with the depth and the rock type, and are given to all of each grid. We conducted numerical ground motion simulations of the largest aftershock (2004/09/07 08:29 JST, MJMA 6.4) by the 3D finite-difference method with non-uniform staggered grids (Pitarka, 1999) in the period of 3 to 20s, based on the two basin velocity structure models; (a) by Kagawa et al. (2004), and (b) by Horikawa et al. (2003). The area of each calculation is 250km (NS) x 300km (EW) x 50km (Depth), including the source and the basin area of 90km x 90km. Past studies (e.g., Yamada and Iwata, 2005) have shown that the sedimentary wedge of the subduction zone of the Philippine Sea plate contributes to the long duration and amplification of the long-period ground motions. In this study, we applied a 1D simple crustal structure to the area outside the basin, which does not take into account of the sedimentary wedge. Therefore, we attempted to reproduce the wave field inside the basin by the following method. We define a site-to-site relation, or a transfer function, between ground motions of a basin site and a reference rock site. Assuming a calculated transfer function is identical to the observed one, simulated ground motion at a basin site is obtained by taking the convolution of calculated transfer function and the observed ground motion of the rock site. We compared simulation results by two velocity structure models with observation in velocity waveforms and pseudo-velocity response spectra. Both models (a) and (b) fairly well reproduced the observation not only on response spectra but also on waveforms at most stations inside the basin. At some stations, especially where the bedrock depth sharply changes, simulation by (b) was better at reproducing the characteristic predominant period than (a), which suggests that model (b) describe the basin-edge shape more precisely. We also conclude that our method can be used to examine the appropriateness of basin velocity structure models.

Keywords: 3d basin structure model, long period ground motion, waveform simulation

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SS003 **Poster presentation** **6353**

Site Response Analysis During the Dec. 26, 2006 Hengchun, Taiwan Earthquake

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A ML7.0 earthquake took place at 20:26:21.0 (local time) on December 26, 2006 at southwest of Hengchun. The epicenter was located in the offshore area. About eight minutes later at 20:34:15.1 another ML7.0 strong shock occurred. The Seismology Center of Central Weather Bureau stated that according to its records there has never been such a large earthquake taking place within 50 km of these two shocks. These earthquakes took place in an area where the Eurasian and Philippine Sea plates interact. Unit 2 of Taipower's Nuclear Power Plant No. 3 (NPP3) was manually shut down. Two backfilled areas found liquefaction near Nuclear Power Plant No. 3. In summary, these earthquakes caused 2 deaths, 42 injuries. They also caused 3 houses to collapse, 12 fires. The earthquakes also caused massive failures of major submarine fiber-optic cables in the offshore areas of Hengchun, resulting in severe disruption of international telephone and internet connections. The horizontal-to-vertical spectral ratio has become popular to determine the predominant period and amplification of a site. In this study, this method is used to identify the nonlinear site effects occurred during the 2006 Hengchun, earthquake or not. To establish this fact, the horizontal-to-vertical spectral ratios of the 2006 Hengchun, earthquakes records are compared to that of the weak motion records before the earthquake occurred in the southwestern area.

Keywords: horizontal to vertical spectr, nonlinear site effect, liquefaction

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SS003 **Poster presentation** **6354**

Seismic Microzonation for a Test Area at Mt Etna : The Use of Seismic Noise as a Measure of Ground Truth

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The importance of local geological conditions for earthquake damages is widely accepted by now and is a central topic in seismic zonation, in particular microzonation projects. Typically the local effects are accounted for by estimating geotechnical parameters for the various geological units being used either to establish suitable site factors in empirical approaches or as physical input parameters in numerical forward modelling techniques. A certain drawback of this approach lies in the lack of ground truth as the behaviour of the wave-propagation medium is not really measured. Seismic noise has been exploited to determine the thickness of soft cover layers, which is obtained from the main peak of the Nakamura H/V spectrum. The study presented here concerns an area of Tremestieri Etneo, a town at the foot of Etna volcano. For this area a number of shallow seismic soundings are available. In 2004 a series of seismic noise measurement where carried out at various sites of Tremestieri Etneo. In the H/V spectrum we found a characteristic amplification in the frequency interval between 1 and 3 Hz. The E-component was by far prevailing. From a polarization analysis we found a clear principal direction perpendicular to the strike of the fault. Similar features were found in seismograms of four small tectonic earthquakes which were recorded at a seismic station operating at one of these sites for several months in 2005. We compare the results obtained with the Nakamura spectra to those found with the nonlinear one-dimensional analyses of three sites, where geotechnical down-hole data are available. The comparisons reveal a clear discrepancy between the two methodologies, as the resonance frequencies from the available geotechnical parameters are above 5 Hz. The differences can be explained by the fact that the boreholes are limited to a depth 30 m of depth, bringing along the risk of ignoring the effects of deeper structures as well as the presence of nearby faults. The strong relation of the polarization characteristics of the seismic noise recordings to the strike direction of the nearby fault makes us doubt that the peak in the H/V spectrum can be interpreted easily as a resonance frequency of some layer in a 1D velocity structure. This makes the use of 1D velocity model for the synthetic generation of accelerograms questionable. On the other hand we can exploit our noise analysis in a heuristic way by adjusting the Fourier spectra of the synthetic accelerograms according to the characteristics of the Nakamura H/V spectra. Finally we estimate response spectra calculated on the base of the modified accelerograms. We demonstrate the results of this approach for earthquake scenarios typical for the region of Mt Etna.

Keywords: noise, microzonation, strong motion

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SS003 **Poster presentation** **6355**

Working with seismic microzonation: improving methods for subsurface modelling

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The geological model of the subsurface is an important starting point for the analysis of site effects in seismic microzonation studies. The aim of the work, which is part of a PhD project aiming to develop methods for the seismic microzonation of some representative test areas of Lombardia Region (northern Italy), is to present a methodology for the development of a 3D geological model of quaternary sediments in urban environment. The test site is the town of Varzi, located in the northern Appennine chain in the southern part of Lombardia region. The choice of this particular place was mainly based on the geological context and on the hazard scenario assigned by Italian code. Varzi is located in a characteristic Appennine Valley covered by terraced quaternary deposits and by clayey colluvial deposits variously involved in slope movements. Moreover, this area can be considered as geologically representative of a large part of the Italian Apennines. This town was also classified as falling in zone 2 on 4 of hazard from Italian code, and is one of the zones most exposed to risk considering that in Lombardia region the value 2 is the highest. The geological and geotechnical data (boreholes, trenches, CPT, DCPT tests) were collected from the public administration or from site investigation reports and a geological and geotechnical GIS was then created. The data were processed, analysed in terms of quality and validated.The study site was divided into several morpho-engineering geological units (areas that may be regarded as homogeneous from the geomorphological and engineering geological point of view) In the same time, a survey campaign with a tromograph (Tromino) provided by Protezione Civile Nazionale, (the national organism for civil protection) is in progress, in order to derive a map of the fundamental frequency of resonance of the ground from single station recordings of ambient vibrations. In this phase of the analyses, the fundamental frequency allows a structural interpretation of the subsurface if the velocity is known, trough the depth of impedance, other than be a low cost-time tool. The combination of these different steps makes possible the construction of a 3-D model of the subsurface with the support of GSI3D program. The final goal is to propose a method fitting both the best understanding of subsurface conditions in advancing a microzonation study and the needs to find an as inexpensive as possible model that could be easily reproduced for similar situations also by professional geologists.

Keywords: seismic microzonation, subsurface modelling

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SS003 **Poster presentation** **6356**

Estimations of the S-Wave Velocity Structures at the Tainan Basin, Taiwan, Using the Array Records of Microtremors

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Jung-Huang Chen

Shallow shear-wave velocities have been widely used for earthquake ground-motion site characterization. Thus, the S-wave velocity structures of the Tainan area, Taiwan are investigated using the array records of microtremors at 18 sites. The dispersion curves at these sites are calculated using the F-K method (Capon, 1969); then, the S-wave velocity structures at the Tainan area are estimated by employing the surface wave inversion technique (Herrmann, 1991). At the frequencies between 0.2 and 2.1Hz, the propagation directions are concentrated between the northwest and south quadrants. The generation of these may be attributed to the effects of the Taiwan Strait on the coast. The harder site (CHM at the Tainan terrace) has higher phase velocities, while the softer site (SIM at the Anping plain) has lower phase velocities, especially at the frequencies of 0.3~5Hz. If the S-wave velocity of bedrock is assumed to be 1500m/sec, the depths of the alluvium at the Tainan area arebetween 400m (CHM) and 1350m (FUP at the Anping plain). The depth of the alluvium gradually increases from CHM at the Tainan terrace (the central part) to the surrounding area. This result is in good agreement with the geology of the Tainan area.

Keywords: microtremor, s wave velocity, f k method

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SS003 **Poster presentation** **6357**

Development of a GIS-based geological-geotechnical model of the Vega Baja (SE Spain) for site effects and microzoning applications

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A geological, geotechnical, and geophysical characterization of the Vega Baja del Segura region is been conducted as a part of the Spanish funded project EVITA2. The main goal of EVITA2 is to develop a prototype of an integrated tool to map seismic hazard scenarios at regional and local scales.Located SE Spain, in the Lower Segura Basin, the Vega Baja can be considered at present as a moderate earthquake activity region although a number of destructive earthquakes have occurred in the past. Both the very recent rapid growth of urban developments together with the specific peculiarities of soil condition in the area have greatly increased seismic risk.We use digital geological cartography and surface geology together with geotechnical data (456 boreholes corresponding to 113 locations of which 130 incorporate in-situ and laboratory tests) as collected from public and private sources and complemented with data in the available literature. We have conducted field surveys of ambient-noise recording for S-wave velocity profiling and horizontal-to-vertical spectral ratio (HVSR) analysis. The empirical results from ambient-noise recordings have been compared and complemented with analytical 1D shear wave propagation modelling, adding constrains to improve the developed geological-geotechnical model.Geological, geotechnical and geophysical geo-referenced data have been harmonized in a common relational database fully compatible with GIS tools. Based on this comprehensive geo-database compiled for the area, the analysis of site effects for different scenario earthquakes is carried out.

Keywords: earthquake hazard, site effects, gis

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SS003 **Poster presentation** **6358**

A Detailed Geophysical Study for Disaster Risk Management and Mitigation in a Highly Seismicity Area

Dr. Pantelis Soupios
Natural Resources and Environment Ass. Professor IAG

Filippos Vallianatos, John P. Makris, Pantelis Soupios, Vasilios Saltas, Ilias Papadopoulos

In the present work, a detailed surface geophysical investigation on the broader area of Yalova city in Turkey was carried out, in the framework of a risk assessment project entitled "Marmara Earthquake Rehabilitation Program- MERP" of the properties of soil and ground water at the site under investigation. City of Yalova has been heavily damaged by strong earthquakes (M>7) eight times during the past 2 centuries, with the last shock in the 17 August 1999, which killed 18,000 people, destroyed 15,400 buildings, and caused $10-25 billion in damage. Electrical resistivity tomography (ERT), vertical electrical sounding (VES), seismic refraction method and horizontal to vertical spectral ratio method (HVSR), in conjunction with the available geological and geotechnical characteristics were used to help determine the dominant direction of fracture strike, subsurface structure of the city, locations of possible fracture zones or conductive lithologic layers, which could be easily correlated with liquidation phenomena. Five groups of similar geological structure are proposed, based on the resulted velocity models. This work is partially supported by the project ARCHIMEDES I: "Support of Research Teams of Technological Educational Institute of Crete", sub-project entitled "Multidisciplinary Seismic Hazard monitoring in the Front of the Hellenic Arc" in the framework of the Operational Programme for Education and Initial Vocational Training.

Keywords: risk management, geophysics, seismology

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SS003 **Poster presentation** **6359**

Earthquake risk mitigation on mediterranean monumental heritage subjected to local site amplification

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Casciati Sara, Marcellini Alberto

An innovative retrofitting technique based on the use of shape memory alloys (SMA), is investigated with reference to a specific case study, represented by one of the Memnon Colossi, at Luxor, in . The famous monument is composed by two 18 m high statues, which stand on a silt deposit of thickness 6 m, underlain by a layer of compacted limestone. The presented paper focuses on the south Memnon Colussus alone. A seismic hazard analysis of the region was performed by Casciati et al. (F. Casciati, S. Casciati and A. Marcellini, 2003), where an earthquake of magnitude 5.5, at a distance of 100 km, was identified as reference ground motion. The retrofitting strategy consists of installing dissipative devices, made of SMA wires, between the cracked stone blocks. In order to preliminarily assess the effects of such a retrofit, a full three-dimensional dynamic soil–foundation–structure interaction (SFSI) analysis is carried out using the finite element (FE) method in the time domain. The statue comprising the upper structure is modeled using 3D brick finite elements; a very refined mesh is created on the basis of a photogrammetric representation (S. Casciati and R. Borja, 2004). FE models of the foundation and the surrounding soil deposit are constructed and coupled with the statue model to analyze the seismic response of the entire system, incorporating the dynamic SFSI effects. The SMA devices (in austenitic phase) are introduced in the model through mono-dimensional beam FE with super-elastic behavior. Numerical simulations are carried out in order to analyze the effectiveness of the proposed retrofitting strategy in reducing the risk of cracks growth under seismic event. Particular attention is paid to the modeling of the seismic excitation and, in particular, to the site amplification effect due to the silt deposit. This issue is addressed by simulating the reference ground motion through a hybrid-stochastic approach, and by computing the local site amplification effect using SHAKE91. The benefic effects of the rehabilitation strategy are evidenced by comparing the results of the analyses with those obtained by not including the SMA devices. Therefore, the proposed methodology can be used as a non-invasive retrofitting technique for historical monuments.

Keywords: soil structure interaction, shape memory alloys, site effects

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SS004 **6360 - 6388**

Symposium
Earthquake Hazard, Risk, and Strong Ground Motion - Estimation of strong ground motion

Convener :
Co-Convener : Dr. John Douglas

The accurate estimation of the characteristics of the shaking that occurs during damaging earthquakes is vital for efficient risk mitigation in terms of land-use planning and the engineering design of structures to adequately withstand these motions. At present there are numerous methods for estimating these characteristics ranging from empirically-based methods using data recorded during previous earthquakes (commonly referred to as attenuation relations), through kinematic simulation methods of various complexity to fully dynamic models. In addition, there are a number of hybrid methods that seek to combine benefits of different approaches. These methods all have their own advantages and limitations that are not often discussed by their proponents. Contributions to this session are sought that discuss these different methods of ground-motion prediction, in particular, with respect to their associated uncertainties and also the advantages and disadvantages of different methods. What is the most appropriate method to use for varying quality and quantity of input data and for different seismotectonic environments? How can the best use be made of the available data? How can the uncertainties associated with a given method be properly accounted for? Ground-motion estimation in regions of the world where strong-motion recording history is short (most regions of the world outside California and Japan) and/or seismic activity moderate poses particular problems since there is limited observational data to allow robust empirical prediction or to constrain free parameters in simulations. Reliable ground-motion estimates are, however, required for these parts of the world in order to correctly estimate the earthquake risk and often, for high importance facilities such as nuclear power stations, for long return periods. Contributions that address the issue of how to provide reliable ground-motion estimates in regions with limited observational data are invited. The associated uncertainties within ground-motion prediction remain high despite many decades of research and many sophisticated techniques. The unchanging level of aleatoric uncertainties within empirical ground-motion estimation equations over the past thirty years are an obvious example of this. However, estimates from simulation methods are similarly affected by large (and often unknown) uncertainties. These large uncertainties oblige earthquake engineers to design structures with large factors of safety that may not be required. Papers that suggest methods to reduce the uncertainties associated with ground-motion estimates by, for example, better characterising the earthquake source, travel path or recording site are requested. In addition, contributions on other aspects of strong ground motion estimation are welcome.

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SS004 **Oral Presentation** **6360**

Investigating the relative importance of site and source effects to strong ground motion variability by using analysis of variance

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ARNRIS BRGM IASPEI

Pierre Gehl

A simple method to quantitatively assess the relative importance of unmodelled site and source effects to the observed variation in ground motions is presented. For the purpose of testing this procedure, four sets of observed strong-motion records, from: Umbria-Marche, Molise, Turkey and French Antilles, are used. The method consists of analysis of variance (ANOVA) using the computed residuals with respect to an empirical ground-motion model for strong-motion records of various earthquakes recorded at a common set of stations. ANOVA divides the overall variance into the components due to site and source effects not modelled by the ground-motion model plus the residual variance not explained by site or source. In addition two-way-fit plots as introduced by Tukey are used to visualise the results. It is found that for two sets of data unmodelled site effects dominate (Umbria-Marche and Molise) whereas for the other two (Turkey and French Antilles) unmodelled source effects dominate. This simple technique could be used to decide, for a given strong-motion dataset, where effort should be concentrated to reduce the large uncertainties in empirical ground-motion estimates.

Keywords: analysis of variance, uncertainties, ground motion estimation

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SS004 **Oral Presentation** **6361**

On the regional dependence of earthquake strong ground motion

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In seismic hazard assessment it is common practice to use ground-motion models, often developed by regression on recorded accelerograms, to predict the expected elastic earthquake response spectra at sites of interest. An important consideration when selecting ground-motion models is the possible dependence of earthquake ground motions on geographical region, i.e. are median ground motions in the region of interest (the target region) for a given magnitude and distance the same as those in the region where a ground-motion model is from (the host region)? and are the aleatoric variabilities of ground motions also similar? These questions can be particularly difficult to tackle in regions where little observed strong-motion data is available, such as in many parts of the world, since there are few records to validate the choice of model. In this study, reasons for regionally-dependent ground motions are discussed and possible regional dependence of ground motions is examined using published ground-motion models, observed accelerograms and also by using ground motions predicted by published stochastic models.

Keywords: regional dependence, ground motion models, stochastic method

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SS004 **Oral Presentation** **6362**

On the scattering in log-normal distribution of the peak ground acceleration residuals in Alborz region, Iran

Mr. Hadi Ghasemi

SS004 Earthquake Hazard, Risk, and Strong Ground M SS004 Earthquake Hazard, Risk, and Strong Ground M IASPEI

Mehdi Zare

The scattering of residuals has great influence on probabilistic seismic hazard assessments which are fairly upgraded from their original method by including the scatter in the integration scheme and several methodologies for desegregation. This article gives the results of the scattering study in the obtained residuals based on the recently developed attenuation relationship for Alborz region. Several statistical tests have been applied to show to what extend the scatter in residuals is truly represented by the normal distribution. As revealed by the results of the present study the lognormal distribution is valid just in the range of three standard deviations around the median value. Thus the truncation in PSHA studies must be considered in the given range.

Keywords: psha, attenuation, residuals

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SS004 **Oral Presentation** **6363**

An estimate of the attenuation relationship for strong ground motion in the Kivu Province, Western Rift Valley of Africa.

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On the basis of the assumption of identical seismic response at three sites (Lwiro , Katale and Kunene) located within the Western Rift Valley of Africa, attenuation relationship based on simu-lating strong motions of large earthquakes using recordings of small earthquakes has been calcu-lated . Results show that the attenuation of average peak ground acceleration Y is related to the magnitude M and the epicentral (hypocentral) distance R according to the the following power laws: M=5.0 Y= 1.42 exp. (1.43 M) R sup. -1.1 M=5.5-6.5 Y= 1.42 exp. (1.43 M) R sup. -1.2 M=7.0 Y= 1.42 exp. (1.43 M) R sup. -1.3 M=7.5 Y= 1.42 exp. (1.43 M) R sup. -1.4 The peak ground acceleration Y and epicentral (hypocentral) distance R are expres-sed respectively in gal and kilometre (km).

Keywords: attenuation relationship, strong ground motion, western rift valley of africa

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SS004 **Oral Presentation** **6364**

Estimation of ground motion at damaged area during 1992 Cairo earthquake using empirical Green's function

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Seismology Researcher

Elsayed A. Fergany, Sumio Sawada

The purpose of this article is to analyze possible causes for failure of the structures at the damaged area following the magnitude M 5.9 Cairo earthquake on 12 October 1992. The degree of earthquake damages various widely with Cairo, Fayium, along the Nile River, and in the Nile Delta basin. These areas are characterized as the areas where the thick unconsolidated sediments develop. Devastating damage was confined to the suburban regions such as El-Faiyum and Al-Ayat where the epicentral area located. Damage statistics for village in the epicentral region imply at the maximum intensity of VII+. To analyze the possible causes of serious damage, we estimated the ground motions at the devastating damaged area. Because no records exist in the damaged area and new observation stations were installed in 1997, good records were obtained by four seismic stations for empirical Green's function to calculate the ground motions in the damaged region. The synthesized ground motions at the four sites in devastating damaged area given peak acceleration to have been near 300 gal. The estimated ground motions were discussed with the wreaking immense damage during the 1992 Cairo earthquake. We concluded that this earthquake caused unexpected damages in compared this ground motions scale with the other countries like as Japan and United States. This immense damage may be attributed to the weakness of building in Egypt which illegally constructed or constructed by poor construction work.

Keywords: ground motion, damaged area, nile deposits

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SS004 **Oral Presentation** **6365**

Empirical PGA prediction equation for the Chi-Chi seismic zone

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Fang-Ru Wu

After 1999 Chi-Chi, Taiwan earthquake, the source area of the Chi-Chi earthquake became another important seismic zone that should be included in the future analysis of seismic hazard in Taiwan. However, the ground motions prediction equations particularly for this seismic zone are still unavailable. Before the Chi-Chi earthquake, the seismicity in this area is low and there is lack of data for such study. The Chi-Chi earthquake and its aftershocks provide a great data set for developing such prediction equations. In this study, we select earthquakes with moment magnitude 5 and above and its epicenter within 30 km of the epicenter of the Chi-Chi earthquake to develop empirical prediction equations. We introduce genetic algorithm in developing empirical equation. Results are compared with that of the two-stage method. No matter the difference in coefficients, these two methods gave similar estimations for most of the observed data. If consider the standard error and the easy implementation, genetic algorithm seems to be a better algorithm for our data set. Based on residual analyses and comparisons with island-wide prediction equations, we conclude that a specific prediction equation for this seismic zone is necessary and site effect term in our model needs further improvements.

Keywords: peak ground acceleration, prediction equation

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SS004 **Oral Presentation** **6366**

Real-time shake maps in Southern Alps area: calibration and validation

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Costa Giovanni, Delise Andrea, Sandron Denis, Suhadolc Peter

We have implemented for Southern Alps area the generation of real-time (within 5 minutes) shake maps for PGA, PGV, SA (0.3, 1.0 and 3.0 s) and macroseismic intensity. The necessary waveforms are retrieved from real-time system Antelope implemented in the framework of an Interreg project. The calibration of Shake Maps software (Wald et al., 1999) requires knowledge of the soil geology and ground-motion relations for the interested region. As for soil classification use is made of the digital maps for the Friuli Venezia Giulia region that classify soils into three categories: rock, stiff soil and loose soil. Work is in progress as it concerns near-border regions of Slovenia and Austria. Two different ground-motion attenuation-with-distance relationships are used in different magnitude ranges. The ground-motion relations for PGA, PGV and SA are computed for Southern Alps area using strong-motion data, recorded from RAF-RAN integrated network, in a large magnitude range (3.0 <= Ml <= 6.3) with the epicentral distances smaller than 100 km. When $M \geq 6.3$, we use the relations proposed by Sabetta and Pugliese (1996) valid for the whole Italian territory. To compute the instrumental intensity, i.e. the expected shaking intensity values from recording ground-motion parameters, the Faccioli and Cauzzi (2006) relationships derived from Italian data is used. Receivers and interpolation grids are set taking into account the geometry and the characteristics of the integrated network of stations available in the area, with a mean spacing in Friuli Venezia Giulia of 20 km. We validate our software by comparing, for important past seismic events in the studied area, the shake-maps results obtained using the actually recorded data with those derived from synthetic seismograms only.

Keywords: shake maps, southern alps, real time

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SS004 **Oral Presentation** **6367**

Long-period earthquake ground displacements recorded on Guadeloupe (French Antilles)

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Displacement time-histories derived from accelerograms of two large recent earthquakes in western North America (Hector Mine, Mw=7.1, and Denali, Mw=7.9) have been shown to feature long-period (~ 10 s) ground motion pulses. Such long-period displacements cause a bump within the displacement response spectrum that is currently not commonly considered within earthquake engineering design spectra. These displacement pulse have also been shown to be persistent and feature on time-histories from widely-separated stations (~ 20 km). Broadband and accelerometric data from the Les Saintes earthquake sequence of 2004-2005 (4.9 < M_w < 5.3) recorded on Guadeloupe (French Antilles) are shown in this study to feature similar long-period motions. The broadband data is used to independently corroborate the displacement time-histories derived through high-pass filtering and double integration of accelerometric data. It is shown that high-quality broadband data is suitable for this purpose. The long-period motions observed cause a bump in displacement response spectra at periods between 5 to 10 s. Such findings strongly suggest that the common practice of assuming that displacement spectra are flat from periods below 4 s needs to be reconsidered. These findings also suggest that the source mechanism of such events may be abnormal for crustal earthquakes and may possible involve the presence of fluids within the source.

Keywords: strong motion, displacement spectra, fluids

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SS004 **Oral Presentation** **6368**

Next Generation Attenuation (NGA) and other recent ground motion models applied to the UK

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The occasion of the production of a new national seismic hazard map for the UK (in connection with the UK National Annexe to Eurocode 8) provides an impetus to reflect on the perennial problem of the selection of strong ground motion models for use in the UK in the absence of sufficient local data for the construction of a UK-specific model. Recent investigations of ground motion data from the UK and NW Europe suggest that such data as exist do not match predicted values from well-used ground motion models commonly adopted. An objection made against the use of such local data from small (<5.5 Mw) earthquakes is that what are essentially weak ground motions cannot be used to scale up to strong ground motions. However, this implies the converse, that models based on strong ground motion form large earthquakes cannot be scaled down to model the sort of smaller events that dominate the hazard in areas of low to moderate seismicity. A hybrid weak-strong model was considered but rejected on the grounds that the weak motion part of the model was still insufficiently well constrained. An attractive solution appears to be the adoption of models from the Next Generation Attenuation (NGA) project. These models, although intended for use in active areas, employ much more advanced scaling procedures than have been used hitherto in strong ground motion modelling, which suggests that these models should be more capable of dealing accurately with situations where the hazard is predominantly from earthquakes in the range 4.0 to 5.5 Mw. The results are compared to those that would be obtained from some models previously used in the UK, and some other models recently developed in Europe.

Keywords: seismic hazard, strong ground motion, next generation attenuation

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SS004 **Oral Presentation** **6369**

On the applicability of one-dimensional crustal structures for ground-motion simulation

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Ground motion simulation methods, such as the finite-difference method (FDM) or the modal summation technique, require a model of the crustal structure through which the seismic waves pass in terms of density, velocity and attenuation parameters, such as Q. The use of such structural models within simulations means that travel path effects, such as the constructive interference of different phases, can be modelled. Currently one-, two- or three-dimensional models are used without much description of the benefits of using a particular dimension of model. Within FDMs, a 2D or 3D structure can be assumed without a significant increase in computational time. One-dimensional models have the advantage of yielding results that are easier to interpret in terms of phases and also they require only one set of simulations for all considered horizontal source and site locations. In addition, the method introduced by Douglas et al. (2004) for the incorporation of the effect of crustal structure into empirical ground motion estimation equations is only practical for one-dimensional structures. The purpose of this paper is to investigate when two-dimensional structures provide significantly different results than using an average one-dimensional model. The difference between the 2D and the derived 1D structure is quantified by a single parameter that seeks to characterise how two-dimensional the structure is. The maximum size this parameter can be before a 2D structure is required for accurate modelling of ground motions is assessed based on a series of FDM simulations. The purpose of this proposed technique is to provide guidance as to when 2D structures should be used or when 1D structures are sufficient, without the requirement to performing many simulations.

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SS004 **Oral Presentation** **6370**

Use of Empirical Green's Function For Estimation of Ground Motion In Urban Regions

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High seismicity, shallow depth of earthquakes and structural vulnerabilities in rural and urban region has caused severe casualties in Iran and the country has suffered economic hardship in the last decades. Most of large cities are active in seismicity but there are not enough data about probable strong ground motion due to effective faults in these areas. Seismic disaster management program confirms the importance of predicting strong ground motion due to main faults in urban region before occurrence of a large earthquake. Tehran , a crowded city in Alborz region, also has high seismic potential with active faults. This big city is located on alluvial layers. The seismologists have expected a disastrous earthquake for the last 177 years. They predicted a tremendous earthquake for near future for Tehran . Therefore it needs to synthesize strong ground motion of faults with high seismic potential. This can be done with Irikura's method(1992).This study is based on using Empirical Green's Function considering the spectral scaling law between large and small events and the scaling relation of source parameters. The essential data are ground motion records from small event that is happened near the main area, related to target event. This method is tested for a small event related to another fault that its main shock has happened. The waveform and spectral levels show synthetic motions agreed well with those observed motions. Finally based on the above test strong ground motion is estimated for a large earthquake that has not happened. The results of this study can be used in seismic risk assessment and finally it is used in the seismic disaster management program to decrease casualties.

Keywords: eathquake, ground, estimation

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SS004 **Oral Presentation** **6371**

Attenuation of macroseismic intensities a tool for estimation of ground motion

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When estimating strong ground motion, either for seismic hazard assessment or early warning purposes, the attenuation of ground shaking is a key parameter to obtain reliable ground motion distributions. Seismic hazard studies, as well as early warning systems, are usually focused on estimating ground shaking levels in terms of peak ground acceleration (PGA), peak ground velocity (PGV) or other recorded parameters. One major drawback of such studies is the very limited strong motion dataset available in many regions even of high seismicity. Furthermore, there is hardly any direct correlation between the distribution of e.g. PGA and damage. To overcome such limitations we study strong ground motion in terms of macroseismic intensity. This makes it possible to include also historical earthquakes in an analysis by using comprehensive intensity point datasets and has the advantage of the results being directly related to the observed earthquake damages. As part of the recently launched EC project SAFER (Seismic eArly warning For EuRope), we study the attenuation of macroseismic intensities for use within early warning systems. Preliminary results will be presented for the Marmara Sea area (Turkey), the Naples area (Italy) and the Vrancea area (Romania). We consider a physically constrained attenuation model and account for the finite fault dimensions of large earthquakes in the regressions. Data from several earthquakes are joined, and for the case of , anisotropy in the macroseismic field is accounted for in the derived attenuation model. Results indicate that our regression model provides a reliable estimate of macroseismic intensities for the studied regions, which can be implemented with earthquake early warning systems for rapid estimation of the ground motion distribution after a large earthquake.

Keywords: macroseismic intensity, attenuation, earthquake ground motion

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SS004 **Oral Presentation** **6372**

Estimation of Parameters of Ground Motion during Future Strong Earthquakes in Sochi Coastal Area (Russia)

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To estimate parameters of oscillations on the surface in Sochi area during future strong earthquakes, we define parameters of scenario earthquakes for the region of Sochi, according to the Seismic Zonation Map of the territoryof Russian Federation, 1997. That is, we define parameters of maximum possible future earthquakes, such as, their magnitudes, source (fault plane) dimensions, coordinates and depths of the hypocenters, as well as azimuths and dips of their fault planes.To calculate acceleration time histories and estimates of strong ground motion parameters, we use the calculation program SMSIM by David Boore, modified in order to account for (1) seismic source dimensions (a seismic source is represented as a set of point sub-sources, and their radiation is summarized in the receiving point) and (2) nonlinear soil response (depending on the composition, depth, and water-saturation of soils, we assume a hard or soft stress-strain diagram, describing the soil behavior).We have estimated some regional parameters of seismic wave radiation and propagation based on long-term (more than 40 years) seismic motion database of the Sochi seismic station.It was found that w2-model fits well to radiation patterns of the region, and frequency-dependent inelastic attenuation can be approximately described by the formula: Q(f) ~180 f. Some other parameters, such as, stress parameter, kappa values, geometrical spreading relationships, and regional crustal amplification were validated in seismic record analysis.In Sochi area, the most substantial local site effects in strong ground motion are resonant amplification of seismic waves in subsurface soils, nonlinearity of soil response, and effects of topography.

Keywords: strong ground motion, artificial accelerogramms, nonlinear soil response

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SS004 **Oral Presentation** **6373**

Scaling relation of mega-fault systems considering fault segmentation

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We are studying scaling relations between seismic moment (Mo) and fault Area (S) or fault length (L) considering fault segmentation. Irikura et al. (2006) compared two types of scaling models; Self-similar scaling, i.e. Somerville et al. (1999) and 3-stage scaling by Irikura and Miyake (2001). We develop the 3-stage scaling introducing an idea about saturation of fault displacement (D) and empirical relation between fault length and number of fault segments [Awata et al. (2006)]. We also consider difference of average stress drop between subsurface and surface earthquakes. Surface earthquake has smaller stress drop than subsurface earthquake [Kagawa et al. (2004)]. The result suggests the following phenomena. 1) Earthquakes smaller than Mo=7.5x1018Nm, follow self-similar scaling relation is with constant stress drop. All the earthquakes are subsurface events. 2) Earthquakes whose fault widths (W) occupies the seismogenic zone, scaling follows the L-model with stress drop increasing with Mo. Here earthquakes are surface events. This phenomenon creates first bending point of 3-stage scaling. 3) Earthquakes whose D reach to observed maximum, scaling follows W-model with stress drop decreasing with Mo. This phenomenon creates second bending point of 3-stage scaling. We found that definition of maximum W controls the first bending point and definitions of maximum D and number of fault segment control the second bending point. We are studying to adjust the parameters described above and obtained 3-stage scaling model that follows the observed data of previous earthquakes. ACKNOWLEDGEMENT: This study was supported by the JNES research topic (P.I.: K. Irikura). REFERENCES: Somerville et al. (1999), SRL. Irikura and Miyake (2001), J. Geography. Awata (2006), AGU 2006 Fall. Irikura et al. (2006), AGU 2006 Fall. Kagawa et al. (2004), EPS.

Keywords: strong ground motion, scaling, mega fault

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SS004 **Oral Presentation** **6374**

Features of seismic waves propagation near fault

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Principal scientist

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It is known a lot of formulae to describe seismic wave attenuation. The most accurate equations after 1994 take into consideration earthquake magnitude, faulting type, distance, and ground condition at the point of observation. It is paid attention to non-linear relations also. These equations consist on 7 and more terms. The standard deviation is about 0.16 decimal logarithmic units when earthquakes of single region are taken under consideration. Different formulae are in good agreement in far-field zone, but in near field zone the discrepancy is large. General feature of all the attenuation models is the approximation of empirical data by pre-chose mathematical expression. As a result part of information about propagation of intensive seismic waves is lost. Near the fault the theory based on assumption of elasticity and small deformations dont work. Therefore it is necessary to study seismic wave attenuation without any even very complicate pre-choose formulae. We have related processing and obtain very interesting results. PGA for earthquakes with different magnitudes are well scaled by fitting data along the distance axis (not along the amplitude one!) according to empirical law ∂lg R/∂MS = 0.32. Here R is the shortest distance to rupture surface. According to empirical data it is possible to divide the area around fault into three zones with very different degrees of amplitude attenuation. In the source zone the vibration amplitude are rising with distance. The maximum acceleration amplitudes are observed on the distance lg R = 0.32MS - 1.65. The near-field zone is characterized by attenuation about ∂lgA/∂lgR = 0.6. And far-field zone is characterized by attenuation about ∂lgA/∂lgR = 1.6. Quantitative characteristic of border between near-field and far-field zones is acceleration A = 170 cm/s. In the source- and near-field- zones on the rock acceleration level is a little larger and on soft ground lower than on medium ground (about 0.15 dec. log. unit). In these zones acceleration level is larger for reverse faulting and lower for normal faulting relative to strike-slip one (about 0.15 dec. log. unit).

Keywords: seismic wave attenuation, source zone, near field zone

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SS004 **Oral Presentation** **6375**

Variability of the ground motion generated by a stochastic summation of empirical Green''s functions : Study of the « Saintes crisis »

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Kohrs-Sansorny Carine, Converset Julien

We worked on the data collected by many accelerometric stations of a Mw 6.4 earthquake that occurred in 2004 around the 'Saintes' Islands (Guadeloupe, French Indies) and its aftershocks. Our aim is to test the variability of the accelerograms and response spectra obtained using a small earthquake summation method (Kohrs-Sansorny et al, 2005) in order to predict the larger earthquake. We test the influence of different parameters as the choice of the small earthquake taken as empirical Green's function, the source model and the simulation parameters. We particularly focus on the choice of the stress-drop ratio between the small and the target event, which is a crucial parameter.

Keywords: strong ground motion, simulation, seismic source

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SS004 **Poster presentation** **6376**

Azimuth-dependent attenuation relations for the intermediate depth Vrancea (Romania) earthquakes based on Fourier amplitude spectra

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Klaus-Peter Bonjer, Friedemann Wenzel, Mircea Radulian, Bogdan Grecu

We present regional azimuth-dependent attenuation relations for Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), Response Spectra Amplitudes (RSA), and seismic intensity (MSK or MMI scale) for the Vrancea intermediate depth earthquakes (SE-Carpathians) and territory of Romania. The Vrancea focal zone is characterised by a high rate of occurrence of large earthquakes in a narrow focal zone (depth 70-170 km). The used earthquake ground motion database includes several hundred acceleration records from more than 120 small magnitude (M < 5.5) earthquakes occurred in 1996-2004 time interval and several records obtained during five larger (M 7.4, 7.2, 6.9, 6.3, and 6.0) earthquakes. The attenuation relationships are based on Fourier Amplitude Spectrum (FAS) source scaling and attenuation models, and generalised site amplification functions. The PGA, PSV, and RSA attenuation relations were calculated using a stochastic technique. The seismic intensity attenuation models were evaluated using the recently developed relations between intensity and FAS. Values of considered ground motion parameters are given as functions of earthquake magnitude, depth and epicentral distance. The attenuation relationships were tested and calibrated using available data from large earthquakes.

Keywords: attenuation, ground motion

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SS004 **Poster presentation** **6377**

Analysis of two methods for instrumental intensity estimations using the database accumulated in Japan

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The database, which contains records of 8 large earthquakes in Japan obtained by K-NET and KIK-NET stations, was used for analysis of two techniques for estimation of instrumental seismic intensity from accelerograms. The first technique is the standard method for JMA intensity evaluation from filtered three-component accelerograms. The second technique is so-called FAS-intensity, which was developed for MM and MSK scales and which is based on correlation between level of Fourier Amplitude spectrum (FAS) and observed intensity. The relation between two types of instrumental intensities (JMAI and spectral MMI) may be described as linear function, but large discrepancy arises in smaller intensity range less than about 4 for JMAI and 6 for MMI. Most likely, the variation is caused by differences in spectral content of ground motion.

Keywords: ground motion, intensity

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SS004 **Poster presentation** **6378**

Probabilistic seismic hazard assessment in Romania: application for crustal seismic active zones

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The seismic active zones in Romania and adjacent areas that are influencing the crustal seismic hazard are: VRI (Vrancea intermediate) , VRN (Vrancea normal), IMF, PD (Predobrogean depression), BD (Barlad Depression), FG-CP and SI (Fagaras-Campulung-Sinaia), TD, CMS1, CMS2, DA (Danubian), BA (Banat), IBAR (Serbia), DUL and SHA (Bulgaria). For each of them we have computed the complete seismicity parameters (e.g. a, b, seismicity rate). It is essential, for a probabilistic estimation of the seismic hazard, to constrain as much as possible how the energy of the seismic waves attenuates when propagating from the source to the site. The attenuation law used for the crustal sources is given in the next equation: I = Io- c1 . log(Dh/h - c2 . a.log(e).(Dh-h); where: c1, c2, h and a are different for each region, and presented in the paper; log(e)=0.006514. As an exemple, for Fagaras zone we have c1=3.46, c2=3.12 , a =0.0013 (1/m), and h=15 km. For the input data set obtained in the present work, we applied the algorithm of McGuire (1976) to compute the seismic hazard map of Romania in the case of crustal earthquakes. We have obtained: seismic hazard curves for Romania, in terms of macroseismic intensities for return periods of 50, 100, 150, 200, 475, 1000, 2000 and 10000 years using only crustal seismic active zones.

Keywords: seismic hazard, romania, crustal surces

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SS004 **Poster presentation** **6379**

Assessment of Strong ground Motions Using the Empirical Greens Function for the 31 March 2006 Silakhor, SW Iran, Earthquake

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Mehdi Zare

The strong motions are the major cause of the earthquake destructions in the seismically hazardous regions. The simulation of the strong ground motions is a method to develop the accelerometric data for design purposes, especially in the region where no accelerogram is already recorded. Such information is essential for the analysis of the specifications of the strong motions in the desired region. The input information such as the seismic moment and earthquake magnitude, strong motion attenuation and site conditions are needed. The simulated motions might be developed for specific design purposes, since they are created based on the known and measurable input parameters. The empirical Greens function method is a method in which the small earthquake records or aftershocks might be used as for the path effects and could be taken as element events for the developing the target motion based on a known recorded main shock. The aftershocks of the 31 March 2006 of Mw=6.0 (recorded by Building and Housing Research Center and the International Institute of Earthquake Engineering and Seismology) are taken as the element event (Greens Functions) and the main shock is developed. The time-histories and resulted spectra are compared for the simulated and observed motions. The results show acceptable coincidence between the simulated and observed values.

Keywords: simulation, strongmotion, silakhorearthquake

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SS004 **Poster presentation** **6380**

Investigation of frequency content and Stress drop based Accelerometric records in Zagros Belt of Iran

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The Zagros mountain belt of Iran is the most seismically active zone. There are more than 4000 three component accelerograms obtained in this belt since 1975 (by the end of 2006). This paper will summarize the results of a study on the frequency content of the strong motions recorded in this region of Iran. The first important earthquake that has been recorded in the Iranian Strong motion network was the Sarkun 1974 Earthquake of Magnitude 6.5 and the latest important recorded event in this belt was the 31 March 31, 2006 Silakhor earthquake with a magnitude of Mw6.0 occurred on the Zagros Main recent fault. The Iranian strong ground motions were recorded by Kinemetrics SMA-1 analog and SSA-2 digital accelerographs (BHRC). This study will summarize the result of a study on the assessment of Mw and a study on the Corner frequency (fc), frequency content and the variations of stress drop. The study showed that stress drops to be obtained between 20 and 300 Bars for the Zagros region. The frequency content of the record show the higher amplitudes for the events, than those of the Central Iran and Alborz earthquakes. The response spectra of the events are mostly representative for lower corner periods and higher amplification of the highest response acceleration, comparing to the maximum acceleration.

Keywords: strongmotion, frequency content, zagros region

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SS004 **Poster presentation** **6381**

Estimation of Ground Motion and Early Warning in Straight of Hormoz (Southern Iran)

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Early warning system (EWS) for earthquake can help to reduce losses due to major earthquakes. In this study we use the information that is recorded by a network of seismic sensors in order to make estimates of ground motion in Straight of Hormoz.Straight of Hormoz is located in southern and is one of the most active seismic regions in Iran.We made seismic scenario for a simulated event and after that with using empirical attenuation lows (with out consideration of directivity effects) and p-wave observation, we estimated ground shaking in Straight of Hormoz. This shake maps are fundamental for disaster management during and after an earthquake event.

Keywords: stronggroundmotion, earlywarning, attenuationlow

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SS004 **Poster presentation** **6382**

Attenuation relations for maximum acceleration produced by vrancea intermediate, moderate earthquakes

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A fundamental element for seismic hazard assessment is the variation of the ground motion amplitude depending on distance, magnitude and local soil conditions. Predicting the maximum acceleration values as a function of earthquake magnitude, hypocentral distance and source radiation using the attenuation relations represents an important goal in the field of seismic hazard as well. In order to apprehend and forecast the effects of strong and major Vrancea earthquakes we have obtained attenuation relations using a data set composed by the peak ground horizontal acceleration from 27 earthquakes recorded by the K2 strong motion array in Romania, array centered on Vrancea seismic region. The database consists in earthquakes of magnitudes and depths between $4.0 \le MW \le 6.0$ /$71 \le h \le 166$ km, occurred from 1997 to 2004. The dependent parameter we have selected the peak ground horizontal acceleration (in time domain) as a measure of site intensity level. This value was corrected for the site effect in each recording station location, with the help of a multiple site factor, named S, and having different values, depending on the soil structure: $0.8 \le S \le 1$ for hard soils, $0.7 \le S \le 0.8$ for soft surface sedimentary soils and $0.65 \le S \le 0.7$ for soft deep sedimentary soils. We have analyzed the attenuation relationships for moderate Vrancea earthquakes, following a two step regression model, on two main directions (NE-SW and NW-SE) and two segments of depths, taking into account the division of the subducted litosphere beneath Vrancea zone (60km $\le h \le$ 110 km and 110km $< h \le$ 180 km). The Vrancea source induces a high seismic risk in the densely built zones of the South-East of Romania because the fundamental periods of the peak accelerations recorded at the large intermediatedepth shocks (1-1.5 s) are close to the natural periods of modern tall structures, contributing to severe damages of such structures. A number of 32 reinforced concrete multi-storey buildings completely collapsed during the shock that hit Bucharest on March 4, 1977. Thats why, predicting the ground motion acceleration during a major earthquake is of crucial importance for assessing more accurately the seismic hazard and for proposing hazard mitigation actions.

Keywords: attenuation relations, peak ground motion, horizontal acceleration

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SS004 **Poster presentation** **6383**

Models of Nonlinear Soil Behavior during the 1999 Chi-Chi, Taiwan, Earthquake Based on Stochastic Finite-Fault Simulations

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Kuo-Liang Wen

The 1999 Chi-Chi,earthquake (Mw=7.6) was one of the strongest earthquakes in recent years recorded by a large number of strong-motion devices. Though only surface records are available, the obtained strong-motion database indicates the variety of ground responses in the near-fault zones. In this study, accelerograms of the Chi-Chi earthquake were simulated at rock and soil sites, and models of soil behavior were constructed at seven soil sites (TCU065, TCU072, TCU138, CHY026, CHY104, CHY074, and CHY015), for which parameters of the soil profiles are known down to depths of at least ~70 m and at 24 other soil sites, for which parameters of the soil profiles are known down to 30-40 m; all the sites were located within ~50 km from the fault.For reconstructing stresses and strains in the soil layers, we used a method similar to that developed for the estimation of soil behavior based on vertical array records. As input for the soil layers, acceleration time histories simulated by stochastic finite-fault modeling with a prescribed slip distribution over the fault plane were taken. In spite of the largeness of the earthquakes magnitude and the proximity of the studied soil sites to the fault plane, the soil behavior at these sites was relatively simple, i.e., a fairly good agreement between the spectra of the observed and simulated accelerograms and between their waveforms was obtained even in cases where a single stress-strain relation was used to describe the behavior of whole soil thickness down to ~70-80 m during strong motion. Obviously, this is due to homogeneity in the characteristics of soil layers in depth. At all the studied sites, resonant oscillations of the soil layers (down to ~40-60 m) and the nonlinearity of the soil response were the main factors defining soil behavior.At TCU065, TCU110, TCU115, CHY101, CHY036, and CHY039 liquefaction phenomena occurred in the upper soil layers, estimated strains achieved ~0.6-0.8%; at other stations, maximum strains in the soil layers were as high as 0.1-0.4%, according to our estimates.Thus, valuable data on the in situ soil behavior during the Chi-Chi earthquake was obtained. Similarity in the behavior of similar soils during the 1995 Kobe, 2000 Tottori (Japan), and Chi-Chi (Taiwan) earthquakes was found, indicating the possibility of forecasting soil behavior in future earthquakes. In the near-fault zones of the three earthquakes, hard-type soil behavior and resonant oscillations in the upper surface layers prevail, both leading to high acceleration amplitudes on the surface.

Keywords: nonlinear soil behavior, stress strain relations, the 1999 chi chi earthquake

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SS004 **Poster presentation** **6384**

Stochastic strong ground motion simulation of the 28 December 1908 M7.0 Messina (Sicily) earthquake: investigating different source scenarios

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The stochastic strong ground motion simulation method for finite sources is applied to test several fault models of the destructive (M7.0) 1908 Messina earthquake in terms of their capability to reproduce the observed macroseismic field. We tested both east- and west-dipping faults, as well as low- and high-angle fault planes that have been previously proposed as responsible for the 1908 catastrophe in the straits of Messina. For each test source we computed the distribution of peak ground acceleration values in and around the 1908 epicentral area and subsequently converted these values to macroseismic intensities using appropriate empirical relations. The relative performance of the tested models was evaluated through comparing the resulting synthetic macroseismic intensities with observed ones. Among the tested models, minimum misfit between observed and synthetic macroseismic intensities, provides a low-angle, east-dipping normal fault included in the Database of Individual Seismogenic Sources (DISS, http://www.ingv.it/DISS/). Our preferred source model satisfactorily predicts the observed intensities within the city of Messina but rather underestimates the very high intensities (XI) observed to the north of Reggio di Calabria. This last discrepancy diminishes if rupture directivity toward north is taken into account.

Keywords: stochastic, messina, macroseismic

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SS004 **Poster presentation** **6385**

Examination of source model construction methodologies for multi-segment-coupling ruptures in long active fault zone

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In strong ground motion prediction of scenario earthquake for a long active fault zone, we need to take into account of multi-segment-coupling rupture during an event. We constructed characterized source models (Irikura et al., 2003) for prediction of strong ground motions during a multi-segment-coupling rupture event based on the several methodologies of source model construction and compared the simulation results among the characterized source models. The Nobi fault zone, mid Japan, where plural fault segments ruptured during the 1891 Nobi earthquake (M8.0) was studied. In this research, twelve characterized source rupture scenario models were constructed by combining two kinds of earthquake magnitude estimations, two kinds of asperity parameter estimations, and three kinds of rupture scenarios. For the estimation of earthquake magnitudes, we used (1-1) the method by the seismological scaling relationship and (1-2) that based on the characteristic earthquake model hypothesis (Schwartz and Coppersmith, 1984) in active fault study. Asperity parameters were estimated by two methods from (2-1) short-period spectral level and (2-2) the empirical relationship that the total area of asperity was 22% of the total area of the causative faults (Somerville et al., 1999). We conducted strong ground motion simulation by the empirical Greens function method (Irikura, 1986) at 99 K-NET stations and 62 KiK-net stations. We compared JMA seismic intensities calculated from the synthetic waveforms with observed seismic intensities of this event by Muramatu and Kominami (1992). The difference between calculated and observed seismic intensities was smallest in the case of (1-1) the seismological scaling relationship, (2-2) the empirical relationship of asperity parameter, with rupturing from the northwestern part. The rupture starting point assumed in the best characterized source model agreed with that from previous research (Mikumo and Ando, 1976).

Keywords: source modeling methodologies, long active fault zone

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SS004 **Poster presentation** **6386**

Estimation on the peak ground acceleration

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SeismicQ is a dimensionless quantity which measures the amount of energy dissipated per radian as seismic waves propagate. Seismic Q varies with the composition of the material and its physical condition. The amount of seismic energy received in building strictly depends on the anelasticity of the media that the seismic wave traveling through. Therefore, the seismic attenuation factor of the subsurface material is the parameters for estimating the displacement near the ground. In this study, we use the new high-quality data recorded by CWBSN and TSMIP to inverse the detailed Q-structures in Taiwan area. The theoretic maximum amplitudes of the ground acceleration in Taiwan area for 30 events have been calculated by using the attenuation equation and the Q-structures. The deviation between these estimated amplitude and the maximum amplitudes of these events observed at stations of CWBSN are obtained. The results show that most of the deviation is small than 30%. It indicates that we can predict the maximum amplitude of ground acceleration for any events occurred in Taiwan area under the accuracy of 70 % (probability).

Keywords: q structure, peakgroundacceleration

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SS004 **Poster presentation** **6387**

Properties of response spectra

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Principal scientist

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The relations between different parameters of response spectra with 5% damping are studying. These parameters must be reciprocal from physical point of view. Therefore spectrum parameters cant be set independently. Spectra parameters are changeable due to source and site properties. But these variations must be in accordance. The parameterization system for spectra has been provided to study this problem. It is proposed system of response spectra parameters: the normalized spectrum level is described by parameter β; the parameter S = lg T2 - lg T1 is proposed to describe spectrum bandwidth, where T1 is the shortest period related to value 0.5βmax on the short-period spectrum slope, and T2 is the longest period related to value 0.5βmax on the long-period spectrum slope. The quality (Q) of oscillation system including both source and ground properties is described by expression Q = Tc / (T2 T1), where Tc is the central or predominant period of oscillations. The best results are obtained when Tc is determined as Tc = sqrt(T1 T2). The processing of strong ground motion records shows that the correlation between parameters is considerable. Preliminary results are obtained using only 748 horizontal spectra. Distributions of lgβ, lgQ and S values can be described by the Gauss law. Mean value of lgβ is 0.54, standard deviation 0.08; mean value of lgQ is 0.19, standard deviation 0.27; mean value of S is 0.60, standard deviation 0.25. Using the orthogonal regression one can obtain: lg β = 0.60 + 0.21 lg Q 0.08; lg β = 0.70 - 0.23 S 0.08. The larger is the bandwidth S the lower is quality Q and the lower is the coefficient β. Such relations often were not taken into account and design spectra in building codes of different countries, as the rule, have different parameters.There are typical errors by computation of design spectra: 1) design spectra usually have low value β; 2) design spectra for different ground type have constant S and different β; 3) design spectra for different ground type have constant β and different S; 4) design spectra for different ground type have constant S and different Tc.

Keywords: design spectra, coefficient beta, oscillation system quality

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SS004 **Poster presentation** **6388**

Soil Amplification by Using Strong Ground Motions Recorded by Different Geological Conditions in Marmara Region in Turkey

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Mithat Firat Ozer

Soil amplification of earthquake motion is one of the most important and most difficult site effects to model. Difficulties of determining soil amplification depend on various behaviours of soils when subjected to an earthquake. These various behaviours of soils can influence the amplitude and spectral content of ground motion.Numerous methodologies have been proposed for estimating the surface ground motion depending on the geological characteristics. In this study we propose empirical multiplication factors by using the strong ground motions recorded by different geological conditions. These factors involve multiplying peak ground acceleration (PGA) at the rock by an empirically derived factor to estimate the PGA at the soft rock, soil, and soft soil. These factors are often functions of the properties of the local soil conditions such as age, thickness, and shear wave velocities of soil deposits. Firstly regional attenuation relationships for PGA which is the northwestern part of Turkey have been developed for rock, soft rock, soil and soft soil conditions. The data base consist of 804 horizontal components of PGA from 89 earthquakes (M>4.0), including the 17 August 1999 Kocaeli earthquake (Mw=7.4) and 12 November 1999 Duzce earthquake (Mw=7.2). Multiple regression analyses have been used to calculate the attenuation relationships. These relationships have been normalized by the attenuation relationships of the rock with an assumed scenario earthquake of magnitude 7.5. The results of these normalizations give us soil amplification factors for the corresponding area. These factors are 1.48 for soft rock, 2.05 for soil, and 2.68 for soft soil.

Keywords: soil, amplification, pga

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SS005 **6389 - 6468**

Symposium
Earthquake Sources - Modelling and Prediction

Convener : Prof. Mitsuhiro Matsuura
Co-Convener : Prof. Alexey Zavyalov

In the last decade there has been great progress in the physics of earthquake generation; that is, the introduction of laboratory-based fault constitutive laws as a basic equation governing earthquake rupture, quantitative description of tectonic loading driven by global plate motion, and a microscopic approach to study fault zone processes. Our vision in the next decade is to develop physics-based realistic simulation models for the entire process of earthquake generation cycles. The assimilation of seismological and geodetical observations into such models will provide a new approach for studying earthquake precursory phenomena and have direct application to earthquake prediction and earthquake hazard quantification. Recent advances in high performance computer technology and numerical simulation methodology are bringing this vision within reach. We address this central subject in earthquake physics from a multidisciplinary point of view. Contributions are invited for the following topics: 1) Fault zone processes and constitutive properties 2) Modelling and simulation of earthquake generation processes 3) Fault system complexity and dynamics 4) Generation and propagation of strong ground motion 5) Tectonic loading, stress-state evolution, and seismicity change 6) Monitoring and modelling of earthquake processes for prediction 7) Earthquake forecasting and evaluation 8) Seismicity as manifestation of critical behavior of the crust

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SS005 **Oral Presentation** **6389**

Active tectonics in the Golpayegan Region, Iran

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The active Arabia-Eurasia collision deforms an area between the Aegean and eastern Iran, and between the northern side of the Caucasus-Kopeh Dagh and the Persian Gulf. The convergence is achieved in the NW Zagros by a combination of shortening on NW-SE-trending folds and thrusts, mainly in the simple folded zone, and by right-lateral strike-slip on the NW-SE-trending main recent fault. There are several active faults to the northeast of Zagros that make a fault system between the Sanandaj-Sirjan Zone parallel to the Zagros thrust fault, with Mesozoic age of the Earths crust consolidation and Iranian microplate. These active faults, all of them are combining dextral and reverse movements. The Shazand Fault with about 186 km length is located in the northeastern part of the Main Zagros Thrust and is stretched parallel it. The Shazand Fault is an oblique slip fault and has reverse and dextral strike slip vectors. Structural and morphotectonical evidences show that the Shazand Fault is an active fault. Drainages displaced by dextral movement about ~4 km along the fault and near the Golpayegan city. Common revenue of the Shazand fault with the Hosseinabad and Muteh faults cuts and rotates the Quaternary alluvial fans and rivers and also uplifts and rotates the Golpayegan depression. Increase of vertical erosion rate in recent years show that the Shazand Fault is ready for movement. There are not any recorded earthquakes data during two hundred years ago that show the earthquake repeat time of several hundred years are possible and may be capable of accumulating large amounts of elastic strain between earthquakes. The Golpayegan town having 2 km and the Khomein town having 8 km distance from the Shazand Fault and they will destruct intensely with each movement of the Shazand Fault.

Keywords: activetectonics, activefault, zagrosthrust

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SS005 **Oral Presentation** **6390**

Use of high resolution satellite images for tracking of accumulation and displacement of faults in the Earths crust, previous to earthquakes, by applying the lineament extraction technique

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Over the last decades strong efforts have been made to apply new spaceborn technologies to the study of strong earthquakes. As it is well known, strong earthquakes are preceded by strain energy accumulation deep in the Earths crust. It is reflected in the accumulation of displacement on faults and their orientation that takes place months and even years before an earthquake. In this study we assume that it is possible to detect, at least partially, the presence and dynamics faults and other structures in the Earths crust, using lineament extraction technique. A lineament is a straight or a somewhat curved feature in a satellite image, which it is possible to detect by a special processing of images based on directional filtering and or Hough transform. We analysed tens of earthquakes occurred in the Pacific coast of the South America with the Richter scale magnitude >4.5, using ASTER/TERRA multispectral satellite images for detection and analysis of changes in the system of lineaments previous to strong earthquakes. All events were located in the regions with small seasonal variations and limited vegetation to facilitate the tracking of features associated with the seismic activity only. It was found that the number and orientation of lineaments changed significantly about one month before an earthquake approximately, and a few months later the system returns to its initial state. This effect increases with the earthquake magnitude. The results obtained open a possibility to develop a methodology able to evaluate the seismic risk in the regions with similar geological conditions.

Keywords: lineament, satellite, prediction

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SS005 **Oral Presentation** **6391**

Seismotectonic model and precursor studies in Northeast India Region

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Northeast India is lying at the juncture of the Himalayan Arc to the north and Burmese Arc to the east, and is one of the most active regions of the world. About 20 large earthquakes (M > 7.0) including two great earthquakes (M > 8.0) occurred in this region during the last 110 years. The 1897 great Shillong earthquake is the first instrumentally recorded earthquake in the country. Since 1964, with the inception of the WWSSN and increase of local networks, location quality of the earthquake epicenters is much improved. In the recent years, since early 1980s, several temporary microearthquake networks and permanent telemetric networks are run along with earthquake precursor investigations in selected areas of the region. Regional earthquake data (ISC and USGS), temporary and permanent close-spaced microearthquake digital network data and geophysical precursors of few felt/large earthquakes have given us some better understanding of seismotectonic model in this region. The seismicity in the main Himalayan seismic belt believed to be due to the collision tectonics between the Indian plate and the Eurasian plate, and the earthquakes are generally correlated with the known regional thrusts, the Main Boundary Thrust (MBT) and Main Central Thrust (MCT). Distribution of epicenters is sparse, and the earthquakes are confined within a depth range 0-70 km. Thrust faulting of the earthquakes are correlated with the regional thrusts. Microearthquake surveys in Arunachal Pradesh, in the northeastern Himalaya, however, revealed that the earthquakes are not correlatable with the regional thrusts. The earthquakes are rather generated by strike-slip mechanism; transverse tectonics is suggested in this part of the Himalaya. The earthquakes in the Burmese arc, on the other hand, are typical of subduction tectonics. Intense activity is observed along the Indo-Burma ranges, and the earthquakes are as deep as 200 km. Normal, thrust and strike-slip faulting of earthquakes are observed. The seismological data reveal a clear subduction or dipping structure beneath the Indo-Burma ranges. The syntaxis zone, the meeting zone of the Himalayan Arc and the Burmese Arc, is seismically active and was the source area for the 1950 great Assam-Tibet earthquake (M 8.7). The Shillong Plateau earthquakes, on the other hand, are referred to the stable continental region (SCR) earthquakes, which are produced by the stress accumulation due to the collision tectonics to the north and subduction tectonics to the east. The microearthquake data in the Shillong Plateau and adjoining areas have revealed seismogenic faults. The great 1897 earthquake (M 8.7) occurred beneath the Plateau. The higher seismic activity is explained by pop-up tectonics of the Shillong Plateau, and by transverse tectonics along a ~300 km long Kopili fault that separates the Shillong Plateau and the Mikir Hills. To the south, the activity in the Tripura fold belt is referred to the plate-boundary earthquakes, the stress is transmitted mainly from the Burmese Arc. The lower seismic activity in the Bengal basin is interpreted to be due to a locked portion of the Indian plate below this basin. The E-W Dauki fault is possibly the surface expression of lateral segmentation of the Indian plate, the Shillong Plateau to the north and the Bengal basin to the south. Continuous monitoring of deep resistivity, microgravity and microearthquakes by temporary networks had been useful in precursor studies for a few felt/large earthquakes in this region. The deep resistivity survey shows that resistivity values may increase or decrease (40%-50%) or may show no change at all depending on the measurement direction, stress pattern, fracture/fault orientation and rock formation. The repeat microgravity survey indicate change in microgravity values (200-250 m gal) before a felt/large earthquake in the region. The temporary microearthquake network data indicate change in microseismicity level and velocity-ratio (Vp/Vs) before a felt/damaging earthquake in the area.

Continuous monitoring of seismicity, deep resistivity and microgravity may be fruitful for precursor research for impending large earthquake in this region.

Keywords: seismotectonics, microseismicity, earthquakeprecursors

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SS005 **Oral Presentation** **6392**

Studying of dynamic changes of large-scale crustal movement by continuous GPS observation data in mainland

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Several methods such as wavelet transformation are used to decompose time series of continuous GPS observation data in Mainland China and its peripheral IGS stations. The results indicate that the signal with lower frequency detected in crustal movement is more credible than the higher frequency information, because most of the signals with higher frequency are submerged in big noises. The dynamic change of Indian plate relative to Qinghai-Xizang block was analyzed. And also the relative crustal movement between the western and eastern Mainland China was studied. A turning of the trend for crustal movement in mid-eastern China was founded between the year 2003 and 2004. It means that the expanding in direction from north to south was enhanced. This kind of change can be explained by effect from the change of the trend of long term Earth rotation, but the changes in part of the stations in southern China may image the effect of the Sumatran earthquake. In addition, micro-dynamic change with low frequency has appeared on the trend of compressional linear movement between Qinghai-Xizang block and Indian plate from 1995. Three obvious abnormities appeared in the relative movement between Bangalore in middle Indian plate and Lhasa in Qinghai-Xizang block in 1997, 2001, and 2004-2005 respectively. It reflected that the compressional movement of Indian plate relative to Qinghai-Xizang block was increasing. While many large earthquakes occurred in the state of the increasing of the relative movement of Indian plate, such as Ms7.9 Mani earthquake in 1997, Ms8.1 Kunlun Mountain earthquake in 2001, Ms9.0 Sumatran earthquake in 2004 and Ms7.8 Pakistan earthquake in 2005. Analyses of earthquake cases show that abnormity in micro-dynamic crustal movement can be observed in the mid-short term before strong earthquakes, while there is not such abnormity before medium earthquake.

Keywords: gps, earthquake

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SS005 **Oral Presentation** **6393**

Seismic Hazard Evaluation in Western Turkey as revealed by stress interaction

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Many strong earthquakes were catastrophic for western Turkey which is our present study area. It has been documented, from studies related to the North Anatolian Fault (NAF) and the Aegean Sea that changes in the stress field due to the coseismic displacement of the stronger events influence the occurrence of the future events of comparable size by advancing their occurrence time and delimiting their location. In the present study the evolution of the stress field since the beginning of the 20th century in the territory of western Turkey and eastern Aegean is examined, in an attempt to testify if the history of cumulative changes in stress can explain the spatial and temporal occurrence patterns of large earthquakes. Coulomb stress changes are calculated assuming that earthquakes can be modeled as static dislocations in an elastic halfspace, and taking into account both the coseismic slip in large (M>6.5) earthquakes and the slow tectonic stress buildup along the major fault segments. The stress change calculations were preformed for strikeslip and normal faults and in each stage of the evolutionary model the stress filed is calculated according to the focal mechanism of the next large event, of which triggering is inspected. The geometry of the major faults and the longterm slip rates on them were defined based on existed information. Thus, the identification of known active faults that are currently in areas where the cumulative changes of Coulomb stress are positive can bring about new insight on the evaluation of future seismic hazard.

Keywords: strong earthquakes, coulomb stress changes, stress field evolution

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SS005 **Oral Presentation** **6394**

Apparent stress scaling: regional and global trends

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Theoretical model of seismic sources implies a scaling relationship for the apparent stress treated as a function of seismic moment and two other parameters: rupture area and average slip acceleration. These parameters represent three different factors - kinematic, geometric, and material - that define the model. The relation suggests two kinds of trends in the log apparent stress vs. log seismic moment space. The regional trend is expected to characterize sets of earthquakes with similar slip acceleration to rupture area ratio. The data points representing such earthquake populations are scattered along the 0.5 slope lines. The regional trend is related to the averaged shape of slip velocity pulses, so it reflects kinematic characteristics of the rupture process. The global trend, represented by the 1/6 slope line, is expected to characterize sets of events of wide range of rupture areas and assumes dependence of rupture area on total slip, so it is related to the rupture initiation, propagation and arrest conditions and, therefore, reflects earthquake rupture dynamics. The expected trends are discussed in the context of available observational seismic data to explain controversies related to the earthquake scaling problem.

Keywords: earthquake physics, apparent stress, earthquake scaling

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SS005 **Oral Presentation** **6395**

Earthquakes caused by unbending subducted slab off Southwest Taiwan

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Shu-Kun Hsu, Chien-Hsin Chang, Mei-Yi Ho, Wen-Bin Doo, Chung-Liang Lo

On Tuesday, 26 December 2006, an earthquake of Mw = 6.9 occurred off Hengchun peninsula, Taiwan. The main shock and aftershocks have caused damage on land of southern Taiwan. The earthquake took place in an area that was less expected to have a big earthquake. In this study, we have collected 136 aftershocks and examined the tectonic context of this earthquake sequence. The earthquakes occurred in the azimuth of about N310 and coincide with the slope of a low Bouguer gravity anomaly zone. The orogen of Taiwan is formed by the collision between the Eurasian Plate and the Philippine Sea Plate. The uplift of the Taiwan orogen has induced a considerable loading on the east-dipping Eurasian Plate. The low Bouguer anomaly zone surrounding the western and southern Taiwan reflects the loading effect on the Eurasian Plate. 2D gravity modeling perpendicular to the general trend of the aftershocks indicates that the earthquakes mainly occurred in the uppermost mantle. Because the main shock is a tensional earthquake as shown by focal mechanism and the hypocenters of main shock and aftershocks are located beneath the crust, we suggest that the earthquakes off Hengchun peninsula are caused by the unbending effect of the subducting Eurasian slab. An interpretation for the unbending source is that the subducting plate off southwest Taiwan contains a transitional crust of ca. 12 km thick in the Eurasian continental margin; in contrast, the overriding plate contains a significant portion of high P velocity structure below the Hengchun peninsula. The similar crustal densities of both the subducting and overriding plates may cause resistance of subduction on the east-dipping Eurasian plate and occasionally induce unbending earthquake events.

Keywords: unbending, subduction, earthquake

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SS005 **Oral Presentation** **6396**

Seismicity patterns of two predicted large earthquakes

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We investigated space-time distribution of seismic events before the M = 7.8 Kronotskoe eq., December 5, 1997 on Kamchatka and M = 8.2 Simushirskoe eq., November 15, 2006 on Kuril arc. It was established as a result of laboratory experiments that the acoustic emission passes several stages during macrofracture development: quiescence, foreshock activation and clustering. The properties of acoustic flow differ in the zone of future macrofracture and in lateral areas. On the basis of this regularities the Region-Time-Length (RTL) and Seismic-Energy-Activation (SEA) algorithms were suggested to reveal the place and time of future earthquake. We checked these algorithms retrospectively on the examples of several strong earthquakes in different regions. In the cases of two before mentioned large earthquakes the real time mid-term forecasts were made. Seismic quiescence (RTL) started 3.7 years before M = 7.8 Kronotskoe eq., December 5, 1997 and 5 years before M = 8.2 Simushirskoe eq. November 15, 2006. Epicenters of these earthquakes were situated on the lateral zones of quiescence anomalies. Foreshock activation anomalies (SEA) were revealed 1.5 year before Kronotskoe eq.; and 4 years before Simushirskoe eq. Real time forecasts (letters to the Russian Earthquake Evaluation Committee with corresponding graphs and maps) were issued 16 months - before Kronotskoe eq. and 4 years - before Simushirskoe eq. The clusters of events in magnitude range of 4-6 appeared in the foreshock activation areas several months before these earthquakes. The attempts were made retrospectively to use the regularities of critical seismic acceleration (Varnes,1989) to calculate time and magnitude of future events. The errors of time dT estimation were equal 2 months - for Kronotskoe and 1 week for Simushirskoe earthquakes. Corresponding errors of magnitude estimation dM were equal 0,5 and 1,3 units. Therefore, the precursory seismicity patterns revealed in this study may give better understanding of the seismogenetic process and provide useful information for the earthquake prediction and seismic risk estimation. The work was supported by the program for leading scientific schooles grant # SSc-5009.2006.5 and Program # 16 of Russian Academy of Sciences.

Keywords: earthquake, forecast

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SS005 **Oral Presentation** **6397**

Anomalously large intensity associated by subduction zone earthquakes: a scattering waveguide in the heterogeneous subducting plate

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It is well recognized that the subducting plate is an efficient waveguide for high-frequency seismic signals. Such effects are often noticed in northern Japan leading to an anomalously large and distorted pattern of intensity extending along the eastern seaboard of the Pacific from deep earthquakes in the plate. The observation is also found in western Japan associated by deep earthquakes in the Philippine-sea plate. Seismograms in the high intensity zone show very large S-wave signals and a following high-frequency coda with very long tails. Such observations are not explained by the traditional plate model comprising just high wave speed and low attenuation material in the slab. The new plate model to produce guided high-frequency signals is characterized by multiple post-critical scattering of seismic waves due to small-scale heterogeneities within the plate. The preferred model of heterogeneity has elongated scatterers parallel to the plate margin with longer (Ax=10km) correlation distances in the plate downdip direction and much shorter correlation distances (Az=0.5km) across the plate thickness. Such quasi-laminated structure in the plate can guide high-frequency signals (f>1Hz) with wavelengths shorter than the correlation distances along the plate, while very low-frequency signals (f<0.2Hz) with longer wavelength are not affected by such small scale heterogeneities. The high wave speed property of the plate at the same time allows seismic waves to escape into the surrounding, low wave speed mantle by refractions of seismic waves. The net result is a frequency-dependent guiding property of the subducting plate with efficient guiding of high-frequency signals by multiple scattering and loss of intermediate frequency signals due to internal velocity gradients. Low frequency signals with wavelength larger than the plate thickness are not significantly affected by the presence of the plate. We demonstrate the presence of frequency selective wave propagation effect from observations of recent intermediate-depth earthquakes in the Philippine sea plate of 12 June 2006 (Mj6.2; h=146km) and in the Pacific plate of 16 Jan. 2007 (Mj5.7; h=170km), and are able to provide a good representation of the behavior from 2-D and 3-D finite-difference calculations for elastic waves with a heterogeneous slab model. The frequency dependence of the models is quite sensitive to the thickness of the plate and thus the wave guiding/anti guiding properties are different in western Japan and northern Japan subdcion zones accompanying a thin (D=35km) Philippine sea plate and thicker Pacific plate (D=80km), respectively, and also depends on the scale lengths of the heterogeneity distribution.

Keywords: strong ground motion, seismic wave propagation, modelling

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SS005 **Oral Presentation** **6398**

Spectral Ratio Analysis of the Two Recent Japanese Earthquake Sequences (Mw6.6) in Japan: Effects of Different Tectonic Conditions to the Seismic Scaling Law

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Fumiko Tajima

Self-similarity in the seismic scaling law may have important implications for the mechanism of earthquake ruptures, and the difference between small and large earthquakes. We investigate the seismic scaling relationship of moment (Mo) versus corner frequency (fc) in relation to seismic activity using a spectral ratio method and the dataset from two Japanese earthquake sequences, the October 23, 2004 mid Niigata prefecture earthquake (MNPE) and the March 20, 2005 west off Fukuoka prefecture earthquake (WOFE) sequences. Both of the earthquakes have the same moment magnitude, Mw6.6 and shallow source depths, 11 and 9 km, respectively. The MNPE produced a large number of aftershocks including six events with Mw5.5 or greater over a period of about two weeks. On the other hand, the WOFE sequence did not produce aftershocks that exceeded Mw5.5. The sum of moment released from the aftershocks (Mw3.5 or greater) during forty days after the main event was 6.19x10^18 Nm for the MNPE sequence and that for the WOFE sequence 2.17x10^17 Nm. These moment releases are equivalent to about Mw6.5 and Mw5.6 events, respectively. In the Mo - fc relation obtained from the MNPE sequence, the fc's tend to decrease with decreasing Mo between Mw3.5 and 6.6 and the stress drop is in the range of 0.1 to 10 MPa. The best fit line determined in a least squares sense has a relation of Mo proportional to fc^-3.41. Moreover, the fc's of small events (Mw3.5 to 4.0) of the MNPE sequence that occurred near the major faults appear to be higher than those located off the major faults. The scatter in the narrow range of Mw may suggest the variation of radiated seismic energy of small events, and deviation from an omega-square model that is based on the assumption of constant rupture velocity. In the WOFE sequence, the stress drop is from 1 to 10 MPa and the best fit line has a relation of Mo proportional to fc^-3.06 in the same Mw range. The fc range of small aftershocks is lower in the MNPE sequence than in the WOFE sequence. In the MNPE sequence which took place in the area of complex fault structure, the small events occurred in the complex process of stress redistribution. The portion of energy used to start the fault ruptures (fracture energy) of events may be larger than that of large events. Our results suggest that there is difference (or variation) in the scaling relation even in the same Mw range, probably reflecting different tectonic or seismogenic conditions.

Keywords: seismic scaling law, tectonic conditions, spectral ratio analysis

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SS005 **Oral Presentation** **6399**

Correlation of earth tides and seismic noise before large earthquakes: observation and modeling

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Investigation of the geophysical fields variations during large earthquake preparation is urgent problem of seismology and geophysics. Earth tides are unique natural process: 1) they act upon whole Earth and 2) they have stable time parameters. This stability permits to use them as natural calibrator for study of geophysical fields anomalies connected with variations of medium stress state. Tidal influence was found in monitoring of different geophysical fields. The modulation of the high-frequency seismic noise (HFSN, frequency - first tens of Hz, amplitudes - about 10-9-10-12 m) by the tides was discovered in 80th [Rykunov et al., 1983)]. This effect was very important: it confirms the endogenous origin of some components of seismic noise and offers the challenge to use it for deflected mode study. Tidal components in seismic nose envelope were detected by data of long-term observations in stations Nachiki, Karymshina (Southern Kamchatka, Russia), Erimo (Hokkaido, Japan), Shikotan (Kuril Is., Russia) in 1990-2007. Periodical components with the periods of main tidal waves were found. The HFSN response to tidal influence is not steady in time. By experimental data obtained in Kamchatka stable synchronization of the HFSN with tides before large local earthquakes was revealed. Available data level permits to turn from observations to modeling of tidal effects in seismic emission. Modeling is carrying out on two main directions: 1. Tidal effects in the HFSN are determined by medium properties during microseismic emission propagation A model is proposed to explain the magnitude of seismic noise modulations by tidal strains and to account for the modulation phase connection with the background stronger tectonic strains. The proposed mechanism is based on the microstructure-induced amplitude-dependent dissipation in rocks [Zaitsev, Matveev, 2006] arising due to the combined action of nonlinear elasticity and conventional linear relaxational losses. 2. Tidal influence upon sources of seismic emission immediately. Tides act upon ensemble of different-scale fissures in the medium. Fissures provide the relaxation of elastic energy by microseismic emission. Model of fissure is relaxation oscillator (integrate-and-fire). Tides modulate the threshold of oscillator activity. So probability of emission increases for fixed tidal phase. The effective radius of the data collection for the HFSN with frequency 30 Hz was estimated as 8 km [Lutikov, 1992]. This value is less than typical epicentral distances for local earthquakes. There was shown [Alexeev et al., 2001] that evolution of near-surface dilatancy regions is possible within range L=200-300 km. So we suppose that the large earthquake source can affect on medium properties and microseismic emission in investigated areas. This research is supported by RFBR Grants 05-05-64276 and 05-02-17355.

Keywords: seismic noise, earth tide, modulation

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SS005 **Oral Presentation** **6400**

Where will be a future strong earthquake on Kamchatka?

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The southern part of Kamchatka peninsula with adjoining to it water area of Pacific Ocean already for a long time attracts attention of Russian seismologists as a place of the future strong earthquake with magnitude M>7.7 for the nearest years. Intensity of seismic influences on territory of the south of Kamchatka and, in particular, for Petropavlovsk-Kamchatski where basically the most part of the population, an economic and social infrastructure of peninsula is concentrated, in an essential measure depends on where particularly there will be a source. On tentative estimations expected intensity of seismic tremor can appear equal I=8-9 points. The author on the basis of the regional catalogue of Kamchatka earthquakes for 1962-2006 constructs a map of aftershock distribution occurred strong earthquakes with K>=13.5 (M>=5.5) which as it is known define source zones of corresponding earthquakes. A number of zones where strong earthquakes were absent are allocated on a map. Using representations about a seismic cycle and results of the long-term seismic forecast on S.A.Fedotovs method, the opportunity of strong earthquake sources occurrence in these zones is discussed. The work has been executed under financial support of RF President Grants for Leading Scientific Schools, grant # SSc-5009.2006.5.

Keywords: earthquake, prediction

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SS005 **Oral Presentation** **6401**

Modeling and monitoring the entire processes of earthquake generation in and around Japan

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Our research group aims to develop a physics-based predictive simulation system for crustal activities in and around Japan, where the four plates of Pacific, North American, Philippine Sea and Eurasian are interacting with each other. The total system consists of a quasi-static tectonic loading model, a dynamic rupture propagation model and seismic/geodetic data inversion programs, developed on a realistic 3-D structure model (CAMP Standard Model). We have already completed a prototype simulation system for crustal activities. Given the past slip history and the present stress state, we can now predict the next step fault-slip motion through computer simulation. As an example we show the joint simulation of quasi-static tectonic loading and dynamic rupture propagation for the 1968 Tokachi-oki earthquake (M8.0). Then, our problem is how to extract useful information to estimate the past slip history and the present stress state from observed seismic and geodetic data. To address this problem we developed two inversion methods using Akaikes Bayesian Information Criterion (ABIC), one of which is the method to estimate the spatiotemporal variation of interplate coupling from geodetic data, and another is the method to estimate seismogenic stress fields from CMT data of seismic events. From the inversion analysis of coseismic, interseismic and episodic crustal movements in the Kanto region, central Japan, we revealed that the North American-Philippine Sea plate interface can be partitioned into four regions with different stress release modes; that is, steady slip without stress accumulation in the northern part of the Boso peninsula, intermittent stress release by a series of slow slip events east off the Boso peninsula, sudden stress release by large interplate earthquakes along the northern Sagami trough, and tectonic stress release by inelastic crustal deformation around the Izu-Mainland collision boundary. From the inversion analysis of about 2500 seismic events (M3.5-5.0) in northeast Japan, we obtained the seismogenic stress field that is consistent with the stress patterns expected from geophysical and geological observations. Combining these inversion methods with the computer simulation of tectonic loading, we can monitor the spatiotemporal variation of interplate coupling and seismogenic stress fields in and around Japan.

Keywords: earthquake generation, computer simulation, inversion analysis

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SS005 **Oral Presentation** **6402**

Long-range earthquake forecasting allowing for aftershocks

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We consider the problem of allowing for aftershocks in the EEPAS (Every Earthquake a Precursor According to Scale) space-time point-process forecasting model. EEPAS is based on the assumption that the precursory scale increase phenomenon and its associated predictive relations are ubiquitous in earthquake catalogues. Under the model, every earthquake is regarded as a precursor, according to scale, of larger earthquakes to follow it in the long term. The earthquakes magnitude determines the scale of the distributions in time, magnitude and location, of the increment that it makes to the future rate density of earthquake occurrence. The increment has a normally distributed magnitude, with mean about one unit higher than that of the precursory earthquake. The model is primarily designed to forecast mainshocks, but we want it to forecast all earthquakes above a given magnitude threshold as well as possible, without having to decluster the catalogue or to discriminate between mainshocks and aftershocks. For regional earthquake likelihood model (RELM) testing in California and New Zealand to meet community authorised standards, the threshold has been set at M 5.0. Some allowance must therefore be made for the expected aftershocks of predicted mainshocks with magnitudes above about M 6.0. To accommodate such aftershocks, we assume that each mainshock has aftershocks that are consistent with both Bths law and the Gutenberg-Richter relation, and have the same distributions in time and location as the mainshock itself. Thus the standard EEPAS model is modified by replacing the normal distribution for magnitude by the superposition of a normal and a truncated negative exponential distribution. This is the EEPAS with aftershocks model. We illustrate the application of this model to the forecasting of earthquakes of moderate-to-large magnitude in the ANSS catalogue of California and the NIED catalogue of the Kanto region, central Japan. In both cases, a small information gain is achieved relative to the standard EEPAS model.

Keywords: earthquake, forecasting, seismicity patterns

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SS005 **Oral Presentation** **6403**

On the recurrence of large earthquakes: some insights from a model based on a realistic interacting fault system.

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The statistical law for large earthquakes recurrence is still matter of debate. Although different and antithetical statistical distributions have been so far proposed, there is not a commonly accepted model yet. We argue that part of these discrepancies is possibly related to the different time behavior of individual seismogenic structure and seismic regions, the latter being composed by interacting structures. Here, we set a quantitative model based on a realistic interacting fault system to investigate on this issue. We define an active fault system in Central Italy that includes causative faults of moderate to large magnitude earthquakes. The main geometric and kinematic parameters of each structure are confidently assessed. Then, we study the evolution through time of the fault system by modeling different seismogenic processes and the interaction among faults by means of co- and post-seismic stress variations. The model produces synthetic catalogs on regional and sub-regional scale, as well as earthquake catalog for each seismogenic structure. The results highlight many interesting features: (i) the regional and sub-regional synthetic seismic catalogs reproduce the main characteristics of the real historical catalog of the last centuries; (ii) the synthetic catalogs show significant long-term nonstationarity with seismic rates that vary on time scales different from the recurrence time of each fault; (iii) the statistical earthquake distribution on faults and on seismic regions are completely different. Finally, we interpret these results in terms of the physics of the process.

Keywords: fault system, interaction, nonstationarity

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SS005 **Oral Presentation** **6404**

Afterslip, aftershocks and rate-and-state friction

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We model afterslip induced by a stress change using the rate-and-state friction law. Depending on the model parameters (B/A, stiffness k/kc, and initial stress), the fault exhibits aftershocks, slow earthquakes, or decaying afterslip. We apply this model to the afterslip of the Southern California Superstition Hills earthquake. The inversion is very badly constrained. In particular, it is not possible to distinguish the stable velocity strengthening regime (A>B) from the unstable velocity weakening regime (B>A and k<kc). Thus, we don't need to involve small-scale spatial or temporal fluctuations of friction parameters in order to explain the transition between stable sliding and seismic slip. Afterslip will induce a progressive reloading of locked faults, which can also trigger aftershocks. Using the relation between stress and seismicity derived from the rate-and-state friction law, we estimate the aftershock rate triggered by afterslip. We found that aftershock rate does not simply scale with stress rate, but exhibits different characteristic times and sometimes a different power-law exponent. This model can thus produce aftershock rate decaying as a power-law of time with an Omori exponent either smaller or larger than 1.

Keywords: afterslip, aftershocks, rate and state

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SS005 **Oral Presentation** **6405**

Extensional Branching of the Arg-e-Bam Fault Generated by the 2003 Bam, Iran, Earthquake: Adapting Theory for Fault Branching

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This study adopts the theory of dynamic fault branching (Poliakov et al. 2002 and Kame et al. 2003) as a means for interpreting the branching of Arg-e-bam fault, which proposed by Nakamura et al. (2005) based on the hypocenter distribution of aftershocks of the M=6.5 December 26, 2003 Bam earthquake (death toll: about 26,000). In that theory the effects of pre-existing stress state, and rupture velocity on dynamic fault branching were shown. We estimate the maximum compression direction with respect to the strike of the Arg-e-Bam fault and check the theory for the Rayleigh-like speed of rupture over the fault (Bouchon et al. 2006). Due to the northward Arg-e-Bam fault rupturing with right-lateral slip (mode II), the eastward branching (extensional side) and its angle with respect to the strike of the main fault in the northern region agrees well with the theory for intermediate inclination of Smax and rupture velocity of 0.9 cs (shear wave velocity) .

Keywords: bam earthquake, fault branching

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SS005 **Oral Presentation** **6406**

A scaling law for slow earthquakes

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Recently a series of unusual earthquake phenomena have been discovered, including: deep episodic tremor1, low-frequency earthquakes (LFEs)2, very low-frequency earthquakes (VLFs)3, slow slip events (SSEs)4, and silent earthquakes5-9. Each of these has been demonstrated to be shear slip, similar to regular earthquakes, but with longer characteristic durations and radiating much less seismic energy. These slow events follow a simple, unified scaling relationship that clearly differentiates their behavior from that of regular earthquakes. Their seismic moment is proportional to the characteristic duration and their moment-rate function is constant, with spectral high-frequency decay of 1/f. This scaling and spectral behavior shows that they can be thought of as different manifestations of the same phenomena and that they comprise a new earthquake category. The observed size dependence of rupture velocity for these events is explained by either a constant low-stress drop model or a diffusional constant slip model. This new scaling law unifies a diverse class of slow seismic events and should lead to a better understanding of the plate subduction process and large earthquake generation.

Keywords: scaling, low frequency earthquake, slow slip

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SS005 **Oral Presentation** **6407**

CMT data inversion using a Bayesian information criterion to estimate seismogenic stress fields

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Information about the stress state in the Earths crust is crucial for understanding earthquake generation. However, it is difficult to directly measure the stress state at the depths. We developed a robust inversion method to estimate the stress fields related to earthquake generation (seismogenic stress fields) from the centroid moment tensors (CMT) of seismic events by using Akaikes Bayesian information criterion (ABIC). The CMT solution of a seismic event is conventionally defined by the surface integral of 2-D moment tensor density over a rupture area. Applying Gauss' divergence theorem, we can transform the surface integral representation into the volume integral over a sufficiently large sphere including the rupture area. Since dynamic rupture propagation, which radiates seismic waves, is controlled by energy flow into the rupture zone from the surrounding medium storing elastic strain energy, the volume integral representation is more essential than the surface integral representation. Thus we represented the CMT of a seismic event by a weighted volume integral of the true but unknown seismogenic stress field. The weighting function is taken to be a 3-D Gaussian-type distribution with its peak at the hypocenter and variance proportional to the two-third power of the seismic moment. Representing each component of the stress field by the superposition of a number of known basis functions, we obtain parameterized linear observation equations. Then, introducing prior constraints on the roughness of the stress fields, we construct a highly flexible stochastic model controlled by hyper-parameters. The optimum values of the hyper-parameters are objectively determined by minimizing ABIC. Given the optimum values of the hyper-parameters, we can obtain the best estimates of model parameters by using a maximum likelihood algorithm. We checked the validity of the inversion method through numerical experiments on two synthetic CMT data sets, assuming the Gutenberg-Richters frequency distribution of random-size faults parallel to the plane of the maximum shear stress in one case and random-size faults with random orientations in the other case. In both cases we succeeded in reproducing the pattern of the true stress field within estimation errors. We applied the inversion method to observed CMT data in plate convergence zones around to reveal the spatial variation of seismogenic stress fields related to plate subduction.

Keywords: stress, inversion, cmt

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SS005 **Oral Presentation** **6408**

Crustal Deformation Associated with the Earthquake Cycle along the Eastern Nankai Trough , Central Japan

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The Nankai Trough is a plate boundary where the Philippine Sea plate subducts beneath southwest Japan. Interplate megathrust earthquakes have repeatedly occur along the Nankai Trough with an average repeat time of 120 years. The last megathrust event in the eastern Nankai Trough was the 1944 Tonankai Earthquake (M8.1). We have studied crustal deformation along the eastern Nankai Trough based on leveling data. The data originate in historical leveling since 1880's, and recent leveling surveys with purposes of vertical reference frame keeping, artificial subsidence monitoring, and earthquake prediction. With an addition of leveling survey by ourselves, we obtained a complete record of spatio-temporal variation in the vertical displacement along the eastern Nankai Trough during last 120 years. We analyzed these data and estimated a model of slip (or slip deficit) distribution on the subducting plate interface. The results demonstrate a striking similarity among interseismic deformation patterns (except for one described later), for both before and after the 1944 Tonankai Earthquake, which can be interpreted as a full-locking effect at the sesimogenic depth on the plate boundary surface. The most recent pattern during 1979-2006 also looks quite similar to those in interseismic periods. However, the deformation pattern during 1979-2000 has a difference characteristic in the location of maximum uplift. Difference between these two deformation patterns is ascribed to the effects of the Tokai Slow Slip Event (2000-2005). This implies that slow slip events are playing an important role in the earthquake deformation cycle, and that similar slow slip events might have occurred every 20-30 years through the earthquake cycle. On the other hand, the deformation pattern for the earliest period, 1885-1900, was almost flat (no deformation) and looks quite different from any other time period. This time period was about 30-50 years after the 1854 Ansei Tokai Earthquake (M8.4), which was the previous, and a much larger megathrust event. The deformation pattern may indicate that postseismic deformation continued for a long time after 1854, and/or earthquake cycles are not exactly cyclic.

Keywords: nankai trough, crustal deformation, earthquake cycle

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SS005 **Oral Presentation** **6409**

Joint Simulation of Quasi-static Stress Accumulation and Earthquake Dynamic Rupture

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The entire process of earthquake generation consists of tectonic loading due to relative plate motion, quasi-static rupture nucleation, dynamic rupture propagation and stop, and restoration of fault strength. This process can be described by a coupled nonlinear system, which consists of an elastic/viscoelastic slip-response function that relates fault slip to shear stress change and a fault constitutive law that prescribes change in shear strength with fault slip and contact time. The shear stress and the shear strength are related with each other through boundary conditions on the fault. The driving force of this system is relative plate motion. On the basis of such an idea, we developed physics-based 3-D simulation models for crustal activities in and around Japan, where the four plates of Pacific, North American, Philippine Sea and Eurasian are interacting with each other in a very complicated way. The total simulation system consists of a crust-mantle structure model, a tectonic loading model and a dynamic rupture model. First, we constructed a realistic 3-D model of plate interfaces in and around Japan by applying an inversion technique to ISC hypocenter distribution data, and computed viscoelastic slip-response functions for this structure model. Second, we introduced the slip- and time-dependent fault constitutive law with an inherent strength-restoration mechanism as a basic equation governing the entire process of earthquake generation. Third, combining all these elements, we developed a simulation model for quasi-static stress accumulation due to relative plate motion. Fourth, we also developed a simulation model for dynamic rupture propagation on a 3-D curved fault surface by applying BIEM. Combining the dynamic rupture propagation model with the quasi-static stress accumulation model, we can simulate the entire process of earthquake generation. With this joint simulation model, we numerically simulated the quasi-static stress accumulation process at the 1968 Tokachi-oki seismogenic region, northeast Japan on the Pacific-North American plate interface, and the subsequent process of rupture initiation, propagation and stop there. In this simulation, we forced dynamic rupture to start by giving a certain amount of stress drop. In the case where the stress level is close to a critical level, started dynamic rupture was accelerated and expanded over the whole seismogenic region. In the case where the stress level is much lower than a critical level, dynamic rupture started but was not accelerated. In the case where the stress level is not close to but not much lower than a critical level, started dynamic rupture was accelerated but expanded to only a part of the seismogenic region. These results indicate that stress accumulation due to relative plate motion essentially control the subsequent dynamic rupture. Thus, elucidating the stress states at seismogenic regions is crucial to predict earthquake generation.

Keywords: earthquake generation, tectonic loading, dynamic rupture

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SS005 **Oral Presentation** **6410**

The regularities of the transient mode of seismicity: field data and laboratory modeling

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Analysis of transient (relaxation) mode of seismicity is vital to the study of the earthquake generation process. Seismicity has the structure that forms under the action of geodynamic processes in the geophysical medium and apparently possesses the property of self-organization. The seismic process involves various feedbacks forming and controlling the seismicity evolution. These feedbacks are difficult to recognize and examine in a stationary regime because background seismicity variations are small and usually their origin is poorly studied. Relaxation processes are the response of a system to a relatively strong effect bringing it out of the stationary state. Their study provides deeper insights into basic properties of the medium and mechanisms controlling the seismicity dynamics. Aftershock sequences are typical example of transient mode of seismicity. General statistical properties of aftershock process can be presented as follows: the intensity decay in the aftershock flow with time obeys the Omori power law; Gutenberg-Richter b-value increases and the fractal dimension of the set of hypocenters (d-value) decreases. b- and d-values can be combined in single parameter on the base of generalized frequency-magnitude relation (or unified scaling law of earthquakes in other terms). This parameter indicate the degree of dependence of failure process intensity on the scale of the failure. From this point of view, the variations of d- and b-values in aftershock process indicates that the typical features of the relaxation in aftershock process along with Omori law is the redistribution of the intensity of the failure process from larger scales to smaller ones. The origin of aftershock sequences is traditionally related to the relaxation of the seismic regime initiated by the main shock. Analysis of laboratory results obtained from relaxation simulation during fracture of rocks showed that statistical relaxation properties are the same as those observed in transient modes of the fracture regime, when a main shock source is absent. With step like loading of a sample (when its deformation abruptly increases and held afterward constant), each loading step gives rise to a sequence of acoustic events similar to aftershock sequences. The properties of sequences of acoustic events examined by determining experimentally their times and sources were found to be the same as in aftershock sequences of earthquakes: activity decay by the Omori law, an increase in b-value, and a decrease in d-value. The inferred results indicate that the presence of a main shock is not a necessary condition for the formation of relaxation processes similar to aftershock sequences. Such processes are likely initiated by an abrupt change in a certain region of the stress field. Main shocks typical for seismicity are only one of the possible sources of local perturbations in the stress field. In our opinion, typical properties of aftershock decay reflect the universal scenario for relaxation of any stress perturbation in the heterogeneous medium. This scenario is mainly controlled by the properties of the geological medium – a stressed heterogeneous hierarchical system. It doesn't depend (or depend slowly) on the nature and properties of the perturbation source. Primary experimental data were obtained in cooperation with S.A.Stanchits (GFZ, Potsdam) in the laboratory of rock mechanics headed by Prof. D. Lockner (Geological Survey, Menlo Park). This work was supported by RFBR grant 05-05-65122 and RF President grant 5009.2006.5.

Keywords: aftershocks, seismicity, laboratory modeling

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SS005 **Oral Presentation** **6411**

Mega-thrust and intra-slab earthquakes beneath Tokyo metropolitan area, Japan

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In central Japan the Philippine Sea plate (PSP) subducts beneath the Tokyo Metropolitan area, the Kanto region, where it causes mega-thrust earthquakes, such as the 1703 Genroku earthquake (M8.0) and the 1923 Kanto earthquake (M7.9) which had 105,000 fatalities. The vertical proximity of this down going lithospheric plate is of concern because the greater Tokyo urban region has a population of 42 million and is the center of approximately 40% of the nation's economic activities. A M7+ earthquake in this region at present has high potential to produce devastating loss of life and property with even greater global economic repercussions. The M7+ earthquake is evaluated to occur with a probability of 70 % in 30 years by the Earthquake Research Committee of Japan. We started the Special Project for Earthquake Disaster Mitigation in Urban Areas, a project to improve information needed for seismic hazards analyses of the largest urban centers.Assessment in Kanto of the seismic hazard produced by the Philippine Sea Plate (PSP) mega-thrust earthquakes requires identification of all significant faults and possible earthquake scenarios and rupture behavior, regional characterizations of PSP geometry and the overlying Honshu arc physical properties (e.g., seismic wave velocities, densities, attenuation), and local near-surface seismic site effects. Our study addresses (1) improved regional characterization of the PSP geometry based on new deep seismic reflection profiles (Sato etal.,2005), reprocessed off-shore profiles (Kimura et al.,2005), and a dense seismic array in the Boso peninsular (Hagiwara et al., 2006) and (2) identification of asperities of the mega-thrust at the top of the PSP. We qualitatively examine the relationship between seismic reflections and asperities inferred by reflection physical properties.We also discuss the relation between a deformation of PSP and intra-slab M7+ earthquakes: the PSP is subducting beneath the Hoshu arc and also colliding with the Pacific plate. The subduction and collision both contribute active seismicity in the Kanto region. We present a high resolution tomographic image to show a low velocity zone which suggests a possible internal failure of the slab; a source region of the M7+ intra-slab earthquake. Our study contributes a new assessment of the seismic hazard in theTokyo metropolitan area

Keywords: mega thrust, earthquake disaster mitigatio, intra slab earthquakes

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SS005 **Oral Presentation** **6412**

Foreshocks and the Prediction of Strong Earthquakes

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Foreshock sequences are characterized by some common properties which are of great interest for the mainshock prediction. The first is that the activity rate, r, increases as the inverse of time in a time interval from hours to a few months before mainshock, and the second is that usually the b-value of the magnitude/frequency relationship is lower than in background seismicity and aftershocks. However, foreshocks precede only some mainshocks and not others. Understanding better why this preferential incidence of foreshocks happens would imply a significant step towards the achievement of the mainshocks prediction. In this paper we examine the incidence of foreshock activity before mainshocks in . We investigated foreshock activity for mainshocks of Ms ≥ 5.5 occurring in the Greek region from 1986 up to December 2006 inclusive. It appears that about 50% of the mainshocks are preceded by foreshocks. However, due to constraints related to the seismic monitoring capabilities some foreshocks pass without notice in the standard earthquake catalogues, such as the sequence of East Aegean Sea , October 2005. Therefore, the real percentage of foreshock sequences should be higher. We indicate how empirical probability approaches along with the variation of the parameters b and r could be utilized for the short-term prediction of the mainshock. In addition we show how such variations can be detected by an automatic system performing statistical tests by updating the data sets produced on a daily basis by the national seismograph system.

Keywords: foreshocks, prediction, greece

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SS005 **Oral Presentation** **6413**

Seismic monitoring of strong earthquakes source areas

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Physically justified choice of seismological parameters for seismic situation monitoring directed to strong earthquakes precursors finding is based on the supposition, that the stress upbuilding process during the strong earthquake preparation leads to simultaneous changes in seism tectonic deformation process. In this way the seism tectonic deformation concept introduction is very important. It is based on the submission that the earthquake is a result of elastic deformations release accumulated owing to slow earth's interior movements. So to the earthquake responds some contribution to this movement. For this contribution determining such source parameters as focal mechanism and value of displacement are used [Yunga, 1990]. From the expression of seism tectonic deformation it is possible to derive two independent parameters for seismic situation monitoring: summarized scalar seismic moment per the sampling interval or cumulative scalar seismic moment, that can be considered as the Benioffs graph analog, and so called order coefficient or ordering index k (0<=k<=1); in general way it slightly depends on magnitude and is considered as a chaotic measure of seismic process. It is possible to introduce ordering index k as the ratio of the matrix norm of average by the sampling interval seismic moment tensorto the average by this sampling interval seismic moment tensor matrix norm. To avoid overwhelming influence of stronger events before averaging the seismic moment tensor matrixes are normalized on the scalar moment. The time series of ordering index k demonstrate natural shift of order and chaotization phases of the seismic process in time, related with originating of strong earthquakes. It was established that the best sampling interval for interpretation is 3 years. Ordering Index was used with the aim of retrospective seismic situation analysis in the source areas a number of strong earthquakes for the last decade in different regions of the World: Shikotan (near South Kuriles), 04.10.1994, Mw=8.3; Kronotskoye (near East coast of Kamchatka), 05.12.1997, Mw=7.8; Taiwan, 20.09.1999, Mw=7.7; near West Coast of Peru, 23.06.2001, Mw=8.2; Sumatra, 26.12.2004, Mw= 9.0, Middle Kuriles, 15.11.2006. Almost in all the cases one can observe the minima values of k for 2-3 years before strong EQ and its increasing up to maximum. It has been shown, that such behaviour of ordering index is connected with process of deep reorganization of background seismicity, at least, in source zone of future strong earthquake outlined on the area of its aftershock process development. Character of such reorganization is connected with forming the eigen vectors of background events CMT matrix practically in parallel the eigen vectors of the main event on the eve, during and right after its occurrence.

Keywords: seism tectonic deformation, seismic moment tensor, matrix norm

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SS005 **Oral Presentation** **6414**

Deep-focus precursors of Sumatra earthquake 2004

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The strongest last decade seismic event occured on December, 26th, 2004 at coasts of island Sumatra on depth about 30 km with moment magnitude Mw=9. It has generated a grandiose tsunami in Indian Ocean and carried away more than 200000 human lives. The reason of so powerful earthquake was discharge of the saved up pressure in Benniof zone on borderIndian lithospheric plate and the Burmese microplate. As a whole this part of Indian Ocean is considered seismically active. On Sumatra the destructive earthquakes had taken place in 1916, 1934, 1935, 1936, 1946 and 1975, but their magnitudes did not exceed 7.0. The purpose of our work was to understand, whether it is possible to predict recent grandiose natural accident by means of existing methods. According to K. Mogis method some large Japanese earthquake origin zones were crossed by directions of near horizontal compressing strain P-axes from shocks which have been before on depths of 100 km and more. With helps Mogis criterions we have found some deep-focus foreshocks for more than 20 events 1931-1999 with magnitudes 7.0-8.3 at north-west Pacific part, but no accordance between these magnitudes and foreshocks quantity were discovered. Thats why these criterions were supplemented on the base of contemporary ideas on geodynamic process nonlinearity. For 23 basic shallow events of 1982-2004 with Mw> 6.3 we took as foreshocks the shocks which have been before on depths of 70 km and more with P-axes of any position directed on their origin zones. It allowed to double foreshocks number found before. Correlative dependences between foreshock process parameters (foreshock numbers N, time periods T from the foreshock process beginning till the strong event moments) and these events magnitudes Mw were constructed. Every large basic event occurred after the foreshock process ending when difference Mw (T)-Mw (N) disappeared practically it did not more 0.2-0.3 Mw. For Sumatra earthquake we found 22 foreshocks with depths 71 - 664 km (N=22) after origin mechanism analysis of more than 150 deep-focus shocks which had taken place in 1976-2004 at surrounding territory -15- 25 N and 85- 115 E. The first one of them had occurred in 1979, the last one in 2004 (T=25 лет). Directions of their P-axes have crossed origin zone of Sumatra event. This zone has the form of an ellipse with long axis of northwest azimuth according to one nodal plane of origin mechanism. Its stretching answered to regional tectonic peculiarities and aftershocks distribution registered by Geophysical Service seismic network of the Russian Academy of Sciences. The sizes of Sumatra origin zone calculated in dependence on magnitude Mw=9.0. It is need to note that a number N of Sumatra event foreshocks and period T of their existence answers to magnitudes Mw=9.3 and 9.05 in accordance with indicated correlations. Apparently the danger of such strong event could be prevented under obligatory condition of deep-focus shocks seismic monitoring and the analysis of their origin mechanisms.

Keywords: foreshock, earthquake, prediction

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SS005 **Oral Presentation** **6415**

Monitoring internal state of fault with acoustic wave transmission

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The internal state of fault, which controls fault strength, varies within an earthquake cycle. It is generally accepted that the strength decreases with slip on the fault during earthquake (slip-weakening) and increases after earthquake (healing). These strength changes are considered to be due to the variation of fault state. We propose below that fault state can be monitored in a nondestructive way by use of acoustic wave transmission across the interface. We performed friction experiments on bare granite surfaces and also on simulated fault gouges in order to examine how we can see the variations of internal state by using acoustic wave transmission and how it relates to fault strength. The experiments were conducted in double direct shear apparatus under normal stress up to 10MPa while continuously measuring the amplitudes of longitudinal or shear waves (a cycle of sine wave with 1 micro second duration) transmitted across the interfaces. For bare surfaces, it is known that the frictional strength is proportional to real contact area (Bowden and Tabor, 1964). Transmissivity of acoustic waves also depend on contact area, but it is also affected by size distribution of contacts (e.g. Kendall and Tabor, 1971). Hence, different factors that can alter the contact state were controlled independently. They include normal stress, quasi-stationary contact time, and slip velocity. The results show that (1) the amplitude at steady state sliding decreases with velocity, (2) during hold, the amplitude increases with quasi-stationary contact time, like log t healing, (3) upon reloading after hold, miniscule preslip before stress peak erases much of the amplitude which has increased during hold, (4) the amplitude increases with normal stress. We inferred the frictional strength as an internal state variable used in rate- and state-dependent friction law as proposed by Nakatani [2001]. The relationship between transmitted amplitude and thus inferred frictional strength was almost linear under constant normal stress. The relation was somewhat different and non-linear when normal stress was varied. A noteworthy finding is that amplitude upon velocity step followed the inferred strength, not the shear stress; so-called direct effect, which is positive dependence on the slip velocity, did not appear in the amplitude. For the simulated fault gouges, fault strength and acoustic transmission are affected by geometrical arrangement of gouge particles in addition to the state of each contact considered above. In a previous friction experiment with simulated fault gouge of Nakatani [1998], time-independent strengthening due to the gouge particle rearrangement caused by reduction of shear stress was observed. He also pointed out that time-dependent strengthening, which is considered to be due to contact growth, was observed only if the shear stress during hold was very high. However, we found that transmitted amplitude increased linearly with the log hold-time independently of the hold stress. During reloading after hold, the amplitude decreased with small slip. It seems that time-dependent strengthening in friction can be observed when this weakening has not been completed before stress peak. We also observed that the amplitude increased with reduction of shear stress, which is corresponding to the time-independent strengthening. Therefore the strength changes caused by the both mechanisms could be observed with acoustic waves. All the observed changes of amplitude corresponded well with the change of gouge layer thickness, although the quantitative relation between them depends on the mechanism. These results suggest that the acoustic wave transmission is a useful tool to monitor the internal state (i.e. frictional strength) even in the fault including gouge. Especially, it can catch the beginning of slip-weakening quite sensitively, which may be difficult to detect by monitoring slip or stress because this occurs with a minuscule amount of preslip.

Keywords: fault strength, monitoring, friction

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SS005 **Oral Presentation** **6416**

Earthquake mechanisms and collision geodynamics: theoretical aspect

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The paper is devoted to connection of regional distribution of earthquake mechanisms in collision domain, which is placed between consolidated part of Eurasian super plate and Indo-Australian super plate, to geodynamical factors. It is shown that multiscale block structure of the Crust plays a decisive role in many characteristics of seismic process. From geodynamic point of view it makes sense to distinguish reological and fault block structure. Properties of blocks with different reology for slow deforming with characteristic times starting from time of earthquake preparation and above may be different to the great extent. The crucial point is the lost (or preserving) of shear stability. Reological block structure is responsible for stress distribution in the region. The most active elements of the system are rigid aseismic blocks. The fault block structure is responsible for realization of movements. The most important elements of the structure are faults. On the ground of the elastic model with some corrections obliged to Coulomb failure criterion and plasticity it was shown that there are several geodynamic situations with different distributions of mechanisms along the depth. These situations are constrained compression, moderately-constrained compression, unconstrained compression, as well as deformation shadow and squeezing of the material. In region of constrained compression (Tien Shan) thrusts dominate. In the domains of moderately constrained compression (for example, Altay-Sayan region) strike-slips in middle depths and thrusts for small depths prevail. In zones of deformation shadows (Baikal and South-West Baikals neighborhood) there are conditions for shallow strike-slips and deep normal faults with strikes parallel to the direction of regional compression. Final orientation of ruptures and the type of strike-slips (left-sided or right-sided) is determined by the system of faults and existing flow of the material in the Crust. A conception is advanced according to which the low and upper crusts participate in the same flow of the material. But in the low Crust this flow manifests itself as quasiplastic flow (partly viscous) and in the upper crust it reveals as brittle-plastic one. At that the driving force in the most cases is the flow in the low crust.

Keywords: earthquake, collision, geodynamics

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SS005 **Oral Presentation** **6417**

Traction-at-split-node method for dynamic rupture propagation: numerical comparison of the finite-difference and finite-element implementations

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The Traction-at-Split-Node (TSN) method for simulation of dynamic rupture propagation has been independently developed by Andrews (1973, 1999) and Day (1977, 1982). Recently Day et al. (2005) showed very good level of agreement of the method with the boundary integral method. Dalguer and Day (2006) demonstrated superior accuracy of the method compared to the thick-fault method (Madariaga et al. 1998) and stress-glut method presented by Andrews (1999). We developed and encoded four implementations of the TSN method (Moczo et al. 2007): FE 2nd-order the finite-element implementation using the restoring force concept and e-invariants; SG FD 2nd-order velocity-stress staggered-grid finite-difference scheme, 2nd-order at grid points close to the fault plane and grid points on the fault plane; SG FD mixed 2nd4th-order velocity-stress staggered-grid finite-difference scheme, 2nd-order at grid points close to the fault plane and 4th-order at grid points on the fault plane; SG FD 4th-order velocity-stress staggered-grid finite-difference scheme, 4th-order at all grid points. We performed a series of numerical simulations of spontaneous rupture propagation on a planar fault in a homogeneous unbounded elastic medium. In order to have a reference solution we followed Dalguer and Day (2007) who used Version 3 of the Southern California Earthquake Center (SCEC) benchmark problem (Harris et al. 2004). The comparison of the RMS misfits for the four implementations of the TSN method leads us to conclusion that the FE 2nd-order implementation of the TSN method has the highest rate of convergence while the rate of convergence of the SG FD 4th-order implementation is the lowest. Because the reference solution, DFM0.05, cannot be considered as the most accurate solution, we, in fact, do not compare accuracy of the individual implementations. We only compare the convergence rates for the particular choice of the reference solution. At the same time it is likely that DFM0.05 is a reasonably accurate solution.

Keywords: earthquake source dynamics, numerical modelling, finite difference method

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SS005 **Oral Presentation** **6418**

Investigation of parameters governing aftershock productivity from a worldwide analysis of earthquake doublets

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In a recent study, Daniel et al. (2006, In prep) showed that aftershock productivity for mainshocks of a given magnitude and focal mechanism can be quite different for the same area. Particularly, they studied an earthquake sequence composed of two almost identical mainshocks, and found that aftershock rate following the second one was clearly weaker than after the first event.We here present an analysis of this behavior on a larger scale, detecting earthquake doublets from a global catalogue. We then study aftershock decay rates and compare aftershock productivities for both mainshocks. Our main interest lies in the understanding of how seismicity following the second earthquake can be modified by occurrence of a previous strong mainshock in a short (few years, few rupture length) space-time window from this second event. We finally discuss parameters influencing such modification, such as time delay between mainshocks, mainshocks magnitude, or distance between events.

Keywords: seismicity, doublets, aftershocks

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SS005 **Oral Presentation** **6419**

Fault interaction by elastic stress changes in vertically inhomogeneous media: an application to the June 2000 South Iceland seismic sequence

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Most of the studies concerning fault interaction deal with static stress changes produced by earthquakes in homogeneous half-spaces. This study considers the coseismic stress changes induced by the June 17 2000 mainshock in the South Iceland Seismic zone near the fault plane where the second mainshock of the sequence occurred on June 21 2000. The two mainshocks occurred on parallel, nearly vertical, strike-slip faults. We compare coseismic stress changes in an elastic 4 layers half-spaceand in an elastic homogeneous half-space (heterogeneous and homogeneous crustal model, respectively). We consider in particular Coulomb Failure Function (CFF) variations, projected on fault planes parallel to the June 21 fault plane. Static stress changes are evaluated as the final value of dynamic stress changes generated with a discrete wave number and reflectivity code. Results are compared with the aftershocks occurred in the time interval between the two mainshocks in a region close to the June 21 fault (seismicity data). According to both the crustal models, only about 10% of the seismicity data occurs in shadow zones (with negative values of static CFF changes), and the June 21 hypocenter locates in a region with a positive CFF change. In the case of the homogeneous model, the maximum values of CFF changes are located on the surface. Using the heterogeneous model, the maximum values of static CFF changes locate below a 3 km depth, where the assumed seismic velocities show the largestincrease. Thus, a relevant difference between the two model results concerns with the first 3 km depth of the June 21 fault region, where larger positive values of CFF changes are expected according to the homogeneous crustal model and only 11.5 % of the seismicity data hypocenters locate. About half of these shallow aftershocks occur in shadow regions according to both the crustal models. On the basis of these results, we suggest that fault interaction studies should take into account vertical elastic heterogeneities of the crust in order to correctly estimate the vertical extension of regions where subsequent seismicity can be favoured by coseismic stress changes.

Keywords: crustal layering, coulomb stress changes, aftershocks

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SS005 **Oral Presentation** **6420**

Extraction of seismicity pattern prior to large earthquakes: implications for fluctuation of multiple seismicity parameters in Central Honshu, Japan

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Identifying specific seismicity patterns prior to large earthquakes is crucial for earthquake forecasting. Various aspects of non-stationary seismic activity on the Earths surface may be associated with the lithospheric plate movements as a far-from-equilibrium self-organized open system. From this viewpoint, we examine multidimensional feature of seismic activity by introducing many seismicity parameters. We target on a wide area spanning about 400 km in central Honshu,where the convergence of four plates causes a highly complex and interactive seismicity within the plate boundary zones. We use the recent earthquake catalog compiled based on a nationwide high-quality seismograph networkfor the periodfrom October 1997 to July 2006. We declustered the catalog by a linking method. To quantify various statistical features of these declustered earthquakes in each successive sampling period, we introduce manyseismicity parameters of space-time-magnitude distribution. They include a and b values of the Gutenberg-Richter (G-R) law of frequency-magnitude relation and deviation parametersof observed distribution from the G-R relation. For the spatial distribution, we adopt quantities such as mean distance of each earthquake pair, fractal dimension, emergent and distinct rate of areas occupied by earthquakes, earthquake density, and so on. The histograms of these seismicity parameters obtained for each sampling period show approximately normal distributions. From the mean and standard deviation (one sigma) of each variable, we define outliers as variable lying outside the two sigma. We also call the time period corresponding to the outlier anomalous period.Time series ofoutliers of each parameter showed a clear tendency to concentrate on specific time span rather than to distribute randomly or uniformly during the investigated period. The cumulative number of all the outliers showed an accelerating increasefrom around the end of 2002 till mid 2004. After the successive increase of anomalous periods, several large earthquakes occurred widely in thearea, including the largest Off Kii-Peninsula M7.4 of September 5, 2004, and the damaging inland Niigata-Chuetsu M6.8 of October 23, 2004. The increase ofanomalous periods is due tosynchronous appearance of several parameters. We assumed aprecursory period reasonably for the two large events from the beginning of May, 2003 till the end of August, 2004, and performed randomization test for the outlier distribution. The result showed that such concentration of outliners observed during the precursory period is rare with the probability less than 5 %. Thus the large and synchronous fluctuation of several seismicity parameters strongly suggests a critical spreading of an evolutionary process during the precursory period which caused an episodic long-range interaction. We emphasize the importance of synthetic analysis of many kinds of seismicity parameters for extracting multiple aspects of seismicity in space-time-magnitude domain.

Keywords: seismicity, earthquakes, forecasting

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SS005 **Oral Presentation** **6421**

Wave attenuation due to shear-induced heterogeneity in granular media for fault slip prediction

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We performed direct shear tests for simulated fault gouge material to detect precursory signals of nucleation of fault motion by transmission waves across the material during shear. It was observed that significant amount of attenuation of the wave at the stage where the shearing stress increases but the shearing displacement is still negligible. Numerical simulations using the Discrete Element Method to understand the mechanism of the drastic attenuation as a precursor of slip found in the physical tests were also performed. As shear goes, the heterogeneity contrast between well stressed force chains and poorly stressed force chains developed in the granular material becomes more and more clear. Therefore, we track all the wave passes particle by particle at each shearing level focusing the wave reflection and refraction. From the analysis of the individual wave from the source, we find out the dispersion and trap due to the structured force chains. Considering the shear-induced heterogeneity scale and wave length for input source, a proposal will be made to apply this mechanism to earthquake prediction, in terms of the precursory fault slip.

Keywords: fault, prediction, heterogeneity

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SS005 **Poster presentation** **6422**

Shock-wave model of earthquake source

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The earthquakes shock-wave model is a fundamentally novel hypothesis which essence is that initiated deeply inside the Earth and propagating through the lithosphere the shock wave is generating the earthquakes source. Arriving at the Earth surface the shock wave is reflected by it producing the unloading (strain) wave. The interaction of the shock and the unloading waves generates ruptures, fractures, ets. Applying numerical models of continuum medium mechanics this insight into earthquakes allows to evaluate the region of seismic hazard, namely to calculate the amplitudes and velocities of the medium slips, that are accompanying the arrival of the shock wave at the Earth surface. In the context of this model the earthquake source is defined as a volume of the far ordered coherent and acoustically active medium in which opening the cracks exchange acoustic waves. Inside this volume the shock wave is generated.

Keywords: earthquake, shock wave, model

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SS005 **Poster presentation** **6423**

Study of crust in South-Western Zagros in Iran using earthquake data inversion

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One of the basic factors responsible for earthquakes is the appropriate crustal velocity structure. The crustal velocity model can help to locate the hypocenter of the earthquakes more properly. In this study, we investigate the velocity structure of the crust and upper mantle beneath the Fars region located in the South western Zagros. We use seismic data collected by the local seismological network that was deployed in Shiraz in 1999. About 628 earthquakes were processed by Shiraz seismic network occurring during the period 19992006 in this region. We selected 31 earthquakes to invert by considering earthquakes that were in the same azimuth with each two seismic stations of the network. An initial crustal model having 3 layers was obtained by reading Pn and Pg phases from recorded waveforms in Shiraz seismic network and analyzed their travel-time curves. Then using a tomography method, we refined the depth and velocity parameters of each layer. We used the software that was developed by Zelt (1993). Taking into account the results that was obtained in this study; we provided the contour maps for the velocity and depth variations. Our interpretation is in good agreement with the geological evidence and the result of other studies.

Keywords: inversion, zagros, zelt

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SS005 **Poster presentation** **6424**

Studying of the relation between crustal movement and strong earthquakes by GPS in mainland China

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This paper analyzed the background and trend of spatial pattern of crustal movement and tectonic deformation in large scale, which are disclosed by current GPS data in Mainland China. Firstly, we discussed the relation between distribution of regional horizontal movement and strain rate field and locations of strong earthquakes. Secondly, we studied principal characteristics of regional deformation field in the earthquake process by analyzing dynamic changes of regional deformation field and strain field accompanying with major earthquake processes, such as the MS 8.1 earthquake in the west of the Kunlun Mountains Pass. Finally, we developed a method to detect the location of strong earthquake from seismic deformation fields in medium-long phase. With the regional GPS data by high spatial resolution, we developed a method of quantitatively analyzing the tectonic deformation in order to predict the location of forthcoming strong earthquakes in active rupture zones, and analyzed the cases in the eastern boundaries of Sichuan-Yunnan block. We divided the main fault area into certain deformation units, then estimated the geometric deformation and relative dislocation parameters of each unit, and quantitatively estimated the slip and strain rate in each segment of the rupture zone. Furthermore, we could determine possible anomalous segments including abnormal properties and amplitudes by analyzing the consistency of the deformations of all segments in the whole rupture zone.

Keywords: gps, modeling, deformation

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SS005 **Poster presentation** **6425**

Source Mechanism and Source Parameters of May 28, 1998 Earthquake, Egypt

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On May 28, 1998, a moderate size earthquake of mb 5.5 occurred offshore the northwestern part of Egypt (lat. 31.45 N and long. 27.64 E). It was widely felt in the northern part of Egypt. Being the largest well recorded event in the area for which seismic data from the global digital network are available, it provides an excellent opportunity to study the tectonic process and present day stress field occurring along the offshore Egyptian coast. The source parameters of this event are determined using three different techniques; modeling of surface wave spectral amplitudes, regional waveform inversion and teleseismic body waveform inversion. The results show a high angle reverse fault mechanism generally trending NNW-SSE. The P-axis trends ENE-WSW consistently with the prevailed compression stress along the southeastern Hellenic arc and southwestern part of the Cyprean arc. This unexpected mechanism is most probably related to a positive inversion of the NW trending offshore normal faults and confirms an extension of the back thrusting effects towards the African margin. The estimated focal depth ranges from 22-25 km indicating a lower crustal origin earthquake owing to deep-seated tectonics. The source time function indicates a single source with rise time and total rupture duration of 2 and 5 sec respectively. The seismic moment (Mo) and the moment magnitude (Mw) determined by the three techniques are 1.03x1017Nm, 5.28, 1.24x1017Nm, 5.33 and 1.68x1017Nm, 5.42 respectively. The calculated fault radius, stress drop and the average dislocation assuming a circular fault model are 7.2 km, 0.63 Mpa and 0.11m respectively.

Keywords: focal mechanism, waveform inversion, seismotectonics of egypt

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SS005 **Poster presentation** **6426**

Focal Mechanisms of Small and Moderate Size Earthquakes Recorded by the Egyptian National Seismic Network (ENSN), Egypt

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Seismic activity in Egypt, while generally moderate constitutes a significant hazard as was demonstrated by the aftermath of the moderate-sized 1992 Cairo earthquake. In this study the digital records of the new installed Egyptian National Seismic Network (ENSN) from 1997 to 2003 is used to evaluate the focal mechanisms with high reliability. The analysis is based on P, SV and SH polarities and their amplitude ratios. The solutions of fifty events are used to examine the mode of tectonic deformation and the present day stress field acting along different tectonic provinces of Egypt. The results exhibit mainly normal faulting generally trending parallel to the Gulf of Suez-Northern Red Sea rifts and tend to lie WNW-ESE to E-W on land inside the Egyptian territory. Some mechanisms reflect small component of shear especially for the events located close to the intersection points of two fault trends. A dominant tension stress prevailed at the NE corner of Africa directed NE-SW to ENE-WSW along the Northern Red Sea- Gulf of Suez-Gulf of Aqaba rifts while trends NNE-SSW on the Egyptian land. Four mechanisms on the northern Red Sea closer to the intersection point of the Northern Red Sea-Gulf of Suez-Gulf of Aqaba faults show strike slip faults with minor normal component with unexpected NW-SE tension stress that reflects a heterogeneous stress at that point or slipping along pre-existence NE-SW fault. Three mechanisms around the Naser's Lake give mainly strike slip faults with minor normal components. The solution of a moderate sized event along the Mediterranean coast show reverse mechanism trends NNW-SSE with P-axis directed ENE-WSW similar to that prevailed at the most eastern side of the Hellenic arc and the western side of the Cyprean arc. The changes from a dominant tension on land to a dominant compression towards the Mediterranean Sea have occurred along the transition zone between the continental-oceanic crusts. This change indicates an extension of the back thrusting effect and/or positive inversion of the pre-existence passive margin due to the sunduction and collision of the African plate with the Eurasian plate.

Keywords: focal mechanism, seismotectonics of egypt, stress field inegypt

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SS005 **Poster presentation** **6427**

The account of effect the Fermipastaulam in mathematical models of seismic processes activization

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The basic problem of the probabilistic approach of earthquakes forecasting is uncertainty of distribution law of the casual processes initiating earthquakes. For the decision of this problem, it is necessary to proceed to use in forecasting numerical methods, to find principles and approaches in an establishment of regularities of casual and chaotic processes. For this purpose, it is possible to use principles and methods of the catastrophes theory. However, the modern catastrophes theory investigates conditions of occurrence of catastrophe or reaction of system to external influence. At that for reception of exact numerical decisions are taken into account 2-3 influencing parameters while for calculation of real seismic processes it is necessary to take into account several tens of connected, loosely-coupled or untied parameters. Paradoxical lack of the catastrophes theory is necessity of use of probabilistic approaches for the forecasting tasks decision. Basis of mathematical model of earthquakes activization is the energy hypothesis about unity and connections of space and terrestrial energy processes, their balance and transformation in lithosphere, an atmosphere, hydrosphere and biosphere. The hypothesis is accepted, that at occurrence of earthquakes the effect of return of oscillatory (energy) activity the Fermi-Pasta-Ulam is appear. Display of effect has steady global and local temporal laws. Occurrence of strong earthquakes has the period of preparation and there is a result of interaction of external and internal energy cyclic processes in lithosphere, the started from any force or energy influences, long before occurrence of earthquakes. In mathematical model "influence - response" earthquakes occurrence is defined by influence of transients of changing control parameters. That is change of solar activity, fluctuation and displacement of a terrestrial axis, change of the Moon phases either any other factors or the parameters describing energy and force influences or changes. Initiating condition of strong earthquakes occurrence are extreme values of transients and extremums of their first and second derivatives. With the help of mathematical model "influence - the response" on the basis of statistics of change cosmophysics and heliogeophysical factors and events of earthquakes are established spatio-temporal laws of earthquakes occurrence, which then are used for definition of global and local function of activization of the earthquakes, being to the point forecast. Depending on a time scale of transients smoothing of control parameters and the established spatio-temporal laws of earthquakes activization "long-range action" forecast functions can make from 7 days till 18 years.

Keywords: earthquake

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SS005 **Poster presentation** **6428**

Application of seismic noise for prediction of strong earthquakes in Kamchatka

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In Kamchatka the procedure for identification of large earthquake precursors by the monitoring of the tidal component of the high-frequency seismic noise (HFSN) was developed. HFSN is the seismic oscillations in the frequency range of the first tens of Hz with the amplitudes about 10-9-10-12 m. For the HFSN registration the narrow-band piezoelectric high-sensitive sensor was used (Q-factor=100, resonance frequency f=30 Hz, sensitivity of the seismometric channel is about 10-12 m). Signal envelope is recorded and analyzed. We have data of continuous long-time HFSN observations from 1992 to now and it is good scientific base for investigations and generalization. The main investigated effects are modulation of HFSN by the Earth tides and temporal variations of the HFSN parameters connected with the large earthquakes preparation. Before local large earthquakes synchronization of HFSN tidal component with tidal wave of gravitational potential was found. So the stabilized phase shift of the HFSN 1-component before strong earthquakes has fixed values. So high sensitivity of seismic noise to Earth tides can be explained by conception of [Alexeev et al., 2001]. In this conception the possibility of formation of near-surface migrating dilatant zones that can variations of geophysical fiels-precursors is shown. Detection of Earth tide HFSN synchronization is very important, as confirmation of the endogenous origin of some seismic noise variations. In given report we present examples shown the connection of HFSN tidal variations with 27 strong Kamchatkan earthquakes since 1992 to 2006 (magnitudes from 5 to 7.8). By all this data generalization we calculated the empirical function for magnitude-epicentral distance connection for predicting earthquakes: M=4+0.008*D. Long-term registration of the HFSN is carried out in Kamchatka by two stations. Now HFSN monitoring is used for large earthquakes prediction in real time operation mode by the Kamchatkan Branch of Russian Advisory Council of Earthquake Prediction. This research is supported by RFBR Grant 05-05-64276a.

Keywords: seismic noise, earthquake prediction, kamchatka

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SS005 **Poster presentation** **6429**

On geodynamical processes in the region of the Northern Tien Shan: possible preparation for large earthquake

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Earlier the authors have suggested a qualitalive model of a preparation for large shallow earthquake, on the grounds of an analysis of geological, geophysical and geochemical data totality. A major element of the model is fluid ascent from the uppermost mantle. The model is connected with a formation of a narrow zone of big vertical extent, saturated by fluids in the lower crust and uppermost mantle. Hydrofractures at a roof of this zone are followed by the fluid ascent into the middle crust, which leads to a sharp decrease of a friction on the fault and a final slip in the source. Such processes should be revealed in changes of some seismicity parameters and in occuring of relatively weak earthquakes with unusual focal mechanisms. The model was tested successfully on examples of the Baisorun earthquake of 1990 (M 6.4) and the Suusamur earthquake of 1992 (M 7.3) in the Northern Tien Shan region (retrospectively). Recently, we have picked out an abnormal zone in the North Tien Shan region on the grounds of the model. This zone, corresponding to the eastern part of the Kirgiz range and the Kochkor depression, was identified with an area of a preparation for future large earthquake. It has been picked out according to results of the earths crust and uppermost mantle mapping for a large region of the Western and Central Tien Shan by short-period shear wave attenuation. The mapping was carried out by a ratio of S and P wave amplitudes on recordings of deep-focus hindukush earthquakes and local quarry blasts, and also by S coda of local events. It was established, that the attenuation field structure changed essentially during the last 5-7 years. This zone is charcterized by very high attenuation in the upper crust (at depth up to ~10 km) and in the uppermost mantle. At the same time, relatively weak attenuation and very high S wave velocities are observed in the middle crust. Subvertical zones of high attenuation in the lower crust and uppermost mantle have been formed at the boundaries of this zone. In 1999-2005, an elliptical structure, formed by epicenters of relatively deep earthquakes (h>15 km), revealed in the abnormal zone. Normal faulting and oblique-normal faulting events prevailed at the boundaries of this structure in 2005. An increase of a total number of weak earthquakes and a growth of a part of relatively deep shocks (h>15 km) are observed here during a few last years. The data obtained testify to the active juvenile fluid ascent in the earths crust of the abnormal zone, which leads possibly to a formation of a source zone of large earthquake. This was declared in a few papers, published in 2004-2006, and in some reports. Large earthquake (Mw 5.8) occured at the eastern border of the abnormal zone. We are continuing monitoring of geodynamical processes in this zone. On the authors opinion, the data obtained testify to the preparation for the larger earthquake (M>~6.5) in the abnormal zone.

Keywords: earthquake, preparation, attenuatin

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SS005 **Poster presentation** **6430**

Synchronization effects of microseismic background oscillations field before strong earthquakes

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Synchronization phenomena of background microseismic oscillations before strong earthquakes M = 8.5, 25.09.2003 near Hokkaido and M = 9.2, 26.12.2004 near Sumatra are investigated by estimating different measures of coherent behavior (based on Fourier and orthogonal wavelet expansions of the signals) within multiple time series in a moving time windows. Periodic components of intensity of large outliers within seismic records and the temporal structure of hidden low-frequency asymmetric pulses (a few minutes duration) were investigated as well. The data obtained at IRIS broadband stations were used for this analysis. The stations are disposed at different distances from the epicenters of earthquakes, up to few thousands kilometers. Synchronization effects within period range 2-60 minutes starting 50 hours and 53 hours before Hokkaido and Sumatra earthquakes correspondingly were detected. The important feature of these synchronization effects is migration of main synchronizing period from first minutes toward few tens minutes, i.e. gradual increasing of the period of collective effect within observed data. One of the remarkable peculiarities of background seismic oscillations are extremely strong low-frequency asymmetric pulses at the ERM (Erimo) station which is located near the epicenter (less than 100 km) of Hokkaido event. Positive or negative polarity of the pulses connected probably with creep events along the fault zone. Analogous pulses were early revealed before the earthquakes on Kamchatka and Sakhalin. The work was supported by ISTC grant 1745.

Keywords: synchronization, prediction, precursors

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SS005 **Poster presentation** **6431**

Probability of seismic realization of radon precursors of earthquakes (m≥3.7) in Armenia and adjacent territories

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For assessment of the probability of seismic realization of Radon (Rn222) anomalies-precursors the study of 24 seismic events (which had occurred from 1983 till 2005 in the territory of Armenia and adjacent territories) were carried out. 64 radon anomalies-precursors of 16 strong regional (M≥6.0) and 8 perceptible local earthquakes (3.7≤M<6.0) were allocated based on retrospective analysis on the data recorded in 27 stations of underground radon measuring network of Armenian National Survey for Seismic Protection (NSSP). Typology of anomalies was carried out and the parameters of anomalies-precursors were determined. Also the parameters and the characteristics of those seismogenic anomalies had been identified. On the basis of the Earthquake Testing Methodology (worked out by Dr. H.Petrosyan) the probability P of seismic realization of radon precursors has been determined. The main results are as follows: Most of precursors are short-term (ΔT - more than 3 days and less than 1 year) and clearly expressed. Operative precursors (ΔT - 3 days and less) had been recorded twice only in two stations. The duration of the anomalies ranged from 1 to 240 days. The highest value of the anomalies is 562 imp/min. The precursors were shown in the distance up to 1300 km from the epicenter of the seismic event (M=7.4). The lowest probability of seismogenic anomalies is P=1/16 and the highest one is P=1. Mean value of probability P of seismic realization of short-term radon precursors is 43% in case of earthquakes (3.7≤M<6.0) which took place in the territory of Armenia. Mean value of probability of seismic realization of short-term radon precursors is 54% in case of strong regional earthquakes (M≥6.0).

Keywords: probability, radon, precursor

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SS005 **Poster presentation** **6432**

Radon precursors of two strong earthquakes in Turkey, 2003

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Studies have been conducted concerning the parameters and characteristics of 27.01.2003 Ercinzan (M=6.1) and 01.05.2003 Bingol (M=6.4) earthquakes /Turkey/, seismogenic anomalies of underground radon registered in Armenian National Radonometric Network (ANRT). On the basis retrospective analysis methodology and using Seishelp software anomalies-precursors of those earthquakes identified. Probability (P) of seismic realization of radon precursors has been decided. The main results are as follows: 6 radon precursors prior to Ercinzan earthquake and 4 radon precursors prior to Bingol earthquake have been allocated. All the anomalies are short-term and clearly expressed. In a number of stations only positive or negative anomalies have been recorded. The same dangerous radon precursors (P=1) were observed several times in two radon station of ANRT. Generally the P probability of seismic realization of radon precursors is P=0,4 in case of Ercinzan earthquake and P=0,6 in case of Bingol earthquake.

Keywords: radon, precursor

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SS005 **Poster presentation** **6433**

Analysis of radons levels to understand expansion and compression processes in the active faults zone in Armenia

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The study was performed at the Armenian National Survey for Seismic Protection (NSSP). Based on the data recorded in 23 stations of underground radon measuring network of NSSP from 2002 till 2004 the expansion and compression processes in the two active faults zone in Armenia were allocated. On the basis of the retrospective analysis methodology the 15 radon anomalies were marked out. From them; seven positive anomalies were located around the one active fault and eight negative anomalies were located around second active fault. Taking into account the positive or negative signs of radon anomalies the movement directions of compression and of earth's upper layer occurring along several active faults zones of Armenia have been evaluated. Results of this work as follows: From 2002 till 2004 the expansion processes have probably occurred in the Yerevan active faults zone and compression processes in Pre-small Caucasus active faults zone.

Keywords: radon, anomaly, fault

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SS005 **Poster presentation** **6434**

The focal mechanism of small earthquakes in relation with the active fault systems of Vrancea Region (Romania)

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Raileanu Victor

The high frequency waveform inversion was applied to determine the source mechanism for a set of small crustal earthquakes located in the area from the bending of the Eastern Carpathians. The local magnitudes of the events vary between 2.4 and 3.8, and their depths range from 7 to 39 km. Observed data are short period velocity seismograms, vertical component, recorded at epicentral distances up to 150 km. Greens functions are generated by multimodal summation in layered anelastic media. The rather complex medium structure in the study area was modeled by considering specific simplified 1-D models for each source-station path. To cope with the uncertainty of the structures we used in the forward modelling, and to estimate roughly the reliability of the mechanisms determined by inversion, a bootstrap-like procedure is implemented: average moment tensors are calculated from a set of solutions obtained using subsets of the complete data set. The well constrained mechanisms are analyzed in relation with the characteristics of the active fault systems, as revealed by recent geophysical investigations. The main fault systems in the area (Peceneaga-Camena and Capidava-Ovidiu) are oriented NW-SE and they display composite type, with both horizontal and vertical displacements. A secondary system with roughly NE-SW orientation and exhibiting both normal and inverse fault type is also present, contributing to the complex architecture of the crust in the study region.

Keywords: vrancea seismic region, seismic moment tensor, active fault systems

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SS005 **Poster presentation** **6435**

Source-site characterization for Vrancea (Romania) intermediate-depth earthquakes

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Time-domain (P pulse shape) and frequency-domain (high-frequency spectral decay and spectral ratios) characteristics of the waveforms model for a set of 150 small-to-large Vrancea earthquakes (1012<Mo<10 21NM) are investigated. All the available data (accelerations, short-period and broad-band velocities) are considered. A large amount of new and high-quality earthquakes data has been recently obtained due to the impetuous development of the seismic network on the Romanian territory. Thus, multiple recordings have been collected within the cooperation programme (Bonjer et al., 2000) and temporary experiments, such as tomography experiment CALIXTO '99 (Wenzel et al., 1999) and urban seismology experiment URS (Ritter et al., 2005). To investigate source and site effects we combine forward modelling with relative techniques of signal analysis, like EGF technique or spectral ratio technique. Significant azimuthal variation in seismic wave attenuation is emphasized as well. The implication of the resulted source and path properties on Vrancea earthquakes scenarios, seismic hazard assessment and structural and tectonic modelling of the S-E Carpathians area are finally discussed.

Keywords: time domain, frequency domain, attenuation

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SS005 **Poster presentation** **6436**

Seismicity and seismotectonics of eastern part of the Pannonian Depression (Romania)

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The paper investigated the seismic crustal activity in this active area of Romania, especially during 1991-2006 time period. In analysed time interval, the authors remarked the seismic sequence from June 12, 1991 to June 30, 1992 when 1132 seismic shocks with magnitudes of 1.6-5.7 where recorded by the local seismic network. Seismicity of this sector of the Pannonian Depression (Romanian Sector) is well know, where was identified some active regions with high observed epicentral intensities (VII-VIII), for example at Banloc, Liebling-Voiteg, Sag-Parta and Timisoara. The focal mechanism solutions indicated two directions of actual tectonic stress corresponding of tectonic blocks from this part of depression: Adria and pannonian. Some crustal shocks were connected by the active faults Lucaret and North Timisoara. The Pannonian block (North of the Lucaret fault) is characterized by compression forces NW-SE oriented. New seismological information were integrated in the general dynamics miodel admitted for this intracarpathian tectonic domain.

Keywords: seismic, crustal, activity

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SS005 **Poster presentation** **6437**

Tectonophysical analysis of jointing area underground and open pit mine

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The paper considers the results of the tectonophysical analysis of the area of the Rassvumchorrsky underground mine and the Central open pit mine of Apatit JSC, the Kola Peninsula, Russia. A typical peculiarity of deposits' mining using the open pit – underground method is the need in taking into consideration the combined geomechanical impact from the open pit and underground excavated area. When the combined mining method is used the number of parameters of the "pit – mine" geosystem grows dramatically. This results in a significant complication in monitoring the state of the mass. In the jointing area due to mining-induced activation there can occur shifts along faults, deformations of the pit benches and walls can be manifested, great seismic events can take place, releasing significant energy. This can entail such consequences as pit walls failure, ore pass breaking and the loss of ore reserves, breakdown of roads, communications and other engineering facilities on the surface. Thus, to provide a geomechanical prediction of the state and character of the mass response in case of combined mining it is necessary to carry out investigations for identifying the basic mining and geological factors, which determine the mass behaviour. At that, one has to bear in mind, that new parts of a deposit are mined, as a rule, in conditions of information shortage as to the mining and geological conditions. Hence, also needed is the assessment of the reliability of prediction of the mining and geological conditions, based on statistic assessment of the information. By generalising the structural mapping and observing the sequence of rock transformation processes in the area of tectonic dislocations in the area of mines jointing it is possible to draw the following conclusions. In the underground mining workings of a mine, in the zone of the pit impact, rockfalls can be observed, which are isometrically shaped rock blocks, not slab partings and scaling lenses, characteristic for rock pressure manifestation. It is connected with both the influence from mining operations in the pit and with the development patterns of the underground mine. It is also necessary to consider the influence of undercut zones on cover rock canopy, when developing the levels located near the surface and the probability of failure of sub-pit divide pillar, as well as the redistribution of stresses, when mining the Rassvumchorrsky deposit. The further continuation of work in the field of tectonophysical analysis is supposed to include the detailed comparison of seismicity parameters of the given part of the mass with fracturing, identified by geological observations as well as with registered changes in configuration of pit workings and benches.

Keywords: tectonophysical, rockfalls, factors

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SS005 **Poster presentation** **6438**

Estimation parameters mining-induced seismicity in Khibiny massif

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In present work within the frame of this problem a comparison is made between focal mechanism type and its other parameters, which useful in estimation natural and mining-induced seismicity registered in Khibiny massif. This problem has been analysed using the catalogue CGM Apatit JSC and for comparison catalogue KB GS RAS on data seismic events. This enables a classification of focal mechanisms in any part in Khibiny massif into predominantly strike-slip, thrust, normal and vertical fault categories. The classification schema, based on isometric parameterisation of CMT-data, is used. It is found that in application to the problem of classification seismic moment tensor may be shown in spherical co-ordinates as a point at the surface of a 3D-sphere. The advantage of this representation is based on preservation of scalar product between objects. The original catalogues was transformed into four separate catalogues accordingly type of CMT-solutions. On other turn every type was classified on magnitudes and within each magnitude interval average value of seismic moments was calculated. We analysed influence of focal mechanism type on rupture length in terms of variations in the absolute value of the slope of the regression of the logarithm of the seismic moment versus magnitude. A rough method for calculating rupture length from seismic moment is presented. This method is based on the assumption of earthquake self-similarity and involved relations between parameter incoming in definition of seismic moment, i.e. fault length, width and average slip. As a result of conducted investigations, parameters of the above-mentioned regression were obtained for all studied groups. This work demonstrated possible systematic bias in geometrical parameters of seismic rupture zones depending of their focal mechanisms.

Keywords: comparison, parameters, seismicity

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SS005 **Poster presentation** **6439**

Modeling constraints of earthquake parameters using chaotic dynamics over Indian Regions.

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Chaotic methods using Lyuponov exponents, strange attractor dimension and Kolmogorov entropy have been applied to the earthquake parameters to understand the modeling constraints and predictability. The earthquake time series was used in the interplate and intraplate regions of the Indian plate. These included Hindukush, Himachal Pradesh, Central India and North East India in Himalayan region. On the other hand similar analysis was done in Koyna, Valsad and near Delhi. The results were also extended to subduction and transform type of Plate boundaries in Andeman Island regions, Japan and Maxico coasts. Interesting result was, found between interplate and intraplate earthquakes. In the Peninsular Indian region, a lower strange attractor dimension was found. This suggested better predictability in the region as compared. Indian Eurasian Himalayan region. It is surmised that the similarity in chaotic dynamics approach suggests similar prediction state in earthquakes forecasting as in the case of weather prediction.

Keywords: chaotic, earthquakes, predictability

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SS005 **Poster presentation** **6440**

Regularity of distribution of regional and local components of the tectonomagnetic field.

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Samvel Oganesyan

Some space-time characteristics of the total magnetic field module for areas of active faults of the earth crust in the territory of Armenia were investigated. As a result of these investigations an anomaly of the secular variation of piesomagnetic nature, that periodically induces positive bay-like variation named the variation of tectonomagnetic field (TE), was revealed. The total (TE) field module can be represented with a sum of regional (TER) and local (TEL) components. It is known that the changes of magnetic parameters of mountain rocks due to accumulation of regional tectonic stresses in the earth crust are responsible for the causes of (TER) whereas the changes of stresses in mountain rocks due to local tectonic stresses dominated in deep fault structures are responsible for the causes of TEL. A regularity of distribution of values of the TE field components was derived. It was shown that a ratio of local component to regional one is inversely proportional to the distance (R) between a forming earthquake center and a point of observation. A value of TE depends only on a value of magnitude (M) of generated center of forthcoming earthquake. The revealed analytical relation between values TE, TER ,TEL and R allows us to control a correctness of the parameter determination of generated earthquake centers and accurately estimate the degree of the seismic hazard.

Keywords: tectonomagnetic field, forming earthquake, seismic hazard

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SS005 **Poster presentation** **6441**

Background seismicity and earth tides: synchronization in source zones of large earthquakes

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We think that the Earth tides can not induce the earthquakes themselves, but ones can exert trigger influence on future source formed by more powerful tectonic processes. Then this influence can be manifested during long time of large earthquake preparation (Saltykov et al., 2004), and small earthquakes of this area will become an object of the tidal influence. Note: these small earthquakes are not foreshocks, this is background seismicity. The technique and the results of the search of such effects are presented. The influence of the Earth tides upon earthquakes with magnitude M>2.5 is investigated. Proposed technique of detection of tidal effects in seismicity allows finding in time and space anomalous zones corresponding to influence of separate tidal waves or tidal wave groups. The statistical significance of the anomalies is tested by method Monte-Carlo. This technique was approved on the catalogue of the Kamchatkan earthquakes 1962-2006. The maps of tidal earthquakes zones designed for whole Kamchatkan seismoactive area during different time interval from 1year to 40 years are presented. It is shown that before large earthquakes with magnitude M>=7 positions of the tidal earthquake zones is close to the sources of these earthquakes. Moreover it is significant that statistics of the tidal earthquakes is differing from statistics of random catalogues: by density of tidal earthquake zones and by quantity of earthquakes in the zone. For the first time the tidal phase data for anomalies were analyzed. It is shown that before some large earthquakes the neighbouring zones are corresponding to different tidal phases. Similar effect can be connected with existence of strain with different signs near future source, and this determined the value of the tidal phase value for anomaly zone. Показаны карты приливных зон на настоящий момент. Some modern zones having high statistical significance can not be connected with large earthquakes, but they are close to area, which marked by different scientists as large earthquake preparation area. This research is supported by RFBR Grant 05-05-64276a.

Keywords: earth tide, syncronization, background seismicity

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SS005 **Poster presentation** **6442**

Estimation of seismic fault slip distribution from marine terrace data using an earthquake cycle model

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It is important to estimate seismic slip distribution of large earthquakes in order to understand seismic source processes and reduce earthquake disaster. The earthquakes whose seismic and geodetic data exist are well investigated. The earthquakes without seismic and geodetic data are investigated using active faults, old literatures, and marine terraces. The data from marine terraces seem to be useful for estimation of slip distribution of plate boundary events at subduction zones. However, slip distribution could not have been estimated by marine terrace data because the data include coseismic, interseismic and permanent displacements, and these displacements could not be divided. This presentation shows how to divide the coseismic, interseismic and permanent displacements using an earthquake cycle model which we proposed (Matsuura and Sato, GJI, 1989; Sato and Matsuura, GJI, 1992). Our earthquake cycle model can estimate the permanent displacements by the steady state subduction, which were ignored in the previous studies. The model also reveals that the difference between the data whose phases in the earthquake cycle are the same (for example, data of all marine terraces are in the phase of just before event) depends only on the permanent displacements. This means that we can estimate the permanent displacements if we have two or more marine terrace data whose ages are different. Since our cycle model can estimate stress relaxation in the asthenosphere, we can divide the coseismic, interseismic and permanent displacements into one another. From the coseismic and interseismic displacements, we can estimate slip distribution of the event. Using the above method, we try to estimate slip distributions of the 1703 Genroku Earthquake (M8), which occurred at the south Kanto area, Japan. The south Kanto area has many marine terraces formed by the same type of earthquakes as the 1703 event (Shishikura 2001). The estimated slip distribution shows more than 20m slip beneath the south end of Boso Peninsula. The estimated permanent uplift rates are up to 3mm/yr. In this presentation, we will discuss about the effects of the configuration of plate boundary and the relation between the Genroku type (1703) and the Taisyo type (1923) events.

Keywords: slip distribution, marine terrace, earthquake cycle

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SS005 **Poster presentation** **6443**

A hybrid intelligent system based on analysis of time variation in radon concentration, environmental parameters and aftershocks of bam earthquake

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A cascade configuration of a linear neural network, such as modified Adaline and a non linear neural network such as Multilayer Perceptron has been employed to process data of radon concentration and environmental parameters. The outputs of the linear neural network with deviation < 0.05 have been chosen as normal data. Normal data have been used for training the non-linear neural network. The goal of this method is its ability to obtain correlation between time variation of radon concentration and earthquake or aftershocks. This method has been employed to obtain a correlation between radon data and the aftershocks of Bam earthquake. It is shown when the numbers of aftershocks increase, variation of radon concentration could be seen more clearly.

Keywords: neuralnetworks, radon, aftershocks

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SS005 **Poster presentation** **6444**

Investigation of crust in Yazd province, central Iran, revealed from local seismic network data

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By using an inversion method we attempted to obtain a model for the earth crust in Yazd province, central Iran. The data set includes earthquakes during 2005 to 2006 time period. We used all available regional and local stations. At first we obtain a set of events located along two stations. The epicenter of each earthquake must be in one side of the stations so that the travel time differences can be determined. In the next step, we used inversion method to obtain the velocity and the thickness of possible layers. Our preliminary results indicate that the crust in this region includes at least two significant layers and the depth of Moho was estimated to be about 50kms. This result is in good agreement with the result of other studies as well as the geological evidences in the region.

Keywords: inversion, crust, yazd

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SS005 **Poster presentation** **6445**

Earthquake triggering by the combination of the static stress step and the dynamic effect

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It is well known that the static stress change caused by a large earthquake can possibly trigger the other earthquakes around it like aftershocks or successive large earthquakes. However, static stress change by itself cannot sufficiently predict seismic activity around a large earthquake. Recent studies reveal that the dynamic effect also plays an important role in the seismicity rate change after a large event. In this study we assume empirically that the seismic waves at site may have a dynamic effect equivalent to a positive static stress change depending on their amplitude. To estimate the static and dynamic effects quantitatively we attempt to add the seismic wave amplitude term to the stress step term in the theoretical model proposed by Dieterich (1994) that relates the static stress change and the seismicity rate change on the physical basis of the rate- and state- dependent friction law. We simply assume that the dynamic effect will be expressed by adding the positive stress step to the static stress step linearly proportional to the maximum acceleration amplitude of seismic waves at the site. This model is applied to the seismic activity at the small inland area in the north-eastern part of Japan, where three neighboring large earthquakes may affect the activity. One of the large earthquakes that caused a positive static stress step at the area induced a clear seismicity rate increase. However, the static stress change by itself cannot explain all of the seismicity rate change because one of the other large earthquakes made a stress shadow at the area, but the seismicity rate did not decrease after the earthquake. By applying the maximum likelihood method to the seismicity rate change data related to all the three large events we have estimated four parameters controlling the model; the friction parameter, the stressing rate corresponding to the background seismicity rate, the stressing rate after the largest stress step, and the stress change coefficient for the seismic wave amplitude. The results show that the model based on the combination of the static and the dynamic effects fits better than does the model based on the only static stress change.

Keywords: triggering, static stress, dynamic effect

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SS005 **Poster presentation** **6446**

Regional stress field reconstructed from earthquake focal mechanisms and strain field from GPS data in China

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The comparison of the parameters of tectonic stress field and modern kinematics of Earth surface is carried out for China. GPS data obtained by CMONOC (Crustal Movement Observation Network of China, about 1000 points) was used for time interval 1998-2004. The deformation field was calculated from horizontal displacement vectors using finite elements approach. Strain tensor was estimated in 1216 points for the grid with step of 1 degree. The bulletin of International Seismological Center was used as a base for the reconstruction of components of the tectonic stress field. Kinematic approach after O.I.Gushenco was applied for estimation of the space-time parameters of regional stress field. The reconstruction was made for time interval 1964-2004 for three separate depth layers: 0-17 km, 17-35 km and 35-70 km. The direction axes of stress tensor ellipsoid was estimated for the same grid as for strain tensor. The comparison of parameters of strain field from GPS data and stress field from earthquake focal mechanisms shown good agreement of these fields. The best agreement is found for layer 0-17 km; the degree of agreement decreases with depth (for layers 17-35 km and 35-70 km). In all cases the higher values of disagreement are correspondent to areas with high gradient of directions of strain tensor ellipsoid, to areas of quasi-uniform deformation and to areas with small values of modern horizontal movement velocities. Obtained results demonstrate importance and effectiveness for investigation of tectonic loading, stress-strain evolution and other branches of geodynamics both used approach to stress field reconstruction and surface GPS observation.This work was carried out in the frame of the China-Russia project "Sino-Russia joint researches on the inner-continent seismo-tectonics and new techniques in earthquake observations and prediction" and was supported by the RF President grant 5009.2006.5; RFBR grant 06-05-64548.

Keywords: stress reconstruction, gps strain, focal mechanism

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SS005 **Poster presentation** **6447**

Estimation of Slip Deficit Distribution on the Subducting Plate Interface

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The coupling on the subducting plate interface between the large earthquakes has been estimated using the geodetic inversion method. In this study, as an example, I conducted the geodetic inversion beneath the Tokai District, the Central Japan, using two different data; one is the vertical data deduced from the leveling observations, and the other is the horizontal data deduced from GPS observations. In the inversion, I employed the analytical solution of the surface displacement due to a triangular dislocation element embedded in an elastic half space in order to represent the curved plate interface. The result of the inversions indicated that, if the vertical data were used, the strongly coupled area is concentrated beneath the Omaezaki area, while the coupled area distributed in the shallower region if the horizontal data were used. The estimated maximum value of coupling from the horizontal data was 40 mm/year, while that from vertical data was 25 mm/year. Because the conditions of the two inversions are almost the same, such difference as shown above was suspected to be due to different type of data. In order to test this hypothesis, I conducted a number of two-dimensional numerical simulations. The results of simulations show, as is in the real case, the estimated slip using the horizontal data did not recover the real slip distributions, whereas the vertical data did. Therefore in the Tokai region, the vertical data may have advantageous compared with the horizontal data. However, this result might apply only in the Tokai district because other factors of parameters of fault geometry might affect the results. In order to derive more general rule of how the data control the results, the real reason lying behind the difference between two types of data will have to be examined. This kind of examination may be very important for designing the network of geodetic surveys, for example.

Keywords: inversion, plate coupling, dislocation

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SS005 **Poster presentation** **6448**

Seismotectonic Deformation of the Central Tien Shan

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The report is devoted to following aspects of Tien Shan seismicity. 1) The results on seismotectonic deformations (STD), determined on the base of focal mechanisms data on more than 700 weak seismic events occurred in 1999-2006 at studied territory of Central Asia ,have been represented. 2) Some seismic events of moderate energy class K, occurred at given territory in1999 2006 have been considered as well as their focal mechanisms. The comparison has been performed of directions of main horizontal stresses, which have been obtained statistically (one way to determine STD) and by focal mechanisms of several moderate earthquakes (the second way) 3) The variation of seismicity of Tien Shan region during the same period has been studied also. Up to now the analysis s STD of Central Asian Crust (Tien Shan crust, at first turn) remains to be urgent, since this area is a territory of intensive recent deformations. The detailed study of straining processes in the crust is fundamental for evaluations of natural and man-made hazards related to geological and geodynamic phenomena. Besides, the development of concept of hierarchical blocking structure of geologic medium, the contribution of non-uniformity and heterogeneity, and effects of self organized criticality (SOC) note that unified (averaged) description of STD is of great importance and interest. The represented results allowed to specify that the main part of studied territory may be characterized by compression regime of straining; the main compression axis being oriented north-north-west, and the main tension axis - being directed to east-north-east. Two kinds of straining mode, namely strike slip and transpression, have been distinguished for the territory under investigation. The analysis of STD depending on depth has revealed that oblique faulting (by well-known classification) is typical for the shallow layer (0-5 km depths).The seismogenerating layer of 5-15 km depths is characterized, mainly, by transpression mode with minor shift component. Three seismic events of moderate energy class occurred at studied territory in last 3 years: M=4.5 earthquake of 2004.01.16; M=4.3 earthquake of 2006.11.08; M=5.7 earthquake of 2006.12.25. Hypocenters of first two earthquakes are located at foothills of Kyrgyz ridge (eastern part) closely one to other. Third earthquake occurred at the northern part side of Jumgal ridge. According to solutions for focal mechanisms obtained with the help of Moment tensor solution program of Y.Yagi, NIED, , the compression axis of these earthquakes is of north-north-west orientation, and the tension axis is directed on east-north-east. This result is in agreement with the directions of compression and tension axes, obtained statistically on the base of STD computations by data on weak seismicity. The hypocenters of all 3 noted events are located in the zone of enhanced values of stressed-strained state angle (omega angle), which have been obtained while STD computations. Two earthquakes occurred at 14-14 km depth, the depth of 3-rd earthquake hypocenter is near 19 km. Noted depths are correspondent with the minimal value of omega angle for the studied territory. The study of seismicity of a zone around epicenters of these earthquakes has demonstrated that averaged seismic activity decreased stating from the beginning 1999. Then, during 2001-2003 its level was steady. In the middle of 2003 the activation of seismicity took place. Currently smooth drop of seismicity occurs rather than continued growth of the activity. Generalizing the results one can deduce that the Crust of Central Asia and Tien Shan is under stressing both: sub-meridianal and sub-lateral directions. Each particular zone (sub-region) inside Tien Shan with surroundings is characterized by own stressed-

strained state resulted from balance of process of elastic energy accumulation and energy release during earthquakes.

Keywords: seimotectonic, deformation, pressure

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SS005 **Poster presentation** **6449**

Quasi-static analysis of strike fault growth in layered media

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We study the effects of structural inhomogeneities on the growth of strike-slip faults. A layered medium is considered, made up of an upper layer bounded by a free surface and welded to a lower half-space with different elastic rigidities. Mode III cracks are employed as mathematical models of strike-slip faults, which are nucleated within the lower medium and then propagate towards the interface. We adopt FEM-$beta$, newly proposed analysis method for failure, to investigate the quasi-statistically self-chosen faulting paths associated with the stress concentrations in layered media. Our results show that planar crack paths are finally self-chosen and that a softer upper layer has significant effects on promoting/arresting of crack growth before/after penetrating the interface. This implies that surface breaks due to strike faulting can be suppressed by a compliant deposit layer beneath the Earth's surface.

Keywords: rupture, fault, fem

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SS005 **Poster presentation** **6450**

Seismic quiescence before Wenan M5.1 earthquake near Beijing in 2006

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In order to obtain the feature of seismicity near and around Wenan earthquake , We define a parameter to describe the level of seismicity during a period as: =(M1+M2+M3+M4+M5)/5, where Mi(i=1,...5) are the top five earthquakes during the period. We choose the catalogue of earthquakes with ML>=2.0 in the circle region withR=100km from 1970, and calculate to obtain the time series of seismic level. In our calculation, time window is chosen as 1 year and the time step is 1 month. The result shows that from the end of 2005, declined rapidly and reached to the minimum value of 2 in January 2006, and Wenan earthquake occurred half year later. This result implies that the seismic anomaly before Wenan earthquake is seismic quiescence. We also studied the seismicity of M>=3.0, M>=4.0, M>=5.0 in the neighboring area and found that the feature of seismicty in the neighboring area is also seismic quiescence in different time scale.

Keywords: seismic quiescence, wenan earthquake, seismicity level

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SS005 **Poster presentation** **6451**

STudy of crust in North-Eastern Iran using earthquake data inversion

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One of the basic factors responsible for earthquakes is the appropriate crustal velocity structure. The crustal velocity model can help to locate the hypocenter of the earthquakes more properly. In this study, we investigate the velocity structure of the crust and upper mantle beneath the khorasan region located in the North Eastern Iran. We use seismic data collected by the local seismological network that was deployed in Khorasan in 2006. About 4449 earthquakes were processed by this network occurring during 2006 in this region. We selected 1450 earthquakes to invert. An initial crustal model having 10 layers was obtained by reading Pn and Pg phases from recorded waveforms in Khorasan seismic network and analyzed their travel-time curves. Then using a tomography method, we refined the depth and velocity parameters of each layer. We used the software that was developed by Kissling (1993). Taking into account the results that was obtained in this study; we provided the contour maps for the velocity and depth variations. Our interpretation is in good agreement with the geological evidence and the result of other studies.

Keywords: inversion, khorasan, earthquake

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SS005 **Poster presentation** **6452**

Dynamic characteristics of geophysical time-series from the long term observations in seismically active region

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The analysis of observation of variations of volumetric deformations, water level in borehole, apparent electric resistivity, relative vertical displacement of a sur-face specify complex behaviour of such systems. The common law is presence at them as determined components (a trend, a seasonal component), and chaotic compo-nents, with positive value of correlation entropy. The opportunity of development of a method of distinguish and separation of these components is considered. It is based not on traditional methods of interpolation and approximation by the set of functions, but use the approaches of nonlinear dynamics. Allocation of components with positive size of the major parameter of Lyapunov is considered. The collected unique data of long term observations actual for earthquake pre-diction geophysical fields in seismically active region of the North-East China al-lowed to analyse values of such dynamic parameters as value of phase space dimen-sion, correlation dimension, correlation entropy, Liapunov coefficient. Estimations are led both in the various spatial points of observation, and on various time scales (from day up to tens years). The analysis of stability of the estimated values in time is car-ried out.Obtained results shown that nonlinear dynamics approaches can be applied for investigation of complex geophysical processes; this application give us new informa-tion concerning dynamic characteristics of these processes. This work was carried out in the frame of the China-Russia project "Sino-Russia joint researches on the inner-continent seismo-tectonics and new techniques in earthquake observations and prediction" and was supported by the RF President grant 5009.2006.5.

Keywords: nonlinear dynamics, geophysical fields, time series

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SS005 **Poster presentation** **6453**

An examination of seismic quiescence based on the brittle-ductile interaction hypothesis

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The seismicity in the Tamba region in southwest Japan, has started to decrease in 2003. The region is located to the northeast of the rupture zone of the 1995 Hyogo-ken Nanbu Earthquake (Mjma7.3). In the region, the seismicity was activated by a static stress change due to the event. The occurrence rate of recent microearthquakes, however, has been lower than that before 2003. Such a seismic quiescence was shown during two and a half years before the event. It has, therefore, been controversial whether a major earthquake will follow the quiescence or not (e.g. Umeda et al., 2005).The attenuation property of coda waves, coda Q^-1 or Qc^-1, reflects the scattering environment in the crust (Aki and Chouet, 1975). Qc^-1 correlates well with the tectonic activity and, thus, is a good indicator of the stress condition (Aki, 1985; Hiramatsu et al., 2000). We monitor the crustal heterogeneity using coda waves in the region.In this study, we investigate a relation between a temporal variation in Qc^-1 and seismicity from 1987 to 2005 and discuss a cause of the quiescence from 2003. We use the same analysis method as Hiramatsu et al. (2000) for the estimation of Qc^-1. We examine the quiescence based on the brittle-ductile interaction hypothesis (Aki, 2004).The hypothesis shows that a simultaneous temporal correlation between Qc^-1 and N (Mc), a number of a characteristic magnitude contributing to a temporal variation in b-value, is disturbed before a major earthquake. The temporal variation in Qc^-1 reflects a variation of fractures in the ductile part of the lithosphere and that in N (Mc) represents a response of the brittle part to the ductile fracture. An observed temporal delay of Qc^-1 relative to N (Mc) before a major earthquake can be explained by the idea that the strain energy stored in the brittle part of lithosphere reaches a saturation limit and starts to flow back to the ductile part (Aki, 2004). At the quiescence in the Tamba region before the 1995 Hyogo-ken Nanbu earthquake, such a delay was observed. In contrast, at the quiescence from 2003 in the Tamba region, no such a delay is found, at least at the end of 2005. We, therefore, consider that the crustal condition from 2001 to 2005 differs from that in the quiescence before the event. This suggests that a large earthquake will not occur during a coming couple of years.We find that the quiescence seems to be associated with the long-term slow slip event in the Tokai region. This supports that this ongoing quiescence differs from that before the 1995 Hyogo-ken Nanbu Earthquake. We interpret that the quiescence may be a reduction stage of seismicity affected by the perturbation of the stress field caused by the Tokai slow slip. A continuous monitoring of both Qc^-1 and seismicity will resolve a future probability of the occurrence of a large earthquake around the region.

Keywords: coda, brittle ductile, quiescence

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SS005 **Poster presentation** **6454**

A tectonomagnetic method for determining the level of seismic hazard

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Regular observations of geomagnetic fields and hydrodynamics have been carried out since 1993 on the territory of Armenia. As a result of the investigations of the anomalies in the secular variations of the tectonomagnetic character, an analytical representation has been derived for the dependence of the tectonomagnetic field amplitude on the parameters of the forming epicenters. By means of this analytical representation, the magnitude, time and distance from the station to the epicenter of the forthcoming earthquake can be predicted. A retrospective analysis was performed of the seismic events from 1994 to 2005. For the 2006 events, the parameters of the epicenter were calculated in advance that is, before the moment of the seismic event. The comparison of the calculated and observed parameters shows that for the magnitude, the error is 0.07, for the distance - 5.8 km, and for the time (the moment of the shock) 1 day, which permits a high accuracy of the forecasting of seismic hazard.

Keywords: seismic hazard, tectonomagnetic field

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SS005 **Poster presentation** **6455**

A few new anomalies of the seismic regime revealed in the vicinity of strong earthquakes possible physical nature and the connection with the possibility of probabilistic and deterministic prognosis of strong earthquakes

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General vicinity of strong earthquake was composed from the Harvard seismic moments catalogue using data on earthquakes occurring in the vicinity of different strong earthquakes taking place in different tectonic situations. This way the general vicinities of strong earthquake belonging to different tectonic zones (subduction zones, middle oceanic rift zones, others) as well as the general vicinity of strong earthquake without any tectonic specificity were constructed. One can suggest that the construction of the generalized vicinity of strong earthquake gives possibility to examine the change in seismic regime typical of such zones better than in the case of a separate examination of vicinities of a number of different strong earthquakes. This last approach was used before. Joint analysis of the hypocenter parameters and those characterizing the seismic moments give possibility to use a few additional parameters characterizing the earthquake. The parameters characterizing the duration of an earthquake process, the size of the rupture zone, the direction of the failure propagation, and the relative involvement of higher and lower frequency modes of seismic vibration in the earthquake process were used in addition to the routinely used parameters: b-value, apparent stress value, and the density of a number of earthquakes. These parameters were calculated and their typical behaviors in the spatial and temporal vicinities of the strong earthquakes were examined in comparison with their behavior in the background area. A few new changes in seismic regime occurring in the temporal and spatial vicinity of the generalized strong earthquakes were found both before and after the generalized strong events. In contrast with the typical expectations in the majority of cases there is no change in these anomalies in the very moment of the generalized strong earthquake, and the anomaly occurring before and after the generalized strong earthquake are very similar. Thus, one can suggest that its no the process of strong earthquake preparation but some change in the properties of the geophysical media correlated with the probability of strong earthquake occurrence. The simple model of the earthquake regime that displays the similar behavior is presented. In this model the probabilistic prognosis of a strong earthquake is possible despite the fact that the model earthquake events are independent and generated in a pure stochastic regime. The physical changes revealed in the seismic regime in the vicinity of strong earthquakes can be explained by change in the properties of geophysical media when it becomes more viscous or plastic, and its strength decreases. These changes could be connected with the increase in activity of the deep fluid regime and with the increase in the rate of the solid state (metamorphic) transformations occurring in the Earths crust and the upper mantle. These possible explanations are being discussed.

Keywords: earthquake preparation, probabalistic prognosis, earthquke source

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SS005 **Poster presentation** **6456**

Source process of the 8th October 2005 earthquake in Pakistan

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To Study the seismicity of Pakistan and investigate the characteristics of the 8th October 2005 destructive earthquake in north Pakistan, the source parameters of the recorded earthquakes by the seismic stations in the world during the past 40 years as well the 8th October 2005 earthquake in Pakistan and its aftershocks where collected. Then the epicenter distribution of earthquakes where over lapped on the faults map in the Middle East . Fault plane solutions of 98 strong earthquakes in and neighbouring regions in and were determined by the polarity of initial p waves. In next stage, the seismic energy released by strong earthquakes in the region was determined from magnitude using Richter relation of magnitude - energy in each 0.50.5 sub square and plotted on the faults map of the region The fault offset of the main earthquake was calculated to be 8 m, its source duration was about 40 s and it cuased a faulting about 120 Km. its stress drop was calculated about 40 bar. The fault offset of the strongest aftershock was calculated to be 2.5 m, its source duration was about 3 s and it cuased a faulting about 10 Km. Its stress drop was calculated about 14 bar. The result indicated that the Pamir-Hindu Kush region was seismically active during the past 40 years which released significant seismic energy each year. Instrumental and historical data indicated that the hypocenter region of the 8th October 2005 earthquake in did not show significant seismic activity during the past 100 years and describe a kind of seismic gap. In other words this earthquake is the largest one ever accured during the past 100 years. The recent earthquake is very similar to the 1978 Tabas earthquake in . The source mechanism of both earthquakes had trust type mechanisms and both had shallow depths and had very similar stress drop. Both earthquakes fallow many strong trust type aftershocks.

Keywords: pakistan, 8th october 2005, fault plane

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SS005 **Poster presentation** **6457**

The 2004 earthquake offshore of the Kii peninsula, Japan: hypocentral relocation, source process and tectonic implication

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On September 5, 2004, two major earthquakes of Mw 7.2 and Mw 7.3 occurred close to the Nankai Trough in southwest Japan. This earthquake sequence is located within the subducting Philippine Sea plate(PHS) with an aftershock distribution that overlapped a portion of the source region of the 1944 Tonankai earthquake (Mw 7.9). Firstly, we include the sP phases into a widely used double-difference earthquake location algorithm (Waldhauser and Ellsworth, 2000) to improve the accuracy of depth determination for earthquakes with magnitudes around 4.0. Secondly, we relocate events with magnitudes greater than 4.2 by combining a teleseismic single-event location method (Engdahl, Hilst and Buland, 1998) for depth and a multiple-event location method (Jordan and Sverdrup, 1981) for epicenter and origin time. Finally, we employ a waveform modeling method (Kikuchi and Kanamori, 1986, 1991) to constrain source mechanisms and rupture histories of the two major earthquakes. All events relocated in a depth range between 10 and 33 km, shallower by about 20 km than those by the Japan Meteorological Agency. The Mw 7.2 and the Mw 7.3 events are relocated in the uppermost mantle of the PHS on primary high-angle reverse faults. Focal mechanisms are consistent with the horizontal and vertical projects of the distribution of aftershocks. We speculate that this earthquake sequence was due to the collision reaction between the PHS and the Zenisu Ridge.

Keywords: hypocentral location, source process, outer rise

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SS005 **Poster presentation** **6458**

Long-term earthquake prediction for the Kuril-Kamchatka Arc for 2006-2011 and successful prediction for the Middle Kuril Island earthquake, 15.XI.2006, Ms=8.2

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Method of long-term earthquake prediction based on regularities of location of large earthquakes (seismic gaps) and their seismic cycle was proposed by S.A. Fedotov in 1965-1967 initially for the Kuril-Kamchatka arc and North-Eastern Japan. Method is known in seismology, was used systematically in the Kuril-Kamchatka region and was developed in 1965-2006. At present a number of the characteristics of the seismicity of Kuril-Kamchatka arc for the five-year time intervals are predicted according to this method. The most active part of the seismogenic zone of Kuril-Kamchatka arc with depths of 0-80 km, which has the length of 2100 km and the width of 100 km, is divided into 17-21 areas. For them stages of seismic cycle are forecasted, the places of seismic gaps are indicated, the relative danger of seismic gaps is determined, the seismic activity A10 (the number of small earthquakes of the energy class Ks=10 or M=3.2 per year over area 1000 km2), magnitudes M of moderate earthquakes, which are expected with probabilities 0.8, 0.5 and 0.15, the maximum magnitudes of earthquakes and probability of the strongest earthquakes with M≥7.7 are predicted. Predictions are renewed through half a year or more frequently if strong earthquakes occur and the parameters of seismicity in the foregoing five years substantially change. For 40 years application of a method the predictions of the strongest earthquakes were justified with probability 0.8-0.9. The previous Shikotan earthquake, 4.X.1994, M=8.1 in the Kuril Islands and Kronotsky earthquake, 5.XII.1997, M=7.8 in Kamchatka were successfully predicted. The prediction of the next such earthquake, 15.XI.2006, M=8.2 in the Middle Kuril Islands is presented. Since the beginning of studies by this method (1965), large seismic gap in the area of the Middle Kuril Islands was considered as one of the probable places of earthquakes M≥7.7 in the Kuril-Kamchatka arc. The long-term predictions for 2006-2011 were given in April and October 2006, before the Middle Kuril Islands earthquake, 15.XI.2006, M=8.2. It was shown that this gap is one among two the most dangerous ones in the Kuril-Kamchatka arc. The earthquake source area precisely filled the forecasted place. Method can be used in other island arcs and regions of the world that have similar structure, features and seismicity. The retrospective long-term prediction for earthquake near the coast of Hokkaido, 25.IX.2003, M=8.1 was the example of the application of the method in other regions of the world.

Keywords: earthquake, long term, prediction

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SS005 **Poster presentation** **6459**

Ground heta flux (GHF) as precursors to seismic events

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Likelihood of earthquake prediction depends, on the ability to detect precursory phenomena. Among the earthquake precursors reported in the literature are meteorological parameters including occurrence of temperature and heat flux changes related to tectonic activities.Here we report on an investigation in to the suitability of ground heat flux (GHF) as an earthquake precursor. We have examined the metrological data of 100 sites close to the epicenter of earthquakes in Alborz north of Tehran . The analysis of GHF from the epicentral regions of earthquakes that occurred in close to the sea and far a way from the sea has been found to show some anomalous behavior before the earthquakes.GHF depend on soil temperature gradient and thermal diffusivity. Changes of soil temperature gradient take place one or two days prior to the earthquakes and depend on which season earthquake happen, possibly due to aquifer behavior in the region. Detailed analysis of thermal diffusivity over the epicentral and adjoining regions of numerous earthquakes have shown some anomalous prior to the earthquakes. The present paper is an attempt to track these changes using meteorological data collected at meteorological station close to the epicenters of earthquakes in .Although further boreholes temperature records are needed to reveal the thermal perturbations in the ground near seismic zones.

Keywords: ground, heat, flux

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SS005 **Poster presentation** **6460**

Use of empirical mode decomposition method for identification of earthquake and explosion records

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Earthquakes are transient and nonstationary. For lack of alternatives, in seismology as well as earthquake engineering, most data are still processed by using the Fourier analysis. The most difficulties in the Fourier spectral analysis are associated with nonlinearity and non-stationary nature of the data. Such methods cannot reveal the detailed information in the dispersion properties, the wave form deformation, and the energy-frequency distribution. In this study, a new technique based on the time-domain Empirical Mode Decomposition (EMD) has been explained, which enables us to analyze both short-term information and long-term structures in seismic waves. It provides insight into long term memory and local time behavior of seismic signals. The decomposition is based on the simple assumption that any data consists of different simple intrinsic modes of oscillations. Each intrinsic mode, linear or nonlinear, represents a simple oscillation which will have the same number of extremes and zero-crossings. Furthermore, the oscillation will also be symmetric with respect to the 'local mean'. At any given time, the data may have many different coexisting modes of oscillation, one superimposing on the others. Each of these oscillatory modes is represented by an Intrinsic Mode Function (IMF). Oscillation modes of Earthquakes and Explosions are compared to each others, relationships between each group of the same data and differences between different data are obtained based on the produced IMFs. This new method is intuitive, direct and adoptive from a posteriori-defined basis, from the decomposition method, based on and derivative from the data. With respect to the advanced methods such as discrete stochastic non-Markov process it has been shown that this technique gives better identification. In non-Markov framework, it is considered that, how much different data show statistical non-Markovian property (long-range memory, and local time behavior). Plotting the maximum frequency of different IMFs via position of them, gives an effective identification tool. In this view, one can consider a straight line as a discrimination boundary between maximum frequency distribution of Earthquakes and Explosions IMFs, in which Explosion and Earthquake data localize up and down of this boundary, respectively. Position of this line at a specified frequency only depends on propagation environment, consequently by this method one can obtain attenuation factor of plates with high accuracy. In this study first the technique is explained and then the obtained results are illustrated and discussed.

Keywords: emperical, intrinsic, non markov

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SS005 **Poster presentation** **6461**

Stick-slip instability analysis and stress evaluation by using the node-to-point contact element strategy

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Earthquakes have been recognized as resulting from stick-slip instabilities along the faults between deformable rocks although the rupture process itself is generally complex due to the non-uniform distribution of stress and strength on faults. To further investigate the occurrence of the earthquake and to predict it in the future, a finite element algorithm for modeling nonlinear frictional contact behaviors between deformable bodies with an arbitrarily shaped contact element strategy, named as the node-to-point contact element strategy based on static-explicit algorithm has been proposed. This algorithm is applied to model the frictional contact behaviors between deformable rocks with stick and finite non-linear frictional slip and also can be used to investigate stress evolution processes of a nonlinear frictional contact system, the fault geometry influence on the nucleation and development process of the stick-slip instability along an intra-plate fault through a typical fault bend model. The influence of a prescribed fault bend on the relative slip velocity, the transition of stick-slip state, the normal contact force and the friction force along the intra-plate fault between the deformable rocks can be investigated. This study will focus on how to extend the algorithm for the simulation of stress evolution phenomena in a frictional contact system. The numerical results of a typical intra-plate fault bend model demonstrate the efficiency and usefulness of this algorithm. These results illustrate the geometrical irregularities of the fault; significantly affect the faulting process and initiation of the stick-slip instability along the intra-plate fault. This current finite element algorithm can be used to simulate all these instability phenomena. By this way also the significant influence of fault bend on the nucleation, termination and restart of the stick-slip instability along the intra-plate fault, and further on the corresponding stress variation of the total frictional contact system can be illustrated.

Keywords: stick slip, stress evolution, node to point

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SS005 **Poster presentation** **6462**

Anomalies of seismic regime of western Himalaya

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The paper includes two parts: the first one describes the development of methods of recognition of anomalies in seismic regime (including EQ precursories), and the second shows the application of these methods to study the seismicity of Western Himalaya.Methodical basis for data preparation is developed. Database allows to conduct following operations: - base acquisition with new incoming data; - control of format errors in initial data, control of validity of earthquake parameters; - recalculation of earthquake energetic parameters to a unified scale, if necessary; - identification and marking of aftershocks, generation of table of parameters of aftershock sequences; - selection and export in ASCII format of parts of the catalog within limits (time interval, latitude, longitude, depth ranges, energetic class, etc.) specified by user; - generation and export of earthquake distributions with respect to depth and magnitude; - selection and export in ASCII format of aftershock sequences of events specified.Estimation of catalogue uniformity, testing of the recurrence plot linearity, testing the complete registration of weak events, unification of magnitude scale, magnitude correlation with source parameters and relationship between magnitude and source size are also investigated.Stages of seismic quiescence and the following foreshock activation were found on the basis of RTL-algorithm. Variations of b-value were also recognized.RTL algorithm for recognizing precursory anomalies of seismic regime is realized as a software prototype. Prognostic RTL anomalies were revealed prior to earthquakes with magnitude that occurred within the area (26-34N; 74-82E) from 1998 till 24.06.03. The first results of application of methods and algorithms of recognition of precursory variations prior to strong earthquakes in the region of Western Hi! malaya a re obtained and seem encouraging. The work is supported by India-Russia ILTP Programme, project B2.41 "Physics of Earthquake Process and Comprehensive Analyses of Multiparameter Observations for Precursory Research".

Keywords: seismicity, database, precursories

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SS005 **Poster presentation** **6463**

Geomagnetic anomalies associated with earthquakes

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There are many websites nowadays available to access geomagnetic data online with desired format and time interval. This is a very good opportunity to evaluate the probability of using these data as an earthquake precursor. First it is necessary to define the geomagnetic anomaly in an appropriate way. In the next step it will be tried to distinguish between geomagnetic anomalies associated with earthquakes and anomalies caused by solar wind or other sources by using auxiliary data. The final stage of this study will be the statistical preview of the relationship between these geomagnetic anomalies and earthquakes. The factors affecting this relationship such as magnitude and mechanism of earthquakes, and the geological setting of the region will be discussed.

Keywords: earthquake, prediction, geomagnetic

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SS005 **Poster presentation** **6464**

Simultaneous Multiple Seismic Event: Koryakia Earthquake M7.6, Eastern Russia On April 20, 2006

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On April 20, 2006, Mw=7.6 large earthquake occurred at Koryakia, Eastern Siberia of . This earthquake is shallow rupture event in crust of Eurasia or Northern American plate. This region has high seismic activity occasionally. Kamenskoe station (KMS), one of Ocean Hemisphere (OHP) Network stations, locates north-west 170km distance from its hypocenter. KMS station is most closed broadband seismic station to this earthquake. The major part of seismic record is over-scale. However P-wave seismogram, initial part of this record, is available. The particle motion on horizontal plane shows that initial P wave arrival corresponds to seismic origination at hypocenter. About 8 sec later, polarity of particle motion change to more east-west direction. It implied apparent super-sound rupture propagation. We analyzed source process inversion using broadband global teleseismic P-wave data. We applied two kinds of condition for the inversion. In first inversion, rupture velocity is limited less than 3.0 km/s. The latter inversion is applied out of rupture velocity limitation. Inversion results show that the recovery of seismograms is poor in the case of normal rupture velocity. Out of rupture velocity restriction is important for the recovery. The inversion result shows that second sub-event occurred 60-80 km apart from hypocenter at 6 sec later. It tells super-shear propagation intuitively. The distribution of subevents is reasonable, since major subevents locate over the aftershock zone. It may mean that initial major rupture determined overall rupture scale and aftershock zone size. In ordinary sense, super-shear rupture propagation are questionable. For the triggering at lower crust, it is interpreted as apparent simultaneous same scale of earthquakes. Usually source inversion is improved a priori condition. In some case like this event, the view of real process may be lost.

Keywords: source process, rupture velocity

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SS005 **Poster presentation** **6465**

Quantitative earthquake prediction: twenty years of real-time application and testing

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We summarize the two decades of experience in real-time prediction of catastrophic earthquakes worldwide. The approach is based originally on theoretical implications that come from non-linear dynamics of complex chaotic systems. The prediction algorithms were designed making use of pattern recognition approach. The predictions by the algorithms are completely reproducible and scale with the magnitude of the incipient earthquake. Their spatial accuracy is limited to the area 5-10 times the linear size of target earthquake. If the data remits, the accuracy could be improved by additional analysis, in some cases, to the size of incipient earthquake as exposed by location of aftershocks. The temporal accuracy of predictions is intermediate term, i.e. in the order of several months to years. Although of limited accuracy, the predictions create a possibility to prevent part of the damage. The algorithms and their parameters remain unchangeable since each application setup. The prediction results accumulated in course the tests prove beyond any reasonable doubt predictability of seismic catastrophic events by monitoring seismic environment. Each case-history of predictions is systematically assembled in the testing archive providing a unique data for further inquiry into earthquake prediction problem.

Keywords: complexity, dynamics, test

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SS005 **Poster presentation** **6466**

Source characteristics of the 28th May 2004 Baladeh-Kojur destructive earthquake in central Alborz, revealed from far field waveform data

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Source characteristics of the 2004 Baladeh-Kojur destructive earthquake is obtained by inverting far field waveform data. The information from field investigation and aftershock activity are considered as supplementary data to constrain the source parameters. The source characteristics of mainshock is explained in terms of at least three major subevents. Rupture initiated in epicentral area with the first subevent and mainly extended towards west in a unilateral manner. The major slip took place during the first 10 seconds and it is concluded that the directivity played main role for producing extensive intensity in the epicentral region. The source mechanism obtained in this study is predominantly trust and is in agreement with the mechanism of other earthquakes as well as the orinatation of tectonic forces in this region. The total seismic moment is calculated to be M0= 4.11018 Nm and the total moment magnitude is Mw = 6.3. The source duration of largest subevent is about 7 seconds and its related rupture extension is about 20 km. The calculated maximum dislocation is about 1.2 m and the estimated maximum stress drop is 6.1 MPa. Macroseismic evidence and recorded accelerograms in Baladeh region indicate that the ground strong motion was intense during the mainshock. Although central Alborz had been seismicly active in historical times there was no evidence that earthquakes as severe as this earthquake had occurred in the vicinity of Baladeh-Kojur region during at least the past 100 years. From the engineering point of view, Baladeh-Kojur earthquake provided ground-motion characteristics of a strong event in the affected area and should be considered as the controlling event for the design of structures with high safety requirements.

Keywords: source model

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SS005 **Poster presentation** **6467**

Investigation on static stress interaction among the 1930 Irpinia Earthquake and other large events in Southern Apennines (Italy)

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Umberto Fracassi, Barbara Palombo, Nicola Alessandro Pino

On July 23rd 1930, a strong earthquake (Ms=6.6) occurred in the Irpinia region, the most seismically active area of the Southern Apennines (Italy). Destructive effects were reported in a wide area of about 6300 km2, causing more than 1400 victims. The same region had already been struck by several large earthquakes in 1456 (Me=6.9), 1694 (Me=6.0), 1702 (Me=6.0), 1732 (Me=6.6), and 1910 (Me=5.9). Other major events have hit Irpinia since the 1930 earthquake, including that of 1962 (Mw = 6.2) and the catastrophic one of 23 Nov 1980 (Mw = 6.9).Formerly published studies concerning the 1930 Irpinia event include analysis of macroseismic data, first motion polarities and a single station waveforms. By using the available bulletins and the historical seismograms, in our previous study we estimated the source parameters in terms of focal mechanism, magnitude, hypocentral location and seismic moment. Fault length, rupture velocity and other characteristics are also obtained by performing body waveform inversion for moment rate retrieval. These results are here used to study the static stress transfer between the 1930 Irpinia earthquake and subsequent large events like the 1962, and 1980 ones in order to investigate the possible fault interaction and earthquake triggering. To improve our knowledge on the region of the1930 event, we also study the Coulomb stress field related to E-W trending seismogenic sources, responsible for the main sub-events of the multiple 1456 historical earthquake. Modelling of such effects is useful both to obtain more information on seismogenic sources and to gain an improved evaluation of seismic hazard in this region.

Keywords: irpinia, stress transfer, earthquake triggering

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SS005 **Poster presentation** **6468**

Analysis of Combined Triggering Factors as a Basis for Earthquake Prediction and Control

Dr. Victor Novikov
Pulsed MHD Power Systems forGeophysics Joint Institute for High Temperatures of RAS

The following postulates and assumptions are used; 1) an existence of seismicity triggered by natural and man-made factors has been proven by many patterns in various places of the world; 2) all earthquakes are triggered; 3) earthquake is triggered by combination of different external factors like natural phenomena: lunisolar earth tides, strong earthquakes, magnetic storms, etc., as well as phenomena resulted from human activity: high-power nuclear and chemical explosions, magnetic storms, etc.; 4) there are algorithms of medium-term earthquake predictionallowing to point an area, where catastrophic event is anticipated within nearest 5-10 years. Based on the following initial data: 1) tectonic energy level accumulated in the Earth crust; 2) critical energy level required for the fault formation; 3) energy level absorbed by the earthquake source from an impact of combination of different triggering factors an algorithm is proposed for short-term prediction based on monitoring of well-recognized triggering factors, orfor controlled combined man-madeimpact on the earthquake source to discharge of tectnic stresses in the Earth crust and to decrease of magnitude of seismic event or its complete prevention.

Keywords: combined, triggering, factors

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SS006 **6469 - 6481**

Symposium
Education and Outreach

Convener : Dr. John Taber
Co-Convener : Dr. Kiyoshi Suyehiro

The 2004 Sumatra-Andaman Islands earthquake and tsunami demonstrated both the level of potential public interest in earthquakes and more importantly, the need for increased education. This need exists at all levels, from educating more school children about the causes and effects of earthquakes to training new seismic network operators in the management and analysis of seismic data. This symposium will focus on effective strategies for education and outreach for this wide range of audiences. Presentations are encouraged on the following topics: (1) Innovative professional education of geophysicists and seismic network operators, including manuals of standard practice and informed use of standard data bases. (2) Formal and informal education of teachers, the public, press, officials, etc., especially using new technologies. (3) Examples of the successful use of school seismographs and seismic networks to engage students and teachers in recording and analyzing seismic data as part of their science curriculum. (3) Interdisciplinary professional outreach, including projects in assessing seismic hazard, seismic risk, and sustainable development. (4) Capacity building in developing countries and underrepresented groups.

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SS006 **Oral Presentation** **6469**

Global Forum For Natural Disasters Mitigation Education And Outreach: Case Study

Prof. Narendra Kumar Choudhary
Reearch IAPSO- CGSI IAPSO

Dr.R.C.Bhattachajee, Dr.N.K.Gupta, Mr.N.E.Khadse, Prof.S.P.Yavalkar, Mr.Vijay Kumar Singhal

The Global Forum for Disaster Management, GFDM was inaugurated during the fourth World Water Forum at Mexicocity,Mexico in 2006 .In recent past the communities around the world witnessed number of disasters like Tsunami, earthquakes , cyclones , hurricanes ,Forest fires,flashfloods landslides and related geo-disasters etc . The Tsunami tragedy along the south Asian coast changed the lives of millions of affected people in Asian countries . Several NGO's around the world played an important role in provision of immediate rehabilitation for the victims of the tsunami ,not only the physical rehabilitation but also providing scientific and technical information to mitigate the disasters. Recognizing the social responsibility, ISDR along with IAPSO-CGSI,UNESCO,UN-WCDR,IHDP,UNEP and other organizations has provided immediate rehabilitation measures for tsunami-affected people in our country . For life to return to normal for the tsunami-affected population, systematic-scientific and technology-based efforts are needed. Also rehabilitation work should focused on cost-effective methods for tsunami rehabilitation. This global forum for disaster management will examine, among other items, the relation between the socio-economic dimension and scientific education and outreach and technological methods and relevance to early rehabilitation programme in various parts of the world .ISDR along with IAPSO- International commission on Grounwater-Seawater Interactions ,National Institute of Technology,Muktainagar-Taluka Education society , Open University geological society, Switzerland has accepted the responsibility of providing necessary infrastructure and Institutional help for Education and Outreach through Global forum for disaster management for conducting research and development and work related to natural disaster management such as tsunami rehabilitation and other geo-disasters mitigation. This presentation is based on the lesson learned from the GFDM - disaster management and mitigation in the Asia - Pacific region through the NGOs and academic and research institutions for social and ecological management during post disaster period .

Keywords: disaster mitigation, geo disaster education, paoples participation

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SS006 **Oral Presentation** **6470**

Earthquake awareness through school education programme in India

Mr. Brijesh Kumar Bansal
IASPEI

During the last 15 years, more than 9 damaging earthquakes of magnitude 6 to 7.9 have taken place in different parts of the country, which have caused considerable loss of life and damage to the property. The Tsunami generic earthquake of December 2004 was of exceptionally large magnitude of 9.3 which devastated several coastal states of Peninsular India. Keeping in view the high vulnerability of earthquake hazard in India, the Department of Science & Technology has initiated a Himalayan School Earthquake Laboratory programme (HIMSELP) to impart earthquake education and creating earthquake awareness amongst the School Children. Seismological observatories have been establishedusing GURALP-ED digital seismograph at 100 schools in northeast India as well as western Himalayas. Similar programme has also been started in the NCR Capital region, Delhi and a few coastal stations which were affected by the Tsunami of 2004. It is found that in addition to the laboratory practice about earthquake parameters, the children are taking keen interest in the programme due to the inclusion of Disaster Management in the syllabus of High School students through the Central Board of Secondary Education. It is interesting to find that the close network of these stations is also providing excellent data for seismological studies, including seismic tomography, undertaken by different Geophysical Institutes in the country.

Keywords: earthquake, school, education

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SS006 **Oral Presentation** **6471**

IRIS Seismographs in Schools Program

Dr. John Taber
IASPEI

Lawrence Braile, John Lahr, Lora Bleacher

Sharing seismic data and the excitement of discovery that it offers with a general audience requires effective tools and an understanding of seismology with an educational perspective. To address this need, the Incorporated Research Institutions for Seismology (IRIS) Education and Outreach (E&O) Program initiated a project in 2000 to distribute educational seismographs to schools (the AS-1), and developed and distributed new display software written by Alan Jones (AmaSeis). One of the best ways for teach people about science is to give them opportunities to work with real scientific instruments and data. The Seismographs in Schools program is doing this for many students in earth science and physics classes around the USA. Over 140 schools are now operating the low-cost, stand-alone systems and are using associated educational modules. The seismographs are capable of recording 1-4 teleseismic earthquakes per month, depending on the site, as well as local earthquakes, mining blasts, and cultural noise. IRIS has helped foster and collaborates with educational seismology efforts of local and regional groups in states throughout the US, and has also provided seed equipment and shared expertise with school seismograph programs in New Zealand, Great Britain, France, Italy, Khazakstan and Costa Rica. IRIS consortium members have created new classroom activities with some assistance from small seed money grants. Available exercises include instrument calibration, magnitude and location estimation, and analysis of seismograms. The AmaSeis software can also be used without a seismograph to display, analyze and interpret seismograms downloaded from the Internet. While AS1 seismographs have the advantage of being independent units that do not require a network connection, it is valuable for teachers and students to be part of a larger group. Information can be shared between teachers using a listserve and data can be shared via the SpiNet site maintained by Science Education Solutions. Near-real-time helicorder images can be posted on a school web site and all these images alo appear on an IRIS web site. Data recorded by the school seismographs can also be compared to national and international data stored at the IRIS Data Management Center via the Rapid Earthquake Viewer, a web application developed by the University of South Carolina. A critical element of the program is an initial training workshop for teachers. Teachers attend a 1.5 day workshop focused on the use of the seismograph before they receive their seismograph. The goals of this workshop are for teachers to be able to set-up, calibrate, operate and troubleshoot their AS-1 seismograph, to be able to use data collected from their AS-1 seismograph as an integral part of their seismology/plate tectonics instruction, and to participate as part of a larger community of educational seismograph users. Where possible, a seismologist visits individual schools after the seismograph has been installed to help answer any questions they may have about the use of the instrument, about other IRIS-supported software, and about seismology in general. Regional clusters of schools are encouraged, particularly if there is involvement from a local university, as this provides better support for the teachers and interactions between schools. Such ongoing support is crucial for the continued use of seismic data in the classroom.

Keywords: education, classroom, seismology

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SS006 **Oral Presentation** **6472**

Outreach activities of solid earth science using various kinds of maps

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Maps that sort and display various kinds of information concerning the earth by geographical locations are powerful tools for outreach of solid earth science, helping intuitive understandings of people. This is rather a matter of course considering that major advances in earth science have been triggered by new information on maps. For example, the continent drift theory is said to be inspired when Alfred Wegener saw the topographic map that surrounds the Atlantic Ocean. From April 2006, the first author is in charge of outreach activities of solid earth science at the Earthquake Research Institute (ERI). He obtained some public interest in lectures on demand at schools by using various kinds of maps such as 1) a world seismicity map specially made by a collaboration between a map maker and ERI (Tsuruoka, 2006), 2) 1:25,000 Digital Elevation Model of Tokyo made by Geographical Survey Institute of Japan, and 3) Google Earth on the Internet. This paper introduces these experiences and examines an effective method of public outreach of solid earth science using various kinds of maps. The world seismicity map shows the hypocenters of earthquakes larger than M5.0 that occurred during the period between 1997 and 2004. The data sources are the Harvard CMT catalog, GTOPO30, and ETOPO5. This map is unique, because it is printed on a large A-1 size paper, allowing a close look at detailed distributions of earthquakes and topography of the earth. This map attracts childrens attention at lectures on demand, probably because of its size and details involved. GSIs 1:25,000 DEM is also printed on a paper slightly larger than A-1 size, and shows micro topography of central Tokyo obtained from airborne laser surveys with colors and shading. When people see this beautiful map colored with blue on the right hand side and with yellow and brown on the left hand side, they do not recognize that this is a map of Tokyo. But careful look reveals that eastern part with blue is lowlands along the Arakawa River, and the western part with yellow is an uptown on the Musasino plateau. This map is educational because it can show that large cities covered with buildings and roads are actually sitting on the natural terrains. Nowadays, Google Earth provides a good observation tool of topography of the earth, allowing a virtual tour from the close up of the school in lecture to the globe in space. Its smooth zooming capacity enables a 3D browse of a crowded city area on the Kanto plane, nearby Mt. Fuji, Japanese archipelago along with Japan and Ogasawara trenches, and even the Pacific and Philippine sea plates, brining a flavor of the richness of the earth to the audience.

Keywords: outreach, maps, google earth

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SS006 **Oral Presentation** **6473**

Education of Community Based Earthquake Risk Management: A Case Study in IRAN

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Vahid Hosseinijenab, Farshid Tofiqi, Mahmoud Fatemi Aqda, Alireza Estelaji, Bahram Abdi Farkoush

Introduction: From the viewpoint of seismicity, is an active country. is vulnerable to earthquake, causing the worst destruction and highest number of fatalities. Unfamiliarity to risk management, lack of disaster management plan and loss of preparedness of response agencies are the effective factors on human risk due to earthquake. This study performed for educating of authorities and experts that were working in some responsible organizations of disaster management, especially health organizations and hospitals. Methods: This study has performed in 2006. Related scientific groups collected scientific materials and designed an integrated workshop in the field of community based earthquake risk assessment and management. Duration of workshop was 5 days. These workshops were carried out three times at 2006. Thirty trainees took part in every workshop. Knowledge of trainees was assessed before and after workshops. Also, effectiveness of workshop on disaster management planning of organizations was assessed after two months, by calling trainees and to hold an interview. Results: The results of this study showed that trainee's knowledge has improved after participating in these workshops. They became familiar with approaches for assessing risk of earthquake in their organizations, including hospitals. Follow up of trainees showed that they decided to reduce risk of earthquake in their organizations by performing methods of risk management that they have learned in the workshop. Conclusion: Participation of authorities and experts that are working in some responsible organizations of disaster management, including hospitals, has obvious effects on their knowledge and practice for risk management.

Keywords: risk, earthquake, education

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SS006 **Oral Presentation** **6474**

WEBSISMO: interactive web site for education and public awareness on earthquakes

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Mariano Garcia-Fernandez, Eduard Rubio, Manuel Gomez

WEBSISMO is a combined scientific, technical and educational project aiming to develop an interactive web site for educational purposes as well as to increase public awareness on earthquakes and seismic risk. The web site consists of a virtual community, which is affected by seismic events of different characteristics. Based on the elements of the community (public or private buildings, structures, lifelines, landscape elements, etc) a number of seismic scenarios can be generated. The elements in the community constitute links to a number of didactic units allowing the user: 1) to understand the origin of earthquakes; 2) to directly observe earthquake effects in buildings and lifelines with a wide range of vulnerabilities; and 3) to be aware of the proper measures to prevent and mitigate earthquake effects. Furthermore, the web site will include the access to updated technical documentation on building codes, microzonation for municipalities and emergency response plans. The concept of WEBSISMO is based on an open architecture that will further allow adapting or modifying specific aspects tailored to the needs of the potential hosting public or private institutions.The chosen media, the Internet, provides one of the most effective ways at present to share knowledge and insights from earthquakes studies and other research that is needed by the community before, during, and after a damaging earthquake to mitigate seismic risk.WEBSISMO is a project funded by the Spanish Ministry of Education and Science, and it has been developed at the Institute of Earth Sciences Jaume Almera-CSIC, in close cooperation with external outreach professionals (GEOMEDIA), and with the additional participation of the Spanish Civil Defence (DGPC), the Spanish National Geographical Institute (IGN), the University of Alicante (UA), and the University Complutense of Madrid (UCM).

Keywords: earthquakes, education, internet

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SS006 **Oral Presentation** **6475**

Education in Environmental Issues

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Inhabitants of this planet, human beings are faced with the urgent task of finding a way to coexist in harmony with earth and nature. This paper discusses the necessity of educating university students who will both lead their own generation and educate the next on environmental issues, now an essential part of general education in a liberal arts course of study. All lives on the earth have benefited by natural phenomena and resources, but on the other hand they have suffered various kinds of natural disasters throughout the world. Since the Industrial Evolution activities of human beings supported by mass production, mass consumption and mass waste and development of science and technology have caused global environmental pollution and destruction. Furthermore several phenomena such as global warming cause natural disasters which will generate other disasters and will inflict great and new damageupon us. For example rapid global warming is connected with unusual weather, results in heavy rain and flood and increases damage by earthquakes, volcanic eruptions or sediment disasters. Without a remarkable improvement in environmental issues, all lives including human beings will not last long. By investigating how students understand environmental issues, how they are aware of the seriousness and how they behave to improve those issues, and by comparing their knowledge, awareness and behavior with those in other countries, what is a desirable image of education in global environment and what can earth scientists do now are suggested.

Keywords: environment, disasters, university education

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SS006 **Oral Presentation** **6476**

European seismological commission: past, present, and future

Dr. Mariano Garcia-Fernandez
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Ina Cecic, Alicewalker

The European Seismological Commission (ESC) is a regional commission of IASPEI, which was formally established as a scientific organisation in 1951. The ESC mission is to promote the science of Seismology within the scientific community of the European and Mediterranean countries (encompassing the area from the Mid-Atlantic Ridge to the Ural Mountains and from the Arctic Ocean to northern Africa), and to extend and enhance scientific co-operation, training and outreach.The ESC had its first General Assembly in 1952 in Stuttgart, Germany. Since then, 30 General Assemblies have been held providing a focal point for European knowledge on earthquakes, the hazard they pose, and how to cope with them.The scientific activities of ESC were originally organized inside Subcommissions that were created to address particular seismological issues by means of specific Working Groups.At the XXX General Assembly in Geneva, 2006, a main change in the organisation of ESC was introduced, modifying the bylaws, with the aim of making its administration more flexible, and to optimize scientific cooperation. The new ESC structure is made up of the Executive Committee, as its main coordinating body, the Titular Members (representatives of the member countries), and the Working Groups, which are set up with the purpose of studying particular scientific problems having clearly defined objectives.The ESC has been the support or the framework for several significant initiatives and contributions in Seismology in the European-Mediterranean region. They include: the first European Maximum Observed Intensity Map, the first European Earthquake Catalogue, the preservation of historical seismograms, the European Mediterranean Seismological Centre (EMSC/CSEM), ORFEUS (Observatories and Research Facilities for European Seismology), the European Macroseismic Scale (EMS98), the European Strong-Motion Database (ESD), the IASPEI New Manual of Seismological Observatory Practice, and the first Unified Seismic Hazard Map of the European-Mediterranean region.It is anticipated that, with its new structure, the ESC will continue to develop its service to the seismological community of the European-Mediterranean region, and, through them, to the greater understanding of earthquakes and the protection of our citizens.

Keywords: european mediterranean, seismology, iaspei

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SS006 **Oral Presentation** **6477**

Tsunami: a movie for the tsunami risk reduction in Italy

Dr. Concetta Nostro
Education and Outreach Istituto Nazionale di Geofisica e Vulcanologia

Maramai Alessandra, Graziani Laura, Baroux Emmanuel, Burrato Pierfrancesco, Castellano Corrado, Arcoraci Luca

is a country well known for the seismic and volcanic hazard. As a matter of fact the first seismological and volcanological observations were done in since the Roman times. However, a similarly great hazard, although not well recognized, is posed by the occurrence of tsunami waves along the Italian coastline. This is testified by a rich catalogue and by field evidence of deposits left over by pre- and historical tsunamis, even in places today considered safe. This observation is of great importance since many of the areas affected by tsunamis in the past are today touristic places. The Italian tsunamis can be caused by different sources: 1- off-shore or near coast in-land earthquakes (e.g. 1627, 1783 and 1908 events); 2- very large earthquakes on distant sources in the Mediterranean (e.g. the 365 Crete subduction zone earthquake); 3- submarine volcanic explosion in the Tyrrhenian sea; 4- submarine landslides triggered by earthquakes and volcanic activity (e.g. 2002 Stromboli landslide). The consequence of such a wide spectrum of sources is that an important part of the more than 7000 km long Italian coast line is exposed to the tsunami risk, and thousands of inhabitants (with numbers increasing during summer) live near hazardous coasts. In order to reduce this risk and following the emotional impact of the december 2004 Sumatra earthquake and tsunami, we developed an outreach program consisting in talks given by scientists and in a movie, both exploring the causes of the tsuanami waves, how do they propagate in deep and shallow waters, and what are the effects on the coasts. Hints are also given on the most dangerous Italian coasts (as deduced by scientific studies), and how to behave in the case of a tsunami approaching the coast. These seminars are open to the general publics, but special programs are developed with schools of all grades. In this talk we want to present the movie used during the seminars and scientific expositions, that was realized from a previous 3D version originally developed for science festivals.

Keywords: tsunami, risk reduction

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SS006 **Oral Presentation** **6478**

How Science Bulletins at AMNH Educated the Public Concerning the 2004 Sumatra-Andaman Islands Tsunami

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R. Kinzler, E.A. Mathez, V. Trakinski, T. Van Bergen, N. Gardner

Science Bulletins, a media production project at the American Museum of Natural History (New York, USA), brings Earth system science data and concepts to over 10 million visitors per year at over 20 institutions around the U.S.A. Our target audience is diverse, from school groups, to families and adults. The Earth Bulletin is an 12minute-long, high-definition video production on the current state of the dynamic Earth. It uses news stories and visualizations based on data primarily from the USGS and other government-agency sources and imagery from medium-resolution satellites to focus public attention on recent natural events and to illustrate the broad scientific concepts of tectonic activity and the processes that underlie climate and weather events. Programming also includes a six-minute-long feature story describing a cutting edge story in the science. These stories are chosen by museum scientists, who are responsible for ensuring coherence, accuracy, and scientific integrity. In addition to describing the modern science, the purposes are to show scientists at work and to put a human face on the scientific endeavor. Over the past six years, feature stories have addressed the volcanic history of present-day Yellowstone National Park, tsunamis, the disappearance of tropical mountain glaciers, the North Atlantic Oscillation, derechos, and the oxygenation of the atmosphere. The feature stories are accessible via the worldwide web with accompanying explanatory material. Periodic surveys of our visitors indicate that these media are popular and are effective at communicating concepts of Earth system science. During this talk we will show the feature story we produced on the 2004 Sumatra-Andaman Islands Tsunami and discuss how each of the elements of science presented helps increase public awareness of the progress being made in this vital area of geosciences research and things that they as individuals can do to protect themselves from harm should they be in a tsunami-prone area. The tsunami feature story includes visualizations of scientific models of tsunamis, along with footage of field research and interviews that communicate the broad nature of tsunami scientific research to the public.

Keywords: tsunami, educational outreach, high definition video

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SS006 **Poster presentation** **6479**

Middle School Seismology; A Study on Authentic Learning and the Use of an AS-1 Seismometer, Google Earth, and Integrated Ocean Drilling Program Data

Mr. Jerry Cook
Science Teacher

Tavia Prouhet

Authentic scientific research provides middle school students real world connections to learning. In this study a middle school teacher fosters in-depth understanding of Earth science concepts through utilization of a state of the art classroom seismometer, coupled with ocean cores and Google Earth. In this lesson sequence students are educated in the basics of seismology and plate tectonics. The lesson in study began with intensive study of seismographic data. The fifth grade science students use an AS-1 seismometer which was obtained through a grant from IRIS. But, fifth graders arent the only ones to benefit from this exciting technology. The seismometer has two monitors available one in the classroom and the other facing out the window so that everyone in the school community can examine the latest earthquake activity. Students are presented with an extensive seismic curriculum and lab-oriented activities and lessons stress the use of real data from the seismometer. In further exploration of plate tectonics concepts student examine virtual ocean cores through the Integrated Ocean Drilling Program (IODP) and Joint Oceanographic Intuitions (JOI) Learning website. Viewing core samples in the virtual world of Google Earth students examine data revealing divergent plate boundaries. Thus, students are presented with problem-solving activities that incorporate authentic, real life questions and issues allowing them to participate in a learning environment where the teacher is not the only source of knowledge. This research reveals details for implementation, classroom lesson sequencing and its effect on student learning.

Keywords: education, seismometer, as 1

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SS006 **Poster presentation** **6480**

Geophysics in russian scientific-educational project

Dr. Alexander Gusev
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Historically thousand-year Kazan city and the two-hundred-year Kazan university (Russia) carry out a role of the scientific-organizational and cultural-educational center of Volga region, Russia. The Kazan State University is one of the oldest and largest institutes of higher learning in the Russia. It was founded on November 5, 1804. The history of Kazan University abounds in the names of outstanding scientists, staunch revolutionaries, eminent public figures, educators, painters, actors. For the further successful development of scientific-educational and innovative-technological activity of the Russian Federation, the Republic Tatarstan, Kazan is offered the national project - the International Center of the Science, Education and the Internet of Technologies "GeoNa" (Geometry of Nature – "GeoNa" is developed wisdom, enthusiasm, pride, grandeur), which including: original designs building "GeoNa" - "Lobachevsky's surface", 59 floors, height 215 m (with a spike 302 m), the general area in 148,000 sq. meters, a modern complex of conference halls (up to 4 thousand seats), center the Internet of Technologies, Computer center, 3D Planetarium, training complex "PhysicsLand", active museum of natural sciences, cognitive system "Spheres of Knowledge", oceanarium with a fresh-water segment (5 million liters), botanical and landscape oases, business-hotel. In center "GeoNa" will be hosted conferences, congresses, fundamental scientific researches of the Moon and planets, scientific-educational actions: presentation of the international scientific programs on investigation of the Solar system; modern electronic lunar and planets databases, introduction of remote control educational technologies, presentation of Hi-tech cosmic technology. Modern GRID-system has included separate computers, local networks, supercomputers, data bases, the communications, software packages: 40-Gb liaison channels, processor capacity 200 Teraflops (2 x 1014 operations in a second), volume of disk - memory is hundreds of PetaB (1017 bytes); inclusion in global computer infrastructure GRID - EGEE (Europe). The "fast" Internet, Modern GRID system, fast data acquisition with the help modern the Internet of technologies, their processing, classification, three-dimensional visual representation of databases with time display on the basis of modern super fast and powerful computer complexes 3D Vision World Systems. 3D and sensual demonstration of fundamental processes inside the Earth: movement of continents and tectonic plates, rotation of a liquid terrestrial core and generation of a magnetic field, magnetic storms, solar flashes and the polar lights, destructive earthquakes and fantastic eruptions of volcano, global warming of the Earth, tsunami and tornado, formation of the Earth and minerals, generation of oil and gas deposits, paleontology, occurrence of the first plants, animal, Human will be presented in geophysical museum "Travel to center of the Earth". A more intense program of exchange between scientific centers and organizations for a better knowledge and planning of their astronomical curricula and the introduction of the teaching of planetary geophysics are proposed. Center "GeoNa" (http://www.geona.ksu.ru) will enable scientists and professors of the Russian universities and special research institutes to join to advanced achievements of space geodesy, air-cosmic information technologies; to establish scientific communications with foreign colleagues in sphere of the high technology and educational projects with world scientific centers.

Keywords: scientific education project

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SS006 **Poster presentation** **6481**

School Seismology in the UK

Mr. Paul Denton
British Geological Survey IASPEI IASPEI

During 2007 the school seismology project is being launched. The aims of this project are to improve interest in science for students aged 11-16 and to improve participation rates in physical sciences for students aged 16+. The objectives of the project are to develop a range of hands-on classroom activities to support the teaching of some fundamental physical science concepts using earthquakes and seismology as a unifying theme. The activities are based of ideas from Larry Braile, the USGS and IRIS, however they have been adapted to suit the educational context. The school seismology project has also developed a simple practical seismometer system for use in schools. The system is a horizontal motion seismometer with a natural period adjustable to 20seconds complete with an amplifier and 16bit digitiser suitable for direct connection to the Amaseis datalogging software. The project has been developed with support from the British Geological Survey (www.bgs.ac.uk), the Science Enhancement Programme (www.sep.org.uk), the British Association for the Advancement of Science(www.the-ba.net)and the National Endowment for Science Technology and the Arts (www.nesta.org.uk).

Keywords: seismology, school

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SW001 **6482 - 6496**

Workshop
Earthquake data in archaeological and historical studies

Convener : Dr. Paola Albini

When a destructive earthquake occurs - as in the most recent cases at Bam (Iran, 2003), Indonesia (2004), Kashmir (2005) etc. - one of the first questions raised by seismologists, media and by the common people concerns the seismic history of the affected places. The importance of the contribution of historical earthquake data to seismological studies, in particular to seismic hazard assessment and related topics, is increasingly acknowledged by the international scientific community. Historical earthquake data stems from the written records of seismic effects of the past, as provided by the historical sources; as such, they supply the most important - if not the unique - evidence of earthquake activity before the early instrumental period (beginning of 20th century), and a very necessary one also in the period up to modern instrumental period (up to 1964). Since about 20 years, thanks to pioneer works, historical seismology has established itself as a discipline with internationally recognized, rigorous procedures, for both retrieving historical data and interpreting them in seismological terms. Investigations are frequently performed by multidisciplinary teams that today release a reliable, semi-quantitative, scientific historical earthquake data set. Around the world, historical earthquake data, and more recently also archaeological evidence related to earthquakes, are collected by many organizations with varying criteria and degrees of commitment; most of them are concerned with national or local data only. A few countries only have a consistent, accessible set of historical earthquake data, interpreted in terms of macroseismic intensity data points; in many countries scattered data are available on paper only. Single investigators, from both the seismological and the historical side, contribute very useful studies, which often feed the grey literature and miss international dissemination. In all, a huge amount of useful literature and data still wait to be made available to the scientific community. The goals of the recently established IASPEI Working Group Historical Seismology (2005) can be summarized as follows: i) to inventory the published and unpublished material supplying historical earthquake data, supplemented by an annotated bibliographical list; ii) to collect and preserve as many inventoried items as possible, both on hard copy and in digital format; iii) to disseminate the material through a dedicated web-site. To discuss the achievements in these fields and to foster the international cooperation and scientific exchange, contributions focusing on these topics are warmly encouraged, both with respect to Archaeoseismology and Historical Seismology studies.

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SW001 **Oral Presentation** **6482**

Archeoseismology along the Dead Sea fault: evidence for earthquake clustering

Prof. Mustapha Meghraoui
IASPEI IASPEI IASPEI

Meghraoui Mustapha, Apame Working Group

The Dead Sea Fault (DSF), a plate boundary in the Middle East is well known for its large historical seismic events. Several populated regions of the Middle East are located along the DSF and are exposed to the occurrence of large seismic events. We conducted the APAME EC project in order to improve observational and experimental field methodologies for seismic-hazard assessment and to develop proper knowledge for the preservation of the cultural heritage. The Dead Sea Fault shows direct offsets and damage historically known as due to earthquakes. Therefore, we combine historical, archeo-paleoseismological and earthquake hazard studies to constrain the level of seismic risk. Several crusader castles, roads and aqueducts located in the Middle East are described with evidence of seismic damage. Field investigations in the Amik Basin (Turkey) exhibited a total of ~ 40 m fault offset across the Sicantarla Tell site that may correspond to a succession of several earthquakes. The remains of lost villages in northern Syria reveal the effect of earthquake including severe damage on a Roman aqueduct (with 13.6 m of left lateral displacement), churches and historical buildings. Paleoseismic results correlates well with severe damage Tell Essaidyeh in Jordan. Detailed archeoseismic and paleoseismic studies, coupled with historical data along the DSF document the effect of past earthquakes and show the long term faulting behaviour associated with clustering of large seismic events (e.g., in the 10th and 11th).

Keywords: archeoseismicity, faulting, clustering

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SW001 **Oral Presentation** **6483**

A little historical information changes the tectonic interpretation: the mystery of the Western Makran

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The Makran subduction zone, which runs along the south-eastern coast of Iran and the southern coast of Pakistan, is a source of great earthquakes and a major control on the seismic hazard of the region. There is a problem, however, in interpreting the apparent aseismicity of the Western Makran. It could indicate a zone locked throughout historical times, or it could be that subduction is occurring aseismically or even not at all. Evidence for seismic activity rests on one event, apparently very large, in 1483, which supposedly caused damage from the Straits of Hormuz to Southern Oman. Historical research, especially taking into consideration the political situation in the region at the end of the 15th century, suggests that this 1483 event was a moderate magnitude earthquake in the vicinity of Qeshm Island that has been misassociated with a second, very badly documented, earthquake that occurred fourteen years later. This new interpretation removes from the earthquake catalogue any evidence for earthquake activity along the Western Makran, and adds weight to a tectonic interpretation that suggests that the active Makran subduction zone is controlled by the Murray Ridge spreading centre, and has a westerly termination at the Sonne Fault. This presents an interesting (even extreme) example of how a piece of obscure historical information concerning political links has a major effect on resolving a question of tectonic interpretation, and with it, strongly influences the estimation of regional seismic hazard.

Keywords: historical earthquakes, tectonics

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SW001 **Oral Presentation** **6484**

Geoarchaeology of the GIant Rapa Nui megalitic Ahu Moai monuments: collapsed and earthquake activity evidences in Easter Island, Chile

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R Marchetti, E.Zarate, S.Haoa

The aim of this research is to improve the knowledge of the geophysical natural hazard in Easter Island , in particular the earthquake activity in the past. We investigate the giant megalithic monuments AHU MOAI , which represent the main Rapa Nui religion architecture. About 90% were building along the coast of the island , after the catastrophic impact caused by the big mega tsunami on December 16, 1575. The tsunami was generated by the earthquake (M 8.5) occurred in southern . According the archaeological, radio carbonic data, field geology and the historic reports of the early western navigation explorers, we estimated this type of Ahu Moai were building between 1575 and approximated 1680. During more than a hundred year the monuments were affected by seismic event and collapsed . About 60% of the Ahu-Moai ruinous, exhibit very well preservation and clears evidences of the seismic activity during that period. We analyse the architecture design, kind of foundations and seismic resistance building ,the heterogeneous, size, volume and weight of the rocks material used in their building ,which generated not only an static unstability and also the dynamic high grade of vulnerability when seismic event occurred even of the lower magnitud. We describe the following AHU: Hanga Tee; Akahanga; Ura uranga te mahina; Tepeu; Te pito kura: Vai mataa; The result are correlated with the local and regional volcano-tectonic activity . The last important earthquake affected the Island was 1987,July 08, with M 6.3.

Keywords: easter island, ahu moaime galithic monuments, archaeologicale arthquakes

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SW001 **Oral Presentation** **6485**

Historical earthquake studies in an open-access archive

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Around the world, the Historical Earthquake Studies increased in number and quality in the last 20 years, as the result of the joint efforts of multidisciplinary teams. In general terms, there is a huge amount of scientific historical earthquake data that sometimes are not available or not easily traceable outside the local or national organizations that have funded and taken care of reporting the investigation. The recently born project aims at establishing an archive of Worldwide Historical Earthquake Studies, through few and simple steps: i) to inventory the published and unpublished material supplying historical earthquake data, supplemented by an annotated bibliographical list; ii) to collect and preserve as many inventoried items as possible, both on hard copy and in digital format; iii) to efficiently organize the data in an up-to-date structured archive in digital form. Modern DBMS offer not only the opportunity of storing the studies (published or not) in a dynamic and well organized way, but they can be of enormous advantage with respect to end-users' access; a dynamic link can be created between each study and the related earthquake/s; simple queries on the archive can produce multiple and multifaceted results, a very useful side-effect for the end user. In view of extending the storing capability of the Archive and being able to add as many studies as possible in their original form, an open-source software (DSpace, http://www.dspace.org/) is currently being adapted. This enhanced capability will offer at the end a fully featured Open-Access Archive of Historical Earthquake Studies, in the form of searchable electronic documents. This solution will create a very robust base from the technological point of view and a friendly web interface for any end-user.

Keywords: historical seismology, archive, open access

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SW001 **Oral Presentation** **6486**

An archaeoseismological model to study the scene building of the great theatre of Larissa (Thessaly, Greece)

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Larissa, the capital of Thessaly, is located in the eastern sector of Central Greece, at the southern border of a Late Quarternary graben, the Tyrnavos Basin. Palaeoseismological, morphotectonic and geophysical investigations as well as historical and instrumental records show evidences for seismic activity in this area. The investigations documented the occurrence of several moderate to strong earthquakes during Holocene time. These active structures show recurrence intervals of few thousands of years. The historical and instrumental records suggest a period of seismic quiescence during the last 400 to 500 years. The present research, based on an archaeoseismological keynote is a multidisciplinary approach to improve our knowledge on past earthquakes, which occurred in the area. This study focuses on the damages observed on the walls of the scene building of the Great Theatre of Larissa. The Theatre was built at the beginning of the 3rd century BC and consists of a semicircular auditorium, an almost circular arena and a main scene building. Archaeological and historical investigations document a partial destruction of the theatre during the 2nd-1st century BC. Recent excavations show that the building complex after it was repaired suffered additional structural damages, probably from seismic loading. The damages investigated in detail are displacements, rotations and the rupture of numerous blocks at the walls of the scene building. In order to test the earthquake hypothesis as cause of the damages a simplified seismotectonic model of the Tyrnavos Basin and its surroundings was used with a composite earthquake source model to calculate synthetic seismograms at the Larissa site for various earthquake scenarios. HVSR measurements in the theatre and its vicinity were used to estimate local site effects. The synthetic seismograms are used as the input acceleration for a numerical model of the walls, which simulates seismically induced in-plane sliding within the walls. First results show that some of the surrounding faults have the potential to produce seismic ground motion that can induce in-plane sliding of blocks. Extended model calculations for the northern wall of the western wing room of the scene building were used to constrain the characterisics of the ground acceleration and infer the causative earthquake by comparing the calculated and observed distribution of the displacements of the blocks. First calculations were done for the Larissa Fault, the closest to the site. The geometry of this 20-22 km long, ESEWNW striking normal fault, which dips 60 degrees to the north suggests a maximum earthquake of M 6.6-6.7. However, the calculations for the northern wall of the western wing room show that it would be sufficient a PGA at the site of 0.27 g, which could be induced by an M 5.6 earthquake associated with the eastern sector of the Larissa Fault.

Keywords: archaeoseismology, active tectonics

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SW001 **Oral Presentation** **6487**

Estimating location and size of historical earthquakes on the Dead Sea using mechanical analyses of damage in archaeological sites

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In order to obtain reliable estimates of the rupture locations and peak ground acceleration associated with historical earthquakes we analyzed damage in ancient buildings using two kinds of mechanical analyses. These analyses are part of a series of studies aimed at obtaining quantitative measures of historical earthquakes. The archaeological structures are relatively easy to date and they provide excellent strain gauges where the original shapes are known. We analyzed displaced blocks in archaeological structures based on the Discountinous Deformation Analysis (DDA) code by Shi (1993) and a landslide that offset an archaeological site using the Newmark displacement method, following Jibson et al.'s (2000) empirical equation. Displacements of stones in masonry arches were analyzed numerically by subjecting the model to sinusoidal and to real earthquake input motions of varying amplitude and frequency until the obtained failure mechanism in the model matched the observed damage at the site. The DDA analysis constrains the duration and paek accelerations at the damaged site. Our analysis also proves that down-sliding of arch blocks can only occur during earthquakes. In another analysis, we take advantage of an archaeological site that is displaced at the margin of a landslide. Using Jibson et al.'s (2000) empirical equation we constrain the 749AD earthquake magnitude as a function of distance from the site that was needed to cause slope instability.

Keywords: archaeoseismology, earthquakes, dead sea fault

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SW001 **Oral Presentation** **6488**

The state-of-play of New Zealands historical earthquake studies

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In New-Zealands short written history of less than 200 years, more than 20 large magnitude ($M \geq 7$) shallow earthquakes have been identified, most of these occurring in the historical period prior to 1964. A number of major multidisciplinary studies of pre-instrumental and early instrumental large earthquakes have been published, and in-depth studies of other major pre-instrumental events are in progress. These studies have produced significant insights into seismic hazard, faulting, and tectonics. A comprehensive effort to identify and evaluate all felt earthquakes in the historical period is also underway. Recently, macroseismic intensity points have been geo-coded. These, along with digitised isoseismal maps, will be available in the near future through the website of New Zealands geohazards monitoring network, GeoNet (www.geonet.org.nz). This presentation will highlight these recent developments and studies.

Keywords: historical earthquakes, seismic hazard, new zealand

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SW001 **Oral Presentation** **6489**

National geophysical data center historical significant earthquake database

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The National Geophysical Data Center (NGDC) catalogs information on destructive earthquakes that meet at least one of the following criteria: moderate damage (approximately $1 million or more), 10 or more deaths, magnitude 7.5 or greater, Modified Mercalli Intensity X or greater, tsunamigenic, or associated with a destructive volcanic eruption. There are over 6,000 earthquakes from 2150 B.C. to the present in the database. The database includes information where available on the event date and time, epicenter, magnitude, focal depth, number of fatalities and injuries, number of buildings destroyed, and damage in U.S. dollars.The data were gathered from over 400 scientific and scholarly sources, regional and worldwide catalogs, individual event reports, and unpublished works. NGDC is currently involved in an intensive effort to improve the database. This process involves verifying the existing entries using the original source materials, removing duplicates, and expanding the database with new sources. The data records have been expanded to include a comments section that provides additional details about each earthquake. All of the references that describe an event are linked to the earthquake record. When there are conflicting reports; all of the reports are considered, the best characterization of the event is added to the data record, and all of the reports are tabulated in the comments section with references to the different sources. NGDC also catalogs information on tsunamis and significant volcanic eruptions. The earthquake, tsunami, and volcanic eruption databases are stored in a relational database management system (RDBMS) which facilitates the integration and access to these related databases. For example, users can search for destructive earthquakes that preceded a volcanic eruption that then generated a damaging tsunami. The examination of catalogs from different disciplines (earthquake, tsunami, and volcano) has improved the quality and completeness of all these databases. These data are accessible over the Web as tables, reports, and interactive maps. The maps provide integrated web-based GIS access to individual GIS layers including significant earthquakes, significant volcanic eruptions, tsunami sources, and various spatial reference layers such as topography, population density, and political boundaries. The map service also provides ftp links and hyperlinks to additional hazards information such as the NGDC collection of hazards photos.

Keywords: earthquake, tsunami, volcano

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SW001 **Oral Presentation** **6490**

The SISMOS facility at INGV

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Anna Nardi, Antonio Rossi, Silvia Filosa, Andrea Bono, Valentino Lauciani, Stefano Pintore

SISMOS is the largest historical seismology preservation facility existing worldwide. At the origin of this facility is the Progetto SISMOS that started in the late 90s and it was aimed primarily toward the preservation of the then mainly on paper Italian seismological patrimony archived by the different observatories exiting in Italy since the late 1800. This patrimony includes mainly historical seismograms and bulletins subject to progressive deterioration and inevitable loss. In 2002, the SISMOS activity was extended to seismograms and bulletins from observatories in 28 countries of the Euro-Mediterranean area through the European Seismological Commission Working Group on the History and Data of Instrumental Seismology, the EuroSeismos project (http://storing.ingv.it/es_web/). The main products of SISMOS available through the Web server (http://sismos.ingv.it) include: digital images of paper record seismograms, digital images of historical seismic bulletins, and software for the analysis of the digital image seismograms. Future products will include: digital vector data of selected seismograms and alphanumeric data of historical bulletins. It is expected that easy access to collections of these seismic records will prompt modern reappraisals of historical earthquakes and lead to revaluations of seismic hazard.The current database includes more than 100,000 seismic records (~25,000 from the EuroSeismos project) and a few hundreds bulletins all available at the SISMOS web site (http://sismos.ingv.it). For seismogram vectorization, SISMOS has developed the software Teseo2 (Pintore et al., CAGEO 31, 1277-1285, 2005) that, in its most recent version, allows for digitization of record digital images to provide ready-to-use seismogram in SAC format after all the required corrections are applied. Current developments aim toward enlargement of the database through the recently funded NERIES project and the analysis of the most important historical earthquakes that have occurred in the EuroMed area.

Keywords: historica seismology, database

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SW001 **Oral Presentation** **6491**

Emending and databasing all historical earthquake documents in the Japanese ancient and medieval ages through interdisciplinary collaboration

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Research Group On Databasing Japanese Ancient And Medieval Historical Earthquake Documents

Almost all of Japans known historical earthquake records since around the 6th century, which are clippings from various historical sources such as official/unofficial national histories, chronicles, diaries, biographies, essays, letters, geographical descriptions, and memoranda, have been published in type-printed books of 29 volumes. They are invaluable primary data for the Japanese historical seismology, although buried historical materials should further be searched for and added. There are, however, two serious problems in these books. One is that they contain rather many unreliable materials since the compilers did not carry out any critical examination of historical sources nor selection, which tends to produce errors in historical earthquake catalogs. The other is that the books are just a huge amount of printed papers, which makes full-scale utilization of massive information including key word searching impossible. In order to improve these situations fundamentally, we have been carrying out since 2003 a research project of constructing a full-text digital database of all historical earthquake documents in the Ancient and Medieval ages (up to ca. A.D. 1600) under the Grants-in-Aid for Scientific Research by MEXT (Ministry of Education, Culture, Sports, Science and Technology). We restricted the target within the Ancient and Medieval ages because historical sources in these times have somewhat different characteristics from those in the Early Modern age and historical records in the latter age are too huge amount to be treated by a small research group. The project is an interdisciplinary collaboration among earth scientists, historians and information scientists. We have been critically examining all the historical documents in the existing collections, selecting them, carefully emending every text, and composing a re-edited collection in digital form. Furthermore, we intend to compose an example of seismic intensity database compatible with the Intensity Data Points (IDP) prevailing in Europe . Owing to the alpha-version database, various problems have been clarified concerning existing books. We plan to open the database on the Web on completion of the project in March 2008 under some kind of open-editing system for its further growth.

Keywords: historical seismology, original historical documents, full text database

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SW001 **Oral Presentation** **6492**

Development of a Macroseismic Database for Earthquakes in Mexico: 1469 to 1912

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Paola Albini

The damaging M=8.1 earthquake in 1985 gave new impulse to seismological studies in . One year later, a long-term joint project between seismologists and historians was launched, aiming at i) identifying all possible sources and repositories of references to historical earthquakes; ii) classifying and structuring the data; iii) publishing a book containing all the information verbatim, without any modifications or interpretation (Garcia-Acosta and Suarez, 1996). Since then, no systematic study has been undertaken to compile a catalogue of historical earthquakes and a database of intensity data points for Mexican historical earthquakes. In 2006, within the framework of an international collaboration, the first steps towards the implementation of a macroseismic database for were taken. Through a systematic analysis of the primary historical information collected and published by Garcia Acosta and Surez (1996), 363 events were evaluated in the period spanning from 1469 to 1912. Through the analysis of available parametric catalogues and monographic studies of individual earthquakes, we found 251 earthquakes that had not been reported before. For 250 out of the 363 earthquakes, intensity values were assessed using the Modified Mercalli Intensity scale (MMI). Together with the macroseismic intensity, the database includes a summary of the damage and felt reports, a description of phenomena reported in association with each earthquake (e.g. surface ruptures, tsunamis, etc) and a reference to problems encountered in the georeferentiation of the locations in question. As of today, the database contains 2447 intensity data points, which are currently being used to estimate magnitude and epicentral location for those events for which sufficient information exists. A parallel ongoing activity concerns the preparation of studies of key earthquakes.

Keywords: historical seismology, database, mexico

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SW001 **Oral Presentation** **6493**

A new method to amend the parameters of historical earthquakes in Bohai Sea, China.

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China is one of the countries with longest history and many earthquakes. In history, many strong earthquakes occurred in Bohai. Owing to the sea, historical earthquake archives are incomplete and it is difficult to determine the parameters correctly. Abundant observations and experiments indicate that a strong earthquake is a physics process. The local crust medium should be weakened by the occurrence of a strong earthquake. The process can not be backtracked and maybe continue for a long term with large amounts of moderate and small earthquakes. We probe a new method to amend the parameters of historical earthquakes through analysis of the coherence between strong historical earthquakes and instrumental recording small earthquakes.

Keywords: historical earthquakes, seismic density, tsunami

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SW001 **Oral Presentation** **6494**

A european archive of historical earthquake data

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Neries Na4 Working Group 2

Within the European Project NERIES (Network of Research Infrastructures for European Seismology), sponsored by the European Commission in the frame of the Specific Programme "Structuring the European Research Area", the NA4 module is devoted to establish a distributed archive of historical earthquake data. The importance of historical data is today widely acknowledged. The return period of the largest and most destructive earthquakes is measured in millennia. For estimating seismic hazard, seismologists thus cannot rely on the instrumental record starting in the early 20th century, but critically depend on the integration of historical earthquake information. On the other hand, historical earthquake data in Europe are still collected and archived in isolation by many of the seismological observatories, with varying criteria and degrees of commitment. Only few countries (Italy, France, and Switzerland) have a consistent, available set of historical earthquake data, interpreted in terms of macroseismic intensity data points (IDP). In other areas, scattered data are available on paper, though the coordinates of the data points are not easily obtainable and the place-names are missing in many cases. While a uniform intensity scale has recently been established for the Euro-Med region (EMS98) and is now widely used, existing databases for historical earthquakes have been compiled using a variety of intensity scales. Homogenisation and consistent documentation of many studies and data across Europe is missing. Catalogues of historical earthquakes extending back up 1,000 years in the past are available in many countries of the Euro-Med region, with various degrees of completeness and accuracy. Several attempts have been made to compile a unified catalogue for the whole region and period; the quality of the resulting catalogues has been hindered by the non-homogeneous quality of the databases and input intensity data. NA4 aims at improving this situation and will establish the required tools leading to the compilation of a comprehensive, digital macroseismic intensity database for the largest European earthquakes (with magnitude >=5.8 at least) and a validated and homogeneous European parametric earthquake catalogue for M>=5, to serve as an authoritative reference for users involved in the assessment of seismic hazard and risk. The main focus is devoted to the time-window before 1900. This paper will present the achievements of the NA4 Working Group after the first year of activity.

Keywords: historical earthquake data, euro mediterranean, archive

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SW001 **Poster presentation** **6495**

Re-evaluation of historical catalogues in the Indian Region.

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Historical earthquake catalogues in the Indian Region were generally based on the felt reports published in the News Papers, writings of Courts and Historians, archaeological, and Paleo seismological investigations. Many new damaging earthquakes ranging in seismic intensity from VIII to XII on MM scale were added in the catalogue based on the above. However, closer examination of some of these earthquakes has brought out discrepancies in the time, of occurrence and in some cases even their location. During the early instrumental era, recent re-interpretation of the great Kangra earthquake of 1905 in western Himalaya based on limited seismological data has raised many questions, due to the inference about two earthquakes one in Kangra and the other near Dehradun. Further look at the data has reaffirmed the occurrence of only one earthquake of 1905 in Kangra. The other inferred earthquake near Dehradun was only a consequence of site response called secondary meizoseismal area similar to that observed during great earthquakes of Bihar Nepal (1934), Bhuj (2001) and Mexico (1985). The historical earthquakes based on limited data often requires a more closer look which can be undertaken only if old the seismograms are preserved for new researches. Microfilming of historical earthquakes was initiated in India Meteorological Department. This was in accordance with the first phase of IASPEI. Program on Historical seismograms and earthquakes. However, the slow methodology and problems in their preservation has now led to the modern method of digital scanning of the record.

Keywords: historical, seismicity, catalogues

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SW001 **Poster presentation** **6496**

The 1740 and 1544 earthquakes in Central Greece

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Sofia Papageorgiou

Historical, archaeological and seismological data are used to model the 1544 and 1740 earthquakes in Central Greece. Archaeological data, in particular, correspond to well-defined clusters of repairs and reconstructions of churches, testifying to recovery from a devastating earthquake; this is mainly because difficult-to-obtain permissions from various authorities and the Sultan himself were required for any church repair, except for specific areas affected by natural calamities during the critical period. The 1740 earthquake was probably the only early event for which full description by a western traveler is available; another short report for this earthquake is also available. The meizoseismal area of this earthquake was defined from a cluster of church reconstruction in areas corresponding to different administrative provinces; this also permits to distinguish the effects of this event from that of the nearby 1743 earthquake. The 1544 earthquake is reported in three different manus to have hit several towns in central , including Zitouni (Lamia), but its modeling is difficult because another 1544 earthquake affecting a town called Zitouni at the Syrian-Turkish borders is also reported. The evaluation of the available historical information, and especially the identification of the areas reported to have been hit by this earthquake, was a first step in this study. A cluster of church reconstruction correlating with this earthquake was also identified. The meizoseismal area of this earthquake was hence defined. Still, this area is too large in comparison with all other large earthquakes. Hence, our conclusion is that the 1544 earthquake reflects an amalgamation of two different, nearly coeval events, with epicenters close to Lamia and Naupactos, respectively.

Keywords: greece, meizoseismal, church repairs

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SW002 **6497 - 6535**

Workshop
Geophysical studies of active faults

Convener : Prof. Massimiliano R. Barchi
Co-Convener : Dr. Thomas Pratt

Identifying and characterizing seismogenic sources is an important task for seismic hazard mapping using either characteristic or probabilistic approaches. Geological and geophysical data are used to identify the location, dimensions (length, dip and depth) and kinematics of active geological structures that can be reasonably associated with one or more historical or recent earthquakes. Different types of geophysical surveys are used to provide images of active faults and growth folding at scales ranging from that of the outcrop (or the paleoseismological trench) to that of the entire crust. Seismic reflection, refraction and tomography data are now available in many seismically active regions of the Earth, particularly along active thrust belts, in extensional areas, and in subduction-zone settings. These data can provide information about the fault geometry and dimensions, completely independent of that provided by instrumental seismology. The depth of imaging of seismic profiles acquired primarily for oil exploration purposes usually comparable with the focal depth of upper crustal earthquakes (< 10 km). At greater depths, deep crustal seismic profiles (BIRPS, COCORP, etc.) and regional tomography studies can help to relate geologic structures with deep earthquakes. At shallower depths, high-resolution seismic reflection and refraction profiles, high-resolution tomography, and electromagnetic surveys (e.g. ground penetrating radar, resistivity, etc.) can be used to image active faults and folds in Quaternary sediments, where age dates can be obtained from soils. Historical seismicity can be used first to locate the seismically active regions, and then reliably associate geological structures with significant earthquakes to evaluate the probability of future occurrence. This session aims to provide an overview of geophysical methods currently used to image seismogenic structures, and provide a selection of case studies of geophysical surveys in seismogenic regions. Studies of active faults and folds from diverse tectonic environments are welcome from seismic interpreters, geophysicists, and modelers, especially when a combined geological/geophysical approach is used.

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SW002 **Oral Presentation** **6497**

Active faults under the Shahreza and Dehaghan cities, Iran

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Active tectonic movements in the northeastern Zagros include right lateral slip at the rate of about 2 mm/a along the Shahreza and Dehaghan faults, and active thrusting and accompanying folding. In the northeastern Zagros thrust zone, there are several right lateral faults that extend NW-SE parallel to the overall trend of the Zagros fault-and-fold belt. These may be either branches of the Main Recent Fault. The Shahreza Fault with about 164 km and Dehaghan Fault with about 198 km length and NW-SE direction are located northeastern Zagros Thrust Zone. The Shahreza and Dehaghan faults cross cut by SW-NE-trending faults in the Shahreza and Dehaghan cities respectively. We use drainage reconstructions to estimate long-term offsets on the Dehaghan fault, an oblique right-lateral strike-slip fault in the northeastern Zagros, on which there have been a number of recent earthquakes. The faults cut and rotate the Quaternary alluvial fans and rivers and uplift the region. A 10 km horizontal offset is inferred from well-preserved geomorphology. Drainage displaced by dextral movement leads to the development of a series of basins along the Dehaghan fault. The northeastern of the Dehaghan Fault makes a 10-m-high scarp in the surface of the first (Late Pleistocene-Holocene) river terrace. The geomorphic evolution of the fault zones at the surface includes both normal and reverse faulting components, reflecting a probable ramp-and-flat structure in cross-section.

Keywords: active fault, zagros thrust, strike slip fault

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SW002 **Oral Presentation** **6498**

Rock mechanical investigation of Doulaei_Tuyserkan Tunnel (Hamedan Province_Iran) by combination seismic method with RMR and suggestion a new method for its optimization

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Land slide is a natural event that has many loss life and economic damage in our country(iran)every year.effect of this phenamena on linear structures suchas roads,railways,lifelines, dams,mine equipments and transportation power lines is more than concentrated structures,because of their long length and passing from the different regions with variable and different geologic conditions and also the cost of it when happen because of above pointed reasons is more than other structures.so that when these structures design and constructed must be noticed more than the other structures. Omitting the dangerous turnning of tuyserkan_jokar road (omitting one of the steepest turnning of this road) and 4 km reduction of distance between the tuyserkan_hamedan is the purpose of this tunnel. In this study at the first the tunnel geographical location, local geology and morphology was investigated.after this the lithologgy, hydrogeology and tectonic of the around of tunnel and then applied stress on tunnel in land slide location and effect of water pressure was studied..finally with combination a new seismic method with rmr method the geomechanical properties of tunnel region was investigated.the syudy showed that these land slides and collapeses are predictable and can prevent from occurance of them with suitable supports and less cost with comparison to usual and ordinary operation.

Keywords: rockmechanics

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SW002 **Oral Presentation** **6499**

San Andreas Fault Zone structure from a new guided wave and other borehole-based seismic observations at the SAFOD drill site

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In this presentation we discuss the use of borehole seismographs and various kinds of seismic signals to study the San Andreas Fault at Parkfield, CA. We have used natural, explosive, and drill bit seismic sources, and single and multiple borehole seismographs in the SAF Observatory at Depth for these studies. We introduce the main topic of our talk by first describing fault zone images obtained through, for example, Kirchhoff migration of some reflected phases observed in SAFOD site microearthquakes and drill bit seismic profiling. We then turn to our main topic, the origin and significance of new type of fault related guided wave observed on a borehole seismograph placed 2.8 km below ground in the SAFOD Main Hole. The new signal arrives between the direct P and S waves, is clearly normally dispersed, and has a sharp Airy phase. The latter phases frequency is centered at ~80 Hz. Given the seismographs location and the fact that other known types of fault guided waves appear on the seismograms, the new signal is likely to be a leaky mode fault guided wave. It is designated here as Fphi. To illustrate its characteristics and estimate the properties of the fault it is propagating along, we have modeled it as a simple guided P wave trapped in a low-P-velocity fault. The model was developed by using background velocity estimates from prior studies, the signals low frequency cutoff, and its Airy phase frequency and arrival time. The model suggests the responsible fault is on the order of 30 m thick and has an average P velocity reduction of ~20%, from a host rock value of ~5 km/s to average fault zone value of ~4 km/s. These values are consistent with values that have been reported to exist along the SAFOD wellbore. We interpret the model as indicating that a narrow, highly fractured, and fluid rich fault is within several tens of meters of the seismometers location, which is sufficiently close to see a fundamental mode Fphi wave. Using these other guided wave and seismic imaging results, we suggest that this fault is part of a system which is connected together to form the plate boundary at SAFOD.

Keywords: borehole seismology, fault guided waves, drillbit profiling

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SW002 **Oral Presentation** **6500**

Modeling of co-seismic deformation caused by seismogenic faults, case study: Bam, Iran, Dec. 2003, earthquake

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This paper focuses on modeling of 3D co-seismic deformation caused by stress accumulation and its release along seismogenic faults based on a homogeneous elastic half-space model .This modeling is often made by dislocations theory. The most commonly used analytic models of fault deformation have been based on the dislocation solutions of Okada [1985 , 1992] . We use this dislocation model to investigate deformation and strain generated by strike-slip and dip-slip faulting. Furthermore we test this model for the Bam (Iran) earthquake, Mw = 6.5 , occurred on 26 December 2003 on a near-vertical strike-slip fault beneath the city of Bam and compare the results of our model with full vector displacement field using radar data from the Envisat satellite of the European Space Agency . The results of our model indicate: 1) The maximum effect in horizontal displacement is 40cm 2) The maximum effect in vertical deformation is 11 cm. This results are agree with displacement field derived from the InSAR radar data of the region.

Keywords: dislocation, co seismic 3d deformation, faulting

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SW002 **Oral Presentation** **6501**

Telemetred multichannel system for geophysical cable

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A new telemetred multichannel system for geophysical cable is presented. The investigation of the boreholes is very important to be done using as many channels as possible in order to have fast and effective results. Multiwire cable which are now used in multichannel systems are very problematic due the connectors, durability and wear. Water tightness must be very high because of the high pressure which exist in boreholes over 1000 meters. Also noises and disturbances generated by external electromagnetic fields are big problems especially in VSP or HSP measuring where all the signals, including the weakest reflection must be recorded at sufficient resolution.Taking in account these requirements, it was designed one modular system which is constructed to function on one coaxial cable where all the channels are located in parallel in frequency domain. This kind of system is called telemetry system and is used mostly in airplane and space equipment. This telemetry system consist of transducer units (each one with three geophones), preamplifiers, circuits to transfer signal to cable, electronic controls and power supply components. These units are connected on a strong main coaxial cable as many as needed.Physically they are in series with cable but electrically are in parallel as on a bus line.

Keywords: telemetred, multichannel, cable

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SW002 **Oral Presentation** **6502**

Electrical tomograhy at the eastern end Of Lago Fagnano. Tierra del Fuego. Argentina

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A main portion of the South America-Scotia plate boundary related to the Magallanes-Fagnano Fault System (MFS) is occupied by the lago Fagnano. Just at its eastern end a sag pond area -which is the surface expression of one basin associated with the MFS- is flanking a monzodioritic intrusion (Hewhoepen pluton). The MFS overprints the fold-and-thrust-belt of the Fuegian Orogene and is associated with basin formation along its length. These basins display the greater sedimentary thickness against the main fault in the major displacement zone. Both Paleogene and Quaternary outcrops show transtensional structures associated with MFS. Evidences of Neotectonic fault activity are displayed in Quarternary outcrops on Lago Fagnano margins as in reflection seismic data from the lake-floor. In both, normal faults are recognized in continuity with the main system fault of the northern Fagnano area. An electric resistivity survey was carried on at the eastern lago Fagnano with the purpose of constraining the subsurface continuation of W-E faults related to MFS and the unexposed portion of the Hewhoepen pluton. A Syscal R1+Switch 48 resistivity-meter system was employed to perform two N-S two-dimensional electrical imaging/tomography surveys. These electric sections are parallel; the first one is 4.0 km long and the second section 0.40 km. The roll-all-on method was applied with a Wenner array using 48 electrodes (each 10 m) connected to a 480 m-long multi-core cable, with four sections and 48 channels. In the first profile, 2 sectors are distinguished by their geoelectric properties. The Northern segment presents very low resistivity, whereas the southern one presents a cover with higher resitivity and a lower part with very low resistivity. The pseudo-section and the obtained 2D inversion model from the southern segment allow inferring two lithologies in the subsurface which display at least two contrasted resistivities, i.e. the uppermost peat blanket and lower sandstones. Both litologies show a network of vertical and horizontal discontinuities defining small fragments dipping southwards. A high resistivity body was also recognized in correspondence with the magnetic anomaly of the Hewhoepen pluton. The second profile (located 1 km apart the first one) shows a sector of very low resistivity that cut all the section (about 40m) in continuity with the position in surface of the main lineaments of the MFS. The results of the resistivity tomography allow inferring the existence of a small basin in the north eastern end of the lake, and the buried eastwards continuity of the stepped transtensive fault system related to the Lago Fagnano pull-apart basin.

Keywords: southernmost andes, transtensive system, electrical tomograhy

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SW002 **Oral Presentation** **6503**

Seismic reflection profiling of active-seismogenic fault systems in Japan

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Due to the convergence of plates, Japanese islands show high seismic activity associated with subduction mega-thrusts and crustal active faults. The knowledge of deep geometry of active-seismogenic fault systems can contribute for better estimation of strong ground motions and evaluation of seismic risk. Since the 1995 Kobe earthquake, a large number of seismic surveys have been performed to obtain shallow to deep seismic image of active fault systems. We introduce some typical seismic sections of crustal active fault and subduction mega-thrust systems obtained mainly onshore common mid-point seismic reflection profiling mainly using vibroseis trucks. Based on theses seismic reflection profiles, following significant features can be summarized. 1) A subduction mega-thrust on the upper surface of the Philippine Sea plate is marked by strong reflection especially along the deeper extension of asperity zone. It is well demonstrated in the Tokyo Bay seismic section (Sato et al., 2005; Science). 2) Geometry of crustal active faults has been strongly affected by the pre-existing crustal/geologic structure. Thrust geometry in late Cretaceous is clearly identified across the Median Tectonic line active fault system, which is late Quaternary strike-slip fault. The high-angle active-reverse faults in northern Honshu were originally formed as Miocene normal faults during the rifting of the Sea of Japan. 3) Deeper extension of active faults commonly merges to the sub-horizontal reflectors in the base of seismogenic zone, as it is suggested by seismic sections across active reverse faults in northern Honshu and Kinki triangle zone, SW Japan. 4) Upper crustal wedge-thrusting is commonly observed in arc-arc collision zones, such as the Hidaka, central Hokkaido and the Izu collision zone, central Honshu. 5) A complicated fault system can be seen in thick sediments, showing fault-related folds, wedge-thrust, emergent thrust and out-of-the syncline fault. Including a spray fault from a subduction mega-thrust, the connectivity of active faults is crucial for better estimation of future's devastative earthquake events.

Keywords: active fault, seismic reflection profiling, japan

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SW002 **Oral Presentation** **6504**

VHR seismic imaging of displacement along an active fault system of the Adriatic Foreland

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The Gargano Promontory, an uplifted portion of the southern Adriatic foreland domain, is characterized by recent seismicity of moderate to intermediate magnitude. Seismological data indicate active E-W strike-slip faulting in a region that has also been struck by large historical earthquakes, particularly along the Mattinata fault system. The pattern of tectonic deformation along the E-W?trending segment of the Gondola Line, the off-shore counterpart of the Mattinata fault, is strikingly similar to that observed on-shore during the Eocene-Pliocene interval.However, the south Adriatic off-shore lacks instrumental seismicity and, despite evidence of a genetic relationship and of a continuity between the Mattinata fault and Gondola Line at regional scale, the seismotectonic potential of the system formed by these two faults has never been investigated in detail.Recently, very high-resolution (VHR) seismic-stratigraphic data allowed us to carry out new investigations in the off-shore, based on precise dating of late Quaternary deposits that appear folded and faulted (locally up to seafloor) all along the E-W segment of the Gondola Line. In particular, the pattern and timing of fold growth and fault propagation in Middle-Late Pleistocene and Holocene-present units have been defined. This pattern of gentle folding and shallow faulting indicates that sediments deposited during the past ca. 450 ka were recurrently deformed along the E-W branch of the Gondola Line.The present work integrates previous studies with the analysis of new and closely-spaced (ca. 500-600 m) VHR seismic lines acquired during a 2006 cruise. The density of the data set allowed us to focus on the distribution in space and time of the vertical displacement measured on the fault planes dissecting shallow deposits and also the seafloor along the E-W branch of the Gondola Line. These displacement values, referred to precisely dated stratigraphic markers, provide a refined tool for constraining the modes of activation from the late Middle Pleistocene to present along the entire fault system being analysed. We discuss the meaning of this activity in the light of the kinematics of the fault system, in the attempt to interpret the pattern of shallow-recent deformation on the south Adriatic shelf in the broader context of the seismotectonic setting of the southern Apennines-foreland region. In this view, we speculate on the possible seismogenic nature of the Gondola Line.

Keywords: vhr seismic lines, adriatic foreland, active fault displacement

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SW002 **Oral Presentation** **6505**

HIgh-resolution imaging of active fault systems in the Agri Basin (Southern Apennines) by controlled source non-linear crustal tomography

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The high Agri river valley is a Quaternary basin located in the axial sector of the Southern Apennines. Following a Mio-Pliocene history of thrust tectonics in the region, Pleistocene extensional tectonics has strongly controlled the basin evolution up to the present. A severe earthquake struck the area in 1857 (equivalent magnitude Me = 6.9) and ongoing instrumental seismicity testifies the high seismic hazard of the area. Active fault systems in the area have been mainly investigated by field studies and commercial reflection profiles. Nonetheless the internal structure of the basin and the geometry and kinematics of the active fault systems bordering the valley are still a matter of debate.New insights on the structural architecture of the basin with a focus on the Quaternary master faults are shed by analysing two high-resolution crustal profiles, about 15 km long, crossing the central sector of the basin. The two profiles have been collected by oil companies using a dense multi-fold wide-angle acquisition geometry with a shot and receiver spacing of 60 and 90 m, respectively. This non-conventional extended/dense acquisition geometry provides a unique opportunity to image the basin structure by high-resolution controlled source tomography. In order to obtain 2D P-velocity models for both lines, we hand-picked first arrivals on one-hundred common shot record sections, selected according to the signal-to-noise ratio. Due to shallow structure complexity, we inverted traveltimes by a non-linear inversion procedure especially designed to image strongly heterogeneous media.The P-velocity images show abrupt vertical and lateral changes. The basin is up to 500 m deep and filled by low-velocity Quaternary deposits (Vp < 3000 m/s), which directly lay on high-velocity Mesozoic carbonates (4500 - 5500 m/s). Lower-Middle Pleistocene slope breccias (2500 - 2700 m/s) fill the eastern part of the basin and are covered by more recent alluvial deposits (1500 - 2000 m/s) with a thickness that progressively increases westward. The carbonate bedrock has an irregular shape with rapid depth variations which is partly inherited by the previous thrust displacements, but is largely controlled by Quaternary normal-faulting. Three major west-dipping fault zones are evident on the eastern side of the basin with cumulative vertical throw of 300 - 500 m. These faults, which have been previously reported in the literature, cut the slope breccias and well match an ancient depocenter located on the eastern side of the basin. Furthermore sharp lateral velocity changes suggest the presence of east-dipping normal faults in the central and western sectors of the basin with minor total throws (< 200 m). Activity along these faults could explain the thickening of the recent alluvial deposits and is in agreement with new microseismicity data collected in the area.

Keywords: active faults, non linear tomography

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SW002 **Oral Presentation** **6506**

Multifractal Analysis of the 1981 Kerman-Sirch and 2003 Bam Earthquakes (Iran) From Aftershock Studies in Nayband Gowk Fault System

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The Kerman-Sirch earthquake of 1981 July 28 (Mw=7.1), and Bam earthquake of 2003 December 26 (Mw=6.6), occurred near the centre and southern termination of the N-S trending Nayband and Gowk fault system which is located on the west side of the Lut block and accommodates part of the 2.5 cm yr-1 northward motion of Arabia relative to Eurasia. The Kerman-Sirch earthquake aftershock cluster is about 35 km long, trends north-south, and distributed north of main shock and the Bam earthquake aftershock cluster is 25 km long, trends north-south, and is located 5 km west of the Bam-Baravat escarpment, exactly beneath the observed surface breaks. The aftershock sequence of two earthquakes is analyzed to study the fractal structure of Nayband-Gowk fault system. The fractal dimension (Dq) has been calculated by using local density function and the Cq(r) spectrum. The results show that spatial distributions of aftershocks in different events on Nayband-Gowk fault system characterized by different fractal clustering patterns, which indicate that each segment has different geodynamic behavior and slip distribution.

Keywords: aftershock, fractal, clustering

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SW002 **Oral Presentation** **6507**

Seismotectonic framework of the 2001 Pondichery

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South Indian shield, lying away from the Indo-Tibetan collision zone on the north and the subduction zone starting from Indo-Burmese border down to Indonesia has been considered hitherto a stable region. However, the high magnitude earthquakes of Koyna (6.0, 1967), Ongole (5.4, 1967), and Badrachalam (5.3, 1969) had changed the age-old belief. About 30 years after these events, a chain of earthquakes during a short span of 10 years at Killari (6.3, 1993), Jabalpur (5.8, 1997), Kerala (5.0, 2000), Karnataka (4.3, 2001), Tamilnadu (5.5, 2001), Pondicherry (5.5, 2001) and Bhuj (7.7, 2001) has led the geologists to develop theories with regard to these intraplate earthquakes. The Indian shield consists of four cratons, namely Dharwar, Craton, Singhbhum Craton, Bastar Craton and Bundelkhand Craton. Their peripheries and the contact zones of these cratons are mobile and are subject to deformations. The northward movement of Indian Plate generating stress, its anti clock-wise rotation giving rise to left lateral shear and occurrence of large earthquakes, for example the recent devastating event in Sumatra (9.3, 2005), at plate margins reactivate the old intraplate faults, fractures and thrusts, resulting in occurrence of earthquakes. The Pondicherry region is located in a high seismicity zone. A fairly large earthquake (5.5, September 5, 2001) 40 km off Pondicherry coast, located at 11.95 N and 80.23 E, with a focal depth of 10 km on the continental slope stands a witness to it. The resent Sumatra quake at the junction of four plates has created so much strain and movements that all the plate margins are at present experiencing adjustments and readjustments giving rise to a large number of aftershocks, and frequent shaking at different places starting from Iran to Philippines on the Indo-Australian Plate margin. In view of this the Pondicherry region needs a relook from the geological point of view. In the present study the Bouguer gravity and marine magnetic data of Pondicherry Basin have been reprocessed by using a new space-domain operator, based on finite element approach (FEA). Combining the observations from geological structures in this basin with the bathymetry, and Bouguer gravity and marine magnetic anomalies, it has been possible to: (i) zero-on to a region which has been reactivated to cause the Pondichery earthquake of September 25, 2001, and (ii) pinpoint the location of this earthquake.

Keywords: reactivation of faults, pondicherry earthquake, potential fields

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SW002 **Oral Presentation** **6508**

Detailed Upper Crustal Structure across the Northern Part of Itoigawa-Shizuoka Tectonic Line, Central Japan

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The 250-km long Itoigawa-Shizuoka Tectonic Line (ISTL), running with NS direction in Central Japan, is a major tectonic boundary between NE and SW Japan. The northern segment of the ISTL corresponds to the western margin of the Northern Fossa Magna (NFM), a sedimentary basin formed as a back-arc rift during the final stage of the opening of the Sea of Japan (ca. 17 Ma). The central to northern part of the ISTL has been under a compressive stress regime since the late Neogene to form an active fault system with the largest slip rates (4 9 mm/yr) in the Japanese islands. The ISTL is the present deformation front under this inversion tectonics, which jumped from the former front of the Otari-Nakayama fault (ONF, 4 km east of the ISTL) at the time of late Pliocene. According to recent GPS measurements and paleo-seismic researches, the northern ISTL is of great importance as a source fault of inland earthquake with the highest risk. In spite of its social as well as geological significance, the deep structure beneath the ISTL and the NFM remained enigmatic. In 2002, a seismic reflection/wide-angle reflection data were acquired along a NW-SE 56.5-km line (Sato et al., 2004) extending from the western end of the ISTL active fault system to the Komoro Basin (KB) crossing the NFM and Central Uplift Zone (CUZ). Wide-angle reflection/refraction analyses based on seismic tomography and ray-tracing technique revealed the detailed structural change across the ISTL and ONF, relatively deeper geometry of this fault system and relatively higher reflectivities at middle and lower crustal levels. Particularly, a large amount of travel time data from the reflection survey delineated a complicated structure near the ISTL in terms of seismic wave velocity. The most prominent features in our model are thick low velocity packages beneath the NFM and the KB, and the doming structure of the high velocity units forming CUZ. Beneath the western part of the NFB, the eastward descending pre-Neogene basement is well mapped down to 4 km. The dip of this basement becomes gentle at a depth of 4 km. The model strongly indicates an abrupt structural change at the ONF. The uppermost velocity west of the fault is very low (1.9-3.1 km/s). Below this low velocity material, a wedge-like body of 2.8-3.7 km/s is subducted down to 1.7-km depth. East of this fault, the velocity increases to 3.4-4.0 km/s. Probably, the ONF represents a boundary of physical property. The velocity contrast across the ISTL, on the contrary, is not prominent, which was probably developed within a rather uniform geological unit. The uppermost part of the pre-Neogene basement has a velocity of 4.8-5.4 km/s, beneath which a 5.73 km/s layer is situated at a depth of 4-5 km depth. The NFM is about 3 km thick east of the ONF, but shows abrupt thinning under the western side of the CUZ. The top of the CUZ is composed of 3.4-3.7 and 4.9-5.4 km/s layers but their total thickness is only 1.8 km. The velocity beneath these layers is estimated as 5.83 km/s. Another basin structure of the KB in the east side of the CUZ consists of 2.5-2.9, 3.3-3.5, 3.7-4.0 and 4.9-5.0 km/s layers beneath which the velocity jumps to 5.8 km/s. The total thickness of the upper four layers exceeds to 5 km in the eastern edge of the profile. The crustal structure in the deeper crust is not resolved well only from our first arrivals because of a rather short profiling length (56.5 km). In some record sections from large energy explosive shots, however, some wide-angle reflections are recognized at offsets of 10-45 km. These reflections have duration times of 0.5 and 1.5 sec. Assuming the middle and lower crustal velocities to be 6.2-6.3 and 6.6-6.9 km/s based on a previous refraction experiment just north of our profile, these duration times correspond to 2-3 and 4-5 km thick reflective zones at depths of about 11 and 22 km, respectively.

Keywords: crustalstructure, seismicprofiling, itoigawa shizuokatectonicline

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SW002 **Oral Presentation** **6509**

Fluids as a tool to investigate potential seismogenic structures

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Geochemical investigations have been carried out over two seismic Italian areas located in the North (the Friuli-Slovenia border) and in the South (the Messina strait Patti Gulf areas). The tectonic regimes of the two areas are totally different: a mainly compressive regime in northern and a dip-slip extensional regime in the South. The fluids released over the Messina strait area are marked by the presence of thermal waters and by CO2-dominated gases, while fluids collected over the Friuli-Slovenia are mainly represented by cold and sometimes sulphurous waters. Although these latter were considered of shallow circulation, being their composition dependent from the lithology of the area (shallow water-rock interactions with limestones, flysh and evaporitic rocks), the first geochemical results show the presence of a dissolved gas phase which composition cannot be simply related to a circulation of fluids at shallow levels. The dissolved gases, in fact, exhibit a chemical composition mainly composed by N2 besides a CO2-dominated gaseous component. This evidence, together with the isotopic ratio of helium provided a clear radiogenic signature for the sampled fluids. This information coupled to the geochemical features of the natural soil degassing displays how the geo-tectonic setting of then area is the responsible for the composition of the circulating fluids as a whole. The Messina strait-Patti gulf seismic areas located in North-eastern Sicily display thermal waters and degassing activities already known since historical times. The gases released in the Patti gulf area (North-eastern coast, Tyrrhenian sea) are characterized by a significant amount of mantle-derived components (as shown by the helium isotopic ratio) and they are associated to cold waters, while the gases released on the eastern coast (Ionian sea) are released together with thermal waters and are radiogenic-derived. The temporal variations shown by the chemical composition can be related to modifications of the tectonic activity that allows modifications in the mixing proportions of the various components of the released fluids. The collected results on fluids geochemistry represent a powerful tool useful not only to highlight the presence of hidden structures but also to reveal the faults activity over two high-risk seismic areas.

Keywords: fluids, seismogenic structures

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SW002 **Oral Presentation** **6510**

Multiscale imaging of shallow fault zones by integrating seismic and resistivity tomographies, reflection profilings and drillings: the Monte Aquila normal fault, southern Apennines, Italy

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Although high-resolution seismics and geoeletrics are common tools to investigate near-surface structures, the detailed imaging of shallow fault zones is a challenging task. Acquisition of good-quality reflection data is often hampered by scattering phenomena from the fault zone, ground-roll and static problems. High-resolution seismic tomography (HRST) can suffer from drawbacks as well, such as the rapid decrease of resolution with depth, while the medium heterogeneity can make improper the use of iterative linearized inversion. Success of both seismic and resistivity tomography hinges on enough strong velocity/resistivity variations across the fault zone, a key requirement not obvious for fault zones in unconsolidated sediments. We present results from an integrated exploration of an active normal fault in the Lucanian Apennines (southern). Seismic and resistivity tomographies are combined with reflection profilings and shallow drillings to image the Monte Aquila Fault (MAF) in two small basins. Small cumulative displacements across the fault and shallow unconsolidated sediments make this target challenging. In the northern basin, a 3-m-high scarp and a previous trench document recent faulting activity. In the southern basin the fault is only inferred from a subtle surface warping. Both multifold wide-angle and near-vertical reflection data were recorded along two 200-m-long profiles. We obtained from this composite data set P-velocity images by multiscale HRST and migrated CMP stack sections by processing of reflection data. Multiscale Electrical Resisitivity Tomographies (ERT) were performed along the same profiles using a dipole-dipole configuration and an electrode spacing ranging from 2 to 10 m. The southern basin is also investigated by several boreholes drilled down to 7 m depth across the surface warping. HRST provides the better results in the trench site. A sharp lateral velocity change reveals a major step in the bedrock caused by an E-dipping fault. This step is located beneath the scarp and the total vertical slip estimated from the velocity images is consistent with field data. Repeated surface faulting is suggested by a thick low-velocity body in the fault hanging-wall, which is interpreted as a colluvial package 12-15 m thick. HRST and ERT are in good agreement in the second site. A rapid deepening of the high-velocity/high resistivity substratum is evident beneath the surface warping. A good-quality stack section shows events truncations in this zone and proves the presence of an E-dipping normal fault. Drillings confirm the abrupt deepening of the bedrock and suggest the presence of colluvial wedges in the fault hanging-wall. Summarizing, our study indicates how the combination of HRST, ERT, reflection profilings and drillings is an effective strategy to accurately image shallow structures related to normal-faulting activity and to pinpoint the fault location (i.e. to optimize paleosismological trenches).

Keywords: multiscale imaging, high resolution tomography, active fault

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SW002 **Oral Presentation** **6511**

Depth variations in seismogenic layer and segmentation of active faults

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An active fault is a very useful indicator for a future large crustal earthquake. However, the source area of an earthquake is located in the deep crust at depth between 3-5 and 25-20km. The area is called the seismogenic layer and changes its depth from place to place. Beside, the change in the thickness or depth of the seismogenic layer seems to relate to the earthquake occurrences. Therefore, it is important to study the relationship between the variations in the cutoff depth of seismicity and those in the active faults. In particular, long faults, such as the Median Tectonic Line of 1500 km in Southwest Japan, have several segments. Ruptures of earthquakes in the seismogenic layer do not always appear at the surface because of surface layers on the seismogenic zone. Well-located depths of earthquakes along an active fault and/or along the strikes of aftershock area for large and moderate earthquakes show that the focal depths become shallower at both end of the areas. This is well-established for the 2000 western Tottori earthquake of Mj7.3 (Mj is the Magnitude scale by JMA), the 2004 Chuetsu earthquake of Mj6.9, the 2005 western off Fukuoka prefecture earthquake of Mj7.0 and the 1989 Loma Prieta earthquake of Mw6.9 etc.. The feature is also well defined in the Atotsugawa fault area in central Japan, where the latest large event of Mj7.0 occurred in 1858. This lead to a plausible assumption that a shallow portion of cutoff depth of seismicity indicates a border of a fault segment. This assumption is applied to the Median Tectonic Line. The change in the cutoff depths of seismicity along the fault is well concordant with the segments determined from the shape of surface ruptures. Changes in the cutoff of seismicity along the Niigata-Kobe Tectonic Line in central Honshu also seem to well coincident with the segment deduced from large earthquakes. Thus, the change in cutoff depth of seismicity is important for the estimation of segmentation of large fault or the size of the earthquakes.

Keywords: large active fault, fault segmentation, seismic activity

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SW002 **Oral Presentation** **6512**

The extensional seismogenic faults of the Umbria-Marche Apennines (Central Italy): geometrical reconstruction and mechanical models

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The geometry and mechanics of seismogenic normal faults is still matter of debate in the scientific community. In particular, the capability of non-planar and/or low-angle normal faults of generating damaging earthquakes (e.g. M. > 5.5) is an open question, with significant implications for seismic hazard .In the Northern Apennines of Italy, the geometry and kinematics of a system of SW-dipping seismogenic normal faults, generating moderate seismicity (5 < M < 7) is constrained by a wide range of geological and geophysical data, including surface geology mapping, seismological data (focal mechanisms and high precision aftershock location) and seismic reflection profiles. The seismological data support the hypothesis that the main seismic ruptures occur along planar faults, dipping 40-50. The integration of all the available data-sources furnishes robust evidence that the fault dip changes with depth, varying from 60-75 in the shallower portions (0-2 km) to 40-50 at intermediate depth (2-8 km, where most of the seismicity is located) to about 20 at greater depth, close to the local seismicity cut-off.The SW-dipping seismogenic faults are antithetic to a larger, NE-dipping LANF, named Alto Tiberina fault (ATF), with a mean dip of 20, releasing continuous microseismicity (M<3.2), along a trace that is constrained by a set of seismic reflection profiles.Considering these observations in the framework of the subsurface geology of the region, some important conclusions can be addressed:- the seismicity cut-off (i.e. the thickness of the seismogenic layer) is mainly controlled by lithological variations within the upper crust; - the mainshocks occur within the Triassic Burano Fm., consisting of alternated anhydrites and dolomites, along rupture planes dipping about 40; - CO_2 overpressures (pore-fluid-factor > 0.85) measured in the subsurface play an important role on both the mainshocks nucleation and aftershocks triggering. This study points to the conclusions that the characterisation of active faults can be better addressed by integrating different methods and data sources (geological, geophysical or seismological).

Keywords: active normal faults, geophysics, northern apennines

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SW002 **Oral Presentation** **6513**

High-resolution seismic profiling across the Vallo di Diano Basin (Southern Apennines, Italy): new constraints on the pleistocene range-bound normal-faulting system

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The Vallo di Diano basin (southern Apennines, Italy) owes its evolution mainly to NW-striking, SW-dipping range-bounding extensional faults (Vallo di Diano Fault System, VDFS). Despite of structural and geomorphic investigations, Late Pleistocene activity of the VDFS is still a matter of debate. Our seismostratigraphic interpretation of proprietary seismic commercial profiles (down to 2 sec TWT) suggests a 1000 m maximum infill thickness, with depositional geometries controlled by the VDFS activity probably since late Pliocene times. However, commercial profiles poorly image the shallow structure of the range-bounding fault system. Geomorphological analysis in the central sector of the basin revealed unreported small scarps aligned with the VDFS and affecting two late Pleistocene fans. Aimed at imaging the shallower portion of the VDFS and at assessing its possible recent activity, we acquired two parallel high-resolution seismic profiles crossing the aforementioned scarps. The first is 1200 m long and crosses a 30 m high scarp affecting a middle Pleistocene fan. The second profile is 400 m long and crosses two small scarps affecting a late Pleistocene fan. Seismic profiles were collected with a non-conventional dense/extended-offset geometry using 168 geophones (5 and 2 m spacing respectively) and a Minivib source (10 and 4 m spacing respectively). We obtained two high-quality stack sections, with coherent reflections from 0.05 to about 0.6 sec TWT, together with two high-resolution P-velocity images from first-arrival travel-time tomography. Stack sections image the subsurface structure up to 1 km depth, while the tomographic models image the shallower portion (40-50 m). The high-resolution profile presents four distinct seismic units separated by three unconformities. The shallowest unit shows sub-horizontal high-frequency low-amplitude reflectors overlapping an articulated erosion surface. Strong and coherent reflectors below this unconformity can be interpreted as two separate alluvial fans with southward progradational patterns and separated by one unconformity. The third and deeper unconformity is represented by a low-frequency and continuous reflector downlapped by the alluvial fans to the south. The very-high resolution profile (1-m CDP spacing) also shows evidence of truncations in the upper reflective portion that can be interpreted as a high-angle SW-dipping normal fault. It is not clear if the fault displaces shallower portions of the alluvial fans, however the fault position well matches a surface scarp. The P-velocity images show rapid lateral variations. Abrupt deepening of a high-velocity substratum and thickening of near-surface low-velocity layers can be related to normal-faulting structures. These features correlate with deeper reflection truncations on the stack sections and partially with the observed scarps suggesting recent faulting activity in the area.

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SW002 **Oral Presentation** **6514**

Multidisciplinary analysis of two complex fault systems in Italy: the Saorge Taggia (western Liguria) and the Garfagnana-North (northern Tuscany) lines.

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We present the results obtained combining different techniques to determine the peculiar characters of two seismic lineations in northern Italy, namely the Garfagnana region (northern Tuscany) and the Taggia area (western Liguria). There, the existence of rather complex fault systems is acknowledged and somewhat mapped, but apart from the geological evidences, very little is known about their extension with depth and the seismotectonic regime.The potential of the systems is also well known. Both areas were characterized, in the past, by destructive earthquakes; in particular the 1831, the 1854 and 1887 (Ms=5.5, 5.5 and 6.4) events struck the western Liguriawhile the Lunigiana-Garfagnana area was interested by a major earthquake in 1920 (Ms=6.4). Therefore, the seismicity is under constant monitoring by the national seismic network (RSNC National Central Seismic Network) and by a pool of local stations, belonging to the regional network (RSLG Regional Seimic network of Lunigiana and Garfagnana) installed since 1999. These additional stations account of the lower magnitude seismicity. In western Liguria the seismic monitoring is also performed by the comprehensive efforts of Italian and French institutions (RSNC, RSNI - Seismic network ofNorthwestern Italyand RENASS Rseau National de Surveillance Sismique). Additionally, several temporary experiments have been conducted to enhance the geometry of the recording stations.Such a concentration of seismic stations, and the availability of several seismograms, enables to reveal, record and localize earthquakes down to very low magnitude threshold (inferior to Ml = 1.8) and with extremely contained errors in the hypocentral parameters. Making use of the resulting databases, several analyses were conducted to determine the shape, size, extension with depth and associated seismicity of both seismogenic lines. The methodology applied is similar for both applications and consists in seismic tomography (1D and 3D velocity models), precise location algorithms NonLinLoc and HypoDD (very constrained and reliable locations) and computation of focal mechanisms, all combined with the constraints provided by geological knowledges.The main findings of the study can be summarize as follows.In the westernLiguria, the results underline that the Saorge Taggia line, the NW-SE strike slip component of the faulting system, shows a remarkable geological complexity and a diffuse seismicity which confirms its active character. Furthermore, the existence of a non-previously mapped branch is revealed on the normal system.In the north-western part of theApenninesthe seismicity shows a gap between the inner and outer areas and a decrease of seismicity after the metamorphic Apuane core; an alignment in correspondence of the hypothetic north Garfagnana fault is also observed.

Keywords: seismotectonics, hypocentral parameters

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SW002 **Oral Presentation** **6515**

High-resolution seismic reflection studies of active faults: a case study from Washington State, USA

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In the past five years, new high-resolution seismic surveys have filled in gaps in our understanding of active structures beneath the Puget Lowland region of Washington State, . The extensive forests have made recognition of active faults difficult, but new Light Distance and Ranging (LIDAR) detailed topographic data have made a major breakthrough in mapping active faults. Extensive regional and high-resolution marine seismic surveys have been fundamental to understanding the tectonic framework of the area. These marine profiles, however, lack coverage beneath water bodies that large ships cannot navigate and beneath city streets underlain by late Pleistocene glacial deposits that are missing from the waterways. Recent land surveys and profiles in restricted waterways can therefore bridge the gap between paleoseismic and marine geophysical studies, and test elements of models proposed by regional-scale geophysical studies. We have also been venturing into more congested areas to seismically image faults in key urban locations. Results from recent surveys have: 1) documented new faults that had long been suspected in the Olympia area; 2) clarified the relationship between the LIDAR scarps and observed structures across the Tacoma fault zone; 3) provided a window into structures beneath the north portion of the western Tacoma fault zone; 4) documented deformation along the Seattle fault near a paleoseismic trench; 5) mapped the eastern part the Seattle fault zone; and 6) documented multiple fault strands in the Seattle fault zone in the cities of Bellevue and Seattle. The results better constrain interpretations of paleoseismic data collected on these faults, and provide targets for future paleoseismic studies.

Keywords: seismology, active faults

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SW002 **Oral Presentation** **6516**

4D Seismic reflection imaging of the deep seismogenic zone

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Seismic surveys by both oil industry and academic groups have long established the unique effectiveness of reflection techniques for detailing fault zone geometry and internal properties in both 2D and 3D at shallow (e.g. < 5 km) depths in sedimentary basins. Moreover, numerous 2D seismic reflection profiles have effectively delineated fault characteristics down to lower crustal and upper mantle depths, although typically with less clarity and very rarely in 3D. Of particular interest here is time lapse, or 4D, reflection imaging which, although challenging to implement, has become a mainstream tool in subsurface oil field monitoring. 4D reflection imaging of active faults zones represents a potentially powerful new means of monitoring subtle physical changes associated with seismogenesis. Here we use synthetic seismograms to evaluate the feasibility of detecting plausible seismogenic processes at depths comparable to those at which major earthquakes nucleate. Using fault geometries inspired by the subduction zones of SW Japan (Shikoku) and SE Mexico (Oaxaca), we investigated the likelihood that surface multichannel reflection surveys might detect morphological asperities, pore pressure variations, and marker offsets at depths of 10-25 km, representing the down dip limit of corresponding seismogenic zones. The models indicate that detecting such temporal changes is a primarily a function of S/N rather than spatial resolution, and are potentially detectable with realistic survey conditions

Keywords: faults, crustal, monitoring

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SW002 **Oral Presentation** **6517**

Fault activity monitoring by PS INSAR technique

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Dangxiong Fault, which strikes NE, is pregnant with strong earthquake. It is also a Left-lateral strike-slip transfer fault zone to link Yajiang Shenzha and Banhu-Nujiang faults. In its south part, where Dangxiong fault and Yajiang fault converge, an earthquake about Ms.8.0 occurred in 1411. And earthquakes of Ms 8.0 (1981) and Ms 7.5 (1952) occurred in the northern area near Banhu-Nujiang fault. The middle segment of Dangxiong fault is fruit of geothermic energy in Yangbajing. So Dangxiong fault plays an important role in the studying of Indian and Asian continental collision because of its typical transfer characteristic. The fault is an active zone of fracture itself, it can respond evidently to the nearby areas strong earthquake. Some artificial corner reflectors were set up near the fault, and some natural PSs had been identified, which can be used to form a network for monitoring the fault movement. Meanwhile, many pairs SAR data of this region had being obtained, including ERS and ENVISAT. The intensity information of numerous accumulated SAR images or the phase characteristics of pixels can be used to identify and detect the natural and artificial PSs. By using the tandem ERS pairs and MERIS data to analyze and remove the atmospheric and other noise, PS InSAR technique can obtain the fault activity to study its response to global strong earthquakes and nearby mid-strong earthquakes.

Keywords: insar, fault activity

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SW002 **Poster presentation** **6518**

Title: An East-West Profile of Crustal Thickness and (Vp/Vs) ratios

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Multibeam data shows the Muertos Trough and the Muertos deformed belt/accretionary wedge associated with the active subduction/thrust zone. The (Vp/Vs)-Depth Structure beneath Puerto Rico was determined, along an east-west profile, to test the hypothesis that the Caribbean plate is being thrusted or subducted under Puerto Rico at the Muertos Trough. We established the Crustal Thickness and (Vp/Vs) ratios beneath the stations by estimating the receiver functions. Waveform data retrieval was conducted using the web-driven Wilber software package from data archives of the Incorporated Research Institutions for Seismology (IRIS). The crustal Vp/Vs ratio ranges from 1.403 to 1.994 with the average of 1.731. There is a wide range of values in the crustal thickness from 10.7 to 58.8 km for an average of 35 km. Crustal thickness increases at the southeastern part of the island; this may be due to the San Lorenzo Batholith. P-to-S conversions beneath the Moho depth reflect the Caribbean lithosphere slab subducting southwestern Puerto Rico.

Keywords: muertos trough, receiver function, puerto rico

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SW002 **Poster presentation** **6519**

Complex model of tectonic evolution of the earth crust structural blocks and radioactive waste disposals locations

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Disposal of high level radioactive wastes (HLRW) in geological formations for a time of 100000 years is, at present, the only possibility of its removal from the biosphere. Therefore, selection of crust sites, in which the ecological safety of HLRW isolation is ensured for its lifetime, is an acute problem in Russia, as well as in: many developed countries. Evaluation of geodynamic and tectonic processes velocity with time, as well as their effects on isolation properties of structural tectonic blocks is a principal condition ensuring safety of HLRW disposal. From practical viewpoint, it is important (area of Krasnoyarsk in Siberia) to predict crust blocks evolution of Nizhnekansky granitoid massif in Russia where work is being carried out to select a site of underground laboratory construction. At the same time, it is well known that this area belongs to the zone of active orogenesis and its long-term geodynamic stability has not been studied yet. The methods to predict tectonic blocks evolution when selecting sites HLW disposal sites is based on the following principles: 1. Evolution of the Earths crust is related to the intensity of tectonic processes development in the region. The decisive factor is the initial level of effective tectonic stresses, block structure of the environment and physical and mechanical features of a rock massif. 2. Tectonic stress field varies in time and space retaining the inherited tendencies of the preceding period of the region tectonic development. Corresponding indicator is the degree of dislocations, geomorphologic characteristics and other features of the geological environment. 3. Modern stress and strain of the geological environment combined with the inherited time-space variation of local fields of tectonic stress determine the development of geomechanical processes of deformation and destruction in each individual region and the possibility of forming new tectonic faults or activating existing faults (zones of weakness and others). It is planned to develop a dedicated finite-element program complex as a calculating tool of modeling stress and strain variation in rocks with time. The study is supported by RFFI (grant no. 05-05-64975) and ISTC (project no.2764).

Keywords: faults radioactive, wastes, tectonic

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SW002 **Poster presentation** **6520**

Interesting results found by continuous observation of strain and in-situ stress measurements in the vicinity of an active fault

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It is important to investigate a behavior of stress and strain in the vicinity of active faults. We performed continuous strain observation and stress measurement in the Mozumi-Sukenobu active fault. Two strain meters were arranged at both sides of the crushed zones. Characteristic strain variations of both sides indicate right lateral movements that are almost the same movements as the fault. The stress measurements indicate also the same pattern as the fault movements though the values are smaller than usual. This is considered that crushed zone of the fault can not accumulate stress. The behavior of strain variation suggests that fault movements are caused by tectonic stress acting but in the vicinity of the fault stress accumulation is small. This paper reports the details of the observation and analyzed results.

Keywords: continuous observation, stress strain, active fault

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SW002 **Poster presentation** **6521**

Seismic anisotropy and its relation with faults and stress field in the Val d' Agri (Southern Italy).

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Shear-wave splitting is measured at 17 seismic stations deployed in the Val DAgri by INGV, which recorded local back-ground seismicity from May 2005 to June 2006 . The splitting results suggest the presence of an anisotropic upper crust (max hypocentral depth 15.5 km). The dominant fast polarisation direction strikes NW-SE parallel to the Apennines orogen and is approximately parallel to the maximum horizontal stress in the region and also parallel to the strike of the main normal faults in the Val DAgri. The size of the delay times, average is 0.1 second suggests 4.5% shear-wave velocity anisotropy. At stations located at the North West portion of the deployment average delay times are larger on the order of 0.2s. These parameters agree with an interpretation of seismic anisotropy in terms of the Extensive-Dilatancy Anisotropy model which considers the rock volume to be pervaded by fluid-saturated microcracks aligned by the active stress field. We cannot completely rule out the contribution of aligned macroscopic fractures as the cause of the shear wave anisotropy even if the parallel shear-wave polarisations we found are diagnostic of transverse isotropy with a horizontal axis of symmetry. This symmetry is commonly explained by parallel stress-aligned microcracks.

Keywords: anisotropy, active stress field

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SW002 **Poster presentation** **6522**

A fine structure of P-wave velocity along the Atotsugawa fault, central Japan

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A high strain rate zone, which was called the Niigata-Kobe Tectonic Zone (NKTZ), was found at the central part of Japan. A large active fault, Atotsugawa fault, is located inside the NKTZ. A seismic experiment with 5 explosive sources and 396 seismic stations was conducted in August 2005 at the Atotsugawa fault area. The 396 seismic stations were located in the survey line with a length of 47 km. The profile line was located along the Atotsugawa fault. A fine seismic structure was obtained along the fault. The P-wave velocity variation was obtained along the fault with the depth was shallower than 6 km. The obtained velocity structure at the most shallow layer was consistent with geological structure. The second layer had lateral variation of the P-wave velocity which was consistent with the geophysical phenomena. The central part of the fault, which was considered as the creep zone, was obtained to be low velocity compared with the both sides of the area. The seismic activity at the low velocity zone was low compared with the both sides of the zone. The depth section of the reflection profile indicated that a boundary with depth around 13 km. The boundary was roughly consistent with the cut-off depth of the microearthquake seismicity. The high seismic activity area was characterized to be reflective on the depth section. This study reveals fine P-wave structure and characteristics at the upper crust along the Atotsugawa fault.

Keywords: p wave structure, atotsugawa fault, seismic experiment

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SW002 **Poster presentation** **6523**

Particularities of mechanic-electrical transformation in tectonically active non-contact faults containing ores.

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The change of quasistatic loads in rock masses leads to the re-distribution of mechanical stresses. This induces the emission of electromagnetic (EMI) signals having a different nature. Nonlinear transformations are caused by elastic waves are observed in poly-metallic ores, which contain sulphide, oxides of metals and their combinations. They are characterized by EMI with degree, which is in 1-2 times intensive than the linear ones. The frequency of radiation (F) reaches 3-7 MHz (extreme frequencies lie in limits: F~ 0.2-0.8, 1.0-1.7, 2.2-3.0, and 4.2-7.0 MHz). The field stress in source achieves Emax.~=5x105 - 5x106 V/cm. We studied the mutual influence of the EMI and the stress-deformed characteristics in ores, which can appear in tectonically active faults in the process of array excavation of rocks. Some experiments were conducted with the complex-ore bodies of sphalerite and galenite are contained in the skarn limestone. The EMI signals can be stably registered using gradient method by means of magnetic antennas (the oriental axial is Z, each pair of antennas is in distances 30-150 m). We conclude that sources of the EMI impulse generation are located only in different places of ore zones. One can observe processes of exhaustion and restoration of their energetic state. The restoration time could be from few minutes until few days. The process of the mechanic-electrical transformation is characterized by signals with frequencies F~ 0.25-370 KHz and 1.2-2.6 MHz. The form of signals, as well as their amplitude and the frequency ranges, depend on geological conditions, on concentration and structure of ore minerals. The non-contact polarization of a mineralization decreases the excitation threshold and increases the amplitude of signal EMI (in separated cases till 30-40%).The energy, which is released in ores, can be in few times more than the energy of activation of the given process. The radiation locally appears in areas of large gradients of mechanical and electrical stresses, in tectonically active deep faults. Such signals likely can be as markers (indicators) of the stress state change and of the developing of the splits system in array of rocks before a strike or an earthquake. Note that it is necessary to take into consideration the presence of poly-metallic ores in the region of EMI observations. This work was supported by the RFBR, project (№ 06-05-64888).

Keywords: mechanicalelectricalstress, flectromagneticsignals, ores

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SW002 **Poster presentation** **6524**

Gravity anomaly in and around the focal area of 2004 Rumoi-Nanbu earthquake: relationship between high Bouguer anomalies and the shallow earthquake

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The Rumoi-Nanbu earthquake (MJ6.1) occurred on December 14, 2004, at southern area of Rumoi sub-prefecture, northern Hokkaido, northern . The focal depth decided by Japan Meteorological Association was 9 km. Soon after the mainshock, temporal seismic observation was executed. Then, detailed aftershock distribution was clarified, and the hypocenter of the mainshock was relocated (Ichiyanagi et al., 2007). The relocated focal depth is about 5 km. Focal plane model derived from GPS data, by Geographical Survey Institute of Japan, is striking N19E and the dip angle is 42E. Aftershock distribution is consistent with this model. Aftershocks distribute in shallow region (< 2 km), and calculated asperity is also shallow (about 3 km) (Maeda et al., 2005). On the other hand, the focal area is covered with thick sediments. The basement depth is reported to 4675 m, by deep borehole data near the focal area (Japan National Oil Co., 1986). To explicate this contradiction, we carried out gravity survey in and around the focal area. The observation had executed during 2005 to 2006, using Scintrex CG-3 type gravimeter (S227, S315). For almost every measurement, altitude was carefully decided by operating GPS observation. Then, we compiled 251 measurement points with existing points including 1453 measurement points, which was offered by Japan Petroleum Exploration Co. Ltd.. Assumed density for the calculation of Bouguer anomaly is set to 2300 kg/m3. This value is derived from G-H and F-H method, and consistent with rock density reported in borehole data. Thus, detailed Bouguer anomaly map was made. There is a good correspondence between high gravity anomaly and aftershock distribution, i.e. aftershock distribution is limited in the zone of high gravity anomaly. The amplitude of this high anomaly is about 10 mGal. Several kilometers east of the focal area is characterized by low gravity anomaly over the older sediments. Generally, older rocks are denser. But in this case, the density of the old Cretaceous sediment seems lower than that of the Tertiary sediment. Paying attention with this feature, we constructed density structure models by forward modeling along a few lines. We referred the deep borehole data, and the surface geology data in this region. The model indicates upheaval of the basement, and existence of dense conglomerate layer outcropping in the focal area. General dome-like structure of the focal area is consistent with geologic data, and the abrupt upheaval of conglomerate layer is shown in geologic map as an anticline. This is also consistent with resistivity structure. We measured density of several rock samples in this region. Conglomerate samples, which were picked in the focal area, showed high density around 2600 kg/m3. The shallow mainshock in the deep sediment region could be explained by upheaval of the basement, i.e. mainshock was ruptured in the dome-like structure. Asperity is also seems inside the basement. Still, the shallow aftershocks are hard to explain with basement upheaval. Shallow dense conglomerate layer might be a solution. Acknowledgment: Japan Petroleum Exploration Co. Ltd. gave us a chance to refer gravity data around Rumoi district. Japan National Oil Co. offered us borehole data. Prof. Akihiko Yamamoto of Ehime University rent us gravimeter while the breakdown of our gravimeter. We are grateful to Forrest Office of Rumoi for corporation. References: Ichiyanagi et al., 2007, Zisin 2, (in press; in Japanese with English abstract). JNOC, 1986, Research report on the pilot drilling at Rumoi (in Japanese). Maeda et al., 2005, Abstract for 2005 annual conference of JAEE (in Japanese).

Keywords: gravity anomaly, shallow earthquake, anticline

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SW002 **Poster presentation** **6525**

3-D velocity structure of the 2003 Bam earthquake area (SE Iran): Existence of a low-Poisson's ratio layer and its relation to heavy damage

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The Bam earthquake of 26 December 2003 caused the worst human disaster (death toll: about 26,000) in that year anywhere in the world. The damage was disproportionately and unexpectedly large given the moderate-magnitude, Mw 6.6, of the earthquake. To understand the generation mechanism of the bam earthquake, we studied three-dimensional Vp, Vs and Poisson's ratio (σ) structures in the Bam area by using the seismic tomography method. We inverted accurate arrival times of 19490 P-waves and 19015 S-waves from 2396 aftershocks recorded by a temporal high-sensitivity seismic network. The 3-D velocity structure of the seismogenic region was well resolved to a depth of 14km with significant velocity variations of up to 5%. The general pattern of aftershock distribution was relocated by using the 3-D structure to delineate a source fault for a length of approximately 20km along a line 4.5km west of the known geological Bam fault; this source fault dips steeply westward and strikes a nearly north south line. The main shallow cluster of aftershocks south of the city of Bam is distributed just under the minor surface ruptures in the desert. The 3-D velocity structure shows a thick layer of high Vs and low σ (minimum: 0.20) at a depth range of 26km. The deeper layer, with a thickness of about 2km, appears to have a low Vs and high σ (maximum: 0.28) from 6km depth beneath Bam to a depth of 9km south of the city. The inferred increase of Poisson's ratio from 2 to 10km in depth may be associated with a change from rigid and SiO_2-rich rock to more mafic rock, including the probable existence of fluids. The main seismic gap of aftershock distribution at the depth range of 2 to 7km coincides well with the large slip zone in the shallow thick layer of high Vs and low σ. The large slip propagating mainly in the shallow rigid layer may be one of the main reasons why the Bam area suffered heavy damage.

Keywords: bam earthquake, tomography, shallow rigid layer

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SW002 **Poster presentation** **6526**

Shallow crustal seismicity, magnitudes and focal mechanisms in the giudicarie belt (eastern Alps, Italy)

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The Giudicarie belt is located in the Eastern Alps. It is a composite thrust system mainly produced by N-S Neogene compression which inverted Permo-Mesozoic extensional structural trends. The Giudicarie belt is characterized by active tectonics, causing low-to-moderate magnitude shallow seismicity. It represents the western boundary of one of the most important seismic provinces in Italy (Slejko et al., 1989). In order to reassess the Giudicarie regional seismicity, we have relocated a set of seismic events recorded by the Trento Province local seismic network (PAT) in the period 1994-2006. Records from adjacent seismic networks (CRS-OGS Trieste, INGV Rome, Swiss Seismological Service Zurich) have been added to better constrain the results. The velocity model used for the earthquake relocation consists of a multi-layer model with constant velocities in each layer, initially based on crustal geometries and Vp inferred from lithospheric Deep Seismic Soundings (Scarascia and Cassinis, 1997). The model is additionally constrained through a minimization of phase residuals from accurately re-picked seismic signals recorded within an epicentral distance of 60-80 km. The events are located with the HYPOELLIPSE numerical code (Lahr, 1999). The duration magnitude (MD) has been computed according to Rebez and Renner (1991). Magnitudes range from 2.5 to 4.8 in the period under consideration. Focal mechanisms have been calculated for the same set of earthquakes from first arrival P-wave polarities, using the FPFIT code (Reasenberg and Oppenheimer, 1985). Available good-quality first motion readings for stations within a maximum epicentral distance of about 200 km have been used to constrain fault plane solutions and minimize strike, dip and rake uncertainties. Focal mechanisms distribution generally shows local variability. Solutions are discussed in order to correlate seismicity with active tectonic structures. Analyses on hypocentral depths and fault plane mechanisms, especially for repeated events, allow to investigate fault plane geometries and present tectonic strain/stress axes orientations. Lahr J.C. (1999) HYPOELLIPSE: a computer program for determining local earthquake hypocentral parameters, magnitude, and first-motion pattern (Y2K compliant version). U.S.G.S. Open File Report 99-23. Reasenberg P. and Oppenheimer D. (1985) FPFIT, FPPLOT and FPPAGE: Fortran computer programs for calculating and displaying earthquake fault-plane solutions. U.S.G.S. Open File Report 85-739. Rebez A. and Renner G. (1991) Duration magnitude for the Northeastern Italy seismometric network. Bollettino di Geofisica Teorica ed Applicata 33 (130-131), 177-186. Scarascia S. and Cassinis R. (1997) Crustal structures in the central-eastern Alpine sector: a revision of the available DSS data. Tectonophysics 271, 157-188. Slejko D., Carulli G.B., Nicolich R., et al. (1989) Seismotectonics of the Eastern Southern-Alps: a review. Bollettino di Geofisica Teorica ed Applicata 31 (122), 109-136.

Keywords: seismotectonics, focal mechanisms, giudicarie belt

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SW002 **Poster presentation** **6527**

Magnetotelluric studies over the Andaman Islands, India

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Magnetotelluric studies over the Middle Andaman islands have delineated a NNE-SSW trending suture, along which the Andaman flysch and the underlying Igneous crust subduct eastwards along a high angle thrust with a dip angle of about 60 degrees. The Andaman flysch, of thickness varying between 4 and 10 km are delineated up to depth of about 17 km along the observed thrust. The crust to the west of the suture has a high resistivity of more than 10000 Ohm-m, as against a moderate resistivity of about 1000Ohm -m observed in the eastern part. The complex variations in its thickness and resistivity are indicative of the intense tectonic movement that this juvenile crust has experienced since the Cretaceous. The crust is underlain by a low resistivity, which could be due to the presence of fluids generated by the metamorphosis of the subducting crust and also expelled from the rocks at deeper levels. However the earthquake focal depths, extending up to about 150 km suggest that the lithosphere may be sufficiently solidified to permit strain accumulation at this depth. Thus the extent of the partial melt may be limited to about 1percent.

Keywords: magnetotelluric, subduction, resistivity

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SW002 **Poster presentation** **6528**

Aftershock activities of the recent moderate earthquakes in southern Marmara REgion

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The recent sequence of two moderate size earthquakes in the MarmaraRegion, (Ml=5.2, Ml= 5.3) and their aftershocks were studied. This activity has been recorded by broad band seismic stations of Kandilli Observatory&ERI (KOERI) thus their fault mechanisms have been analyzed. These two moderate size earthquakes occurred at the Gulf of Gemlik and north of ManyasLake; show that new seismic activity associated with the southern strand of The North Anatolian Fault Zone (NAFZ). This fault zone and its branches are the most active tectonic system in the Marmara Region of . Its northern part is dominated by the northern branch of the NAFZ and the southern branch of the fault is dominated throughout the southern Marmara Sea. This region is characterized by the normal and oblique slip EW-trending faults and shows evidence of spatial and temporal partitioning of deformation. According to the previous research for this region, the slip rate of the southern strand of NAFZ is less than the northern strand and than having the moderate size earthquakes.An earthquake with magnitude 5.2 occurredin Manyas Lake at October 20, 2006 and another earthquake with magnitude 5.3 occurred in gulf of Gemlik October 24, 2006. The analysis of these regional earthquakes provides useful information to better characterize the geology and seismotectonics of the Marmara Region. It should be noted that most of the moderate-size earthquakes recorded in this region did not rupture the surface, thus, their source mechanisms solutions provide essential information for the association of the activity with mapped faults and possibly help identification of unknown faults in the region. The Regional Moment Tensor (RMT) inversion method has been applied to analyse of this activity. The moment tensor inversion was performed in three frequency bands, which depend on the magnitude of the event; ranging from periods 10-30 sec for 3.65, up to the window 50-200 sec for the largest events occurring in the region. To understand the faulting characteristics, we have determined the moment tensor solutions of these two shocks also some of their (12 events) aftershocks. Majority of the events show strike slip with an oblique component. Focal mechanism solutions and the alignment of the aftershock epicenters of both events have been correlated with faulting frame of this Region. The observed solutions for Gemlik event show NE-SW oriented strike-slip faulting and aftershocks determinations occurring by this event also align in the northeast directions in accordance with the mainshock mechanism.

Keywords: marmararegion, moderate sizeearthquake, aftershocks

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SW002 **Poster presentation** **6529**

A microseismic study in the NE Alps: the Alpago-Cansiglio experiment

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In the past years we have investigated the geometry and the kinematics of active faults in Italy. Different areas where future large earthquakes are expected were identified and thoroughly monitored with local seismic networks to detect background seismicity. This project has been financed by the FIRB-MIUR and carried out as a joint effort by the department CNT at INGV, Rome and the department CRS at INOGS, Udine. Here we present the preliminary results obtained from the seismic data collected along the Vittorio Veneto-Valdobbiadene fault segment in the Venetian Alps (NE Italy), an area located between two significant historical earthquakes: the 1695 Asolo (Me 6.7) and the 1936 (Ms 5.8) Cansiglio events. Our goal is to reconstruct, using local seismic tomography, the 3-D sub-surface structure of faults, identifying the Vp and Vp/Vs anomalies in the target volume. During the first half of June 2004, we have installed 22 digital temporary seismic stations equipped with three component sensors, in a rectangular-shaped array with regular nodal distance of 10 km. In the period between the June 2004 and May 2005 we have recorded a dataset of 310 local earthquakes located within the study area. We have selected a subset of 130 events to calculate a well-constrained 1-D velocity model of the area. On the base of the 1-D velocity model we have performed a 3-D local earthquake tomography parameterizing the target volume with 5 layers located at depth ranging from 0 to 16 Km and with a regular nodal distance of 7 Km. The data set consists of 1560 P- and 960 S- high quality wave arrival times. The results show that the crust is characterized by sharp lateral and vertical Vp and Vp/Vs anomalies due to the complexity of the geological structures. Particularly in the area close the Montello Hill, we note a high Vp velocity anomaly at a depth of 2,5-4 Km in correspondence of the Bassano thrust. The relocated earthquakes are located in correspondence with the conjugate normal faults. A positive Vp velocity anomaly, located at a depth between 7-13 Km , is due to the Montello thrust structure, shows seismicity clustered at the top.

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SW002 **Poster presentation** **6530**

Integrated Research Project for Active Fault System along Itoigawa-Shizioka Tectonic Line

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The 250-km long Itoigawa-Shizuoka Tectonic Line (ISTL), running with NS direction in Central Japan, is a major tectonic boundary between NE andSW Japan . The northern segment of the ISTL has been under a compressive stress regime since the late Neogene to form an active fault system with the largest slip rates (4-9 mm/yr). This part is recognized as an earthquake fault with the highest risk. A 5-year research project on active fault systems along ISTL starting in 2005 is aimed to improve estimation on source properties of the forthcoming earthquake (occurrence time, magnitude etc.) and strong motions in populated areas. Prior to the present project, the pilot research project was carried out from 2002-2004. These projects cover several geophysical and geological researches, including seismic reflection survey, earthquake observation, magnetotelluric survey, GPS measurement, tectonic geomorphological survey, paleoseismological research and strong motion study. Seismic reflection and gravity surveys, magnetotelluric survey and dense array observation of earthquake were conducted in the same field to ensure interdisciplinary interpretation for the obtained results. In the pilot survey, Matumoto area and Fujimi area were selected to investigate the regional difference between the northern and middle part of ISTL. In 2006, the southern part of the ISTL are intensively investigated. The ISTL in Matsumoto area shows a gentle eastward dip. In Fujimi and Shimotsuburai-Ichinose areas, on the other hand, it dips westward, showing remarkable regional difference in fault geometry.Relatively long-term seismic observation also has been conducted in order to elucidate precise seismic activity along ISTL and reveal deeper crustal heterogeneity. Seismic omography from this observation also indicates clear structural difference along the ISTL. Namely, in the northern part, the low velocity body exists in the shallower part east of the northern ISTL, while, in the middle or southern part of the ISTL, low velocity material is situated west of the fault zone. These are in good agreement with those of seismic reflection and gravity survey. Digital elevation model is acquired along the ISTL, from which detailed slip rate distribution is being clarified along the ISTL. Slip rate distribution is being elucidated along the northern part of the ISTL. Such distribution is quite important for the estimation asperity along the ISTL and strong motion evaluation.Strong motion observation started in 2005 in Matsumoto area. In this year, seismic reflection survey including S-wave structure will be undertaken, from which the mechanism of strong motion on the populated basin is expected to be clarified. The most important finding so far obtained is the regional structural difference between northern and southern parts of ISTL. Namely, the active fault in the northern part shows a gentle eastward dip while a westward dip in the southern part, indicating the existence of clear segment boundary around the Suwa Lake.

Keywords: itoigawa sizuokatectonicline, crustalstructure, centraljapan

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SW002 **Poster presentation** **6531**

An active fault as imaged by ground penetrating radar investigation

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In this work a procedure to study active faults with Ground Penetrating Radar (GPR) investigations has been developed, demonstrating that GPR on one hand can be complementary with previous paleoseismic trench work and on the other hand can help to locate sites where trenches can be dug with some confidence. The GPR investigations were conducted across an active fault in the Norcia basin (Central Italy), a Quaternary intra mountain graben, bounded by a major SW dipping, active seismogenic fault. Trenches excavated in late Pleistocene-Holocene deposits across this fault have found evidence of surface ruptures in the past 20 ka. The GPR investigations successfully supplied general stratigraphic information, such as presence and geometry of sediments and their main contacts.We used the GPR both to define the radar image of the main normal fault, doing Common Offset profiles in the area where trenches have been dug, and to obtain the values of ε<sub<r</sub< for the sedimentary layers involved in the fault mechanism, performing Common Mid-Point profiles at the hangingwall and footwall of the fault. As in all geophysical techniques, the quality of the data is strongly dependent on the geological environment and on the contrast between the physical properties of the juxtaposed formations, and could not be always satisfactory. To avoid this problem, in the second step we constrained the obtained results through numerical simulations: To constrain the values of ε<sub<r</sub< obtained with the Common Mid-Point we constructed synthetic signals that were compared with field scans: we defined the thickness of the sedimentary layers involved in the fault mechanism. Thus study provided two results: first, the information obtained was usefully applied to a better planning of trenching sites and for extending the results to adjacent areas, also helping to reconstruct the geometry of sedimentary structures at shallower depths in areas where other data are not available. Secondly, this study has demonstrated that the GPR method can be successfully used in paleoseismology, trying to overcome the common difficulty of data interpretation for fault zones using the most possible information coming from trenches, from the data itself and constraining the results with numerical simulations.

Keywords: gpr, active fault, numerical modelling

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SW002 **Poster presentation** **6532**

Seismic reflection constraints on the seismogenic layer thickness of the Umbria-Marche Apennines of Italy

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Massimiliano Barchi, Eusebio Stucchi, Maria Grazia Ciaccio

The subdivision of the continental crust into a brittle and a ductile part is usually made on the basis geophysical data like heat flow, Bouguer anomaly and seismic tomography. Within the upper brittle crust, different deformation mechanisms can occur: frictional sliding expresses as shallow seismicity within the upper part of the brittle crust (seismogenic layer), while a transitional creep (aseismic deformation) occur in the lower part of the brittle crust. The definition of the depth of the seismogenic layer /transition between seismic and aseismic deformation) within the brittle crust be made by identifying important lithological or structural boundaries within the upper crust stratigraphy.We present a reconstruction of the subsurface geology of the Northern Apennines in Central Italy down to about 12 km where most of the shallow extensional seismicity occurs. We interpreted three reprocessed seismic reflection profiles acquired by Eni in the '80s with acquisition depths up tp about 4s (twt) corresponding to about 12 km and crossing the area struck by the Umbria-Marche earthquake of 1997-98 with maximum magnitude of Mw=5.9.The interpretation is constrained by detailed surface geology, oil-drilling and high quality seismic sections few kilometers NW of the study area. The interpreted seismic sections are of variable quality and well show the 3D-geometry of the top of the basement (base of the sedimentary cover) of the area. By comparing the subsurface structural setting with the distribution of the 1997-98 seismicity (accurately located by local networks) we infer that the seismicity cut-off corresponds to the top of the phyllitic basement. This reflector is characterised by an inversion of P-wave velocities suggesting that its rheology may control the depth of the seismogenic layer of the area.

Keywords: seismic profiles, seismogenic layer, norther apennines

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SW002 **Poster presentation** **6533**

Background seismicity in the Lucanian Apennines (Southern Italy) recorded by a dense temporary seismic network installed in the Val d'Agri area

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We present preliminary analysis of the background seismicity recorded in the Val dAgri area (southern Apennines seismic belt) focusing on the identification and characterization of active fault systems. Fault systems active in the area have been mainly investigated by field studies and commercial reflection profiles. Nonetheless their geometry and kinematic are still a matter of debate and even the causative fault of the destructive 1857 Basilicata earthquake (Me = 6.9 and Imax = XI) is not constrained. We installed from May 2005 to June 2006 a dense temporary seismic network composed of 19 digital 3C continuously-recording seismic stations, over a 1500 km2 area in the axial zone of the Lucanian Apennines. The investigated area includes the Val dAgri basin and partially the Vallo di Diano basin westward and the Mt.Alpi southward. The average receivers spacing is about 5 km. We applied a trigger algorithm to detect low magnitude earthquakes on the continuously recorded data. An automatic picking system was used to read P-wave arrival times on digital waveforms in order to obtain preliminary hypocentral locations. We recorded a large number (about 2000) of low-magnitude earthquakes (0.5 < ML < 2.7) testifying an unexpected high rate of background seismicity release (about 5.4 events/day) almost continuous in time. We selected from this dataset about 700 events according to the number of P-phase reading, the azimuthal coverage and rms residuals, and hand-picked S-wave arrival times to better constrain hypocentral locations. Large part of the events concentrates at shallow depth (< 5 km) between the southern margin of the Val dAgri basin and Mt.Alpi area. Seismic events also cluster in space and time deeper (8 15 km) along the western and eastern flank of the Val dAgri basin.

Keywords: seismicity, southern apennines

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SW002 **Poster presentation** **6534**

Imaging active faults in slow deformation zones by geoelectromagnetic methods

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Geophysical methods play an important role in paleoseismological studies since they are effective in obtaining detailed subsurface information and subsequent and fast characterization of neotectonic activity. This includes ground-penetrating radar (GPR) and electrical methods. Electromagnetic methods like magnetotellurics (MT) are a useful to imagine deeper faults and for studies at a bigger scale. These methods have been used to study different seismogenic faults in the Iberian Peninsula. We present the main results obtained in analyzing four different cases: The Alhama de Murcia fault (case 1) and the Carboneras fault (case 2) are left-lateral strike-slip faults located at the Eastern Betic Shear Zone. The El Camp fault (case 3) in NE of Iberia and the Maladeta North fault (case 4) in the Central Pyrenees are normal faults. In cases 1 and 3, previous to these geophysical studies, several trench sites were opened with the aim of paleoseismologic studies. This fact allows us to evaluate the suitability of these geophysical methods. In both cases, the 2D geoelectrical model obtained from the Electrical Resistivity Tomography (ERT) shows a good correlation with the geological characterization of the trenches. GPR profiles show a good image of the subsurface structure, but in case 1, this method has not provided a clear signature of the fault due to the low contrast of electrical permitivity between the hangingwall and the footwall.

Keywords: electrical permittivity, resistivity

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SW002 **Poster presentation** **6535**

Geodynamics of North Europe and North Atlantic Region

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The maps of distribution the vectors of slide rock mass and the vectors of maximal displacement rock mass were received. The data are from the Harvard Centroid-Moment-Tensor (CMT) Catalog and Catalogue of focal mechanisms of earthquakes 1964-1990 (Moskow, 1994), for the period from 1976 to the present time for the North Europe and North Atlantic regions. The results generalized and systematized for depth, magnitude, time. Comparison the maps showed that the both methods have the similar dynamic of vectorial directions, the pathways with high seismic activity and the areas with original dynamics of vectors.

Keywords: seismicity, dynamic, vectors

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SW003 **6536 - 6548**

Workshop
Seismogenic zones: emergence of in situ fault zone observations to the understanding of earthquake physics

Convener : Dr. Kiyoshi Suyehiro
Co-Convener : Dr. Kuo-Fong Ma

Recent and future experiments penetrating the seismic fault zone provide direct and first hand information critical to the understanding of earthquake physics. Deep drillings, which sample and quantify the fault zone materials and allow in situ monitoring of the fault zone, are expected to reveal important physical properties as temperature and deformation parameters in relation to the understanding of earthquake cycle. However, the challenge is how these observations relate to the deformation and rupture of the whole fault zone or to the stress field that causes earthquakes. This session will look at the present status and future plans of such experiments and try to identify ways to connect these observations in different scales.

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SW003 **Oral Presentation** **6536**

Depth migrated seismic images of the crust beneath the 2001 BHUJ (M = 7.7) epicentral Region in the Western India

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Pre-stack depth migration is applied to seismic reflection data along three short (~35-km) profiles near the epicentral region of the 2001 M = 7.7 Bhuj earthquake and this delineates the seismic images of the crust near the epicentral region. A zone of high reflectivity is observed in the lower crust starting at a depth of ~22 km. The crust-mantle boundary, defined as the base of the strong reflectivity, deepens from 35 km near the coast to 45 km in the vicinity of the Bhuj epicentral region, which is approximately equal to the average value (40-44 km) for the continental India (Kaila and Sain, 1997). This observation contradicts the suggestion that seismic activity in the Bhuj region is due to thin, rifted crust, such that which is found along the East African Rift (Mechie et al., 1994; Mooney and Christensen, 1994). The 45 km crustal thickness compares favorably with the 42-46 km crustal thickness of the New Madrid Seismic Zone (Mooney et al., 1983). Furthermore, the 22 km depth to the top of the reflective lower crust in the Bhuj region agrees well with the 26 km depth of the 7.3 km/s lower crust beneath the New Madrid. Thus, the Bhuj region appears to have a rifted crustal structure, comparable to the New Madrid rift zone. The thick and highly-reflective crust at the epicentral zone may be the result of crustal thickening due to the compressive regime of the past 55 Ma. Alternatively, this thickening could be attributed to magmatic intrusions which date back to Mesozoic rifting associated with the break-up of Gondwanaland. As the high-angle reverse faults and near-vertical strike-slip faults are rarely imaged on the seismic reflection data, it is not surprising that these data do not image the fault associated with the 2001 Bhuj earthquake (Biswas, 2005). The geometry of this fault is best defined by the aftershocks, as reported by Kayal et al. (2002), Negeshi et al. (2002), and Mishra and Zhao (2003). These aftershocks reach depths as great as 37 km. The seismic images demonstrate that all the seismicity is contained within the crust. There is no evidence on our seismic profiles for offsets in the crust-mantle boundary. On the contrary, the Moho appears to be flat with a smooth dip from the coast to the interior of the continent. The presence of seismic reflections some 10-15 km below the Moho is an unexpected and relatively rare observation on the present profiles. We interpret these reflections as either mantle shear zones or mafic igneous intrusions that are associated with the rifting that occurred as India separated from Africa in the late Mesozoic.

Keywords: crustal seismic images, thick crust at bhuj epicenter, high reflectivity lower crust

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SW003 **Oral Presentation** **6537**

Low dynamic fault strength at seismic slip rates: experimental evidence

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One of the primary issues in earthquake mechanics is the determination of dynamic fault strength (rock friction sensu latu) at seismic slip rates. Given the lack of determination through seismological methods, elucidating constraints arise from experimental, theoretical and field geology studies. Conventional rock friction experiments, showing rate and state dependence and modest variations of the friction coefficient, were functional to the interpretation of a variety of earthquake-related processes (e.g., earthquake nucleation and aftershock dynamics). However, they were conducted at inadequately small slip and slip rates (< 20 mm and <1 mm/s, respectively), as compared to the coseismic range (0-20 m and 1-4 m/s). Recent seismological observations are compatible with a sizable drop in fault strength with slip (slip-weakening) and slip rate (velocity-weakening). Among these observations, it was ascertained that 1) some large earthquakes exhibit a high seismic radiation efficiency, 2) the radiated energy (or apparent stress drop) increases with earthquake size, 3) dynamic stress drops are as large as 100 MPa in contrast to static stress drops of 0.1-10 MPa. Those considerations imply the action of unconventional fault weakening mechanisms (thermal pressurization, melt lubrication, flash heating, elastohydrodynamic lubrication, silica gel lubrication, etc.). Under the challenge of understanding the mechanism of coseismic fault weakening, experimental skill is starting to develop and exploratory, provocative results are already available for frictional tests at high slip rates. Noteworthy, a significant decrease in rock friction (up to one order of magnitude) is observed when cohesive (silicate-, calcite- and quartz-built rocks) and non-cohesive (fault gouges) rocks are slid at seismic slip rates in rotary-shear apparatuses (non conventional rock friction experiments). Under these extreme deformation conditions thermal effects become outstanding: significant fault weakening is related to the activation tribochemical and physico-chemical processes and to the production of unstable materials as gels and melts in the slipping zone. However, our understanding of these dynamic weakening processes (thermal dissociation, frictional melting, gelification, etc.) is so limited that they have not been introduced explicitly in any earthquake rupture model yet. In this contribution we will discuss the experimental results obtained in non-conventional rock friction experiments, their application to earthquake source dynamics, and compare the artificial fault products with those collected from natural seismogenic faults.

Keywords: fault strength, fault rocks, earthquake

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SW003 **Oral Presentation** **6538**

In Situ Observations of Fault Dynamics from TCDP boreholes

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Taiwan Chelungpu-fault drilling project drilled two holes, 4km/sec), was observed in TCDP 7-level BHS. No S-waves were observed in this event. Whether this event is an association of a new open crack after high pressure Fluid Injection Test (FIT) was examined. With the high resolution TCDP 7-level BHS and FIT in an active fault zone, we try to construct a physical model for the nucleation and rupture behavior within the fault zone.

Keywords: faultzonedynamics

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SW003 **Oral Presentation** **6539**

Dynamic mechanochemistry of seismic slip -nano spherules lubrication

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The Chelungpu fault, which was activated during 1999 Chi-Chi Earthquake, had been drilled to penetrate and recover the earthquake slip zone materials at deeper level (1100 m depth) in the crust, from year 2004 to 2005. Three holes are drilled (Hole A, B and C) and recovered the drilled core materials. Identification of slip layers of Chi-Chi Earthquake, thermal property measurements across the slip zones, estimates of frictional heat energy during earthquake, and quantifications of true fracture energy have been conducted using Hole A and C core (Tanaka et al 2006, GRL, Ma, Tanaka et al., 2006, Nature, Tanaka et al 2007, GRL). We present here the results of nano-scale observations for slip zone materials by using HR-TEM and TXM technique and fundamental process of generating nano-grains is discussed. Hole C core contained slip concentration zone, which is 12 cm in thickness, in which four independent layers composed of fine crushed materials were identified. The zone is directly juxtaposed with lower undamaged host mudstone by planner surface. Each of four layers shows about 3 cm in thickness, which contains crushed grains with maximum diameter of 0.1 mm. Further, each layer contains ultra-fine grained layer at the bottom, about 1 cm in thickness, which contains no visible grains. XRD analysis clarified that the materials in this layer are mostly composed of quartz. Grain size distribution is measured under OM, SEM, and HR-TEM, from 100 nm to 100 um in grain diameter. The distribution follows the fractal model (N(D) = 0.0045D.2.3; N, numbers of grains, D, grain diameter). Under SEM (SEI) observation, many of fractured grains areenveloped by viscous thin film, which extends from one side of fractured grains. This texture is similar with that observed by Otsuki for his samples after slip deformation experiments. Minimum size of grains observed under HR-TEM is 3 nm. The grain size distribution for grains larger than 100 nm in diameter follows the fractal law and grain shape is highly irregular. Grains smaller than100 nm show some specific characteristics, that is, smaller the grains, more the spherical shapes and more equi-granular. Thus, the grains smaller than 100 nm are no longer described by fractal distribution model. We refer tentatively these grains as nano spherules. By SAD and EDX analysis under HR-TEM, the nano spherules are mainly composed of crystallized quartz associated with minor amounts of carbonates (siderite) and amorphous materials. The result corresponds well with that of XRD analysis. These observations lead following three conclusions, (1) nano spherules are not generated just by fracturing, based on their shapes and grain size distributions. (2) Considering the results of SEM observations, nano spherules would compose viscous materials enveloping larger fractured grains. (3) Mica clay minerals and feldspars, which are common in host mudstone rocks, are disappeared in ultra-fine grained layer. This implies that chemical process of dissolution -elements dissipation -SiO2 precipitation occurred associated with mechanical fracturing. Therefore nano spherules would be generated through mechano-chemical process during co-seismic slip. Dynamic shear strength drop are recently observed by rapid slip experiments (DiToro et al., 2004, Nature). Some experiments reported that the products contain gelled materials. Large differences of ultra-fine products between previous reports and our observations are existence of nano spherules and their crystallinity. If the nano-spherules are generated during seismic slip, dynamic weakening would be expected because mode of friction turns into rolling friction, which is 10 to 20% of shear friction, by huge amounts of equigranular and spherical grains. This may be alternative explanations for dynamic weakening. Quantitative process of dynamic fracturing -dissolution and precipitation of nano grains will be discussed in our presentation.

Keywords: mechanochemistry, lubrication

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SW003 **Oral Presentation** **6540**

Advanced ocean floor network and simulating phenomena of earthquakes and tsunamis around the Nankai Trough in southwestern Japan - Towards the understanding of mega thrust earthquakes -

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The Nankai Trough is well known as the mega thrust earthquake with an interval of 100-150years. In this area, there are three seismogenic zones such as the Nankai, Tonankai and Tokai seismogenic zone. Therefore, in many researches focusing on the mega-thrust earthquakes around the Nankai trough, the structural researches using refractions and reflections seismic has succeeded to image the key structures to understand recurrences of mega thrust earthquakes around the Nankai Trough. Moreover, results of earthquake recurrence cycle simulation show that the first ruptures seems to occurred around the Tonankai earthquake rupture zone in each recurrence cycle, and the clear segment boundary between the Tonankai and Nankai earthquake rupture zones off the Kii peninsula was analyzed using tsunami data. The 1944 Tonankai and the 1946 Nankai earthquakes, each hypocenter was located off the Kii peninsula. So, the imaged irregular structures such as a key structure at the segment boundary between the Tonankai and Nankai earthquake rupture zone seems to act as the controller of the Tonankai-Nankai mega-thrust earthquake recurrence system. By the advanced simulation study of recurrence cycles of mega-thrust earthquakes around the Nankai Trough, these irregular structures seem to act as a controller of recurrence cycle and pattern of mega-thrust earthquakes in the Nankai Trough. Based on these researches, we proposed and have been starting to deploy the dense ocean floor observatory network system equipped with multi-kinds of sensors such as seismometers, pressure gauges etc., focusing on the understanding of crustal activities off Kii peninsula including the Tonankai/Nankai earthquake rupture zones. The new project of MEXT as a kind of Japanese government is starting from FY2006. This observatory system will be the one of most advanced scientific tools to understand the mega thrust earthquakes around the Nankai trough. This advanced dense ocean floor observatory network system has useful functions and purposes as follows, 1) Redundancy, Extension and advanced maintenance system using the looped cable system, junction boxes and the ROV/AUV etc. 2) Speedy evaluation and notification for earthquakes and tsunamis Especially, the evaluation and notification for tsunami will be improved remarkably using dense ocean floor observatories. Recent earthquakes of Kuril generated the tsunamis with large later phases diffracted and reflected from seamount chains. In these cases, ocean floor network will observe these unpredictable large later phases using only seismic waves. In fact, JAMSTEC Kushiro ocean floor observatory off southeastern Hokkaido in northern part of Japan, could detect these later phases clearly. It is the significant evidence to observe tsunamis using the ocean floor network. 3) Provide observed data such as ocean floor deformation derived from pressure gauges to improve the simulation and modeling researches about the mega-thrust earthquakes 4) Understanding of the interaction between the crust and upper mantle around subduction zone. In this paper, we will explain the advanced dense ocean floor observatory network system in detail and emphasize the purpose and importance of this system. Finally, we would like to extend the local network to regional and global network for the geosciences and huge disaster reductions with the international collaborations with network communities.

Keywords: advancedoceanfloornetwork, earthquakesandtsunamis, megathrustearthquakes

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SW003 **Oral Presentation** **6541**

Multiple-scale approach to understanding the Nankai subduction earthquake physics

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Drilling into the seismogenic zone and instrumenting the hole across the plate boundary where the subducting plate is currently locked is our near future goal (5 years) to be accomplished by the newly built riser-drilling vessel, Chikyu as part of the IODP (Integrated Ocean Drilling Program). After much scientific debate and consideration, the target area has been designated to be offshore Kii Peninsula in central Japan. Here the plate boundary is deemed reachable and M8 events initiated from this area repeatedly historically. The task is formidable to drill more than 6 km from 2.5 km deep seafloor and furthermore instrument the hole in high-pressure, high-temperature environment. However, this could be the only means in obtaining key near-field observations in understanding earthquake physics. Many scientists and engineers from Japan, US, and Europe are engaged in carrying out this large-scale mission. It is not easy to claim to acquire some 'representative' material of a fault locked zone by punching a tiny hole and collecting the materials from a large fault zone of more than 100 x 100 square km which is expected to be highly heterogeneous. The key here is to get samples for lab experiments for frictional properties governing the fault slip and at the same time be able to determine the physical and chemical conditions at the time of past earthquake slips. A major objective for instrumenting the hole is to monitor the ongoing deformation surrounding the fault, which may be largely influenced by water distribution and motion. In Japan, the construction of a cabled seafloor network with seismic and pressure sensors over the western part of the 1944 Tonankai Earthquake fault zone across the Nankai Trough (DONET) has started to be completed in 4 years. Already there is a cable system over the eastern part operating since 1978 by the Japan Meteorological Agency to be renewed soon. Dense seismic and geodetic networks on land have detected slow episodic motions and low frequency seismic events, which seem to be caused by the plate's slow slips and associated deformations possibly activated by fluid motions. These anomalous events add to complexities but at the same time provide us with how strain accumulates in the interseismic period. They are estimated to occur on both sides of the seismogenic zone. Therefore, the seafloor network is expected to more clearly define these events around the top end of the seismogenic zone. We have been conducting 2D detailed crustal structure surveys in the area, which will be the basis of understanding the ongoing dynamics. In development is the capability to detect the seafloor deformation by acoustic means utilizing GPS platform at sea surface and linking acoustically to seafloor. Another planned development is the application of synthetic aperture radar interferometry into oceans using autonomous underwater vehicles. Access to the actual future slip zone is the core of this multiple-scale approach to physically understanding earthquake occurrences. However, all other measurements must accompany such an undertaking as described. High speed computing capability is necessary to model the whole process in 3D in high resolution.

Keywords: seismogenic zone, drilling, network

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SW003 **Oral Presentation** **6542**

Geophysical investigation from Taiwan Chelungpu-fault Drilling Project (TCDP): Stress field and Anisotropy

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TCDP drilled two boreholes penetrating the Chelungpu fault, where the large displacement was observed during the 1999 Chi-Chi, Taiwan, earthquake. A comprehensive geophysical log had been carried out through the hole to understand the geophysical status of the borehole. In borehole breakouts and drilling induced tensile fractures, the local variations in the direction of maximum horizontal stress (SHMax) were observed at the depth of 1111 m, where the direction of N15E was observed compared to the tectonic stress direction of N112E. The simulation of reverse faulting stress regime reproduces the rotation phenomena as breakout directions varied with depth. The hydraulic fracturing experiments and density log help us to constrain the values of stress magnitude. Considering the influence of titling formations, Dipole Sonic Imager (DSI) shows that the fast polarization direction of shear wave is consistent with SHMAX determined from borehole breakouts. Comparison on the seismic velocity anisotropy and borehole breakouts, the anomalies, which might be associated with the existence of slip zones, at the similar depth and stress direction were confirmed. On the base of the geophysical information, the stress field before the Chi-Chi earthquake was estimated. Our results show that the magnitude of the maximum horizontal stress (SHMax) changed from 45 MPa to 12 MPa, which is smaller than the value of Shmin estimated from the logs near the fault It suggests the exchanges in the maximum and minimum stress directions after the earthquake. Thus, the reverse regime before the earthquake had been changed to strike-slip regime. This result agrees with the most of the strike-slip focal mechanisms of the aftershocks in the northern portion of the fault after the earthquake. For the state-of-the-art TCDP borehole seismometers installed in the borehole after drilling, the anisotropy behavior of the micro-earthquakes will be also examined to observe the possible difference in polarization crossing the fault zones to the comparison of the DSI log.

Keywords: stress field, anisotropy, chichi earthquake

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SW003 **Oral Presentation** **6543**

Methods for analyses of high resolution temperature logs in deep boreholes

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High-resolution temperature logs are essential not only for the detailed study of thermal structures but also for detecting the heat produced by fault rupture. We have made an effort to detect temperature signatures along faults that recently ruptured in large earthquakes. One way to locate the fault plane after the earthquake is to measure the thermal anomaly that may be produced by the frictional heat associated with the slip. The thermal anomaly, if measured, will also be direct information to constrain the energy budget of an earthquake. We carried out temperature measurements in a borehole that penetrates the Chelungpu fault, Taiwan, using a high-resolution borehole temperature instrument. The instrument consists of quartz oscillator temperature detectors with a resolution of 0.001 K. One problem with the instrument is the large response delay caused by the thermal inertia of the case of the instrument, which may affect the recorded temperature logs. For example, a sharp, or peaky, temperature anomaly becomes broadened. We need to develop methods to calibrate the measured high-resolution temperature logs. Here we examined two methods to calibrate the response of the instrument. One method is to fit the transient temperature response to a step temperature change by a model that characterizes the thermal time constant. The other method is to calculate a transfer function, or impulse response function for the instrument, using a reference thermometer that measures the temperature without the effects of thermal inertia. To test the methods for calibration, we carried out temperature measurements in a 350-m-deep borehole. We obtained high-resolution temperature logs using the quartz thermometer along with small-size reference thermometers whose instrument response is negligibly small. We assume that the temperature logs measured by small-size reference thermometers represent the true temperature structure. We imposed temperature changes by abruptly changing the depth of the instrument. The quartz thermometer recorded the temperature transients caused by the step-like temperature changes. A single time constant of 5 minutes basically fits the response of the instrument for the sudden temperature changes. However, detailed examination revealed that multiple time constants are necessary to model the instrument response that consists of components with different thermal inertia. We also calculated the transfer function between the temperature logs obtained by the large quartz oscillator instrument, and the small-size reference thermometers. The temperature logs modified by the calculated transfer function fit well to the logs obtained by the small-size reference thermometers. Using the time constant and transfer function, we removed instrument response from the data obtained at the Chelungpu fault, which can be interpreted together with thermal properties measured from cores.

Keywords: temperature log, frictional heat, thermal conductivity

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SW003 **Oral Presentation** **6544**

Hydro-thermo-mechanical characterization of the Aigion Fault from the AIG10 well investigation

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Mai Linh Doan, Jean Sulem

The Corinth Rift, in western Greece, is one of the most active continental Rift in the world, with an opening rate of 1.5 cm/yr. Its deformation process is being monitored with a broad range of sensors dispatched across the rift, near the city of Aegio, some 40 km east of Patras. In particular, the 1000 m deep AIG10 borehole that intersects the 10 km long, 60 dipping, normal Aigion fault provides a unique opportunity to investigate, in situ, the hydromechanical behaviour of this active fault.At 760 m, where it is intersected by the borehole, the fault separates two aquifers. The upper aquifer is fully hydraulically decoupled from surface aquifers and is developed in tectonized platy limestone, with a 0.5 MPa original pressure. Below the fault, the limestone is heavily karstified and the artesian overpressure reaches about 0.85MPa. Hence the fault supports a 0.35 MPa differential pressure thanks to the 0.5 m thick clay layer that has been smeared along the 17030 m fault offset. From various trenching investigations (Pantosti et al., 2004) the slip rate of the fault is evaluated to range from 1.6 mm/y to 4.3 mm/y, so that the fault is about 65 ky old. Inside the clayey layer, a clear shearing surface with marked slip lines is observed on a plane that makes a 38 angle with the main fault plane. On the basis of an elastoplastic constitutive model calibrated with triaxial tests on the clay, it is shown that shear band formation is possible. From the analysis of the orientation of the slip lines, it is concluded that the orientation of the principal stress directions are locally almost parallel and perpendicular to the fault plane. This demonstrates that this small recent fault behaves locally as a weak fault.Various thermal logs have been conducted that provide a well constrained temperature profile above the fault and demonstrate a lack of thermal gradient below the fault. Thermal conductivity measurements conducted on various parts of the cored material as well as on the drilling cuttings for uncored well sections indicate that the regional heat flux is equal to 53mW/m2, which shows that the rifting process is not affecting yet the regional heat flow.But the temperature just above the fault is higher than expected from a purely conductive model. This discrepancy is not caused by fluid flow above the fault, as shown by the long term monitoring of downhole pressure. It cannot be attributed either to the slip, given the magnitude of the fault offset and the absence of recent significant seismic motion. It is proposed that this heat anomaly is induced by a convection cell below the fault, a feature that is consistent with the absence of observed thermal gradient below the fault.

Keywords: fault zone, stress field, thermal profile

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SW003 **Oral Presentation** **6545**

Fault slip detected by borehole deformation

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Tsutomu Kiguchi

After the 1995 Kobe earthquake (M=7.2), we drilled boreholes along the Nojima fault, which exhibited surface rupture after the earthquake. The borehole at Hirabayashi, where the maximum slip of 2 m was observed, penetrated the core of the Nojima fault. We analyzed the borehole radius data by BHTV (ultrasonic borehole televiewer) to detect borehole deformation for the Nojima Hirabayashi borehole. The borehole was drilled one year after the 1995 Kobe earthquake to encounter the fault core at 624 632 m depth. We observed several deformation at this depth interval, and the borehole showed almost no deformation for other depth intervals. We interpreted that the deformation at the fault core is due to slip along the fault, and estimated stress state. The results show that vertical and minimum horizontal stress is almost equal and direction of maximum horizontal stress is almost parallel to the strike of the Nojima fault.

Keywords: stress, fault, seismogeniczone

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SW003 **Poster presentation** **6546**

Comparison of profiles of volumetric water content in three fault zones retrieved from the Hole-B of TCDP and its implication

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In the second drilling hole, Hole-B, of Taiwan Chelungpu-fault Drilling Project (TCDP), core samples were continuously retrieved in depth range of 950-1350 m including the Chelungpu fault slipped during 1999 Chi-Chi, Taiwan, earthquake. We did various non-destructive measurements including volumetric water content, density, thermal conductivities etc. on all the core samples of total length 400m. Especially, the water contents profiles in the three fault zones encountered at 1136m, 1194m and 1243m respectively, in the Hole-B, were successfully determined in a 10 cm interval which is enough thick to make comparing the profiles in the three fault zones. As a result, the profile of volumetric water content revealed a peak in the center of all three fault zones, respectively. Importantly, the water content value in the 1136m fault zone was highest in the three fault zones. A possible explanation of the measured results can be considered as that 1136 m fault zone is youngest due to the compaction effect depends on the elapsed time from seismic slipping.

Keywords: water content, fault, tcdp

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SW003 **Poster presentation** **6547**

Multi-component observations in deep boreholes (Deeper than 1 KM) operated by Tono Research Institute of Earthquake Science (TRIES) - It's outstanding observation power and some interesting results -

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Yasuhiro Asai, Makoto Ohkubo, Tsuneo Yamauchi, Harumi Aoki

Observation in deep boreholes can avoid the problems of both artificial noises and meteorological disturbances and enables the performance of high S/N ratio observations for detecting very small signals. Therefore, we have developed multi-component borehole instruments in order to achieve it. The instruments are composed of 7 strainmeters (4 horizontal, 2 inclined and one vertical), 2 tiltmeters, 3 seismometers, 4 magnetometers and a thermometer of high resolution. Resolution of A/D transformation of the instruments is 22 bits and sampling rates are 200Hz for seismometers, 20Hz for strainmeters, 10Hz for tiltmeters and 1Hz for thermometer. We first perform in-situ stress measurements by the use of overcoring method at the bottom of the boreholes by utilizing an intelligent type strain meter without outside cable developed by us before installation of the instruments. We then install the instruments by cementing at the bottom of the deep boreholes with expansion grout and have constructed borehole array stations. The deepest borehole (JRJ) is 1030m deep and the second (BYB) is 1020m. Data obtained from the sensors in the instruments are transmitted to a surface by using only one coaxial cable and then sent to TRIES. We have constructed data base of the stations. We also developed a new analysis method for strain records. The method enables to know from one station data a source time function, magnitude and a direction of epicenter for an earthquake easily and quickly. We will introduce the details of our system and some interesting results obtained from the borehole observation.

Keywords: multi component observation, deep borehole, interesting results

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SW003 **Poster presentation** **6548**

Log Data and Borehole Image Analysis of Hole-B, Taiwan Chelungpu-fault Drilling Project

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Philippe Gaillot, Kyaw Thu Moe, Weiren Lin, Yun-Hao Wu, Hisao Ito, Sheng-Rong Song

Log data and digital borehole images collected from Hole-B of theChelungpu-fault Drilling Project are analyzed to establish the relationships between deformation structures and in-situ stress, and to identify the rupture zone of the 7.6Mw 1999 Chi-Chi earthquake. Based on standard scalar logs, three log units and five subunits are recognized and are consistent with lithologic units defined from visual core description. Fracture analysis based on the borehole images shows two pairs of conjugated conductive fractures in the strike of N030 and N110. Three major fault zones, FZB1133, FZB1191, and FZB1240, are recognized from visual borehole image inspection at wireline logging depth of 1133, 1191, and 20m depth interval around FZB1133, SHmax has an azimuth of N210 resulting from the stress perturbations of the Chi-Chi earthquake. The integration of in-situ stress, log data and deformation structures suggests that all fractures are conductive but might not have being activated by the Chi-Chi event.

Keywords: chichi earthquake, logging, fault

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SW004 **6549 - 6579**

Workshop
Modernizing ISC procedures: model evaluation and magnitudes

Convener : Dr. Johannes Schweitzer
Co-Convener : Dr. Dmitry Storchak, Dr. James Dewey

The International Seismological Centre (ISC) has developed and put into operation a new Data Management System. As a result, it is now possible to review and subsequently introduce more up-to-date methods of locating seismic events into the ISC operations. A first workshop on modernizing ISC procedures was held during the 2005 Santiago IASPEI General Assembly. Using a list of 156 well-located test events (GT0/GT5) selected from the IASPEI collection of Ground-Truth events, a number of prominent seismologists studied the effects of different location algorithms on location accuracies. The first workshop participants recommended that the ISC consider changing from the Jeffreys-Bullen velocity model, currently used in operations to locate seismic events, to a modern spherical Earth model with consistent travel-time tables for all major seismic phases. In particular the AK135 velocity model was recommended as the best candidate for this purpose. To make sure that introducing new travel times into the ISC operation does not cause unwanted or unforeseen biases, the ISC was asked to produce its bulletin for two or three data months using the AK135 tables as well as JB. These two bulletin versions will be made available to the seismological community from the ISC and NORSAR web pages. For the present workshop, we encourage seismologists to use their local knowledge of different geographic and tectonic regions to conduct critical comparisons of the ISC JB bulletin and the experimental ISC AK135 bulletin. Also at the Santiago General Assembly, the IASPEI Commission on Seismological Observations and Interpretation provisionally accepted proposed standard procedures for computing the widely used magnitude types ML, MS, mb, mB, and mb(Lg). For ML and mb(Lg), the standard procedures explicitly allow for regionalization, to account for geographical variations in seismic wave attenuation. For MS, standard procedures are proposed for MS measured from waves with periods near 20s [MS(20)] and MS measured from waves in a much broader period-range [MS(BB)]. Papers are invited on implications of implementing the procedures. Papers are especially welcome on regionalization of ML and mb(Lg), on the value of mB and MS(BB) for characterizing the seismic source, and on comparison of magnitudes computed with the recommended standard procedures with magnitudes computed by network-specific procedures. The IASPEI-recommended standard procedures are posted at the IASPEI web site at www.iaspei.org. Also planned is a program to announce test-events, for which station operators will be encouraged to report amplitude measurements to the ISC, which will in turn make the measurements available for analysis by workshop participants. Interested participants are invited to contact the Workshop conveners for updated information on the test-event program.

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SW004 **Oral Presentation** **6549**

Implementation of standards for making magnitude measurements from digital data

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At the Santiago, Chile, IASPEI General Assembly, 2005, the IASPEI Commission of Seismological Observations and Interpretation provisionally accepted standard procedures for computing the widely used magnitude types ML, MS, mb, mB, MW and mb(Lg) that were proposed by the Working Group On Magnitude Measurements. In the case of MS, standards were accepted for measuring MS(20) from surface waves having periods within a few seconds of 20s, and for measuring MS(BB) from surface waves having periods in the range 3s < T < 60s. Implementation of the IASPEI standard procedures has begun at the U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) and the China Earthquake Network Center (CENC). The International Seismological Centre has requested that contributing agencies submit amplitudes and periods that are computed by the standard procedures. A slight discrepancy in Mw reported by the USGS/NEIC and by the Global CMT Project has been resolved by agreement of the two centers to each adopt the IASPEI standard formula. Some investigations have been carried out to test legacy magnitude procedures that are different in detail from the IASPEI standard procedures. To the extent that the new IASPEI procedures produce results that are similar to the legacy procedures, adoption of the IASPEI standard procedures will not produce a major change in catalogs previously based on the legacy procedures. Continued adoption of standard procedures will reduce a serious source of variation in magnitude measurements and add to the value of these measurements for studies of seismic hazard, earthquake source parameters, and the attenuation structure of the earth. Working Group members are James W. Dewey (chair,dewey@usgs.gov), Peter Bormann (pb65@gmx.net), Petr Firbas, Irina Gabsatarova (ira@gsras.ru), Sren Gregersen (sg@geus.dk), Alexander A. Gusev (gusev@emsd.iks.ru), Jens Havskov (Jens.Havskov@geo.uib.no), Won-Young Kim (wykim@ldeo.columbia.edu), Klaus Klinge (klinge@szgrf.bgr.de), Howard J. Patton (patton@lanl.gov),Bruce W. Presgrave (presgrave@usgs.gov), Liu Ruifeng (liurf@seis.ac.cn), Dmitry Storchak (dmitry@isc.ac.uk),Robert A. Uhrhammer (bob@seismo.berkeley.edu), Karl Veith (Karl.Veith@itt.com).

Keywords: magnitude, standard procedures

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SW004 **Oral Presentation** **6550**

AUtomatic computation of IASPEI standard magnitudes at the U.S. geological Survey/National earthquake information center (USGS/NEIC)

Dr. James Dewey
National Earthquake Information Center U.S. Geological Survey IASPEI

Carol Bryan, Ray Buland, Harley Benz

The U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) is testing computer algorithms for automatic computation of earthquake magnitudes from digital data, following standard procedures that were adopted by the IASPEI Commission of Seismological Observations and Interpretation at the Santiago, Chile, IASPEI General Assembly, 2005. The USGS/NEIC produces the widely used PDE catalog of earthquakes. Our use of automated procedures is required by the large volume of seismographic data being processed by the USGS/NEIC, and by the necessity that magnitudes be computed rapidly for emergency response applications in the aftermath of damaging earthquakes. In the case of magnitude type MS(20), MS measured from surface waves having periods within a few seconds of 20s, the IASPEI standard procedure is identical with the procedure previously used by the USGS/NEIC. For the short-period magnitudes mb and mb(Lg), the IASPEI standard procedure is slightly different than the previously used procedure. Adoption of the IASPEI standard procedures may therefore lead to slight systematic changes in mb and mb(Lg) computed at the USGS/NEIC. Our preliminary assessment is that the effect on mb will be to slightly increase mb, by less than 0.1 magnitude units on average. We also foresee an increase in mb(Lg), by 0.1 - 0.2 magnitude units on average. The USGS/NEIC had not previously computed the broadband magnitude types mB, measured from intermediate and long-period P-waves, and MS(BB), measured from surface waves having periods in the range 3s < T < 60s. The IASPEI procedures for these magnitudes have now been implemented on a real-time USGS/NEIC testbed, and we will present an evaluation of the performance of these magnitudes. The fact that USGS/NEIC magnitudes are initially computed without human oversight requires the application of real-time quality-checking procedures to ensure that the magnitudes are measured from earthquake generated signal rather than seismic noise, and the computation of event magnitudes from station magnitudes requires the application of averaging techniques that are robust in the possible presence of some extreme errors.

Keywords: magnitude, standard procedures, usgs neic

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SW004 **Oral Presentation** **6551**

Regression problems for magnitudes

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Least-squares linear regression is so popular that it is sometimes applied without checking whether its basic requirements are satisfied. In particular, in studying earthquake phenomena, it is at times disregarded that (a) the uncertainty on the independent variable must be at least one order of magnitude smaller than the one on the dependent variable, that (b) both data and uncertainties are normally distributed and that (c) residuals are constant. This may easily lead to wrong results. Through an extensive set of simulations we investigate the performance of different linear regression procedures commonly used to convert magnitudes from one type into another one, an operation which also has strong influence on the slope of the frequency-magnitude (the b-value of the Gutenberg-Richter) distribution. We systematically investigate the bias introduced by the standard least square regressions and the orthogonal regressions (or similar procedures) as a function of the true slope between magnitudes, of the ratio (E) between magnitude variances and of the absolute variances of magnitudes. We compute such bias through simulations very close to the real cases inferred from the German and Chinese broadband networks and find that the commonly used standard regression may induce systematic errors in magnitude conversion as high as 0.30.4. This can introduce apparent catalogue incompleteness, as well as a heavy bias in the estimates of the slope of the frequencymagnitude distributions. General orthogonal regression is found to be superior or equal to the standard least squares in all the cases investigated and its use is recommended. However, problems arise when the ratio, E, between the variances of the magnitudes to be related (the knowledge of which is required to apply the general orthogonal regression) cannot be computed. For 0.7 < E < 1.8 the orthogonal regression under the E = 1 assumption performs better than standard regressions. For values outside this interval neither procedure is capable of correct estimates. Therefore it is recommended to estimate the absolute errors and their ratio from empirical data and apply the general orthogonal regression. This requires that estimates of event magnitudes and standard deviations are published by seismological data centers.

Keywords: magnitude conversion, orthogonal regression, statistical methods

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SW004 **Oral Presentation** **6552**

Why there is an urgent need for magnitude measurement standards?

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Since the introduction of the local (Richter, 1935) and teleseismic magnitude scales (Gutenberg, 1945; Gutenberg and Richter, 1956) several modifications have been introduced at individual station as well as regional and global data centres. These changes were often not in concordance with original definitions, measurement practices and commonly used classical magnitude conversion relationships. These modification sometimes ignored also later recommendations by IASPEI or of the Manual of Seismological Observatory Practice (Willmore, 1979), which aimed at specifying procedures and proposing a more deive and unique magnitude nomenclature. This has resulted in drifting magnitude baselines. The long-term use of magnitude data from bulletins and catalogues for seismicity studies and hazard assessment is thus jeopardized and research applications become highly questionable. Moreover, the event magnitudes, even those published with identical nomenclature but produced by different agencies, are sometimes no longer compatible. They may show significant, systematic and magnitude-dependent deviations of which the user community is often not aware. These differences may reach in some cases more than one magnitude unit (m.u.). Examples are given and the physical reasons for such biases discussed. They are related to the moment and stress-drop dependent variability of radiated seismic source spectra and source duration in the context of the period range and bandwidth of seismic records and the measurement time windows applied. In order to reduce procedure-dependent systematic biases and scatter of magnitude data a strict standardization of measurement procedures is inevitable. Additionally, we will show, that disadvantages of the common band-limited body and surface-wave magnitudes mb and Ms(20) can largely be overcome by global re-introduction into seismological observatory practice of the broadband magnitudes mB and Ms(BB) as complementary standards. They are superior to band-limited magnitude estimates because they will always sample the maximum ground motion velocity amplitudes and thus be more reliable measures of the seismic energy released, at least that of the strongest sub-event in a multiple rupture process. Accordingly, mB is much better suited than standard short-period mb as a fast first estimate of an alarm magnitude from teleseismic data, this the more so, since it can easily be expanded by automatic procedures into a near real-time, non-saturating cumulative amplitude mBc (see another talk in session SS001).

Keywords: magnitude, standard, procedures

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SW004 **Oral Presentation** **6553**

First results of application of the new IASPEI standards for teleseismic magnitude measurements to data of the Chinese and the German Regional Seismic Broadband networks

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At the IASPEI General Assembly 2005 in Santiago de Chile the Commission on Seismic Observation and Interpretation (CoSOI) adopted new magnitude measurement standards for digital data with the aim to assure best possible agreement with original definitions and thus long-term continuity of magnitude data in earthquake catalogues but at the same time to reduce procedure-dependent inconsistencies between magnitude data of the same type and to better exploit the advantages of modern digital broadband data and analysis procedures. The new measurement procedures for teleseismic body and surface-wave magnitudes have been applied to digital broadband data of the Chinese Earthquake Network Center (CENC) and the German Regional Seismic Network (GRSN). The main conclusions are: - In the average, there is a nearly ideal agreement between Ms(20) and Ms(BB) for magnitudes larger 6.5. However, for smaller earthquakes and measurements in the regional distance range Ms(20) tends to underestimate the magnitude since the dominating periods at the Rayleigh-wave amplitude maximum are then usually <18 s. In the analyzed GRSN BB records these periods varied between 10s and 60 s. - Standard mb equals Ms(BB) and Mw(HRV) around 6.0 and 6.2, respectively, and underestimates these long-period magnitude data by about 1.2 to 1.5 m.u. for values around M = 9. - The introduction of the new mb standard will reduce, however, the saturation of mb, as determined traditionally at NEIC or at the CENC, for strong earthquakes by about 0.3 to 0.5 m.u. - In contrast, standard mB equals standard Ms(BB) around 7 and Mw(HRV) around 7.3. Although mB is larger for smaller and smaller for larger Ms(BB) or Mw(HRV), respectively, the difference to these long-period magnitudes does, on average, never exceed 0.6 m.u. in the range 4 < M < 9, i.e., the body-wave saturation for great earthquakes is, when compared with standard mb, further reduced by about 0.8 m.u.. - The average dominating periods of P waves in velocity proportional BB records vary between about 2 s to 3s for mB around 5 and about 14 s to 20 s for mB around 8. These periods correspond to the corner periods of the source spectra for the dominating (sub-)rupture events. For given magnitudes the periods may differ from the average periods by a factor of 2 to 3 due to differences in stress drop. - The average standard deviations of Ms(20) and Ms(BB) event magnitudes determined at the GRSN are comparable (0.11 m.u) and differ on average for individual events by only 0.02 m.u.. In contrast, the standard deviation of new mb event magnitudes are significantly larger (SD = 0.23 m.u.) than those for mB (SD = 0.15 m.u.). They become, however, comparable for week events with small signal-to-noise ratio. For CENC data the average SD of all new standard magnitudes ranges between 0.20 and 0.22 m.u.

Keywords: iaspei, magnitude, standards

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SW004 **Oral Presentation** **6554**

Poster Presentation 1

Dr. Johannes Schweitzer
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This contribution is made of five Poster Presentations

Keywords:

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SW004 **Oral Presentation** **6555**

Poster Presentation 2

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This session is made of five Poster Presentations

Keywords:

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SW004 **Oral Presentation** **6556**

Poster Presentation 3

Dr. Johannes Schweitzer
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This contribution is made of five Poster Presentations

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SW004 **Oral Presentation** **6557**

Poster Presentation 4

Dr. Johannes Schweitzer
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This contribution is made of five Poster Presentation

Keywords:

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SW004 **Oral Presentation** **6558**

Discussion 1

Dr. Johannes Schweitzer
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This contribution is devoted to a discussion about the Posters presented

Keywords:

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SW004 **Oral Presentation** **6559**

Discussion 2

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This contribution is devoted to an open discussion

Keywords:

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SW004 **Poster presentation** **6560**

Comparison of seismic events location by using JB and AK135 velocity model in China Earthquake Networks Center(CENC)

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The China Earthquake Networks Center (CENC), a non-profit agency directly under the management of China Earthquake Administration (CEA), was established on October 18, 2004 with a mission to earthquake monitoring and prediction, earthquake fast response. The main missions of CENC includes: (1) managing the operation of national seismic network with 47 stations and the regional Seismic network with 107 stations in the Capital Circle Area , rapidly determining the location and size of all destructive and feeling earthquakes. (2) collecting the data from national seismic network and 31 regional Seismic networks, and producing national earthquake bulletin in uniform format, seismic phase data, earthquake source mechanism solutions, continuous waveform and event waveform in SEED format. (3) constituting database for the data from national Seismic network and regional Seismic networks, providing the data service for government, scientist and public, and undertaking the task of international data exchange。 CENC has used Jeffreys-Bullen (JB) velocity model to locate seismic events for about 30 years, to ensure that introducing new travel times into the CENC operation does not cause unwanted or unforeseen biases, CENC want to produce its bulletin for 2 or 3 data months using the AK135 tables as well as JB. These two bulletin versions, covering the period of Aug-Oct 2004, have been made available to the seismological community. The results shows that we can safely use AK135 in place of JB with no consistent loss of location accuracy.

Keywords: ak135

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SW004 **Poster presentation** **6561**

Earthquake relocation of China Continent and vicinity during the period of January to October 2004

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Ruifeng Liu, Zongliang Wu

In response to the call of SW004 for Modernizing the ISC Procedures, we made earthquake relocation research for about 300 earthquakes in China continent and vicinity during the period from January to October of 2004. It is a major problem we are facing in earthquake relocation that the inversion of hypocenter is strongly coupled with inversion of velocity structure model. In this work the orthogonal projection operator (PB=BB+, where B is the matrix of partial derivatives for hypocenter parameters, B+ is the Moore-Penrose generalized inverse matrix of the matrix B) is introduced to separate the two kinds of parameters: velocity structures and earthquake hypocenters. After decoupling by using PB orthogonal projection operator we got a compatible system of the equations for hypocenter parameters. When determining hypocenter parameters, we modify the partial derivatives matrix regarding matrix balance for better focal depths. During the period from January to October of 2004, there are more than 300 events (Mb>3.5) occurred in China continent and vicinity. Most of them are distributed in the western part of China. We assemble arrival time data from local and regional stations, and relocate these events by using the above described method. The results are compared with the results of ISC-JB and ISC-EHB. The study is supported by the Chinese National Science Foundation(40234042). 1. SW004 2. Modernizing ISC procedures: model evaluation and magnitudes 3. Parameter separation, China continent, ISC 4. sunrm, SUN Ruomei, Institute of Geology & Geophysics, Chinese Academy of Sciences, Beituchengxilu No. 19, 100029 Beijing- CHINA Tel. +86 10 62007425, Fax. +86 10 62010846 e-mail: sunrm0@yahoo.com.cn or sunrm@mail.iggcas.ac.cn 5. P 6. 7. NO 8 Yes Ruomei SUN

Keywords: parameter separation, china continent, isc

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SW004 **Poster presentation** **6562**

Comparison of ISC seismic event locations with data of Polish mining industry.

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The International Seismological Centre (ISC) uses the Jeffreys-Bullen (JB) velocity model as standard. For the first 10 months of 2004 ISC also recomputed its locations using a different velocity model - AK135. This paper presents a comparison of ISC JB and AK135 epicenter locations with high-precision locations performed as part of operations by the mining industry in Poland. Induced events are the main source of seismicity in Poland and are concentrated in two large mining areas: Upper Silesian Coal Basin and Lubin Copper Basin. Locations from the mining industry are based on seismic arrivals from 15 to 50 stations, that are installed on various excavation levels, ventilation shafts above or, in a few cases, in wells below the level where most events occur. Effectively 3-D station positioning, combined with local engineering knowledge, guarantees very precise location. As a result, positions of the events are known with an accuracy of 300m. Origin times though cannot be relied upon since local seismic networks use internal timing that is not synchronized with UTC. The timing nevertheless is accurate enough to associate locations given by mines with the data from the closest station of Polish seismic network and therefore with corresponding events in the ISC bulletin. Accurate local data offer a unique benchmark that can be used to verify that using the AK135 velocity model in ISC operations does not cause unexpected systematical biases in locations in Poland and vicinity.

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SW004 **Poster presentation** **6563**

Comparisons between location features of ISC(using JB & AK135 models) and IRSC for seismic events in Iran

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Mehdi Rezapour

Some researches have pointed out the existence of bias in the ISC Catalogue due to different factor such as velocity model which is currently used in the ISC Agency for locating seismic events. In the IASPEI workshop during the 2005 Santiago the participants recommended that the ISC considers changing from the Jeffreys-Bullen (JB) velocity model, to a modern spherical Earth model such as AK135 with consistent travel-time tables for all major seismic phases. To ensure that introducing new travel times into the ISC operation does not cause unwanted or unforeseen biases, the ISC was asked to produce its bulletin for 2 or 3 data months using the AK135 tables as well as JB. In this research the location features of occurred earthquakes in Iran which is located by Iranian Seismological Center (IRSC) using data of a local seismic network, and local crustal model are compared with those determined by ISC using either Jeffreys-Bullen or AK135 velocity models. This comparison covers the period of Aug-Oct 2004. Location features for some of international seismological center (ISC) well-located earthquakes in , are examined by local seismic networks. Also, to reduce the level of location uncertainty, we employed a progressive technique such as hypoDD technique to relocate earthquakes. In this study, considering various seismotectonic provinces and their characteristics, we discuss about location accuracies for estimating reliable hypocentral parameters. Primary investigation for ISC and IRSC solutions shows that the difference is significant for some cases. Also, the comparison shows that locations reported by dense local seismic networks are more reliable than ISC reports.

Keywords: locationuncertainty, velocitystructure

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SW004 **Poster presentation** **6564**

Comparison of the regional earthquake parameters in Russia for estimate modernizing ISC procedures.

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Results of a location which available to the seismological community in version ISC Bulletin with JB and AK135 solutions, covered the period of Jan-Oct 2004, were compared with regional data of the Geophysical Survey Russian Academy of the Sciences (GSRAS). These regional data were obtained with using regional travel tables and velocity models. The comparisons were done for some seismic regions of Russian Federation located at Northern Caucasus, Siberia and Far East and conducted for: about 300 earthquakes in Kuril-Okhotsk region; about 270 earthquakes in Kamchatka-Komandory region; about 100 earthquakes in Altay-Sayany and Baykal regions; about 40 earthquakes in Northern Caucasus region. Diagrams of deviations of next parameters: origin time, latitude, longitude and focal depth were constructed and will be presented for discussion of an opportunity of replacement Jeffreys-Bullen velocity model with a modern Earth model AK135 in ISC procedures.

Keywords: velocity, model

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SW004 **Poster presentation** **6565**

Evaluation of ISC JB and ISC AK135 bulletİNS for Turkey

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An introduction of the new Data Management system allowed the ISC to start investigating ways of improving its standard procedures, especially event location. As the first step towards improving the location accuracy, the ISC was recommended by IASPEI to consider moving from Jeffreys-Bullen to a AK-135 velocity model, as the model better representing real Earth. The ISC produced and made available a considerable set of events, covering the period from January to October 2004, where both JB and AK135 hypocenter solutions are available. As a local agency, we intend to verify and assess the sample results of new relocated events in Turkey based on the data of KOERI network and our knowledge of local tectonics.

Keywords: ak 135velocitymodel, jeffrey bullen, eventlocation

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SW004 **Poster presentation** **6566**

Testing the AK135 model for locating seismic events in the wider Fennoscandia-European Arctic Region

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During the last General Assembly, IASPEI recommended that the International Seismological Centre (ISC) and other international data centers should replace the Jeffreys-Bullen tables with the more accurate travel-time AK135 tables for locating seismic events. On the average, AK135 has shown to be superior to the Jeffreys-Bullen tables, in particular if P- and S-type onsets are jointly included and if PKP phases and later onsets were associated. However, it is still unknown if a change of the travel-time tables will lead to undesired regional location anomalies. To evaluate the effect of using AK135 instead of the Jeffreys-Bullen tables, the ISC produced for a 10 months time period (January October 2004) parallel bulletins using both travel-time tables.In this contribution we are comparing the results in these bulletins for all 63 events in the region 55 90 N and -15 90 E with the regional bulletins of NORSAR and other local or regional bulletins in the region. Since local velocity models will always produce slightly different event locations, the focus in this study is on the question if the use of AK135 reduces or increases the discrepancies between the ISC and the local/regional bulletins.

Keywords: ak135 tables, jeffreys bullen tables, isc event location

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SW004 **Poster presentation** **6567**

Analysis of station travel times residuals based on the AK135 velocity model and phase weighting scheme in location procedures

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The International Seismological Centre (ISC) currently uses the Jeffreys-Bullen (JB) velocity model in its routine operation. Based on IASPEI recommendation, ISC is now considering substitute it with the modern 1D velocity model AK135 (Kennett et al, 1995). To evaluate possible outcome, we have examined travel time residuals to seismic stations that recorded 156 well-located globally distributed events (GT0/GT5) and studied their statistical characteristics. The set of events were selected from the IASPEI collection of Ground-Truth events. Travel time residuals were computed with respect to GT and with respect to solutions obtained using AK135 velocity model. The main motivation of analyzing travel time residuals is to re-examine the applicability of different weighting scheme in earthquake location. Alternative weighting schemes were compared by integrating them into the Geiger based location algorithm (ISCloc) and a grid-search algorithm for location (GSL).

Keywords: location, isc, ak135

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SW004 **Poster presentation** **6568**

Assessment of the ISC JB and AK135 locations in the NW of South America

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We analyzed and compared the JB-AK135 ISC bulletin for January to October 2004 for NW South America, the region between 12N 10S and 60W 85W. The NW of South America is part of the lithospheric boundary between Caribbean, Nazca, South America plates. This complex region comprises subduction, intraplate and nest seismicity. Using phase arrival-time data reported to the ISC, we select events with P readings recorded at more than 20 degrees, with S and PKP readings because of the AK135 effective representation. In this poster we used two approaches: statistical and seismo-tectonical. Firstly, to avoid results influenced more by observation than by differences in the model, we relocated the selected group of events using controlled station geometries generated by bootstrap technique. The spatial differences in both depth and latitude-longitude position were statistically analyzed. We also analyzed and compared station residuals by distance for both catalogs to understand their uncertainty and relation with the locations. The second approach is based in the seismo-tectonic local knowledge gained during more than 50 years of studies and observations in the region. This includes operation of local and regional networks (IGP, IGQ, RSNC, OSSO, and others). Using this knowledge, we compared JB and AK135 hypocentre solutions, provided by the ISC, with those recorded and processed by seismic local networks.

Keywords: south america seismicity, bootstrap, velocity model

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SW004 **Poster presentation** **6569**

Seismicity Along the Alaska-Aleutian Arc: Case studies for Model Evaluation

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Natalia A. Ruppert

The Alaska-Aleutian subduction zone extends along the Aleutian arc and terminates in the Alaskan Interior around 64oN latitude. In this poster we will present results from various seismicity studies, and contrast the results with the ISC Bulletins created with the two velocity models being critically compared. The Alaska Earthquake Information Center (AEIC) ~400 station regional network will help to provide both ground truth information in the well instrumented regions of Alaska, as well as contrasting results to the two ISC models in the Aleutian Island areas of sparse regional station coverage. First, we discuss using the AEIC earthquake catalog to more well define segmentation in the eastern end of the subduction zone. Modern relocation techniques show much more compact hypocenter clustering, revealing details about fine structure within the wadati-benioff zone. In particular, boundaries can now be identified between the Kenai and McKinley blocks, and in addition there is evidence for further segmentation within the McKinley block. In this region we typically have a very good distribution of regional stations yielding high quality recordings of earthquakes. The distribution of earthquakes ranges from crustal events northward of the subduction zone, to a mix of events ranging to a depth of about 200 km. This study area should prove to be a very good test bed for the comparison of the ISC model results.As we move to the south and east of the studied segmentation zones we discuss the routine location of subduction zone earthquakes as well as specific relocation studies of the larger events. The regional network coverage varies (and generally degrades) as we move from mainland Alaska, through the Alaska Peninsula, and on into the Aleutian Islands. Here we suffer from not only a sparse number of stations, but a more linear network coverage restricted by the distribution of islands. Relocation and moment tensor inversion magnitudes of particular strong events will be compared between the regional catalog and the two ISC catalogs. Of interest to us is the relative strength of location and magnitude precision and accuracy of the three catalogs as the regional network coverage increasingly degrades to the east.

Keywords: alaska, seismicity

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SW004 **Poster presentation** **6570**

ISC bulletin with AK-135 velocity model for earthquakes in the Levant and East Mediterranean region with application to advanced location techniques

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The IASPEI General Assembly in 2005 recommended that the International Seismological Centre (ISC) consider changing from the old Jeffreys-Bullen spherical velocity model of the Earth to the modern AK135 model. We contribute to the verification process of implementing AK135 model in ISC routine operations by checking ISC location solutions based on AK135 for 42 earthquakes of magnitude M>= 3.5 that occurred in the Levant and the east Mediterranean sea and were also located by the seismic network of Israel (ISN) and the Cyprus (CSN). As expected, the "new" model provides almost the same results as the old JB model and, in general, the location results are in agreement with ISN and CSN solutions. However, there seem to be a greater discrepancy for location solutions south-west of Cyprus and in the Red Sea. These differences could be attributed mainly to the spatial distribution of the seismic stations used in the calculations. Considering these results and understanding that a 1D global velocity model is likely to introduce errors in calculating travel times in this area where a 3D velocity model seem to be rather complicated, we used the data provided by ISC to test a new robust locator - the network beam forming (NB) - applying full grid-search and a directive grid-search . The initial estimate for the search was provided by the modernized arrival order locator (MAOL). The NB approach is similar to beamforming used in array station operations: a simple but robust statistic of semblance over complex exponents, applied to normalized difference between phase readings and the travel time calculated to each station from the postulated hypocentre. Apparently, the NB performance judged on the basis of error statistics locating reference events yields better results than the currently used ISCloc.

Keywords: velocity model ak135 jb, robust location, network beamforming

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SW004 **Poster presentation** **6571**

Assessing ISC locations using the data of Iranian National Broadband Seismic Network (INSN)

Mr. Mohsen Dezvareh

SS001 Seismic Observations And Interpretation SS001 Seismic Observations And Interpretation IASPEI

Iranian plateau has been registered as one of the most active areas of the world and it frequently suffers destructive and catastrophic earthquakes that cause lose of human life and economical damages. Considering the great importance of seismological studies in , Iranian National Broadband Seismic Network (INSN) has been installed since 1995. Main goals of INSN are study the seismotectonic of , earthquake location and deriving crust and structure upper mantle beneath Iranian plateau. More than 5000 instrumentally recorded earthquakes occurring in the region during 1995 to 2003. Many of these events had located by 2 stations and there was an uncertainty in location and magnitude. In commencement of 2003 INSN changed recording systems to Guralp instruments by more sensitivity, high quality, good maintenance and number of stations reached to 14 stations. We limited ourselves to study of earthquakes during the past 30 months (2004/07/01- 2006/12/31) by new instruments. At this period INSN recorded and Located more than 2800 events that occurred specially in Iran and determined earthquakes characteristics (lactation and Magnitude ML) These events recorded by Minimum 3 stations and have magnitude M>2.5. We compared our results with other centers and looked in more than 95 percent of events these results confirm our model and calculation. Uncertainties in EHB epicenters are on the order of 2-4 km and uncertainty for focal depth estimates are on the order of 1-2 km.Some of typical earthquakes e.g. Zarand, Dorud, Hajiabad, Qeshm are good evidences for this confirm that have good agreement with other international institutes e.g. NEIC, ISC, EMSC from view point of earthquake characteristics (origin time, lat, long, focal depths and magnitude).

Keywords: insn, broadbandstations, earthquakelocation

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SW004 **Poster presentation** **6572**

The Comparison between the ISC Bulletin and the CWB Catalog for Earthquakes Occurred in the Taiwan Region

Dr. Wen-Tzong Liang

Mei-Yi Ho

The Central Weather Bureau (CWB) is the official organization to routinely detect and report information for any earthquake occurred in the Taiwan region. In terms of dense seismic arrays deployed in the Taiwan region and the modern seismological technology, the CWB is capable of detecting earthquakes with local magnitude (ML) down to smaller than 0.5. During the disastrous 1999 Chi-Chi, Taiwan Earthquake (Mw=7.6), the CWB offered precise earthquake information of both location and ground shakings in 2 minutes that greatly help relieve victims of the disaster. In addition to the early automatic report, the CWB also publishes reloacated earthquake catalogs which have been widely used to map the seismotectonic structures in the vicinity of Taiwan. To help evaluate the ISC relocated earthquake information by applying modern procedures and various reference earth models, we compare the ISC results with the published CWB event catalog on location, origin time and magnitude. In this study, only events with quality A in the CWB catalog are discussed. This is to reduce the effect caused by location uncertainties for relatively poorly constrained earthquakes outside the network. We will present ourcompared results between CWB catalog and ISC_JB/ISC_AK bulettins in both tables and figures.

Keywords: isc bulletin, cwb catalog, earthquake location

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SW004 **Poster presentation** **6573**

Comparing the AK135 model with the ISC J-B model for central american earthquakes locations

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We have compared earthquakes locations, provided by ISC, which were done using the AK135 velocity model with locations done using the J-B velocity model for earthquakes occurred in Central America from January to October 2004. When both data sets are plotted and compared in a map of Central America it can be noticed that the locations from the AK135 model delineate less diffusely a major structural feature as the Central American subduction zone, but that is not the case with events located along the Cayman Through and its extension in Guataemala, the Motagua Polochic Fault.

Keywords: locations

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SW004 **Poster presentation** **6574**

Modernizing the ISC Procedures: Model Evaluation for the Italian region

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We discuss hypocentral locations obtained by ISC using two different reference models (JB and AK135) for some moderate magnitude earthquakes occurred in the Italian Peninsula in the period January-October 2004. The comparison between those locations with both the Seismic Bulletin of the Italian National Central Seismic Network, published on-line fortnightly since 2002 (http://www.ingv.it/%7eroma/reti/rms/bollettino/index.php), and our knowledge offers preliminary indications on location procedure and velocity model choice. Unfortunately, the number of events with magnitude larger than 3.5 occurred during this time lapse in Italy is scarce. We observe as well that most of the earthquakes are located at the boundaries of independent seismic networks with a poor azimuthal and distance coverage. Furthermore, the low magnitude of these events, along with the complex tectonics of the italian-mediterannean region, hampers an unambiguous association of earthquake hypocenters with well-known active structures. Within these limitations, which lead to non-thoroughly quantitative assessments, we examine and address possible discrepancies between the two ISC solutions.

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SW004 **Poster presentation** **6575**

Evaluation of the AK135 velocity model performance in earthquake location in the broader area of Greece

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Accurate earthquake location constitutes the starting point for advanced seismological research. The possibilities to improve International Seismological Centre (ISC) locations were investigated and discussed during the 2005 IASPEI General Assembly in Chile. It was then suggested that the Jeffreys-Bullen (JB) travel-time tables should be replaced by the AK135 tables, the latter providing more accurate solutions on a global scale. Research presented during that General Assembly provides no insight however on the performance of the AK135 model on a regional scale and no information regarding possible regional biases. The comparison between the two models for the broader area of Greece (34-41N and 19-29E) is discussed in this contribution, using the corresponding bulletins (ISC_JB and ISC_AK) produced by the ISC for the 10 month interval between January and October 2004. The two different solutions provided by the ISC, for the 270 seismic events falling within the above mentioned region, will be compared to those catalogued in local and/or regional bulletins and the resulting deviations between them will be evaluated. Thus, it is expected to derive solid conclusions regarding the performance of both global models for the complex geotectonic setting in the area of Greece.

Keywords: ak135 model, local regional bulletins, greece

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SW004 **Poster presentation** **6576**

Relocating ISC bulletin events with AK135

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J.Harris

Traditionally, for more than 4 decades, the Jeffreys-Bullen (JB) velocity model was used at the International Seismological Centre (ISC) to compute hypocentral solutions of seismic events. Following calls for modernization of ISC location procedures, the first workshop was held during the 2005 Santiago IASPEI General Assembly. Using a list of 156 well-located test events (GT0/GT5) selected from the IASPEI collection of Ground-Truth events, a number of seismologists studied the effects of different location algorithms on location accuracies. The workshop participants recommended a number of solutions, most importantly that the ISC considers changing from the Jeffreys-Bullen (JB) velocity model to a modern spherical Earth model with consistent travel-time tables for all major seismic phases. In particular the AK135 velocity model was recommended as the best candidate for this purpose. To ensure that introducing new travel times into the ISC operation does not cause unwanted or unforeseen biases, the ISC was asked to produce its Bulletin for several data months using the AK135 model as well as JB and make it available to seismological community for regional evaluation. We relocated a large selection of ISC events, covering the period from January to October 2004, using AK135 seismic velocity model. In this presentation we give the results of this work along with essential details of how it was performed.

Keywords: isc, bulletin, ak135

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SW004 **Poster presentation** **6577**

Comparison of hypocenters determined using Jeffreys-Bullen and AK135 velocity models for earthquakes in Japan

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In Japan, locations of seismic events are performed as a daily routine by Japan Meteorological Agency, JMA, using waveform data from not only JMA own network but also Hi-net founded by National Research Institute of Earth Science and Disaster Prevention (NIED) and also those of universities. The catalog of hypocenters compiled by this routine is called JMA catalog of integrated analysis. More than 1200 stations with interval of approximately 20 km spacing throughout islands are used as a unified dense network for the location of seismic events in the integrated analysis. Hypocenters determined by ISC using Jeffreys-Bullen (JB) and AK135 velocity models are compared with those of the JMA catalog of integrated analysis on the assumption that locations in the JMA catalog is more precise than those of ISC for local events because of its high density of the unified network. Differences in locations of inland events are carefully investigated in particular because the preciseness of location is much better than that of offshore events, especially for focal depth of the events. Followings are found in the comparison: (1) Focal depth using AK135 model is generally shallower than that of JB model throughout Japan for both inland and offshore events, and also for both events in crust and those in subducting plates, (2) The difference in focal depth is less than several km for island events among three hypocenters: JMA, AK135 model and JB model, (3) Regarding inland events at northwest to central Japan, locations of the JMA catalog of integrated analysis are closer to AK135 model than those of JB model. As a whole, though the difference is slight, locations of AK135 model are close to the JMA catalog of integrated analysis. It is considered that the hypocenters using AK135 model are better than those using JB model.

Keywords: isc, hypocenter, japan

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SW004 **Poster presentation** **6578**

ISC localization using JB and AK135 velocity models: A comparison in the Andean Region between latitudes from 19°S to 45°S

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The Andean Region between from 19°S (South of Bolivian Orocline) to 45°S present a active continental margin, where the oceanic Nazca Plate subduce the continental South American Plate, developing Andean Orogeny and thickening continental crust. Interplate seismic activity is concentrated in the east of Chile and southeast of Bolivia, at shallower depths of ~45Km. Plate subducted seismicity is extended from west of Argentina and center of Bolivia toward east, in correlation with a changing depth from 100Km to 650Km. Crustal seismicity is mostly located in Chile and west of Argentina between latitudes 31°-35°S. Traditionally, ISC use Jeffeys-Bullen global velocity model for entire Earth. As a part of Modernizing Location Method program, ISC have relocated 507 earthquakes in the here considered region using the more precise AK 135 velocity model. As result of comparing both set of hypocenters, we observed systematic localizations variation. In general, and for all depths, when the model AK135 is used, it can be seeing a great dispersion variations on the localizations related to the JB model. There average depth differences is ~7Km, mostly deeper for the AK135. That is consistent because JB present propagation velocities slightly faster than AK135. That is particularly certain for hypocenters of 100Km depth or more, where differences between both set are around 7Km and with relativity little dispersion. The same occur with concerning on differences in latitude and longitude, where those are relativity little. Specifically, a set of crustal earthquakes distributed over the interested region shown systematic differences, either nulls or ~ 2.5Km, likely due localization algorithms, but not related to the model velocity. Nevertheless in general, locations for earthquakes with depth less than 45Km show a great dispersion in the differences of depth determinations. It is consistent with velocities of different lithospheres, continental and oceanic, more over the Andean root velocity anomaly might be introducing a significant variations in the locations close to it.

Keywords: south american, locations, differences

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SW004 **Poster presentation** **6579**

Relocation of earthquakes off the west coast of British Columbia, Canada using processing routines at the International Seismological Centre and various travel time tables

Dr. Alison Bird

As part of efforts by the International Seismological Centre to refine and modernize the location of earthquakes, it was decided that an updated, modern spherical Earth velocity model, with consistent travel-time tables for all major seismic phases, should be used. The AK135 velocity model was of particular interest in this procedure, replacing the out-dated Jeffreys-Bullen travel time tables. A comparison of test events world-wide included a selection of earthquakes along the west coast of British Columbia, Canada. This region has the benefit of accommodating all three major types of plate boundary. The highly active Queen Charlotte transform fault along the northern west coast is the location of Canada's largest instrumentally recorded earthquake (a magnitude 8.1 in 1949). The area to the west of Vancouver Island is the prime area of focus in this study. The Juan de Fuca Ridge experiences considerable seismicity, including that induced by sub-sea volcanism, and the 1000km-long Cascadia Subduction Zone, immediately west of Vancouver Island, is potentially the most seismically hazardous area in the country, including a history of megathrust earthquakes. As Canada does not yet operate ocean-bottom seismometers, all off-shore earthquakes are located via stations in a limited azimuthal range and, at times, at distances greater than 150km. Close examination of such events will be presented, with preliminary results supporting the conversion of the ISC's location process to that using AK135 travel time tables.

Keywords: ak 135, earthquake, location

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SW005 **6580 - 6594**

Workshop
Reference Events for Improved Locations

Co-Convener :

Good locations for seismic sources are needed as the starting point for quantitative studies of Earth structure, tectonics, and earthquake physics, as well as for emergency management following a damaging earthquake, for studies of earthquake hazard and risk, and in the context of monitoring compliance with test ban treaties. Considerable progress has been made in recent years in improving the precision with which seismic events are located --- that is, in obtaining good relative locations between a set of events in the same general region. But there are continuing needs to improve the accuracy of event locations --- that is, improving estimates of the absolute location of seismic events. To this end, a Working Group on Reference Events for Improved Locations (REIL) under the IASPEI Commission on Seismological Observation and Interpretation has been established to develop a set of earthquakes or other seismic sources for which hypocenter information (origin time, depth, latitude, longitude) is accurately known, and whose seismic signals are large enough to be detected at distances out to 1000 km and perhaps teleseismically. Such earthquakes (or other seismic sources) are called "reference events." By building up a large enough set of reference events, it is anticipated that empirical information on travel times as a function of distance, phase, and azimuth (and eventually as a function of depth) can be obtained for individual stations detecting the events. From stations calibrated in this way, we anticipate that it will be possible to improve the accuracy of earthquake locations over broad regions for which reference events are available. The data derived from these reference events can also be used to test and improve 3-D Earth models. The development of an ever larger set of reference events is potentially an international effort that will have significant impact on improving the quality of regional and global seismicity bulletins. This Workshop invites contributions on: (1) Effective seismological and non-seismological methods for obtaining reference events in different regions, (2) Methods for implementing the use of travel-times that differ for each station (as determined in part from reference events), in the work of event location; (3) Evaluation of the accuracy of bulletin locations, as currently published using traditional methods, and as they might be published using improved methods, and (4) Use of reference events in testing 3-D Earth models and in other applications. The Workshop will include opportunities for discussion of effective methods to acquire and disseminate information on reference events.

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SW005 **Oral Presentation** **6580**

InSAR reference event locations

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The problem of combining geodesy and seismic data to better determine characteristics of seismic sources is an extraordinarily complex and multi-dimensional inverse problem. One of the major hurdles in combining seismic and geodetic data is that the relative magnitude and styles of error in each data set are poorly understood. Both data and modeling errors contribute to the confidence limits that are appropriate for the best-fit earthquake location, mechanism and slip distribution given a particular set of SAR interferograms. Here I examine the effects of spatially correlated noise due to atmospheric water vapor, crustal elastic structure, and fault slip complexity on the error bounds on location of the 2005 Qeshm Island earthquake in Southern Iran. I present confidence limits that reflect each type of error, and the describe degree of bias that can be present when the analysis is oversimplified.

Keywords: insar, earthquake locations, iran

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SW005 **Oral Presentation** **6581**

Use of a Multiple Event Relocation Method to Validate and Generate Seismic Reference Events

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E. R. Engdahl

The Hypocentroidal Decomposition (HDC) method of multiple event location has been adapted to the problem of generating datasets of reference earthquakes whose hypocenters and origin times are known both with unusual accuracy and with quantifiable uncertainty. Like many methods of multiple event location, HDC constrains the relative locations of a cluster of seismic events by eliminating path-correlated errors from observed travel times. Location bias for the cluster as a whole is reduced by incorporating into the cluster one or more calibration events, whose locations are known from independent evidence. The HDC cluster is shifted in space and time, without changing relative locations, to optimally match the available calibration data. Calibration information may be derived from high-resolution aftershock studies with temporary seismic networks, remote sensing studies such as InSAR, and geological information such as mapped fault traces. Formal uncertainties of all calibration data and the HDC-derived relative locations are carried through the calibration analysis. Use of multiple forms of calibration events allows us to evaluate the consistency of candidate calibration data. Because of the natural separation of the HDC analysis into estimates of the relative locations (cluster vectors) and the location in absolute coordinates of the hypocentroid of the cluster, it is also possible to use arrival times only from seismic stations at short epicentral distance for the hypocentroid and thus calibrate a cluster directly. In this case we use an appropriate local velocity model to calculate theoretical travel times.

Keywords: earthquake, reference, location

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SW005 **Oral Presentation** **6582**

Generating reference events by RCA method

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In the hybrid Hypocentroidal Decomposition and Reciprocal Cluster Analysis (HDC-RCA) method, HDC determines the accurate relative locations in an event cluster using regional and/or teleseismic data only. However, the absolute locations could be still biased due to velocity heterogeneities unaccounted for by the ak135 global 1D model used in the HDC analysis. RCA brings in new information by adding local phases, and invokes the reciprocity principle by relocating the local station network centroid using a local velocity model and with the events fixed as fictitious stations. Since the location of the local station network centroid is exactly known, the mislocation vector between the true and relocated centroids represents the offset with which the entire event cluster must be shifted to obtain unbiased absolute locations. We show that RCA is able to produce ground truth (GT5: location accuracy of 5 km or better) events from a cluster of earthquakes without relying upon prior ground truth information or dense local networks. We have developed applicability criteria to determine under what conditions RCA is able to identify ground truth events in an event cluster at a high, 95% confidence level. When the applicability criteria are satisfied, the HDC-RCA approach may result in GT5 locations where the local network alone is unable to assure GT5 location quality. We demonstrate the performance of the HDC-RCA method on several event clusters with previously determined GT5 events as well as on clusters for which GT events were not previously determined. We are systematically processing event clusters extracted from the EHB (Engdahl et al, 1998) bulletin and recent updates. This effort will lead to a large number of new GT5 events with global coverage.

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SW005 **Oral Presentation** **6583**

Contribution of the U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) to the identification and cataloging of seismic reference events

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Harley Benz, Ray Buland, Bruce Presgrave, Stuart Sipkin

The U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) will participate in the identification and cataloging of seismic reference events. For decades, the USGS/NEIC has identified explosions and rockbursts whose sources are known independently of seismological data. There are two additional sources of data that may provide a number of candidate reference events. First, the USGS/NEIC publishes hypocenters that are computed by local and regional networks, and subsets of these contributed hypocenters are well enough recorded to be used for calibration purposes. It is necessary that we work with the regional centers to identify the criteria that the events must satisfy. Second, for some tectonic earthquakes that do not occur in the midst of dense regional seismograph networks, the USGS/NEIC obtains geologic, geodetic, or imagery information soon after the earthquake that can help constrain the location of the events epicenter. For purposes of cataloging reference events, we think it is important that allowance be made for different levels of event accuracy. An event that is not located with sufficient accuracy for use in development of velocity models, for example, might still be helpful as a reference event in a seismic-hazard context. The USGS/NEIC is exploring the use of reference events in its routine calculation of epicenters of non-reference events in some regions. An important issue is how we would best document the use of reference events in the process of our locating non-reference events.

Keywords: hypocenter, calibration, reference

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SW005 **Oral Presentation** **6584**

Reference events to improve earthquake locations - a new ISC service

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Oriol Gaspa Rebull, E. Robert Engdahl, Paul G. Richards

A project to improve the accuracy of earthquake locations in many regions and eventually worldwide has been organized under an IASPEI Working Group on Reference Events for Improved Locations (WG-REIL). The International Seismological Centre (ISC), in collaboration with the IASPEI Working Group, will assume final responsibility for the collection, evaluation, archival and dissemination of reference events.The immediate goal of the Working Group is to develop a set of earthquakes or other seismic sources for which hypocenter information (origin time, latitude, longitude, depth) is accurately known, and whose seismic signals are large enough to be detected at distances out to 1000 km and perhaps teleseismically. Such seismic sources are termed "reference events". The role of the ISC in promoting these objectives is two fold; Build and maintain a web page that may be used to propose on-line candidate reference events and to provide information that will be used to ascertain the candidacy and validate the suggested accuracy. This would probably include automatic search of the ISC Bulletin for events that meet agreed criteria. ISC will also build and maintain a database of reference events and will provide on-line search facilities for information that was contributed and stored in the ISC database about events that were qualified as reference events. The evaluation process will be carried out by members of WG-REIL who will also provide guidelines to meet that task. Meanwhile, the ISC web-page will provide simple on-line services, primarily allowing contributions by means of non-formatted electronic documents that facilitate the contribution of data and nominees for reference events. The first version will be launched before the IUGG meeting in Perugia in July 2007 and be announced during the workshop on that meeting. Further changes and modifications are subject to the criteria and guidelines to be set forth by the WG-REIL

Keywords: reference events, ground truth, isc

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SW005 **Oral Presentation** **6585**

Tectonic activities of the big Beijing metropolitan area from relocated earthquakes based on reference events

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Reference seismic events are widely used in earthquake location calibration studies. In order to test the locating accuracy of the digital seismic network of the Big Beijing Metropolitan area, 6 shots with chemical charges of 1,000kg to 2,500kg were conducted near Beijing from April 23 to 24, 2002. There are another two mining explosions in 2002, one on Jan. 22 with chemical charge of about 7,000kg in Sanhe and another on Dec. 29 with chemical charge of 1,301,000kg in Qianan. The earthquakes occurred in the Big Beijing Metropolitan area from 1980 to 2006 were relocated by the double-difference method. In order to test the applicability of the double-difference location method and the velocity structure errors to earthquake locations in the study area, above 8 chemical explosions in different sites were used as reference events to determine suitable parameters for relocation methods and velocity model. The relocated seismicity is clearly associated with regional tectonics, and is also in agreement with the existence of deep faults imaged by wide-angle and deep seismic reflection profiling. The vast majority of the earthquakes, with the depth range 5-20 km, are located in the upper and middle crust, which implies the two potential seismotectonic mechanisms with deep dynamics and local tectonic blocks motion and deformation. The moderate and strong earthquakes tend to occur in the brittle upper crust and ductile-brittle transition in the lower crust. The seismic activities also demonstrate the pattern of seismic gaps and some potential traces of the steep-inclined buried faults in the Big Beijing Metropolitan area.

Keywords: referenceevents, bigbeijingmetropolitanarea, seismotectonics

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SW005 **Oral Presentation** **6586**

Validating 3-D tomography models using reference events

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Wim Spakman

Seismic tomography has provided high-resolution models of the Earths crust and mantle which can be used to improve travel time prediction and earthquake location. The aim of this study is to validate such a global 3-D velocity model obtained from travel time tomography with well located reference events for subsequent application to the relocation of a global earthquake data set. Improvements of the 3-D tomography model compared to previous models are achieved by incorporating new data from stations in Europe and North America in an existing global travel time data set. Additionally, we advanced the tomographic method to use a 3-D reference model instead of a standard 1-D Earth reference model. The 3-D reference model is based on a combination of tomography models that use travel times and models that use independent observations from surface waves, normal modes and long period body waves. Compared to previous models using a similar tomographic method, more detail is seen in the resulting tomography model in the upper 400 km of the mantle due to the new data and additional core phases help to constrain anomalies in the lowermost mantle. The resulting model combines the long wavelength structure as "seen" by long period seismic information contained in the 3-D reference model with the detailed mantle structure obtained from short period data during inversion. To validate the 3-D velocity model with regard to travel time prediction and earthquake location, tests with reference events in Eurasia and North America are performed. Theoretical arrival times are computed for 58,000 observed P phases of 300 such events (using their exact locations) with both, a standard 1-D Earth reference model and our 3-D tomography model. Particularly at epicentral distances up to 70 degrees, the 3-D velocity model predicts the travel times better. The ground truth events are subsequently relocated with the 3-D velocity model using a directed grid search technique and, for comparison, with a standard 1-D reference model including a travel time correction for average regional Earth structure below the stations. On average, relocation with the 3-D velocity model gives smaller epicenter mislocations than with a 1-D reference model and the origin time errors are reduced. The relocation vectors are smallest in North America and parts of the Mediterranean region, which suggests that the events in those regions are well-constrained by travel time observations and that the 3-D model provides a good representation of Earth structure in those regions.

Keywords: tomography, traveltimes, event location

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SW005 **Oral Presentation** **6587**

Effective seismological and non-seismological methods for obtaining reference events in different regions

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Many bulletins reporting earthquake locations provide absolute hypocenter estimates together with uncertainty estimates that are significantly lower than the true uncertainty in the location. The cause of such discrepancies is commonly that the programs used for location do not take account of errors in the travel time model used to interpret observed arrival times. Pick errors in the arrival times also contribute. In practice, it usually requires special efforts to obtain location estimates of seismic sources for which the uncertainty in absolute epicenter location is 5 km or less at the two-sigma level (95% confidence interval). We use the notation GT5 for such events. For a number of reasons, we anticipate that useful reference events will probably lie in the magnitude range from 3.5 to 6. It is desirable to obtain even higher quality events, such as GT2 or even GT1, if they can be found. The highest quality (GT0) can sometimes be obtained from controlled explosions. However, the occurrence of GT2, GT1, or GT0 events is quite limited. GT5 appears to be the minimum quality of reference events needed to provide useful independent information on travel times. There is no single correct way to obtain reference events with GT5 quality or better. Different methods that have been successful include: (1) Epicenter accuracy based on seismic network criteria (Bondar et al. 2004); (2) Locations (GT1 or GT2) obtained by using stations installed for aftershock studies that have S - P times less than 0.25 s with RMS residuals not greater than 0.01 s using a local Earth model: (3) Locations derived from teleseismic and regional stations, together with the double difference algorithm, to obtain precise relative location estimates for clusters of earthquakes. Reference events of GT5 quality are then obtained from some of the events in each cluster, by converting the relative locations using a database of active fault locations, and, in some cases, information derived from local networks; and (4) InSAR satellite data to identify ground disturbance, and traditional mapping of surface rupture for faults that break through to the surface. Examples of each of these methods will be presented.

Keywords: reference, event, criteria

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SW005 **Oral Presentation** **6588**

Introduction to workshop on reference events

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Good locations of seismic sources are needed as the starting point for many user communities, including those that study Earth structure, tectonics, earthquake physics, and seismic hazard. In this Introduction to the Workshop, I shall comment on the inaccuracy of location estimates as routinely available today, and shall review some of the steps that have led to the present plans of the IASPEI Working Group on Reference Events for Improved Locations (REIL) and its collaboration with the International Seismological Centre. Other papers in the Workshop will describe those plans in more detail. A simple way to investigate the level of mislocation that routinely must be present in published bulletins, is to compare the locations of the same set of events as published by different organizations (whether or not they use similar data). Such comparisons can be startling, and clearly demonstrate deficiencies though not necessarily why they have occurred. Another approach is to take sets of earthquake doublets, which must have occurred within about one km of each other, and see how far apart are their routinely-estimated locations (though this is an assessment of precision rather than accuracy). And for decades seismologists have compared their location estimates of explosions with hypocentre information obtained independently by non-seismic means --- this approach being the gold standard for reference events, though it is unfortunate that such hypocentre information is not usually archived. For example, numerous chemical explosions with their refraction and reflection picks out to thousands of km were documented in the US in the 1960s, and these need to be placed in modern databases. A major point, expected to emerge in this Workshop, is that a wide variety of activities can usefully contribute to the accumulation of reference events of great utility to present-day analysts. A purpose of the Workshop, is to identify the most important of these activities.

Keywords: reference events, earthquake location

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SW005 **Oral Presentation** **6589**

Precise hypocenter determination of aftershock of large interplate earthquakes near Japan arc using ocean bottom seismometers

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The seismicity of the Japan arc region is as high as that observed in other areas of subduction of oceanic plates. Aftershock observation using pop-up type OBSs was carried out to obtain the detailed aftershock activity after large interplate earthquakes around the Japan island arc. The Tokachi-Oki earthquake (M8.0) occurred on September 26, 2003. In 1999, three OBSs and two tsunami meters were deployed off Kushiro and Tokachi in the Kuril Trench region by Japan Agency for Marine-Earth Science and Technology. These sensors are connected by an ocean bottom cable and the data from the sensors are transmitted to the land in real-time. The cabled OBSs recorded the mainshock and continue the observation after the mainshock. The data from the cabled OBSs contribute to the improvement of the hypocenter location in the source region. However, the cabled OBS network has large intervals of more than 30km. To reveal precise aftershock distribution, a spatial dense OBS network covered the source region is needed. We deployed forty-seven ocean bottom seismometers (OBSs) and two ocean bottom pressure meters (OBPs) at thirty-eight sites in the source region to study the aftershock activity on four days after the mainshock . The observation lasted one and half months. For accurate determination of aftershock distributions, deployed OBSs have a spacing of 15 km near the trench in contrast to 20 km in the landward region. More than 700 aftershocks including 14 events with magnitudes greater than 5 were located. In the source region, most of aftershocks were located in a depth range of 15 - 20 km, and occurred in the subducting oceanic crust, the 5.5-km/s layer of the landward plate and the plate boundary. Although the main shock could not be observed by the OBS network, the depth of the mainshock is inferred to be 15 - 20 km from the aftershock distribution. From an epicentral distribution, aftershocks occurred within the small slip region of the mainshock rather than the large slip region. In addition, the epicentral distribution of aftershocks except near the large slip region, is similar to that of the earthquakes occurring before the mainshock. The hypocentral distribution forms a dipping plane toward the land and we infer that this plane shows the upper boundary of the Pacific Plate. It is clear from this example that OBS observation is useful to determination of precise locations of earthquakes which occurring in the marine area. In addition, an OBS with a small three-component accelerometer as seismic sensor was developed recently. This type OBS records both high-sensitivity seismogram and low-sensitivity (strong motion) accelerograms which are suitable to locate large earthquakes precisely.

Keywords: obs, aftershock, hypocenter location

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SW005 **Oral Presentation** **6590**

Searching for reference events in the Euro-Med bulletin

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IASPEI

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The European-Mediterranean Seismological Centre (EMSC) is in charge of collecting seismological parametric data recorded by the local networks in the Euro-Mediterranean region. After data merging, the EMSC regularly produces a comprehensive bulletin for the region, with few months delay after earthquake occurrence and a magnitude completeness of three. Thanks to the close relationships the EMSC has developed with the network operators of the region to optimize data collection, the Euro-Med bulletin reproduces the seismicity as imaged by the local agencies when events occur within their network region and improve event location in border regions and off-shore. Therefore this bulletin offers complementary information to the ones computed by international institutes such as the NEIC and ISC. We first describe the Euro-Med bulletin production and the different type of events provided in the bulletin (associated, reported or deprecated, event type, etc). Then we show the results over eight years from 1998 to 2005. This bulletin was computed using data from 73 local agencies representing more than 1,700 stations in the Euro-Med region. In total, 61,000 events are included in the EMB 98-05. Upon this dataset, we have performed a detailed analysis of the location quality. The location variability with the station contribution will be shown as a function of the azimuthal gap. In addition, we have applied the criteria as defined within the IASPEI working group and by Bondar et al. (2004) to extract reference events.

Keywords: euro med bulletin, emsc

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SW005 **Oral Presentation** **6591**

Aftershock seismicity of the 26 December 2004 Sumatra-Andaman earthquake determined by an OBS network above the epicentral area

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Only two months after the Sumatra Andaman earthquake on 26 December 2004, we deployed a network of ocean bottom seismographs (OBS) above the rupture area in the south of Sumatra Island using R/V Natsushima of JAMSTEC. The OBS network consisted of 17 short-term deployed OBSs in 20 February 13 March 2005 (1922 days), and two long-term OBSs until the end of July. The short-term OBSs were deployed relatively densely in 100 * 50 km area. Using the OBS network data, 2946 events were located in 20 February-11 March, 2005. These events are able to delineate detailed geometry of the plate boundary in which slip should occur during the main shock. Aftershock seismicity associated with the subducting slab starts 40 km inward from the Sunda trench axis; it ceases at 50 km depth beneath the Aceh Basin, approximately 240 km inward from the trench axis. Aftershocks in 120170 km from the trench axis consist of a surface with a dip of 1012. Beyond the southwestern edge of the Aceh Basin, the aftershock activity showed a slightly increased dipping angle of 1520. Three along-arc bands of shallow seismicity were also identified by the OBS aftershock seismicity that might be associated with the present evolutional activity of the accretionary prism offshore Sumatra Island. Of these events located by the OBS data, 17 events were located by the global network (in PDE catalog). All of these earthquakes are sitting along the dipping plate that subducted from the Indian Ocean. Some events are relocated with a shift of as much as 50 km horizontally and 25 km in depth. We believe these collocated events are very useful to calibrate the location of aftershocks of the Sumatra-Andaman earthquake by the global network, because the OBS network provides very unique geometry to look at these aftershocks. The accuracy of the OBS located events depends on reliability of seismic structure used as well as reading accuracy. Our OBS network was located very close to the aftershock hypocenters, but seismic structure of the seafloor sediment and the crust should be very complex. So we need to evaluate the ability of the OBS network data to use for calibration of the global network. We used 1-D seismic structure for location, with station correction determined by minimizing misfit between observations and calculations for all events. The root mean square (rms) value of the misfit was less than 0.5 s and 1.0 s, respectively, for P-phases and S-phases. We also inspected dependence of traveltime misfit on epicentral distance for each OBS. No marked dependence was apparent except for some stations. Even for these stations, the average deviation from our model is less than one second.

Keywords: sumatra, earthquake, ocean bottom seismograph

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SW005 **Oral Presentation** **6592**

Reference Events in sub-Saharan Africa and expected improvements from AfricaArray

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Although the general pattern of seismicity in sub-Saharan African has long been known, there are very few seismic events with accurate hypocentral locations in sub-Saharan Africa because of the paucity of seismic stations. This situation is beginning to change. A number of IRIS PASSCAL deployments in eastern Africa have provided sufficient data coverage for accurately locating a number of events. Careful analyses of data sets from Tanzania and Ethiopia have yielded a handful of events that can be considered to be reference events, but unfortunately most of the local/regional events recorded by these deployments are too small to be well recorded beyond a few hundred kilometers and therefore are of limited use as reference events. For southern Africa, mine-related seismic events were recorded at local and regional distances by the PASSCAL Southern African Seismic Experiment, and accurate hypocenters for many of these events exist from analyses of in-mine data. Although the largest mine-related events are between magnitudes 3 and 4, they are well recorded at distances of 1000 km or more because of efficient wave propagation across the southern African shield. A recent 32-station PASSCAL project in Cameroon has the potential to yield a number of reference events for western Africa. A number of magnitude 4 events occurred within the network during 2005. AfricaArray is a 2-year old initiative to build science capacity in geophysics in Africa, and as part of this initiative, as permanent network of 20 to 30 broadband seismic stations is being built in eastern and southern Africa. Temporary deployments of PASSCAL stations are scheduled in Uganda and Tanzania between 2007 and 2010. The combination of an increased number of permanent stations with more densely spaced temporary stations in between should yield many new reference events for eastern Africa. In addition, as part of AfricaArray, a 5-station mine network has been installed around three deep gold mines in South Africa, and data from these stations, when used with in-mine data and regional data from permanent AfricaArray stations, will provide many reference events well recorded at local and regional distances for southern Africa.

Keywords: earthquakes, location, africa

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SW005 **Oral Presentation** **6593**

Establishing Reference Events by Combining Seismic and Near-Surface Information: Examples from China

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Seismic event location within the context of monitoring the Comprehensive Nuclear-Test-Ban Treaty entails a priori knowledge of the travel time of seismic phases for a given source to stations of the International Monitoring System (IMS). We present an approach to provide such travel-time information (or ground truth, GT) by determining seismic reference events using seismic and near surface information. High-resolution double-difference analysis of earthquake clusters that include potential GT events are used to image the active fault at seismogenic depth in areas of dense seismicity. The resulting detailed fault structure is then correlated with the tectonic structure derived from mapped fault information at the surface to validate the absolute locations. We have used this approach to generate 59 reference events with M>3.5, distributed in six clusters in central and eastern China, for the calibration of six seismic stations of the IMS in China. We use the Annual Bulletin of Chinese Earthquakes, which lists about 1000 earthquakes in and near China each year with consistent phase picks at regional stations. The scatter in relative travel-time residuals is reduced from 1.28 sec before to 0.61 sec after relocation, consistent with the relocated positions of the events. The degree of correlation between seismicity structure and well characterized fault data indicates that, in four clusters, the locations of the new reference events are accurate to within 5 km (GT5), and in two clusters within 10 km (GT10). Additional case studies from crustal earthquakes in Turkey and California are presented.

Keywords: ctbt monitoring, earthquake location, china

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SW005 **Poster presentation** **6594**

Advances in earthquake location and seismogenic fault detection in critical network conditions

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By investigation of seismic sequences we compared the efficiency of linear and non-linear location methods in nearly critical network conditions and report the first example in the literature of comparison between location error estimates from the respective methods in 3D velocity structures. In the network conditions of sequences investigated, the SIMUL (linear) and BAYLOC (non-linear) algorithms furnished hypocenter coordinates of comparable accuracy but different location error estimates. We also obtained this result by relocation of synthetic events in the same network model conditions of the real sequences, and the location errors from SIMUL were found in general less accurate than those from BAYLOC. This finding can be explained as due to the linearization process which lowers the accuracy of linear location error estimates but does not produce, however, any apparent incremental bias in the hypocentral coordinates with respect to non-linear methods. So, we extend to location in 3D structures a conclusion drawn by previous investigators for 1D location. This situation implies different efficiency of the respective algorithms as regard to the evaluation of hypocenter trend significance for seismogenic fault detection, in particular the non-linear algorithms will be more efficient. Because location error estimates may be crucial to establish whether the hypocenter trend of a sequence does really mark the seismogenic structure or simply reflects ill conditioning of the location process, we based on the BAYLOC location probability concept our approach to hypocenter trend evaluation for seismogenic fault detection. This procedure, named ISO-TEST, works through isotropic generation of synthetic hypocenters inside the sequence volume (simulations) and comparison by misfit variables of the location probability function of the sequence with probability functions from simulations.

Keywords: seismology, earthquake location

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SW006 **6595 - 6624**

Workshop
Induced seismicity

Convener : Prof. Stanislaw Lasocki
Co-Convener : Dr. Aderson Do Nascimento, Dr. Rajender Chadha, Prof. Hans-Joachim Kuempel

The increased need for energy and minerals requires a variety of complex industrial processes to be performed under more and more difficult environmental conditions. Among these, the unstable fracturing of rocks, resulting from stress field alterations induced by human activity threatens various technical processes. Consequently, microseismic monitoring is called upon by the industry to assist the extraction of minerals and hydrocarbons, the injection of fluids into the ground related to the use of geothermal energy and waste disposal, as well as in geotechnical projects such as underground nuclear waste repositories, hydrocarbon storage caverns, tunnels, underground water purification plants, and water dams. The hazards associated with triggered earthquakes are, however, still frequently unpredictable and uncontrollable. In order to achieve the desired level of control, the mechanism of these kind phenomena must be fully understood. The goal of this session is to summarize a present state of knowledge about the induced and triggered seismicity processes and to discuss future trends in the field. Its purpose is also to provide an overview of the capabilities and limitations of current monitoring techniques and interpretation methods as applied to triggered earthquakes to assess and mitigate the seismic hazard.

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SW006 **Oral Presentation** **6595**

Non-linear modelling of induced seismic event probability

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Detailed, mine-scale non-linear numerical models have been calibrated using a large number of observations of displacement and damage at two deep mines. The measure of calibration was the reproduction of accurate displacements. The calibrated models were then used to investigate the correlation between Dissipated Plastic Energy (DPE) rate and seismic event probability. A strong, non-linear relation between DPE and event probability was observed that describes the development, peak, and decline in seismicity as rock is deformed. The correlations are present for events at all magnitudes, and the relation between DPE and event probability is consistent with the relation between event magnitude and frequency described by the Gutenberg Richter equation. In addition to a strong correlation between event occurrence and DPE, increments of plastic strain have been decomposed and described in a manner paralleling the common decomposition undertaken for measured seismic moment tensors. Consideration of DPE, coupled with Plastic strain decomposition assists in describing the nucleii of seismic strain. The application of DPE analysis and plastic strain decomposition during the design and sequencing of excavations allows a more quantitative description of seismic hazards.

Keywords: induced, probability, seismicity

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SW006 **Oral Presentation** **6596**

Induced earthquakes associated with geothermal energy extraction in Kamchatka (Russia)

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Hydrothermal fields suitable for electric power production are located in the areas of high geodynamic, volcanic and seismic activity. Kamchatka is one of such regions. Level of seismic hazard and risk in these local areas can increase unpredictably due to human activity by geothermal energy extraction. Although geothermal energy is a clean and sustainable energy source, its development has some impact on the environment: surface disturbances, induced seismicity, subsidence, hydrothermal eruptions. Independent of the technology applied the main phases of development and production are the same: exploration; production tests; GeoPP construction and operation. Different environmental impacts (seismicity) can be expected at each step. By prevailing opinion increased pore pressure during injection is a simple mechanism for induced seismicity through fault slip when effective stress across the fault is reduced. Injection into a steam zone causes localized pressure drop from condensation at the liquid interface, and the resulting local stress changes could also induce earthquakes. Some induced seismicity seems to originate from pressure decline rather than increase. Thermal stresses induced by local pressure change in a steam zone or by cold water injection can also trigger earthquakes. Pre-existing state of high tectonic stress seems to be necessary before relatively small pressure changes can induce seismicity. In given report data about seismicity in areas of high-temperature exploited Pauzhetsky and Mutnovsky hydrothermal fields (Southern Kamchatka) are shown. Three geothermal power plants (Pauzhetsky, 11 MW, Verkhne-Mutnovsky, 12 MW and Mutnovsky, 50 MW) began to work here in 1967, 1999 and 2002 accordingly. By data of Kamchatkan regional seismic network it was shown that after the exploitation start shallow earthquakes were registered directly from exploited zones. But earlier it was presumed that local seismicity is absent in these areas. Some of earthquakes in Pauzhetsky hydrothermal field with M=5 were sensible without damage of buildings and wells. Seismicity was related in swarms. The most intensive ground motions had intensity about 6. Activization began 6 years after exploitation start. It is first example of induced seismicity appearance in hydrothermal field in Russia. In Mutnovsky hydrothermal field first sallow earthquakes from exploited area were recorded by Kamchatkan regional seismic network in 1996 in phase of deposit production tests. Maximum magnitude was about 3. Intensive deposit exploitation changes reservoir pressure; parameters and state of hydroterms and internal conditions of upper crust and it can be the reason of inducted seismicity. In the report some phenomena connected with Mutnovsky geothermal field exploitation are present. It is seismic events, temporal changes of wells parameters, hydrothermal explosion and appearance of new surface hydrothermal manifestation. Seismic information in Mutnovsky hydrothermal field is not complete because there are not seismic stations in the local exploited zone and small events are lost.

Keywords: hydrothermal field, induced seismicity, kamchatka

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SW006 **Oral Presentation** **6597**

Reservoir - induced seismicity in Georgia

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We present the evidence of reservoirinduced changes of the regional seismic activity around Enguri high dam reservoir located in the western Georgia are found to be influenced by the water level of the reservoir. We base our assumption on results of the water level variation data sets of Enguri high dam reservoir and the seismic data sets recorded by the special local network. The Enguri reservoir was built in 1971-1983, the height of the dam is 272 m, the average volume of water in the reservoir is 1.1109 m3. Preliminary flooding of the territory started at the end of December 1977; since 1987 the water level in reservoir changes seasonally, almost periodically. Thus we have defined three distinct periods of our analysis, namely, (i) before impoundment, (ii) flooding and reservoir filling and (iii) periodic change of water level. After the general increase of seismic activity during nonperiodic water level change, i.e. during initial loading and filling of the reservoir known as reservoir induced seismicity [Talwani, 1997; Simpson, 2003] variation of the water level in the lake became periodic. For this time period the probability of large events decreased significantly. As a model of real seismicity we have also analysed laboratory acoustic emission data obtained during stick-slip with superimposed weak periodic perturbations. According to our data, after the general increase of seismic activity during nonperiodic water level change during initial flooding and filling of the reservoir, the probability of large events decreased significantly when variation of the water level in the lake became periodic. This small periodic influence on complex seismic process may invoke synchronization of regional seismic activity as well as the decrease of probability of large earthquakes occurrence around reservoir

Keywords: seismicity, triggering, influence

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SW006 **Oral Presentation** **6598**

LAke Nasser; 25 years of monitoring advantages and disadvantages

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Lake Nasser is the second largest man-made lake in the world. Impoundement started in 1964 with planned total capacity 162 million cubic kilometers and surface area of 6000 square kilometers. Following an earthquake of magnitude 5.7 in 1981 several scientific programs were initiated. In this work 25 years of monitoring data will be reviewed. This includes seismicity, local and regional tectonics, geology, hydrogeology, crustal deformation, dam stability as well as silting in the lake. Like many other cases in the world seismicity around the lake decreased considerably after almost 20 years of impoundment. It is also found that seismicity is not correlated with water loading and level fluctuations. The dam as well as other related structures did not have any significant instability. Monitoring crustal deformation around active faults showed only minor horizontal displacement. 22.2 million cubic meters of silting per year will become serious problem on the long-run. Multi-national plan on all levels to minimize silting effect is unavoidable.

Keywords: induced seismicity, lake nasser

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SW006 **Oral Presentation** **6599**

Anisotropy effects on microseismic event location

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Seismic waveforms from sedimentary environments often show strong shear-wave splitting, with velocity differences of up to 40% between vertically and horizontally polarised S waves. If not accounted for, this anisotropy can result in large location errors for mining-induced microseismic events. A method is described here for using calibration shot data, possibly augmented with data from mining-induced seismic events, to infer the parameters of a vertical transverse-isotropic velocity model. This simple 5-parameter model provides a good fit to arrival times from coal-environment data, and results in dramatic shifts in interpreted event locations.

Keywords: anisotropy, source location, microseismic

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SW006 **Oral Presentation** **6600**

Quasi-static and dynamic deformations of the rock mass surounding deep level mining excavations

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Underground sites in several gold mines in South Africa were instrumented with tilt-meters and closure-meters integrated with seismic monitors in order to understand the rock mass behaviour around deep level mining. Both the rate of tilt and closure, defined as quasi-static deformations, were analysed in combination with the ground motion, defined as dynamic deformations, for different geotechnical areas and different mining structures. A strong correlation between the dynamic and quasi-static deformations was found for all areas studied, indicated by rapid increase of the tilt and closure during the seismic loading. The rate of the quasi-static deformations before a string seismic event was found to be different from the rate of the quasi-static deformations after a strong seismic event. The tilt measured in a tunnel located deep in the footwall and closure between the hangingwall and the footwall measured in stopes increases rapidly during the seismic events and blasts and may show Omori type behaviour similar to the rate of aftershocks. Much of the tilt and stope closure, however, occurs independently of the seismic events with. A hypothesis that the quasi-static deformations is caused either by viscous post-failure processes or by sub-critical slip is proposed. An attempt to characterize a specific mining structure by quantifying the amount of quasi-static and dynamic deformations was carried out.

Keywords: mining seismicity, rock deformations, underground monitoring

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SW006 **Oral Presentation** **6601**

Seismicity induced by hydrocarbon production

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This paper reviews the scientific advances regarding seismicity induced by hydrocarbon production. Very generally, induced seismicity in hydrocarbon fields can be grouped into two categories: seismic activity related to fluid injection and seismic activity related to fluid extraction. Both phenomena will be discussed from an observational as well as from a theoretical viewpoint, with a strong emphasis on the cases reported so far. Independent of the causative mechanism, seismic monitoring is the primary tool to study seismicity induced by hydrocarbon production. Two techniques which have experienced rapid development over the last years, time-lapse monitoring and passive microseismic monitoring, are particularly interesting in this context and will be discussed in detail. This discussion is complemented with an overview of recent advances regarding processing tools, geological factors affecting seismicity and seismic hazard.

Keywords: induced, seismicity, hydrocarbon

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SW006 **Oral Presentation** **6602**

Cyclic annual variations in the Koyna-Warna reservoirs and triggered earthquakes

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The Koyna region in western India has been experiencing continuous triggered earthquakes since the initial impoundment of the reservoir during early 1960s. Earthquakes of M 5.0 continue to occur and the region remains seismically active with earthquakes occurring repeatedly along two major fault systems in NE-SW and NW-SE directions. To understand the cause-and-effect relationship between the annual cycles of reservoir levels and earthquakes in the region, cross-correlation analysis between time series of the Koyna and Warna reservoir levels and the strain factor (Energy 1/2) calculated for earthquakes of M 3.0 occurred in the region during 1963-1999 was done. Our results suggest that the initial seismicity in the Koyna region during 1963 was triggered after the region attained steady state pore pressure by diffusion processes, particularly occurred along vertical strike-slip faults. Subsequently, major episodes of earthquake energy release till 1999 show a periodic behavior related to the annual filling of both the Koyna and Warna reservoirs. Two stages of earthquake energy release are evident till 1996 coinciding with annual filling and draining of the reservoirs. Since 1996, the energy release episodes correlate mostly with draining cycle of the reservoir levels indicating a shift in the present day earthquake activity in the region, which may be due to a combined effect of both the Koyna and Warna reservoirs. To explain the causal relationship between the reservoir water level fluctuations at the surface and earthquakes at hypocentral depths in terms of diffusion processes, we modeled the pore pressure front diffusion with time, in an inhomogeneous medium. It is seen that water level change of the order of 1 m in 5 days in the surface loading can propagate 5-15 % of pore pressure front, corresponding to 0.75-2.25 bars, to the hypocentral depth of 6-8 km in the presence of a vertical conducting fault. These small stress perturbations are sufficient to trigger seismicity on pre-existing, critically stressed faults in the Koyna-Warna region.

Keywords: triggered earthquakes, cross correlation, reservoir water levels

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SW006 **Oral Presentation** **6603**

Source parameters estimation of reservoir-induced earthquakes in northeastern Brazil using Empirical Greens Function analysis

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In the Au dam area (NE Brazil), a digital seismograph local network was deployed for nearly three years and recorded one of the best examples of Reservoir-induced seismicity on a near-homogeneous Precambrian crystalline basement. The hypocentral error location are approximately 100m and are very suitable for investigating a possible relationship between pore-pressure diffusion and source parameters like stress drop, rupture velocity, source duration and rupture length. In order to obtain these source parameters from recorded seismograms, attenuation and site effects have to be removed. Empirical Green's Functions (EGF) is an alternative way to extract the earthquake source information from the recorded digital seismograms. Here we present results from EGF analysis of 6 earthquakes in the Au dam area. Estimates of source duration and corner frequency imply low stress drop (10 to 100 MPa) for these shallow reservoir-induced seismicity events. These are similar to tectonic earthquakes, suggesting that hypocentral depths and the presence of water do not affect stress drop.

Keywords: reservoir induced seismicity, source parameters, directivity

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SW006 **Oral Presentation** **6604**

Is earthquake forecast possible at Koyna, India?

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Dodla Shashidhar, Metilda Pereira, Prantik Mandal, N. Purnachandra Rao, M. Kousalya, H. V. Satyanarayana, Vijaya Raghavan, Satish Saha, G. Kiran Kumar, Kantha Rao, Narendra Kumar, Amiya Maji, D. Nagesh

Koyna, located near the west coast of India, is known to be one of the most significant sites of artificial water reservoir triggered earthquakes in the world. The seismic activity at Koyna has been monitored carefully with the deployment of a dense network since August 2005. Enhanced seismic activity was observed in August 2005 with two clusters identified during 9- 23 of August 2005. It appeared that all the criteria that govern the occurrence of an M ~ 5 earthquake were present. On 25 August 2005 a short communication was sent to Current Science entitled An earthquake of M~5 may occur in the Koyna region. An earthquake of M 4.8 occurred on August 30, 2005 making this forecast come true. As a matter of fact seismic activity in Koyna region during the period of August to December 2005 has been much higher compared to the same periods during the previous four years. Further in the middle of May 2006, a nucleation centered around 17.1 N latitude and 73.8 E longitude within a radius of 10 km was identified. The phenomenon was verified for 4 moderate earthquakes of the past on August 30, November 13, December 26 of 2005 and April 17 of 2006. In view of the above, a forecast was made for the occurrence of an M 4+ earthquake at 19:05 hrs IST on 16 May 2006 and communicated to Dr. K. R. Rao, Editor Current Science, and Dr. B. P. Radhakrishna, President Geological Society of India. On the basis of the data available from 7 seismic stations operating in the Koyna region, we have identified a nucleation, which started on 12th May 2006. This may lead to the occurrence of an M~4 earthquake in the next 15 days. This shallow earthquake (focal depth less than 8 km) will occur within a radius of 10 km centered at 17.1 N, 73.8 E. On the basis of our previous experience of studying nucleation-preceding earthquakes in the Koyna region, we expect this earthquake to occur over the next 15 days time (till 31st May, 2006), with a 50% probability. An earthquake of M4.2 did occur in the region on 21 May 2006 at 20:29:01.2(UTC). The epicenter of this earthquake (17.171 N latitude, 73.777 E longitude) lies within 10 km of the predicted epicenter, with a depth of 4.7 km. Several other studies, such as gravity, radon emission, crustal deformation, water level changes in the bore-wells, changes in magnetic field, are in progress and are expected to improve our understanding in precursory studies prior to the occurrence of moderate earthquakes in the Koyna region.

Keywords: nucleation, earthquake forecast, reservoir triggeredseismicity

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SW006 **Oral Presentation** **6605**

Enhancemant of heavy oil extraction using microseismic monitoring

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Richard Smith, Colum Keith

Since the early seventies, extraction of oil from deep layers of oilsands in western Canada has been based on thermal methods such as Cyclic Steam Stimulation. This operation subjects well casings and adjacent formations to thermal fatigue and shear deformations that can occasionally result in casing failures, obviously with negative consequences for the oil production and the environment. Over the last decade, microseismic monitoring at Imperial Oil's Cold Lake oil field, one of the largest sources of crude oil in Canada, has been undertaken in order to detect casing failures as well as seismic activity originating from the rock mass. Casing failure detection is based on a theoretical model characterizing seismic wave radiation following a well casing failure episode. The use of this model proved to lead to successful detection of casing failures in over 80% of the cases. The present paper establishes the framework used for the seismic detection of casing failures, presents a summary of the successful detection results so far and some recent advances in the detection of casing failures. A collection of seismic events due to confirmed casing failures as well as microseismic events originating from the rock mass were analyzed and different seismic source parameters were calculated (energy, magnitude, seismic moment, etc). The paper describes the results of this analysis in terms of seismic characteristics of casing failure events, as well as a strategy that may allow for the automatic detection of such failures in real time. The paper also describes the positive operational impacts resulting from the detection of casing failures by the microseismic systems.

Keywords: microseismic, oil sands, casing failure

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SW006 **Oral Presentation** **6606**

Study of Koyna earthquakes using principal component analysis

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Several cases of earthquakes near reservoirs have been reported in different parts of the world during the last few decades. In general, seismic avtivity has been found to decline after the occurrence of the largest magnitude.Of these, the seismic activity near the Koyna reservoir is distinctly different since earthquakes of magnitude upto 5 continue to occur even after 40 years of the occurrence of the largest earthquake of magnitude 6.5 in 1967. An indepth analysis of such earthquakes has been undertaken in this paper using the Principal Component Analysis.For this purpose 12 parameters related to seismicity, mechanism of earthquakes, reservoir height, its volume have been selected and their interdependence examined using the new approach.It was found that earthquakes of 1967 and 1973 had the largest loading due to the reservoir height and the total seismic energy release in the first Principal Component. However the influence of these parameters was found to be negligible for 1980 earthquake. The results could be explained through the difference in the seismicity patterns of therse earthquakes.

Keywords: reservoir, associated, earthquakes

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SW006 **Oral Presentation** **6607**

A study of the origin of seismic events in Upper Silesian Coal Basin in Poland.

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It is generally held that seismicity associated with mining operations is not homogeneous but consists of at least two components. The first component is local, directly linked to extraction activity in mining excavations, whereas the second one is controlled by the regional stress build up on more than one mine scale. We investigated seismic catalogs from Upper Silesian Coal Basin in Poland, the seismically active region of underground coal mining carried on by some 40 collieries, in an attempt to identify and separate these two components of seismicity. Here we present results of some problem-oriented analyses of event size and epicenter distributions. The source size distribution of mining events was tested for multimodality. In most of the studied cases the distribution appeared to be apparently multicomponental. A nonparametric, kernel estimator with varying smoothing factor was used to locate on magnitude scale a crossing point between the local component, which is generally composed of smaller events and the regional, larger magnitude component. Furthermore, an analysis of deflections was applied to investigate the trends of epicenter migration of regional events. This analysis transforms a series of event epicenters into a series of defections i.e. the azimuths of lines connecting every two subsequent epicenters. Modes of deflection distribution indicate principal directions of epicenter migration. The results of these two techniques applied to the seismicty of USCB support recent hypotheses addressing the internal structure and low tectonic instability of the deep crustal basement of the USCB.

Keywords: mining seismicity, multimodality, deflections

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SW006 **Oral Presentation** **6608**

Acoustic emission induced by oscillating load in a laboratory experiment as a model of triggered seismicity

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The acoustic emission (AE) response in a Westerly granite sample was monitored during deformation at a confining pressure of 160 MPa. The sample was a pre-fractured cylinder with a diameter of 76.2 mm. Multiple stick-slip events were induced by loading the sample at a nominal strain rate of 10-7 s-1. During the experiment, small amplitude sinusoidal stress oscillations were superimposed on the steady axial shortening rate. The stress oscillations had periods of 175 and 570 seconds and amplitudes that were a few percent of the frictional sliding strength of the fractured sample to simulate periodic loading observed in nature (e.g., earth tides or other sources). The AE acquisition system included 13 piezosensors to record waveforms and provide a representative database for further analysis. A correlation was observed between the sinusoidal loading and the AE response. Although in some cases, the magnitude of the response diminished with continued loading. The correlation of the AE response was more pronounced at the higher frequency. A space-time spectral analysis for a point process was used to investigate details of the periodic components of the AE activity. The first result of this analysis was the demonstration of correlation between the applied oscillating load and the resulting AE activity. Also, correlations are most pronounced following stick-slip events as AE aftershock sequences. This result suggests a higher strain sensitivity of the fault surface when it is in a transient, unstable mode following dynamic rupture events.This work is supported by RF President grant 5009.2006.5 and INTAS grant 05-1000008-7889 and by project The transient geophysical processes in areas of strong natural and human-induced impacts: field observations and physical modeling of the India-Russia ILTP Programme.

Keywords: acoustic emission, load synchronization, modeling

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SW006 **Oral Presentation** **6609**

Inversion of a cavity surface from seismic wave arrival times

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For block-caving mines, the capital expenditure of the mine is incurred before mining commences. Once the mining starts and the cave propagates upwards, the only control over mining is the extraction rate of broken rock beneath the cave. Some recent problems at block-caving mines (e.g. Northparkes mine in Australia) have illustrated the need to monitor the progression of the cave surface, as the relation between this surface and extraction is crucial to safe and efficient mining. Seismic monitoring remains the most cost-effective technique for reliable cave monitoring, but the large velocity contrast between the low-velocity zone of crushed rock within the cave and the high velocity host rock presents some interesting challenges. In these mining situations, the base of the cave is known, and we would like to know where the upper cave surface is as mining progresses. Using the arrival-time data obtained at seismic sensors around the lower part of the cave from the numerous microseismic events occurring along the cave outer edges, we have the foundation of an overdetermined but non-linear seismic tomography problem. In contrast with the classical linear tomography problem involving a medium subdivided into hundreds of cells of constant velocity, we restrict the velocity model severely by using less than 20 free parameters.These parameters control the shape of the low velocity zone (the cave), the possible intermediate velocity zone of fractured rock surrounding the cave and the high velocity unaltered rock around the cavity. Moreover, the high velocity contrasts between broken and unaltered rock necessitates ray-tracing to be done as the assumption of straight seismic rays is not valid. To achieve this, we use Sethians Fast Marching Method for calculation of the P- and S-wave arrivals at arbitrary sensor locations given any seismic event source location and arbitrary velocity model. Various synthetic velocity models, parametrized in terms of this small number of free variables and assuming parabolic shapes and non-uniform B-spline surfaces (NURBS), can be created from P- and S-wave arrival times given certain fixed model parameters, sensor and event locations. For the inversion problem of finding optimal values for the unknown model parameters, the common simplex algorithm of Melder and Nead is used to perturb these parameters in order to minimize the difference between observed and calculated arrival times for all recorded seismic events. During evaluation of the cost function for a particular choice of free parameters, the seismic events are re-located using ray-tracing with the velocity model corresponding to the free parameters. The method has been applied to simulated typical mining situations, and successfully recovers the cave position that was used to create the synthetic arrival time data. A sensitivity analysis to errors has been performed using various staring values for the variable parameters and different grid point densities, of which the results are also discussed.

Keywords: tomography, velocity, cave

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SW006 **Oral Presentation** **6610**

Examples of Time Distribution of Seismic Events in Mines

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The underlying assumption when calculating probabilities and recurrence times from the size distribution of seismic events is that their inter-event times are randomly distributed. If inter-event times are power law distributed, or clustered, such assumption underestimates hazard for short times and overestimates it in long term. When deciding on the inter-event time distribution, one should not only look at the empirical density and cumulative distribution functions, because the shape of the body of different distributions may look similar. Data from four mines was tested using the Quantile-Quantile plots, excess-over-threshold plots, the coefficient of variation and the Anderson-Darling or Chi-squared statistic. In three out of four mines the inter-event time distribution of larger seismic events was random. The fourth data set show fat-tailed time characteristics with probability of having m > 4 event in the following two weeks 5.8% and three months later the probability of having such a event in the following two weeks dropped to 4.0%. Under the random assumption this probability would be constant, 4.5%.

Keywords: timedistribution, fattailed, random

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SW006 **Oral Presentation** **6611**

Estimating thickness of soft sediments in mining area using the HVSR method

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Legnica-Glogow Copper District (LGCD) in Poland is a region of high seismic activity caused by mining works carried on in three underground copper mines. Ground effect of the seismic events can be significant. Ground motion occasionally exceeds 0.1 g. The region is considerably urbanized and many buildings are located in large seismic impact zones. Therefore a knowledge on the thickness of soft sediments and amplification factors over LGCD is of primary importance. The Horizontal to Vertical Spectral Ratio method (the HVSR method) is widely used in natural seismicity investigations. In the present study it was applied to ground motion signals caused by the induced seismic events of LGCD. Acceleration signals from 11 ground motion recording stations were processed to calculate the HVSR-s The smoothed HVSR-s served for estimating Vs profiles using an inversion technique, and frequency of the HVSR main picks was used for finding the thickness of soft sediments. Finally, the geometry of the soft sediments was mapped. The estimated map of sediments was then correlated with borehole data. In general, the agreement between the estimates and borehole information was considerably well.

Keywords: hvsr

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SW006 **Oral Presentation** **6612**

Thermal signatures of groundwater flows associated with induced seismicity in Bebedouro (São Paulo)

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Macro-seismic and geothermal studies were carried out in Bebedouro, state of So Paulo (Brazil) where occurrence of seismic activity has been found to be induced by opening of groundwater wells. Results of field investigations reveal that seismic activity began in 2004 soon after completion of groundwater wells with depths greater than 100 meters for irrigation purposes. More than 100 events were recorded since then, mainly in an area of 2 x 4 km in the vicinity of the wells, some with magnitudes of up to 2.9. Local geological sequences encountered include Paleozoic sedimentary formations of the Paran Basin overlain by flood basalts of the Cretaceous period and Tertiary sediments. Geothermal studies were carried out in six wells in an attempt to identify thermal signatures of groundwater flows. The results reveal the existence of transient thermal regimes in all of the wells, characterized by the presence of two distinct zones, designated as CTZ and TGZ. In the top CTZ temperatures remain nearly constant to depths of about 100 meters, whereas in the underlying TGZ temperatures increase rapidly with depth. These results have been interpreted as indicative of significant down flow of fluids in the top zone and active conductive cooling of the underlying zone. Model fits to temperature profiles indicate fluid movements with velocities of 2 to 8m/h in CTZ and flow rates of 2 to 10m3/h. Model fits to temperature data from the lower TGZ section indicate the presence of ongoing conductive cooling, characterized by time scales of 0.4 to 1.2 years. The results of thermal modeling have been helpful in identifying the underlying process responsible for micro-seismic activity in this region. According to the current interpretation down flow of fluids from the upper sedimentary strata to under-saturated fracture zones in the lower basaltic layer is responsible for the occurrence of micro-seismic activity.

Keywords: thermalsignatures, inducedseismicity, bebedouro

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SW006 **Oral Presentation** **6613**

Analysis of Seismicity Triggered by High-Power Electric Pulses

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A new phenomenon pf seismicity triggered by man-made high-power electric pulses has been discovered based on results of field full-scale and laboratory small-scale experiments.An effect of high-power electromagnetic pulses of magneto-hydrodynamic (MHD) generator on the seismic regime over the Northern Tien Shan and Pamir regions has been studied. The MHD generator provideselectric current of 0.28 to 2.8 kA within 1.7 to 12.1 s in the connected emitting dipole with electrode spacing of 4.5 km.It was found that occurrence of local earthquakes after firing runs of MHD generator became higher than before them. An increased level of seismic activity was observed within 3 to 6 days after the firing runs. It was suggested that electromagnetic pulses result in discharge of energy accumulated by the Earth crust due to tectonic deformation processes. The energy is released in the form of series of relatively slight earthquakes instead of one catastrophic event. Detailed analysis of seismicity of theNorthern Tien Shan shows that the electromagnetic impact of MHD generator pulses results in deep and prolonged alteration of seismic process in the region under study and adjacent territories. During series of experiments with the pulsed MHD generator relative portion of more weak seismic events, seismic activity of the region, and its clustering increase.For verification of field results and to clear a possible mechanism of interaction of electromagnetic field with rocks under stressed conditions various laboratory experiments have been performed. The experiments were carried out under the biaxial compression in models composed of sand and cement. At different stages of loading of the models series of measurements of acoustic activity (AE) were conducted, each of them included repeated cycles of electric actions, applied to the model. The two modes of electrical action were realized: repetitive pulse train with pause between and single electrical pulse. It was established that electrical impact results in increase of AE in both cases. All results obtained by statistical analysis of field experiments and laboratory testing pointed to a possibility of application of high-power electromagnetic pulses for earthquake control by regulation of seismic flow and release of energy accumulated in the Earth crust in the form of large number of non-dangerous seismic events.

Keywords: earthquake, electromagnetic, triggering

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SW006 **Poster presentation** **6614**

Parameters of ground motion model induced with mining exploitation

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In Poland, there are copper mines in Lower Silesia and coalmines in Upper Silesia where seismic tremors appear. They produces strong ground motion and cause buildings damage mostly weak sometimes serious. The damage appears in epicenter zone and the motion intensity vanishes rapidly with distance. It is difficult to assess the space distribution of seismic signals structure. The wide band of wave frequency transmitted through rock masses, the influence of focal mechanism and amplification of seismic vibrations due to geological structure cause uncertainty in seismic signals distribution. The tops of seismic wave amplitudes, commonly used for description potential of seismic wave destruction have particularly high level of uncertainty. Also time of dynamic loading should be considered in estimation of predicted influence of seismic vibration on buildings response. In paper it is proposed to estimate parameters of model, describing the envelopment of particle ground motion acceleration, due to mining tremors, with formula u=G0.t.e-kt .The estimation of parameters G0 and k from smoothed power spectrum gives ability to estimate the maximum value of signal envelopment and its length. Ground motion recorded in coalmine is analyzed and building damage risk is assessed on the base of some combination of G0 and k parameters.

Keywords: mining tremors, ground motion model, power spectrum estimation

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SW006 **Poster presentation** **6615**

Monte Carlo uncertainty analysis of the source tomography for mining-induced seismic events

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The seismic source tomography uncertainty analysis has been carried out for the two induced seismic events that occured in Rudna copper mine in Poland. Selected earthquakes of magnitude Mw=3.0 and Mw=2.9 were recorded by the seismic network composed of over 60 short period, vertical seismometers recording ground velocity, located on the level of copper ore deposits. In the first stage, the relative source time function (RSTF) inversion was performed using empirical Green's function technique. The pseudospectral decomposition of the sought RSTF by a finite sum of gaussian kernel functions as well as the adaptive simulated annealing was used. In the second stage, the ensemble of rstfs was inverted for the kinematic, spatio-temporal history of the rupture. The seismic source was composed of 49 subfaults of 20x20m size forming the square fault plane of 140x140m. The Haskell's source model was assumed, where the rupture propagated unilaterraly with a constant rupture velocity. At the both inversion stages, the inversion uncertainties were estimated by the Markov Chain Monte Carlo sampling technique. The obtained results indicate a spatio-temporal complexity of the seismic moment release for studied earthquakes.

Keywords: source time function, source tomography, monte carlo methods

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SW006 **Poster presentation** **6616**

The ways of decreasing the mining-induced seismicity in deep open pits

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Serguei Reshetnyak, Stepan Savchenko

In case waste rock dumps measuring a few billion tons and tailing dumps with another hundreds million tons are located close to the deep open pits, it is necessary to have instrumental control installed for pit walls monitoring. To decrease the concentration of stresses next to the pit bottom the following concept has been tested – changing the geometry of the lower pit part, i.e. instead of trapezoid shape in the vertical cross-section a shape with smooth passages from walls to the pit bottom should be applied by wider berms. The studies have been performed using the boundary elements method for 2-dimensional definition. The 700 and 1000 m deep pits with traditional (flat) and new (smooth-round) bottom across and along the strike of the ore body have been considered. Three variants have been investigated as force fields: 1) action of only gravitational forces; 2) joint action of gravitational and horizontal tectonic stresses; 3) joint action of gravitational and tectonic forces with distributed loading near one of the pit walls simulating waste dump disposal. The open pit influence on the natural stresses distribution within the mass covers the distance of 1-1.5 of the characteristic size of the pit, i.e. to the depth of (1-1.5) h, where h – is the pit depth, while sideward – over (1-1.5) L, where L – is the horizontal size of the pit in its upper part. The rock below the pit bottom being influenced by only gravitational forces with tensile horizontal stresses occurring, thus, results in the formation of vertical fractures. In case of concurrent action of gravitational and tectonic forces in this part of the mass high compressive stresses appear which can result in the formation of fractures, parallel to the pit bottom and its swelling. This fact is an indicator of horizontal compressive tectonic stresses operating in the mass. At the concurrent action of gravitational and tectonic forces in the bottom part of the rock mass high horizontal tensile stresses are formed, especially in the lower part of the wall, with the magnitude of vertical gradient of 13 MPa per 100 m of the pit depth. Vertical stresses in the basic part of the mass near the open pit, except when the loading occurs, are distributed in accordance with the value of the multiplication of gravity horizontal constituent and the vertical distance from the day surface or the pit limit. The rounding of the pit bottom results in certain changes of the character of stresses distribution and values. In this example those changes are not, however, determining, which stipulates the need in looking for additional more efficient measures and other ways for decreasing the concentration of stresses in the surroundings of deep open pit.

Keywords: stress, solutions, open pit

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SW006 **Poster presentation** **6617**

Low energy microseismological emission as source of information about rock mass condition in tremor occurrence time estimation.

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One of the main problems in underground mining are rock mass tremors. To try predict such events it is necessary to gain information about the rock mass condition before a tremor occurs. The low energy microseismological emission recorded in the frequency range of 30 Hz 1000 Hz is a source of such information. Emission recorded in that frequency range is one of the main indicators of rock mass fracturing processes. In the paper the meaning of microseismology emission for mining tremor prediction is discussed. The concept is based on the PASH method used for investigating the fracturing process of a rock mass. A probability assessment of a seismic hazard is carried out by analyzing the microseismic emission. Traditionally, seismic hazard is based on the physical energy of such events. However, in microseismology, it is not possible in practice to estimate event energy. Therefore, it was assumed to carry out the seismic hazard assessment based on an analysis of time intervals between events. The concept is justified by the presence of a linear statistical relationship between such intervals and the logarithmic derivative of event energies. As a result, an estimation of hazard parameters in an Θ-window is possible. The dynamics of the fracturing process is the reason that hazard analysis should be carried out on the basis of measurement data recorded in Θ-time windows no greater than several dozens hours apart. It follows then, that emission recorded in the microseismology range only, because of its high activity and great number of recorded events, allows for statistical analysis. Moving the Θ-window by step of Δ and by subsequent repetitions of hazard parameter estimation, time series of those parameters are obtained. Time series include random factor and therefore their expected value is estimated. Such obtained time series of hazard parameters form the basis for defining of a so called Indicating function. This allows for time estimation of rockburst occurrence and assessment of the rockburst risk level. This paper was elaborated within the framework of a research project of the Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Cracow, founded by the Polish Ministry of Education and Science.

Keywords: tremors, microseismology, hazard

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SW006 **Poster presentation** **6618**

Specifics of the mining-induced seismicity in the Khibiny massif

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Earthquakes taking place in the central part of the Kola Peninsula (Russia) attract researchers' attention, most of which unambiguously relate these events the impact of large-scale mining operations on the Earth crust, under the influence of which stresses are redistributed in both the near mining field and at signifi-cant distance from them as well. Besides, under the influence of unloading (stoping operations) or loading (formation of large waste rock dumps and tailings) processes, regimes of deformation of different geody-namical blocks are upset, thereby, the natural tectonic processes in the Earth crust of the region become more intense, which, in turn, changes the seismic regime and is manifested through the increase of seis-micity. The mining operations depth increase resulted in manifestations of mining-induced seismicity, first, in underground mines and later in open pits. Rockbursts in underground mines were first registered at rela-tively little depth, which testifies of the presence of tectonic component of the stress of rock mass. As mining operations started developing below the level of the valley part of the relief, rockbursts were fol-lowed by tectonic rockbursts, while later, by mining-induced earthquakes. A proof of that are shallow-focus earthquakes with magnitude of 3-4, that have occurred in the mine fields since 1984. Seismic events, resulted in the destroying of workings and communications in the mine and buildings on the surface, are considered to be either tectonic rockbursts or mining-induced earth-quakes. The analysis of the foci location shows, that all earthquakes, with rare exception, occur in the ac-tive faults zones and are grouped in the intermediate vicinity of the area of mining operations. We have performed the analysis of rockbursts and mining-induced earthquakes parameters, instrumen-tally registered in the Khibiny massif in the area of large-scale mining operations. All the events have been divided into groups, following the reason, that triggered the event: 1 – natural phenomena; 2 – natu-ral – mining-induced; 3 – mining-induced. They have been further split into subgroups, according to place of manifestation: 1 – at the underground mining; 2 – at the open pit mining; 3 – at the combined mining; 4 – in the mass. Within the subgroups, they have been sorted out according to the manifestation depth, to the destroying scale and to the events energy. The calculated events focal mechanisms have also been taken into consideration in the analysis. The results of studies allows us to hope for a more grounded assessment of the mining-induced seis-micity, its prediction and prevention or reduction of the rock pressure manifestations influence on the mining operations.

Keywords: seismicity, parameters, assessment

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SW006 **Poster presentation** **6619**

Induced seismicity monitoring of an underground salt cavity under a controlled pressure excitation

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Within the framework of a research project launched to assess the feasibility of seismic monitoring of underground growing cavities, this specific work focus on the analysis of the induced microseismicity generated by a controlled pressure experiment recently carried out in a salt mine environment. A local seismic array has been installed over a stable underground cavity within a salt layer located in the Lorraine basin (north-east France). The array includes four 3D components and three 1D component geophones (40 Hz - 1 kHz) deployed at depths between 30 m to 125 m in cemented boreholes drilled in the vicinity of the studied salt cavity. The underground cavity under monitoring is located within a salt layer at 180 m depth and it presents a rather irregular shape that can be approximated by a cylindrical volume of 50 m height and 100 m diameter. Presently, the cavity is full of saturated brine inducing a significant pressure on its walls (~2.2 MPa) to keep the overburden mechanically stable. Nevertheless some small microsesimic events where recorded by the array and analysed (~500 events in two years of recording). In October 2005, a controlled pressure transient experiment has been carried out in the cavity in order to analyse the mechanical response of the overburden by tracking the induced microseismicity. The recorded events are mainly grouped in clusters of 2 to 30 seconds of signal duration with non-emergeant first arrivals and rather low frequency content (between 20 to 120 Hz). Some of these events have been spatially located by travel-time picking close to the actual cavity and its immediate roof. Preliminary source spectral analysis suggests rather slow sources possibly related to fluid pressure variations, and/or resonant modes due to the dynamic excitation of the brine-filled cavity. Rock-debris falling into the cavity from delamination of clayley marls in the immediate roof is possibly another source of seismic excitation. No clear evidence of classical brittle ruptures in the competent layers of the overburden has been observed up to now. Current work is focused on the discrimination of all these possible mechanisms to better understand the damage processes within the rock mass.

Keywords: microseismicity, salt cavity

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SW006 **Poster presentation** **6620**

Studying of earthquakes source migration, caused by reservoir impoundment

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Elastic stress increase following filling of the reservoir, will cause increasing in pore water pressure in saturated rocks (due to the decrease in pore volume associated with compaction) and shallow earthquakes near to reservoir. Induced Seismicity suggests that the crust is in a critical state and fluctuations of water, behind the dam could trigger release of this energy, so these fluctuations are important parameter of seismic behavior of dam. Now its obvious that after impounding of a dam, Seismicity rate of the area increases and many non active areas beings active. In this study we concentrated on effects of impoundments on the Seismicity of karun3 dam, located in south west of Iran at the Zagros province. By means of a local network installed before impounding in order to studying seismic sources, we had sufficient data to study the Seismicity around dam. We analyzed earthquakes accrued around reservoir of approximately 2 years before and 2 years after impounding. Great amount of data allowed us to have exact consideration of Seismicity before and after of impoundments. Results show some faults and areas being active after impounding. In addition, directivity of earthquake epicenter consideration shows a distinct change of earthquake location. Calculating of Seismicity parameters and energy release of earthquakes verify this change. Earthquake swarms in this case have made a new regime of Seismicity for the area. The gradient of water level curve seemed to have an important role in Seismicity; abrupt change will cause high rates of earthquake occurrence.

Keywords: epicenter distribution, energy release, water level

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SW006 **Poster presentation** **6621**

Can't groundwater level be induced by shear waves?

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Water level fluctuations of many open wells are observed due to the passage of teleseismic earthquake waves. These oscillations of water level resemble seismograms and were referred to be hydroseismograms. The first published observations of hydroseismograms were by Blanchard and Byerly [1935]. They referred to the apparatus that recorded the hydroseismogram as a phreatic seismograph and recognized the phase arrivals of P, S and Rayleigh waves on their hydroseismograms with absence of Love waves. They suggested a simple model by assuming that the aquifer was an open cavity and that a volumetric change of the cavity induced a change in the well level. They attributed the phase that corresponded to the arrival of the S wave to the mode conversion of a shear wave to a compressional wave at the free surface, and explained the absence of love waves on the basis of the theoretical prediction that there is no dilatation of the cavity due to Love waves. Many later reports supported this view (Eaton and Takasaki, 1959; Cooper, 1965; Liu, 1989; Kano and Yanagidani, 2006). While Rexin et al. (1962) used the same apparatus and observed P, PP, PPP, S, SKS, PS, PPS, SS, LR as well as LQ (Love) waves in the Nunn-Bush well in Milwaukee. They explained this as a result of passage of the Love wave train effectively changing the local vertical and therefore affecting the relative elevation of water level within the reservoir at most points. In this research, we used a 16bit recorder system to line with hydraulic sensor and digitally sampled water level in 50Hz at a near 3000 meter deep Zhouzhi well and recorded the 2004 greatSumatra earthquake. We exactly compared the Hydroseismogram with seismograms recorded in Xian CDSN station which is 68km away from the deep well. We captured the body waves and surface waves completely and we can not deny the Love waves of the water level record. We try to suggest a shear-compaction/dilatation conceptual model to explain the observation results.

Keywords: groundwaterlevel, shear waves, 2004 sumatra earthquake

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SW006 **Poster presentation** **6622**

Relocation of mining induced seismic events occurred in upper Silesian coal mine district (Poland)

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This presentation deals with a comparison of probabilistic Monte Carlo based (MC)and Double difference (DD) location methods. Both algorithms were applied to relocate mining induced events from Upper Silesian (Poland) coal mine district, recorded between 1997 - 2004. MC approach shows explicitly a very strong correlation between the origin time and depths of events. Adding velocity to inversion procedure shows also correlation between the origin time and velocity as well velocity and depths. This observation well confirm the problem with an accurate location in complicated geological environments and demonstrates the usefulness of the DD approach.

Keywords: mining seismicity, induced seismicity, location

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SW006 **Poster presentation** **6623**

Focal mechanism determination of micro earthquakes induced in reservoir

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Activities performed on reservoir as fluid injections or oil and gas extractions induce microseismic events (ML < = 0). If the location of this microseismicity is a common method to image active faults, the determination of focal mechanism to characterize the fault type is less frequent. The knowledge of source geometry still brings important information about strain and fracturation in reservoir. Furthermore it is possible to obtain state of stress by focal mechanism inversion. The study of space-time evolution of stress in response to various activities in the reservoir can be a good tool for reservoir management. Consequently, we address the problem of focal mechanism determination for the micro-events induced in the reservoir, using few 3-components seismological records. For this, we develop a non linear inversion approach based on a Metropolis probabilistic optimization method (1953). We invert the first arrival amplitude of P, SV and SH waves and determine the 3 parameters (strike, dip and rake of fault plane) characterizing a double couple focal mechanism. We validate our approach with synthetics data computed in a homogeneous isotropic unbounded medium. Such medium is a simple approximation of reservoir with well sensors. We use a point source model with a triangular source time function. Results of tests show the influence of medium attenuation, network design and signal to noise ratio on the efficiency of the inversion. We apply our method to a data set of 112 micro earthquakes induced in a gas stocking site. These events are recorded by a network of 5 sensors set up in 5 different wells at a 250 m depth. Results of inverse with synthetic and real data will be presented.

Keywords: focal mechanism, non linear inversion, induced seismicity

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SW006 **Poster presentation** **6624**

Monitoring and modeling induced seismicity in the Netherlands

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In the North of the Netherlands exploitation of gas fields causes induced seismicity. Since 1986 app. 500 earthquakes have been recorded of magnitude (Ml) between -0.2 and 3.5. Because the recorded events are shallow (2-3km depth) and the region is densely populated, people often report damage (small cracks in walls) for magnitudes from 2,5 onwards. The KNMI is presently upgrading and extending a borehole network of seismometers to monitor seismicity in the region. In addition a network of accelerometers is in development. Observed waveforms show a significant amplitude variation at close epicentral distances (0-10km). We believe this variation is due to source effects. Since seismicity patterns show a lining up with existing faults at the top of the gas reservoirs, waveform amplitudes from re-activated faults are modeled and compared with recorded accelerations at close distances to the fault. Results of this modeling will be shown.

Keywords: monitoring, induced, modeling

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