# International Lithosphere Program – ILP

# "Solid Earth – Basic Science for the Human Habitat"

## ILP's Second Potsdam Conference
## 6-8 October 2010

## GFZ German Research Centre for Geosciences

Programme & Proceedings

Edited by
Alexander Rudloff, Roland Oberhänsli & Sierd Cloetingh

October 2010

## Introduction

In July 2007 GFZ hosted the ILP's first Potsdam Conference, titled "Frontiers in Integrated Solid Earth Sciences". The results of this meeting were presented in an over 400 pages large Springer book, the first volume of a new series on the International Year of Planet Earth (IYPE).
This time we were happy to welcome the ILP family and friends to Potsdam in autumn. Overall more than 70 scientists from more than 20 states worldwide came together and shared their results, ideas and visions.

## Group picture

## Acknowledgements

The organizers highly appreciated the motivated support by Anne Jähkel and Oliver Oswald during the conference. Without Christine Gerschke's work before, during and after the conference it would not has been possible to host such an event. Thanks to Elisabeth Gantz for the photo documenting of the meeting.

Financial support by the GFZ is gratefully acknowledged.

# ILP's Second Potsdam Conference, 6-8 Oct. 2010

## Programme

## Wednesday, 6 Oct. 2010

**12:00 p.m.** **Registration (GFZ, Building H)**

**2:00 p.m.** **Opening Session**
**Welcome address on behalf of GFZ – Michael H. Weber**
**Opening – Sierd Cloetingh**
**Technical remarks – Alexander Rudloff**

**3:00 p.m.** **Session: "Circum-Arctic Lithosphere Evolution"**
**Chair: Victoria PEASE**

Pease, V. (8-01): *"Circum-Arctic Lithosphere Evolution (CALE)"*
Jokat, W. (8-02): *"New insights into the tectonic evolution of the Amerasia Basin, Arctic Ocean"*
Stephenson, R. (8-03): *"The topography of the Eurekan Orogen of Ellesmere Island and the Canadian-Greenland polar continental margin"*

**4:00 p.m.** **Coffee Break & Group Picture**

**4:30 p.m.** **Session: „Sedimentary Basins"**
**Chair: Magdalena SCHECK-WENDEROTH**

Sippel, J., Scheck-Wenderoth, M., Lewerenz, B., Kröger, K. (9-01): *"The Thermal Field Below Permafrost - A Crustal Model of the Beaufort Mackenzie Basin (Arctic Canada)"*
Autin, J., Scheck-Wenderoth, M., Loegering, M. J., Anka, Z., Vallejo, E., Rodriguez, J. F., Marchal, D., Reichert, C., di Primio, R. (9-02): *"Colorado Basin Structure and Rifting, Argentine passive margin"*
Thybo, H. (9-03): *"Moho and magmatism in extensional settings"*
Roure, F., Scheck-Wenderoth, M. (9-04): *"The ILP Task Force Sedimentary Basins"*

**5:50 p.m.** **Session: „Volcanoes and Society" (Part I)**
**Chairs: Alessandro TIBALDI, Meral DOGAN**

Dogan, A.U., Dogan, M., Peate, D. (10-01): *"Chemostratigraphy concept as applied to some volcanostratigraphic units at Cappadocia, Central Anatolia, Turkey"*
Dogan, M., Dogan, A.U., Balic-Zunic, T. (10-02): *"Chemostratigraphy as applied to some volcanostratigraphic units at Ihlara Valley, Central Anatolia, Turkey"*
Cavallo, A., Dogan, A.U., Dogan, M., Mattioli, M., Renzulli, A., Rimoldi, B., Tibaldi, A. (10-03): "First investigations about erionite and offretite in Italian volcanic environments"
Cardaci, C. (10-04): *"The Civil Protection volcanic risk management in Italy"*

**8:00 p.m.** **ILP Dinner („Historisches Gewölbe" im Kutschstall, Am Neuer Markt 9)**

## Programme (continued)

## Thursday, 7 Oct. 2010

**8:30 a.m. Session: „Volcanoes and Society" (Part II)**
**Chairs: Alessandro TIBALDI, Meral DOGAN**

Thompson, R. N. (10-05): *"Living beside an explosive volcano during a long eruption requires changes to standard public outreach tactics"*
Sigmarsson, O. (10-06): *"Dynamic magma mixing during the 2010 Eyjafjallajökull eruption, Iceland"*
Apuani, T., Merri, A., Corazzato, C., Tibaldi, A. (10-07): *"Numerical modeling of the Etna flank instability: relations between geological settings, magmatic activity and flank dynamic"*
Rust, D., Teeuw, R., Argyriou, N., Dewdney, C., Solana, C. (10-08): *"Assessing volcano flank instability in Dominica, Lesser Antilles arc"*
Bathke, H., Walter, T. R., Shirzaei, M. (10-09): *"Deformation at Llaima volcano, southern Andes"*

**10:10 a.m. Coffee Break**

**10:40 a.m. Session: "From Microseismicity to Large Earthquakes"**
**Chair: Marco BOHNHOFF**

De Martini, P.M. (1-01): *"Global and Regional Parameters of Paleoseismology; Implications for Fault Scaling and Future Earthquake Hazard"*
Bohnhoff, M., et al. (1-02): *"From Microseismicity to Large Earthquakes: Studies Related to Seismic Hazard Assessment, Carbon Sequestration and Sustainable Resource Management"*
Korjenkov A.M., Rust D., Tibaldi A., Abdieva S.V. (1-03): *"Strong paleoearthquakes along the Talas-Fergana Fault, Kyrgyzstan"*
Shirzaei, M., Walter, T. R. (1-04): *"The 12 Jan 2010, Haiti earthquake affected by a seismic fault slip"*
Sudhaus, H., Walter, T. R. (1-05): *"Strategies for improved earthquake source modelling using InSAR (Interferometric Synthetic Aperture Radar)"*

**12:20 p.m. Session: "3D Geomechanical Modelling of Geodynamic Processes"**
**Chair: Oliver HEIDBACH**

Tesauro, M. (4-01): *"Global map of strength and elastic thickness of the lithosphere"*
Elesin, Y., Artemieva, I., Thybo, H. (4-02): *"Numerical modelling of the evolution of Baikal Rift Zone"*

**1:00 p.m. Lunch Break**

**2:00 p.m. Session: "What is the Lithosphere-Asthenosphere Boundary?"**
**Chairs: Ulrich ACHAUER, Jaroslava PLOMEROVA**

Achauer, U. (6-01): *"What is the lithosphere-asthenosphere boundary – a quest for information"*
~~Artemieva, I. (6-02): *"Defining the LAB: semantics versus physics"*~~ (cancelled)
Plomerova, J., Babuska, V. (6-03): "European LAB constrained from seismic anisotropy"
Jung, S. (6-04): *"The nature of the asthenosphere-lithosphere boundary – constraints from high precision multi-isotope (Sr, Nd, Pb, Hf, Os) and HFSE (Zr-Nb-Ta-Hf) data"*

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## Programme (continued)

**3:20 p.m. Session: "Mantle Dynamics and Plate Architecture Beneath North Africa"**
**Chair: Carlos GARRIDO**

Garrido, C.J., Bodinier, J.L. (7-01): *"MeDyna – Mantle Dynamic and Plate Architecture Beneath North Africa"*
Hidas, K. (7-02): *"Deformation and melt localization in the subcontinental lithospheric mantle: a case study from the Ronda peridotite massif, Spain"*
Marchesi, C. (7-03): *"Trace element and Sr-Nd-Pb isotopic compositions of Cr-rich pyroxenites from the Ronda massif (Southern Spain): geodynamics implications for the westernmost Mediterranean in Cenozoic time"*

**4:20 p.m. Coffee Break and Poster Session (for Details, see pages 4 and 5)**

## Friday, 8 Oct. 2010

**9:00 a.m. Session: „The Unconventionals"**
**Chair: Hans-Martin SCHULZ**

Littke, R., Krooss, B., Uffmann, U.K., Schulz, H.M., Horsfield, B. (11-01): *"Unconventional fossil fuels in Germany - overview and research perspectives"*
Doornenbal, H. (11-02): *"An overview of unconventional gas in The Netherlands"*
Moretti, I,, Vially, R., Bessereau, G. (11-03): *"Shale gas in France: source rocks and their maturity in French sedimentary basins"*

**10:00 a.m. Session: "Probing Subduction Zones"**
**Chairs: Philippe AGARD**

Agard, Ph. (3-01): *"Petrogeodynamics of HP-LT rocks: state of the art and application to processes along the subduction channel"*

**10:20 a.m. Coffee Break**

**10:50 a.m. Session: "Continental Collisional Orogens and Deep Subduction"**
**Chairs: Larissa DOBRZHINETSKAYA, Wali FARYAD**

Dobrzhinetskaya, L. (2-01): *"Frontiers in Ultra-High Pressure Metamorphism researches"*
Jahn, S. (2-02): *"Fluids under extreme conditions of pressure and temperature: insights from ab initio molecular dynamics simulations" – INVITED*
Nagel, T. (2-03): *"Metamorphic Diamonds and multiple regional high-pressure and ultra-high pressure events in the Rhodopes" - INVITED*
Faryad, S. W. (2-04): *"Significance of garnet peridotite and garnet clinopyroxenite studies for understanding deep subduction in the Moldanubian zone of the Bohemian Massif"*
Nita, B., Malinowski, M., Dobrzhinetskaya, L., Perchuc, E. (2-05): *"Anomalous mantle beneath collisional orogen of the Alps and its mineralogical interpretation" – INVITED*

**12:30 p.m. Closing Session**

**1:00 p.m. End of Meeting**

## Poster Session

Korjenkov A.M., Abdieva S.V., Morozova E.A., Vakhrameeva P.S. (P1-01): *"Unknown historical earthquakes in north-west of the Issyk-Kul Lake region, western Tien Shan"*

Li, Z., Yang, J., Li ,T. (P2-01): *"Helium isotopic composition of the eclogites from the Lasha Terrane, Tibet: Information from deep mantle"*

Shirzaei, M., Walter, T. R. (P2-02): *"Volcanic and tectonic deformation monitoring in central Alborz, northern Iran, using advanced InSAR time series"*

Liu, F., Gerdes, A. (P2-03): *"Differential subduction and exhumation of crustal slices in the Sulu HP-UHP metamorphic terrane"*

Nahodilová, R., Faryad, S. W., Dolejš, D., Tropper, P., Konzett, J. (P2-04): *"High-pressure partial melting of the Moldanubian felsic granulites in the Bohemian Massif"*

Okrostsvaridze, A., Tormey, D., Bluahsvili, D. (P2-05): *"Ascent Distance of Anatectic Granitoid Melts in Collisional Orogens: The Greater Caucasus"*

Bakun-Czubarow, N., Dobrzhinetskaya, L., Jung, H. (P2-06): *"Garnet peridotites with microtextural memory of UDO within Bohemian Massif - their significance for mantle dynamics and terrane structure of Central European Variscides"*

Abratis, M., Brey, G., Viereck-Goette, L. (P6-01): *"Age and textural anisotropy of the SCLM derived from studies on xenoliths of the Central European Cenozoic Igneous Province (CECIP)"*

Babuska, V., Plomerova, J. (P6-02): *"Continental mantle lithosphere as a patchwork of micro-plates with their own pre-assembly 3D seismic anisotropy signature"*

Frets, E. (P7-01): *"Preliminary structure of the Beni Bousera peridotite massif, Northern Morocco"*

Konc, Z. (P7-02): *"Nature of the lithospheric mantle beneath SE Iberian Volcanic Province inferred from alkaline basalt hosted mantle xenoliths"*

Kourim, F., Alard, O., Bendaoud, A., Bodinier, J.-L., Bosch, D., Dautria, J.-M., Demouchy, S., Kienast, J.-R., Ouzegane, K., Tommasi, A., Vauchez, A., Yahiaoui, R. (P7-03): *"Lithosphere architecture and mantle dynamics underneath the Ahaggar volcanic swell: a view from xenoliths"*

Artemieva, I.M., Thybo, H. (P8-01): *"An Overview of Structure and Evolution of the Lithosphere in the North Atlantic Region"*

Baristeas, N., Anka, Z., di Primio, R., Rodriguez, J. F., Marchal, D., Vallejo, E. (P9-01): *"Seismo-Stratigraphic Analysis and Characterization of Hydrocarbon Leakage Indicators in the Malvinas Basin, Offshore Argentine Continental Margin"*

Hartwig, A., Boyd, D., Kuhlmann, G., Adams, S., Campher, C., Anka, Z., Di Primio, R., Albrecht, T., Singh, V. (P9-02): *"Characterization of Hydrocarbon Generation and Migration Dynamics Based on Seismic Interpretation and Basin Modeling: an Integrated Study of the Orange Basin, South Africa"*

Ostanin, I., Anka, Z., Di Primio, R., Skeie, J. E. (P9-03): *"Identification of a large polygonal-fault network in the Hammerfest Basin: implications on migration and leakage of hydrocarbons in the South Western Barents Sea"*

Alberico, I., Petrosino, P., Maglione, G., Armiero, V., Bruno, L., Lirer, L., Dal Piaz, A. (P10-01): *"Tools for a better hazard management at Campi Flegrei volcanic field"*

Pasquarè, F.A., Tormey, D.,Vezzoli, L., Okrostsvaridze, A., Tutberidze, B. (P10-02): *"Mitigating the consequences of extreme events on strategic facilities: Evaluation of volcanic and seismic risk in the Caspian oil and gas pipelines in the Republic of Georgia"*

Balic-Zunic, T., Jakobsson, S. P., Garavelli, A., Mitolo, D., Jónasson, K., Acquafredda, P., Morten Jølnæs Jacobsen, M. J. (P10-03): *"Mineralogy of encrustations from the recently and presently active Icelandic volcanoes"*

Bayraktutan, M. S. (P10-04): *"Environmental and social impacts of volcanic-geothermal activities in eastern Anatolia, Turkey"*

## Poster Session (continued)

Corazzato, C., Tibaldi, A., Cavallo, A., Bonali, F., Lanza, F., Nardin, A. (P10-05): *"Plio-Quaternary kinematics and geometry of the Calama-Olacapato-El Toro fault zone across the Puna Plateau, Argentina"*

Paguican, E.M.R, Lagmay, A.M.F, van Wyk de Vries, B., Quina, G. (P10-06): *"Revisiting the historical debris avalanche deposit at the footslopes of Iriga Volcano, Philippines"*

Santo, A.P., Corselli, C., Tessarolo, C., Tibaldi, A. (P10-07): *"The hidden volcanic hazard: the low-water submarine volcanoes of the Sicily Channel, Mediterranean Sea"*

Tibaldi, A., Bistacchi, A., Pasquarè, F. A., Rust, D. (P10-08): *"Magma migration below volcanoes: the Isle of Skye, Scotland, intrusive system revisited"*

Tormey, D.,Pasquarè, F.A., Vezzoli, L., Okrostsvaridze, A., Tutberidze B. (P10-09): *"Determination of Risk Response Measures for Strategic Facilities: Caspian Oil and Gas Pipelines in the Republic of Georgia"*

Bonali F.L., Tibaldi A., Cavallo A., Corazzato C., Lanza F., Nardin A. (P10-10): *"Elastic stress interaction between faulting and volcanoes along the Calama-Olacapato-El Toro fault zone, Central Andes"*

Cavallo, A., Nardin, A., Tibaldi, A., Corazzato, C., Lanza, F., Bonali, F. (P10-11): *"Relationship between structures, petrochemical features and hydrothermal alteration along the Plio-Quaternary Olacapato-San Antonio fault zone (NW Argentina)"*

Dogan, M., Dogan, A. U., Tibaldi, A., Yesilyurt-Yenice, F. I., Alaygut, D., Ozbay, S. S., Akkus, M., Tosun, S. (P10-12): *"Comprehensive Review of Pleistocene Volcanics of Italy Using Classical Geochemical-Petrological Discriminant Diagrams"*

Dogan, A. U., Dogan, M., Tibaldi, A., Kuleci, I. H., Dogruel, Z., Unsal, O., Senyurt, Y. Y. (P10-13): *"Comprehensive Review of Pleistocene to Recent Volcanics of Italy Using Classical Geochemical-Petrological Discriminant Diagrams"*

Kadirov, F.A., Gadirov, A.H. (P10-14): *"Model of Mud Volcano by Geophysical and Geodetic Data"*

Yesilyurt – Yenice, F. I. (P10-15): *"Mineralogical composition of Mt. Erciyes lavas to calculate with MELTS model"*

Viereck-Goette, L., Koch, M., Lepetit, P., Abratis, M. (P10-16): *"Mesothelioma epidemic in Cappadocia, Turkey – risk assessment by geological survey"*

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# Age and textural anisotropy of the SCLM derived from studies on xenoliths of the Central European Cenozoic Igneous Province (CECIP)

**Michael Abratis[1], Gerd Brey[2], Lothar Viereck-Goette[1]**

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Abundant peridotite xenoliths in mafic magmas represent direct samples of the sub-continental lithospheric mantle (SCLM) and are therefore valuable sources of information on the composition, structure and age of the mantle lithosphere. Previous work on the Central European Cenozoic Igneous Province (CECIP) and on peridotite xenoliths includes whole rock and mineral chemistry and radiometric ages of the mafic host volcanics, peridotite petrology and geothermobarometry. These studies showed that the lithospheric mantle was commonly sampled by ascending magmas over a broad range of depths and that the mantle was variably metasomatized by fluids and melts. Lu-Hf dating of peridotite xenoliths has recently proven to be suitable to date a depletion event of 310-370 Ma and thus the formation age of the lithospheric mantle (Wittig et al. 2007; Lazarov et al., 2009). Earlier efforts with Rb-Sr or Sm-Nd provided Mesozoic (< 200Ma) or Hercynian (~365 Ma) secondary metasomatic ages (Stosch et al., 1980; Witt-Eickschen & Kramm, 1997).

Peridotite xenoliths of the CECIP will be analysed for their formation (Lu-Hf age) and (if secondarily overprinted) metasomatic ages (Rb-Sr or Sm-Nd ages) as well as for their degree of anisotropy. The textural anisotropy (crystal preferred orientation - CPO) of the mantle rocks will be determined by electron backscatter diffraction attached to a secondary electron microscope (EBSD-SEM) and could give information on the type and intensity of stress that effected the respective portion of the SCLM. Determination of the CPO in mantle xenoliths would thus permit to deduce the origin of mantle anisotropies imaged by seismic methods (e.g. Babuška & Plomerová, 2006). The combined study of xenolith geochemistry, ages and fabrics will allow to describe compositional and textural variations in the mantle lithosphere in space and time.

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# What is the lithosphere-asthenosphere boundary – a quest for information

by

U. Achauer

The lithosphere-asthenosphere boundary (LAB) is the most extensive and active plate boundary on the Earth. It is inextricably linked to the properties of the underlying low velocity zone, which is of key importance to the architecture of continental and oceanic lithosphere and to the dynamics of plate tectonics. However, the LAB beneath the continents is relatively cryptic compared to other first-order structural subdivisions of Earth. Some aspects of the boundary are attributable to changes in physical properties along the geotherm, but new results suggest the possible influence of small amounts of melt, variations in hydration of nominally anhydrous minerals, grain size or in lattice preferred orientations. Though we face different physical definitions of the LAB in dependence on methods used to map the boundary, a general understanding "WHAT is the LAB is still missing".
From the recent DefLAB workshop it may be concluded that while a lithosphere-asthenosphere boundary is seen by most disciplines in Earth Sciences, the definition, the depth and what it means from the structural, the rheological and physico-chemical point of view is highly debated. There seem to be several "boundaries", namely the LAB-S (seismological), the LAB-M (mechanical), the LAB-T (thermal), the LAB-C (chemical) and the LAB-E (electromagnetic), all called by the colleagues from the particular fields in Earth Science "LAB" which differ in depth and thickness (i.e. whether they are discrete or more like a transitional layer) and most likely will not "define" at all the same thing!

It is evident that only a multi-disciplinary approach, bringing together all disciplines from Earth Sciences will help us to shed light on the above question and to better understand and communicate between the different fields in Earth Sciences, what the lithosphere-asthenosphere boundary is all about, what it's origin is and what role it has played and still plays in the evolution of our planet.

In this presentation we shall highlight some new results as well as discuss the differences between the different disciplines.

## Petrogeodynamics of HP-LT rocks: state of the art and application to processes along the subduction channel

P. Agard and the members of the new ILP task force "Probing subduction zones"

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Based on examples from the Betics, Oman, Turkey and the W. Alps, this contribution attempts to (1) critically evaluate the precision with which metamorphic P-T-t histories are retrieved at present and (2) discuss the implications on our understanding of processes taking place along the subduction channel. Emphasis is also placed on showing how timely it is to combine these data with geophysical and geochemical data, as well as with thermomechanical models.

Thanks to improved interconsistent thermodynamic databases, multiple thermodynamic softwares and analytical tools, numerous quantitative constraints on metamorphic histories are now accessible. I herein assess the merits and shortcomings of our present knowledge. I then focus on processes related with oceanic and continental subduction, based on our current knowledge of metamorphic histories worlwide.

In the W. Alps in particular, the comparison between the metamorphic evolution of the Schistes Lustrés paleoaccretionary complex and that of major ophiolitic bodies returned from the Alpine subduction (Zermatt-Saas, Avic, Rocciavre, Monviso) allows placing constraints on the nature and characteristics of the plate interface (eg, the so-called 'subduction channel') and reconstructing the geodynamic processes at work in a subduction zone. The dimensions of the bodies sliced up and stacked in the subduction channel, the depths and possible mechanisms at which this happens, and the role of fluid transfer are discussed, as well as along strike variations of the exhumation processes within the same subduction zone.

# Tools for a better hazard management at Campi Flegrei volcanic field

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## Abstract

The Campi Flegrei territorial system was interested in the most recent years by intense urban growth in terms of expansion, overlooking volcanic risk. The vulnerability of this areas is partly a consequence of decades of spatial planning policies that failed to take proper account of hazards in spatial planning. In this active volcanic area, where a short period evacuation could be necessary, the emergency management cannot be based only on the hazard map, but the systemic vulnerability must be also taken into account. To approach this problem a spatial relational GIS procedure was used to draw the emergency planning zone, the systemic vulnerability and collection zones maps essential to communicate scientific results to the population living in this dangerous area.
At this aim, following the concept of regional evacuation, the emergency planning zone was drawn as the whole of the area threatened by the volcanic events occurred in the last 10 ka. Inside this area the spatial relation between the population density distribution and the outflows of routes, railway stations and harbours, necessary to leave the dangerous area, were investigated and 59 zones with different capability to support the residents evacuation in case of volcanic unrest were identified in the systemic vulnerability map.
Basing on the concept that people could leave the dangerous area by transport means made available by Civil Protection, and using the threshold value of over-crowding of 0,70 people/ m2, the zones where people could be collected and immediately evacuated in case of an imminent and dangerous volcanic event were also identified.
These maps turn out to be powerful communication tools which help planners and disaster authorities in mitigating damages from volcanic hazards. They can contribute to enhance the volcanic hazard perception in Campi Flegrei volcanic field. The final step of the research here presented, in fact, was an assessment of the degree of risk perception aiming at investigating if and how much young people living in Campi Flegrei area are aware of inhabiting an active volcanic zone and how much they really know about the possibility of occurrence of an eruptive event in the future and the presence of evacuation plans. This phase of the study brought us to hypotesize innovative tools to improve the degree of knowledge of territory and to render population aware of living in an active volcanic area.

# Numerical modeling of the Etna flank instability: relations between geological settings, magmatic activity and flank dynamic.

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Mount Etna is the largest active European stratovolcano, located on the eastern coast of Sicily (southern Italy). As many active volcanoes it is subject to flank instability phenomena which can be attributed to the combination of different causes, such as gravity, rising magma along the feeding systems, and a very complex local and regional tectonic context. Different instability mechanisms were suggested to explain the Etna flank dynamics based on the recording deformation pattern and character. Shallow and deep deformations, mainly associated with both eruptive and seismic events, are concentrated along recognized fracture and fault systems, mobilising the eastern and south-eastern flank of the Etna volcano. Being the volcano flanks heavily urbanized, the comprehension of the gravitative dynamics is a major issue for public safety and civil protection.

The Etna geological setting is represented by the Hyblean platform to the south, subducted beneath the Apennine-Maghrebian thrust chain to the north and west. On the eastern flank of Etna, the Pleistocene subetnean clay unit is interposed between the Apennine-Maghrebian flysh units and the volcanic edifice products. The northern flank of the unstable mass is bounded by the Pernicana fault system, the southern flank boundary is not as well defined and is more diffuse. Several volcanotectonic elements, represented by both rift zones and faults, affect on the volcano dynamics.

A three-dimensional stress-strain analysis of the Etna edifice, performed by a difference finite numerical code (FLAC3D), is presented in this work, focusing on the relations between geological features and instability evidences, and aimed at evaluating the predisposing and triggering factors.

The analysis is well supported by dedicated structural-mechanical field survey, which provided the quantitative description of representative rock masses and allowed to determine the rock mass strength and deformability parameters, by geotechnical laboratory tests on the subetnean clay *(Koor et al., 2009),* and by previous bi-dimensional numerical modelling *(Corazzato et al., 2009)*.

The numerical model extends 40X60 km. An elasto-plastic constitutive law was adopted and an homogeneous Mohr-Coulomb strength criterion was chosen for each of the geological units: *volcanic edifice*, *subetnean clays*, *Apennine-Maghrebian flysh*. The groundwater conditions were imposed; no water flow was simulated, but two extreme conditions, drained and undrained, were analyzed.

The model was implemented to simulate the volcano deformation pattern. First the role of the Pleistocene subetnean clay was investigated; then two "structural weakness zone" - the Pernicana fault system and the NE rift – were introduced and their effects on the flank instability evaluated. The results are expressed in terms of stress-strain field, displacement pattern, plasticity states, shear strain increments. Two main instability mechanisms were identified: the first deep seated, and the second one at shallow depth, with sliding surface located inside the subetnean quaternary clay. Both mechanisms contribute to explain the actual deformation pattern and some of the main structures of the Etna flank.. The effect of magma pressure exerted on the active dyke walls during eruptions was then simulated and relations between magmatic activity and flank instability were investigated.

# An Overview of Structure and Evolution of the Lithosphere in the North Atlantic Region

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***University of Copenhagen, Denmark***

We present a review of the structure of the crust and the upper mantle in an area which covers about 1/8 of the globe and encompasses most of Europe, Iceland, Greenland, and Svalbard. Using the results from seismic (reflection and refraction profiles, P- and S-wave body-wave and surface-wave tomography), thermal, gravity, and petrologic studies (based both on the results of the authors and on literature compilations), we propose an integrated model of the structure and physical properties of the crust (a newly constrained model by the authors) and the upper mantle in the entire region down to a depth of 250-300 km. Our primary attention is to the lithosphere structure of the onshore parts of the region, but the less well constrained deep structure of the North Atlantic is also discussed. The results are summarized in a series of maps of lateral variations in crustal and lithospheric thicknesses, seismic shear wave velocity at different depth slices, heat flow and lithosphere temperatures, as well as density and compositional variations in the lithospheric mantle.

# Defining the LAB: semantics versus physics

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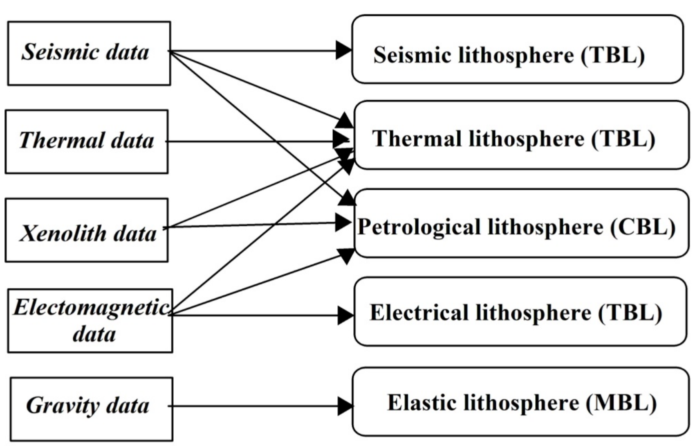
It is hardly possible to define the "base of the lithosphere", or the "lithosphere-asthenosphere boundary", without defining first what is the lithosphere. Depending on the geophysical techniques (and physical properties of mantle rocks indirectly measured in geophysical surveys), the lithospheric base has different practical definitions. The definition of the thermal lithosphere (or TBL - the layer with dominating conductive heat transfer above the convecting mantle) is the most straightforward, while most of other definitions (i.e. seismic, electrical, elastic) are based on a sharp change in temperature-dependent physical properties at the transition from conductive and rheologically strong to convecting and rheologically weak upper mantle, and thus crucially depend on the thermal regime of the upper mantle. Given that lithosphere definitions employed in geophysical studies are based on measurements of different physical properties of upper mantle rocks, they may (and, in general, do) refer to outer layers of the Earth with significantly different thicknesses. Additional complication arises from the fact that petrologically defined lithosphere should not necessarily (and, in general, does not) correspond to its geophysical definitions.

The existence of an excessive number of the "lithosphere" definitions explains why the term "lithosphere", which became a convenient and widely used concept in geosciences, is considered by Don Anderson (1995) to "become an unnecessarily confusing concept". Alternatively, one may argue that because of the complexity of the concept and because of its multi-disciplinary nature, the concept of the lithosphere is "necessarily confusing". A great deal of confusion arises not only from the fact that different "lithospheres" (seismic, thermal, electrical, petrologic, flexural) are distinguished, but also from the fact that the same very terms are used in approaches utilizing different techniques (see figure). Since these techniques often assess different physical properties of mantle rocks, they may refer to different phenomena and to different depth intervals in the upper mantle. Thus, I argue that while the concept of the "lithosphere" (despite being confusing) is very useful, the concept of the "lithosphere-asthenosphere boundary" is, on the contrary, misleading.




The text and the figure are cited with some modifications from: Artemieva I.M., 2009. The continental lithosphere: Reconciling thermal, seismic, and petrologic data. Lithos, 109, 23-46, doi /10.1016/j.lithos.2008.09.015.

# Colorado Basin Structure and Rifting, Argentine passive margin

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The Argentine margin presents a strong segmentation with considerable strike-slip movements along the fracture zones. We focus on the volcanic segment (between the Salado and Colorado transfer zones), which is characterized by seaward dipping reflectors (SDR) all along the ocean-continent transition [e.g. *Franke et al.*, 2006; *Gladczenko et al.*, 1997; *Hinz et al.*, 1999]. The segment is structured by E-W trending basins, which differs from the South African margin basins and cannot be explained by classical models of rifting. Thus the study of the relationship between the basins and the Argentine margin itself will allow the understanding of their contemporary development. Moreover the comparison of the conjugate margins suggests a particular evolution of rifting and break-up. We firstly focus on the Colorado Basin, which is thought to be the conjugate of the well studied Orange Basin [*Hirsch et al.*, 2009] at the South African margin [e.g. Franke et al., 2006].

This work presents results of a combined approach using seismic interpretation and structural, isostatic and thermal modelling highlighting the structure of the crust. The seismic interpretation shows two rift-related discordances: one intra syn-rift and the break-up unconformity. The overlying sediments of the sag phase are less deformed (no sedimentary wedges). The axis of the Colorado Basin trends E-W in the western part, where the deepest pre-rift series are preserved. In contrast, the basin axis turns to a NW-SE direction in its eastern part, where mainly post-rift sediments accumulated. The most distal part reaches the margin slope and opens into the oceanic basin. The general basin direction is almost orthogonal to the present-day margin trend. The most frequent hypothesis explaining this geometry is that the Colorado Basin is an aborted rift resulting from a previous RRR triple junction [e.g. Franke et al., 2002]. The structural interpretation partly supports this hypothesis and shows two main directions of faulting: margin-parallel faults (~N30°) and rift-parallel faults (~N125°). A specific distribution of the two fault sets is observed: margin-parallel faults are restrained to the most distal part of the margin.

Starting with a 3D structural model of the basin fill based on seismic and well data the deeper structure of the crust beneath the Colorado Basin can be evaluate using isostatic and thermal modelling.

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# Continental mantle lithosphere as a patchwork of micro-plates with their own pre-assembly 3D seismic anisotropy signature

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The concept of mobile terranes, or micro-continents, is considered as one of the most important additions to plate tectonics. However, we have only vague ideas about a role of large volumes of the mantle lithosphere in the formation of paleo-continents, in their brake-up and in later assemblage of their pieces into a new continent. Knowledge of seismic anisotropy is key to our understanding of tectonic fabrics in the deep lithosphere and sublithospheric mantle. To study building elements of the European continent, we have modelled three-dimensional seismic anisotropy of the mantle lithosphere from anisotropic parameters of teleseismic body waves. We invert and interpret jointly body-wave anisotropic parameters based on data from dense networks of temporary and permanent stations in several European regions. Changes in orientation of the large-scale anisotropy, caused by systematic preferred orientation of olivine, identify boundaries of domains of mantle lithosphere. Individual domains are characterized by a consistent large-scale orientation of anisotropy approximated by hexagonal or orthorhombic symmetry with generally inclined symmetry axes. The domains are separated by mapped tectonic boundaries (sutures), which cut the entire lithosphere. Such boundaries play important role in the lithosphere architecture and its dynamics, e.g. in the location of intraplate earthquakes and volcanic fields. Besides the change of anisotropy orientation at domain boundaries, we often observe a change of the lithosphere and/or crust thicknesses. We do not detect any fabric of the mantle lithosphere, which could have been produced by a collision of microcontinents in a volume detectable by large-scale seismic anisotropy. The observations of consistent anisotropy within individual blocks of the mantle lithosphere reflect frozen-in olivine preferred orientation, most probably formed prior to the assembly of microcontinents that created the modern European landmass (Babuska and Plomerova, PEPI 2006). West Australia also consists of terranes with the seismic structure preserved in each terrane prior to their assembly (Reading et al., Geology 2007). All these findings support a plate-tectonic view of the continental lithosphere as a mosaic of rigid blocks of the mantle lithosphere with complicated but relatively sharp contact zones. These contacts are blurred by the easily deformed overlying crust terranes.

# Garnet peridotites with microtextural memory of UDO within Bohemian Massif – their significance for mantle dynamics and terrane structure of Central European Variscides

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Within the Bohemian Massif there can be found garnet-bearing peridotites which preserved microtextural memory of ultradeep origin – UDO. The peridotites are Mg–Cr pyrope lherzolites, associated with garnet pyroxenite and/or eclogite layers. The rocks under consideration occur either as small boudins within felsic granulites in the Sowie Mountains Block (SMB) of Saxothuringian zone in the Polish West Sudetes, or within migmatitic gneisses of Kutna Hora (KH) complex in Gföhl unit of Moldanubian zone in Czech Republic. The rocks display inequigranular texture with large (up to 12 mm in diameter) garnet porphyroblasts set in a fine-grained peridotitic groundmass. In the garnet porphyroblasts there can be found three types of solid inclusions: 1) one- or two-phase oriented solid inclusions of rutile, ilmenite-geikielite solid solutions, pyroxenes, olivine, most likely topotaxially exsolved from precursor Ti-rich, majoritic-like pyrope, mainly along its {111} planes, rarely along {110} planes; 2) randomly distributed metasomatic type inclusions of crichtonite, magnesite, phlogopite, pentlandite; 3) multiphase oriented inclusions of rutile, $ilmenite_{ss}$, olivine, pyroxenes, spinels. The majoritic-like precursor for rich in topotaxial exsolutions garnet cores was not supersilicic but contained Ti-rich and Al-deficient molecules: $Ca_2Na(AlTi)Si_30_{12}$ and $M_3(MgTi)Si_30_{12}$ being indicators of UDO for garnets. On the basis of the preserved microtextural memory of UDO we can draw the conclusion that the garnet peridotites in question once were equilibrated at depths in excess of 200 km. During ascent to lower lithosphere and decompression the majoritic-like garnets topotaxially exsolved rutile, $ilmenite_{ss}$, olivine and pyroxenes. The results of EBSD studies of rutile needles exsolved in garnet cores have revealed strong correlation between [110] axes of rutile and [111] axes of garnet as well as [001] axes of rutile and [110] axes of garnet, whereas other axes of the both minerals are not strongly correlated, what can point to the simultaneous decompressional precipitation and rotation of rutile needles caused by deformation of the uplifted rocks.

For the provenance of the both KH and SMB garnet lherzolites we can postulate the following scenario: a) depleted, asthenospheric garnet lherzolites were uplifted to SCLM beneath Tepla-Barrandia, when – during decompression – the exsolution of Rt, $Ilm_{ss}$, Px and Ol from Ti-rich garnet took place; b) in Devonian bilateral subduction of Saxothurigia (that started earlier) and Moldanubia beneath Tepla-Barrandia took place; c) the wedge mantle peridotites beneath Tepla-Barrandia underwent mantle metasomatism caused by fluids/melts coming from subducted oceanic plates; d) the SMG garnet lherzolites were incorporated into felsic granulites and rapidly uplifted in Emsian, about 400 Ma ago, while KH lherzolites were incorporated into gneisses and exhumed in Tournasian, 340 Ma ago. The episode of uplift of UDO peridotites to SCLM, might be in the both cases – HK and SMB – unrelated to the Variscan continental collisional events. As to terrane tectonics of the Bohemian Massif, most likely, SMB belonged to the Tepla-Barrandia terrane. The results of recent palaeomagnetic studies confirmed this hypothesis, as during Emsian-Eifelian SMB was located to the south from the remaining West Sudetes and accreted them during Late Devonian.

# Mineralogy of encrustations from recently active Icelandic volcanoes

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Among the products of volcanic activity, encrustations formed through the action of gases and hot solutions form an important and very specific part. Their significance has several aspects. They can be a long-lasting source of pollution, they document the release of volcanic gases and liquids and, finally, they display a complex and intriguing mineralogy. Study of the mineralogy of encrustations gives valuable information on the composition and properties of fluids, the polluting and economic potential and can reveal new mineral phases with interesting and valuable properties. Due to the nature of the material, which for the most part is fine grained and heterogeneous because of fast deposition under frequently changing and non-equilibrium conditions, it is also one of the most demanding tasks in mineralogy.

Our collaborative research team has until now studied encrustations from three recent eruptions in Iceland: Surtsey (1963-67), Eldfell (1973) and Hekla (1991), and has started an investigation of material from the 2010 eruption on Fimmvörduhals on the flank of the Eyjafjallajökull volcano. The volcanoes are situated in South Iceland and follow a SW-NE direction through the Vestmannaeyjar archipelago to the most prominent in-land volcanoes of the Eastern Volcanic Zone. The composition of volcanic rocks changes gradually along this zone (from alkalic to transitional-alkalic) and so does the general composition of encrustations. We have recorded differences which successively change from sulphate-dominated at Surtsey at the SW tip to fluoride-dominated at Hekla at the NE end. At all sites the encrustations are very rich in mineral varieties with altogether over 50 different species. Among them, several new minerals have been recorded for the first time. We are presently studying these encrustations with a combination of high-resolution X-ray diffraction and electron microscopy in order to fully define their chemical composition and structure and get a better understanding of the conditions of their formation.

# Seismo-Stratigraphic Analysis and Characterization of Hydrocarbon Leakage Indicators in the Malvinas Basin, Offshore Argentine Continental Margin

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The goals of the study are to understand the geological long term evolution of the basin since rifting, to construct a 3D basin geo model and the interpretation of the abundance and distribution of hydrocarbon migration/leakage indicators present in the basin.

The Malvinas Basin is located south on the wide offshore Argentine continental margin, the signature of sea level fluctuations is expected to be well preserved on the stratigraphic succession of its wide-shelf area. Additionally, evidences of an active petroleum system and gas leakages have been reported for the eastern margin of the basin . We present here the first results from the interpretation of 650 2D seismic-reflection profiles, which cover the shelf and upper-slope of the basin. Additionally, 25 exploration wells were used as control points to tie to the seismic grid.

Five major seismo-stratigraphic units, informally named U1 to U5 a/b, were identified and correlated with the main tectonic phases of the margin. U1 (Pre-168 Ma) represents the seismic basement and deepens gradually southwards and is affected by several E-W and NW-SE normal faults rooted in the basement. U2 (168-150.5 Ma, syn rift phase) thickens and deepens southwards. It fills regional depressions, onlaps the basement and is locally affected by basement faulting. U3 (150.5-68 Ma, sag phase) is an aggraditional unit identified over the entire basin. It is predominantly affected by normal faults to the south. U4 (68-42.5 Ma, transtensional foredeep phase) overlies unconformly U3 and thickens to the south. The unit only has a few normal faults and some reactivated reversed faults in the south. Finally, U5 a/b (42,5~0 Ma, transpressional foreland phase) represents an interesting stratigraphic switch from aggradation to progradation. While on the west of the basin there are clinoforms prograding eastwards and downlapping the basal section, a northward onlapping wedge is identified in the deeper southern part of the basin.

Several seismic features interpreted as gas chimneys were mapped. Some of these features located to the western part of the basin seem to be sealed within unit U4, whilst another population on the eastern upper-slope reach the seafloor ending up in seafloor pockmarks.

All of them are found mostly above the basement normal faults, suggesting a control from the reactivating rifting tectonics. The source of gas may be located within the deepest units and its thermogenic origin has been proved from isotopic analysis on gravity cores.

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## Deformation at Llaima volcano, southern Andes

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### Abstract

Llaima volcano, with an edifice height of 3125 m and a volume of about 400 $km^3$, is one of the largest and most active volcanoes in South America. Its eruptive history suggest a potential for very large and hazardous eruptions including pyroclastic flows, air falls and material remobilization in the form of lahars affecting regions even at the lower apron and beyond, posing a significant risk to civilizations, infrastructure and traffic ways. Llaima volcano is near constantly active; since the 17th century strombolian eruptions occurred at a mean frequency of one eruptive phase every five years. Although this strong activity and socioeconomic importance the source of magma, possible magma reservoirs and deformations prior to or associated with eruptions are hitherto unknown. One of the problems for establishing a monitoring system is that Llaima is difficult to access and located in vegetated, topographically rough terrain.

To better understand the volcano physics, we created an InSAR time series based on the SBAS and PS technique using 18 Envisat images from Dezember 2002 to November 2008.

Applying the StaMPS software we obtained several thousands of stable pixels in the vicinity of the volcano, that allow to investigate a spatiotemporal displacement field. Associated with the recent eruptions, we observed non-linear subsidence at the vicinity of the volcano base. We assessed the validity of the deformation signal, using statistical tests and discussed the possible influence of atmospheric and topographic errors.

To investigate the cause of the observed spatiotemporal deformation we employed an inverse source modelling approach, and simulated the dislocation source as an analytical pressurized spherical model. The inverted source can reproduce the observed deformation and allows to constrain the location of the magma reservoir under Llaima.

Environmental and social impacts of volcanic-geothermal activities in eastern Anatolia,Turkey.
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ABSTRACT

This article focused on health, security and environmental apsects of volcanic-geothermal activity in eastern Anatolia, occurred during the last 10 Ka. Examples of hazardous effects of volcanism on ancient civilizations and safety of communities are summarized in choronological order. The region of study included in Urartu Plateau which covers eastern Anatolia- South Caucasus- NW Iran. Urartu Plateau, the second largest volcanic plateau after Tibet, developed along the south margin of Eurasian Plate, in front of continent-continent collision suture. To the frontal-north of Arabian Plate, between active collisional suture and Caucasus.
Various modes of volcanic- geothermal processes caused destruction around major complexes, such as Big Agri (Ararat) and Tendurek volcanoes. Debris flows, dust and poisonous gas eruptions caused big life loss and destruction of environment. Valleys were dammed, rivers diverted which caused flooding and erosion. In this article, historical volcanic disasters and their impacts on environment reported. Landslides and debris flows caused heavy destruction not only on human life, but also on earth surface morphology, hydrogeological regime and biological environment.
Geothermal fluids and gases caused severe healt problems in region north of Lake Van and Tendurek-Agri volcanoes. One of the last destruction occurred in 1840 in wide area around Agri Volcano. Nemrut Volcano to west of Lake Van caused similar destructive impacts on sorround-ing area. Geothermal fluid and gas extrusion in and around Nemrut Crater effected the area.
This report includes the Noahs Flood and Ark researches carried out around Mt Ararat volcanic complex, both on volcano itself and mudflows around. Noas Ark site in mudflow south of Mt Ararat has world wide attension. Geophysical survey data obtained from mudflow and glacier are presented. These volcanic activities in east Anatolia were associated to seismic activities as well.

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# Elastic stress interaction between faulting and volcanoes along the Calama-Olacapato-El Toro fault zone, Central Andes

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Abstract

The aim of this work is to describe the relationship between tectonics, earthquakes and volcanism along a Plio-Quaternary fault zone using Coulomb stress-change hypothesis. We investigated how the tectonic motions transferred stresses to nearby faults and volcanoes, using a series of representative models obtained by the Coulomb 3.1 software. We explored the elastic stress interaction between the Negro de Chorrillos and San Jerónimo Quaternary volcanoes, which lie exactly along the longest Quaternary transcurrent fault zone in the Central Andes: the Calama-Olacapato-El Toro (COT) structure. The COT fault zone transversally crosses the Andean chain and the Puna Plateau at about 24°S. This plateau is one of the two largest on Earth, together with the Tibetan Plateau, and has an average elevation of 3.7 km. It mostly resulted from post-Oligocene tectonics with some motions still active during Quaternary times. We identified a series of NW-striking fault segments along the COT structure that offset Pliocene or Pleistocene volcanic deposits with left-lateral strike-slip kinematics and a vertical component of relative uplift of the northeastern tectonic block. These kinematics are confirmed by offset landforms and deposits, as well as by slickenside lineations measured along the fault plane. The geometry in plan view of the fault trace suggests a vertical geometry of the main slip plane. Paleostress tensors have been reconstructed by numerical inversion of the striated fault plane data. These new results have been integrated with other data coming from the World Stress Map in order to have a robust dataset to improve a Coulomb failure model for the studied area. This modelling provides information on the tectonic evolution of the area, on the interaction between motions along the different fault segments, and on how much fault displacement might influence volcanic activity along the COT fault zone. The latter focus has also been investigated in the adjoining northern area where the huge, active Tuzgle volcano lies.

## C. Cardaci - The Civil Protection volcanic risk management in Italy

The southern part of Italy has the highest concentration of active volcanoes of entire Europe: Stromboli (persistent activity), Etna (persistent activity), Vulcano (1888-1890), Vesuvio (1944), Campi Flegrei (1538), Lipari (VI-VII century), Pantelleria (1891), Ischia (1302) and Colli Albani (about 36.000 years ago). The recent eruptive events of Stromboli (2002-2003 and 2007) and Etna (2002-2003 and 2006) have been a starting point for the forecasting, prevention and mitigation of the volcanic risk for the italian Civil Protection Department (DPC), together with emergency planning activities, that are mostly important for those volcanoes that are know quiescent, like Vesuvio and Campi Flegrei, but at the same time represent a great threat for the surrounding population (i.e. about 600.000 people living in red area around the Vesuvio).

Stromboli is a volcanic island of the Aeolian archipelago in the Tyrrhenian Sea, just north of the Sicilian coasts. The island and the volcano, in permanent activity with mild explosions every 10-20 minutes, represent a major attraction for the tourists that reach several thousand units in the summer period, while in winter period the island is only populated by a few hundred of autochthonous people distributed in the two villages of Stromboli and Ginostra. Though Stromboli is defined a "nor good, nor bad" volcano, in the past years there have been several phenomena that represented a very high risk for the population. On 30$^{th}$ of December 2002, a landslide along the Sciara del Fuoco flank triggered a tsunami that affected all the coasts of the island, the ones of the other islands of the archipelago and also Sicily. Fortunately, being winter, there were only severe damages to the houses located nearby the coastal areas and no casualties were registered. On the 5$^{th}$ of April 2003 a paroxysmal explosion occurred from the summit craters ejecting metric sized bombs and blocks that hit a house and a water tank in Ginostra village. Starting from 2003, the DPC, in cooperation with the scientific community and the local population, undertook several countermeasures to mitigate the volcanic risk: issue of a daily criticality bulletin, regulated excursions to the summit craters, institution of a permanent Advanced Operative Centre (COA), new and safer network of trekking trails, installation of six shelters for people recovery in case of strong explosions, installation of vertical emergency signals, implementation of a highly integrated multiparametric monitoring network, information to the population and tourists with brochures and leaflets, and also an exercise that took place in 2005.

Etna volcano with the strong ash emissions of 2002-2003 and 2006 eruptions brought severe problems to the air traffic management, in particular to the international airport of Catania Fontanarossa, located at about 30 km SE of the volcano, but also to the surrounding cities that had to deal with severe ash fall that caused problems to transportation infrastructures and to the population. In order to better manage flight operations in presence of volcanic ash DPC, together with the Institute of Geophysics and Volcanology (INGV) and all the Italian aeronautical authorities, issues every day three hour ash dispersion simulation maps of the probable plume direction valid for the next 48 hours to support, in case of eruption, the air traffic management authorities of the local airspace.

Vesuvio, which erupted last time in 1944 and at now quiescent, represents one of the most high risk volcanoes from a civil protection point of view, due to the hundred of thousands of people living in the surrounding areas classified at high risk. The DPC, through a dedicated expertise Commission, is updating the National Emergency Plan for the Vesuvio which considers the total evacuation of the "red area" (about 500.000 people) within 72 hours. In 2006 took place an international civil protection exercise (M.E.SIM.EX) simulating a reactivation of the volcano, in which all the procedures of the emergency plan were successfully tested.

# First investigations about erionite and offretite in Italian volcanic environments

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Abstract

Erionite and offretite belong to the zeolite mineral family (hydrated alumino-tectosilicates), alteration minerals widespread in Italy and in other states. Although zeolites represent one of most widespread mineral groups in the Earth's crust, in Europe there are no systematic studies on the distribution of erionite or similar fibrous zeolites in the environment. This is mostly due to the fact that previous approaches to the hazard posed by fibrous zeolites were conducted only on erionite and only by physicians, who investigated areas with an anomalous incidence of mesothelioma, such as in Turkey (the erionite group has been classified as highly carcinogenic - Class 1 by the WHO). The knowledge of the epidemiology of mesothelioma linked to erionite in Italy is extremely scarce, and the phenomenon is still little investigated. While the mesothelioma cases attributed to asbestos exposure are well known and recorded, little or nothing is known about domestic cases from exposure to airborne erionite fibers. We carried out first preliminary investigations and sampling in selected areas around Verona and Vicenza (north-eastern Italy), in Tertiary volcanic rocks, mainly basalts. We carried out mineralogical investigations by means of XRD, SEM-EDS and OM. Erionite is a quite rare zeolite in these rocks and is characterized, in general, by elongated hexagonal prisms. The crystals can be isolated or in small sub-spherical aggregates, in vugs of basaltic rocks; very often, the prisms are highly elongated and have a high aspect ratio (asbestiform habit). Intergrowths and overgrowths with other minerals are quite common, and the morphological similarities with offretite often makes impossible a clear distinction (based on macroscopic observation and optical microscopy) between these two zeolites. The analyzed erionite crystals (EDS) have a Si/(Si + Al) ratio between 0.70 and 0.73, and the dominant extra-framework cations are mainly Ca and K, but some samples contain high amounts of Na. Mg is generally low, and the Mg/(Ca + Na) ratio is between 0.01 and 0.2. Whereas erionite is quite rare, offretite is a widespread zeolite in the volcanic rocks of this area, that crystallizes in vugs usually as small, more or less elongated hexagonal prisms, sometimes as complex clusters or thin fibrous bundles. The offretite samples show a fairly homogeneous chemical composition (EDS): the Si/(Si + Al) ratio varies between 0.68 and 0.72, and the dominant extra-framework cation is Ca, with very little or no Na. In sites where the presence of erionite and offretite has been validated by laboratory tests, we will plan airborne fibers sampling campaigns, in order to characterize the potentially contaminated areas; epidemiologic preliminary analyses will be needed to correlate the cases of mesothelioma reported in the area to the potential risk.

# Relationship between structures, petrochemical features and hydrothermal alteration along the Plio-Quaternary Olacapato-San Antonio fault zone (NW Argentina)

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Abstract

The aim of this work is to describe the relationships between tectonic structures, volcanism, petrochemical features and hydrothermal alteration along the Plio-Quaternary Olacapato-San Antonio de los Cobres fault zone, that transversally crosses the Andean chain and the Puna Plateau at about 24° S. This fault zone belongs to the larger Calama-Olacapato-El Toro (COT) structure, where extensive Miocene–Quaternary magmatic activity developed in arc and backarc settings and formed transverse volcanic chains, comprising stratovolcanoes and large calderas with widespread ignimbrite sheets and intrusions. The magmatic products are variable in age and in geochemical characteristics from the active volcanic arc to the Eastern Cordillera. The Pliocene–Quaternary monogenetic and mainly basaltic-andesite centers may relate to lithospheric delamination in an extensional regime, active since ca. 3–4 Ma. The investigated area is characterised by calcalkaline volcanic products of different ages resting on a basement of mainly Palaeozoic metamorphic and igneous rocks. We collected structural data and sampled Plio-Quaternary volcanic deposits (e.g. Negro de Chorrillos and San Jerónimo), basement rocks and hydrothermal alteration zones that occur along this fault zone. We performed first preliminary minero-petrographic studies by means of OM and XRD. The petrographic data of volcanics indicate the calc-alkaline affinity: andesitic, dacitic and minor basaltic rocks are porphyritic with phenocrysts of plagioclase, orthopyroxene, amphibole and minor clinopyroxene and biotite, in a glassy groundmass. Low-T hydrothermal alteration (usually argillic), probably related to the Plio-Quaternary volcanism, occurs along discrete segments of the fault zone, involving both volcanic deposits and basement rocks. The preliminary geochemical analyses (ICP-MS and ICP-AES) fall in the sub-alkaline field and show a range from basaltic andesite to dacites, with considerable variation in the $K_2O$ content. The aim of our further investigations is to improve the knowledge of the tectonic and magmatic evolution of this area, reflecting different magma sources and crustal thicknesses.

# Plio-Quaternary kinematics and geometry of the Calama-Olacapato-El Toro fault zone across the Puna Plateau, Argentina

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Abstract
The Calama-Olacapato-El Toro (COT) fault zone transversally crosses the Andean chain and the Puna Plateau at about 24° S. We describe the field geological structural data collected along this fault zone where it crosses the Puna Plateau (Argentina). The investigated area goes from the Chile-Argentina border to a few km east of the San Antonio del Los Cobres village, along an ideal NW-SE strip that follows the surface trace of the COT fault zone. Available radiometric dating and local stratigraphic controls enabled us to date the main tectonic events. Fault kinematics has been reconstructed through the individuation of striated fault planes and the offset of surface deposits and landforms. A series of main faults have been detected in the area, aligned along the known surface trace of the COT lineament. Our observations suggest that it consists of a series of discrete NW-striking fault segments partially overlapping laterally. The strike range of the various fault segments is in the order of 5-20°. The surface trace is rectilinear suggesting a vertical dip at least in the uppermost crust. Kinematics is characterised by oblique movements with a dominant left-lateral strike-slip component. A vertical component is usually present in the form of relative uplift of the northeastern tectonic block. These faults offset Pliocene or Pleistocene volcanic deposits suggesting a Plio-Quaternary activity of the Puna Plateau segment of the COT fault zone. In some places along the Puna Plateau, open fissures have also been observed along the COT fault zone. These fissures are only partially filled and are not located along or close to slopes. Moreover they affect "hard" rock deposits. Thus, they cannot be interpreted as due to local gravity deformations or "soft" sediment compaction. Taking into account also the low erosion rate of the area, we believe that these fissures might be interpreted as an evidence of prehistoric/historic surface faulting. We carried out also paleoseismic investigations along a trench crossing the main fault trace, which suggest that here faulting occurred through multiple events with surface ruptures. Further westward in the Chilean region, field evidence of Plio-Quaternary motions disappears, and the COT lineament should be older in age there. We will also present other structural data depicting the kinematics and geometry of the secondary faults detected along the COT fault zone, as well as the paleostress tensors reconstructed by numerical inversion of the striated fault plane data.

# Frontiers in Ultra-High Pressure Metamorphism researches

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Ultrahigh pressure metamorphism (UHPM) is a relatively new but fast growing discipline related to the deep subduction of slabs of continental and/or oceanic crust into the Earth's mantle and their return towards the surface as important components of mountain belts. The discipline was established ~25 years ago after discoveries of high pressure minerals, coesite and diamond, in the rocks of the continental affinities, a place where such minerals are "forbiden"according to main geological concepts. Exposures of UHPM rocks, once thought to be restricted to European Mountain systems, are being found in Asia, Africa, South and North Americas and Greenland. They provide us with information on the mineral assemblages, fluid inclusions, microstructures, rheologies, major and trace element chemistries, stable and radiogenic isotope characteristics and timing relationships in slabs that have been subducted to depth up to some 200-350 km. Geologic processes under UHPM conditions are by their very nature difficult to unravel because of the intense overprinting experienced by the rocks on their way back up to the Earth's surface. However, detailed studies in outcrops and in mineral/rock slides in laboratories with the aid of advanced state-of-art analytical instruments and techniques provide unprecedented integrated knowledge about processes operating in deep Earth's horizons at converging plate boundaries. UHPM rocks consist of the fragments of continental/oceanic crust rocks and associated mafic-ultramafic intrusions and/or mantle peridotite initially formed at shallow lithosphere, but which subsequently have experienced a recrystallization within or above coesite and diamond stability fields (>2.7 – 4 GPa, ~700 – 1000$^{o}$C). Before coesite and diamond discoveries, the eclogites and peridotites that are characteristic of UHPM terranes were considered geological curiosities of limited occurrence and significance. The number of scientists working on UHPM and related mantle rocks has been increasing steadily each year as their significance has become more and more apparent, numbering now several hundred extremely active international scientists.
The current explosion of research on UHPM terranes reflects their significance for understanding large-scale mantle dynamics, major elements of plate tectonics such as continental collisions, deep subduction and exhumation, mountains building, geochemical recycling "from surface to the core", and a deep storage of light elements participating in green-house effects in the atmosphere. Therefore the frontiers of UHPM discipline bridge together knowledge related to processes that trigger and control interaction between continental/oceanic crust and deep Earth's interior.

# Numerical modelling of the evolution of Baikal Rift Zone

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We perform high-resolution 2D finite difference modelling of Baikal rift formation in order to find the range of parameters that define its current structure and depth. We assume that the passive rifting hypothesis is applicable to the rift formation. The study investigate the relative role of the pre-existing faults and their strength as well as the strength of the faults in Sayan-Baikal fold range, intensity of sedimentation processes, rheology of the crust, Moho temperature and fault position relative to the transition zone. We find that the pre-existing faults and their strength are the main parameters responsible for the asymmetric graben structure of the Baikal rift. High sedimentation rates relative to the extension speed are required to make such deep basin. We also find that the faults in Sayan-Baikal fold range should be sufficiently strong to avoid significant faulting in that area.

# Significance of garnet peridotite and garnet clinopyroxenite studies for understanding deep subduction in the Moldanubian zone of the Bohemian Massif

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Garnet-bearing ultramafic rocks and HT eclogites enclosed in high-pressure granulites and migmatitic gneisses of the Bohemian massif are milestones for understanding Variscan orogeny. Though the UHPT conditions (3-5 GPa/1000-1200 $^{o}$C) are established for grt-peridotites by many authors (Medaris et al., 1990; Carswell, 1991, Backer, 1997; Faryad, 2009), there is no clear understanding if the ultramafic rocks represent directly exhumed mantle fragments, or they were subducted to such depth prior to their exhumation. We have studied grt-peridotites with host garnet clinopyroxenite and eclogite from the central and eastern part of the Moldanubian zone to reconstruct their burial and exhumation paths. Though the peridotites are strongly serpentinized they still preserve relicts of garnet, pyroxenes, olivine, and spinel. Garnet crystals ($Py_{66-78}$, $Alm_{16-23}$, $Grs_{12-17}$) are mostly homogenous, but some of them show slight decrease of Mg and increase of Fe, Ca and Cr towards the rims. Some garnet grains contain inclusions of Cr-spinel, and in this case the host garnet has high Cr content (13 mol % uvarovite) at the contact with the Cr-spinel inclusions. Interpretation of compositional map of garnet suggests that Cr-rich domains are formed due to dissolution of the former Cr-spinel into garnet. Clinopyroxene is diopside, but some garnet peridotites contain clinopyroxene with 10 mol % of jadeite component.

Garnet clinopyroxenite besides of CPx consists of 5-10 vol % of garnet may contain a few olivine and accessory spinel. Contacts between the clinopyroxenite layers (veins?) and serpentinized grt-peridotites are sharp and no deformation or any metasomatic textures are observed along their boundaries. In the clinopyroxenite, olivine occurs as inclusions in garnet and in clinopyroxene, and also interstitially between clinopyroxene grains. Similar to grt-peridotite, garnet from clinopyroxenite may contain spinel inclusions. Pyroxene forms porphyroclasts that occur in a fine-grained matrix with metamorphic fabrics, which consists of clinopyroxene and small amounts of garnet, orthopyroxene and amphibole. The clinopyroxene porphyroclasts contain garnet + orthopyroxene lamellae as well as ilmenite rods that have orientation parallel to (100) planes of the porphyroclasts. Orthopyroxene porphyroclasts host garnet and clinopyroxene lamellae, which are characterized by similar lattice preferred orientation. In both cases, lamellar orthopyroxene, clinopyroxene and garnet were partially replaced by secondary amphibole. Composition of exsolution phases and that of host pyroxene reintegrated according to measured modal proportions, demonstrate that the primary pyroxenes were enriched in Al and contained 8-11 mol% Tschermak components. Both conventional thermobarometry and thermodynamic modelling of the reintegrated pyroxene indicate that primary clinopyroxene and orthopyroxene megacrysts were crystallized at 1300-1400 $^{o}$C and 2.2-2.5 GPa (Faryad, et al., 2010). Unmixing and exsolution of garnet and a second pyroxene phase occurred in response to cooling and pressure increase before the peak pressure of 4.5-5.0 GPa was reached at approximately 1100 °C. This scenario is consistent with a burial of hot upper-mantle ultramafics along cold subduction channel followed by subsequent exhumation and tectonic incorporation into crustal (now felsic granulites) rocks.

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**Characterization of Hydrocarbon Generation and Migration Dynamics Based on Seismic Interpretation and Basin Modeling: an Integrated Study of the Orange Basin, South Africa**

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Gas chimneys, pockmarks, seafloor mounds, and seismic anomalies associated with gas migration have been identified throughout the Orange Basin, South Africa. Using a 2-D seismic dataset covering exploration blocks 1 through 4, located on the western passive margin of South Africa gas escape features have been identified on a basin-scale. Seismic interpretation as well as identification and characterization of gas leakage are the first steps for the construction of a basin-wide petroleum system model. Integration of previous research results with ongoing investigation of blocks 1 and 3D seismic datasets of block 2 provide new insights and a basin-wide view into the gas migration and seepage dynamics of the South African Orange Basin.

Based on their association with the basin elements, gas leakage in the Orange Basin has been classified into two main categories: stratigraphic and structurally controlled. Stratigraphically-controlled gas chimneys occur above onlaps and pinch-outs of Aptian aged sequences. These chimneys either reach the surface, are sealed within the Miocene, or terminate at the Cretaceous-Paleogene unconformity (22At1). Their occurrence throughout the study area is constrained to the shelf up to water depths of less than 400 m. Active structurally-controlled gas chimneys and seafloor mounds are only found in the northern part of the basin. They occur dominantly in the extensional domain west of the present-day shelf break and above Cretaceous normal faults.

A fundamental understanding of the controls on present-day and paleo gas seepage is essential when calibrating the reconstructed thermal and burial history of the Orange Basin, especially with respect to the simulation of hydrocarbon generation, migration, sequestration, and leakage. Our efforts are leading to an integrated 3-D petroleum system model of the entire Orange Basin, in which new compositional kinetics for Aptian/Albian and Cenomanian/Turonian source rock samples from DSDP wells will be used to constrain thermogenic methane contribution to the hydro- and atmosphere as a function of geologic time.

# Fluids under extreme conditions of pressure and temperature: insights from *ab initio* molecular dynamics simulations

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Aqueous fluids play an important role in most geochemical processes at the Earth's crust and upper mantle. They are involved in processes such as weathering, the formation of ore deposits or metamorphic reactions. Properties and function of aqueous fluids in these geological processes are closely related to their molecular structure at the relevant conditions of pressure, $P$, temperature, $T$, and composition, $x$. Speciation is one of the key parameters that link properties of interest, e.g. mineral solubilities, electrical conductivities and chemical activities, but also element partitioning and isotopic fractionation between fluids and minerals. Experimental measurements of fluid properties at extreme conditions are challenging. Since the structure of the fluid changes continuously with $P$, $T$ and $x$, *in situ* methods are required. Furthermore, the data obtained in a single experiment (e.g. diffraction or different types of spectroscopy) is usually not sufficient to fully determine the molecular structure of a fluid. Molecular simulations have become a powerful complementary approach to study fluid structure and properties. Especially *ab initio* techniques that are based on a quantum mechanical description of particle interactions and are free of empirical parameters have the accuracy and general applicability to be fully predictive even at extreme conditions. In this talk, results of recent *ab initio* molecular dynamics simulations of supercritical aqueous fluids will be presented. The simulation data provide insight into the changes in solute speciation with $P$, $T$ and $x$. They are also used to interpret results from *in situ* high $P$-$T$ Raman spectroscopy experiments performed in a hydrothermal diamond anvil cell. Finally, a new method to predict the equilibrium isotopic fractionation between different species in the fluid or between fluids and minerals will be discussed.

# New insights into the tectonic evolution of the Amerasia Basin, Arctic Ocean

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The tectonic evolution of the older part of the Arctic Ocean, the Amerasia Basin is still not sufficiently understood, despite of a good coverage of aerogeophysical data. In contrast to the Eurasia Basin no seafloor spreading anomalies can be identified for most parts of the Amerasia Basin. The critical information needed for progress is dateable basement samples from various ridges and plateaus, sufficient marine seismic data and a sound understanding of the geology of Siberia and Alaska. This contribution reports new geophysical data along the East Siberian margin. The objective of the 2008 RV Polarstern cruise was to gather new information on the deeper structure of the Mendeleev Ridge at its junction with the Siberian shelf, and the Makarov/Podvodnikov Basin which is situated between the Mendeleev and Lomonosov ridges. Favourable ice conditions allowed data collection along an almost continuous 1000 km-long seismic transect along 81°N with a 300 m streamer and a 32 ltr airgun array, as well as several seismic profiles across the East Siberian margin. The seismic data imaged the entire sedimentary column down to the acoustic basement, and provide the following simple insights into the tectonic evolution:

- The Amerasian margin of the Lomonosov Ridge along our transect is very wide. It shows all characteristics of a rifted continental margin. Most likely rotated basement blocks are successively covered by sediments, which are not affected by any tectonic faulting. Thus, most of the Makarov/Podvodnikov Basin along the transect is underlain by stretched continental crust from the Lomonosov Ridge margin.
- The Marakov-facing margin of the Mendeleev Ridge has a completely different appearance. The ridge is more or less the same age as the small part of oceanic crust beneath the Makarov/Podvodnikov Basin, and was later covered by sediments.
- Approximately 1000 m below the seafloor the Lomonosov Ridge hosts a prominent reflector, previously attributed to be 10-20 Myr old. Considering the entire basin geometry as well as the drilling results from the ACEX campaign, it is more likely that this reflector has an age of at least 55 Myrs. Beneath this unconformity several kilometers of sediment are observed.

This has several significant consequences for any geodynamic models:

- The Laptev Sea stratigraphy from which the younger age of the unconformity was deduced, is incorrect.
- The Makarov/Podvodnikov Basin is definitely of Cretaceous age.
- The oceanic Mendeleev Ridge most likely formed contemporaneously with the initial formation of oceanic crust in the Makarov/Podvodnikov Basin. The oceanic crust is estimated to be 100 Myrs old.
- The rifting and/or formation of the seafloor spreading stopped with the eruption of the Mendeleev Ridge. Alternatively, the stress regime changed from perpendicular to the Lomonosov Ridge margin to strike slip.

# The nature of the asthenosphere-lithosphere boundary – constraints from high precision multi-isotope (Sr, Nd, Pb, Hf, Os) and HFSE (Zr-Nb-Ta-Hf) data

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The planned project aims at an evaluation of the Os and Hf isotope systems (beside some Sr, Nd and Pb isotopes on samples that have not been analysed) and the High Field Strength Element (Nb-Ta-Zr-Hf) budget of Tertiary alkaline lavas. Extension of this approach to mantle xenoliths is probable but the amount of existing data is far less than the amount of data on the lavas. In a first approach, the data from the lavas will be used to constrain the source components (lithospheric vs. asthenospheric) and their geochemical evolution linked to geodynamic processes. Early studies, based on major and trace element and Sr, Nd and Pb isotope data, concluded that the isotope chemistry of the basalts is the result of partial melting of a heterogenous, lower mantle source whereas subsequent work emphasized the role of lithosphere contributions and crustal contamination, even in so-called „primitive" alkaline volcanic rocks. However, the isotope signal provided by the lavas is too heterogeneous to be related to melting of a single source with or without crustal contamination. Consequently, it has been emphasized that a significant number of lavas could come from various sources including the TBL (thermal boundary layer) which broadly coincides with the LAB (lithosphere/asthenosphere boundary). High-precision Ar-Ar dating will be used to asses the timescales and rates of these processes.

Within the project, it is planned to obtain a representative data set on a number of Tertiary alkaline volcanic centers. These include (from E to W) the Hocheifel, Siebengebirge, Westerwald, Vogelsberg and Rhön areas. A large number of Sr, Nd and Pb isotope data is available through previous studies. The specific properties of the Sr, Nd and Pb isotope systems in decyphering mantle and crustal processes are well known and the Re-Os isotope system is also an excellent tool to distinguish between mantle heterogeneity and crustal contamination because the subcontinental lithospheric mantle (SCLM) has characteristically unradiogenic (subchondritic) $^{187}Os/^{188}Os$ ratios which are distinct from both typical asthenospheric signatures and the $^{187}Os/^{188}Os$ ratios of most ocean island basalts. The continental crust develops variable but consistently higher $^{187}Os/^{188}Os$ ratios than those typical for the mantle. The variability of the Hf isotope composition of continental basalts may also place constraints on contamination processes especially when high-Lu/Hf contaminants are involved but may additionally be used to infer partial melting processes within the garnet or spinel peridotite stability fields. Variations of high-field strength element (HFSE) ratios (Zr/Hf, Nb/Ta) in terrestrial reservoirs are also critical for understanding crust-mantle differentiation and mantle and lithosphere evolution.

Since it is highly likely that most of the primitive alkaline volcanic rocks come from the TBL and the TBL coincides with the LAB, the main questions raised in this project are (i) what can we learn about partial melting depths, processes and sources involved during petrogenesis based on isotope and HFSE compositions of so-called „primitive" alkaline volcanic rocks, (ii) what are the effects of crustal contamination and crystal fractionation on the isotope and HFSE composition of the volcanic products and how can we distinguish these effects from those imparted by the melting process, (iii) where is the locus of partial melting (lithosphere or asthenosphere or both?) and what is the role of the LAB (site of melting?, conduit?, storage reservoir?) (iv) is there any correlation between age and location or chemical/isotope composition of the volcanic rocks? Results from the isotope investigations will be connected with constraints from major and trace element data and experimental studies to provide a compositional range-depth-temperature frame which will help to define the chemical nature of the lithosphere/asthenosphere boundary. Therefore, such data can be used by geophysical groups to improve and refine the knowledge about the nature and depth of the LAB. Geophysical data that constrain the LAB are in turn needed later to refine suggestions about lithospheric vs. asthenospheric mantle sources using coupled Sm-Nd/Lu-Hf isotope systematics.

# MODEL OF MUD VOLCANO BY GEOPHYSICAL AND GEODETIC DATA.

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Manifestations of mud volcanism, or mud diapirs, are widespread in Azerbaijan. The number of mud volcanoes located on land and at sea exceeds 300. At present, a strong correlation is believed to exist between mud volcanism manifestations and the presence of oil and gas accumulations. Many mud volcanoes are active at the present time. Of all mud volcanoes of Azerbaijan, the Lokbatan mud volcano is most active. Its first recorded eruption took place in 1864. Its last eruption occurred on October 24, 2001, and the release of gases and their combustion have continued ever since. The study of the mechanism responsible for the formation and activation of mud volcanoes is still a topical problem. Repeated high-precision gravity, geodetic, and geothermal measurements in the occurrence areas of mud volcanoes is indispensable for constructing a model of their deep structure and studying the dynamics of processes associated with their activation. This work presents results of detailed geophysical and geodetic measurements in the southern Apsheron mud volcanism area (the Lokbatan, Akhtarma-Puta, and Gushkhana volcanoes). A gravitational model of the deep structure is constructed, and the dynamics of the Lokbatan mud volcano is studied.

Several profiles of various directions were chosen for gravity and geodetic measurements in the occurrence area of mud volcanoes. One of the profiles studied starts at the Lokbatan gravimetric-geodetic reference point and extends for 11 km in the E-W direction through the Lokbatan, Akhtarma-Puta, and Gushkhana mud volcanoes. Intervals between measurements points do not exceed 250 m. Residual gravity at these points was measured with gravimeters of the GNU-K2 and GNU-KB types on a simple circuit. Longitudes and latitudes of measurement points were determined from GPS data, and the elevations of these points, with an N1 002 Karl Zeiss high-precision compensating level. In calculating the Bouguer anomaly, the height was measured from the lowest level (at the Lokbatan point), and the density of the intermediate layer was set at 1.82 g/cm$^3$. The measurements started immediately after the last eruption.

Mud volcanoes concentrate within the area of negative gravity values varying from -100 to -30 mGal. The area of mud volcanoes is bounded on the east by the Kyzylagach-Lagich gravity step. A plot of Bouguer gravity anomalies along the Lokbatan-Akhtarma-Puta-Gushkhana profile was constructed for various densities of the intermediate layer (1.82, 2.00, and 2.30 g/cm$^3$). As a result, local negative anomalies of -5, -3, and -2 mGal were obtained in the areas of the Lokbatan, Akhtarma-Puta, and Gushkhana mud volcanoes, respectively. The initial geological-geophysical section of the sedimentary cover along the Lokbatan-Akhtarma-Puta-Gushkhana profile is represented by seven contact boundaries: (1) Akchagyl base; (2) tentative seismic horizon in the productive sequence; (3) top of the Kirmakinsk arenaceous formation; (4) base of the Kirmakinsk formation; (5) boundary between Middle Pliocene-Lower Pliocene and Lower Miocene-Oligocene sequences; (6) boundary between the Oligocene and the Eocene; and (7) Mesozoic surface. The density increments at these contact boundaries are (from top to bottom) 0.01, 0.04, 0.08, -0.2, 0.25, 0.15, and 0.3 g/cm$^3$, respectively. The field calculated in terms of the model described diverges from the observed field above the mud volcanoes. The excess mass under the mud volcanoes in the initial model of the section was compensated in these parts of the profile by the introduction of decompaction zones and additional contact boundaries with a density increment of -0.15 g/cm$^3$ at depths of 3 km and less.

CONCLUSION. (1) Local gravity anomalies of –5, –3, and –2 mGal are observed over the Lokbatan, Akhtarma-Puta, and Gushkhana mud volcanoes, respectively.

(2) As was shown by gravitational modeling, decompaction areas that are interpreted as ascending convective flows in a clayey layer exist under mud volcano vents.

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## Strong paleoearthquakes along the Talas-Fergana Fault, Kyrgyzstan

The Talas-Fergana Fault (TFF) is the largest wrench structure in Central Asia. It forms an obliquely-oriented boundary between the northeastern and southwestern parts of Tien Shan. The last one includes the Fergana depression, Chatkal-Kurama mountain system and Alay valley. A wide belt of latitudinal oriented ranges, which are located between the Kazakh platform and Tarim basin, represents the Northeastern Tien Shan. Most researchers interpret the TFF as a right-lateral strike-slip fault active in Palaeozoic times. Right-lateral movements took place again in the late Cenozoic because of crustal shortening linked to the India-Eurasia collision. The tectonic movements along the intracontinental strike-slip faults contribute to absorb part of the regional crustal shortening; strike-slip motions along the TTF are necessary for the complete assessment of the active deformation of the Tien Shan orogen. Our focus is to improve the understanding of the intracontinental deformation of the Tien Shan mountain belt as a whole and the occurrence of strong earthquakes along the whole length of the TFF.

The paleoseismological study of the TFF zone has revealed the following results:

- the whole fault zone on the territory of Kyrgyzstan is marked by paleoseismic deformations, comprising fault scarps, upslope facing scarps, and right-lateral displacements of gullies and watersheds. Moreover, along this fault zone there are several aligned rockslides and landslides that can be interpreted as related to seismic and palaeoseismic events.

- The collected data for determining the $^{14}C$ absolute age of the mentioned seismotectonic deformations indicate that at least 18 strong earthquakes occurred in the fault zone during the last 15,800 years. Reoccurrence interval of the strong earthquakes along the TFF zone during the second half of the Holocene is about 300 years.

- By the analysis of the distribution of strong earthquakes, the TFF zone in Kyrgyzstan could be divided into three segments. A strong earthquake migration along the fault zone in the second half of the Holocene was determined. We assume that the next strong seismic event along the fault zone most probably will occur along its SE segment.

- The parameters of the seismotectonic deformations testify to a $M > 7$ for the largest past earthquakes, their seismic intensity was $I > IX$. These data must be taken into consideration for creating a new Map of the Seismic Zoning of the Kyrgyz Republic territory.

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## Unknown historical earthquakes in north-west of the Issyk-Kul Lake region, western Tien Shan

Tien Shan is the northern front of Himalayan mountain belt formed as the result of Indian and Eurasian lithosphere plates' collision. Here there is a series of most seismically active zones of the orogen which generated strongest earthquakes with M>8. In tie with almost complete absence of the historical records, the only way to reconstruct the strong earthquake catalog for past centuries is to use a paleoseismological method. Since 1984 we studied NW part of the Issyk-Kul Lake region where there is an echelon like substitution of the anticlines of different trends – components of the Kungey mega-anticline. Here we have revealed a series of active tectonic structures: faults and folds which are responsible for strong earthquakes' manifestation.

Our 2008 field works along foothills of the Kungey Ala-Too Range in the Iiri-Taldybulak river basin have revealed two unknown historical earthquakes. One earthquake, occurred in the end of VII century AD along the southern rupture, has formed a fault scarp which crosses the river's flood plain and ancient settlement – *Tash-koro*. Other earthquake, occurred in the end of IX century AD along the northern rupture, has increased the height of fault scarp which crosses Early-Holocene, Late-Pleistocene and Mid-Pleistocene terraces.

For this region there were historical data about the occurrence of strong seismic event about 500 AD. Collected published archeological materials testify to another strong earthquake which occurred in XIV century AD. It is important to mention that counted above seismic events coincide with declines of the nomadic civilizations of *Usuns, Turks and Mongols* in the territory of the northern Tien Shan and Semirechie (Seven Rivers region)

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# Lithosphere architecture and mantle dynamics underneath the Ahaggar volcanic swell: a view from xenoliths

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We report preliminary results on an ongoing study of mantle xenoliths from the Neogene to Quaternary Tahalra volcanic district, located on the south-western flank of the Ahaggar volcanic swell, in southern Algeria (Fig. 1). With 60 volcanic vents spread over 1800 km$^2$, this district is one of the largest volcanic fields in the Ahaggar area.

Our study is part of an international and multidisciplinary joint venture combining geophysical observations with works on mantle xenoliths and volcanics to unravel the architecture of the Ahaggar lithospheric plate and its relations with upwelling asthenospheric mantle. The first step of the project is focused on the major North-South Panafrican shear zone structuring the architecture of the Ahaggar shield and coined the "4º50 Fault" (Fig.1). This notably includes geophysical imaging (magnetotellurics and seismology) of deep structures associated with the shear zone, combined with a detailed analysis of mantle xenoliths from the Tahalra volcanic district. As it spreads East-West across the 4º50 fault, the latter provides information on the lithospheric mantle on either side of the shear-zone and underneath. Given the inferred key structural importance of the 4º50 fault, the strategic position of the Tahalra volcanic district and the common occurrence of mantle xenoliths in this district (Dautria, 1988 – PhD thesis, Montpellier), this area represents a bench test for the overall Ahaggar project.

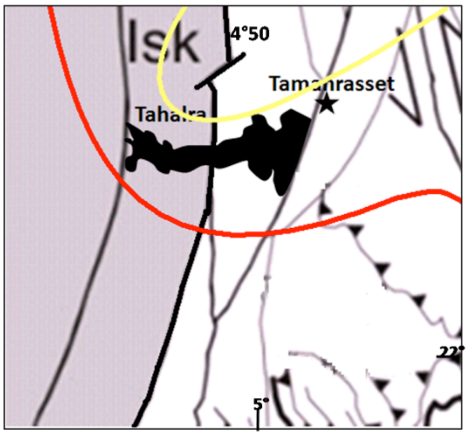


**Figure.1**: black: Neogene-Quaternary volcanics (Tahalra district); grey: Iskal Terrane (Neoproterozoic); white, LATEA terrane (mainly Paleoproterozoic); red line, limit of the Ahaggar negative gravity anomaly (-120 mgal); yellow line: 600 m topographic level, underlining the south-western end of the Ahaggar swell.

To characterize the textural and chemical variability of lithospheric mantle with a resolution as high as possible, we have collected representative xenoliths from a large number of localities throughout the Tahara district. Investigations on mantle xenolilts involve petrology and detailed textural and mineralogical characterization, petrophysics (including CPO analyses with SEM-EBSD) and geochemical analyses for trace elements and radiogenic isotopes.

# Helium isotopic composition of the eclogites from the Lasha Terrane, Tibet: Information from deep mantle

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In 2006, a new occurrence of eclogite has been discovered in the Lhasa terrane, northeast of Lhasa, Tibet along the northern margin of the Gangdese magmatic arc (Yang et al, 2006). Helium isotopic composition of the eclogites from the Lasha Terrane, Tibet was presented in the paper. The $^3$He and $^4$He abundance of garnet in the eclogites from the Lasha Terrane are varied in the range of $2.778\times10^{-12}$~$8.134\times10^{-12}$ $cm^3STP/g$ and $0.112\times10^{-6}$~$0.527\times10^{-6}$ $cm^3STP/g$, respectively. The $^3$He and $^4$He abundance of omphacite are varied in the range of $4.319\times10^{-12}$~$9.372\times10^{-12}$ $cm^3STP/g$ and $1.782\times10^{-6}$~$4.932\times10^{-6}cm^3STP/g$, respectively. Compared to the garnet selected from the same sample, the omphacite has relatively higher $^3$He and $^4$He abundance than that of the garnet. It suggests that the isotopic geochemical characteristics of helium in eclogites have a close relationship with generation and source of the rocks. The $^3He/^4He$ ratios of the omphacite and the garnet of the Lasha eclogites are varied in the range of 1.15~25.48 Ra. They are higher than that of the crust, and the $^3He/^4He$ ratios of some samples are higher than that of the MORB (7~9 Ra). It might indicate that the helium of the Lasha eclogites is a mixed crust-mantle source. The appearance of some very high $^3He/^4He$ ratios revealed effectively a plume process.

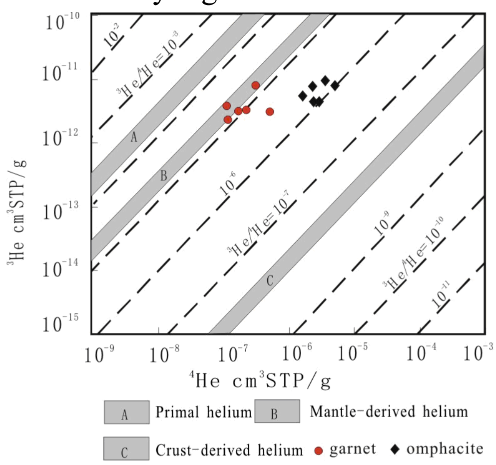


Fig. 1 Helium isotopic composition and evolution in the eclogite from the Lasha Terrane, Tibet (A, B, C after Mamyin and Tolstikhin, 1984)

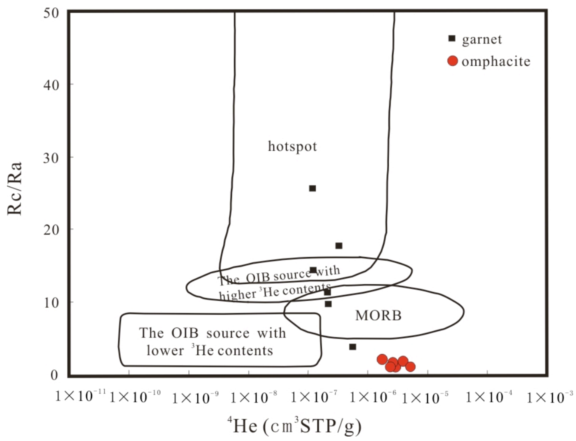


Fig. 2 The He isotopes characteristics of the eclogite from the Lasha Terrane, Tibet

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# Differential subduction and exhumation of crustal slice in the Sulu HP and UHP metamorphic terrane

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The Sulu orogen could be divided into one high-pressure (HP) crustal slice (slice I) and two ultrahigh-pressurepressure (UHP) crustal slices (slice II and slice III) from southeast to northwest. A combined set of mineral inclusions, cathodoluminescence (CL) images, U-Pb SHRIMP dating, and trace element and Lu-Hf in situ laser ablation ICP-(MC)-MS zircon analyses were obtained from orthogneisses in both slice II and III. Most zircons separated from six orthogneiss samples have three distinct domains: (1) inherited (magmatic) cores, with clear oscillatory zoning, low-P mineral inclusions of Qtz + Kfs + Pl + Ap and high Th/U ratios (> 0.54), indicating their crystallization from felsic magmatic protolith; (2) coesite-bearing mantles, with high-luminescent CL image, UHP mineral inclusions of Coe + Grt + Phe + Ap and low Th/U ratios (< 0.10), corresponding to the UHP metamorphic stage; (3) outmost rims, with low-luminescent CL image, Low-P mineral inclusions such as albite and quartz and low Th/U ratios (< 0.08), corresponding to the late amphibolite-facies retrograde stage. Although the inherited (magmatic) cores of zircons from 6 orthogneiss samples recorded similar protolith ages of 785-770 Ma, the coesite-bearing mantles and albite- and quartz-bearing rims show different UHP metamorphic ages and late amphibolite-facies retrograde ages in both slice II and III. The $^{206}Pb/^{238}U$ ages for both UHP and retrograde zircon domains from the slices III are 218 ± 3 Ma–217 ± 4 Ma and 202 ± 4 Ma, respectively, which are significantly younger than the UHP age of 228 ± 3 Ma and retrograde ages of 215 ± 3 Ma in the slice II. Moreover, Ar-Ar dating of biotite from six paragneiss samples also shows gradually younger amphibolite-facies retrograde age of 233 ± 0.9 Ma-231 ± 0.8 Ma for slice I, 215 ± 0.5 Ma–212 ± 0.7 Ma for slice II and 203 ± 0.6 Ma–201 ± 0.6 Ma for slice III, respectively. Combined with reported U-Pb SHRIMP ages for gneissic rocks from the Sulu orogen, we found that the metamorphic ages, including peak metamorphic and late amphibolite-facies retrograde ages of these three HP-UHP units gradually decrease from southeast to northwest. This age mapping reveals that the three HP-UHP units represent 3 exhumed crustal slices, which have different subduction and exhumation histories. Firstly, the subducted crustal slice I was detached from the underlying subducted continental lithosphere at about 50–60 km, and experienced HP metamorphism, then exhumed because of the buoyancy. In the meantime, subduction of underlying crustal slice II continued until about 100-120 km depth and experienced UHP metamorphism, then was detached from the underlying

subducted crustal slice III and exhumed to the crustal level. Following the UHP slice II, the underlying crustal slice III repeatedly experienced similar geodynamic process of deep-subduction, UHP metamorphism and exhumation. Finally, a multiple HP-UHP metamorphic belt, comprised by one HP crustal slice and two UHP crustal slices, were formed in the Sulu orogen.

Zircon from epidote- and biotite-bearing orthogneiss and garnet-bearing orthogneiss in both slice II and III shows significantly different Hf isotope compositions in inherited (magmatic) core, the first type with slightly negative to positive εHf (t) values (-2.7–2.2) and younger $T_{DM}$ ages of 1.38–1.67 Ga whereas the second type with evidently negative εHf (t) values (-11.1–-17.3) and older $T_{DM}$ ages of 2.17–2.47 Ga. These data indicate that two different types of felsic magmatism with contrasting origins for their protoliths; the first type of felsic magmatism was generated by reworking of juvenile crust, and the second type of felsic magmatism was derived from rifting anatexis of Paleoproterozoic crust. However, their protoliths formed at mid-Neoproterozoic corresponding to the breakup of the supercontinent Rodinia at about 780 Ma. A combined study of U-Pb, REE and Lu-Hf isotopes in zircons from UHP orthogneisses reveals the genetic relationship of $^{206}Pb/^{238}U$ age, initial Hf isotope composition, and Th/U and $^{176}Lu/^{177}Hf$ ratios among the domains of different origins. Both the UHP and retrograde domains are characterized by low Th/U and $^{176}Lu/^{177}Hf$ ratios, but high εHf(t) values with respect to the igneous core of Neoproperozoic ages. For the UHP domains and igneous core, there are positive correlations between Th/U and $^{176}Lu/^{177}Hf$ ratios, indicating the concurrent effect of UHP metamorphism on both U-Th-Pb and Lu-Hf isotope systems. In contrast, the consistency of REE patterns, εHf(t) values, and Th/U and $^{176}Lu/^{177}Hf$ ratios between UHP and retrograde domains suggests that the late amphibolite-facies retrogression did not significantly modify REE compositions, U-Th-Pb and Lu-Hf isiotope system of the UHP metamorphic system.

# Comprehensive Review of Pleistocene Volcanics of Italy Using Classical Geochemical-Petrological Discriminant Diagrams

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Italian volcanic rocks are very complex and show wide variations in petrology and geochemistry. Therefore discussions about their origin, magma genesis, and petrogenesis still continue. We compiled data from the literature and systematically evaluated the data using all classical geochemical-petrological techniques. Main trust of the paper is to create a data bank for further future geochemical analysis using experimental methods so that we contribute the debate on complex geodynamic setting and magmatism of Italy. In this study, we re-evaluated the following volcanics of Italy; Pantelleria (0.32 Ma-0.005 Ma), Procida (0.05 Ma-0.01 Ma), Salina (0.43 Ma-0.013 Ma), Albani (0.6 Ma-0.02 Ma), Alucidi (0.06 Ma-0.028 Ma), Filicudi (0.4 Ma-0.04 Ma), Sabatini (0.8 Ma-0.04 Ma), Panarea (0.15 Ma-0.045 Ma), Vico (0.42 Ma-0.1 Ma), Roccamonfina (0.58 Ma-0.1 Ma), Ernici (0.7 Ma-0.1 Ma), Ventotene (0.8 Ma-0.1 Ma), Ustica (0.75 Ma-0.13 Ma), Vulture (0.8 Ma-0.13 Ma), Vulsini (0.6 Ma-0.15 Ma), Linosa (1.06 Ma-0.53 Ma), and Sardini (3.5 Ma-2.1 Ma). The total number of data points was more than 1200.

# Chemostratigraphy as Applied to Some Volcanostratigraphic Units at Ihlara Valley, Central Anatolia, Turkey

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Chemostratigraphy, application of quantitative mineralogy-petrology-geochemistry to sedimentary or volcanic sequences, is a concept that can be applied to characterize and correlate complex volcanostratigraphic formations to solve difficult geologic problems. This type of research requires state-of-the-art instrumentation and techniques, which recently became feasible. The mineralogy-petrology-geochemistry of the Ihlara Valley area which is the subject of this study and contains important volcanostratigraphic units is complex and properly applied chemostratigraphy is a very useful tool to solve the existing problems in unit correlations. In this research, we first compiled all previous data on the major and some trace elements to establish the major stratigraphic units. In the next step, we used high resolution field emission scanning electron microscopy, inductively coupled plasma-mass spectrometry, and powder x-ray diffraction techniques to obtain new data from volcanostratigraphic sequences of Selime, Yaprak Hisar, and Belisirma villages of the Ihlara Valley and correlate these units. Work in progress will involve using more complete geochemical data including trace and rare earth elements, powder x-ray diffraction, and stable isotopic data for correlation and extrapolation of these units.

# High-pressure partial melting of the Moldanubian felsic granulites in the Bohemian Massif

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Felsic granulites from the Kutná Hora complex in the Moldanubian zone of central Europe exhibit modal layering and discordant leucocratic veining, which is interpreted as evidence for partial melting along the exhumation path from the eclogite to granulite facies. The granulites consist of quartz, ternary feldspar, garnet, biotite, kyanite, and rutile. In the bulk rock garnet grains show relatively high Ca contents corresponding to 28-41 mol. % grossular end member. They have remarkably flat compositional profiles in their cores but their rims exhibit an increase in pyrope and a decrease in grossular and almandine components. In contrast, garnets from the leucocratic layers have relatively low Ca contents (15-26 mol. % grossular) that further decrease towards the rims. Mineral assemblage and garnet chemical zoning suggest a *pT* path from the eclogite facies conditions to muscovite dehydration melting conditions at 900 $^{o}$C and 2.0-2.2 GPa and subsequent retrogression to 850 $^{o}$C and 1.4 GPa where the partial melt has crystallized. Phase formation and melt productivity were independently determined by experiments in the piston-cylinder apparatus at 850-1100 $^{o}$C and 1.7-2.1 GPa. Both the thermodynamic calculations and phase equilibrium experiments suggest that the partial melt was produced by the dehydration melting: muscovite + omphacite + quartz = melt + K-feldspar + kyanite. The melt fraction was controled by the whole-rock $H_2O$ budget present throughout the eclogite facies, estimated to be 0.21 wt. % $H_2O$ and accomodated by shifting the equilibrium: phengite + quartz = K-feldspar + kyanite + $H_2O$. Minimum water solubilities in silicic melts restrict the bulk fertility to 2.8-4.2 wt. % melt during decompression but the actual melt fraction varied by as much as 28 wt. % on centimeter scale due to deformation-enhanced melt redistribution. The melt accumulation was probably controlled by shear instabilities and strain accommodation within foliation-parallel sites, eventually leading to the formation of modal layering. The presence of partial melt was responsible for attaining the decompression equilibria at 850-900 $^{o}$C, thus eliminating any potential relics of precursor high-pressure phases such as phengite or omphacite. In contrast, adjacent mafic granulites and eclogites, which apparently share the same metamorphic path but have not undergone partial melting often preserve relics or inclusions of eclogite-facies mineral assemblages. The presence of partially molten domains of felsic granulites in the Variscan orogenic continental root probably exerts major rheological control on the incorporation and immersion of lenses and boudins of mafic granulites, eclogites and garnet-bearing ultramafics and their common extrusion *via* an exhumation channel to the middle continental crust.

**Keywords**: felsic granulite, high-pressure metamorphism, partial melting, Bohemian Massif, Variscan orogeny

# Anomalous mantle beneath collisional orogen of the Alps and its mineralogical interpretation

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Recognition of ultrahigh pressure metamorphic terranes incorporated within continental collisional orogen of the Alps provided prominent information about processes of crust-mantle interaction during deep subduction and mountain chains building that change "face" and climate of our planet. We have obtained consistent two-dimensional P-wave velocity models of the upper mantle below the Alpine orogen in Central Europe from four different azimuthal zones. One-dimensional averages of those models from the region of their intersection plotted against AK135 reference models exhibit the following main features: (i) low velocity zone between 90 and 220 km depth with highly heterogeneous velocity structure (alternate layers with high and low velocities), and (ii) significant velocity jump of up to 4 percent at a depth of around 300 km. High-velocity anomaly beneath the Alps is observed in four models obtained for different angles of illumination by seismic rays. It extends at an average depth of 300 km and is characteristic of high P-wave velocity of 9 km/s. It has a feature of a first-order seismic discontinuity owing to the fact it generates the refracted as well as the reflected waves. The 300-km discontinuity was reported in several regional-scale studies world-wide but it is the first time we have proven its clear existence beneath the Central Europe. We attribute the origin of the 300-km discontinuity to the phase transformation of coesite to stishovite which is petrologically feasible at that depth. We suggest that such a transformation took place due to excess of silica delivered to that depth by subducted slab of continental crust which fragments are still stagnated beneath the orogen marking therefore the 300-km seismic discontinuity. The proposed velocity model beneath the Alps can be used as a regionalized reference model for use in seismic tomography studies, instead of highly averaged global one.

# Ascent Distance of Anatectic Granitoid Melts in Collisional Orogens: The Greater Caucasus

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The Greater Caucasus preserves a collisional orogen that extends for more than 1200 km in a NW-SE direction between the Black and Caspian Seas. Two major structural stages are recognized: the Pre-Mesozoic crystalline basement (200 km x 40 km) and the Meso-Cenozoic volcanic-sedimentary cover. The basement is predominantly constructed of an anatectic granite-migmatitic complex of Hercynian age. The generation of granitoid magmas by partial melting of a metaterrigenous protolith is well exposed here, and allows detailed study of the melt-forming processes.

Collisional anatectic granitoid melts are generated primarily in the arches of anticlines in the crystalline basement complex. Investigation of the structure, PT regime and fluid system indicate that anticline arches are favorable locations based on three contributing factors: 1) local pressure reduction; 2) local temperature increase; and 3) enrichment with light fluids.

The PT regime of granitoid melt generation at depth has been well studied, but the transport distances of those melts are not well known. This information is useful in constraining the physical conditions of granitoid melt generation and ascent. In the crystalline basement of the Greater Caucasus the distances of movement of anatectic granitoid melts are not long, varying up to hundred meters. One exposure allowed a more precise measurement of the ascent distance directly.

At the upper reaches of the river Gvandra (Abkhazia), anatectic microcline granitoid is intruded into upper Paleozoic biotite-sillimanite migmatites. The granitoid is conspicuous in relief (thickness approximately 700 m). The age of the intrusion is 312±5 ma (Rb-Sr age). The Gvandra intrusive consists of light grey, porphyritic S type granites with microcline phenocrysts and groundmass phenocrysts of Mik+Pl ±Ort+Bt+Mu±Chl±Ep+Apt+Zn+Mgt.

The southern contact of the Gvanda granitoid intrusive is located 2,5 m from the migmatites. The granitoid contains thin-layered biotite gneiss xenoliths occur at an elevation of 2,950m above sea level, ranging in size from 5 cm up to 70 cm. At elevation 2,700m above sea level, a 30m thick exposure of thin-layered biotite gneisses is exposed, apparently the source of the xenoliths in the granitoid. Detailed petrographic, petrochemical, geochemical and mineralogical investigation of the above mentioned xenoliths and thin-layered biotite gneisses confirm that they have the same source, and indicate that the xenoliths in the Gvandra granitoid intrusive were derived from the layered biotite gneiss formation.

Taking in to account the geometry of the layered biotite gneiss, granitoid melt viscosity, and the specific weight of the xenoliths, we can infer that the Gvanda granitoid intrusive moved in vertical direction for 500-600 m before stopping. Although not precise, the measurement demonstrates that the ascent distance of the granitoid melt was not far from the source area.

# Identification of a large polygonal-fault network in the Hammerfest Basin: implications on migration and leakage of hydrocarbons in the South Western Barents Sea.

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The Barents Sea has a significant impact on society due to the existence of large energy resources and commercial fisheries. The Hammerfest Basin, located in the SW Barents Sea is an active frontier for hydrocarbon exploration and an excellent setting for scientific research due to its complex geological setting and history. Additionally, petroleum systems in the region are highly sensitive to thermal and tectonic changes.

Natural gas seeps are common in sedimentary basins and can be found worldwide. The process of liquid and gaseous hydrocarbon leakage is highly important as it (1) is responsible for input of greenhouse gases (such as Methane) into the hydrosphere/ atmosphere, (2) indicates reservoir leakage, (3) impacts benthic ecosystems and (4) can lead to submarine slides due to slope instability. Understanding present day and paleo gas seepage is essential when reconstructing basin evolution in terms of its thermal and burial history. We use a commercial three dimensional (3D) seismic dataset covering 950 $km^2$ and complimented by 3500 km of regional 2D seismic profiles and several exploration boreholes to identify and characterize the fluid migration pathways and their sea floor expression in the basin.

A polygonal fault interval was identified in our study area, which could imply a permeable complex network of pathways that could facilitate the migration of hydrocarbons. The polygonal fault interval appears in the Campanian-Maastrichtian, restricted to a ~43 m thick tier, penetrating into the underlying Cenomanian-Aptian/Albian lithologies. Polygonal faults seem to develop orthogonally to both lithological boundaries and regional tectonic faults, where the straight fault segments extend away from the boundary/fault and link into more common polygonal fault patterns. The lithological control on the occurrence of polygonal fault patterns could indicate a change in rock properties and can be used to differentiate between different sediment types. There are three main orientations of polygonal fault networks sampled in three different areas of the study area: dominant ENE/WSW, secondary NEN/SWS and a minor NE/ SW. The dominant orientation is similar to the main regional tectonic fault trend (EW), suggesting a tectonic influence upon the development of polygonal faults.

Interplay between reactivated tectonic faults and polygonal fault systems provides a plumbing system for thermogenic fluids and gas to migrate to the surface where they are expressed as pockmarks. To the best of our knowledge, a cause-effect relation between large-scale tectonic faults and the polygonal fault system has not been proposed before for this basin. Further efforts will be focused on studying whether significant release of thermogenic fluids and gases can be associated with major tectonic event during basins evolutional history.

# Revisiting the historical debris avalanche deposit at the footslopes of Iriga Volcano, Philippines

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Abstract

Volcanic rockslide-debris avalanches are low-frequency, high-volume events generated by volcanic sector collapse that begins as a rockslide and progressively disintegrates on steep edifice slopes. They are linked to edifice instability and a triggering mechanism, related either to a volcanic event, extreme rainfall or tectonic movement. The case of the Iriga debris avalanche with a volume of 1.5 cu km (Aguila et al, 1986) and runout length of about 10 km has long been associated with a non-volcanic trigger. We revisit the debris field of Iriga avalanche to investigate its causal mechanisms and determine its time of occurrence. The absence of a soil layer between the pyroclastic flow (PF) deposit and hummocks, the mixture of the PF deposit with avalanche-related lava blocks, and hummocks comprised of PF deposits may indicate an eruptive event close in timing with respect to the debris avalanche. These new findings reveal that Mt Iriga may be more explosive in nature than previously thought. Also, a previously unidentified debris avalanche field in the west-northwest sector of Iriga volcano was identified. This debris avalanche is older than the more obvious debris avalanche field in the southeast sector, which is associated with a well-formed horseshoe-shaped amphitheatre crater. This study will contribute to the identification of hazards at Iriga volcano and can serve as basis for hazards mitigation plans in the region.

# Mitigating the consequences of extreme events on strategic facilities: Evaluation of volcanic and seismic risk in the Caspian oil and gas pipelines in the Republic of Georgia

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Volcanic hazard assessment typically evaluates the risks posed to humans and the environment. However, the risk of volcanic activity to strategically-important human infrastructure must also be considered in hazard assessments. The volcanic risk posed to strategic pipelines, for example, was dramatically demonstrated by the 2002 eruption of Volcan Reventador in Ecuador. Lava flows from the volcano severed a Petro-Ecuador oil pipeline, producing a major oil spill and disruption of supply. The event also disrupted construction of the *Oleoducto de Crudos Pesados* (OCP) pipeline in the same region.

In this work we identify and quantify new seismic and volcanic risks threatening the strategic Caspian oil and gas pipelines through the Republic of Georgia, in the vicinity of the recent Abuli Samsari volcanic range, and evaluate risk reduction measures, mitigation measures, and monitoring. The age of volcanic centers in the Abuli-Samsari Ridge is younger towards the north, and hence towards the pipelines. A young, <10,000 y lava flow from Tavkvetili Volcano is adjacent to an automatic block valve station for the BTC. Future volcanic activity might develop in the form of fissural eruptions or growth of localized vents along an about N-S tectonically-controlled direction. Our study has shown that the section of the pipeline route in the Abuli-Samsari Ridge area is subject to risk from new magmatic activity that was not previously recognized in the design of the pipelines.

As regards seismic risk, we identified a major, 25-km long, NW-SE trending strike-slip fault; based on the analysis of fault planes along this major transcurrent structure, a N-S trend of the maximum, horizontal compressive stress ($\sigma 1$) was determined, which is in good agreement with data instrumentally derived after the 1986 Paravani earthquake ($M = 5.6$) and its aftershock. We believe this strike-slip stress regime (and the related trend of the $\sigma 1$) can be regarded as the one affecting the pipeline area. Movement along the fault could produce surface rupture, and produce an earthquake at least equal to the Paravani event.

The original design of the pipelines included mitigation measures for geohazards, including burial of the pipeline for its entire length, increased wall thickness, block valve spacing near recognized hazards, and monitoring of known landslide hazards. However, the original design did not consider volcanic risk, or the specific seismic hazards revealed by this study.

# CIRCUM-ARCTIC LITHOSPHERE EVOLUTION (*CALE*)

Victoria Pease

The geological evolution of the Arctic region is one of the last unknowns in global plate tectonics. The Arctic Ocean basins are relatively inaccessible to direct sampling and known mostly from 'remote' geophysical methods. For example, the Amerasia Basin at c. 3800 meters below sea level is virtually unexplored. Its age and spreading history have been inferred from structural and stratigraphic relationships observed on the basin margins. These inferences have not been confirmed by observations within the basin itself. On-shore, the Arctic region comprises remote wilderness areas far from supporting infrastructure and consequently is mapped mostly at a reconnaissance scale; the lack of age control on units, structural fabrics, timing of fold and thrust belts, etc., makes it difficult to correlate geology from one region to another, to extrapolate geology from on-shore to off-shore, or to constrain the development of Arctic ocean basins using circum-Arctic geologic data.

In the past decade a number of campaigns in the Arctic region have focused on marine, aerogeophysical and geological investigations, however, very few of these initiatives actually integrate on-shore and off-shore geology. Furthermore, in recent years new methods and surveys have become available which allow us to test existing, and confidently formulate new, hypotheses regarding various submarine features of the Arctic, such as:

- *Where are the plate boundaries associated with the Amerasia Basin?*
- *How and when did the Canada Basin open?*
- *What was the pre-drift setting of the Chukchi Borderland?*
- *Which tectonic processes formed the Laptev, East Siberian, and Chukchi sea shelves?*
- *How and when did the major ridges in the Amerasia Basin form?*
- *Where are the Early Tertiary plate boundaries in the Arctic?*
- *What is the relationship between segmentation of the Gakkel Ridge and ultra-slow spreading processes?*
- *Has the axial geometry of the Gakkel Ridge changed since rifting? If not, why?*
- *What structures connect seafloor spreading on the Gakkel Ridge to continental extension on the Laptev Shelf?*
- *Where are the continuations of pre-Eocene orogens in the Arctic?*
- *How do these crustal-scale discontinuities influence Arctic tectonic evolution?*
- *What is the nature, age, internal structure and stratigraphy of the main sedimentary basins?*
- *How has this tectonic evolution affected the sedimentation history of the Arctic basins?*

Circum-Arctic Lithosphere Evolution (*CALE*) is a multinational and multi-disciplinary research program investigating these questions in order to understand circum-Arctic lithosphere evolution in general, and to unravel the tectonic development of the Amerasia Basin in particular.

# European LAB constrained from seismic anisotropy

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Exploiting the long memory of the fabric of the deep continental lithosphere, we define the lithosphere-asthenosphere boundary (LAB) as a boundary between a fossil anisotropy in the lithospheric mantle and an underlying seismic anisotropy related to present-day flow in the asthenosphere. We present a uniform updated model of the European LAB recalculated from data collected during our regional studies of seismic anisotropy and other tomographic experiments (Plomerová and Babuška, Lithos 2010). An analysis of static terms of teleseismic P-wave travel time deviations shows that the LAB topography is more distinct beneath the Phanerozoic part of Europe than beneath its Precambrian part and deepens down to ~220 km beneath the two Alpine roots, the South Carpathians and eastward of the Trans-European Suture Zone.

In general, there are similarities between the LAB models derived from various geophysical parameters and techniques, as well as diversities, which might reflect differences in resolution and accuracy of individual methods. On the other hand, different physical parameters can 'see' different LABs and diverse lithosphere structures. Therefore, we advocate the necessity of combining different methods and datasets, and especially 3D approaches considering both seismic anisotropy and the general orientation of symmetry axes to construct more realistic models of large-scale lithospheric structure. We propose processes which could create the observed fossil fabric of the continental lithosphere as a consequence of successive subduction and accretion of micro-continent fragments outboard of continental cratons and a gradual stabilization of the LAB by a mantle flow after a detachment of the lower parts of subducting slabs.

International Lithosphere Program

**The Task Force Sedimentary Basins**

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The Task Force on Sedimentary Basins addresses the dynamics of sedimentary basins on different scales and aims to bring together studies focussing on geodynamics, tectonics, sedimentology / palaeontology, and geochemistry. We promote the dialogue between researchers studying the basin fill with those investigating the deeper structure as well as with those developing numerical and analogue experiments of processes that take place in basins of different geo-tectonic settings. To combine basin-fill related research with concepts of deep lithospheric deformation and to evaluate the relationship between the two end members, contributions have been received integrating data from different depth levels of the lithosphere as deep seismic sounding and analysis of the potential fields with observations from the shallower parts of the basin system as subsidence pattern, stress, vertical motions and active faulting. In addition contributions analyzing the interactions between deep earth and surface processes, i.e., thermicity, phase-transitions, fluid circulations and transfers, fluid-rock interactions, interactions between tectonics, erosion, sedimentation and climate and studies yielding constraints on the variety of conceptual and quantitative models explaining the origin and evolution of basins in different tectonic settings are integrated.

We also provide support for young scientists (PhD and post-docs) to participate in the activities of this international network.

The activities of the task force include regular meetings involving colleagues from universities, research institutes as well as the industry and several publications.

**2005 workshop in France (Foreland fold and thrust belts)** O. Lacombe (UPMC, France), J. Lavé (Univ. Grenoble, France), F. Roure (IFP) and J. Vergés (Barcelona) were the convenors of the first workshop of the new ILP Task Force on sedimentary basins, focusing on Foreland Fold-and-Thrust Belts (FFTB). This first meeting was held in December, 2005, hosted at IFP, being jointly sponsored by the Société Géologique de France and the Sociedad Geologica de España, with additional support from the industry, i.e. Shell, Total and Conoco-Phillips.

**2006 workshop in Canada (Circum-Polar basins)** D. Kirkwood (Laval University), D. Lavoie, M. Malo (INRS) and K. Osadetz (Geological Survey of Canada) organized the second workshop of the Task Force on September 18-22, 2006, at Laval University in Québec. This meeting benefited also from the sponsorship of Fugro, Gastem, INRS, Junex, Natural Resources Canada, Total and Shell, and focused on the History of convergent and passive margins in the Polar Realm: Sedimentary and tectonic processes, transitions and resources.

**2007 workshop in Morocco (Subsidence and uplift in African basins and margins)**G. Bertotti (VU-Amsterdam), D. Frizon de Lamotte (University of Cergy-Pontoise), A. Teixell (University Autonoma of Barcelona) and M. Charroud (University of Fes) organized ILP sessions dedicated to discuss the history of vertical movements in African basins and margins, which were hosted by the MAPG (Moroccan Association of Petroleum Geologists) on October 28-31, 2007, during their first international conference and exhibition held in Marrakech. Numerous companies sponsored this first international conference of MAPG.

**2008 workshop in Mexico (Geodynamics of Mexican basins, with focus on the Gulf of California and its surroundings)** CICESE (Center of Scientific Research and Graduate Studies in Ensenada) and the Mexican Geophysical Union (Unión Geofisica Mexicana, UGM) hosted the 2008 workshop in Ensenada, Baja California, Mexico, from September 21 to 26. This workshop, organized by L. Delgado (CICESE) and F. Ortuño (Instituto Mexicano del Petróleo), involved also the other ILP Task Forces dealing with mantle processes, volcanism and paleostress.

**2009 workshop in Abu Dhabi: "Lithosphere dynamics and sedimentary basins: the Arabian plate and analogues"** Thanks to the help of the local organizing committee an excellent 5th workshop of the task force took place from December 6-11 in Abu Dhabi, hosted by the Ministry of Energy of the Emirates. 170 participants from 20 countries (60% from the Middle-East, with 30% from research institutes, 30% from universities and 30 % from industry) have attended 2,5 days of conference, + one pre-conference field trip to Al Ain + one post-conference field trip to Dibba. Proceedings are to be published in 2010 in a special issue of the Arabian Journal of Geosciences and one Springer volume (Frontiers in Earth Sciences series).

**2010** The **sixth workshop of the Task Force is scheduled for 7-12 November 2010 in Albania**, and is organized jointly with the Polytechnic university of Tirana, the seismological institute and the National Energy Agency. The aims of this meeting and companion field trip would be to learn more from this natural laboratory with very active tectonics, in the scope of Topo-Europe, with presentation of the results of recent GPS campaigns and other geophysical studies supported by NATO, and further studies dealing with fluid-rock interactions and coupled fluid flow and thermal modelling.

Following the success of their first international meeting in 2007, Moroccan colleagues have asked us to participate to a 2nd joint MAPG-ILP-AAPG in Marrakech, May 2-5, 2010, with ILP sessions chaired by F. Guillocheau (Topo-Africa), L. Jolivet (the fate of the Mediterranean slab), G. Manatschal (Atlantic margins) and G. Bertotti (active tectonics and unroofing history).

**List of publications**


Springer, 2007, Proceedings of the first workshop of the Task Force: Thrust belts and Foreland Basins, Lacombe O., Lavé J., Roure F. and Vergès J., eds., (25 papers)

Bulletin of Canadian Petroleum Geology, 2008, Proceedings of the 2nd Task Force 6 workshop (Québec meeting): edited by Donna Kirkwood, Michel Malo, Kirk Osadetz and Denis Lavoie.

Special issue Tectonophysics, 2009, Proceedings of the 3rd Task Force workshop (Marrakech meeting): edited by G. Bertotti, D. Frizon de Lamotte, A. Teixell and M. Charroud.

Special issue Tectonophysics, 2009, Outcomes from 2007 EGU Vienna meeting: edited by Magdalena Scheck-Wenderoth, U. Bayer and F. Roure.

Special issue Marine and Petroleum Geology, 2010, "The link between shallow and deep processes in sedimentary basins" Outcomes from 2008 EGU Vienna and IGC Oslo meetings: edited by M. Scheck-Wenderoth, U. Bayer and F. Roure.

Special issue Marine and Petroleum Geology, Volume 27, Issue 3, March 2010, Pages 563-564: The link between shallow and deep processes in sedimentary basins. Outcomes from 2009 EGU Vienna meeting: edited by M. Scheck-Wenderoth, U. Bayer and F. Roure

Special issue of Arabian Journal of Earth Sciences, 2010. Proceedings of the 5th Task Force workshop (Abu Dhabi meeting): in review

# Assessing volcano flank instability in Dominica, Lesser Antilles arc

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A multidisciplinary geological and geophysical study is underway to assess newly recognised flank instability on the north slope of Morne aux Diables volcano, the northernmost of nine volcanic centres on the island of Dominica. Bathymetric data suggests that offshore the slope is truncated by an active fault structure with a dip-slip component that causes uplift of the unstable flank. Onshore, field, remote sensing and VLF geophysical surveys reveal an unstable complex, occurring above inferred deep-seated rotational failure planes, that includes open water-filled fissures associated with spreading and toppling failures. Large-scale failures have the potential to generate devastating tsunami that would inundate coastal zones of Guadeloupe only 30 km to the north. A relatively small potential landslide block of ~1 M tonnes on the seaward margin of the instability complex that has large tension cracks on its upslope margin is particularly notable. Failure of this block could destabilise an even larger adjacent upslope block (~ 3 M tonnes), and preliminary modelling calculations indicate that landslides at these scales could trigger tsunami waves, locally reaching up to 4 m in height, which would cause significant inundation along the southern coast of Guadeloupe. Such failures might be expected to be triggered by earthquakes occurring at the subduction interface, or in the overlying upper plate. However, a ML 6.0 event in 2004 some 20 km NW of Dominica did not generate significant landsliding. It may be that a combination of large earthquakes occurring in the wet season is required to initiate renewed movement on deep-seated failure planes.

# The hidden volcanic hazard: the low-water submarine volcanoes of the Sicily Channel, Mediterranean Sea

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The Sicily Channel (central-western Mediterranean) represents a Pliocene-Pleistocene rift system bordered by NW-SE-striking normal faults, cutting the accretionary prism of the Maghrebide-Sicilian-Apennine orogen. This sector, floored by a variably thinned and faulted continental crust, was the site of intense magmatic activity. Geophysical data suggest that tectonic deformation along the rift is still active but the processes that generated rifting in this zone are not fully understood although this sector is crucial for the comprehension of the magmatism of the northern African plate. Magmatism (Miocene to Present in age), both subaerial and submarine, has generated a wide spectrum of volcanic rocks with different affinities, and originated the Linosa and Pantelleria islands and several seamounts (e.g. Cimotoe, Tetide, Graham, Foerstner, Terribile), mainly located along extensional NW-SE-striking faults. On the seafloor of the Sicily Channel several recent submarine volcanoes of various dimensions occur. Some of these volcanoes have erupted during historical times; others are covered by undisturbed Pliocene-Quaternary sediments and have been detected by seismic profiles and magnetic survey. Unfortunately, studies of volcanism in the Sicily Channel have been limited almost exclusively to the subaerial portions of the volcanoes. The best known eruption of Sicily Channel occurred in correspondence of the Graham Bank in 1831 AD. This bank is located about 50 km south of the Sicily coast, shows a N-S-elongated shape and rises from a sedimentary basement sited about 350 m below sea level. The eruption produced the ephemeral Isola Ferdinandea that was rapidly dismantled by marine erosion. In 1891, a likely submarine eruption from a centre 5 km NW of Pantelleria was documented and in 1941, above the SE portion of the Graham Bank, gaseous emissions were observed. During the 2002-03 volcano-seismic crisis, an increase in submarine degassing at the summit of the Graham Bank stirred worries about a possible renewal of volcanic activity.

Although submarine volcanism at the general level, and particularly in the Mediterranean, is a very widespread phenomenon, it hasn't been intensely studied due to the difficulties in reaching and analysing the submarine centres. This represents an important gap to fill even considering that very recently (May 2006), on the northern slope of the Graham Bank, intense fumarolic emissions, which could suggest the presence of a shallow-depth magmatic body, have been documented. According to recent marine geological surveys, the Graham Bank belongs to a much wider volcanic complex that rises about 350 m from the sea floor, has a base diameter of 30x25 km and is constituted by numerous small volcanic edifices, some of them unknown. In particular, on the Graham Bank, the Ferdinandea volcano is associated to several cones of similar dimensions. Although the described volcanic complex has to be regarded as active and critical in terms of hazard, the knowledge of its volcanological characteristics is limited to the scanty accounts of the 1831 eruption and to a few petrological, geochemical and isotopic data carried out on rocks dredged from the Graham Bank during the surveys of the '70-.80. These data possibly indicate the presence in the Sicily Channel of a HIMU-FOZO mantle source and the existence of a fossil plume that variably contributed to magmatogenesis, in response to variable lithospheric stretching.

# The 12 Jan 2010, Haiti earthquake affected by aseismic fault slip

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On 12 Jan 2010 a destructive strike slip earthquake (Mw 7.1) occurred in oblique convergence zone of Hispaniola. Over 222,000 were killed, most in Port au Prince, the capital city of Haiti at ~80 km eastward distance to the mainshock. The earthquake ruptured along a 50 km trace, which is only a part of the much larger Enriquillo Fault Zone (EFZ) that last broke in 1751 along a length of ~150 km. Assuming an average slip rate of 5-9 mm/yr[1] the amount of slip deficit accumulated at the entire EFZ is estimated to be on the order of 1.5 – 2.5 meters[2]. This may imply that a much larger portion of the EFZ is ready for earthquake occurrences. Here we present results of a deformation field investigation in the period of 2004-2009 using ScanSAR data. The data and models reveal that the fault segment to the west of the 2010 earthquake was aseismically slipping for years, with a rate being similar as the interseismic convergence rate. Therefore, this study shows that the accumulating stress was partly released by aseismic slip. Coulomb stress calculations suggest that this may have enhanced the occurrence of the 2010 earthquake disaster, similar as now another fault segment further to the east is stressed. The observed relation between aseismic slip and the 2010 earthquake confirmed the importance of aseismic slip in earthquake understanding and for seismic hazard mitigation.

## Volcanic and tectonic deformation monitoring in central Alborz, northern Iran, using advanced InSAR time series

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Central Alborz (CA) accommodates ~5 mm/yr of shortening and ~4 mm/yr of left lateral strike-slip motion between Arabia and Eurasia plates (Vernant et al., 2004) onto strike slip and thrust faults. CA also hosts the dormant Damavand volcano.

Curently little is known about the present day deformation field in CA. Although, the seismic fault systems, in particular Mosha and North Tehran faults, are the source of several destructive earthquakes in the history (Ambraseys and Melville, 1982). Therefore, continuous monitoring these volcanic and tectonic systems is of importance for estimating the realistic hazard associated with Tehran city with ~13 Mio inhabitants.

In this study by employing advanced Interferometric Synthetic Aperture Radar time series, we try to establish an observatory scheme for high spatial and temporal monitoring the deformation field at these volcanic and tectonic systems. These observations provide new insights into dynamic of each system and helps better understanding their behavior and the mutual relationships. This also would be asoitable ground for reliable hazard evaluation in Tehran area.

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# Dynamic magma mixing during the 2010 Eyjafjallajökull eruption, Iceland

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After more than a decade of seismic unrest and significant deformation, Eyjafjallajökull volcano remained fairly calm until end of 2009. From December 2009 until 20 March 2010, the volcano experienced unrest (up to 14 km deep earthquakes) and sustained inflation. Seismic activity migrated upwards towards the surface, ending with a somewhat surprising lateral eruption on the Fimmvörðuháls pass, mid-way between Eyjafjallajökull and the more active Katla central volcano. Relatively primitive basalts with narrow MgO-concentration range (8-9 wt%) were emitted. They are comprised of homogeneous phenocryst (olivine, plagioclase and Cr-rich spinel). The highly vesicular texture of these basalt show abundant microlite crystallization most likely caused by degassing. Measured volatile concentrations in melt inclusions are high. The gas-rich Fimmvörðuháls basalt represents the parental magma of the Eyjafjallajökull volcano. A day after the last basalt emission on 14 April its summit crater became active. Vulcanian eruption produced fine-powdered tephra of trachy-andesitic composition that plots on a binary mixing-line between the 1821 trachy-dacite and evolved basalt composition similar to the groundmass glass of the Fimmvörðuháls basalts. The tephra from the 17 April is composed of three magma types having glass compositions of 49-51%, 60-61% and 69-70% $SiO_2$ that illustrates a mechanical magma mingling without enough time for homogenization before eruption. After 27 April only glass with $SiO_2$ of 58-60% is observed. On 4 Mai a deep seismic swarm occurred with consequent higher magma output as measured from the height of the eruption column on 5 Mai. The tephra from 5 Mai is comprised of well-mixed glass with $SiO_2$ of 62-63% but has 50µm zoned-olivines with 10 µm tick rim having a composition of $Fo_{48-50}$. The core has $Fo_{80}$, a composition similar to the olivines of the Fimmvörðuháls basalts. These results indicate a direct link between the arrival of primitive basalts, deep seismicity, increased magma pressure in the plumbing system, and higher magma output rate. Taken together, the second phase of the Eyjafjallajökull eruption is caused by dynamic magma mixing of older silicic intrusion remobilized by the crystallizing primitive basalt. The mafic end-member appears of deeper origin with time sustained by episodic inflow of mantle-derived basalts.

## The Thermal Field Below Permafrost - A Crustal Model of the Beaufort Mackenzie Basin (Arctic Canada)

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The Beaufort-Mackenzie Basin is a petroliferous province in northwest Arctic Canada and one of the best-known segments of the Arctic Ocean margin due to decades of exploration. Our study is part of the programme *MOM* (Methane On the Move), which aims to quantify the methane contribution from natural petroleum systems to the atmosphere over geological times. Models reflecting the potential of a sedimentary basin to release methane require well-assessed boundary conditions such as the crustal structure and large-scale temperature variation. We focus on the crustal-scale thermal field of the Beaufort-Mackenzie Basin. This Basin has formed on a post-rift, continental margin which, during the Late Cretaceous and Tertiary, developed into the foreland of the North American Cordilleran foldbelt providing space for the accumulation of up to 16 km of foreland deposits. We present a 3D geological model which integrates the present-day topography, published tops of Tertiary and Upper Cretaceous units, as well as tops of deeper Mesozoic formations derived from wells and 2D reflection seismic lines. Physical and thermal rock properties have been included based on published geophysical data compilations and the sequence stratigraphic framework established for the region. To determine the position and geometry of the crust-mantle boundary, an isostatic calculation (Airy´s model) is applied to the geological model. Finally, we present calculations of the steady-state 3D conductive thermal field and their relevance for the formations below the base of permafrost.

## The topography of the Eurekan Orogen of Ellesmere Island and the Canadian-Greenland polar continental margin

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Ellesmere Island, in Canada's Arctic, comprises a series of ~SW-NE trending tectonic provinces, the crustal structure and geological expression of which represent a combination of interplate, accretionary orogenesis in the Palaeozoic (Caledonian equivalent and Ellesmerian orogenies) and intraplate orogenesis in the Paleogene (Eurekan Orogeny). The present-day topography of Ellesmere Island is closely related to the crustal architecture of these tectonic provinces, which includes the adjacent polar continental margin. The first-order crustal structure of the area has been deduced from the regional gravity field: the high topography of northwest Ellesmere Island is isostatically compensated by a thick crust; the Hazen Trough (Hazen Foldbelt) running most of the length of central Ellesmere Island is underlain by a shallow Moho; and the central Ellesmere fold-and-thrust belt loads (Greenland-Laurentian) cratonic basement that flexes to the northwest beneath it. The first-order geological and crustal structure can be explained by a model, supported by the preliminary analogue modelling results, that depends on lithosphere-scale structures imposed during Palaeozoic orogenesis being reactivated during Eurekan (Paleogene) intraplate shortening ("mega-basin inversion"). In order to test this model – and to complement the scarce seismological data that are available in the area (only two receiver function estimates of Moho depth) – a passive seismology campaign is underway. Eight temporary seismic observatories were installed, using instruments and equipment provided by SEIS-UK, across Ellesmere Island in June and July of this year and will be removed in 2012. The objectives are to collect sufficient high quality seismological data for (i) receiver function analyses (Moho depth and other first-order crustal and upper mantle discontinuities) for the structurally diverse tectonic provinces of the Eurekan Orogen, (ii) shear-wave splitting analyses to determine the presence, geometry, and character of possible lithosphere anisotropy within the Ellesmere Island lithosphere and (iii) surface wave studies to determine lithosphere thickness and for joint inversion studies in this frontier region. The results will comprise a key element of a Canada-Greenland polar margin lithospheric transect within the CALE (Circum-Arctic lithosphere evolution) task force of ILP.

# Strategies for improved earthquake source modelling using InSAR (Interferometric Synthetic Aperture Radar)

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We present strategies of data error treatment in earthquake source studies using InSAR data and how we can assess model parameter uncertainties arising from data error. Earthquake source modelling is an active and important research field. In particular, modelling based on surface deformation data from the young InSAR technique develops fast and provided information about the locations, geometries, dimensions and fault displacements of earthquake sources already for many significant earthquakes of the past two decades (Massonnet & Feigl 1998). For some of these earthquakes more than one source model exists, however, and these models inferred by different research teams tend to differ from one another (Mai et al. 2007). At the same time, estimations of the model parameter uncertainties are not always provided. Without such estimations it is impossible to compare different models and to judge whether or not these differences are significant (Sudhaus & Jónsson 2009).

Model parameter uncertainties arise partly form data errors. In the presented source studies we combine independent geodetic data sets under consideration of the individual data errors, and we assess the model parameter uncertainties related to the data and data errors. The data error covariances we use are based on empirical estimates.

The consequent and consistent handling of data errors in modelling and the propagation of errors to model uncertainties is not only relevant as a quality measure of the individual source model itself, but for any research that integrates these models. Earthquake source models are used, e.g. in local and regional hazard assessments, deterministic or probabilistic, as well as in calculations of Coulomb failure stress changes and in aftershock fore-casting. The impact and need to propagate the uncertainties of earthquake source models in such studies is dicussed e.g. in Hainzl et al. (2009) and Baumann et al. (2009).

Within the framework of PROGRESS (Potsdam Research Cluster for Georisk Analysis, Environmental Change and Sustainability), we intend to test and apply comprehensive approaches for hazard assessments in Central Asia.

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# Living beside an explosive volcano during a long eruption requires changes to standard public outreach tactics.

The normal procedure during a volcanic eruption close to humans is for scientists (often from elsewhere) and the local civil authorities to produce such items as hazard maps and communicate them to the residents via the press, public meetings etc. But certain changes to this situation take place when the eruption is long-lasting, as on Montserrat, Lesser Antilles, for the last 15 years. Then the educated residents rapidly become such expert amateur volcanologists that they are extremely resistant to being told what to do by so-called experts lacking their own long close-up experience of the volcano and its behaviour. Once the initial phase of terror and evacuations is over, residents become so completely accustomed to the volcano and its eruptions and subsequent lahars that they tend to treat it as a sort of theatrical performance [http://www.youtube.com/watch?v=z7bTnKjFZQY]. Although such casual public attitudes can lead to tragic fatalities early in the eruption (as on 25 June 1997), growing group experience subsequently allows residents to live and work extraordinarily near to lethal hazards [http://www.montserratvolcano.org/war.htm]. Furthermore, the residents watch the scientists doing their work within so-called exclusion- or danger-zones and rapidly work out for themselves how to wander as they wish within such nominally closed areas. Likewise, they mostly make their own local evacuation decisions and need no input from the authorities when doing so.

The risk as such situations develop is that scientists, civil authorities or both feel their authority to be challenged. This can lead to pointless confrontations and mutual loss of ability to communicate. It may be that the best way to combat such potential problems is to actively introduce the residents, especially school children, to the nearby dangers around the volcano. The emphasis on children is required because of the inevitable tendency of adventurous ones to take matters into their own hands and explore anything seen as "forbidden". If such things will happen in any case, it makes good communication sense to introduce such children, and others who may be interested, to such places as areas recently devastated by pyroclastic flows and surges. This is application of the same approach to education that makes adults teach children to swim and also how to behave near roads and other such potentially lethal places.

The remaining area of extreme complexity is the background of cultural beliefs held by each of the local population. The tendency is for scientists to do their science and then try as amateur communicators, or via a so-called professional in this field, to transmit their messages to the residents. Both they and governments then wonder when huge communication problems arise. Montserrat is a good example of such situations. The multigenerational black residents call themselves Irish and are indeed as close to the Irish in genetics, history and culture as those in, say, Boston. The incoming black immigrants come from a huge range of equally complex cultural backgrounds. Both black and Caucasian residents include a substantial proportion who are fundamentalist Christians and see an eruption and its effects through the same eyes as rural Catholic Sicilians or Mexicans. In turn, all these groups with theistic religious beliefs persistently cling to cultural remnants of their distant animistic ancestors. For example, I am incapable of resisting literally "touching wood" in appropriate situations! The only way for scientists from elsewhere to overcome such deep potential communication problems is to deliver their messages exclusively via local intermediaries within each of the diverse belief communities and to have the humility to realise that they simply cannot communicate directly without horrendous misunderstandings.

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# Moho and magmatism in extensional settings

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The Moho is defined by an abrupt change in seismic velocity, which is often attributed to the petrological crust-mantle boundary. However, other types of transitions may explain observed pronounced seismic reflections, such as metamorphic changes in iso-chemical rocks from granulitic lower crustal rocks to eclogitic facies, pronounced shear zones, or magmatic intrusions. Therefore, it is of crucial importance to have high-resolution models of the seismic velocity around the Moho. Further, the seismic reflectivity in normal-incidence and wide-angle may provide valuable constraints on the structure at the crust-mantle boundary. In areas influenced by strong magmatism with mantle source, e.g. at rift zones and other extended regions, the resulting transition between crust and mantle may assume several forms.

New data from a >100 km long and 20 km thick non-reflective zone in the Danish Basin with extremely high seismic velocity (6.8-7.8 km/s) demonstrates that the Moho reflector at the base of the high-velocity body is interrupted in a ca. 20 km wide zone. The high velocity body is interpreted as a mafic batholith in the crust, and the Moho-free zone as the feeder channels of the batholith. Variation in seismic amplitude along the strike of the batholith provides indication for the mafic content of the deepest rocks in the body. We further observe extremely strong wide-angle reflectivity from a ca. 4 km thick zone with high velocity, extending for up to 100 km away from the batholith. We interpret this reflective depth interval as a zone of magmatic underplating in the form of sills, which intruded during the late stage of the formation of the batholith. The magma probably had the same source as the body, and it intruded along the Moho in the late stage of magmatism due to pressure changes caused by cooling.

The presently active rift zones in Eastern Africa and at Lake Baikal thicker, as well as extinct rift zones, show extremely strong reflectivity of the lower crust and upper mantle. All rifting models predict Moho uplift due to crustal thinning, and reduced seismic velocity in the uppermost mantle due to decompression or heating from the Earth‘s interior. However, seismic data from several rift zones show no or very little Moho topography that can be related to the rifting process. At all these rift zones, we observe a localized zone in the lower crust which has exceptionally high seismic velocity and is highly reflective. We suggest that rift related crustal thinning took place, but the expected Moho uplift was compensated by magmatic intrusion into the lower crust at the high-velocity zone. This finding has significant implications for modelling the evolution of sedimentary basins around rift structures.

As such, compelling evidence is emerging for a strong role of magmatism on the character of the Moho interface, not least in extensional areas.

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# Magma migration below volcanoes: the Isle of Skye, Scotland, intrusive system revisited

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Abstract
The mechanics of emplacement of intrusive sheets (inclined sheets and vertical dykes) from shallow magma chambers beneath volcanoes is crucial in understanding the processes of magma migration and volcano evolution. The correct interpretation of deformation and stress patterns related to sheet emplacement can also contribute to volcanic and seismic hazard assessment at active volcanoes. Sheet emplacement is generally seen as the propagation of purely dilational joints, which follow trajectories perpendicular to the least compressive principal stress axis σ3. However, sheet emplacement along hybrid fractures that also show a shear component (and hence form an acute angle to σ3) has been observed in the field and in analogue models and postulated by mechanical models. New-generation numerical models and field data help in understanding fundamental volcano-tectonic processes, such as sheet/dyke propagation, magma chamber inflation, volcano stress field and internal growth.
Here we describe new structural field data of more than 1100 intrusive sheets, collected at the classical Cuillins cone-sheet complex (Isle of Skye, United Kingdom). Moreover, we use elasto-plastic finite element models to complete the interpretation of the resulting field data. These sheets have a constant average dip (45°), with pure dilational or hybrid opening/shear kinematics. Our numerical models, which for the first time consider the total stress field including gravity, tectonics and magma overpressure, show that only in the case of an inflating shallow oblate magma chamber can cone-sheets be predicted. They do not develop with spherical or prolate magma chambers and/or under deflation. Radial dykes dominate beyond a critical distance of 1-1.2 diameters of the magma chamber, whilst cone-sheets are confined immediately above it.
The result is a new model of cone-sheet emplacement that sheds new light on how the substratum can deform and magma can migrate below volcanoes. These results may also be used to infer the geometry and tensional state of magma chambers under active volcanoes.

# Determination of Risk Response Measures for Strategic Facilities: Caspian Oil and Gas Pipelines in the Republic of Georgia

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The Caspian region is one of the major oil and gas producing areas in the world, with much of the production coming through the Republic of Georgia, between the Greater Caucasus and Lesser Caucasus ranges. The likelihood of future volcanic, seismic, and related geohazards along the right of way for these strategic pipelines threatens these vital energy links. At the time of pipeline design and construction, the Abuli-Samsari Ridge was thought to be inactive, posing a minor seismic risk and landslide risk. However, recent work has shown that the area is volcanically and seismically active, and has quantified the hazards. Using these data, we have evaluated the adequacy of the design and operation of the pipeline in light of the new risk assessment.

We have developed a more transparent risk communication method to allow greater use of scientific information in the final decision-making process regarding the acceptability of risks and consequences. Most widely-used methods can be difficult for stakeholders and the general public to understand. Societal risk decisions are of crucial importance because they shape the location and design of strategic infrastructure, and as such the risks that society is willing to accept. Although complex, it is important that stakeholders be able to understand the key issues and the consequences of decisions. For this geohazard risk analysis, we use a risk matrix for presenting the results of the hazard assessment. This approach ranks the risks according to the likelihood and consequences of an event by a simple scale, such as high, medium, or low, or a numerical scale. Each threat is assigned to a cell of the matrix based on its likelihood and consequence. Effects with both a high likelihood and a high consequence receive a higher priority for risk reduction, mitigation measures, or monitoring. Although the use of the matrix is a simplified approach, the approach presents an easy-to-understand framework for decision making.

The result of the analysis is that the pipelines were designed in such a way that they significantly reduce the risk posed by the newly-identified geohazards in the vicinity of the Abuli-Samsari Ridge. Recommendations for reducing the response time in the event of a volcanic or seismic event are developed, because long-term shutdown of these regionally significant pipelines would be damaging to the economies of Western Europe.

# Comprehensive Review of Pleistocene to Recent Volcanics of Italy Using Classical Geochemical-Petrological Discriminant Diagrams

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Volcanic rocks in Italy are widely distributed and geochemistry of the rocks is highly complex. We compiled data from the literature and evaluated vigorously using all classis geochemical-petrological techniques. Main trust of the paper is to find more representative location(s) for further geochemical data collection for an experimental research and thus contribute on refining on complex geodynamic setting and magmatism of Italy. In this paper, we re-evaluated the following volcanics from Italy; Stromboli (0.2 Ma-present), Etna (0.6 Ma-present), Somma-Vesuvio (0.03 Ma-79 AD, 472 AD, 1631 AD, 1944 AD), Vulcano (0.12 Ma-1888 AD, 1890 AD), Campi Flegrei (0.2 Ma-1538 AD), Ischia (0.15 Ma-1302 AD), and Lipari (0.22 Ma-580 AD).The total number of data points was more than 1300.

# Chemostratigraphy Concept as Applied to Some Volcanostratigraphic Units at Cappadocia, Central Anatolia, Turkey

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Chemostratigraphy - applying quantitative mineralogy-petrology-geochemistry techniques to complex sedimentary and/or volcanic sequences - is a useful tool for addressing many difficult-to-solve geologic problems, particularly local and regional correlations of units. With the advancement of modern analytical instrumentations and techniques (morphological, mineralogical, chemical), it is becoming more feasible to apply such chemostratigraphic methods on a more routine basis. For example, the stratigraphy of the Cappadocia region is complex and some of the volcanostratigraphic units are very important. Therefore, the correct application of chemostratigraphy can be an excellent tool to solve stratigraphic and mineralogical-geochemical problems. In the study area, the generalized stratigraphic column of the Cappadocia volcanostratigraphic units include, from older to younger, Kavak, Akdag, Zelve, Lower Damsa unit, Sarimaden, Upper Damsa unit, Topuzdag, Cemilkoy, Tahar, Gordeles, Sofular, Kizilkaya, Incesu, and Valibaba. The original maps and the general stratigraphy of the area were initially made by Pasquare in 1970's, and he visited the area in 2007 and together with Dogan and his team checked the details of mapping. Dogan and Dogan have been working on this area for the past 15 years; however no attempt had been made to quantitatively correlate these units. In this research, we first compiled all previous data, mostly major element and some trace element data, to establish the compositions of the main stratigraphic units. Next, we used high resolution electron microscopy, inductively coupled plasma-mass spectroscopy, and powder x-ray diffraction to further characterize some of the units. Work in progress will involve using more complete geochemical data including trace and rare elements and stable isotopic data for correlation and extrapolation of these units.

# Mesothelioma epidemic in Cappadocia/Turkey: Geological mapping as basis of risk assessments

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A mesothelioma epidemic known since 1978 causes > 50 % of all deaths in three villages in Cappadocia, Central Turkey [1,2]. The high mortality was shown to be linked to the chronic dust exposure to Erionite, $(K_2,Ca,Na_2)_2[Al_4Si_{14}O_{36}]\cdot 15(H_2O)$, which is known to be a human carcinogen and was detected in the dust of these villages [3]. Erionite is a mineral of the chabazitic zeolite group and is commonly found in altered silicic tuffs/ignimbrites in saline lacustrine sediment successions, e.g. in the USA in Nevada, Oregon and California, as well as in Japan, New Zealand and some European countries [4]. However, except for Cappadocia, nowhere else Erionite exposure could be linked to such a high mortality. Recent studies in Cappadocia [5] revealed, that mesothelioma caused by Erionite may be genetically predisposed.

The landscape of central Cappadocia, especially the Nevşehir Plateau, is characterized by scenic erosional structures in thirteen rhyolitic to dacitic ignimbrites and two fall-out tuffs (fig. 1, 2) [6]. The ignimbrites are dominantly non-welded and cover an area of 2.000 $km^2$ to more than 10.000 $km^2$ with volumes of several 10s to some 100 $km^3$. The succession is of Late Miocene age (11-5.5 Ma) as indicated by Ar-Ar-dating [7]. Most of the traditional houses were dug as dwellings into the soft, non-welded ignimbrites. More recent houses are built with carved blocks of the ignimbrites, most often unplastered. Inhabitants of villages are thus continuously exposed to dust of tuffs since infancy.

Since ten years we study the distribution, lithology, petrography and chemistry of the succession of ignimbrites, fall-out tuffs and interlayered sediments in Cappadocia [6]. Our field studies indicate, that in Cappadocia three depositional environments can be distinguished on/in which the ignimbrites came to rest during the Late Miocene: (a) lacustrine basins, (b) laharic depositional fans with pedogene overprint and (c) erosional surfaces (fig. 3, 4 and 5). Our results show, that the lateral distribution of Erionite is very restricted; it only occurs within those tuffs that were deposited in lacustrine environments, supporting studies on silicic tuffs deposited in saline lacustrine deposits [4]. Thus, geological studies were needed on the distribution of potentially Erionite-bearing ignimbrite facies generated by a self-produced hydrothermal system during emplacement in lacustrine basins. In cooperation based on ERASMUS agreements with the universities of Niğde and Sivas we started mapping the depositional facies of sediments directly underlying the base of each ignimbrite within diploma thesis (fig. 4, 5 and 6a-d) [8].

The results indicate, that the two ignimbrites younger than 7 Ma only overlay terrestrial sediments. Ignimbrites between 10 and 7 Ma in age overlay lacustrine sediments only in the north. The emplacement facies of ignimbrites older than 10 Ma have not been studied yet. The facies maps indicate variable southward extensions of the Paleo-Ürgüp-Basin in the north onto the laharic paleo-plaines of the recent Nevşehir Plateau (fig. 6a-d). Maps documenting the lateral variations in the depositional facies of each ignimbrite form the necessary base of any exposure assessment to Erionite fibres, not only in Cappadocia, but principally in any field of ignimbrites of differentiated subalkalic composition.

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# MINERALOGICAL COMPOSITION OF MT. ERCIYES LAVAS TO CALCULATE WITH MELTS MODEL

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The Quaternary-aged Mount Erciyes stratovolcano, which culminates at 3917 m, is situated on the Central Anatolia, Turkey. Calc-alkaline rocks of Mt. Erciyes stratovolcano range in composition from basalt to rhyolite but are dominated by andesite and dacite.

In this research, the MELTS algorithm of Ghiorso and Sacks (1995) has been used to calculate the mineralogical composition. Pressure conditions were chosen 500 and 750 bar, 1, 2, 3, and 4 Kbar; temperature conditions were selected from 850 to 1250 °C for all pressure conditions, and $H_2O$ contents were assumed 2 mol.

In this modeling of Mt. Erciyes, andesite was selected as representative mineral due to its lower silica content (%57.92) and it is accepted as primitive magma. Pressure conditions were chosen 1000 bar; at $fo_2$~NNO in the temperature conditions were selected from 1250 to 850 °C, and $H_2O$ contents were assumed 2 mol. The temperature was reduced 10ºC at each step of the crystallization calculation.

At 1000 bar and 1082.38 °C, the andesite is crystalline, and it contains orthopyroxene. At 1072.38 °C and 1000 bar, its mineralogy is orthopyroxene and feldispar (anorthite %74.39, albite %24.91, sanidine %0.70). At 1022.38 °C and 1000 bar, the andesite mineralogy consists of orthopyroxene, clinopyroxene, feldispar (anorthite %68.42, albite % 30.68, sanidine %0.95), and spinel group minerals (magnetite, spinel, ulvospinel, hercynite). At 882.38 °C and 1000 bar, the andesite is completely crystalline and its mineralogy consist of orthopyroxene, clinopyroxene, feldispar (anorthite %43.69, albite %53.55, sanidine % 2.76), spinel group minerals (magnetite, spinel, ulvospinel, hercynite), and rhombohedral oxides (ilmenite, geikielite, hematite and pyrophanite).