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Exploring Structural Controls on Great Earthquakes along the Sumatra Subduction Zone

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A series of linked marine and land studies have recently targeted the Sumatra subduction zone focusing on the boundaries of the 2004 and 2005 plate boundary earthquake ruptures in Indonesia. The collaborative UK-Indonesian-US-French-German research effort aims to image the crustal structure of the margin to examine controls on along-strike and up-dip earthquake rupture propagation. The project collected extensive marine geophysical, geological, and seismological data across the offshore and onshore parts of the subduction zone of North-Central Sumatra (Figs. 1, 2), and included the largest research vessel exchange program undertaken to date.

Using the German vessel *RV Sonne,* the group acquired 4750 km of multichannel seismic reflection data, and conducted a combined active-source refraction experiment with 95 ocean bottom seismometers (OBS) and 50 stations on land. This experiment was followed by earthquake monitoring over 10 months with up to 60 instruments, including 10 OBS. In addition, the project collected deep-towed sidescan sonar data, multi and piston cores and two heat flow transects as well as along-track multibeam bathymetry, gravity and magnetics data. 140 days of shiptime during 2008 and 2009 were bartered through the Ocean Facilities Exchange Group, primarily funded by the UK Natural Environment Research Council with additional funding from the US National Science Foundation. Additional passive seismic arrays were deployed in the Toba volcano area by GFZ Potsdam, and also farther south in the area of the 2007 plate boundary rupture, in total, monitoring nearly 800 km of plate margin for 6-12 months. In parallel with the onshore-offshore field data collection, the UK-funded project is also developing new methods to refine slip distribution inversions for the earthquakes of 2004, 2005 and 2007.

The fundamental science objective is to examine how margin architecture and properties control earthquake rupture location and propagation. The main survey spanned two segment boundaries of the subduction zone (Fig. 1): 1) between the 2004 and 2005 ruptures at Simeulue Island; and 2) at the southern limit of the 2005 rupture, adjacent to the short 1935 rupture segment, at the Nias and Batu Islands. These extensive geological

and geophysical data examine variations, at a range of scales, in seismicity, forearc deformation, plate boundary properties, lithospheric structure and sedimentary properties and processes. The combined studies are especially relevant given the societal impact of the 2004 earthquake and tsunami and the continued potential for great earthquakes both along this margin and other analogous subduction margins; improved understanding of rupture processes will aid understanding and preparedness for future major subduction zone earthquakes. Data from the passive deployment are already helping to characterize the structural context of the 2009 Padang earthquake, within the subducting Australian Plate. Results are also being used to identify potential borehole sites for an evolving Integrated Ocean Drilling Program proposal, the first to target the Sumatran margin. IODP drilling aims to analyze sediment and fault properties and to monitor post-seismic deformation, to further understand the relationship between physical properties, structure and the earthquake rupture process. To discuss integration of results and future research plans in this region, recent (April, 2010) and future (2011) workshops are bringing together diverse international research groups.

Figure 1. Data collected during the combined project, showing offshore tracklines, onshore and offshore instrument/seismometer locations, core sites, and heatflow stations. Tracklines overlain on multibeam bathymetric data from this study overlain on GEBCO low resolution bathymetry. Black stars - major earthquake epicenters . Inset: epicenters and approximate rupture zones of recent large plate boundary earthquakes. UKSC=UK Sumatra Consortium; UTIG=UT Institute for Geophysics.

Figure 2. a) Deployment of TOBI deep-towed sidescan sonar offshore Sumatra. b) Example onshore seismometer station during long term deployment.

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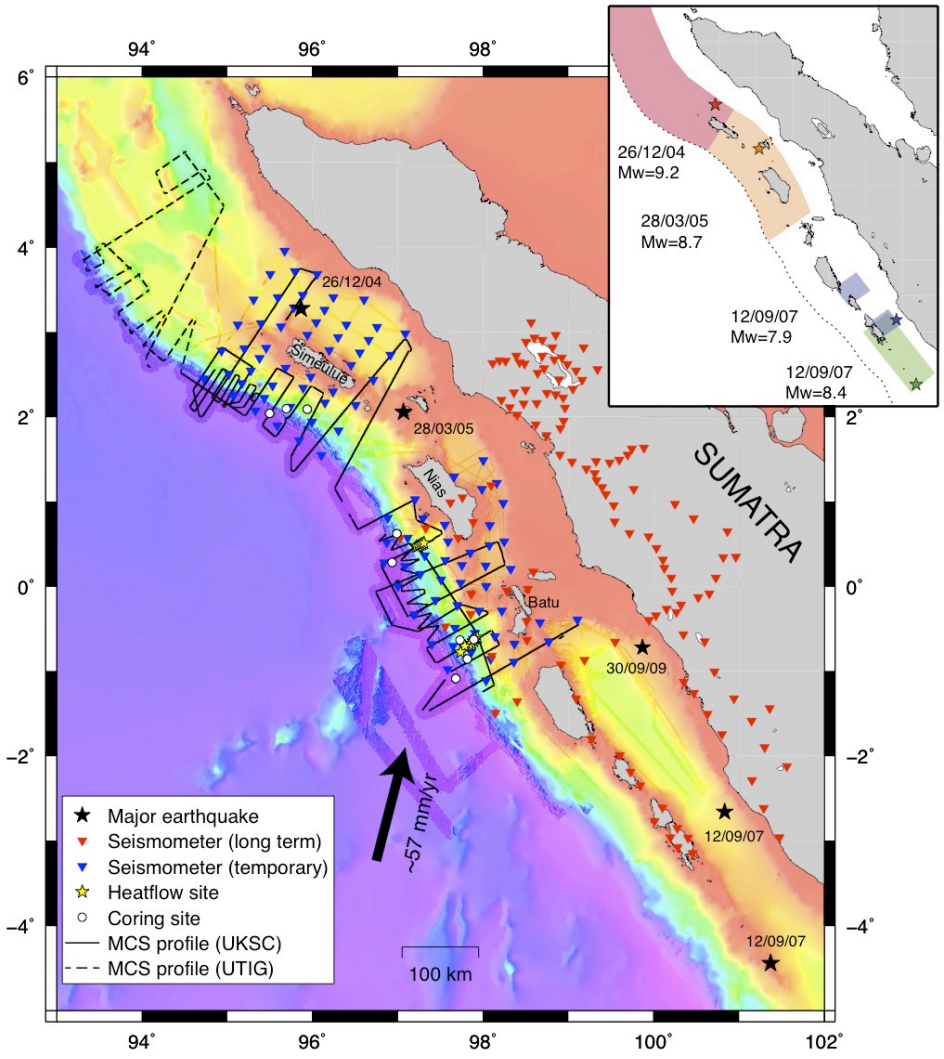
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Mw=8.4
26/12/04
Simeulue
28/03/05
Nias
Batu
30/09/09
12/09/07
12/09/07
SUMATRA
~57 mm/yr
100 km
Major earthquake
Seismometer (long term)
Seismometer (temporary)
Heatflow site
Coring site
MCS profile (UKSC)
MCS profile (UTIG)

Figure 1

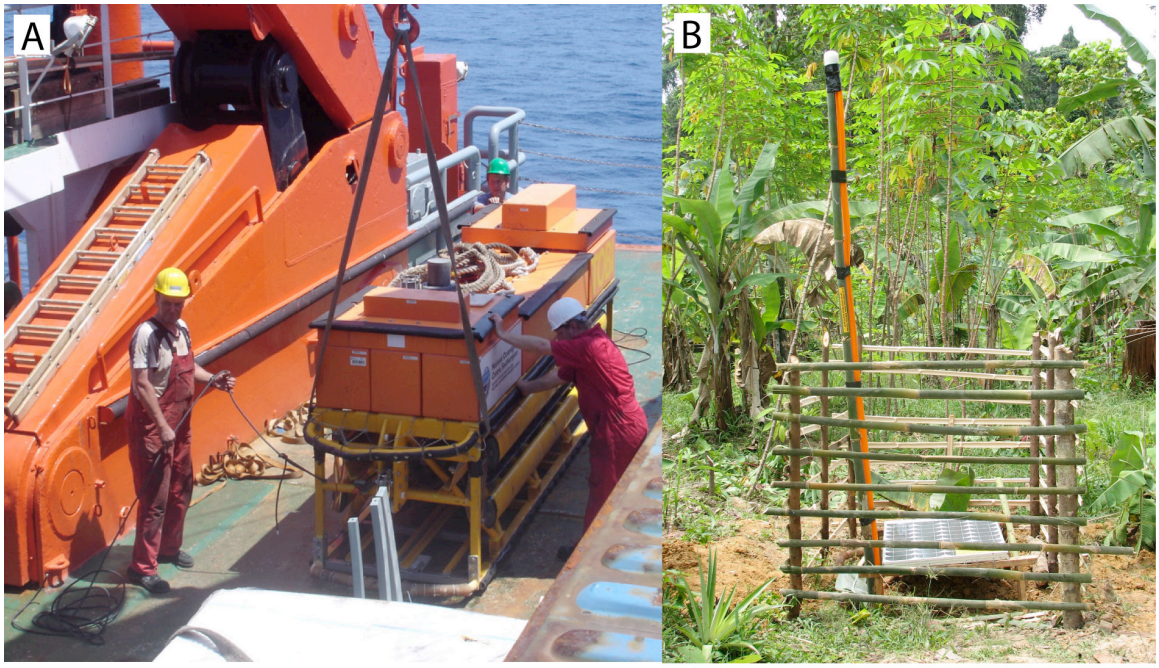

Figure 2