Rupture propagation through accretionary forearcs during subduction megathrust earthquakes

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Introduction:

In March 2011 the M9.0 Tohoku-Oki earthquake ruptured the Japan trench subduction zone and caused a huge tsunami that caused widespread devastation along the northeastern coast of Japan. A distinctive feature of this earthquake was the enormous slip (>50m) that occurred in the accretionary forearc. It was accompanied by a particularly low heat production, determined from drilling after the earthquake (Fulton et al. 2013), indicating that the co-seismic slip was almost frictionless. This project will experimentally investigate the processes that could lead to drastic co-seismic weakening that is consistent with the observations of the Tohoku-Oki earthquake and other recent tsunamigenic megathrust earthquakes.

Recent work in Liverpool suggested that clay-rich fault rocks, such as those that might be expected in accretionary forearcs, undergo dramatic thermal pressurization during earthquake slip (Faulkner et al. 2011). This occurs when energy released during the earthquake heats up the pore fluid and increases its pressure. When this happens, the pore fluid reduces the effective normal stress leading to slip under very low shear stress. However, in the high-velocity friction experiments that have been conducted up to now, the sample is unconfined and any pore pressure excess due to heating can escape, and consequently we don't really know how effective the process of thermal pressurization can be (Ujiie et al. 2013). In a new and unique frictional apparatus recently developed in the Liverpool lab, confined experiments will be possible, allowing investigation of the degree to which thermal pressurization acts during seismic slip in fault gouge.

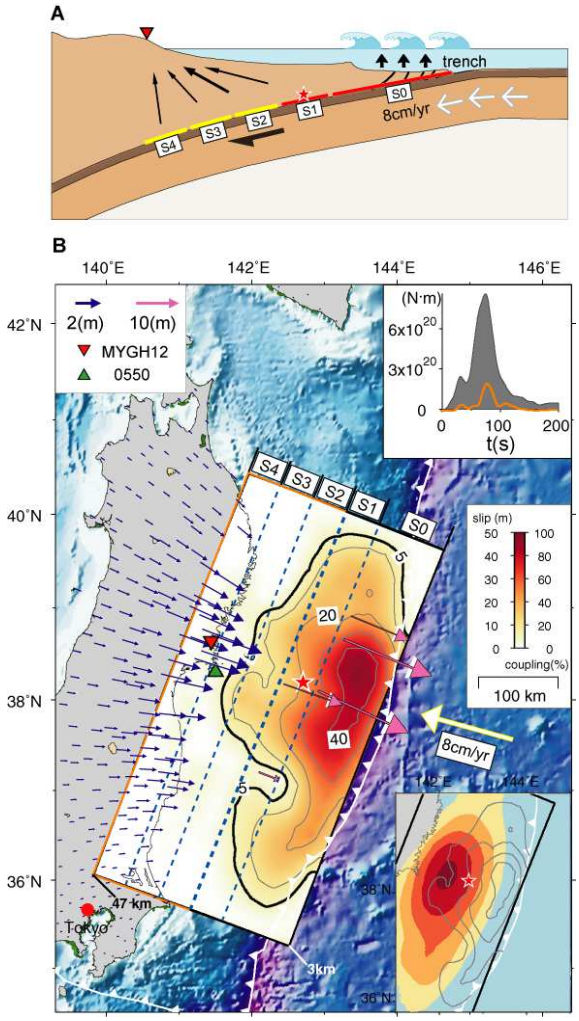

Figure 1. A recent slip model for Tohoku-Oki earthquake, 2011. The contours of slip show the very large increase in slip as the earthquake ruptured to the trench (Wei et al. 2012).

Project Summary

The project aims to quantify the friction of clay-rich faults during seismic slip and relate this to specific characteristics of recent subduction megathrust earthquakes. The type of questions we want to address include: How efficient is the process of thermal pressurization in confined experiments? Can thermal pressurization occur in any subduction zone

and if so, why do only some subduction earthquakes produce tsunamis? Is there a threshold level of slip required to produce runaway accretionary forearc slip? What are the implications for other clay-rich faults zones?

The project will involve fieldwork and working with high-pressure, high-temperature deformation apparatus. The data will be used in large scale rupture models. No prior knowledge of experiments is required and all training in the techniques will be given. However, a student with an enjoyment of practical, hands-on activities would be ideal!. The field component will aim to map natural deformation structures in the Shimanto complex in southern Japan The project will also include a microstructural component, as the products of the experiments would need to be microstructurally analyzed. This will also allow natural structures and microstructures to be compared with experimental microstructures. There may possibly be opportunities to participate in Integrated Ocean Drilling Program (IODP) cruises that are planned to drill into accretionary prisms in the near future – NanTroSEIZE, for example (http://www.iodp.org/NanTroSEIZE).

Students with a strong background in geophysics or geology are encouraged to apply. The student will be trained in use and development of high-pressure high-temperature experimental rock deformation apparatus.

Figure 2. View along the coastline of Shikoku Island in Japan where an uplifted part of an accretionary complex (Shimanto Complex) is exposed (example pictured right).

References

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