Geophysical Research Abstracts,
Vol. 11, EGU2009-1727, 2009
EGU General Assembly 2009

The role of near-trench extension at convergent plate boundaries

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Knowledge of how convergent plate boundary coupling in the seismogenic zone controls the nucleation of subduction zone earthquakes is fundamental to assess seismic risks. Increased data at convergent margins has revealed the complexity of the earthquake cycle through the detection of strain-release processes like episodic tremors and slip events, low frequency earthquakes, afterslip, slip heterogeneity along the fault plane. The processes controlling the earthquake cycle and their interactions are still far from being understood; improved understanding will require better characterization of the fault zone.
Here we compare in-situ observations from two major subduction zones drilled by ODP and IODP (Costa Rica Trench and Nankai Trough) with a well-preserved fossil convergent plate boundary zone in the Northern Apennines of Italy. At all three sites, deformation in the region above and at the updip limit of the seismogenic zone is dominated by extension and normal faulting (i.e. maximum principal stress is oriented sub-vertically). Episodes of reverse shearing are also present, but occur with less intensity, alternating with extension.
Ocean Drilling Program Legs 170 and 205 offshore Costa Rica provide structural observations of the frontal part of the upper plate and décollement at about 2 km from the trench. Analysis of drilled cores reveals the presence of normal faults cutting the frontal part of the upper plate. Normal faults are also seen from seismic reflection to develop along all the forearc (about 60 km from the trench). The décollement damage zone is a few tens of meters in width; it develops mainly within frontal prism material. A clear cm-thick fault core is observed 1.6 km from the trench. Both the upper plate and the décollement damage zone show the co-existence of two distinct fracturing processes in which extension fracturing is frequent in the upper part of the damage zone farthest from the fault core, while both extension and shear fracturing occur approaching the fault core.
Recent drilling at Nankai has confirmed sub-horizontal extension in the upper plate there by observation of core-scale normal faulting (Lewis et al., 2008) and anelastic strain recovery determination (Byrne et al., 2008).
In the fossil erosive megathrust system preserved in the Apennines, two décollements are simultaneously active at the roof and base of the subduction channel. The uppermost (nonseismogenic) portion of the megathrust appears to alternate between tensional and compressional modes of failure during the seismic cycle along the deeper portions of the megathrust.
The presence of extensional strain along the plate boundary of convergent margins indicates that the décollements are able to transmit lithostatic loads. This implies their weak nature until at least intermediate ($\tilde{3}$ km) depths where, in the fossil example, the basal décollement became partially locked. Fluid pressure cycles have not yet been well established at the frontmost part of convergent margins. Where the coexistence of extensional and shear fracturing is present, it seems to be best explained by fluid pressure variations in response to variations of the compressional regime during the seismic cycle.

Byrne ,T., et al. (2008), In Situ Stress Determinations from Anelastic Strain Recovery (ASR): Preliminary Results and Comparisons to Borehole Breakout and Core-scale Fault Data from IODP Expeditions 314, 315 and 316 to the Nankai Trough, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract T22B-05
Lewis, J. et al. (2008), Subhorizontal Extension of the Upper Plate at NantroSEIZE Sites C0001 and C0002, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract T31B-2005