Monitoring microseismicity

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High-quality 2D multichannel seismic reflection data collected in July-August 2002 during the NFS funded EW0207 cruise are currently being processed at Lamont, Woods Hole and Scripps institutions. The first finalized reflection sections (1, 3 and 17) at the Lamont-Doherty Earth Observatory approximately follow the corridor outlined by the newly proposed drill hole sites for the IODP Proposal 545 (Fisher, A. T. et al., 2003).

Observations on reflection images. At several places, reflection sections clearly show faulting within the sediments and the shallow basement. Fault offsets gradually diminish upsection with sediment age, from older to younger, which suggests growth faulting caused by long-term slip within the basement structure. The faults do not appear to break the topmost sediments indicating a very slow faulting process or lack of current tectonic activity. Folding due to compaction at places where there are large offsets in the basement structure, and faulting in the sediments where there are only small offsets in the basement further suggest both: That the sediment rupture is not caused by compaction but rather by steady movements in the basement that produces growth faults; That the faulting does not necessarily occur at the pre-existing planes of weakness formed at the Jaun de Fuca ridge. The main fault zone covers the area between the proposed Deep Ridge (DR) and Second Ridge (SR) drill sites. Largest fault offsets are found in the middle of this ~30 km wide area. Several faults within the sediments are also visible at ~40 km west from the SR drill sites and ~23 km east of the First Ridge (FR) drill sites. Deep and steep crustal reflection events in this area most likely outline faults that cut through the oceanic crust and appear to extend from the faults within the sediments to the anomalously bright Moho.

Ridge flanks are generally considered to be tectonically stable and the origin of the imaged normal faulting is not well understood. The Juan de Fuca trench is only about 100 km east from the main fault area and bending of the oceanic slab due to subduction is a likely driving force for the observed faulting. However, this force cannot be large because plate bending in warm subduction zones such as Cascadia is gentle. The faulting is not continuous along the ridge flank and its magnitude does not monotonously decrease away from the trench, as would be expected from pure slab bending, indicating other factors in the faulting process. Magnetic and bathymetry data tie the two fault areas to propagator wakes. The oceanic crust formed at ridge propagators may be weaker than the oceanic crust formed at ridges, and could thus represent a zone of preexisting weakness first to be faulted. The obliqueness of the subduction zone may also result in anomalous stress and strain distribution within the approaching Juan de Fuca plate.

Proposal for monitoring microseismicity. Location, magnitude and source mechanism of local microseismicity, in combination with available high-quality reflection, magnetic, gravity and bathymetry data, is essential for in-depth understanding of the origin, geometry and current activity of the observed faulting on the eastern Juan de Fuca ridge flank. A more complete understanding of the faulting, at both small and large scale, would lead to a better understanding of crustal evolution and the nature of fluid flow at buried ridge flanks. Although numerous experiments done or planned at the ODP and newly proposed IODP drill sites have and will provide a great wealth of geologic and hydrogeologic information, they cover only a small area and do not provide information on fluid flow below the extrusive layer 2A. New reflection data (ew0207 cruise) show that faulting can extend all the way through the sediments and crust to the Moho. Strong reflections within isotropic and layered crustal gabbros are not likely unless the rocks are serpentinized at fault planes, which is indicative of fluid flow deep into the crust. Anomalously bright Moho observed where the deep faults plunge into the upper lithospheric mantle suggests that fluid exchange may extend much deeper than generally thought. The IODP experiments also may be biased when done within anomalous crust formed at ridge propagators.

Hydrophones of the SOund SUrveillance System (SOSUS) currently are capable of detecting only moderate-size earthquakes (magnitude 2.5 to 3 and greater) in the study area. Seismometers placed in existing drill holes, or planned for new IODP drill holes, can record local microseismicity but the density of instruments is insufficient for accurate determination of hypocenters or source mechanisms. Therefore, it would be of great value to monitor microseismicity at three study areas:

•At the main fault zone between the proposed DR and SR drill sites;

•At the fault zone between proposed SR and FR drill sites, where the faults in the sediments appear to connect to deep faults that extend all the way to the Moho;

•At the Juan de Fuca ridge some tens of kilometers to the west.

The optimal time to run this experiment (9-12 months) is during the proposed IODP drilling and/or during subsequent long-term seafloor pump testing powered by cable, when changes in pore fluid pressure may result in increased microseismicity within these fault zones. Ideally, three groups of 8 to 12 ocean bottom seismometers (OBS) would be placed at the seafloor. Each OBS group would form a pre-designed pattern to allow for monitoring of microseismicity throughout the sedimentary and crustal sections within an area with a diameter of 5-10 km. The first group of OBSs is planned to continuously monitor the processes near the Juan de Fuca ridge axis within the Endeavor Integrated Study Site, where significant magmatic and tectonic perturbations are expected. The second and third groups of OBSs would be placed in the main fault zone area (between the SR and DR holes) and in the area of the large crustal faulting (between the FR and SR holes). Placing the third group of OBSs between FR and SR holes may be of particular value because faulting in this area cuts across the whole crust and the sediments. To carry out this part of the experiment one of the FR drill sites needs to be moved about 23 km east and long-term seafloor pumping powered by cable has to done at this new drill site.

The proposed experiment will make use of natural and induced microseismicity to accomplish the following goals:

- To determine if the observed growth faults in the sediments are currently active;

- To determine if the deep faults that cut the crystalline crust are active;

- To study the connection between the sediment rupture and deep crustal faults;

- To obtain additional information about the fault distribution, geometry and fault mechanisms;

- To examine how pore fluid pressure changes induced by pump-tests influence the rate of microseismic activity within the fault zones;

- To investigate the role of propagator wakes as zones of pre-existing crustal weakeness;

- To explore the relationship between local seismicity (both on and off axis) and the physical and chemical changes observed at the borehole sites;

- To gain knowledge about the full, crustal scale fluid flow at ridge flanks.