Fault Weakening by Hydrothermal Fluid Flow: Fact vs. Friction

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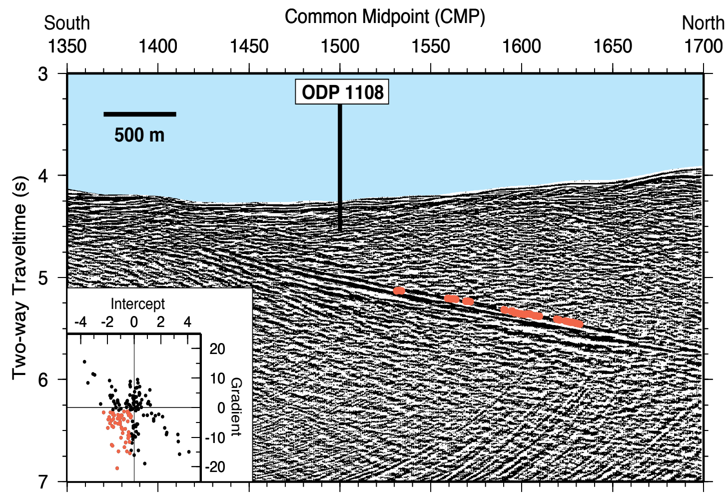
Determining the composition and physical properties of low-angle normal faults (faults that dip at an angle of less than 35°) is important for understanding how such faults slip and allow extension of the crust and lithosphere. ODP and seismic reflection data provide evidence for fluid flow within an active low-angle normal fault in the western Woodlark Basin of Papua New Guinea. The normal fault is located at the transition between seafloor spreading and continental rifting less than 5 km ahead of the westward propagating Woodlark spreading center. Seismic reflection profiles (Mutter et al., 1993; Taylor et al.,1996) show that the normal fault has an offset of 10 to 12 km and dips 25°-30° to a depth of about 9 km. Earthquake studies in the region indicate that a magnitude 6.2 earthquake occurred at about 5 km depth on or close to the normal fault (Abers et al., 1997). It has been theorized that in order for normal faults to slip at such low angles, low-strength fault gouge or high-pressure pore fluids are needed to reduce friction on the fault plane. However, until recently these conditions have not been observed within an active normal fault.

ODP Leg 180 obtained direct measurements of a low-angle normal fault from the exposed footwall and recovered a 4 m-long core containing talc, serpentine, chlorite and magnetite minerals. This mineral composition is typically found on transform and normal faults along mid-ocean ridges where it is formed by shearing and hydrothermal alteration of oceanic rocks. Modeling of the fault zone seismic reflection shows that at 4-5 km below sea level the normal fault contains a 33 m-thick layer interpreted to contain fault gouge (Floyd et al., 2001). Isolated portions of the fault reveal anomalously low seismic velocities and reflection amplitude variation with offset (AVO) properties that suggest high pressure pore fluids are present within the gouge layer.

The occurrence of hydrothermally altered material on the exposed footwall of the fault together with High fluid pressures may reduce friction and promote normal fault slip at low angles by supporting the weight of the overlying rock. seismic evidence for fluids at depth suggest that hydrothermal fluid flow may be actively weakening the fault zone and providing conditions that are favorable for normal faulting at low angles in this region.



Fluid-rich portions of the fault zone (marked in red) are identified by analysis of the seismic amplitude variations as a function of offset (AVO) between the seismic source and receiver. These fluid-rich zones lie in the lower left quadrant of the AVO crossplot (inset). It is estimated that the low-velocity portions of the fault zone have a porosity of 61%, twice the porosity of the gouge material recovered by drilling, which is best explained by the presence of high pore fluid pressures within the fault zone.

References:

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