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Stress and pore pressure measurements from IODP riser drilling during NanTroSEIZE Stage 2: Expedition 319, Kumano Basin

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In summer 2009, Integrated Ocean Drilling Program (IODP) Expedition 319 drilled a 1600 m deep riser borehole (Site C0009) in the Kumano Basin offshore SW Japan, to investigate the properties, structure and state of stress in the hanging wall above the subduction plate boundary. This first riser-based scientific drilling in IODP history allowed several new scientific measurements, including: (1) direct measurement of in situ minimum principal stress magnitude, pore pressure and fluid mobility (permeability) using the Modular Formation Dynamics Tester (MDT) wireline tool; and (2) measurement of minimum stress magnitude from Leak-off Tests (LOT). In addition, continuous monitoring of mud weight, mud gas, annular pressure, and mud losses provide additional data to constrain formation pore fluid pressure and stress magnitude. At Site C0009, we conducted 2 LOTs below a casing shoe at 708.6 m depth and 11 successful MDT measurements, including 9 single probe tests to measure pore pressure and fluid mobility and 2 dual packer tests - 1 to measure permeability by a drawdown test, and 1 to measure in situ stress.

Measured pore pressures are approximately hydrostatic to 1463.7 m depth. We observed only minor gas shows when drilling ahead (interpreted to reflect in-place methane being liberated by mechanical crushing of the rock at the bit) but little or no gas during pipe connections. The suppression of gas shows indicates that the borehole mud pressure exceeded the formation pore pressure; this observation is consistent with the MDT pore pressure measurements. Permeabilities range from approx. 10^{-16} m^2 to 10^{-14} m^2. The observed variation is broadly consistent with lithologic changes defined in gamma ray logs, and we observe a weak correlation between gamma ray values and measured permeability. The MDT measurement at 874.3 mbsf and the LOT at 708.6 m yield values for the least principal stress (Shmin) of 34.8 MPa and 30.2 MPa, respectively. Both are smaller than the vertical stress (Sv) computed from density logs. Partial mud circulation losses occurred when the borehole mud pressure exceeded the leak-off stress measured at the base of the casing shoe; this provides an additional indirect constraint on Shmin magnitude. Mud pressure slightly in excess of the leak-off stress may have also generated poorly-developed drilling-induced tensile fractures (DITF) observed in resistivity image logs between approx. 750 and 1000 mbsf. From the presence of DITF, Shmin measurements, and assuming rock tensile strength is negligible, we determine that SHmax is 43.8 MPa for the MDT stress measurement, and 31.4 MPa for the LOT. Using the MDT measurement of Shmin, the resulting principal stress magnitudes define a strike-slip faulting regime with effective stresses of Shmax' = 15.1 MPa, Sv' = 7.3 MPa, and Shmin' = 6.4 MPa. In contrast, using the LOT measurement of Shmin, the stress magnitudes indicate a normal faulting regime in which Sv' = 6.2 MPa, Shmax' = 3.8 MPa, and Shmin' = 2.6 MPa. The results from the LOT test are highly consistent with the presence and orientation of normal faults that offset the seafloor observed in seismic reflection data. In contrast, the MDT measurement is inconsistent with active normal faulting.

Keywords: Riser drilling, IODP, Stress, Pore Pressure