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Estimation of in-situ stress and strength along the Nankai Trough subduction megathrust
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Understanding the mechanics that underlie the spectrum of fault slip behaviors observed along subduction megathrusts requires a sound investigation of depth-varying in-situ stress conditions, absolute fault strength, and fault rheology. The porosity reduction of sediments with progressive burial plays an important role in deformation style in the shallow portion of subduction zones because the deformation mode and strength of porous rocks are largely dependent on both porosity and pressure. Here, we report on results of triaxial deformation experiments on (1) modern sediments currently subducting at the Nankai Trough; and (2) tectonic melange near the Nobeoka thrust in the exhumed Shimanto complex, which is an ancient out-of-sequence-thrust or plate boundary, to provide constraints on the stress state and strength along the plate boundary.

For the mudstone core samples (porosity of 43%) recovered from the Nankai Trough in the IODP NanTroSEIZE project, we conducted triaxial compression and extension tests under a range of loading paths at room temperature, and measured sonic velocity and porosity during the tests. We then used these data to develop empirical relations between sonic velocity, porosity, and stress, in order to estimate in situ stress along the megathrust plate boundary from P-wave velocities defined by seismic survey data. Different loading paths do not affect the relationship between P-wave velocity and porosity, but they do affect the relationship between porosity and effective mean stress: at the same effective mean stress, sediments are more compacted with increasing differential stress. Based on expected in situ stresses and pore pressures for a range of possible scenarios under different loading paths, we suggest that the Kumano basin is loaded in a uniaxial stress condition, whereas the prism and underthrust section are most likely loaded along a near critical stress condition with lateral compression. We find that the Kumano Basin is likely to be hydrostatically pressured, whereas the prism and underthrust section in the vicinity of the plate boundary are moderately overpressured ($\lambda *$= ˜0.5 in average) and significantly overpressured ($\lambda *$= ˜0.85 in average).

For the tectonic melange samples (porosity of 2%) from the footwall of the Nobeoka thrust fault in the NOBELL project, we conducted triaxial compression tests along a conventional tri-axial loading path, where confining pressure is kept constant and axial stress is progressively increased. The cylindrical specimens were deformed at an axial displacement rate of 0.5 μm/s, corresponding to strain rates of 1.6×10^{-5} s^{-1}, and at a temperature of 250 ℃ and an effective pressure (Pe) of 120 MPa (confining pressure of 200 MPa and pore pressure of 80 MPa) or 20 MPa (confining pressure of 200 MPa and pore pressure of 180 MPa). The temperature was chosen based on the estimated temperature (250-300 ℃) at which the melange were formed [Kondo et al., 2005]. The two different effective pressures of 120 MPa and 20 MPa correspond to estimated stress conditions at ˜8 km (geothermal gradient of ˜30 ℃/km), for hydrostatic and 90% of lithostatic pore pressures, respectively. The experimental results show that the melange samples deform in a brittle manner at Pe = 20 MPa. The strengths reach a peak at 80-90 MPa, followed by strain weakening to residual strengths of 40-60 MPa. At Pe = 120 MPa, on the other hand, the foliated cataclasite deforms in a hybrid brittle-ductile mode, with a steady-state strength of ˜300 MPa. Because the brittle-ductile transition of the melange samples lies on the extrapolation of critical loading on the Nankai mudstone samples, the melange samples in the ancient prism may provide a good analog for the mechanical behavior of underthrust rocks at seismogenic depth in the modern Nankai Trough. The strength of these clay-rich sediments increases as they compact with depth, but is not as high as that of sandstones or carbonates.

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