

Insights into the style of deformation in the Hikurangi subduction zone from rock physics measurements: elastic properties, permeability, and fracture healing

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Abstract

The Hikurangi subduction zone exhibits a north-to-south variation in deformation style. The plate interface in the south is locked, and megathrust earthquakes could accommodate the long-term plate convergence. In contrast, the northern megathrust regularly experiences shallow slow-slip events possibly extending into the thrust faults of the sedimentary prism. Understanding such a difference could reveal slip behavior and seismic cycle controls and help earthquake forecasting globally. One hypothesis is that the prism rock properties and fluid pressures affect these different slip behaviors. To test such a hypothesis, we measured the physical properties of rocks from the northern Hikurangi margin, focusing on ultrasonic elastic properties, permeability, and fracture healing. Such lithologies are equivalent to rocks buried to a few km depths within the accretionary prism. We found that all rocks contain >18 vol% of clay minerals. The hydraulic permeability of rock samples that are proxies for the deep part of the prism (i.e., 5 to 10 km depth) is three to four orders of magnitude lower than the values estimated by different authors for the prism as a whole. The results suggest that active faults and fractures in the accretionary prism must play a key role in draining fluids from the base of the prism and potentially from the subducting plate. Tests on a fractured sample show that fractures heal in tens of days, and permeability decreases over a short period relative to slip cycles of just a few weeks. Microphotography and micro-CT images suggest that healing is achieved by clay expansion. The observed healing could be underestimated as achieved under high confining pressure (up to 200 MPa) but at room temperature and humidity. We conclude that slow slip events in the northern Hikurangi margin may have a critical role in briefly increasing permeability at the beginning of the slip cycle, thus regulating pore pressure in the prism and allowing drainage.

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