

Mudstones in the Subduction System of SW Japan: Highlights from the Nankai Trough Seismogenic Zone Experiment

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ABSTRACT

The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) is the largest project in the history of scientific ocean drilling. To date, 15 sites have been drilled during 10 expeditions along the Kumano transect of the subduction margin offshore SW Japan. IODP Sites C0011 and C0012 in the Shikoku Basin (subducting Philippine Sea Plate) captured the inputs of sediments and igneous crust to the subduction zone. IODP Expedition 348 (Site C0002) set a new record for sampling depth in the accretionary prism, with cores recovered at depths of 2163-2218 mbsf (7096-7277 ft) and cuttings recovered continuously to 3058 mbsf (10,033 ft). This presentation will focus on three noteworthy discoveries about the mudrocks that were recovered during NanTroSEIZE: (a) an enigmatic interval of anomalously high porosity within the subduction inputs; (b) systematic, gradual changes in detrital clay mineral assemblages throughout the history of deposition; and (c) mineral assemblages and clay diagenesis within the deep accretionary prism.

Mudstones within the zones anomalously high-porosity contain unusually large proportions of dispersed volcanic ash (glass shards and pumice). Temperatures at the base of these zones vary from site to site, so thermally driven diagenesis alone cannot account for the anomaly. Instead, dispersed ash affects mudstone microstructure by forming cohesive aggregates that inhibit collapse of intergranular pore space. Partial dissolution of glass shards also contributes silica for precipitation of weak cement. Deeper stratigraphic intervals with smaller amounts of dispersed ash show no such effects, regardless of temperature or depth.

The clay mineral assemblages of Shikoku Basin show consistent temporal changes, particularly over the last 10 Myr, with gradual reductions of detrital smectite and gradual increases in illite and chlorite (moving up-section). At Sites C0011 and C0012, percentages of smectite within bulk mudstones decrease by roughly 3 wt-% for every 1-million-year reduction in age. Causes of this trend are multifaceted but probably include: (1) intensification of the Kuroshio Current after closure of the Isthmus of Panama (at about 3 Ma); (2)

blockage of transport routes from the East China Sea toward Shikoku Basin by rifting of the Okinawa Trough and subaerial buildup of the Ryukyu Arc (peaking at about 7 Ma); and (3) progressive uplift and denudation of detrital source rocks in the Outer Zone of Japan, which gradually stripped away the near-surface products of anomalous near-trench magmatism and exposed deeper plutonic roots and surrounding meta-sedimentary strata of the Shimanto Belt. These systematic changes in clay mineral assemblages are important because they modulate friction properties, consolidation behavior, and fluid production from dehydration reactions as the strata move deeper into the subduction zone.

Strata near the top of the accretionary prism at Site C0002 are as young as 5.6 Ma, but the deeper intervals have an apparent depositional age of 9.56-10.73 Ma. The steeply dipping Miocene strata lie within the hanging wall of the subduction megathrust and are buried beneath Quaternary turbidites of the Kumano Basin. The most abundant clay mineral is smectite, followed by illite, chlorite, and kaolinite. The accreted mudstones at Site C0002, however, contain significantly lower percentages of smectite (<25% of the bulk mudstone) as compared to coeval Miocene strata at Sites C0011 and C0012; those present-day subduction inputs generally contain >40% smectite in the bulk mudstone. One likely reason for the difference is an overprint of the detrital assemblages by smectite-to-illite diagenesis; that reaction results in a steady down-hole increase in illite within the liS mixed-layer phase. The extent of liS reaction progress is consistent with kinetic models in which the peak heating time is limited to about 1 Myr, as might be expected with rapid Quaternary accumulation of sediment within the overlying Kumano Basin. Another possible reason for lower percentages of smectite, however, is a spatial shift in the depositional environments and detrital provenance of subduction inputs during the Miocene. The mud-dominant facies of the older accretionary prism is enigmatic (when compared to the sand-rich frontal prism), and its original depositional setting remains uncertain. The older accreted mudstones might have been deposited in a trench during a time period in which supplies of sandy sediment were restricted. An alternative explanation involves northeastward migration of the triple junction that joins the Japan, Izu-Bonin, and Nankai plate boundaries. The depositional settings prior to accretion may have shifted over time from the NE side of the triple junction (subducting Pacific plate) to the SW side (subducting Philippine Sea plate). Regardless of exactly how and when the paleogeography evolved, smaller initial percentages of detrital smectite, combined with the gradual diagenetic loss of smectite with depth, are important for predicting how material properties change toward the seismogenic plate interface. We should see progressive reductions in the volumetric contribution of pore fluid from 1/S dehydration toward the base of the hanging wall. On the other hand, fluids should be more abundant below the plate interface, sourced from thermally immature, smectite-rich, Shikoku Basin sediments.