Deep processes in the Nankai accretionary prism from geochemical constraints, IODP Site C0002

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The NanTroSEIZE project is designed to answer several questions about the deep accretionary prism and the plate-boundary fault (PBF), including questions about the factors controlling the transition from seismic to aseismic behavior along faults; the mechanics of strain accumulation and release; the strength of the PBF and surrounding crustal material; and the role of faults within the PBF system in seismogenesis. We present stable isotope data and U-Th ages from carbonate cements and veins that provide timing constraints on deformation, fluid flow, and changes in material properties and which can shed light on deep-prism processes.

Sediments within the prism are predominantly Pliocene to upper Miocene fine-grained material. The prism is highly deformed, with bedding dips from 45˚-90˚, while the overlying Kumano Basin sediments are relatively undeformed; thus, the Kumano Basin constrains the timing of deformation in the prism as mostly older than 1.6 Ma. The prism is highly faulted, with numerous fractures filled by calcite veins with slickensides or slickenfibers. Thus, crosscutting relationships during vein formation suggest repeated cycles of faulting and flow of fluid at elevated pore pressures. Coring demonstrates that carbonate veins are intimately associated with shear fabrics in a fault at 2205 mbsf. Overall the concentration of carbonate decreases with depth, yet the abundance of deformed carbonate veins increases. Local maxima in carbonate abundances may be associated with faults.

Carbonate vein and cement isotope data are from within the accretionary prism from 1440 to 3045 mbsf. Carbon isotope values (δ^{13}C vs. VPDB) range from -11.7 to -0.8‰ with a median value of -3.5‰. Methane from drilling mud gas was typically much lighter, (-70 to -50‰) over the same depth interval. Thus the carbonate isotopes require substantial carbon input from recrystallization of marine sedimentary carbonate. Oxygen isotope values (δ^{18}O vs. VPDB) are typically light, ranging from -11.8 to 0.3‰ with a median of -7.8‰. The low δ^{18}O can be due to infiltration by isotopically light formation waters or crystallization at elevated temperatures; our clumped isotope data support the latter.

Carbonate clumped isotope analyses provide temperature information independent of fluid isotopic compositions. Preliminary temperatures determined to date from Site C0002 range from 54 to 111˚C (±5˚ C or less). Most carbonates have temperatures with values near or lower than modeled temperature gradients from previous studies. The maximum temperatures at certain depth intervals define a gradient

subparallel to the modeled gradients but at values 7-17˚C higher. This could indicate locally anomalous temperatures or a change in the thermal gradient over time.

We selected some samples for U-Th age determinations, which can date carbonates up to 650 ka in age. We were able to obtain maximum ages from eight carbonates of ~108 ka to 561 ka; these ages predate deposition of most of the Kumano forearc basin, and thus these veins postdate contraction in the prism.

Our results bear on temperatures in the prism at discrete times during its history, and the timing of fault deformation and fluid flow along fractures. Clumped isotope data can successfully provide quantitative temperature estimates from parts of the prism not easily accessible by other means. The data presented here are consistent generally with semi-quantitative temperature estimates, yet differ in detail and may be related to discrete flow of overpressured fluids. Our results show that brittle deformation is still an important process in the deep prism. These relatively recent deformation features may be related to microseismicity or very low frequency earthquakes. Finally, it is clear that crystallization of carbonate in faults related to ongoing fluid migration is likely still altering physical properties of materials in the upper plate of the plate-boundary fault.

Keywords: Nankai, Site C0002, geochemistry, temperature, carbonate clumped isotopes, fluids

