Recent Migration of Deep, Hot, Barite-forming Fluid in the Nankai Subduction Margin (IODP 370 Site C0023)

*Man-Yin Tsang[1], Shin Toyoda[2], Jun-ichiro Ishibashi[3], Stephen Bowden[3,4], Akira Ijiri[1], Shigeyuki Wakaki[5], Satoshi Tonai[6], Yuki Morono[5], Yuzuru Yamamoto[1]

1. Kobe University, 2. Okayama University of Science, 3. Kobe Ocean-Bottom Exploration Center, 4. University of Aberdeen, 5. Japan Agency for Marine-Earth Science and Technology, 6. Kochi University

The migration of fluids in the crust and sediments at subduction zones is a commonly invoked phenomenon in many areas of geoscience, including diagenetic, ore-forming and metamorphic processes. Fluid migration is envisaged to be triggered by seismic events or vice versa and involves sudden changes in formation pressure. Thus fluid migration is likely important across a subduction zone (large scale), but will have localized and observable effects at a small scale, such as the precipitation of minerals from solution.

Observing the effects of migrating fluids might be difficult because an observation would need to be made at the right place and time. In contrast, mineralization, formed as a consequence of fluid migration, has greater persistence and stability on geological timescales. Expedition 370 of the International Ocean Discovery Program (IODP) drilled the toe of the Nankai Accretionary Prism (Site C0023; Middle Miocene to present) and identified fracture-filling barite ($BaSO_4$) crystals in sediment cores (820-1075 meters below seafloor; Tsang et al., 2020). The barite crystals record the characteristics of the fluids that flowed through the underthrust sediments and serve as a rare record of fluid flow in an active subseafloor subduction zone.

The barite appears as veins, slicken-cysts, and void-filling crystals within faults, voids and stratabound intervals rich in carbonate. Aqueous fluid inclusions within the largest barite vein have trapping temperatures from 146 to 219 degrees Celsius, up to 112 degrees hotter than the present-day sediment at the same depth. At the same time, the heating was of sufficiently short duration that it did not affect other indicators of thermal maturity such as vitrinite reflectance or petroleum biomarkers. Therefore, the influx of hot fluids in this seismically active region likely created thermal aureoles that existed only temporarily on a geological timescale.

To provide numerical constraints on the timing of the mineralization, we have modified the electron spin resonance (ESR) dating method for dating hydrothermal barite, so that it can be used to date this deep, diagenetic barite at the Nankai Subduction Zone. We confirm that ESR dating is applicable to this type of barite. ESR dating and ^{226}Ra-^{210}Pb disequilibrium dating methods suggest that most of the barite was formed in the Holocene and some within the last century. Therefore, the fluid flow associated with barite precipitation was a very young event and may continue to the present day.

Strontium and sulfur isotope ratios of the barite suggest that the barite formed from a mixture of porewater and deeper fluid from the basaltic basement. This aligns with a previous finding based on helium isotopes that the modern pore fluid has a partial mantle origin (Kastner et al., 1993). Intriguingly, the barite occurrence coincides with an interval with very low cell counts (Heuer et al., 2020). Using the low abundance of microbial cells as a sensor for temperature extremes, hot barite-forming fluids can be interpreted to have provided sufficient heat to kill off living cells within the deep sediment.

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