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7 years of NanTroSEIZE: Achievements and Lessons Learned

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The objectives of Integrated Ocean Drilling Program (IODP) Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) include characterizing the nature of fault slip and strain accumulation, fault and wall rock composition, fault architecture, and state variables throughout an active plate boundary system. A deep riser drilling into the locked portion of the Tonankai asperity at IODP Hole C0002F began during IODP Expedition 326 in 2010. After one-year delay due to 3.11 Tohoku event (which gave severe damage to D/V Chikyu), the hole was deepened to 2005 m below seafloor during Expedition 338 in 2012, then deepened to ˜3000 m during Expedition 348 in 2013. In addition to the intermittent coring, continuous information was acquired through logging-while-drilling, mud-gas monitoring and cutting analyses. NanTrosEIZE also targets understanding shallow characteristics of subducting Shikoku Basin, forearc slope and Kumano forearc basin.

Through LWD and core analyses, shallow stress state along NanTroSEIZE transect has been revealed. Fault regime changes from normal/strike-slip at <˜500m to strike-slip in the deeper part (>˜500 m). Maximum compressional stress is vertical throughout the transect, indicating that the gravitational effect is dominant. Maximum horizontal stress is parallel to the subduction direction, with secondary contribution by the plate convergence. It is consistent with the result from circular air-gun shooting around the vertical seismic array in the central Kumano Basin, which revealed a Vp anisotropy (˜5%) in the Kumano Basin that suggests subduction-parallel compression.

Through drilling at two subduction input sites in the Shikoku Basin, we identified a significant Source of fluid in seismogenic zone; ˜30 vol% saponite in the basalt sample. This suggests that in the deeper portion of plate boundary, fluid production from basaltic rock (saponite-chlorite) can be greater than from smectite-illite conversion and sediment compaction.

Lab. friction studies in the shallow megasplay fault zone confirmed that shallow faults are velocity-strengthening at slow slip rates. On the other hand, the frictional coefficient during high-velocity (˜1 m/s) slips is very low under the undrained condition, suggesting that earthquake rupture propagates easily through clay-rich fault gouge by high-velocity weakening.

Lines of evidence strongly support the activity of shallow portion of megasplay and decollement. Mud breccia in the surface of splay footwall side indicates the earthquake-induced collapse and reworking. Vitrinite reflectance anomaly localized at the fault reveals past thermal anomaly >380degC, indicative of coseismic slip near the deafloor that should have generated a huge tsunami. XRF scanner analysis of microbreccia fault zone in the shallow megasplay indicates an increased illitization relative to surrounding host rock, representing an additional evidence of possible frictional heating and mechano-chemical clay mineral alteration.

Borehole observatories are essential in order to detect and monitor a small and low-frequency deformation that is continuing around the plate boundary. First complex borehole observatory, including geodetic, seismic and hydrological sensors, was successfully installed in the southern Kumano Basin and connected to cable network for realtime monitoring.

So far we drilled at 13 sites, participated by >170 scientists from 15 countries, and published more than 60 scientific papers. Such achievements were made possible by tremendous efforts by CDEX, who tackled with numerous technical challenges such as mechanical setbacks of riser and vessel, concern about the expedition time available (cost and budget), typhoon/low pressure evacuation, and riser drilling in the 5-knot Kuroshio current.

Keywords: IODP, Chikyu, seismogenic zone, Nankai Trough