A high-resolution seismic image of possible fluid migration pathway associated with the 2011 Tohoku earthquake

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Large megathrust earthquakes along subduction zones pose a seismic and tsunami threat to densely populated coastal cities. The 2011 Tohoku earthquake (M9.0) ruptured the interface between the subducting Pacific plate and the overlying Okhotsk plate, yielding massive tsunamis. Pore fluid along the plate interface might play an important role in the occurrence of large megathrust earthquake. Helium isotopes are useful in identifying the origin of fluids and may provide the key information about the source of interplate fluids. Geochemical evidences demonstrated a sharp increase in mantle-derived helium in bottom seawater near the rupture zone one month after the 2011 Tohoku earthquake. The timing and location indicate that fluids were released from the mantle on the seafloor along the plate interface. The movement of the fluids was rapid with a velocity of ~4 km per day, suggesting that over-pressurized fluid is discharged along the plate interface. Considering the location of helium isotope anomalies at the forearc seafloor, there must be fluid migrations along out-of-sequence thrust (OOST) fault planes from the plate interface up to the forearc seafloor. However, the fluid migration pathway, i.e., OOST fault plane, has never been identified so far, probably because of low-resolution seismic image.
In order to elucidate the fluid behavior along the OOST fault plane, we have carried out geophysical and geochemical investigations in the Tohoku forearc using R/V Shinsei-maru (KS16-17 cruise) in November 2016. During the cruise, we have done: (1) high-resolution seismic imaging by parametric sub-bottom profiler (SBP), (2) seafloor mapping by multi-beam echo-sounder, (3) bottom seawater sampling by CTD sampler, (4) seafloor sediment sampling by multiple corer, and (5) onboard magnetic and gravity observations. We observe a clear seismic reflection image of fault scarp on a high-resolution SBP line near the Site N3 at which the helium isotope anomaly was observed one month after the 2011 Tohoku earthquake. A possible OOST fault is likely to produce tilting structure of the topmost sedimentary layer. Despite low continuity of the reflector, deep crustal multi-channel seismic reflection data exhibit a possible OOST fault plane with reverse polarity reflection upward from deep plate-interface, suggesting the fluid migration along the fault associated with the 2011 Tohoku earthquake. In this paper we will show preliminary results of the cruise KS16-17.

Keywords: high-resolution seismic image, fluid migration pathway, Tohoku earthquake

