Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS01-P05 Room:Convention Hall Time:May 19 18:15-19:30

Seismic imaging in the Japan Trench axis area off Miyagi, northeastern Japan

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On March 11, 2011, the M9 great Tohoku megathrust earthquake ruptured the plate boundary at the Japan Trench off eastern Honshu, Japan. Several seismological, geodetic and tsunami wave inversion studies indicate a large magnitude of slip (30-60m) occurred on the shallow portions of the plate boundary. Differential bathymetric and seafloor geodetic studies also document large coseismic displacement near the trench. Thus, it is important to understand the detailed structure of the shallow portion of the subduction zone and the trench axis area of the Japan Trench to evaluate mechanisms of deformation and the geometry of the structures that accommodated shallow slip.

We conducted a high resolution reflection seismic survey in the vicinity of the Japan Trench axis off Tohoku in October-November, 2011. The high-resolution seismic profiles we obtained successfully image the detailed structure around the Japan Trench axis, and were used for site selection of the rapid response drilling program for IODP Expedition 343 (JFAST). We identify four seismic units in the study area: an acoustically transparent frontal wedge (Unit I), a sequence of parallel continuous reflections interpreted as sediments on the incoming plate (Unit II), a sequence of relatively strong reflections correlated to chert recovered in DSDP Site 436 (Unit III), and acoustic basement of the Pacific plate (Unit IV). The incoming Pacific plate sediments, including the basal chert layer (Units II and III), have been offset by normal faulting during plate bending seaward of the trench. Mapping of the relief on the igneous oceanic basement (Unit IV) shows that the trench axis in the survey area is located in a graben. The relief observed on the basement landward of the trench is related to the subduction of horsts and graben formed seaward of the trench. The hemipelagic/pelagic sediments (Unit II) overlying the basal chert layer (Unit III) are imbricated at the trench axis. The detachment surface is located slightly above the top of the chert-rich layer (Unit III) in the trench axis graben. We observe a seaward-dipping reflection branching off the top of the chert-rich layer (Unit III) at the edge of a horst block at the base of the landward trench slope. This reflection short-cuts the horst-graben normal fault, and soles into a horizon slightly above the top of chert-rich layer (Unit III) in the trench graben. This reflection is interpreted as a part of the decollement in the lowermost Japan Trench inner slope, and was likely generated by an increase of the loading and failure of the underthrust hemipelagic/pelagic sediments. The imbricate structure of the graben-fill sediments could have been developed by a combination of aseismic deformation as well as repeated megathrust earthquakes which caused failure and slip along the seaward dipping decollement. These data clearly image structures resulting from deformation and sediment subduction at the Japan Trench in the region that ruptured during the March 11, 2011 great Tohoku earthquake.

In January 2013, we carried out another seismic survey around the JFAST drill site using larger volume of sounding sources, longer streamer cable, and ocean bottom seismographs. Preliminary processed data provide seismic profiles with enhanced quality in the deeper portion. We will also present the velocity model deduced from the analysis of these seismic data.

Keywords: seismic image, Japan Trench, Tohoku earthquake