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Recent advances in reflection seismology and improved seismic imaging of deep reflection data in the transition zones

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Deep seismic reflection profiling across the area of land-marine transition zones in Japan has been imposed serious restrictions and compromises on both data processing and acquisition. In addition to complex subsurface structure, rugged acquisition topography, crookedness of seismic lines, irregular distribution of shots, and large noise level often result in deterioration of the data quality and poor reflection image in seismic profile. During the last 15 years, the quest for greater resolution with large number of active channels led to the innovation of digital recording system with the delta-sigma converter. The full range of the seismic signal can be recorded in binary fixed -point formats with 24 bits without distortion and loss of resolution. Increased precision and channel capacity in the recording system makes it possible to realize the deep seismic exploration with dense seismic array in the land and transition-zone environment in Japan. The combination of telemetry and independent recording system provides the deployment of long survey line with dense seismic array. Furthermore, the data acquisition of regional refraction, low-fold wide-angle reflection and standard reflection survey for the several targets on the same seismic line has been optimized by the integration of different seismic sources focused on effective low-frequency bandwidth of seismic signature. In general, deep seismic profiling using a long streamer cable in the transition zones has unavoidable problem in the operation due to active fishery and large vessels on the sailing routes. The method to mitigate these problems is the two-vessel seismic exploration using flip-flop shooting and short digital-streamer cable. The two-vessel profiling can accommodate the simultaneous acquisition of large-aperture reflection/refraction data to delineate pre-Tertiary basement and the Miocene rift system of Honshu Island. A supplementary land and ocean-bottom seismic line with 4C sensors provides the dense seismic reflection profile in the transition zone. In seismic data processing, the high-resolution velocity estimation can be realized by the simultaneous acquisition of wide-angle reflection and refraction data. In our study, the uncertainty of the tomography solutions is estimated using a nonlinear Monte Carlo approach with randomized initial models, and the velocity structure of upper crust is constrained by subsequent forward reflection and refraction modeling. In recent years, many case studies have demonstrated that the Common-Reflection-Surface (CRS) stack based on paraxial ray theory produces reliable stack sections with a pronounced signal-to-noise ratio. In the static corrections, the global optimization method is key processing method to accommodate the high multimodal character of objective function on deep seismic data. Ocean-bottom cable with 4C sensors has presented a number of imaging opportunities in P-S wave reflection profiling and Vp/Vs estimation for the delineation of volcanic stratigraphy. In 2008, the Headquarters for Earthquake Research Promotion Japan started a program of deep seismic profiling to reveal regional characterization of the Niigata basin, central Japan. We refer two deep seismic profiles in this program to review the recent advances in reflection seismology.

Keywords: reflection seismology, deep seismic profiling, 4C OBC, dual-vessel streamer survey, refraction tomography, P-S converted wave