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Integrated seismic imaging of crustal structure for multi-scale, multi-mode deep reflection data

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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 shot points, and large noise level often result in deterioration of the data quality and poor reflection image in seismic profile. The combination of telemetry and independent recording system provides the deployment of 100-200km long survey line across the area of land-marine transition zones with dense seismic array. Multi-scale and multi-mode survey layout has been realized by the simultaneous data acquisition of regional refraction, low-fold wide-angle reflection and standard reflection survey for the several targets on the same seismic line optimized by the integration of different seismic sources and supplementary three-component digital accelerometers with broader frequency responses. In our study, multilateral approach beyond the conventional CMP stack is applied to the multi-scale, multi-mode seismic data for the extraction of deep crustal reflection patterns. The high-resolution velocity structure can be estimated by the hybrid profiling of wide-angle reflection and refraction data. 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 an efficient alternative profile to conventional CMP stack with a pronounced signal-to-noise ratio. The CRS-driven velocity attribute with the short-wavelength structural heterogeneity has the potential imaging capabilities including velocity model for improved prestack depth migration. In our study, multi-dip reflection surfaces method is adopted for the imaging of wide-angle deep reflections. In order to build the detailed basin-scale geophysical model, we developed a processing workflow based on the combined tomographic analysis of refraction, P-P and P-S reflection profile. Multi-component seismic reflection data using ocean-bottom cable with 4C MEMS sensors has presented imaging capabilities in P-S wave reflection profiling and Vp/Vs estimation for the delineation of volcanic stratigraphy in our study. 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 and multilateral approaches in reflection seismology.

Keywords: reflection seismology, deep seismic profiling, 4C OBC, refraction tomography, P-S converted wave, common reflection surface method