Recent advances in reflection seismology and application to deep seismic exploration

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Systematic survey of the continental lithosphere by deep seismic reflection profiling developed for the petroleum exploration has revolutionized the view of crust and upper mantle structure. National programs such as COCORP in the United States has provided the detailed information on geotectonic characteristics of lithosphere. In Japan, marine seismic exploration to reveal the inner trench slope of the Nankai trough and accretionary prism has been extensively carried out since the late 1970's. However, deep seismic reflection surveying in land and transition zones imposes 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 poor data quality. 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. In seismic data acquisition, 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 based on the integration of different seismic sources focused on effective low-frequency bandwidth of seismic signature. In seismic data processing, the high-resolution velocity estimation can be realized by the simultaneous acquisition of wide-angle reflection and refraction data. It has been proposed that refraction and reflection static corrections are key steps to improving the image of deep seismic reflections with low S/N and discontinuous patterns. The global optimization method is required for reflection static corrections to accommodate the high multimodal character of objective function on deep seismic data. Recent advances in relative-amplitude-preserved processing with surface-consistent amplitude and wavelet compensation has potential to detect the location of asperities on subduction mega-thrust based on their reflectivity distribution. Another advances in prestack depth migration of wide-angle seismic data has the potential to increase the ability to image deep-crustal structure, particularly when closely spaced data are collected.

The Headquarters for Earthquake Research Promotion Japan started a program of deep seismic profiling to reveal regional characterization of metropolitan area in 2002. We refer several deep seismic profiles in this program to review the recent advances in reflection seismology.