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Multi-scale seismic reflection imaging of active fold-and-thrust belts in Niigata backarc basin in central Japan

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Structural characters of en echelon, active fold and thrust structures in backarc, thick sedimentary basins and their structural links to deeper structures are commonly complicated, depending on inherited structural and mechanical factors including their kinematic histories, present and past sedimentary environments, volcanisms, fault reactivation, and thermal and/or dynamic subsidence. In this study we present multi-scale seismic reflection profiles across active fold-and-thrust belts in Niigata backarc basin in central Japan to analyze their structures from shallow to otherwise inaccessible deeper levels. Niigata basin is underlain by ca. 8-km-thick Neogene sediments, which are deformed by highly active fold-and-thrust belts, where large devastating earthquakes have occurred in these several hundred years. Deep seismic reflection profile (2010 Mishima-Higashiyama Line) across the 2007 Chuetsu-oki earthquake (M6.8) source region illuminates highly complicated fold-and-thrust structures. Pairs of west-dipping thrusts merge into a shallow, easterly dipping thrust fault, on which the mainshock of the 2007 earthquake was located. In addition, decollement folding enhanced by over-pressured Miocene mudstone on the hangingwall of the deeper thrust also complicates styles of deformation at higher structural levels. In spite of these structural complexities, tight structural and stratigraphic constraints on the seismic reflection profile by rich dataset of industrial boreholes provide west-dipping thrust trajectories sole into the deeper thrust at depth of ca. 10 km. We also collected and processed shallow high-resolution seismic reflection data in order to resolve shallow structures and to understand structural linkage between active faults and folds recognized at ground surface and deeper, complicated fold and thrust structures. We deployed 200 seismic channels, 10-Hz geophones, and mini-vibrator as a seismic source along about 7-km-long seismic line. Common midpoint stacking by use of initial velocity analysis successfully illuminates subsurface geometries of active fault-related fold to 1-1.5 two-way time. Detailed seismic reflection analyses including refraction and residual statics, migration, deconvolution, and time-space variant bandpass filters, and depth-conversion by use of stacking velocities enable to obtain subsurface depth section of these active structures. The high-resolution depth section shows that upward extension of the west-dipping thrust imaged in the deeper section is consistent with emergent thrust fault defined by middle Pleistocene conglomerates, sand- and mudstone are thrust over younger fluvial sediments. It is of interest that several active fault/fold scarps on the footwall side of the emergent thrust are underlain by west dipping thrusts marked by fault cutoffs recognized by discontinuities of reflectors. These west-dipping thrusts are interpreted to merge into sedimentary layers shallower than 1 km. Gently upward geometries of the footwall strata show that they are upward folded at northward propagation of a right stepping en echelon active anticline to the south. These observations suggest that interactions between adjacent en echelon, lateral propagating active folds strongly controls styles of faulting at structural highest levels, manifested by topographic fault or fold scarps.