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Development of an active wedge-thrust: A case study of the eastern boundary fault of the Echigo plain, central Japan

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The Niigata basin is located along the Japan Sea coast of the central Honshu and characterized by thick (max. 8 km) Neogene back-arc sediments and arc-parallel folds-and-thrusts. Thrust faults in the basement have generated devastative earthquakes, such as 1964 Niigata (Mw 7.6), 2004 Chuetsu (Mw 6.6) and 2007 Chuetsu-oki (Mw 6.6) earthquakes. Due to thick sedimentary cover, the relationship between active folding and source fault is poorly understood. We performed deep and shallow high-resolution seismic reflection profiling and discuss the development of active wedge-thrust in the eastern part of the Echigo plain, Niigata, Japan. Deep seismic data were acquired along a 70-km-long seismic line using air-guns and vibroseis trucks (Sato et al., 2009). Shallow high-resolution data was obtained by Mini-vib (IVI T15000) and 240 ch recording system (Kato et al., 2009). Subsurface geology was interpreted based on seismic sections, velocity profiles, surface geology and borehole data.

The eastern boundary fault of the Echigo plain is an eastward dipping (40 degrees) thrust and its deeper extension clearly demonstrated down to 7 km in depth by velocity profiles showing a lower velocity zone at the foot wall and narrow east-dipping reflectors. The fault is a blind thrust and it becomes flat at the depth of 1 km and the detachment fault lies in the middle Miocene mudstone of the Teradomari Formation. At the toe of the thrust, a structural triangle zone has been developed associated with wedge thrusts and an anticlinorium. The shallow part (< 2 km) of hanging wall of lower detachment (main thrust) consists of mudstone and the wave length of folds in the hanging wall becomes smaller to the front of the thrust. Deformation of hanging wall is more intense at the thrust front. On the hanging wall of upper detachment, 1-km-thick fluvial sediments are widely distributed. The mechanisms of the concentration of strain at the intercutaneous wedge and formation of triangle zone is explained by following factors; 1) the hanging wall of the main thrust consists of soft Neogene mudstone, 2) existence of “competent” gravels at hanging wall of upper detachment. Namely, a soft and tapered mudstone unit forming the thrust toe of hanging wall collided with “hard” fluvial sediments and wedge thrusts were formed at the front with intense deformation. Deformation of river terraces of the hanging wall is concordant with this major geologic structure, showing an active fold with 7-km-long wave length. From the study of tectonic geomorphology vertical growth rate of the anticlinal axis is estimated to 1 mm/year (Kobayashi et al., 2002). The eastern boundary fault of the Echigo plain is an active blind thrust and its lateral extent is marked by the concentrated deformation zone as the arc-shape in map view. Together with the results of historical record (Matsu-ura et al., 2006), it is highly probable that this fault is responsible for the 1828 Sanjo earthquake (M7.2).