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Progress of illitization along an imbricate frontal thrust at shallow depths in an accretionary prism

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ABSTRACT

Fossil imbricate thrusts, branching from a décollement in an ancient accretionary prism (the Miura–Boso accretionary prism), are exposed in the southern parts of the Miura and Boso peninsulas in central Japan. An analysis of the clay mineralogy of fault rocks along one of the imbricate thrust faults, the Shirako Fault, revealed local illitization of mixed-layer illite–smectite (I–S) and the partial breakdown of kaolinite. The shape of the I(001)–S(001) reflection in the X-ray diffraction pattern suggests that the illite fraction in I–S crystallites within the fault gouge is ~9% more than in the surrounding rocks. These results imply that there has been a local temperature anomaly within the slip zone, attributable to frictional heating induced by high-velocity slip. A thermal model, coupled with a kinetic simulation of illitization in I–S, suggests that the reaction was probably facilitated by multiple high-velocity slips at a peak temperature of ~450 °C, suggesting repeated seismic rupture propagations to the prism toe, as also inferred from the modern accretionary prism (in the Nankai Trough).

1. Introduction

Sediments entering a subduction zone accumulate to form a wedge-shaped accretionary prism cut by a sequence of frontal thrust faults, including in-sequence frontal thrusts and out-of-sequence thrusts (e.g., Moore and Silver, 1987). Seismic activity along such thrusts is of great concern in terms of the generation of tsunamis. These thrusts are generally deep-rooted along a plate interface (i.e., décollement), and extend upwards to the seafloor. The propagation of high-velocity slip to such shallow crustal levels would cause rapid deformation of the seafloor, potentially resulting in a tsunami. For example, the rupture area of the 1944 Tonankai earthquake, as determined from seismic and tsunami waveform inversion (Baba and Cummins, 2005; Ichinose et al., 2003; Kikuchi et al., 2003; Tanioka and Satake, 2001), is close to the trace of an out-of-sequence thrust (a megasplay fault) at the Nankai margin (Moore et al., 2007; Park et al., 2002).

In general, deformation of the shallow portions of subduction zones has been considered aseismic (Byrne et al., 1988); however, recent studies on fault rocks at shallow depths in the Nankai Trough, recovered by the Integrated Ocean Drilling Program (IODP) Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), have shown several geological records of local thermogenesis, possibly associated with frictional heating during high-velocity slip. For example, Sakaguchi et al. (2011) measured vitrinite reflectance of coal fragments in core samples from a megasplay fault located at a depth of 271 m below the seafloor (site C0004 of Expedition 316), and reported a distinct reflectance anomaly on a slip plane. Based on a kinetic model of vitrinite maturation, the authors estimated a transient temperature rise of the order of 390 °C. Another significant aspect in this work is the finding that even a frontal thrust (site C0007 of Expedition 316) may have experienced a temperature rise in excess of 300 °C. Besides vitrinite reflectance anomalies within the slip zone of the megasplay fault, X-ray diffraction (XRD) and X-ray fluorescence mapping revealed local illitization (Yamaguchi et al., 2011). This illitization was also interpreted to be a result of local rises in temperature within the slip zone. Although these mineralogical/geochemical anomalies might have resulted from historical high-velocity slip near the seafloor, the faulting processes at such shallow depths in a subduction zone remain largely unknown, and multidisciplinary investigations are required to gain a better understanding of the mechanics and behaviors of these faults.

One of the obstacles against such an approach is that the volume of core samples is very limited; one way to overcome this difficulty is to target fossil fault zones hosted in subaerial exposures of on-land accretionary prisms. For example, Hamada et al. (2011a) analyzed the behavior of trace elements across a reverse fault in an ancient accretionary prism–the Hota Group (burial depth of ~1–4 km), central Japan–and identified past heating events that produced a local temperature increase of more than 350 °C; however, it was not well established as to whether or not the analyzed fault was subduction-related. The Miura–Boso accretionary prism is another ancient accretionary prism, exposed in the southern parts of the Miura and Boso

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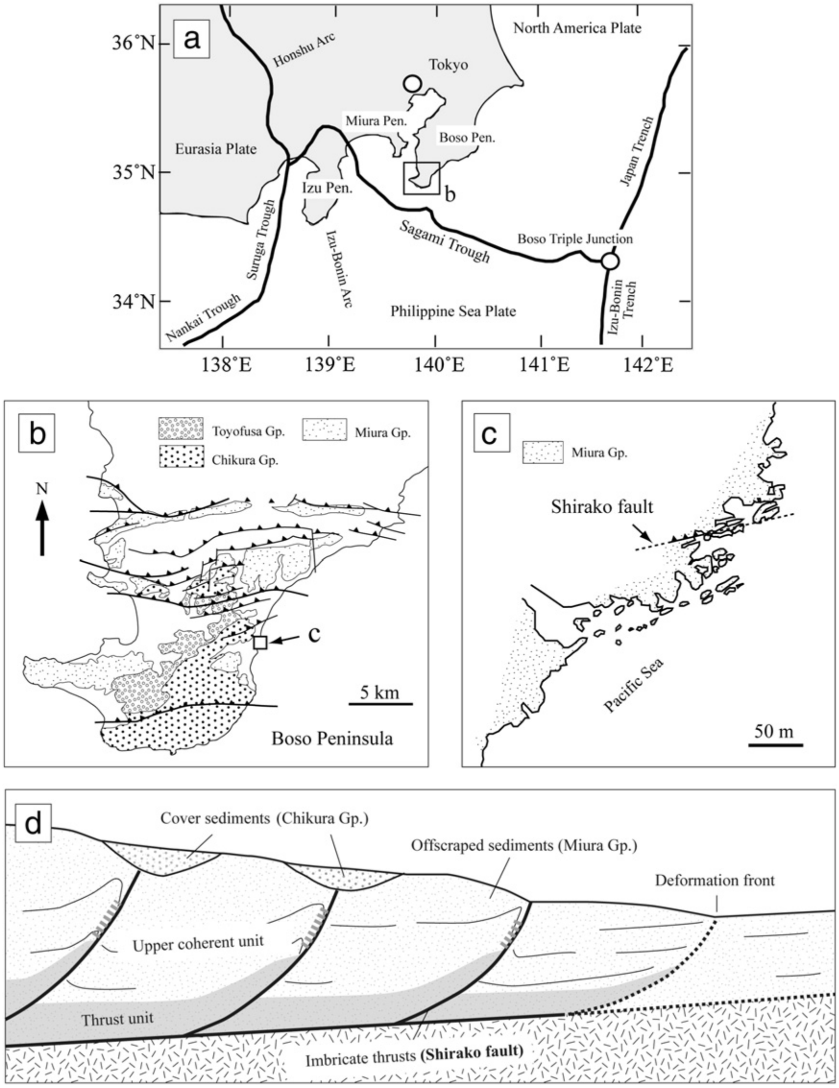

Fig. 1. (a) Plate configuration in Central Japan. (b) Geological map of the Boso peninsula. (c) Enlarged location map of the area around the Shirako Fault. (d) Schematic cross-section through the Miura–Boso accretionary prism (Yamamoto, 2006).

Fig. 2. Representative outcrop photo showing a trace of the slip zone of the Shirako Fault (solid arrow heads).