

Localisation of plastic flow in the mid-crust along a crustal-scale fault: Insight from the Hatagawa Fault Zone, NE Japan

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ABSTRACT

This study examines plastic flow in fault rocks exposed along the Hatagawa Fault Zone (HFZ) of NE Japan. The fault zone, developed in 110 Ma granitoids, ceased activity by 98.1 ± 2.5 Ma. Three different fault rocks (mylonites with microstructures A and B, and cataclasite) are exposed along the fault. Microstructure A formed at the brittle–plastic transition. The temperature conditions for microstructure B were higher than those for microstructure A; those for the cataclasite were lowest. Microstructure A is exposed in limited areas (maximum length extent of approximately 6 km) along the HFZ. The distribution of microstructure A is considered to represent the latest-stage localised zones of plastic flow, associated with strain weakening accompanied by dynamic recrystallisation of feldspar, suggesting the restriction of plastic displacement to certain intervals at depth ranges with P – T conditions of the brittle–plastic transition. Many zones of localised deformation containing crush zones are observed in rocks with microstructure A, suggesting that numerous fractures nucleated due to the ductile fracturing of highly deformed fine-grained feldspar in the outcrop extent of microstructure A. The nucleation of large earthquakes was possibly promoted by interaction between fractures that nucleated by ductile fracture and stress concentrations associated with the restricted development of plastic displacement.

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1. Introduction

The hypocentres of inland earthquakes are generally located in the shallow part of the Earth's crust, and mainshocks usually occur in the deepest part of the seismogenic zone (Sibson, 1982, 1984; Das and Scholz, 1983; USGS Staff, 1990; Nakamura and Ando, 1996). The temperature of the base of the seismogenic zone is between 300 and 400 °C (Ito, 1999), corresponding to the brittle–plastic transition in the Earth's crust (Sibson, 1982, 1984). These observations suggest the important role of plastic behaviour along the deep-level extensions of seismogenic faults in the generation of large inland earthquakes (Shimamoto, 1989; Scholz, 1990).

One possible nucleation mechanism of large inland earthquakes is interaction between the plastic behaviour of the deeper parts of crustal-scale fault zones and the frictional behaviour of shallower parts (Iio and Kobayashi, 2002; Shibazaki, 2002; Iio et al., 2004). To understand this interaction, it is necessary to determine the behaviours of fault zones around the base of the seismogenic zone (depth = 10–20 km), which presumably are located near the brittle–plastic transition; however, such regions are generally inaccessible along major active faults. Therefore, the investigation of exhumed crustal-scale fault zones for which deeper crustal sections (including the vicinity of the brittle–plastic transition) are exposed at the surface is an important strategy in understanding fault behaviour in such regions (e.g., Stewart et al., 2000).

Mixed brittle–plastic fault rocks reported along the Hatagawa Fault Zone (HFZ) of NE Japan (Takagi et al., 2000; Tomita et al., 2002; Shigematsu et al., 2004) represent an exhumed fault zone deformed in the vicinity of the brittle–plastic transition. In the present study, fault rocks were examined along the HFZ with the

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aim of understanding fault behaviour around the base of the seismogenic zone.

2. Hatagawa Fault Zone

Two NNW–SSE-trending major crustal-scale faults are exposed at the eastern margin of the Abukuma Mountains, NE Japan. The western fault, the HFZ (Watanabe et al., 1953; Sendo, 1958) (Fig. 1), separates the Abukuma belt from the South Kitakami belt (Kubo and Yamamoto, 1990; Kubo et al., 1990). The Abukuma belt, which lies to the west of the HFZ, consists mainly of magnetite-free Cretaceous granitoids; the South Kitakami belt, which lies to the east, is dominated by magnetite-bearing Cretaceous granitoids. The HFZ contains three structural zones: a cataclasite zone of up to 100 m in width, mylonite zones with a sinistral sense of shear and

a maximum width of >1 km, and small shear zones of less than 1 m in width (Takagi et al., 2000; Shigematsu and Yamagishi, 2002; Tomita et al., 2002) (Fig. 2). An undeformed granodiorite porphyry dike intruded into the cataclasite zone has been dated at 98.1 ± 2.5 Ma, indicating that major activity along the HFZ had ceased by this time (Tomita et al., 2002).

We studied a 45-km-long section along the HFZ (Fig. 1), focusing on the relationship between the cataclasite and mylonite zones.

3. Fault rocks within the HFZ

3.1. Mylonite zones with a sinistral sense of shear

Mylonite zones with a sinistral sense of shear are heterogeneously exposed along the entire 45 km length of the HFZ

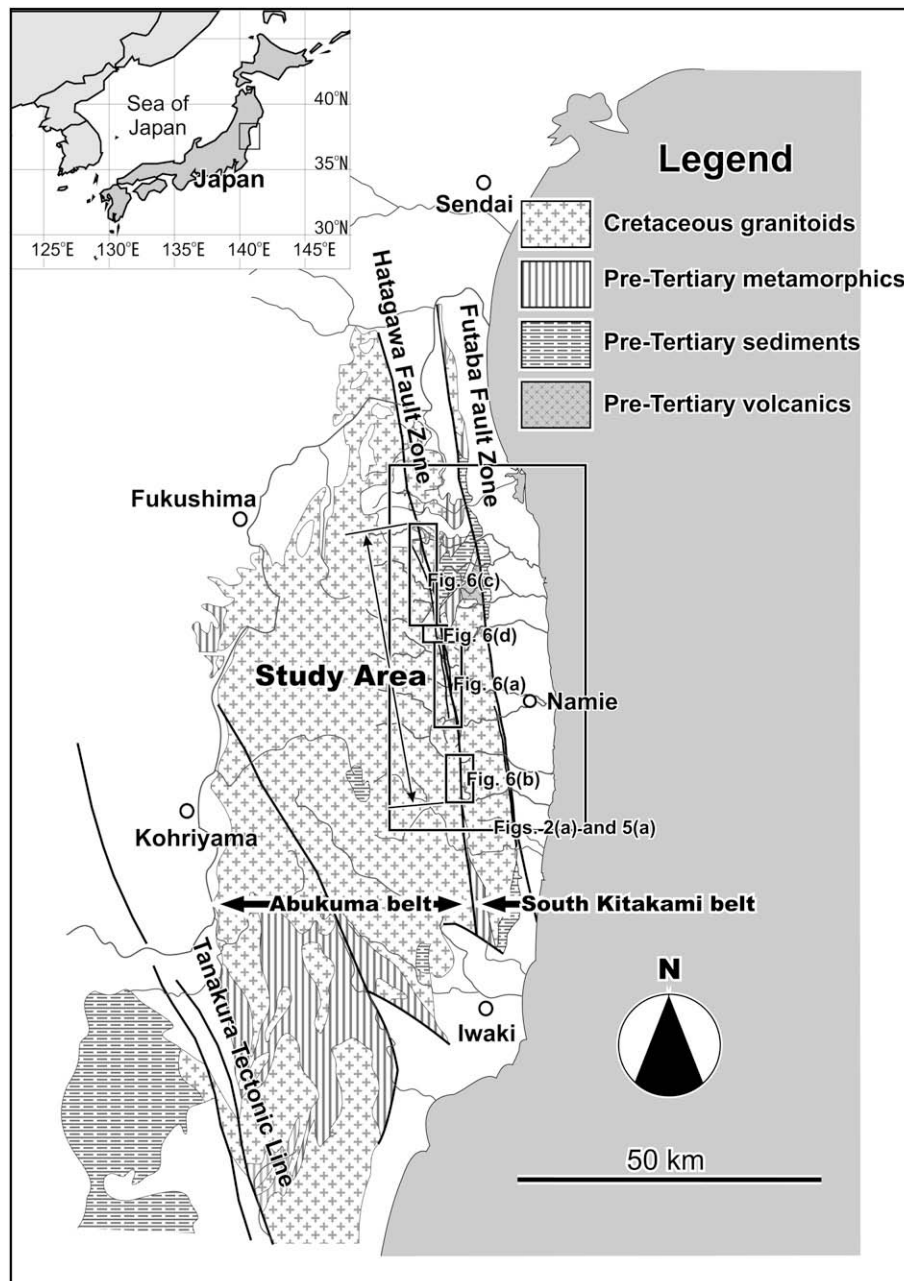


Fig. 1. Geological map showing the location of the study area, pre-Tertiary rocks, and major faults. The areas shown in Figs. 2a, 5a, and 6 are indicated by rectangles.

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