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Stress accumulation process in and around the Atotsugawa fault, central Japan, estimated from focal mechanism analysis

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ABSTRACT

We estimated 275 focal mechanisms from P-wave first-motion polarities of small earthquakes obtained in an extensive seismic survey during 2004–2008 in and around the Atotsugawa fault, central Japan, where ongoing dextral shear strain concentration has been observed. Along the fault trace, the azimuth direction of P-axes is oriented WNW–ESE, which agrees well with previous studies. The regional stress disturbance is detected by stress inversion analysis. The azimuth of the maximum principal stress axis systematically rotates counterclockwise as the distance from the fault trace decreases. The regional stress disturbance is explained by a cumulative slip deficit in the shallower portion of the Atotsugawa fault relative to the surrounding fault surface (i.e., the eastern, western, and deeper extensions of the fault plane).

1. Introduction

Many studies have been conducted on deformation processes of continental crust, particularly the role of active faults. Previous studies can be classified into two groups. One group proposed that block motion due to slip on active faults is dominant (e.g., Avouac and Tapponnier, 1993; Tapponnier et al., 1982). The other group considered crustal deformation as being distributed and/or continuous and so fault slip is less dominant (e.g., England and Molnar, 1997; Molnar, 1988). This long-standing debate mostly focuses on continental collision zones, and so is not directly applicable to volcanic island arcs where the thermal structure and fluid distribution in the crust are essentially heterogeneous (e.g., Nakajima and Hasegawa, 2007; Nakamura et al., 2008; Tanaka et al., 2004). In the Honshu Arc, Japan, which is the best-studied island arc, it has been proposed that water dehydrated from the subducting oceanic slab reaches the crust and reduces the lower crustal strength, causing strain concentration (Iio et al., 2002). In fact, the location of the remarkable strain concentration zone called the Niigata–Kobe Tectonic Zone (NKTZ) detected by global positioning system (GPS) measurements (Fig. 1, Sagiya et al., 2000) has a close correlation with the distribution of high ^{3}He/^{4}He ratios (Iio et al., 2002). However, the mechanism of stress build-up inside this strain concentration zone is poorly known. In this study, we focus on the Atotsugawa fault, the best-studied strike-slip fault in the NKTZ to examine the mechanism of stress build-up and its spatial variation inside the NKTZ.

The stress field can be estimated by inversion methods using the focal mechanisms of small earthquakes (e.g., Gephart and Forsyth, 1984; Michael, 1987). Imanishi et al. (2011) deployed a dense network of seismometers along the Atotsugawa Fault, and conducted stress inversion from microearthquakes. Using the depth dependence of the stress field, they showed that the shallow part of the fault is locked and the deeper part is creeping. However, regional stress rotation, as observed in the San Andreas fault (Hardebeck and Hauksson, 1999), was not examined because their seismic network only covered the area in the proximity of the fault trace. Katsumata et al. (2010) deployed a dense and wide seismic network in and around the Atotsugawa fault, and estimated the stress field in that region. The study of Katsumata et al. (2010) was a preliminary report that used the data obtained during the first half of the survey period (January 2005 to December 2006), and so the mechanism of stress build-up was not examined. In this study, first, we use all the data obtained during the project (November 2004 to December 2008) to determine the focal mechanisms of small

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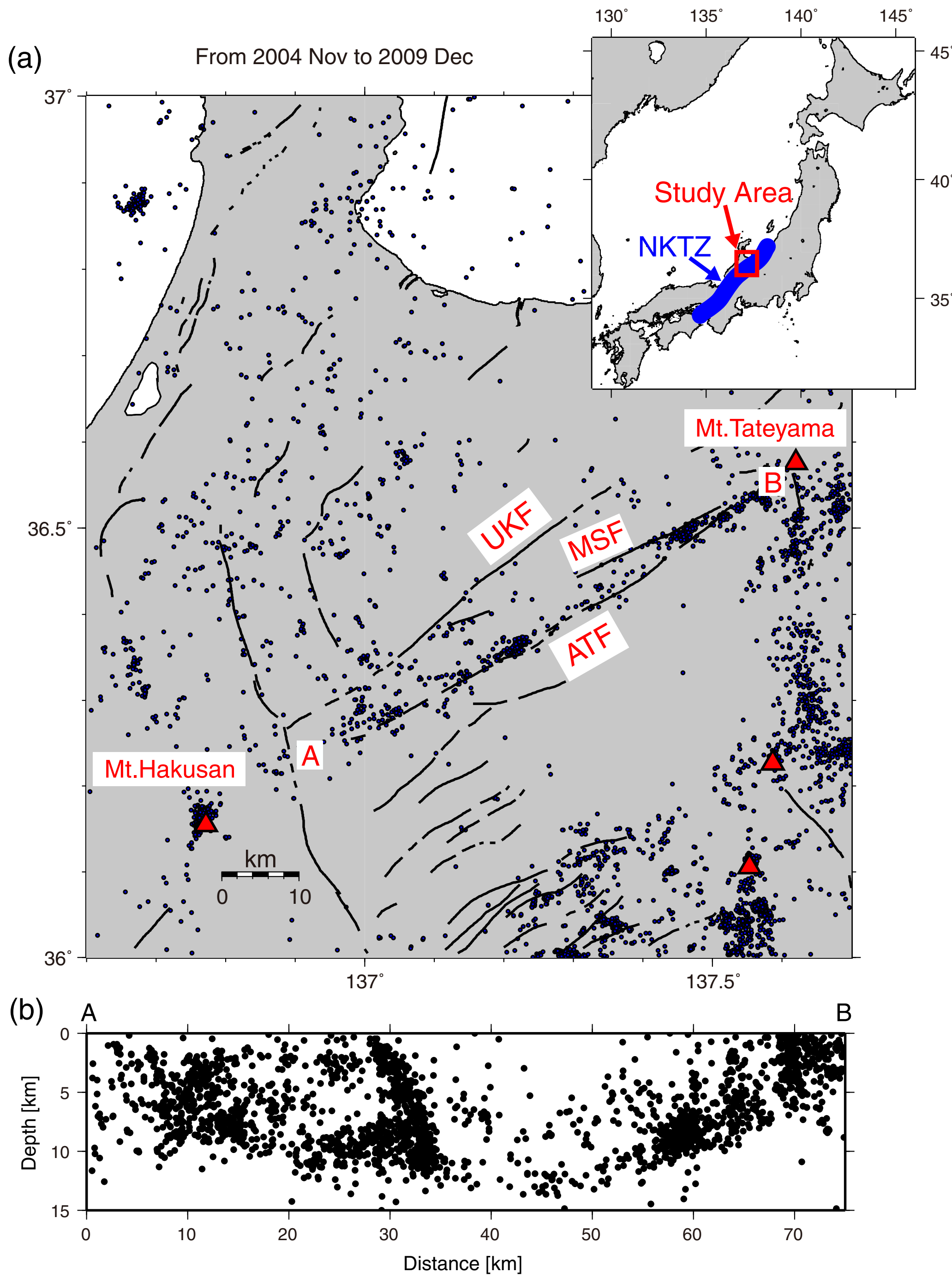

Fig. 1. Seismotectonics of the studied area. (a) Epicentral distribution of shallow earthquakes in and around the Atotsugawa fault observed from November 2004 to December 2009. Red triangles indicate active volcanoes. Black lines indicate active faults. ATF: Atotsugawa fault; MSF: Mozumi-Sukenobu fault; UKF: Ushikubi fault. We can recognize a clear lineament of seismicity along the Atotsugawa fault. The strain concentration zone (Niigata–Kobe Tectonic Zone) and the study area are indicated by a blue line and a red rectangle, respectively, in the inset. (b) Hypocentral cross-section along line A–B in (a). Earthquakes within a distance of 2.5 km from the line are projected.

earthquakes, and examine the regional stress field in and around the Atotsugawa fault. Using these focal mechanisms, next, we construct a model of the stress accumulation mechanism around the fault.

2. Tectonic setting

The Atotsugawa fault system is a 70-km-long dextral strike-slip fault system in the central part of Japan (Fig. 1). It consists of three faults, i.e., the Atotsugawa fault, the Mozumi-Sukenobu fault, and the Ushikubi fault. This study focuses on the Atotsugawa fault as it is the longest and seismically most active (e.g., Takeuchi et al., 2003). The Atotsugawa fault has been identified as being a remarkable lineament of earthquakes (e.g., Ito et al., 2007; Wada and Kishimoto, 1974) (Fig. 1a). The recurrence interval of large earthquakes has been estimated to be about 2500 years (Takeuchi et al., 2003). Currently, most earthquakes along the Atotsugawa fault are very small (M < 2), and thus a dense network of seismometers is required. Determination of the precise hypocenter has confirmed that the fault shape is almost vertical