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Localized changes in geomagnetic total intensity values prior to the 1995 Hyogo-ken Nanbu (Kobe) earthquake

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ABSTRACT

Changes in total geomagnetic field intensity, of 2–3 nT, were observed prior to the 1995 Hyogo-ken Nanbu (Kobe) earthquake at the Amagase (AMG) site, located approximately 70 km from the epicenter. We examined whether the observed variations are local signals arising from the Earth's crust, or global variations that are unlikely to originate from the crust. To remove global-scale variations in total geomagnetic intensity data, we employed a regional geomagnetic field model. Using data recorded at five reference sites in Japan, we estimated global-scale variations in total geomagnetic intensity, and removed them from the observed total geomagnetic intensity at the AMG site. The reminder still showed variations during the period prior to the Kobe earthquake. In addition, these pre-seismic variations include two of the largest shifts recorded during the entire observation period at the AMG site, raising the possibility that these variations were indeed related to the earthquake. These variations cannot be interpreted as signals arising from the area close to the seismic source because of the large distance between the epicenter and the site. Therefore, our results raise the possibility that the physical state of the Earth's crust shows marked changes over a wide region in the lead-up to a seismic event.

1. Introduction

Anomalies in the geomagnetic field associated with or prior to large earthquakes were first reported more than a century ago by Tanakadate and Nagaoka (1893), who documented magnetic field variations associated with the 1891 Great Mino-Owari earthquake (M 8.0), Central Japan. Rikitake (1968) reported that the amplitude of change in the geomagnetic field associated with earthquakes showed a marked decrease since the invention of the proton magnetometer, which measures absolute values of total magnetic field intensity. The author attributed the large amplitudes of pre-seismic and co-seismic variations in the magnetic field to the low accuracy of the early observations. However, in conclusion, the author did not discount the existence of co-seismic variations in the geomagnetic field.

The reliability of geomagnetic observations has been improved with the use of modern instruments. In fact, geomagnetic observations synchronous with tectonic events are now used in studies of corresponding events (e.g., Napoli et al., 2008; Sasai et al., 2002). If pre-seismic variations in the geomagnetic field can be detected, and if they are related to the seismic event itself, then such variations would also provide information on the physical state of the Earth prior to the event, which is important in understanding the controls on the occurrence of earthquakes. In this sense, it is important to investigate the relation between geomagnetic variations and earthquakes, even if such pre-seismic variations cannot be used for earthquake prediction.

Sakanaka et al. (1998) reported possible precursory variations in the total geomagnetic field intensity prior to the 1995 Hyogo-ken Nanbu earthquake (Kobe earthquake) (Mw. 7.1). This event was one of the most devastating intra-plate earthquakes in Japan for several decades, resulting in severe damages, more than 6400 deaths, and motivating intensive research on the event itself. In addition to the studies on purely seismological aspects of the event, some studies have been devoted to the detection of precursory phenomena, including changes in seismicity (Enescu and Ito, 2001), geochemistry (Igarashi et al., 1995), ground surface temperature (Tronin et al., 2002), and electromagnetic fields across a wide range of frequencies (Nagao et al., 2002).

Sakanaka et al. (1998) visually inspected the total geomagnetic field intensities recorded at the Amagase (AMG) magnetic station (N34°52′48″, E135°50′09″), with reference to the Kakioka Magnetic Observatory (KAK, N36°13′56″, E140°11′11″) (Fig. 1a), during the period from the end of 1992 to 1997, and stated that "one of the

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