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Geomagnetic fluctuations during the 1999 Chi-Chi earthquake in Taiwan

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On 21 September 1999 (Taiwan local time), a major earthquake measuring M7.3 occurred near the town of Chi-Chi in central Taiwan. After the Chi-Chi earthquake, geomagnetic data recorded by a network of 8 stations equipped with continuous recording systems was analyzed. The results revealed that the total geomagnetic intensity of the Liyutan station, about 8 kilometers from the northern end of the Chelungpu fault (considered to be related to the earthquake), fluctuated significantly for more than a month prior to the earthquake. The fluctuation features continued and then stopped after the Chia-Yi earthquake (M6.2) occurred near the southern end of the Chelungpu fault on 22 October 1999. The variation of intensity reached 200 nTs. Geomagnetic fluctuations were also found at the Tsengwen station, located about 42 kilometers from the southern end of the Chelungpu fault and 30 kilometers from the Chia-Yi earthquake. These geomagnetic disruptions with highly anomalous amplitudes associated with the Chi-Chi and Chia-Yi earthquakes appear to have been the result of the accumulation and release of crustal stress that led to the subsequently severe surface rupture at the time of the earthquakes.

Key words: Geomagnetic fluctuations, Chi-Chi earthquake, crustal stress.

1. Introduction

Taiwan has experienced many disastrous earthquakes in the past and can expect more in the future. Therefore, the study of earthquake prediction to lessen or, at least better anticipate an earthquake hazard has become a more important research topic in Taiwan.

Change in the magnetic field observed on the earth's surface at the time of an earthquake's occurrence is widely accepted. Many examples of geomagnetic changes associated with earthquakes have been reported (e.g., Yamazaki and Rikitake, 1970; Smith and Johnston, 1976; Honkura, 1985). In China, according to Zhu (1976), 15 months prior to the 1975 Haicheng earthquake (M7.3), geomagnetic change at Luda showed an anomalous variation (compared with that at Beijing) of more than 20 nTs. Oike (1978) and Noritomi (1978) reported that the total geomagnetic force began to increase at Beijing three months prior to the 1976 Tangshan earthquake (M7.8), reaching a maximum of 7 nTs. The ULF (Ultra-low-frequency) magnetic field signature has also been recognized as a precursor to earthquakes, such as Loma Prieta (Fraser-Smith *et al*., 1990) and Guam (Hayakawa *et al*., 1996). ULF emission data at Lunping (as a reference station of geomagnetic network of Taiwan, about 130 km away from the epicenter of the Chi-Chi earthquake) has recently been viewed as a convincing precursory signature for the Chi-Chi earthquake (Akinaga *et al*., 2001).

In Taiwan, fluctuation in the geomagnetic field associated with change in tectonic stress is identified as one facet of the earthquake prediction research program. Thus, an island-wide geomagnetic network of eight stations equipped with continuous recording systems was completed in 1988 by the Institute of Earth Sciences, Academia Sinica (Fig. 1).

At 1:47 local time, 21 September (20 September 17:47 UT), 1999, Taiwan's largest earthquake of the 20th century struck the center of the island near the small town of Chi-Chi. In this earthquake, about 2500 lives were lost and thousands of buildings were destroyed. The mechanism of the earthquake was a thrust fault with a strike of N 5°E and a dip of 34° (Chang *et al*., 2000). The Chi-Chi earthquake triggered the Chelungpu fault (Fig. 1), some 90 km long, north-south trending, and mostly of the thrust type. The fault trace bent toward the northeast at its northern tip where the largest surface rupture was measured to be about 5.6 m horizontally and 9.8 m vertically (Central Geological Survey, 1999).

After the Chi-Chi earthquake, the data recorded at the stations of the geomagnetic network were examined. Clear fluctuations in geomagnetic intensity were shown at the Liyutan station and also at the Tsengwen station. This paper will focus on the fluctuations associated possibly with the Chi-Chi and Chia-Yi earthquakes.

2. Instrumentation

An earthquake prediction research program in Taiwan was started in 1979 via a joint effort between the Institute of Earth Sciences, Academia Sinica and the University of Southern California, funded by the National Science Council, R.O.C. and the U.S. Geological Survey (Tsai *et al*., 1983). Detecting local geomagnetic changes associated with earthquakes was a part of this program. A network of 24 geomagnetic stations has been in operation since 1979. Twenty-two of these stations were occupied periodically with a portable magne-