Available online at www.sciencedirect.com
ScienceDirect
Tectonophysics 429 (2007) 125–132
TECTONOPHYSICS
www.elsevier.com/locate/tecto

Seismic reversal pattern for the 1999 Chi-Chi, Taiwan, M_W 7.6 earthquake

Yih-Min Wu [a], Chien-chih Chen [b,*]

[a] *Department of Geosciences, National Taiwan University, Taipei, 106 Taiwan ROC*
[b] *Department of Earth Sciences and Inst. Geophysics, National Central University, Jhongli, 320 Taiwan ROC*

Received 19 April 2006; received in revised form 3 August 2006; accepted 30 September 2006
Available online 16 November 2006

Abstract

We in this study have calculated the standard normal deviate *Z*-value to investigate the variations in seismicity patterns in the Taiwan region before and after the Chi-Chi earthquake. We have found that the areas with relatively high seismicity in the eastern Taiwan became abnormally quiet before the Chi-Chi earthquake while the area in the central Taiwan with relatively low seismicity showed unusually active. Such a spatially changing pattern in seismicity strikingly demonstrates the phenomenon of "seismic reversal," and we here thus present a complete, representative cycle of "seismic reversal" embedding in the changes of seismicity patterns before and after the Chi-Chi earthquake.

Keywords: Seismic reversal; Seismic quiescence; Seismic activation; Chi-Chi earthquake

1. Introduction

Taiwan is located on the western Circum-Pacific seismic belt. In the vicinity of Taiwan, the Philippine Sea plate subducts northward under the Eurasian plate along the Ryukyu trench to the northeast of Taiwan, whereas the Eurasian plate subducts eastward under the Philippine Sea plate off the southern tip of Taiwan (Tsai et al., 1977; Wu, 1978). Tectonically, most of the Taiwan region is under NW–SE compression with a measured convergence rate of about 8 cm/year (Yu et al., 1997). The collision of those two plates causes the Taiwan area many complex geological features and high seismicity (Wang, 1998). Many disastrous earthquakes had occurred in this area in the past.

The 1999, M_W 7.6, Chi-Chi earthquake is the largest event on the Taiwan Island in the last century (Shin et al., 2000; Chang et al., 2000; Wu et al., 2000; Teng et al., 2001). It heavy struck the central Taiwan and resulted in serious damage (Tsai et al., 2001; Wu et al., 2002, 2003a, 2004). Solid star shown in Fig. 1 denotes the epicenter of the Chi-Chi main shock and nearby lines show its surface ruptures.

There was no any precursory phenomenon reported *before* the occurrence of the Chi-Chi earthquake, although many *retrospective* studies related to various precursory phenomena of this event can be found (e.g. Chen et al., 2000; Liu et al., 2000, 2001; Akinaga et al., 2001; Ohta et al., 2001; Chuo et al., 2002; Song et al., 2003; Lee and Tsai, 2004; Liu et al., 2004; Yen et al., 2004). Very recently, there also appear some *retrospective* analyses of seismicity in the Taiwan region, focusing on searching the signature of seismicity changes before the Chi-Chi earthquake. By using the

* Corresponding author. Tel.: +886 3 422 7151x65653; fax: +886 3 422 2044.
E-mail address: chencc@ncu.edu.tw (C. Chen).

0040-1951/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2006.09.015

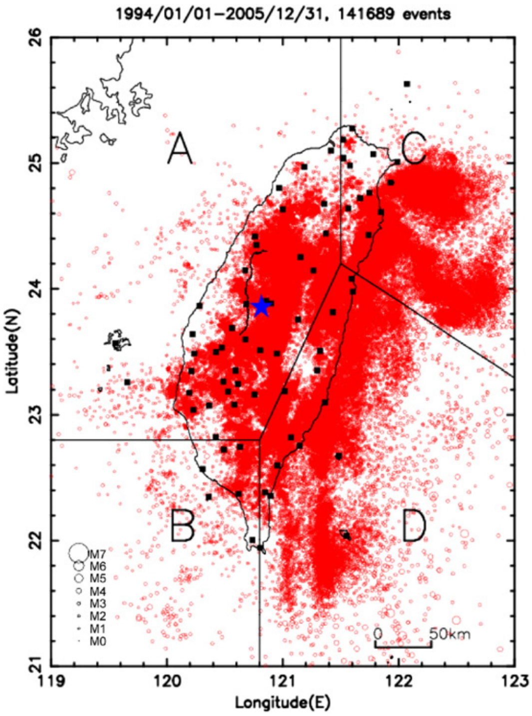

Fig. 1. Epicenters of selected 141,689 events used in this study (open circles). The locations of the telemetered stations of the Central Weather Bureau Seismic Network are marked by solid squares. The epicenter of the Chi-Chi earthquake is indicated by solid star, whereas the solid line marks the surface rupture induced by the main shock. We divide the study area into four seismic zones: Zones A, B, C and D, based on seismic characteristics and tectonics.

CWB catalogue released in Shin and Teng (2001), Chen (2003) has found activation of moderate-sized earthquakes before the Chi-Chi event and discussed the important implication to the self-organizing spinodal model of earthquakes (Rundle et al., 2000). Examination of the frequency-magnitude statistics of seismicity in the years prior to the Chi-Chi earthquake shows that precursory activation of earthquakes with magnitude larger than 5 started at the end of 1993, lasting about 6 years up to the main shock. On the other hand, Wu and Chiao (2006) found that the Chi-Chi earthquake was preceded by a notable decrease in regional seismicity rate of smaller events with magnitude larger than 2. The anomalous reduced seismicity started from January 1999 and lasted about 9 months up to the occurrence of the main shock. It should be noted that seismic activation mainly emphasizes the increasing activity of moderate-sized earthquakes (e.g. Sykes and Jaume, 1990) while earthquake magnitude participates in quiescence could be even small (e.g. Wiemer and Wyss, 1994; Zoller et al., 2000; Huang et al., 2001). With the pattern informatics (PI) method, systematic scan (Sheu et al., 2002; Chen et al., 2005) over the whole Taiwan region for the anomalous area of seismic activity indicates that the location of the epicenter of the Chi-Chi main shock had exhibited strongly anomalous activity before the occurrence of the Chi-Chi earthquake. While a weak signature of the Chi-Chi event appears on the so-called PI map in Sheu et al. (2002), a more striking and correlated PI hotspot patchwork was obtained by the modified PI method in Chen et al. (2005).

The seismicity patterns reflect a space-time correlation with the crustal stress and strain fields. By means of the seismicity variation within a time interval, we could investigate the anomalous seismicity patterns related to a forthcoming large earthquake. Abovementioned four papers regarding the Chi-Chi earthquake (Sheu et al., 2002; Chen, 2003; Chen et al., 2005; Wu and Chiao, 2006) focused their issues on the seismicity variation before the main shock. Here, in the present study, we further analyze seismicity data from 1994 to 2005. Thus we compare seismic activities before and after the Chi-Chi earthquake. We find that seismicity patterns in the Taiwan region greatly changed before and after the Chi-Chi earthquake. We thus conclude the phenomenon of "seismic reversal" (Shebalin and Keilis-Borok, 1999) may take place to the Chi-Chi sequence.

2. Data

Catalog data from the Taiwan Central Weather Bureau (CWB) were used in this study. The Taiwan Telemetered Seismographic Network (TTSN) (Wang, 1989) merged to the CWB seismic network and updated to modern seismometers since 1991. It is characterized by an integrated earthquake observation system, the Central Weather Bureau Seismic Network (CWBSN). The CWBSN consists of a central recording system with 73 telemetered stations that are equipped with 3-component S13 seismometers. Solid squares shown in Fig. 1 are the CWBSN stations. Seismic signals digitized at 12 bits and 100 Hz for each station are transmitted through a dedicated telephone line to the central station located at the Bureau in Taipei. The signals are then used to manually pick the P and S arrivals for determining the earthquake location and the local magnitude M_L (Shin, 1993). The location error for the CWB catalogue has not been systematically estimated. But, based on previous analyses (Wu et al., 2003b; Kuochen et al., 2004), the error of hypocenter location is about within 5 km and 10 km in the western and eastern Taiwan, respectively.

The CWBSN system was operated in a trigger-recording mode before the end of 1993. Since 1994, the