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3-D Velocity Models in the Central Taiwan Region

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1. Introduction

The destructive Mw 7.6 Chi-Chi earthquake shook the entire island of Taiwan on 21 September, 1999 (20 September 17:47 at UTC). The earthquake was followed by tremendous amount of aftershocks for the next a few months including ten strong aftershocks with magnitude greater than 6.0 (Figure 1). North-south trending about 85 km long surface rupture with vertical thrust and left lateral strike slip offsets as large as the maximum 9.5 meters displacement was charted by field investigations. Here we show high resolution P- and S-wave velocity models in the devastating 1999 Chi-Chi, Taiwan, earthquake source area and its vicinity to understand the generating mechanism of the main shock and aftershock sequence.

2. Data, Method and Analysis

High quality P-wave and S-wave arrival times are selected from three sets of data: the island wide seismic network continuously operated by the Central Weather Bureau of Taiwan and two temporary seismic networks operated by the Institute of Earth Sciences, Academia Sinica (IESAS). Central Weather Bureau Seismic Network has been a major seismic network in Taiwan since 1993. IESAS organized and deployed a temporary strong motion seismic network in the epicentral area of the Chi-Chi earthquake to monitor the earthquake activity following the destructive M_W 7.6 event. Another temporary seismic network was organized and operated for 24 days to monitor the aftershock activity followed by 1998 magnitude 6.2 earthquake in the Chiayi area. A few selection criteria, including but not limited to observation quality and spatial distribution of sources, have been applied to ensure the highest possible data quality and ray coverage. The combined data set to invert tomographic image of the study area includes 57,263 P-wave arrivals and 38,373 S-wave arrivals from 6,440 earthquakes recorded by 70 stations. The tomography inversion and earthquake relocation package initially developed by Benz et al. (1996) was used to determine reliable 3-D P- and S-wave velocity models. Details of the inversion method have been described elsewhere (Kim et al., 2005). After the determination of reliable 3-D velocity models, all relocatable earthquakes in the CWBSN catalog have been relocated to obtain the best possible hypocenters and to take advantage of abundant earthquakes in understanding the

Keywords: earthquake, active fault, 3-D velocity model, aftershock

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dynamics of active faults. P and S arrival time RMS residuals decreased from the initial 0.42 and 0.50 seconds to 0.20 and 0.29 seconds, respectively, after 9 iterations.

3. Results and Discussions

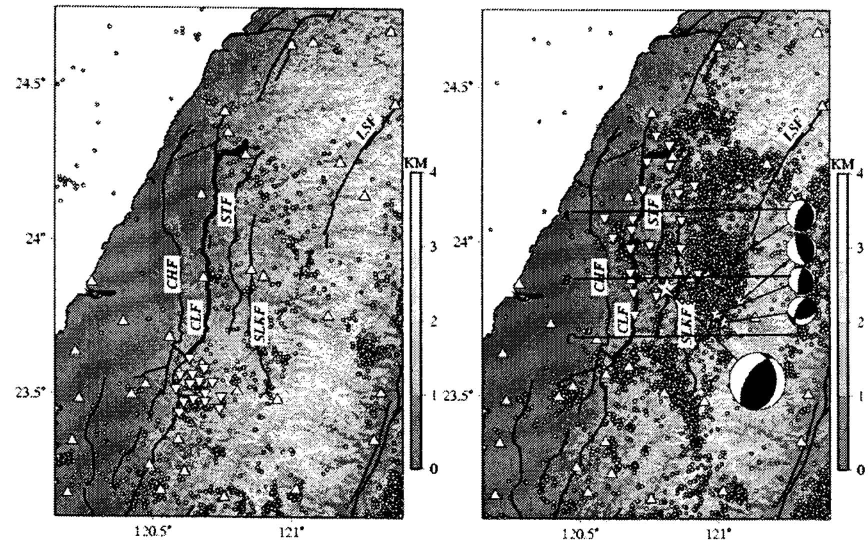
The study area includes major known structures observed at the surface, and covers 130 km in the east-west direction, 180 km in the north-south direction, and 64 km (4 km above and 60 km below the sea level) in depth. One of the distinguished features in the map views is the migration of the lower velocity anomaly to the east with the increasing depth from 6 km to 15 km. In general, materials located between the Chelungpu fault and the Shuilikeng fault at shallow depths less than 15 km are characterized by low velocity anomalies. In profiles of P- and S-wave velocity anomalies (Figure 2), a sharp east-dipping boundary extending from the Shangtung fault or the Shuilikeng fault at the surface to the depth about 15 km is dividing low-velocity anomaly materials in the west and high-velocity anomaly materials in the east.

In general, aftershocks did not occur near the mainshock hypocenter, instead, occurred to form crescent shaped epicentral distribution avoiding the mainshock source region. In the northern profile, A-A', earthquakes with magnitude greater than 4.0 are located at shallow depths less than 12 km mostly in the eastern part of the model area within the high Vp, high Vs, and high Vp/Vs ratio anomaly region. In the middle profiles, B-B', earthquakes at depths between 8 km to 15 km form a tight cluster in the west. In the east of the profile, two distinct clusters of earthquake hypocenters are readily observable. First, an east dipping seismicity cluster in the high Vp, high Vs, and high Vp/Vs ratio anomaly at shallow depths less than 15 km, which is continued from the northern profile, A-A'. Another cluster, a steeply west dipping earthquake cluster is observed at deeper depths between 15 km to 35 km. A cluster of earthquakes, including two large aftershocks with M_L greater than 5.0, occurred at shallow depths less than 15 km beneath the central segment of the Chelungpu fault. At the extension of the northern ending edge of the Chelungpu fault surface rupture, numerous earthquakes also occurred.

Velocity anomalies observed at the shallow depth of the inverted models broadly correlates with the surface geology observations: a lower velocity anomaly region where a thick sedimentary basin in the western Taiwan is observed and a higher velocity anomaly region in the Central Mountain Range where highly metamorphosed rocks are expected. The characteristic seismic features in the Chi-Chi earthquake hypocenter region, as presented in the results, are the low Vp, low Vs, and slightly high Vp/Vs ratio. Resultant velocity models from this study and evidences from other studies (Tanaka et al., 2002; Ma et al., 2003) imply the fluid in the source area might have been involved during the nucleation processes.

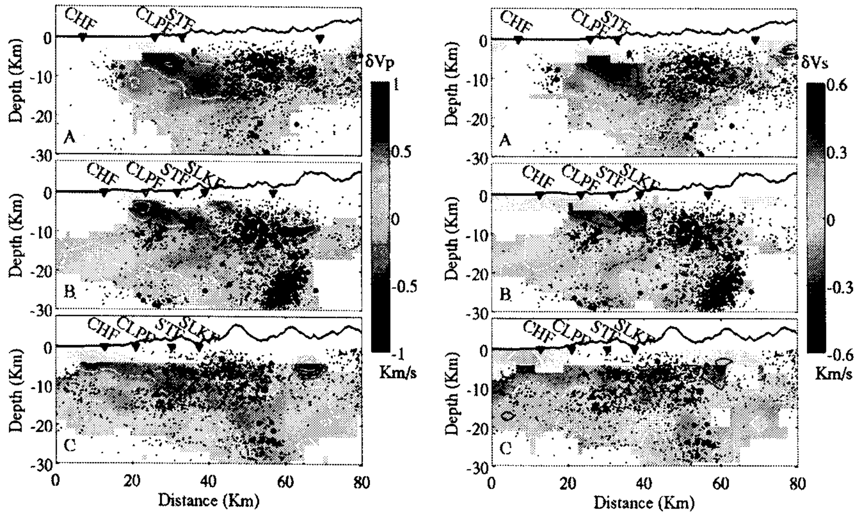
Acknowledgements

The study was supported by KORDI grants PM43300, PE97605, and PP07401.



(a) (b)

Figure 1. Distribution of earthquake epicenters (a) before the main event between 1991 and 1999 and (b) after the main event for 6 months.



(a) (b)

Figure 2. Profiles for (a) Vp anomaly and (b) Vs anomaly. Earthquake hypocenters with magnitude greater than 1.5 and 4.0 are shown by black dots and small red circles, respectively. The Mw=7.6 Chi-Chi earthquake hypocenter is shown by a red asterisk. Earthquakes within 10 km from the profile are shown.