Chapter 2. Earthquake and Damage

2.1 Earthquake Fault

2.1.1 Tectonic Background

The island of Taiwan is located in the complex junction where the Eurasian and Philippine Sea plate collide as shown in Figure 2.1.1 (Institute of Earth Sciences, Academia Sinica, 1999). The Philippine Sea plate subducts along the Ryukyu Trench beneath the Eurasian plate in the east of Taiwan. From the south of Taiwan to Luzon, however, the Eurasian plate subducts beneath the Philippine plate. Due to this complex collision, fold and thrust belts produce the uplift of the Central Range and the Western Foothills. Generated active faults are concentrated in the Western Foothills and the east of Taiwan because of the tectonic force mechanism.

Figure 2.1.2 shows the cross-section of the structure of Taiwan (Seno, 1994). The plate movement generated the Central and Coastal Ranges and the collision in the Longitudinal Valley. This tectonic phenomenon is very similar to that of the Izu Peninsula region in Japan. Therefore, the movement of two plates is the main cause of earthquake occurrence and created the active fault of Chelungpu and other faults as shown in Figure 2.1.3 (Institute of Earth Sciences, Academia Sinica, 1999). According to the record of historical earthquakes, three large events occurred in 1935 (M7.1), 1941 (M7.1) and 1964 (M7.0) respectively in the Western Foothills.

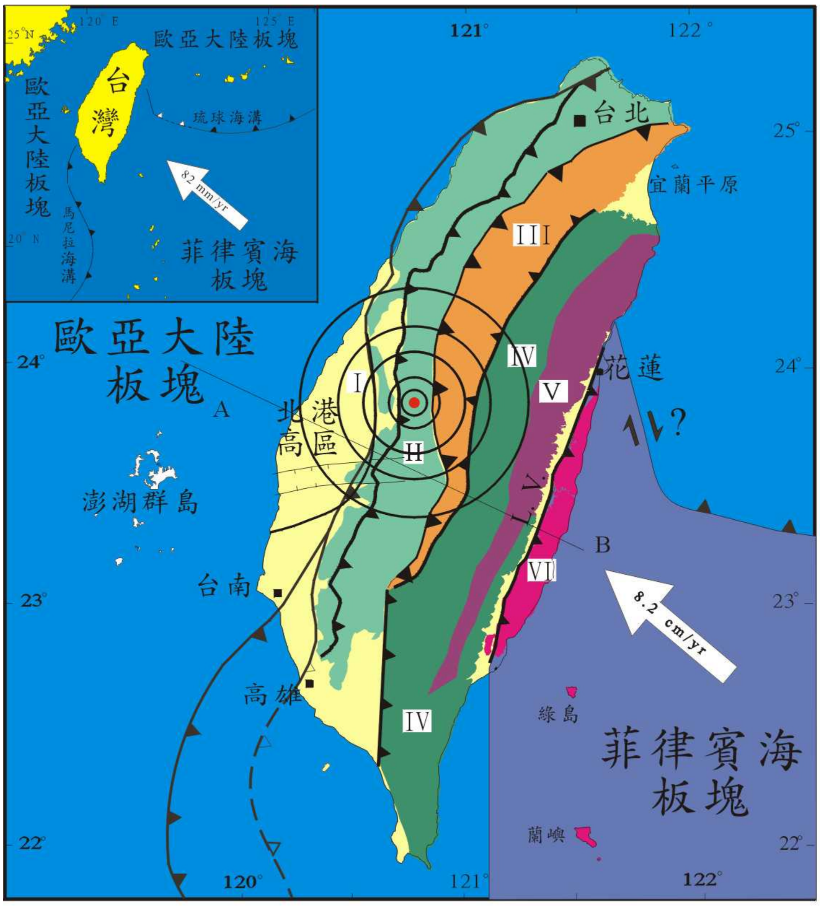

Figure 2.1.1 Tectonic interpretation of the Taiwan (Institute of Earth Sciences, Academia Sinica, 1999).

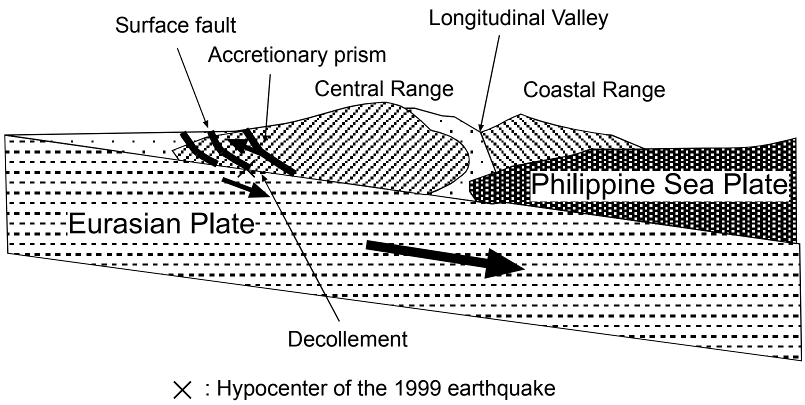

Figure 2.1.2 Cross-section of structure of the Taiwan (Seno, 1994).

Figure 2.1.3 Distribution of active faults in the Taiwan (Institute of Earth Sciences, Academia Sinica, 1999).

2.1.2 General Geology and Earthquake Fault

Figure 2.1.4 shows geological distribution divided into five types of layer depending on the surface geology and main active faults (Institute of Earth Sciences, Academia Sinica, 1999). The terrace and Toukoshan formation belonging to the Quaternary have been broadly spread on the western side of Chelungpu fault. On the other side of the fault, the Pliocene, Miocene, Pre-Miocene and Toukoshan formation running parallel to the fault is distributed separately in four areas. Most folds are asymmetric and have been pushed over toward NW by a strong force coming from the east or east-west direction.

The occurrence of the main event caused ground deformation and surface fractures along the Chelungpu active fault, which is the central segment of the Chuchih Fault System in the western part of Taiwan. The visible surface ruptures or earthquake faults were observed about 10 km along the Chelungpu fault. Approximate 10m vertical displacement was observed at the Shih-kang Dam site as shown in Photo 2.1.1. Photos 2.1.2 to 2.1.4 show typical surface rupture sites associated with Chi-Chi earthquake, and the vertical displacement is summarized in Table 2.1.1 on the bases of eye measurement.

2.1.3 The 1999 Chi-Chi Earthquake

The Chi-Chi Earthquake occurred in the early morning of 21 September 2000 with an epicenter located at 120.810E and 23.850N, near the town of Chi-Chi, Nantou Country. The magnitude of the earthquake was recorded 7.3 on the Richter Scale. The source depth ranges from 7 km to 11 km as reported by the Taiwan Rapid Earthquake Information Release System of the Seismological Center of the Central Weather Bureau of Taiwan (CWB). The moment magnitude determined by the United State Geological Survey (USGS) was Mw=7.7.

The surface ruptures appeared in the NS direction along the foothill over 80 km in length. According to the CWB, epicenters of main- and after-shocks were distributed along about 100 km line in the NNE-SSW direction, and the location of epicenters spread both north and south. The focal depth of the main- shock was distributed in the shallow depth of less than 10 km, and the depth of hypocenter of after-shocks was distributed along the fault rupture propagation from the shallow to deep part of the fault plan as shown in Figure 2.1.5 (Earthquake Information Center, 1999).

Figure 2.1.6 and Table 2.1.2 show the analysis of the focal mechanism proposed by Yagi and Kikuchi (1994). The total rupture time of main event was 40 seconds with a seismic moment of 2.4x1020Nm, 80km x 40km rupture area, averaged dislocation of 2.5 m and 3.3MPa average stress drop.

References

Earthquake Information Center, Earthquake Research Institute, University of Tokyo (1999), http://wwweic.eri.u-tokyo.ac.jp/topics/taiwan/yoshin2e.html.

Institute of Earth Sciences, Academia Sinica (1999), http://www.earth.sinica.edu.tw/921/921chichi_geo.htm.

Seno, T. (1999), "Tectonics in the Taiwan region," Jisin, No.46, pp.461 – 477 (in Japanese with English abstract).

Yagi, Y. and Kikuchi, M. (1999), http://wwweic.eri.u-tokyo.ac.jp/yuji/tai/tai.html.

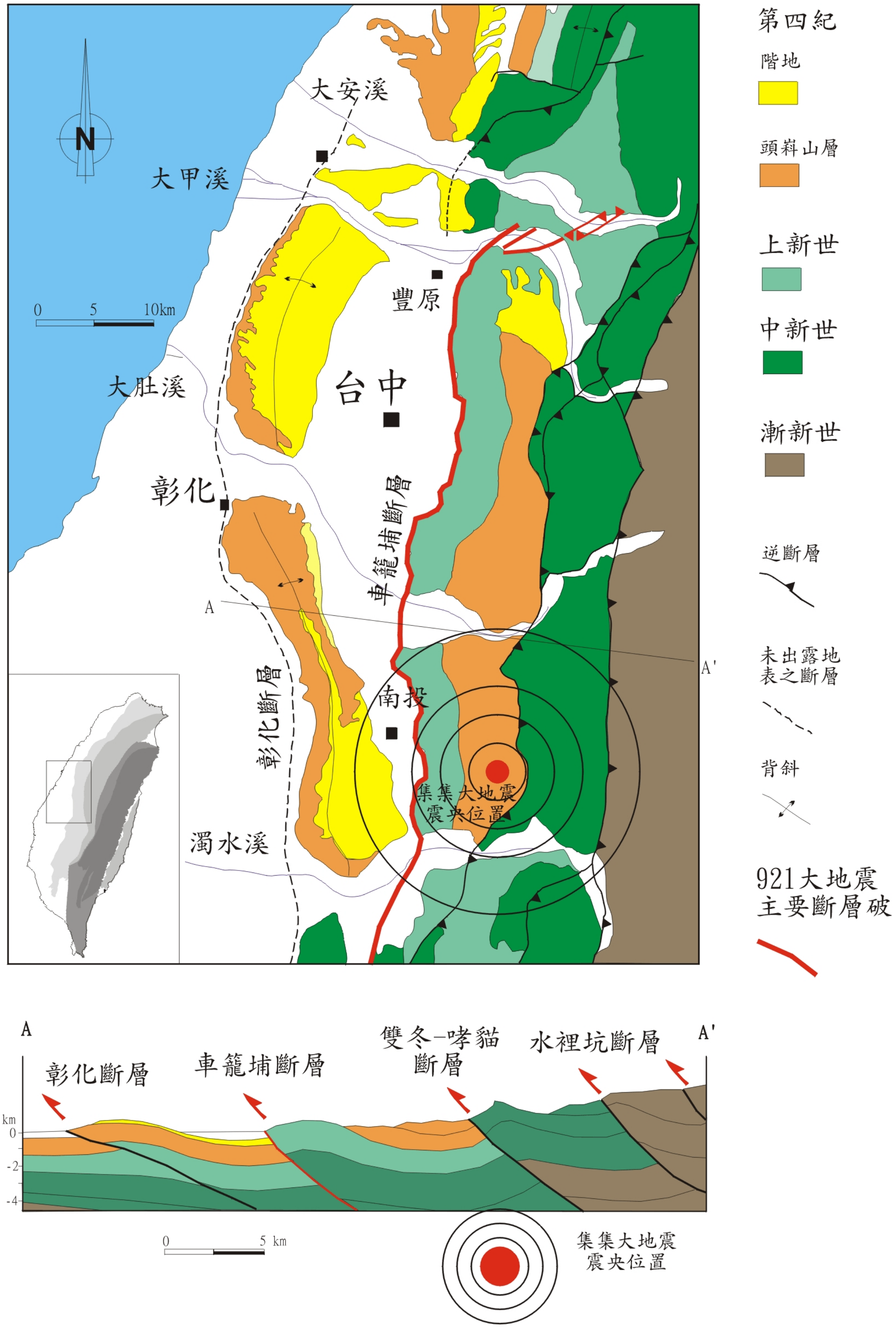

Figure 2.1.4 Schematic map of the fault traces and general geology of the 1999 Chi-Chi Earthquake (Institute of Earth Sciences, Academia Sinica, 1999).

Photo 2.1.1 The Chelungpu fault running through the Shih-kang Dam site (Refer to color photo 15).

Photo 2.1.2 The Chelungpu fault running through the Pi-feng Bridge.

Photo 2.1.3 The Chelungpu fault running through the stadium in Wufeng (Refer to color photo 3).

Photo 2.1.4 The Chelungpu fault running through the road in Chushan.

Table 2.1.1 Observed vertical displacement of Chelungpu fault.

Site Name	Vertical Displacement (m)
Shih-kang Dam, Taichung County	10
Tachia River, Fengyuan, Taichung County	6
Provincoal Road 3, Fengyuan, Taichung County	5
County Road 129, Takeng, Taichung City	3
Wufeng, Taichung County	2 - 3
Mingchien, Nantou County	2 - 3
Chushan, Nantou County	1 - 1.5

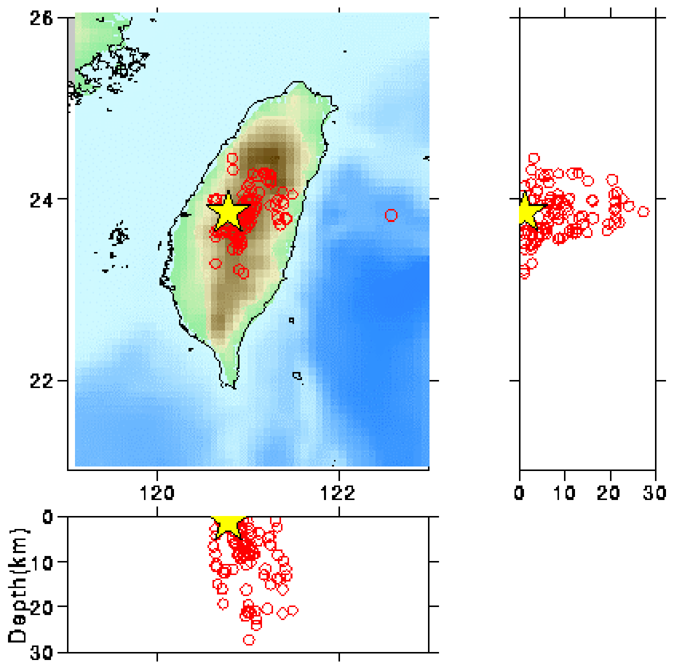

Figure 2.1.5 Distribution of main and after shocks (Earthquake Information Center, 1999).

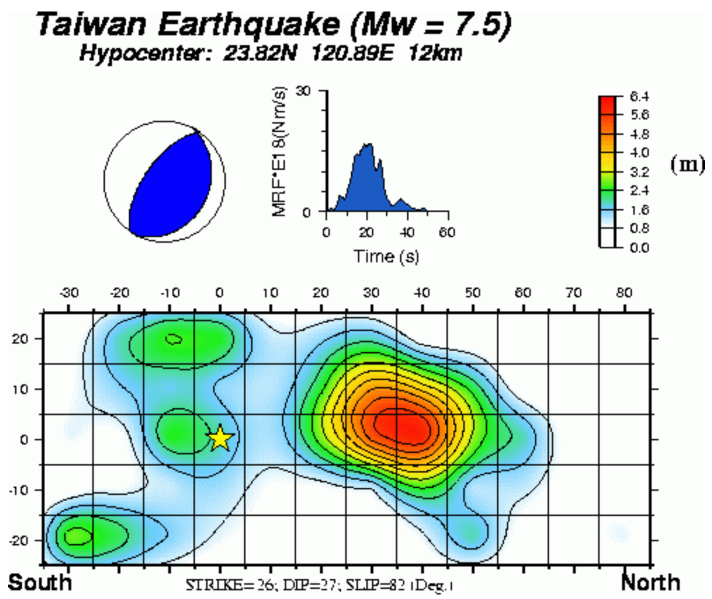

Figure 2.1.6 Focal mechanism and source process of earthquake. (Yagi and Kikuchi, 1999).
Upper: source mechanism and time function, lower: distribution of fault-slip

Table 2.1.2 List of fault parameters (source: Yagi and Kikuchi, 1999).

Epicenter	23.82N, 120.89E
(strike, dip, slip)	(26, 27, 82) (HRV CMT)
Seismic moment	Mo=2.4x10**20 Nm (Mw=7.5)
Source duration	T=28 s
Centroid depth	H=11 km
Rupture area	S=80 km x 40 km
Averaged dislocation	D=2.2 m
Averaged stress drop	3.3 MPa