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Paleoseismic Study of the Chelungpu Fault in the Mingjian Area

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ABSTRACT

Our profile observation at a trench near the Chelungpu fault rupture in the Mingjian area, central Taiwan, confirms the existence of at least one buried old fault trace that was probably due to a previous coseismic displacement. The paleoseismic analysis reveals clear evidence of recurrence timing of the Chelungpu fault occurring younger than 200 yr BP by ^{14}C dating. Based on the historical earthquake record, AD 1792 and AD 1848 earthquakes were the two markedly damaging earthquakes striking central Taiwan. We suggest that one of the strong earthquakes may have caused the above-mentioned paleoseismic rupture.

Key words: Chelungpu fault, paleoseismic study, central Taiwan

INTRODUCTION

Repeated coseismic displacements along a fault commonly display clear morphological expressions. Particularly, thrust faults make apparently vertical offsets at both sides of the fault zone, such as the Chi-Chi earthquake ruptures (Chen *et al.*, 2000a). In central Taiwan, the Chelungpu fault was documented to be an active mountain-front thrust fault bounding the Western Foothills and Taichung piggyback basin (Chen *et al.*, 2000b). Several terraces were conspicuously preserved on the hanging wall of the Chelungpu fault. Here, stream terraces on the frontal foothills are also well exposed adjacent to the recent fault rupture. West of the foothills on the footwall of the Chelungpu fault, however, terraces are not found in the subsided Taichung basin (Chen *et al.*, 2000a). Based on the field investigation and ^{14}C dating for terraces, the Chi-Chi earthquake ruptures frequently followed the preexisting Holocene terrace scarps that have already been recognized as a Holocene fault scarp by ^{14}C dating (Chen *et al.*, 2001a). Uplifted Holocene terraces are important indicators of active tectonics, and its presence can be interpreted as a geomorphic expression of active faulting (Pantosti *et al.*, 1996). Therefore, the Quaternary fold-and-thrust belts along the Chelungpu fault in central Taiwan is one of the best areas for neotectonic studies. In this study, we are to discuss paleoseismicity of the Chelungpu fault with the help of careful observation along a trenched profile. Paleoseismic information combining with the trench and geomorphic observations suggest the paleoseismic occurrence of the Chelungpu fault.

These displacements have soon been leveled or modified by reconstruction engineering and severe surface erosion and deposition especially by heavy rain. In one of the engineering projects, we, fortunately, found a trench nearly perpendicular to the rupture, where another rupture trace is hidden parallel with the present rupture. This profile is therefore deemed important for the assessment of the paleoseismity of the Chelungpu fault.

STRATIGRAPHY

This section is located near Mingjian town on the north riverbank of the Choshui River (Fig. 1). A north-trending trace of the earthquake rupture cuts across the Mingjian and the Choshui River. The Chi-Chi earthquake caused vertical displacement ranging from 0.6 m to 3 m adjacent to Mingjian (CGS, 1999; Chen *et al.*, 2000a; Chiang *et al.*, 2000). The rupture across the Chi-Chi railroad and river embankment adjacent to this section shows particularly obvious surface deformation. At the railroad, field measurement shows a vertical displacement about 3 m and horizontal shortening about 5.5 m, and slip direction was oriented N80°W showing pure thrusting related with the rupture (Fig. 2), while at the north Choshui River embankment, we obtained the oriented slip direction of N90°W, 1.5 m vertical and 1.9 m horizontal displacements (Fig. 3; Chen *et al.*, 2000a).

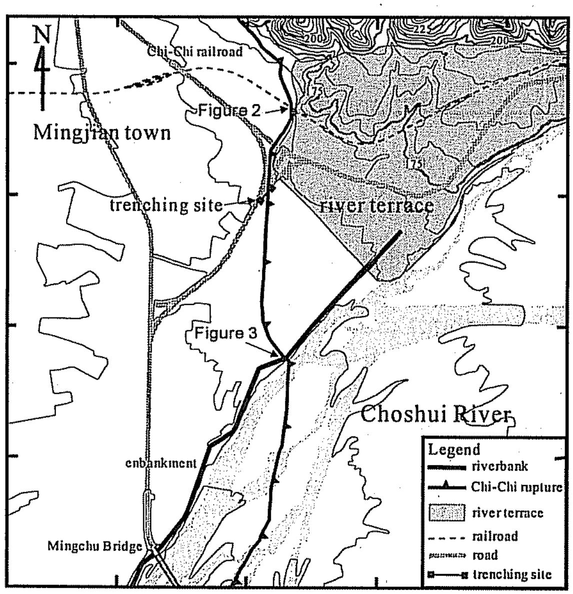

Figure 1

Figure 1. Geomorphic and earthquake rupture map of the Mingjian region. Locations of other figures are also shown.

Figure 2. The earthquake rupture across the Chi-Chi railroad in the Mingjian , the eastern side shows a ground uplift of about 3 m.

Figure 3. At this location on the north embankment along the Choshui River, the road obviously shows a horizontal offset of 1.9 m caused by left-lateral thrust faulting.

This section was excavated across the fault scarp for a distance of 80 m in the northeast trend. Here, the fault cuts through a succession of Holocene fluvial deposits that can be divided into four units: coarse gravels, sand, brown fine sandy clay, and backfill sediments in the ascending order (Fig. 4). The stratigraphically lowest deposits exposed in this profile consist of unconsolidated coarse-gravel and boulder beds of at least 3-5 m thickness, which represent major channel deposits of the Choshui River. Clasts range from 5-20 cm in diameter and are well-rounded, well-sorted and clast-supported, and are composed of quartzite obviously derived from the Central Range. Preserved thickness of the overlying sand horizon is about 1.5 m and well sorted. This horizon is interpreted as fluvial deposits in a flood plain as commonly seen in the current Choshui River. ^{14}C dating of charcoal obtained from the sand horizon has yielded an age of < 200 yr BP (sample MJ200704-4), thus confirming its Holocene age. The third unit, brown silt clay horizon exhibits mottled feature, high organic contents and prismatic soil structure, suggesting a soil layer developed on the uppermost overbank deposits, where a pottery bowl and porcelain flakes are discovered. The depositional age of the clay horizon should not be too far from that of the sand horizon, because the earliest immigrants reportedly came to live in Mingjian about AD 1860 (Lee, 1832).

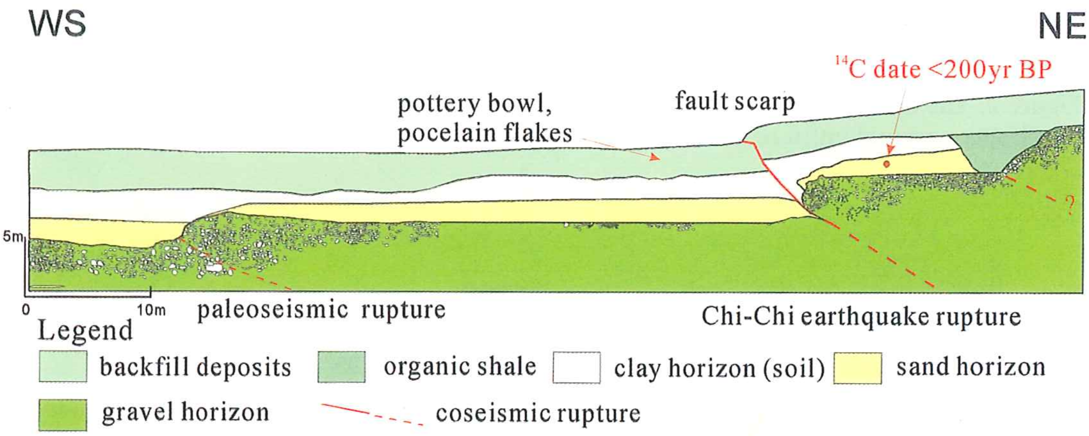

Figure 4. The sedimentary sequence is divided into gravel, sand, clay and backfill horizons in the ascending order. The Chi-Chi earthquake rupture and a buried paleoseismic rupture are identified from this profile according to the relationship between fault and strata. ^{14}C age obtained from the sand horizon is younger than 200 yr BP.

CHI-CHI EARTHQUAKE RUPTURE

Based on the surface measurements, the Chi-Chi earthquake rupture produced a broad warping on the upthrown block of a frontal fault scarp with 1-3 m vertical displacement adjacent to this profile. The excavation shows that the gravel deposits have an about 2.5 m vertical displacement by an east-dipping reverse fault. The fault plane near the surface strikes approximately north-south and dips 40° to the east (Fig. 5). The reverse fault exhibits development of a fault-bend fold in the hanging wall near the top of the fault. The rupture cuts through fluvial and backfill deposits and reaches the surface. The displacement, however, during the Chi-Chi earthquake is inconsistent in the clay and backfill horizons where only 1 m displacement in terms of bedding-plane offset is commonly observed. Much of the near-surface deformation becomes ductile deformation as the rupture propagated through unconsolidated deposits. Commonly, the displacement in clay and backfill horizons with reference to bedding may not represent complete offset during the rupturing. Actually, the two horizons are obviously thickening and tilting on the hanging wall by folding and faulting deformations.

Figure 5. The gravel horizon thrust onto the sand and clay horizons, and the gravel bed dragged by the Chi-Chi earthquake rupture forming an anticline in the hanging wall.

PALEOSEISMIC FAULT

Fluvial deposits at the site are affected by a paleoseismic fault with a vertical offset of 1 m referring to the sand horizon. The stratigraphically lowest gravel horizon is also dislocated about 1 m height and forms a west-facing scarp on top of the sand horizon (Figs. 4 and 6). The sand horizon near the rupture was eroded, and the clay horizon covers the sand and gravel horizons. The clay horizon is not ruptured nor displaced. Therefore, a paleoseismic fault must have occurred before deposition of the younger clayey overbank deposits, and we suggest the top of the sand horizon formed a free surface representing an obvious fault scarp of about 1 m height during the paleoseismic event. Thickness of the clay horizon on the downthrown side of the fault is about 1.9 m while that of the upthrown side about 0.8 m. Attitude of the paleoseismic rupture is unclear, because the rupture cutting through a gravel bed is very difficult to identify. In addition, based on our trenching studies, thick-bedded sediments frequently control the near surface deformation, so that the true fault plane may not be still observable along a preexisting fault zone (Chen *et al.*, 2001b). The Chi-Chi rupture formed on the hanging wall of the paleoseismic rupture about 45 m apart from it. A fault commonly bifurcates upward if it cuts through thick-bedded sediments. Therefore the bifurcated faulting often formed an unobvious gentle fault scarp.

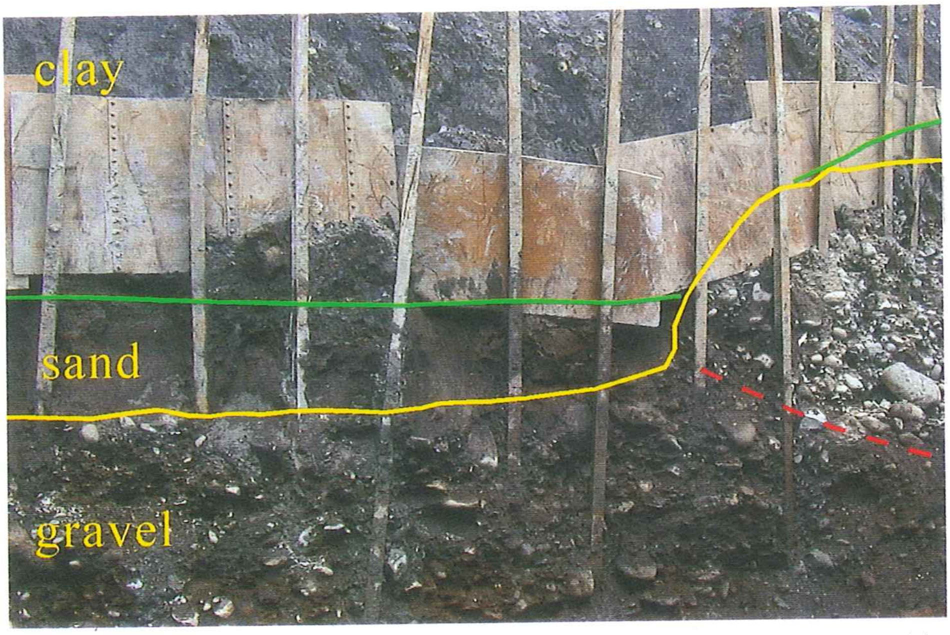

Figure 6. A paleoseismic rupture forming a fault scarp displaces the gravel and sand horizons overlain by the clay horizon.

In the east part of the profile, on top of the gravel horizon a scarp morphology was noted in the upthrown block of the Chi-Chi rupture, which shows a vertical separation of 2.5 m. An organic shale lens including lot of driftwoods was deposited at the foot of a scarp of eroded sand and clay horizons, which creates a depression retaining water under the scarp. Although it is possible that a fault has ruptured these sedimentary horizons, but there is no evidence by observation of their structural and stratigraphic relations. Hence, we cannot ascertain whether or not the scarp is a fault-generated.

DISCUSSIONS AND CONCLUSIONS

Based on geologic characteristics, we divided the Chi-Chi earthquake master rupture into three segments, the Shihkang, Tsaotun and Chushan segments along the Shihkang, Chelungpu and Tajianshan faults, respectively (Chen *et al.*, 2000a). The excavated section is across the southernmost Chelungpu fault. Therefore, the conclusion of this research is in connection with occurrence of the Chelungpu fault.

Presently, we are still unable to strictly constrain recurrence of the paleoseismic event by using ^{14}C dating. Certainly, we need much more detailed trenching and dating studies to achieve the aim. However, the historical seismic record may be helpful in suggesting a probable age corresponding to the paleoseismic rupture in the excavated section. The historical data of seismic events in Taiwan only cover the past four hundred years. Based on the historical earthquake record, it was documented that AD 1792 and AD 1848 powerful earthquakes struck the Taichung, Changhua, Nantou and parts of Chaiyi counties (Hsieh and Tsai, 1985), and their radius of felt area was greater than 300 km. A seismic modeling of the two earthquakes estimated their magnitude to be about 7.1 (Tsai, 1986). In addition, the paleoseismic rupture in the excavated section has a vertical displacement of more than 1 m which is compatible in magnitude (about $M7$) with the Chi-Chi earthquake rupture in the adjacent area. Therefore, we suggest that one of the above earthquakes produced the paleoseismic rupture observed in the excavated section, because we are not able to find any other larger earthquakes occurring within the central Taiwan since 200 years.

Studies of the fold-and-thrust belts in central Taiwan have shown that the Chelungpu fault was formed at the beginning of middle Pleistocene, about 0.7-0.5 Ma (Chen *et al.*, 2000b, 2001c). Seismic reflection profile indicates that the late Pliocene Chinshui Shale is overthrust onto the recent fluvial deposits along the Chelungpu fault with the vertical displacement of about 5000 m (Chang, 1971; Chiu, 1971, Suppe, 1981). Then, we can roughly estimate the long-term vertical offset of each larger earthquake based on the above data assuming the recurrence timing is approximately 200 years. The vertical offset produced by each surface-faulting earthquake is obtained to be about 1.5-2 m since middle Pleistocene. The evaluation is approximately the same order with the observation on the paleoseismic and the Chi-Chi earthquake ruptures. Therefore, the recurrence timing of about 200 years by ^{14}C dating seems to be reasonable.

REFERENCES

CGS. (1999) Report of the geological survey of the 1999 Chi-Chi earthquake (in Chinese): *Cent. Geol. Surv.*, Taipei, 315p.

Chang, S. S. L. (1971) Subsurface geologic study of the Taichung basin, Taiwan: *Petrol. Geol. Taiwan*, **8**, 21-45.

Chen, W. S., Chen, Y. G., Liu, T. K., Huang, N. W., Lin, C. C., Sung, S. H., and Lee, K. J., (2000a) Characteristics of the Chi-Chi earthquake ruptures: *Spec. Publ. Cent. Geol. Surv.*, **12**, 137-154.

Chen, W. S., Erh, C. H., Chen, M. M., Yang, C. C., Cheng, I. S., Liu, T. K., Honrg, C. S., Shea, K. S., Yeh, M. G., Wu, J. C., Ko, C. T., Lin, C. C., and Huang, N. W. (2000b) The evolution of foreland basins in the Western Taiwan: Evidence from the Plio-Pleistocene sequences: *Bull. Cent. Geol. Surv.*, **13**, 137-156.

Chen, W. S., Huang, B. S., Chen, Y. G., Lee, Y. H., Yang, C. N., Lo, C. H., Cheng, H. C., Sung, Q. C., Huang, N. W., Lin, C. C., Sung, S. H., and Lee, K. J. (2001a) Chi-Chi Earthquake: A case study on the role of thrust-ramp structures for generating earthquakes: accepted by *Bull. Seis. Soc. Am.*, **91**.

Chen, W. S., Lee, K. J., Lee, L. S., Chen, Y. G., Sung, Q. C., Cheng, H. C., and Lee, Y. H. (2001b) Trenching study of the Chelungpu and Tajianshan faults: *Geological Society China 2001 Annual Meeting, abstract*, 205-207.

Chen, W. S., Ridgway, K. D., Horng, C. S., Chen, Y. G., Shea, K. S., and Yeh, M. G. (2001c) Stratigraphic architecture, magnetostratigraphy, and incised-valley systems of the Pliocene-Pleistocene collisional marine foreland basin of Taiwan: accepted by *Geol. Soc. Am. Bull.*, **113**, 10.

Chiang, C. J., E, C. H., Liu, S. H., Huang, C. J., Lu, S., and Huang, J. (2000) Electrical resistivity prospecting for the Chelungpu Fault in the Choshui riverbed: *Spec. Publ. Cent. Geol. Surv.*,**12**, 211-233.

Chiu, H. T. (1971) Folds in the Northern Half of Western Taiwan: *Petrol. Geol. Taiwan*, **8**, 7-19.

Hsieh, U. S., and Tsai, M. B. (1985) Historical earthquakes catalogues in China: *Beijing press*, 1-4.

Lee, T. B., (1832) Changhua County Record.

Lee, Y. H., Wu, W. Y., Shih, T. S., Lu, S. T., Shieh, M. L., and Cheng, H. C. (2000) Deformation characteristics of surface ruptures of the Chi-Chi Earthquake, east of the Pifeng Bridge: *Spec. Publ. Cent. Geol. Surv.*, **12**, 19-40.

Pantosti, D., D'Addezio, G., and Cinti, F. R. (1996) Paleoseismicity of the Ovindoli-Pezza fault, central Apennines, Italy: A history including a large, previously unrecorded earthquake in the Middle Ages (860-1300 A.D.): *Jour. Geophy. Res.*, **101**, 5937-5959.

Suppe, J. (1981) Mechanics of mountain building and metamorphism in Taiwan: *Mem. Geol. Soc. China*, **4**, 67-89.

Tsai, Y. B. (1986) A study of disastrous earthquakes in Taiwan, 1683-1895: *Bull. Inst. Earth Sci., Academia Sinica*, **5**, 1-44.