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PALEOSEISMIC STUDY OF THE CHELUNGPU FAULT IN THE WANFUNG AREA

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ABSTRACT

The excavation in the Wanfung area has provided evidence for at least three earthquake ruptures, including the 1999 Chi-Chi one. The Chi-Chi earthquake formed an obviously major reverse fault, backthrust, and several minor normal faults, accompanied by a teardrop-shape anticline in the fault tip. Paleoseismic ruptures I and II show the vertical displacement of 0.4 m and 1.2 m, respectively, which is similar in magnitude to the offset by the Chi-Chi earthquake in this area. Based on the stratigraphical and structural relations, and ^{14}C dating, rupture II may not have occurred before 300 yr B.P. From the historical record, it may be suggested that the paleoseismic rupture II may have been caused by either the 1792 A.D. or 1848 A.D. strong earthquake in central Taiwan.

Key words: Chelungpu fault, paleoseismic study, central Taiwan

INTRODUCTION

This is a followup study of the Mingjian trenching site after the Chi-Chi earthquake. The Wanfung site, to the south of Wufung, was excavated during reconstruction of rice field across the Chi-Chi earthquake rupture, exhibiting some noteworthy paleoseismic subsurface features (Fig. 1). We divided the Chi-Chi earthquake major rupture into the Shihkang, Tsaotun and Chushan segments (Chen *et al.*, 2000), and the Wangfung trenching site is across the Tsaotun segments. The major rupture has a sinuous trace along the frontal foothills that follows the boundary between the Western Foothills and Taichung piggyback basin (Chen *et al.*, 2000; Chen *et al.*, 2001b). However, the rupture in this site is some 200-300 m apart from the foothills, cutting through the Wushi-River alluvial fan. The fluvial boulder deposits here exceed 15 m in thickness in a hole by the site. We would take advantage of the engineering excavation and try to report about the Holocene rate of slip along the Chelungpu fault and some evidence for the recurrence interval of large earthquakes in this particular area.

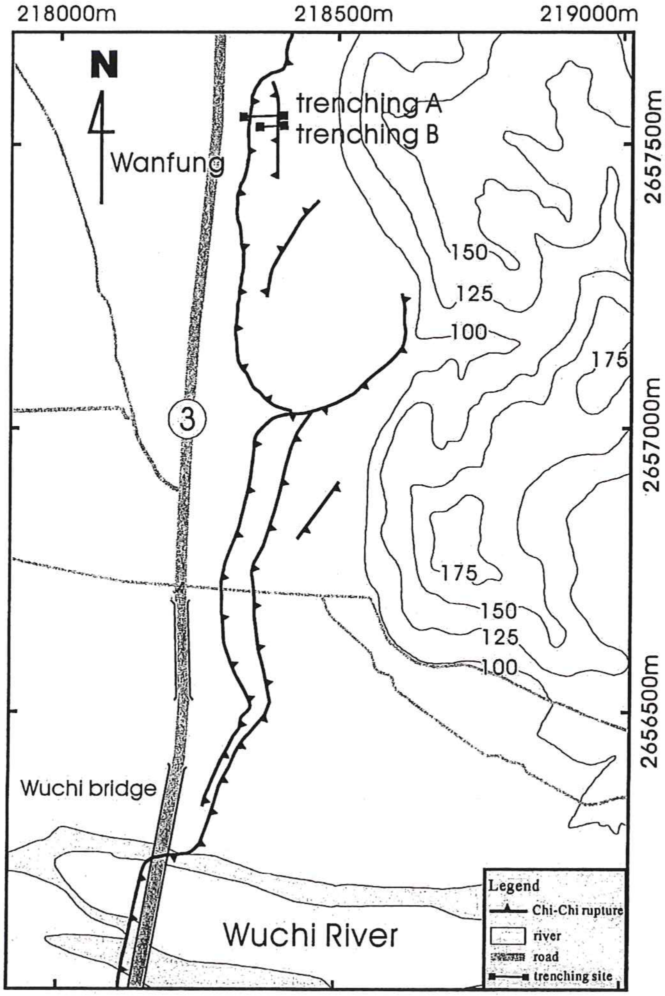

Figure 1. Geomorphic and earthquake rupture map of the Wanfung region.

STRATIGRAPHICAL RELATIONS

The Wushi River flows in a 20-50-m-wide braided channel that lies on an alluvial plain. The excavated profile is at this alluvial plain, exposing near-surface deposits of about 3.5 m thick, which can be divided into boulder, alternating sand/paleosoil, and backfill deposits in the ascending order. The lower horizon, boulder deposits in the excavated profile consists of well-rounded and -sorted cobble, boulder and lenticular coarse sands which represent a high-energy braided channel. Clasts range from 10-100 cm in diameter and are well-rounded, which are composed mainly of quartzite derived from the Hsuehshan Range. Two charcoal samples (WF000327Ds, WF000327D) from the boulder bed yield age estimates of 42,850±1,080 yr B. P. and 32,520 ± 290 yr B.P. (Fig. 2). Top surface of the boulder bed shows a step shape, reflecting scarp topography, which is buried by several sand and paleosoil layers. Furthermore, a gravel wedge was deposited at the foot of the scarp which can be interpreted as a scarp-derived colluvial deposits (Fig. 3).

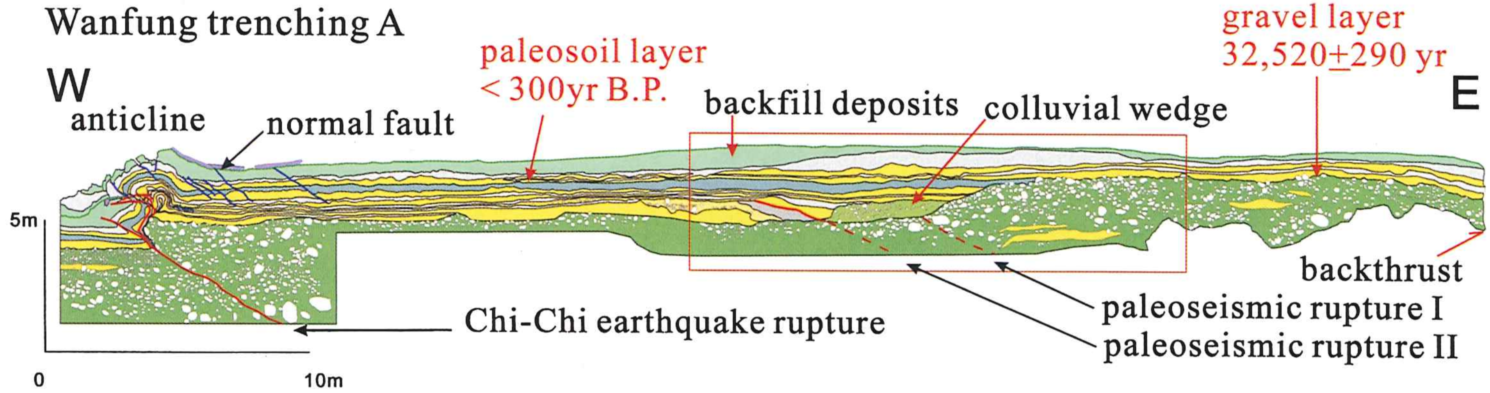

Figure 2. Trenching A can be divided into three units: coarse gravels, alternating sand and paleosoil, and backfill sediments in the ascending order. In this profile, we can find the Chi-Chi earthquake rupture and two paleoseismic ruptures.

Figure 3. Top of the gravel layer formed a free surface representing an obvious fault scarp of about 1.2 m height during the paleoseismic I event. On the downthrown side of the rupture I is deposited wedge-shaped colluvial deposits. In addition, several sand and paleosoil layers unconformably cover the scarp.

Throughout the profile, the boulder bed is overlain by several layers of alternating sand and paleosoil layers, which represent overbank deposits of the Wushi River. The overbank deposits exhibit slight soil development, containing abundant organic material and mottled features, forming dark brown clays. A charcoal sample (WF000327A) from one of the paleosoil deposits yields an estimated ^{14}C date of younger than 300 yr B.P. (Fig. 2). The stratigraphically upper deposits on the surface consist of backfilled gray clay of about 0.5 m thick. The upper part of the sand and paleosoil layers underlying the backfill deposits is highly modified by human activity.

SEISMIC RUPTURES

This profile crosses the 1999 Chi-Chi earthquake rupture and shows in addition two paleoseismic ones. They were all brought up by thrusts showing an average strike of N-S trending, displacing Holocene and modern alluvial fans. Apparent lack of obvious scarps along the paleoseismic sites suggests that erosion and sedimentation of the Wuchi River has obscured all topographic evidence of fault activity. However, the rupture features are well preserved underground. Thanks to deformation and displacement, the paleoseismic ruptures I and II can be still identified along the trenching profile (Fig. 2). Both ruptures are now covered by the sand and paleosoil layers which represent older events.

Rupture I in the trenching A represents the oldest event, which deformed the lowest unit of boulder bed forming a west-facing scarp about 1.2 m high (Fig. 2). A colluvial wedge has developed under the scarp on the footwall, which is composed of gravel and coarse sand without stratification. Here it is difficult to identify a fault zone within the boulder bed proper (Chen *et al.*, 2001a), but two lenticular sandy beds within the boulder bed near the scarp have developed bending displaying deformation of the rupture I. Therefore, we infer that this deformation and the scarp were produced by an old coseismic event that occurred before the deposition of the colluvial wedge.

Rupture II is clearly shown in the trenching B profile adjacent to the main section (Fig. 4). The rupture cut through the lowest sand and paleosoil bed and the colluvial wedge forming a dragged antiform on the hanging wall. It is an east-dipping thrust fault at an angle of 24°, with a vertical displacement of about 0.4 m (Fig. 4a). Gravels within the rupture zone are imbricated along the fault plane. Rupture II is overlain by a thick-bedded brown paleosoil which is dated by ^{14}C to be a modern age (< 300 yr B.P.). The event, therefore, may be very young occurring after deposition of the colluvial wedge.

The Chi-Chi earthquake brought up complex structural features in this site, an obviously major reverse fault, backthrust, several minor normal faults and anticline (Fig. 5). The amount of the vertical displacement, as referring to dislocated fences, roads and scarps along the fault trace, was commonly from 0.5 to 1.8 m (CGS, 1999; Chen *et al.*, 2001b). By measurement along a dislocated fence in this site, we got vertical displacement of about 1.3 m, horizontal shortening about 1.8 m, and slip direction N90oW, showing pure thrusting related with the rupture. By calculation from the displacements, we obtained a dip angle of 36° near the surface. The surface ruptures are also accompanied by a backthrust on the hanging wall 50 m apart from the major thrust fault.

The surface folding in the fault tips takes a form of a teardrop fold (mushroom shape) associated with tensile cracks, thrusts and normal faults, and both limbs of the fold are overturned (Fig. 5). The tensile cracks are well developed near the roof of the mushroom fold showing surface stretching of backfilled clayey deposits during the folding. In addition, the soft-sediment layers in the hinge zone further exhibit bending and flexing that display a flexural-flow fold in the fault tips.

DISCUSSIONS AND CONCLUSIONS

Colluvial wedges have been a useful criterion in identifying paleoseismic events, which are usually deposited near the fault scarp (Swan *et al.*, 1980; Schwartz and Coppersmith, 1984). Based on the trenching observation, the coseismic ruptures in the Wangfung site occurred farther away from the foothill toes, and cut through the Wushi alluvial fan. Furthermore, we have difficulties in finding colluvial deposits along the rupture within alluvial fans due to post-seismic modification by the Wushi River. At this site, fortunately, we were able to find a colluvial wedge at the foot of a fault-generated river-terrace scarp, which is buried along with the simultaneous deformation of rupture I. Originally, alluvial terraces should have occurred on the hanging wall during successive thrusting events, but we did not find any more terrace deposits along the frontal foothills in this region (Chen *et al.*, 2000; Chen *et al.*, 2001b). The gravel, boulder and cobble deposits in the Wushi alluvial plain are evidently transported by debris-flow process of flash floods during the storm season. They are stratigraphically beneath the sand and paleosoil deposits dated to be younger than 300 yr B.P. The two charcoal samples collected from the boulder bed yielded date that is unreasonably old and probably not representative of the deposition of the boulder bed, because the surface of the boulder has been kept so fresh without slight laterization, that we hardly believe that the boulder bed is older than Holocene in age (Liu, 1990; Chen and Liu, 1991). Therefore, we interpret that these charcoal samples may be a piece of reworked detritus derived from older terraces or colluvial deposits.

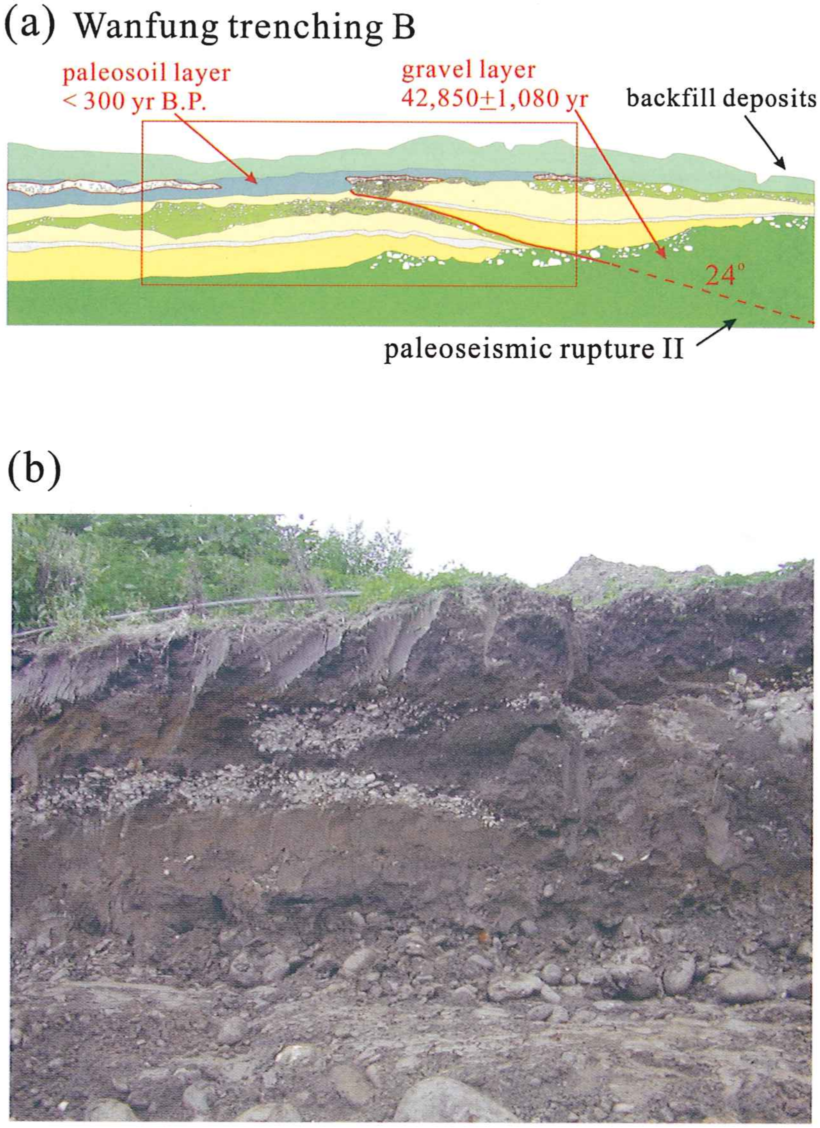

Figure 4. Trenching B clearly exposed paleoseismic rupture II with a 24°-east-dipping fault plane and about 40 cm vertical displacement.

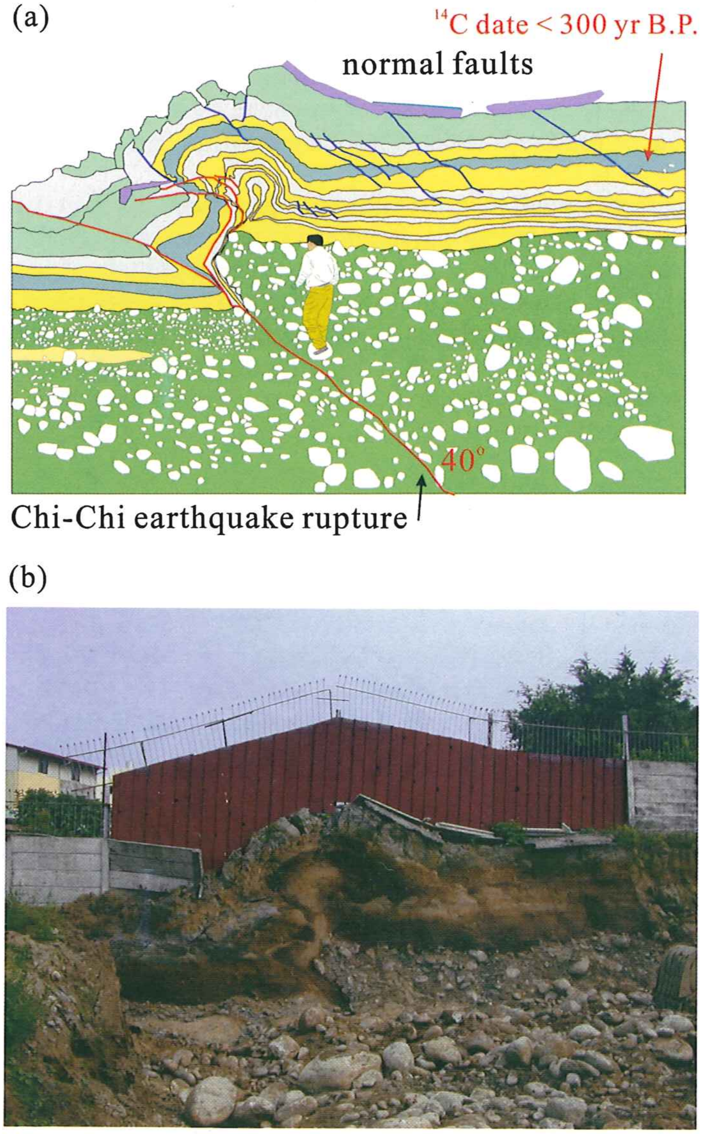

Figure 5. The Chi-Chi earthquake rupture formed a mushroom-shaped, overturned fold at the fault tip, which is associated with several minor thrusts.

We interpret the presence of the above stratigraphic and structural relations in this profile as evidence for the two paleoseismic ruptures. Rupture I cuts through the boulder bed and is overlain by the sand and paleosoil deposits preserving a 1.2-m-high fault scarp. Apparently, there is possibility to infer that rupture I occurred before the deposition of the lower sand deposits. Actually, we have no constraint on the time gap between the depositions of the boulder and the sand deposits. However, close observation of rupture II reveal that sandy seams of the sand and paleosoil deposits above the boulder bed and the colluvial deposits were evidently penetrated by the rupture, and, all the more, between the former deposits and the latter, there seems no sedimentational break represented, for example, by unconformities. Therefore, we believe that the timing of rupture II event is not very far from that of the sand and paleosoil deposits.

Paleoseismic ruptures I and II have the vertical displacement of about 0.4 and 1.2m which is similar to that of the Chi-Chi earthquake ruptures in the adjacent area ranging from 0.3m to 1.8 m (CGS, 1999; Chen *et al.*, 2000). We infer that the magnitude of these paleoseismic events resemble that of the Chi-Chi earthquake. Based on the historical earthquake record since 400 yr B.P., it was documented that in 1792 A.D. and 1848 A.D. two strong earthquakes struck central Taiwan (Hsieh and Tsai, 1985). We suggest that one of the above earthquakes may have caused the paleoseismic rupture II, which may be correlated with the paleoseismic rupture at the Mingjian site (Chen *et al.*, 2001a).

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