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NCU in Taiwan

Heterogeneous Structures of 1999 Chi-Chi Earthquake, Thrust Termination in and near Chushan Excavation Site, Central Taiwan

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Motivation:

The surface deformation zone characterized by a 0.5 to 2-meter-high escarpment has a wide variation in width and ranges 15 to 70 m, and is highly asymmetrical relative to the toe of the escarpment (Fig. 1). Exposures in the Chushan trench, excavated across the earthquake ground rupture, show on the one hand the heterogeneous structure of a steep, monoclinal-like fold and on the other hand strikingly different surface deformation profiles on either side of the 14 m wide trench, that do not reflect in any obvious way the subsurface structure (Figs. 2 and 3.)

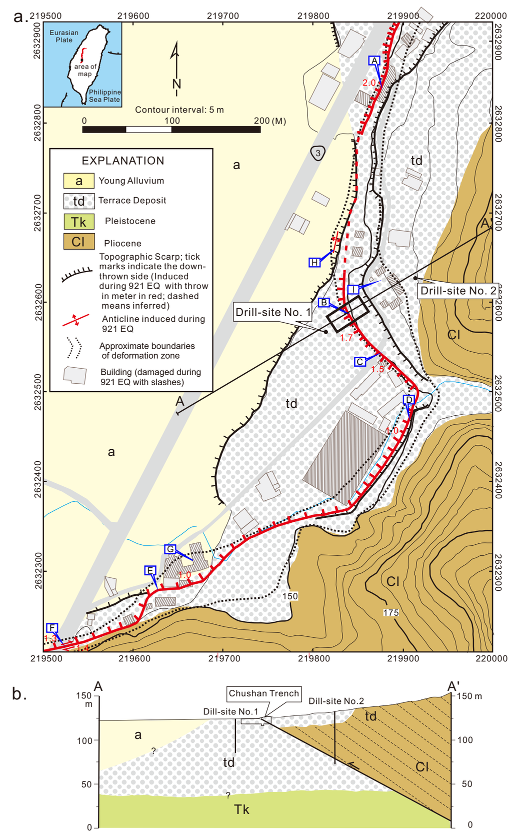


Fig. 1. Local geologic setting of Chushan trench

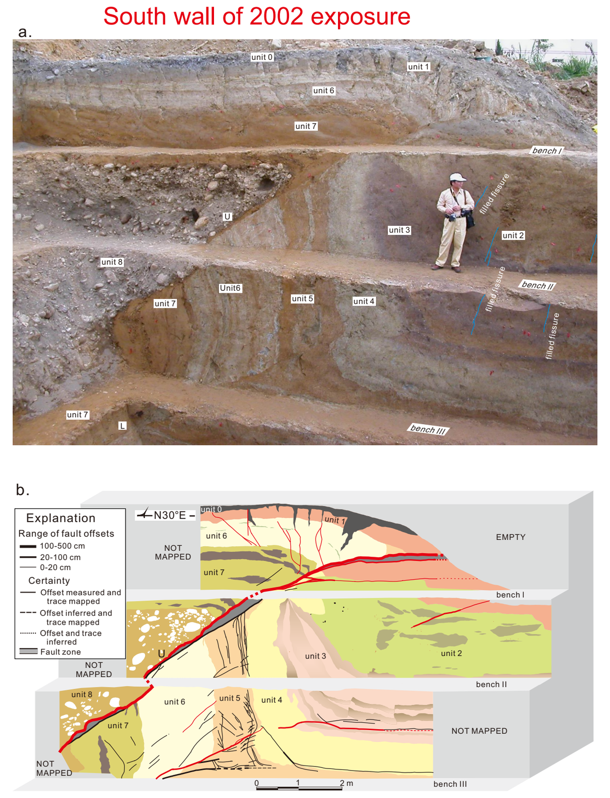


Fig. 2. Parabola-like surface profile and cross section of structures exposed in the 2002 south wall of Chushan trench.

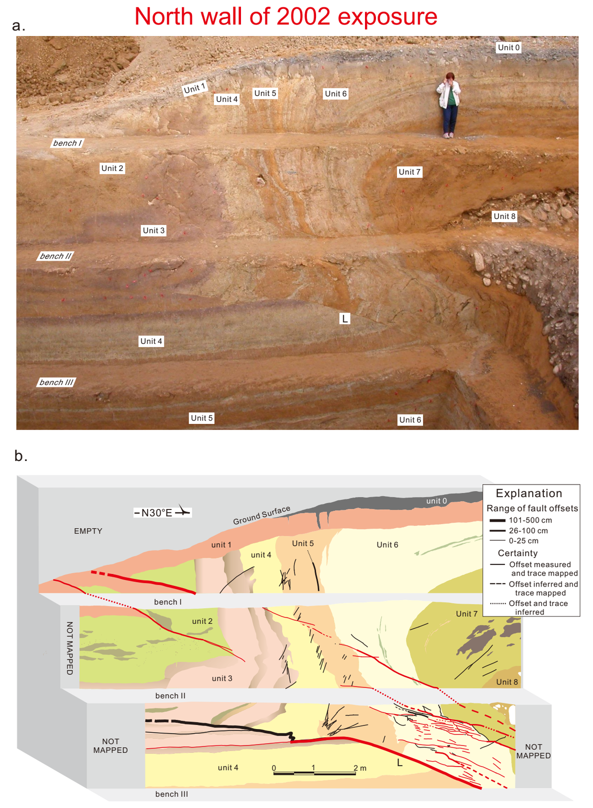


Fig. 3. Monocline-like surface profile and cross section of structures exposed in the 2002 north wall of Chushan trench.

Aims:

- Documenting the surface and subsurface deformation at thrust termination.
- Discussing how and why the structures evolved/interrelated laterally and temporally.
- Proposing possible mechanisms or reasons for the formation of these structures.

Setting of Chushan trench:

After the earthquake, but before the trench was excavated, the ground surface in the escarpment appeared as a low warp (Fig. 4a). Chushan trench (Fig. 4a) was excavated in Nov. 2002 in the Tanliwun area, in the southern part of the Chi-Chi earthquake ground rupture, approximately 5 km north of Chushan town. There are two terraces in the Tanliwun area with a 5-m difference in altitude between them (Fig. 1).The sedimentary units exposed in the Chushan trench are defined in Fig. 5. Most units in the trench, except man–made–fill and the cobbly gravel, are fine–grained soils.

Fig. 4. (a) Trench site prior to the excavation. (b) Oblique view of Chushan trench in 2002.

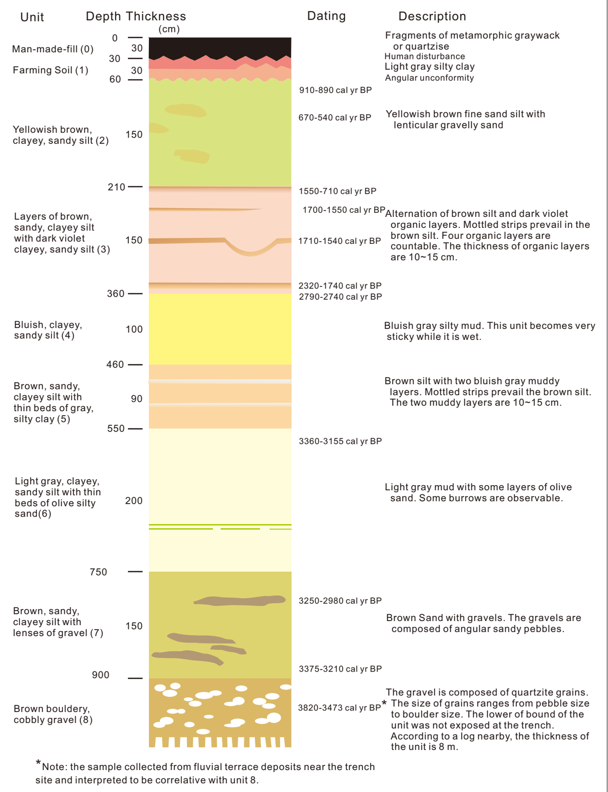


Fig. 5. Stratigraphic column of Chushan trench. Radiocarbon dates in years (calibrated) before present (BP) (dates from Chen et al., 2007).

Deformation near Chushan excavation site, Tanliwun

The deformation zone (DZ) roughly trends along the toe of the hills, and characterized by an escarpment (Fig. 6), is highly asymmetrical relative to the toe of the escarpment. Note that the escarpment was mainly located on the lower terrace but the deformation zone was not restricted to the lower terrace (Fig. 1).

- Typically, the width of the deformation in the hanging wall was much wider than the width of the deformation in the foot wall.
- An example of deformation in the hanging wall on the escarpment is presented in the detailed maps of the deformation in a Sanhu Yuan, rural Taiwanese homestead (Fig. 7). Brick house H6 as bent, distorted and cracked (Fig. 8). The structures in the asphalt in the courtyard and the deformation within house H6 clearly reflect thrusting resulting from NE-SW compression in the Shanhu Yuan, which is consistent with the thrusting in the Chushan trench.(Fig. 4a).
- The ground distortion and fractures in Fig. 9 are evidences of deformation in the footwall of the main rupture.

Fig. 6. Chi-Chi earthquake-induced escarpments (locations shown in Fig. 1).

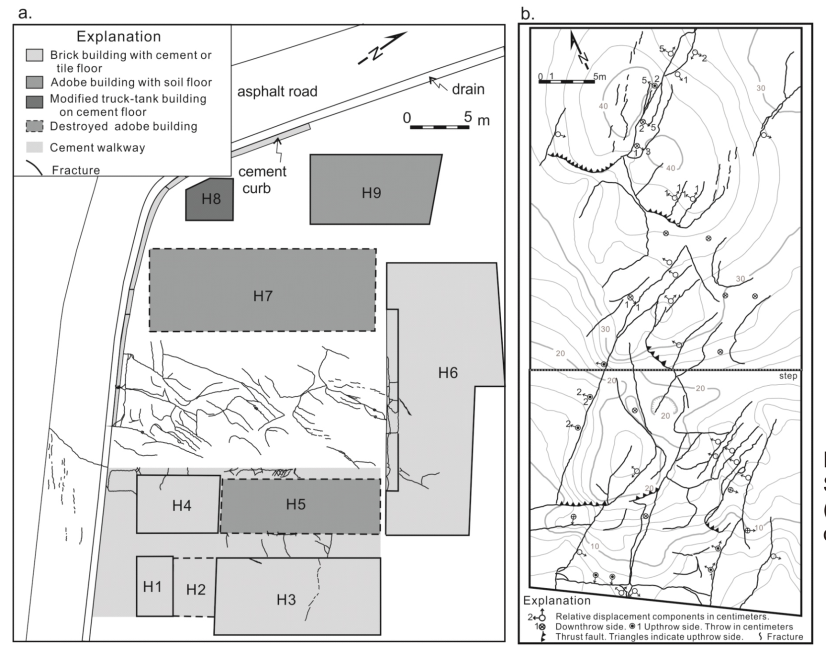


Fig. 7. Deformation of a Shanhu Yuan, traditional Taiwanese homestead, in Hanging wall. (location I, Fig. 1)

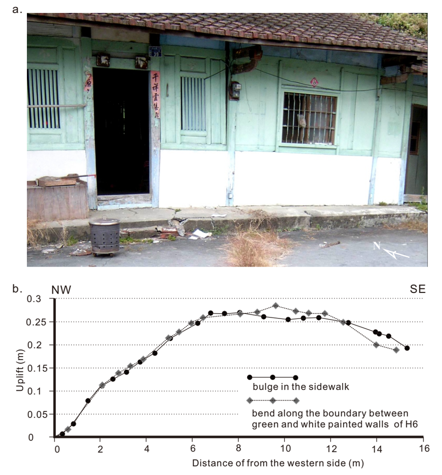


Fig. 8. Example of a damaged building in the Shanhu Yuan. (a) NE view of the building (house H6 in Fig. 7a). (b) Survey of the deformation along markers.

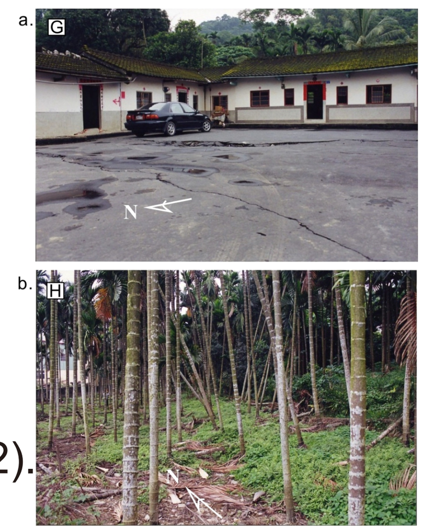


Fig. 9. Geological features in the footwall induced by Chi-Chi earthquake faulting (locations G and H shown in Fig. 1).

Deformation exposed on walls of Chushan trench

- Two main faults: The trace of the upper main fault is labeled U in the south wall (Fig. 2).The trace of the lower main fault is labeled L in the north wall (Fig. 3).
- Fault-related folds: Several sedimentary layers define a highly asymmetric syncline in the footwall block of the upper main fault (Fig. 2). Sedimentary layers are deflected into a highly asymmetric anticline in the hanging wall of the lower main fault (Fig. 3)
- Structures on 2005 and 2012 exposures (Figs.10 and 11).

Fig. 10. North wall of 2005 exposure.

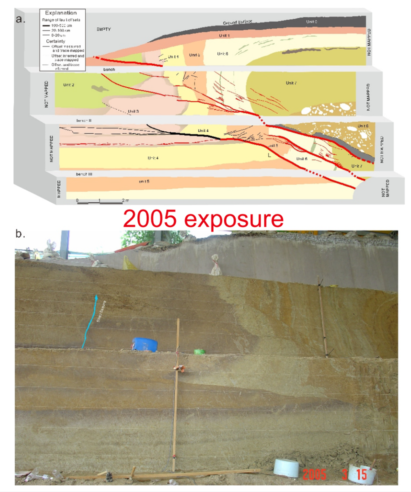
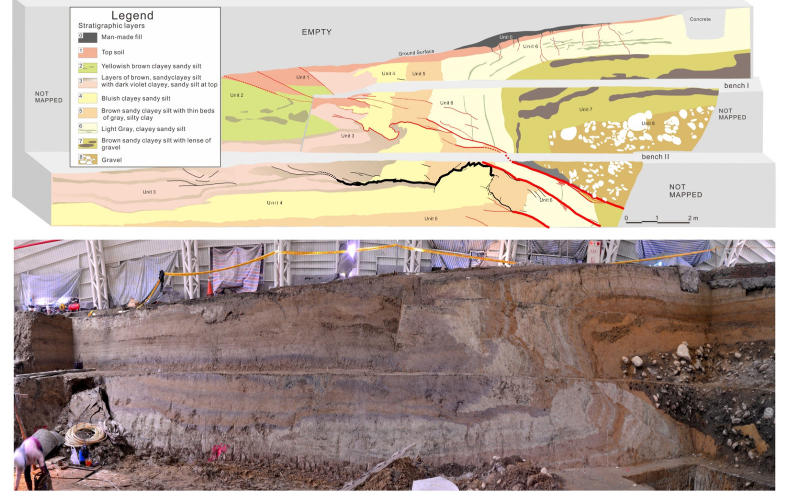


Fig. 11. North wall of 2012 exposure.



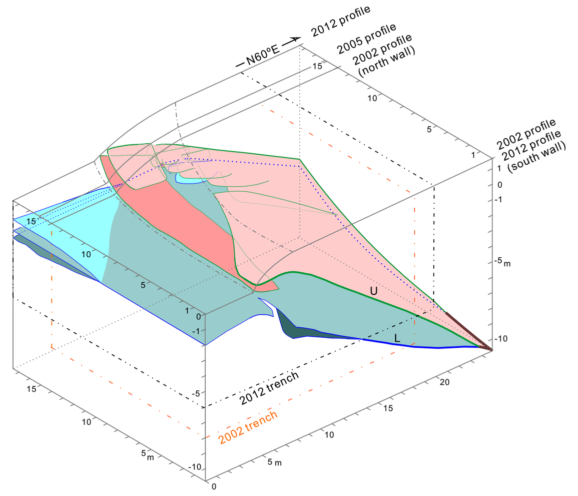


Fig. 12. An illustrative three-dimension sketch of faults in Chushan trench.

- Fig.12 is a diagrammatic sketch of the faults in three dimensions based on the collated information of the trench walls in different years.

Discussion

Width variation of the deformation zone at Tanliwun

- The width variation cannot be reasonably explained by a theoretical model proposed by *Huang and Johnson* [2010]. Based on our observations, we think the wider deformation zone in the hanging wall might result from slip on a few branches of the dominant fault as shown in Fig. 13.

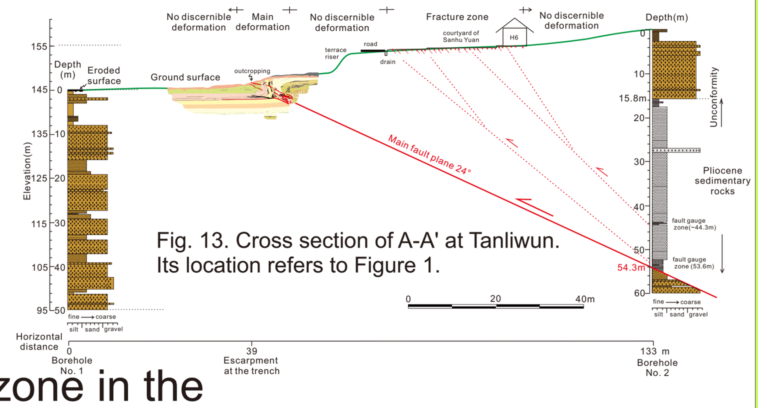


Fig. 13. Cross section of A-A' at Tanliwun. Its location refers to Figure 1.

Factors responsible for the difference of the surface deformation profiles and the difference of the main structures on north and south walls

- Based on our observations (Fig. 14) and Huang [2006], who showed that the mononcline-like ground surface contributed by a pile of small faults below could be similar to the one contributed by a single blind fault. We conclude the change of surface deformation profiles may depend on the depth of the upper tip of the relevant main fault or an equivalent blind fault.
- Regarding about the shape transformation of the escarpment and the difference of the main stuctures on north and south walls, it is likely due to a combined contribution, including the effects of the inherited structure (Fig. 15), the bend of the dominant fault (inferred from the trace of Chi-Chi earthquake-induced escarpment), and the coseismic slip during last three earthquakes.

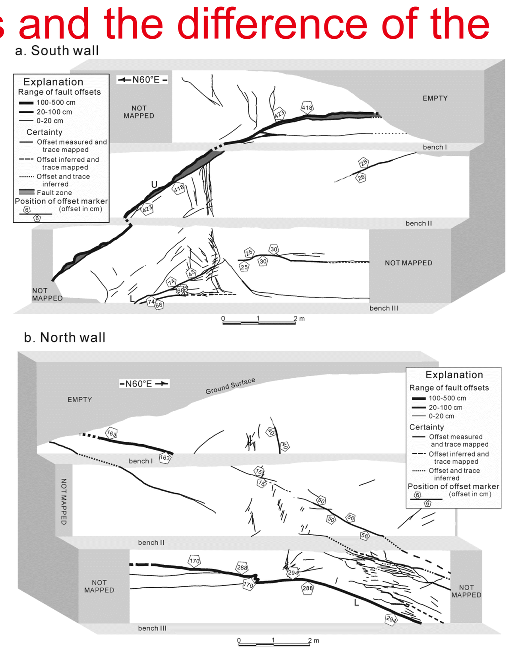


Fig. 14. Traces of faults.

- Crucial observations to construct the restoration in Fig. 15 are listed as follows: (1) The activity and separations of the faults shown in Figs. 2, 3 and 14. (2) The gentle flat ground surface before the Chi-Chi earthquake. (3) Filled fractures with an upper bound at two-third of Unit 2 from its bottom and their upward converging pattern at the syncline (blue lines in Fig. 2a). (4) The fault-related fold of Unit 3 at the upper tip of the main lower fault on the 2005 north wall and a filled fracture penetrating the fold (Fig. 10) . (5) The small remain of Unit 5 above the upper main fault and remain of Unit 4 in Unit 2 below the upper main fault on the 2002 south wall (Fig. 2).

Conclusions

- The wide width variation of the surface DZ likely resulted from the effect of branching from the dominant fault at tens of meter depth.
- The surface profile of the escarpment should be controlled by the depth of the upper fault tip.
- The variation on the main fault-related folds in the trench walls seems due to the geometrical heterogeneity of the newly faults, which developed across a pre-existing monocline during last three earthquakes.
- These newly faults are likely the branches of the dominant fault below the trench, which generated the monocline.

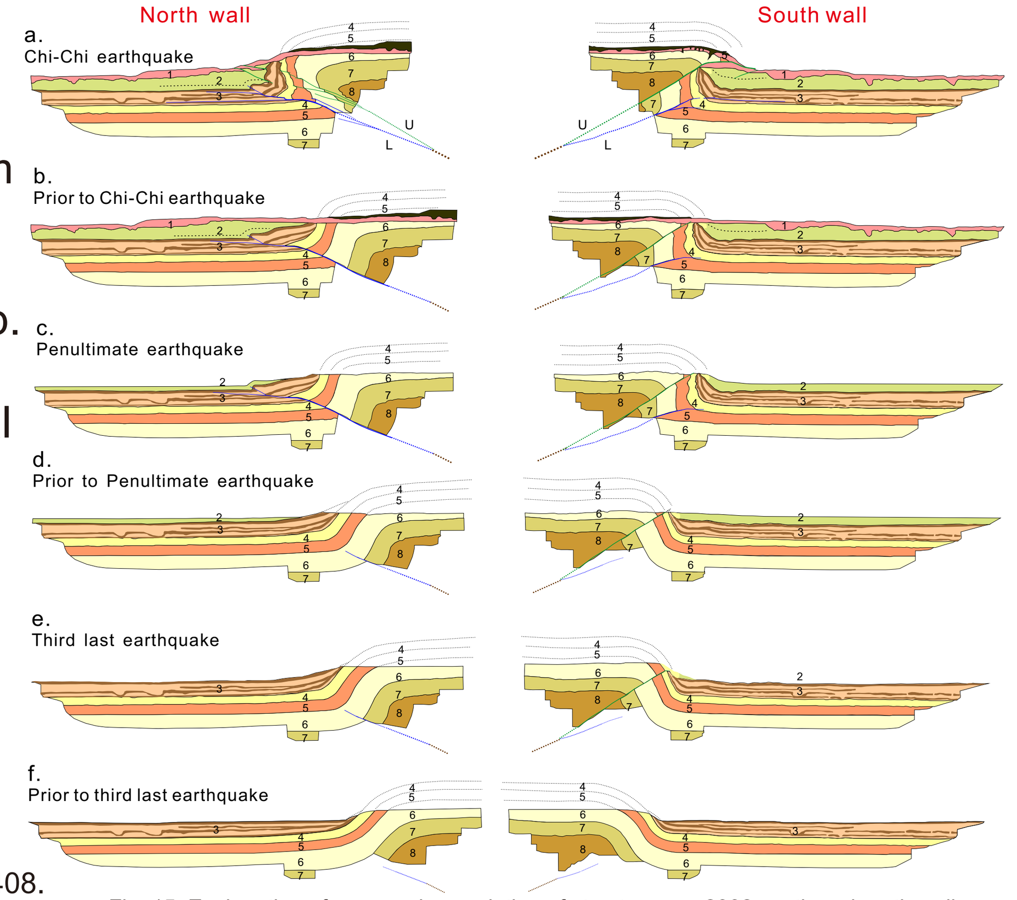


Fig. 15. Explanation of progressive evolution of structures on 2002 south and north walls of Chushan trench.

References

- Chen, W. S. et al. (2007), *Bull. Seismol. Soc. Am.*, 97(1B), 1-13.
- Huang, W.-J., and A. M. Johnson (2010), *J. Geophys. Res.*, 115, B03408.
- Huang, W.-J. (2006), *Ph.D. dissertation, 435 pp., Purdue Univ.*