ACTIVE DEFORMATION OF A TRISHEAR FOLD IN THE SLATE BELT OF SOUTHERN TAIWAN

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Introduction

The Taiwan orogeny is located in the convergent boundary between the Philippine Sea Plate and the Eurasian Plate and has grown during the last few million years as the Philippine Sea Plate collided with the continental margin of China. The resulting collision zone is composed of several tectonostratigraphic units separated by major structural boundaries. To better understand the kinematics of one of these major boundaries, we completed a 3-week field program along the Laonung River in southern Taiwan and integrated available geodetic data and crustal tomography data. In this area, the geometry of penetrative slaty cleavage and associated stretching lineations indicate a regional-scale, SSW-plunging antiform that verges to the NW.

The absence of a crenulation cleavage in outcrops and thin sections and the abundance of late-stage faults and brittle structures suggest that the fold is a post-metamorphic structure. The vertical displacement rate data provided by leveling and GPS surveys from the past decade and the dated strath terraces along the Laonung River show higher uplift rates in the crest of antiform, suggesting that the anticline is an active structure. We then use the geometry of the folded cleavage and a trishear folding mechanism to model the development of this regional-scale fold.

The results suggest that the dominate structure is a high angle reverse fault, which agrees with the relatively linear trace of the inferred fault zone, locally recognized as the Tulungwan fault. Recent tomography data show overturned velocity contours beneath the Central Range suggesting the present of a crustal-scale, west-verging thrust. We therefor propose that the Tulungwan Fault is a branch a crustal-scale detachment in the southern Central Range.

Geological Setting

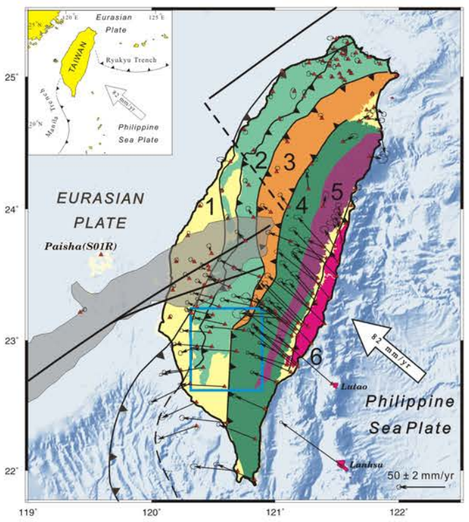


Figure 1

Tectonostratigraphic map of Taiwan modified from Lee et al., 2002. Black solid lines are the interpreted boundary of continental crust based on magnetic anomaly and Mesozoic basement morphology, and the black dash line is interpreted continental edge fracture zone (Byrne et al., 2011). GPS vectors represent the velocity relative to station S01R between 1999-1995 (Lin et al., 2010). White arrow represents the convergent direction and rate between Philippine Sea Plate and Eurasian Plate (Yu et al., 1997).
The color areas represent the tectonostratigraphic units. 1 = Coastal Plan; 2 = Western Foothills; 3 = Hsuehshan Range; 4 = Central Range; 5 = Tanonao Metamorphic Complex; 6 = Coastal Range. The shaded area represents the continental margin magnetic anomaly from Hsu (Hsu et al., 1998). Box shows the location of figure 3.

Structure Map of Study Area

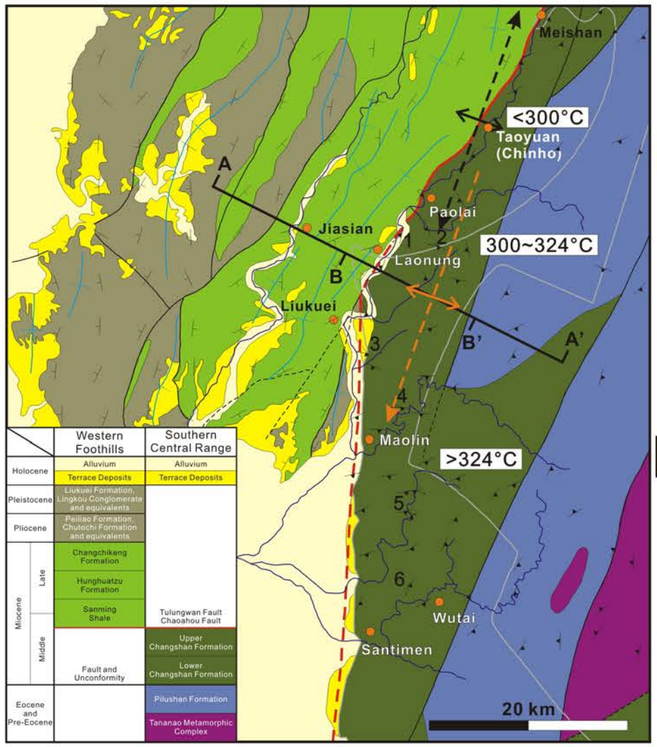
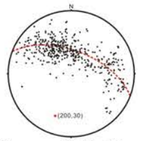
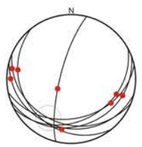


Figure 2

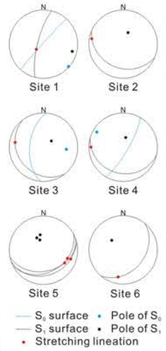
Geological map of study area, modified from Chen et al., 2000 and CPC, 1989. Stratigraphy table is modified from Chen et al., 2000; Sung et al., 2000 and Wiltschko et al., 2010. Red line shows the northeast-southwest trending Tulungwan Fault and north-south trending Chaochou Fault. AA' shows the location of cross-section shown in figure 6. Orange anticline is the location of folded S_1, black anticline shows the location of active doming structure. Grey lines are paleo-teperature calculated from illite crystallinity (Chen and Wang, 1995) based on the fountain by Ji and Browne, 2000.



Pi diagram of folded S_1.



Plot of all S_1 surfaces and stretching lineations of the six sites. Note the trend and plunge rotation axis (dashed circle) is consistent with the (200,30).



Recent Activity Along the Tulungwan Fault

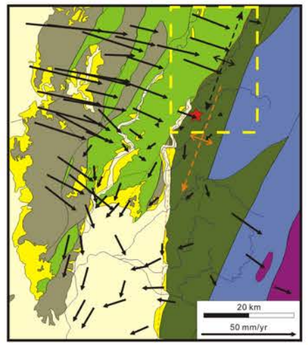


Figure 3

Velocity vectors relative to the red star (S708). Yellow dashed line box show the location of figure 4. GPS data from Chen 2006.

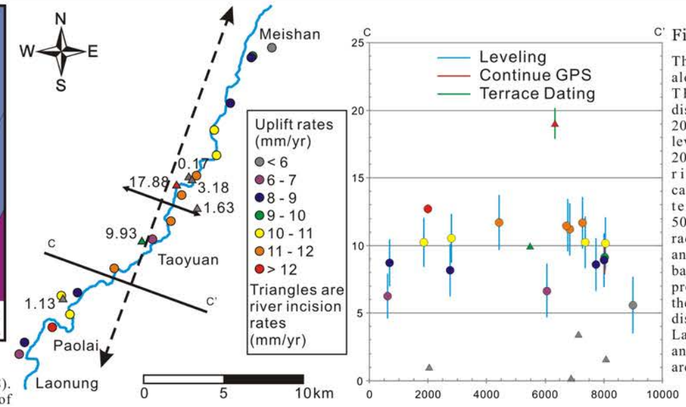


Figure 4

The vertical displacement along the Laonung River. The circles show the displacement from 2000 to 2008 measured by GPS and leveling survey (Ching et al., 2011), and the triangles show river incision rates calculated from the strath terrace during the past 50,000 years according to the radiocarbon dating (Hsieh and Chyi, 2010). The color bars in the displacement rate profile indicate the error of the uplift data. The doming displacement pattern of the Laonung River area suggest an active antiform in this area.

Kinematic Model of the Fold

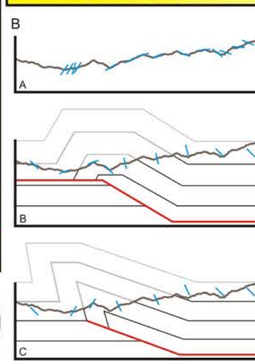


Figure 5

(A) Topographic profile with apparent dip with measured S1.
(B) Modeled S1 using fault-bend-fold model.
(C) Modeled S1 using fault-propagation-fold model.

In both cases, S_1 is assumed to have been ~45° to S_0. Note the missmach between model simulated S_1 and measured S_1.

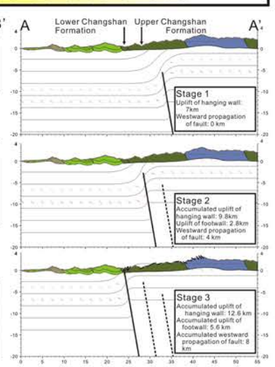


Figure 6

Trishear fold model showing three stages of evolution. For the initial model, we assumed a high angle reverse fault, a 60° trishear angle and 7 km of total displacement. This initial model (stage 1), however, doesn't match the wavelength of the observed cleavage antiform. A possible solution shown in stage 2 and 3, see also future work, is progressive westward stepping of the high angle reverse fault. In all three models, red tick marks represent the Lower Changshan Formation, and the orange tick marks represent the Upper Changshan Formation. The geology west of Tulungwan Fault is modified from Sung et al., 2000.

Conclusion

The southern Central Range is a oblique collision between the slate belt and the passive continental margin.

(1) The penetrative cleavage has been deformed into a late-stage antiformal structure.

(2) The antiform is interpreted to be active based on:

a. Vertical displacement rate data provided by leveling and GPS surveys from the past decade show higher uplift rates in the crest of antiform.

b. Dated strath terraces (as old as 18,000 yrs) along the Laonung River (Hsieh and Chyi, 2010) also show higher uplift rates in the crest of antiform.

(3) We model the antiform as an westward stepping trishear fold as this model results in an appropriate rotation of the cleavage with 60° of trishear zone and 7 km of offset between hanging wall and footwall. Fault-related flat-ramp folds were also considered but these models do not produce the observed cleavage rotations. Westward stepping of a high angle reverse fault is proposed to produce the observed wavelength of the fold.

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