Active Fault-Related Folding In The Central Taiwan Foreland Basin

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Widespread folded terraces reflect the present-day activity of fault-related folds at the western edge of Taiwan fold-and-thrust belt, which is where fault-bend fold theory was first developed and applied to

petroleum structures (Suppe 1983). Patterns of coseismic uplift in the devastating 1999 Chi-Chi earthquake (Mw=7.6), with its 90km long surface rupture, indicate that these fault-related folds can grow abruptly on a coseismic timescale. Here we present the structure of the two most active frontal thrusts in the central Taiwan thrust belt and document their associated fault-related folding based on surface geologic data, wells and seismic reflection profiles: [1] the Pakuashan frontal anticline above the Changhua blind thrust and [2] the Chelungpu-Sanyi ramp-flat thrust system, which is the most important fault to slip in the Chi-Chi earthquake. In addition there are constraints on coseismic displacement and fault-related folding from surface ruptures, geodesy and seismology. Both these structures lie above the shallow (3-6km) Chinshui Shale detachment (Pliocene).

The Pakuashan anticline, sitting above the Changhua blind thrust, appears to be quite active from a geomorphic perspective, displaying multiple folded alluvial terraces. Constrained by published and unpublished seismic lines, wells and surface geology, this anticline shows the characteristic geometry of simple-shear fault-bend folding (Suppe, Connors & Zhang, 2003), including a very long (~6-7km) back limb with gentle dip (~10°) that is significantly less than the ramp dip (15-20°), a narrow front limb (~ 2km, 15-20°) and evidence of progressive back-limb rotation from seismic images and tilting of terraces (Ota et al. 2002). A distinctive feature of such simple-shear fault-bend folding is that slip goes to zero at the base of the ramp and is transferred to a bedding-parallel shear zone. In the case of the Pakuashan anticline the shear zone is 770m thick and lies in the lower Cholan Formation and Chinshui Shale. This zone displays heterogeneous simple shear, ranging between 60° and 80°, with a total shear displacement of 2.5 km. The eastward continuation of this shear zone deforms the Chelungpu fault, causing it to flatten substantially, but there is no direct fault linkage between the Chelungpu fault and the Changhua thrust ramp.

In contrast the Chelungpu-Sanyi thrust system is bedding-parallel, displaying nearly classic ramp-flat geometry. The thrust plane can be clearly traced by extrapolating the surface geology downward and this relationship has been proved by unpublished seismic lines. The Chelungpu thrust displays this ramp-flat geometry not only in the east-west direction but north-south also, which is shown in a 3D fault model. Around the depth of 5~6 km, the basal stratigraphic unit, Chinshui shale, along the Chelungpu thrust joins with the same footwall stratigraphic unit to a shallow detachment which then steps down to around ~10 km to connect to the Taiwan Main detachment illuminated by 10-year seismicity. This regional image also points out different fault segments might have different faulting behaviors, which has been discussed by Perfettini and Avouac in 2004.

The devastating 1999 Chi-Chi earthquake demonstrates the Chelungpu thrust is currently active. The correlation between the Chelungpu thrust and coseismic deformation is extremely well. Projected coseismic slip vectors agree with the ramp-flat fault geometry in 2D sections. Also photogrammetric (Spot) and GPS coseismic displacement fields, and the seismologic models of slip history inverted from teleseismic, strong motion and GPS data show large slip concentrates right above the Chelungpu thrust ramp and slip patterns strongly correlate with 3D geometric segmentation of the thrust.