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Incremental vs. geological growth of folds: Examples of Tungshih anticline and Neiwan syncline during Taiwan Mw7.6 1999 ChiChi earthquake

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The coseismic growth of folds during earthquakes is a fundamental process in the evolution of mountain range fronts. Linking this incremental growth to the observable finite geometry of the structure is challenging because extrapolating short-term deformation data to long-term geological times is problematic for many tectonic issues. We address this issue by using an exceptional example from the Taiwan Western foothills where two folded structures, the Tungshih anticline and Neiwan syncline, have been activated during 1999 Mw7.6 ChiChi earthquake.
At an earthquake timescale, high-resolution topographic and kinematic data obtained from aerial photo processing allow for documenting the coseismic growth of the anticline-syncline couple. Field results indicate that about 9 $\pm$ 1 m of horizontal shortening has been consumed in the anticline, which grew vertically by as much as 10 $\pm$ 1 m at maximum. The adjacent syncline experienced a 1 m $\pm$ 1 m uplift and -1 m $\pm$ 1 m subsidence apart its limbs. Folding mechanisms activated during the earthquake were identified for both folds. It is limb rotation and kink-band migration for the anticline western and eastern limbs, respectively, and kink-band migration for the syncline. From the 3-D dataset of fold growth, we estimated that about 10 100 $\pm$ 1 000 m2 of rocks have been pushed into the fold core, accounting for the exceptional vertical uplift.
At a geological timescale, we used a seismic line across Tungshih anticline to document the shortening history recorded in the subsurface geometry. Using the "thickness-relief method", we measured that the whole anticline records 538 m of total shortening. This quantity is divided into 243 m of shortening of the upper Cholan strata and an additional 295 m confined to the lower Chinshui shale strata. It implies that two detachments exist: a first at the base of the Chinshui shale, and a second 149 m above the first. To explain this deformation pattern, we interpret Tungshih anticline as an "open-system detachment fold" that has grown during two types of earthquakes: "ChiChi-like" and "non-ChiChi-like" earthquakes. The "ChiChi-like" earthquakes entail deformation accommodated solely by the growth of the anticline with all fault slip entering on the lower detachment consumed in fold growth. In contrast, "non-ChiChi-like" earthquakes are associated with little fold growth; most of the fault slip that enters the anticline on the lower detachment exits on the upper detachment, with little slip consumed.