Surface effects of active folding, illustrated with examples from the TianShan intracontinental mountain belt (China)

Aurélia Hubert-Ferrari[1,] , John Suppe[2],

[1] Observatoire Royal de Belgique, av. ciculaire 3, 1180 Brussels
[2] Department of Geosciences, Princeton University, Princeton, NJ 08544, USA

The combination of good surface exposure and subsurface imaging allow us to directly relate the anticlinal morphology to its deep active structure. The two studied Yakeng and Quilitak folds are located at the front of the Kuche-fold –and-thrust belt of the Southern Tianshan. The folds have fundamentally different folding mechanisms, which is reflected in their contrasting geomorphology.

Seismic reflection profiles show that the Yakeng anticline is gentle detachment fold with limb dip generally less than 5-6 degrees. By measuring area of structural relief as a function of elevation we constrain its magnitude and the history of growth. The analysis yields a total shortening of 1200 m with the beginning of growth at horizon 14 time and an approximately linear upward decrease in shortening through the 2.4 km thick growth sequence. Furthermore during most of its growth Yakeng was completely buried with a constant ratio between shortening and cumulated sediment height of 0.2. A recent growth acceleration probably triggered by diapiric flow, leading to its topographic emergence. At the surface the low ridge formed by Yakeng anticline is similar to the deep structure. Its two-stage growth is also visible in the morphology. Yakeng emergence has been completely disrupted the river network and changed the sedimentation pattern. Before that time, wide alluvial fans were covering the northern part of the present Yakeng structural high. Finally a quantitative comparison between the warped surface of Yakeng and its deep shape shows that Yakeng topography is a direct image at reduced amplitude of its deep structure. Yakeng is thus a self-similar fold where the instantaneous uplift rate varies smoothly across the structure and is collocated to the finite uplift.

In contrast, the Quilitak anticline does not directly reflect its deep structure. Quilitak is a complex fault-bend-fold having a deep width of 10 to 20 km and forming at the surface a 5 to 7 km wide mountainous ridge with a cumulated relief of ~1000 m. The edges of the Quilitak relief

forms continuous linear front characterized by steep triangular facets. We demonstrate that this striking morphology corresponds to an active axial surface- or hinge- along which an abrupt change in bedding dip occurs. The Quilitak front is this a cumulative fold scarp resulting for the folding of an erosional surface south of Quilitak high across an active axial surface pinned to the underlying fault bend and thus fixed relative to the rocks. Fold scarp formation occurs because active axial surface are fixed locus of instantaneous uplift. Quilitak morphology thus directly reflects the deep kink-band folding mechanism which implies that active axial surface is a fixed locus of instantaneous uplift.

Recent alluvial sediments deposited on top of the eroded southern front of Quilitak have recorded a bed-by-bed image of the formation of fold scarps. Quantitative sections logged in the field shows the whole complexity of processes occurring in hinges. The hinge appears to have a finite width within which progressive folding occurs. Furthermore the existence of marked unconformities or disconformities within the hinge points out the importance erosion/sedimentation processes relative to tectonic processes. Finally the folding kinematics can be modeled using a curved-hinge kink-band migration model where the sharp axial-surface line used in fault-bend folding expands to be of finite ~110m width, and the wide axial surface zone behaves like curved similar fold. Our logged section can be fitted using this forward model of growth folding. The best fitting model then provides a measure of horizontal displacement for each bed-horizons.

Figure 12. The Quilitak anticline: relationship between morphology and structure. Axial surface map was reported on top of Landsat image. Positions of seismic lines are indicated. The Quilitak topographic ridge as defined by its sharp edges A and B bears little apparent relation with the deep anticline width defined by the distance between axial surfaces X and Y.