Miocene to present kinematics of fault-bend folding across the northern Tianshan (China), derived from structural, seismic, and magnetostratigraphic data

Julien Charreau[1], Jean-Philippe Avouac[1], Yan Chen2, Stéphane Dominguez[3], Stuart Gilder[4]

1. Tectonics Observatory; 2. Institut des Sciences de la Terre d'Orléans;
3. Géoscience Montpellier; 4. Ludwig Maximilians University

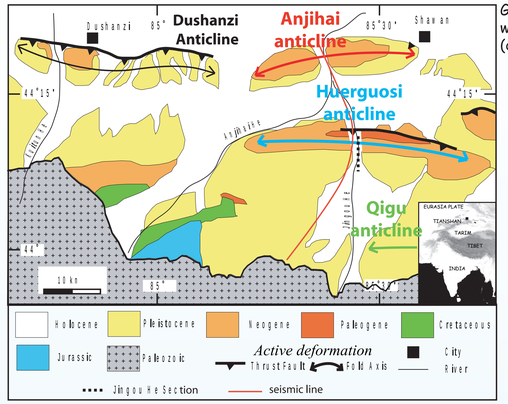
Problematics

A number of techniques are available to estimate crustal deformation over periods ranging from the coseismic time scale to tens of thousands of years. Describing quantitatively crustal deformation over the million-year time scale over which finite geological deformation develops remains a challenge.

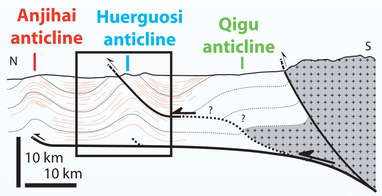
Approach

If the context is favorable, syntectonic sedimentary layers, commonly called growth strata, can provide a record of tectonic deformation over this longterm time scale. But it is often difficult to identify growth strata and interpret them quantitatively. Here we describe a case example where the history of folding and thrusting across an active anticline, the Huerguosi anticline in the northern Tianshan, can be recovered due to constraints on the subsurface geometry and age of pre-growth and growth strata derived from seismic imaging and magnetostratigraphy.

Geological Settings

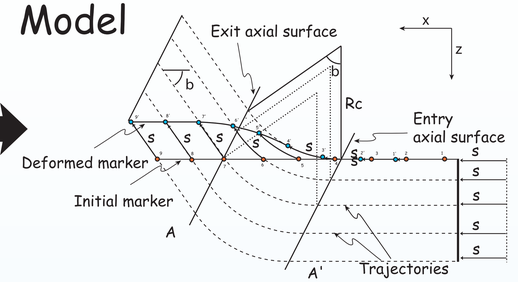


Geological map of northern Tianshan piedmont with locations of magnetostratigraphic study (dashed line) and seismic profile (red line).

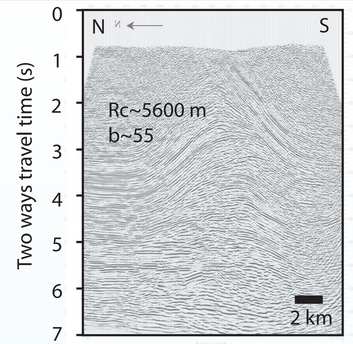


Cross section derived from seismic profile (line drawing interpretation shown by red lines).

Model

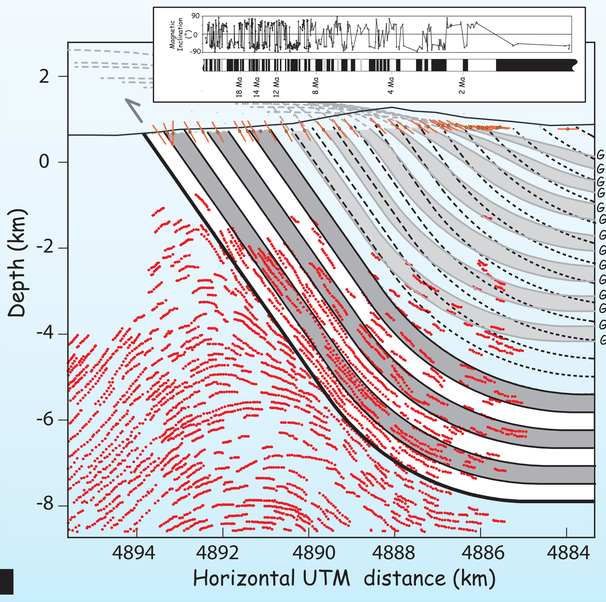


Structural model showing particle trajectories and deformation of an initially flat layer horizon deposited across the fold zone, assuming fold-bend folding but with hinge of finite width that bound a curved

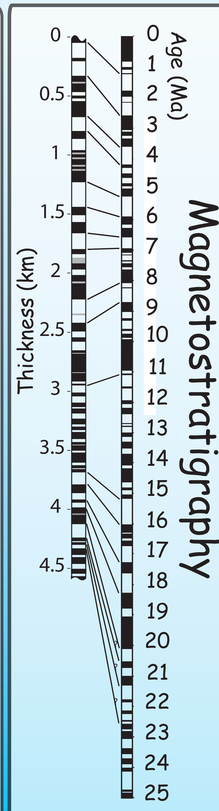


Seismic line runs across the Huerguosi anticline.

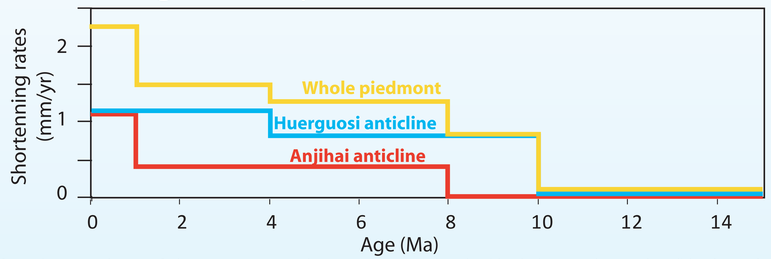
Model vs. Seismic line



Line drawing of seismic profile across Huerguosi anticline and measured dip angles along Jingou He River. Pre-growth (black continuous and dashed line), and growth (continuous gray line) strata predicted by fault-bend folding are also shown. Measured magnetic inclinations and inferred chronology are at top.

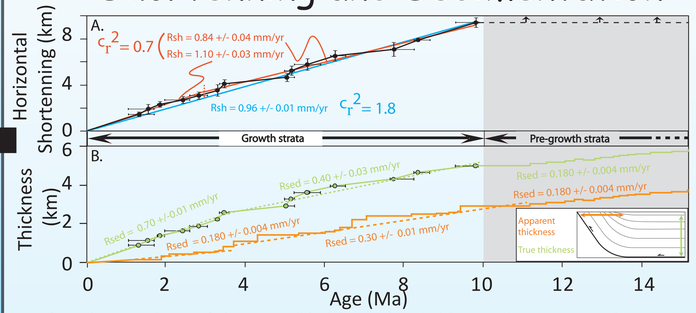


Shortenning history of the northern Tianshan



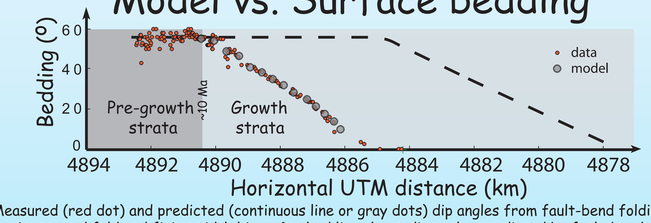
Inferred time evolution of shortening across the Huerguosi anticline (red line) the Anjiahi anticline (bleu line, after Daeron et al., 2006) and the whole northern Tianshan piedmont.

Shortenning and Sedimentation



A -Inferred time evolution of shortening (black line and symbols) across Huerguosi anticline.
B - Time evolution of sedimentation during deposition of growth strata (orange line). Green line shows estimated sedimentation history in the piggyback basin, where it is not diminished by fold growth rate.

Model vs. Surface bedding



Measured (red dot) and predicted (continuous line or gray dots) dip angles from fault-bend folding, assuming curved fold and finite width hinge. Dashed line shows dip angles predicted by fault-bend folding for pre-growth strata. Sediments deposited south of 4891.5 km are clearly growth strata. UTM—Universal Transverse Mercator. The shortening history is obtained by least-squares fitting of the measured dip angles of the growth strata.

Conclusion

We combine surface structural measurements, subsurface seismic imaging, and magnetostratigraphic dating to retrieve, through geometric modeling, the detailed history of fold growth and sedimentation across the Huerguosi anticline. The model assumes a fault-bend folding mechanism, consistent with subsurface fold geometry. The shortening rate across the anticline is shown to have been remarkably constant: it increased only slightly from 0.84 ± 0.04 mm/yr between 10 and 4 Ma to 1.14 ± 0.02 mm/yr over the past 4 m.y. This approach also allows correcting syntectonic sedimentation rates for the effect of the fold growth and shows that the sedimentation rates in the piggyback basin increased abruptly from ~0.4 to ~0.7 mm/yr ca. 4 Ma.
The Cenozoic shortening history accross the whole northern Tianshan piedmont can be retrieved from applying this approach to the various folds accross in the area.