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Active Faulting and Folding in the Kochkorka Intermontane Basin of the Ky

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1. INTRODUCTION

Deformed Neogene strata and Pleistocene river terraces record basinward-propagating thrust faulting along the southern margin of Kochkorka Valley, an intermontane basin in the Kyrgyz Tien Shan of central Asia (Figures 1 and 2). The Tien Shan, which likely accommodate 1/2 to 1/3 of the modern India/Eurasia relative plate motion (Abdrakhmatov et al., 1996, Nature, **384**, 450-453), offer an opportune glimpse into the process of intracontinental mountain building. Fundamental to understanding the kinematic evolution of the Kyrgyz central Tien Shan is to characterize how strain is partitioned between its "foreland" and intermontane basins. The preservation of multiple, clearly deformed fluvial terraces and nearly continuous exposure of underlying Neogene sediments make the southern margin of Kochkorka basin particularly favorable for determining the geometry, style, and rate of shortening within an intermontane basin. Our preliminary interpretation suggests that the north-vergent, basinward-propagating structure is best explained by a fault-bend fold geometry with a daylighting frontal thrust fault. Progressively deformed strath terraces deform in a manner grossly similar to models that assume kink-band folding. Terrace deformation does not fit the model in detail. Semi-independent estimates of the amount of shortening, using fold height and fold area, compare favorably and support the fault-bend fold model as a viable hypothesis for the structural geometry.

Based on radiocarbon ages of the lowest profiled terrace and the fold geometry, we estimate the rate of shortening to be 1.7 (+1.6 / -1.3) mm/yr. Our best estimate suggests that the southern margin of Kochkorka basin accomodates about one-tenth of the shortening across the central Tien Shan as determined by GPS geodesy.

Figure 1. DEM of northern India and central Asia.

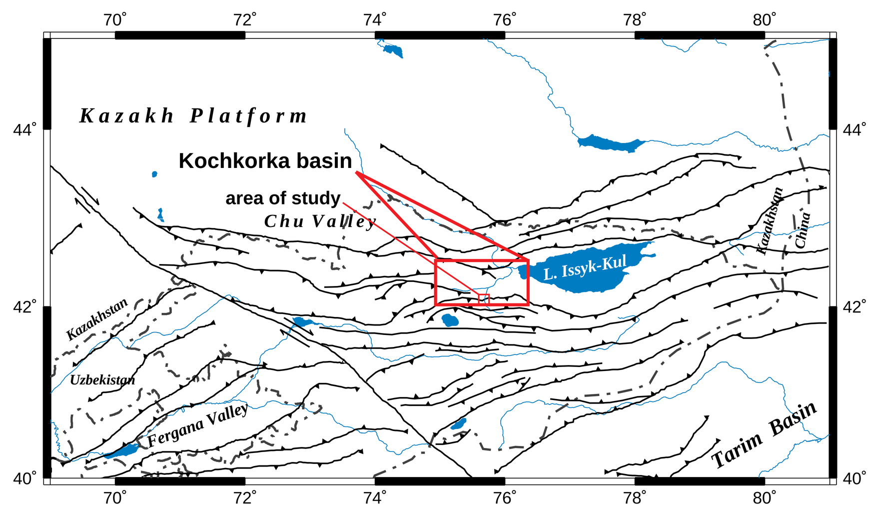


Figure 2. Central Tien Shan mountains of Kyrgyzstan and China, showing major faults and the study area.

2. METHODS

We mapped the Neogene structure and Pleistocene terrace surfaces along the north-flowing Djuanarik River using 1:50,000 scale stereo air photographs and 1:100,000 scale topographic maps (40m contour interval) (Figure 4). We profiled four sets of progressively deformed Pleistocene fluvial terraces plus the present Djuanarik River using differential GPS (Figure 3). We measured over 70 points along the ~7 km of river from the mountain front to the frontal thrust fault. The terraces are incised into Neogene sandstone and siltstone, and are on top of 1-5 m of coarse fluvial gravel. Eolian silt and colluvial silt and sand cap the terraces. We consistently measured at the contact between fluvial gravel and overlying loess and colluvium at the top of each terrace riser. Uncertainties in the GPS measurements are on the order of centimeters; uncertainties in the location of the contact are on the order of centimeters to decimeters.

Radiocarbon dating of charcoal and land snail shell, collected from the deposits capping the lowest deformed terrace (Qt $_{III(2)}$), provides minimum ages for paleo-river abandonment and terrace formation. We were unsuccessful collecting datable material from older surfaces. Shell material was cleaned by hand-picking and ultrasonic cleaning, then treated with dilute H_2O_2 and leached with dilute HCl, to destroy organic material and soil carbonate accreted to the shell surfaces. Powder X-ray defraction (XRD) analyses on shell show no measureable soil carbonate or alteration from primary aragonite to calcite. Charcoal samples were prepared by standard techniques. All samples were dated at the Center for Accelerator Mass Spectrometry (CAMS) at Lawrence Livermore National Labs.

Figure 3. GPS antenna and surveyor measuring the height of a Pleistocene terrace relative to a simultaneously-recording base station. Photo is looking North down the Djuanarik River. The fault-bend fold is in the middle distance.

MAP SYMBOLS

D
U
Thrust fault. Dashed where approximate, dotted where concealed. U = upthrown side, D = downthrown side.

Axial surface in Neogene strata. Arrowed side has the steeper dip and points in the down-dip direction.

43
Strike and dip

Figure 4. Map of structure and Pleistocene terrace surfaces, southern Kochkorka basin. Base is a mosaic of two aerial photographs

South

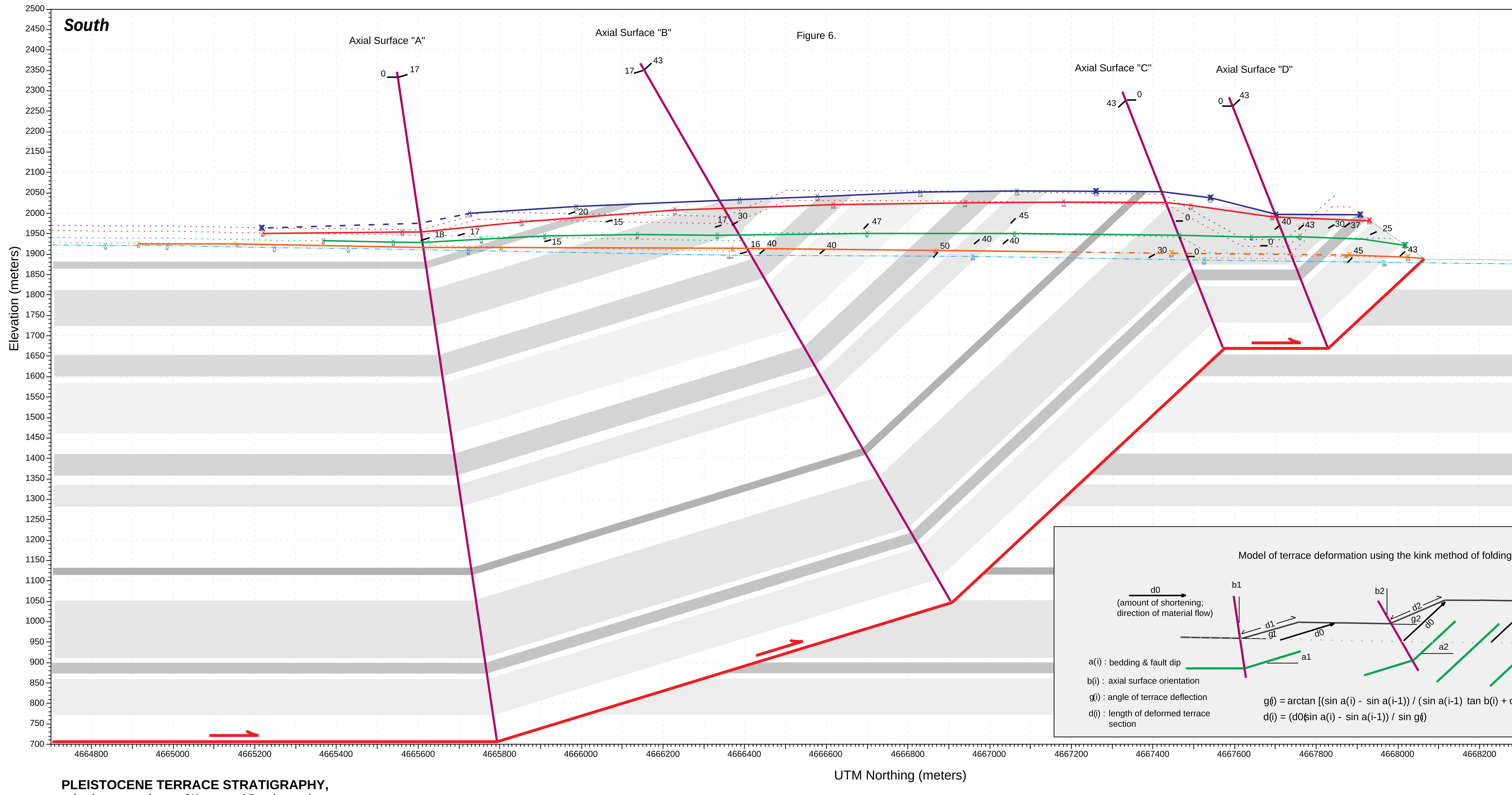
Figure 5. Photomosaic of the Djuanarik River ramp anticline. View is to the west. The four terrace surfaces profiled are marked by orange, green, red, and blue dashed lines (in order of increasing terrace age and height). Locations of axial surfaces are magenta lines. Notice the active mountain front at the far left of the photo; the older two terraces are offset by a range-bounding fault.

3. RESULTS AND DISCUSSION I - Terrace profiles and cross section.

Well-defined dip panels within exposed Neogene sediments result from bedding-parallel slip on underlying ramp and flat fault structure (Figures 5 and 6). The modeled structure is a modification of a simple fault-bend fold with conservation of line length and bedding thickness (Suppe, 1983, Am J. Science, **283**, 684-721). A daylighting frontal thrust fault constrains the depth to detachment, approximately 1200 meters below the modern river. The rear axial surface ("A") of the fault-bend fold is manifested by an abrupt start of a 1- 5 degree backtilt of the terrace profiles. The cumulative amount of shortening along the underlying fault is recorded by relative uplift of the terraces and northward growth of the backtilted surface; the hinge of each successively older terrace has clearly propagated more to the north, consistent with material moving up a subsurface thrust fault ramp. The forelimb deformation seen in the older terrace surfaces coincides with the dip panel change in the underlying Neogene strata (axial surface "C"). While the coincidence of terrace and underlying Neogene deformation is consistent with the modeled structure, terrace deformation is not as dramatic as predicted by pure kink-band folding (short dashed lines on Figure 6 and inset). Alternative structural interpretations are welcome.

4. RESULTS AND DISCUSSION II - Evolution of the Djuanarik ramp a

The panels to the right illustrate our concept for the history of the Djuanari modeled as a fault-bend fold with conservation of line length and bedding of the structure. This sequence illustrates a possible evolution of basinwa Kochkorka basin.



PLEISTOCENE TERRACE STRATIGRAPHY,
adopting nomenclature of Kyrgyz and Russian workers

Plan view	Section view	
Qt $_{II(1)}$		**Oldest preserved geomorphic surface in the study area; remnants are isolated along the margins of Qt $_{II(2)}$**
Qt $_{II(2)}$		**Most widespread upper surface; this is a typical geomorphic position for "Q II" terraces in the Krygyz Tien Shan. Based on extrapolating the Q III(2) slip rate, the "Q II" terraces are likely close to 100,000 years old.**
Qt $_{III(1)}$		**Oldest of the "Q III" level terraces; remnants in the study area are narrow and poorly preserved. Slip rate extrapolation suggests that the terrace is about 30,000 years old, so should be datable by radiocarbon.**
Qt $_{III(2)}$		**Youngest of the obviously deformed terraces. Radiocarbon dates of land snail shell and charcoal suggest that this terrace was abandoned about 6,000 years ago.**

older

EXPLANATION OF CROSS SECTION SYMBOLS

Measured terrace profile, dashed where approximate. Circles and small numbers show differential GPS data points. The error in instrument precision is smaller than the circle symbol.

Predicted terrace profile from the fault-bend fold model. The model assumes that incremental deformation occurs by pure kink folding, similar to the deformation seen in the strata

17 43 **Axial surfaces bisect th and terrace surfaces.**

Layered sandstone and Formation, schematical

37 **Apparent dip in bedding**

Flat and ramp geometry thrust fault.