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Rapid uplift of the Kumkuli Basin since ~5 Ma as a consequence of large-scale transpressional faulting within the northern Tibetan Plateau

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Motivation

- Since at least Miocene time, NE convergence between India and Eurasia has been accommodated by N-S striking normal faults at high elevation, thrust faulting at lower elevations, and strike slip faulting in both domains.
- In northern Tibet, a series of E-W to NW-SE striking thrust faults, likely accommodate strain transfer between two major strike-slip faults: the Altyn Tagh and Kunlun faults. However, rates and timing of fault initiation in this region are poorly known.
- We investigate shortening of the Kumkuli Basin in order to constrain fault initiation, magnitude of shortening, and shortening rates in order to gain insight on the interaction between these two faults and contribution of strike-slip step-overs to plateau building.

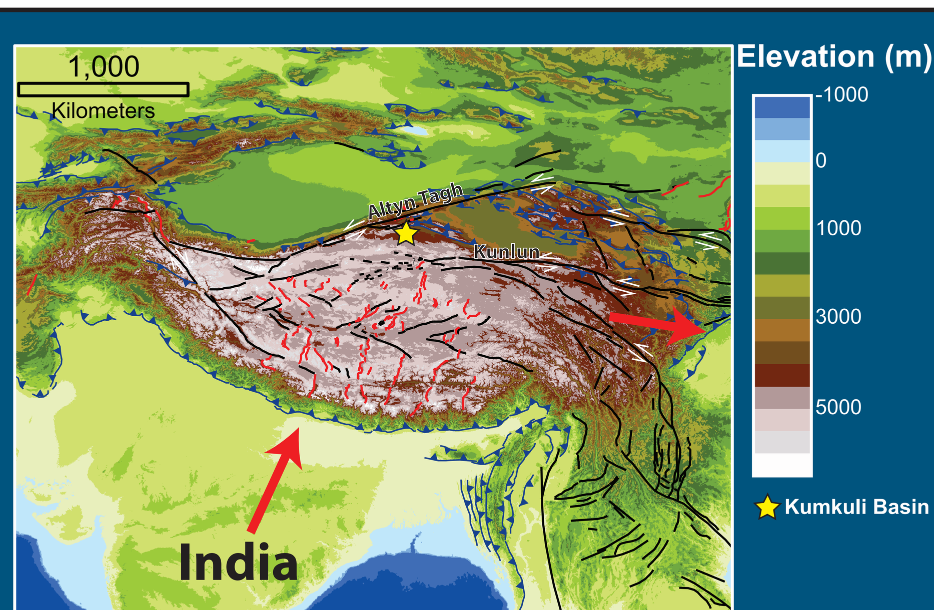

Figure 1 - Active faults of the Tibetan Plateau from Taylor and Yin (2009) highlighting the left-lateral Kunlun and Altyn Tagh faults, and the location of the Kumkuli Basin within Tibet. Red arrows show convergence of India with Eurasia, and eastward movement of material from the high plateau.

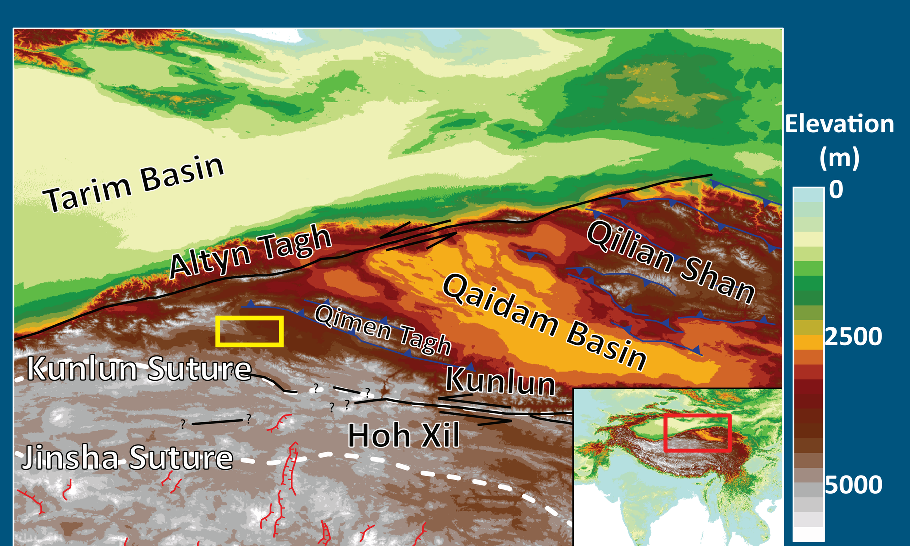

Figure 2 - Active faults near the Kumkuli Basin (outlined in yellow box), with names of regional topographic features.

Sedimentary Units

Sedimentary sequences of the Kumkuli Basin were fist described by Zhang et al, (1996, 2001) with stratigraphic ages defined by pollen, ostracode and gastropod assemblages. We corroborate the Miocene age of the Shibiliang Formation with a trace fossil cast (Figure 3 A), which must be no older than the early Miocene based on the earliest medium-bodied Artiodactyl fossils found in the region (Wang et al., 2003).

Quaternary - Fuvial and alluvial deposits comprised of material eroded from the Oligo-Miocene formations. Key features of this system are three sets of alluvial fan surfaces in the southern portion of the map area, which have been uplifted on an actively growing fault bend fold (Figures 4 & 5).

Hongliang Fm. - Silty and/or carbonaceous red fine grained sandstones to mudstones, with interbedded siltstones. Xiao et al., (2005) document that the Hongliang is capped by a >100 m thick conglomerate which may indicate an increase in stream power related to the initiation of shortening

Shibiliang Fm. - Red fine to medium grained well-sorted litharenites and siltstones, with interbedded limestones and gypsum layers. The presence of symmetric ripples, mud cracks, and channel scour indicates a fluvial to lacustrine depositional setting.

Shimagou Fm. - Clast-supported pebble conglomerate with a coarse to medium sandstone matrix. Clasts are composed predominantly of limestones. The Shimagou is interpreted as a braided fluvial system, with published (Xiao et al., 2005) paleocurrent directions indicating transport to the north or northeast. Clast compositions and paleocurrent directions are compatible with sediment sourcing in the Hoh Xil basin to the immediate south.

Deformation Styles and Shortening

West:
- Open east-west trending folds (Figure 4 A)
- Meter-scale north-south trending folds (Figure 4 B) present near major surface faults.

East:
- Northeast verging tight to isoclinal folds (Figure 4 C)
- No smaller scale folding

- Compressive stresses are northeast-southwest, and accommodated differently across the basin.
- Differences in thrust orientations may be due to pre-existing basement structures.
- Folded alluvial fan surfaces indicate Plio-Quaternary deformation (star denotes sample location for age dating). 9 km of shortening has occurred since Pliocene time with 350 m of shortening represented by the folded Plio-Quaternary alluvial fan surfaces. This deformation inverts the Oligocene and younger Kumkuli sedimentary basin into a modest mountain range of ~500 m relief at an average elevation of 4800 m.

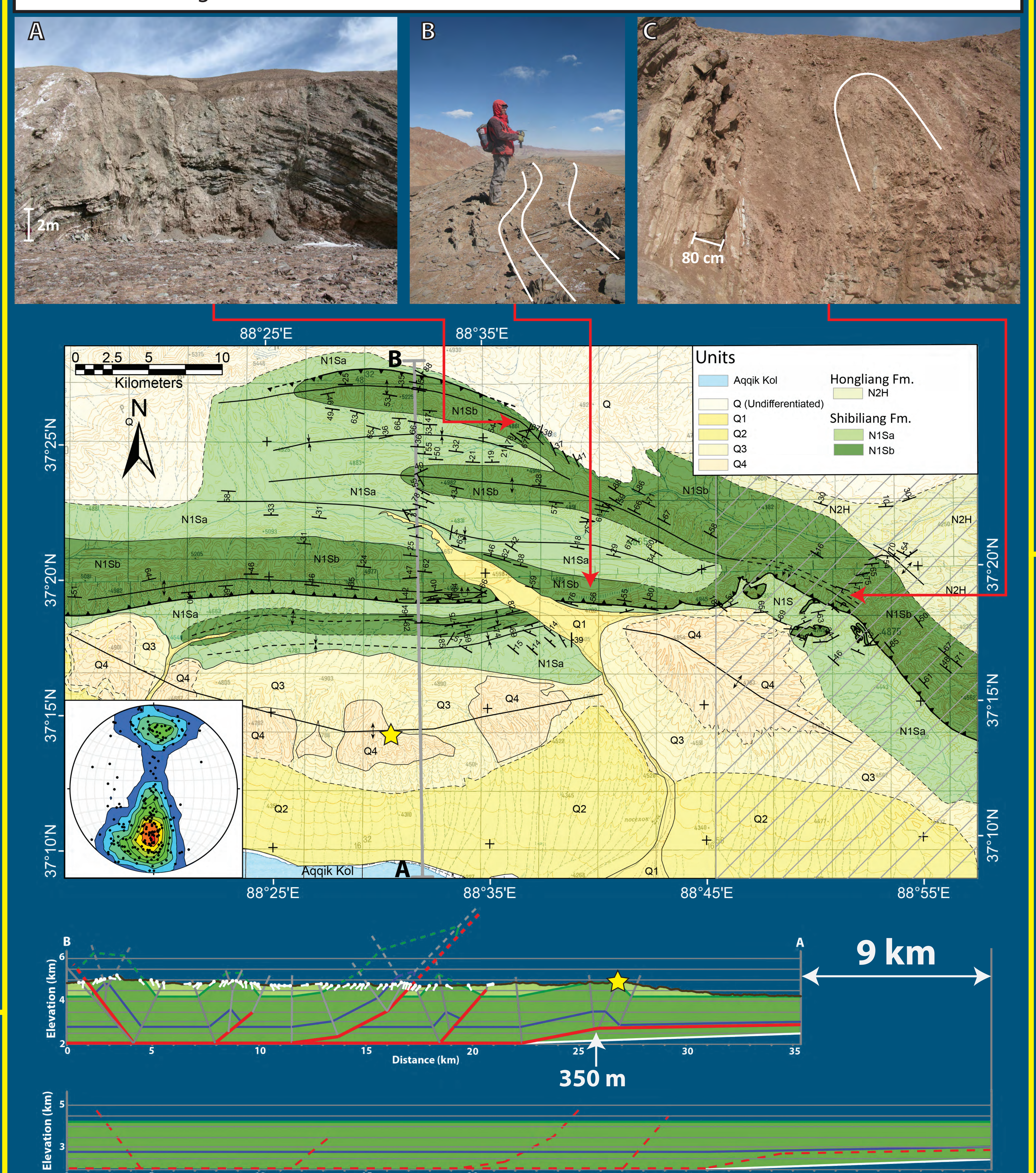

Figure 4 - Geologic map and balanced cross section of the Kumkuli Basin. Photos A and C are taken looking west, and B to the east.

Figure 3 - Sedimentary features of the Shibiliang Fm. A - Miocene ungulate track cast. B - Symmetrical ripple casts. C - Trough cross bed. D - Mud cracks in carbonaceous siltstone.

^{36}Cl Surface Exposure Dating

- Samples collected along a depth profile at ridge top of Quaternary fold.
- Alluvial fan material comprised primarily of siltstones and limestones from Miocene basin strata and surrounding ranges.
- Samples analyzed at PRIME Lab for ^{36}Cl concentrations.
- We use equations from the spreadsheet calculator of Schimmelpfennig et al (2009) to derive the age, initial ^{36}Cl concentrations and density of our sample.
- We assume a zero erosion rate, which is consistent with the hyperarid environment of the Kumkuli Basin.

- **Resulting surface age is 210 ± 12 ka with 95% confidence.**
- **As the fold accommodated 350 ± 175 m of north-south shortening, rates are 1.7 ± 0.9 mm/yr.**
- **Constant shortening rates imply deformation initiated at ~5 Ma, consistent with conglomerates in the Hongliang Fm.**

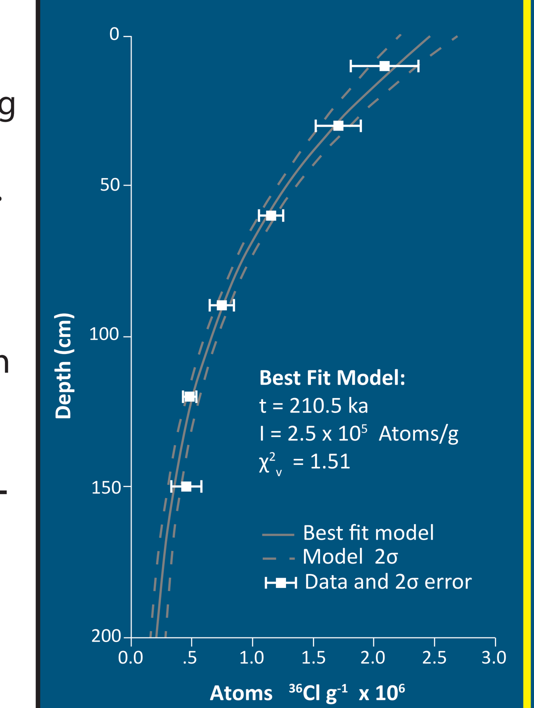

Figure 5 - Field site for 36Cl cosmogenic radionuclide dating at ridge top of Quaternary fold.

Geomorphic Reconstruction

- We reconstruct the original depositional surface of the dated alluvial fan using the modern elevations of nearby streams (B and C in Figure 5).
- The western stream (C) has been unaffected by Plio-Quaternary deformation.
- Modern stream elevations are interpreted as representing the depositional elevation of the sampled alluvial fan.
- Difference between stream and modern fan elevations then equals total uplift.
- The difference in estimates from streams B and C is interpreted as an uncertainty.
- We assume aggradation has been negligible, resulting in a minimum estimate of uplift rates.

- **We estimate 694 ± 21 m of uplift at the sample site, yielding 3.3 ± 0.3 mm/yr uplift rates.**

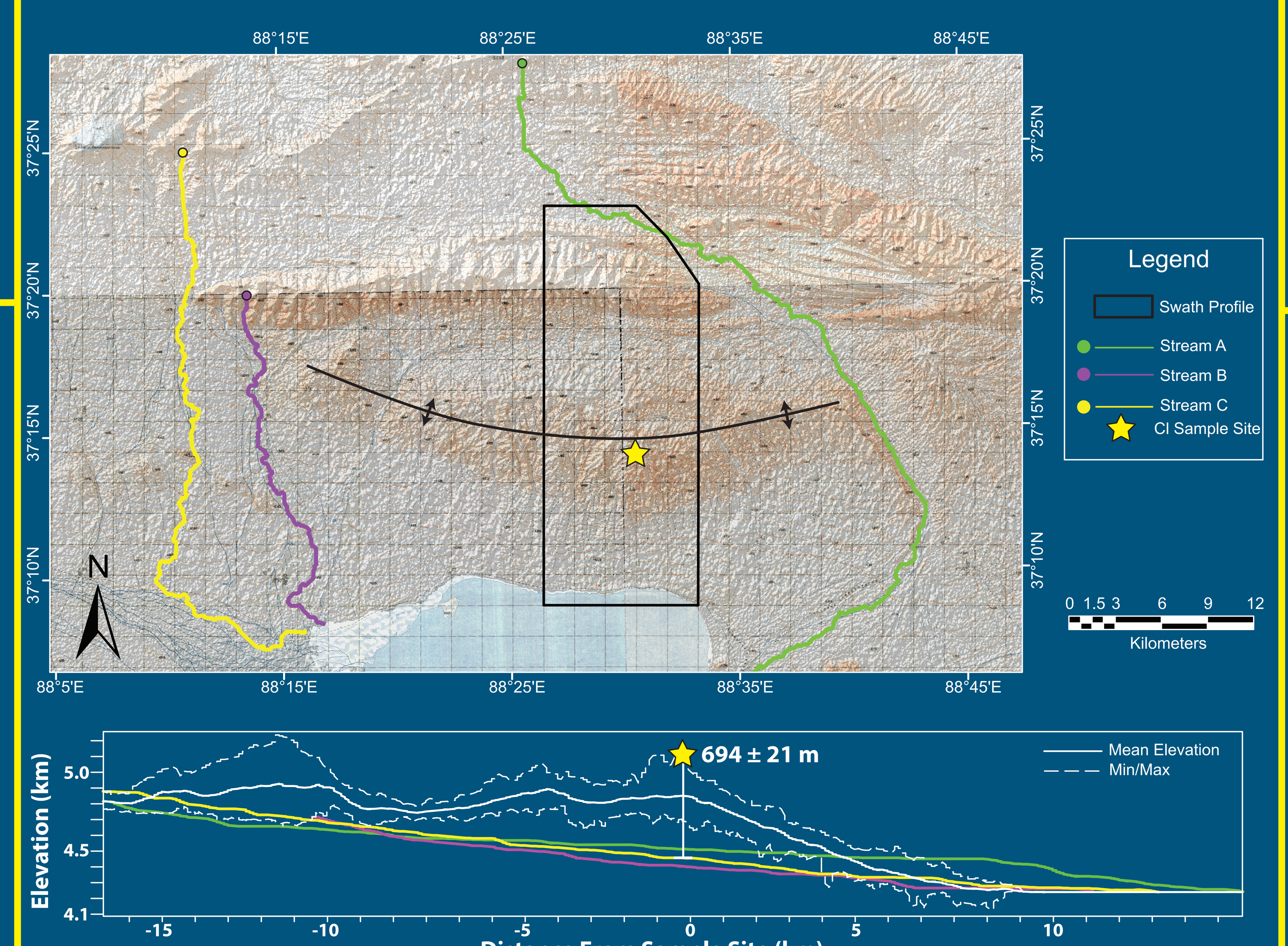

Figure 5 - Topographic map of a portion of the Kumkuli Basin, and selected streams (top). Selected stream profiles, with A representing a disturbed stream, B a stream affected by older (Pliocene ?) deformation, and C an undisturbed stream (bottom). The latter two are used to reconstruct the original depositional surface of the alluvial fan and estimate total uplift.

Discussion

- Deformation in the Kumkuli Basin verges to the northeast.
- Shortening in Kumkuli may be a consequence of slip on the Kunlun and Altyn Tagh Faults
- Regional seismicity shows that the Kunlun Fault may be linked to the Manyi segment, after a distinct southwesterly turn near Bukudaban Feng (Figure 6).
- The initial turn is delineated by the course of the M_w 7.8 Kokoxili rupture (Lasserre et al., 2005; Klinger et al., 2005)
- The joint Kunlun-Manyi fault would run sub-parallel to the Altyn Tagh Fault.
- The Kunlun-Manyi and Altyn Tagh then define a broad regional shear zone, iwhich contains the Kumkuli Basin.

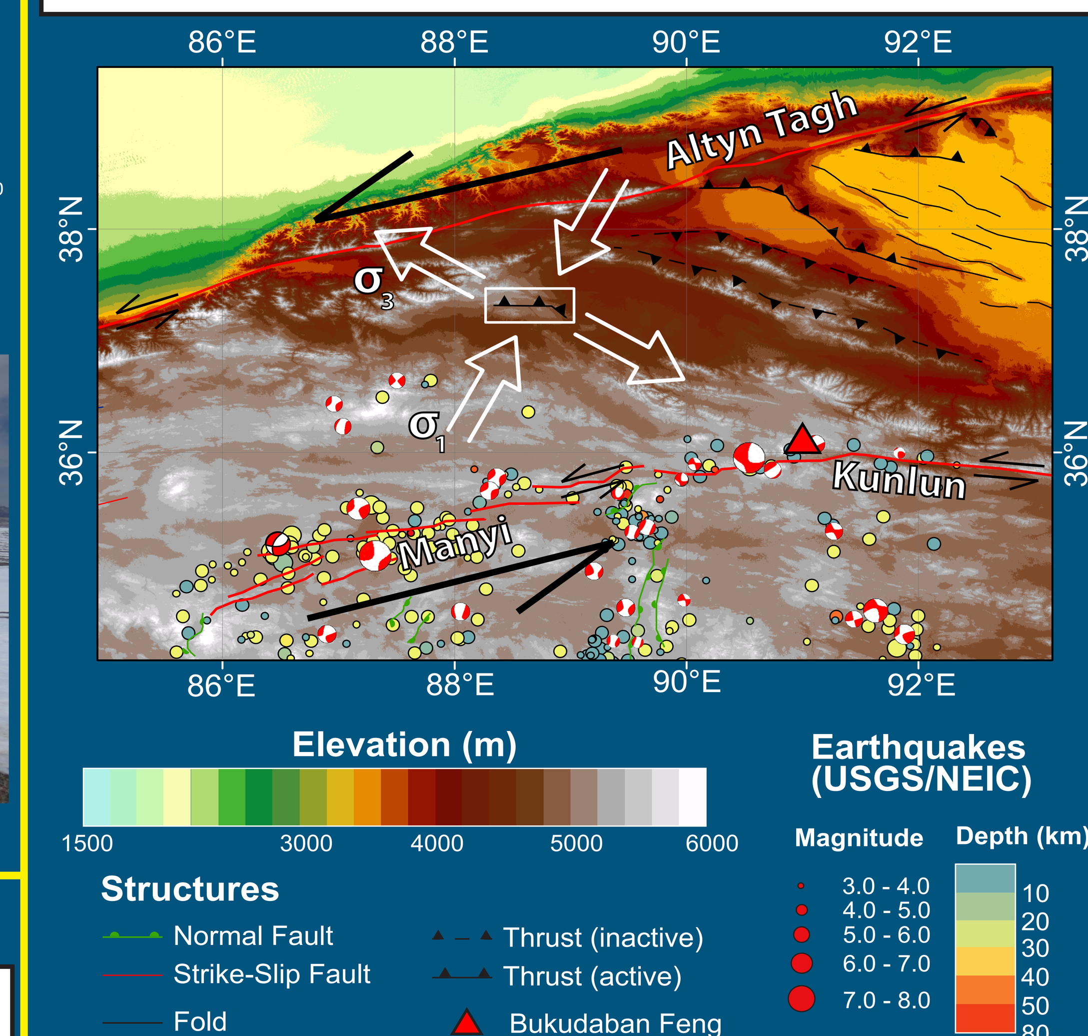

Figure 6 - Interpretation of regional faulting as a lithospheric shear zone between the Altyn Tagh Fault (ATF) and the Manyi segment of the Kunlun Fault. White box shows location of Kumkuli Basin and inferred stresses within the shear zone.

Conclusions

- Shortening in Kumkuli Basin initiated in Pliocene time, and has accommodated ~9 km of shortening at rates of 1.7 ± 0.9 mm/yr.
- The youngest phase of shortening in Kumkuli has resulted in ~700 m of uplift of Pleistocene alluvial fan strata at rates of 3.3 ± 0.3 mm/yr.
- We propose that the Kunlun Fault transfers slip to the Manyi segment.
- We relate shortening in the Kumkuli Basin to a large step-over between the Kunlun and Altyn Tagh strike-slip faults at the western termination of the Kunlun fault. While deformation rates are relatively high for this part of Tibet (> 1 mm/yr), low percent strain (21%) suggests that transpressional deformation between major strike-slip faults likely made a minor contribution to crustal thickening.

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