Structural, paleogeographic and topographic evolution of the northern Tibetan Plateau margin: Evidence from the southern Tarim basin, northern Hexi Corridor, and Qaidam basin

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The sedimentary record on and adjacent to the northern Tibetan Plateau is providing new constraints on the absolute and relative timing of upper crustal deformation, exhumation, and topographic growth. Furthermore, these rocks record changing depositional environments through the Cenozoic and provide a recorder for isotopic, detrital thermochronologic and other measures of tectonic activity at Earth's surface.

The sequence of Cenozoic deformation on the northern margin of the plateau is poorly understood prior to the late Oligocene, resulting from a lack of extensive Paleocene-Eocene sedimentary deposits. However, the Oligocene-Pliocene sedimentary record is relatively complete in the Qaidam, Tarim and Hexi Corridor basins, as well as numerous smaller intermontane basins within the Altun Shan, Qilian Shan, and Kunlun Shan. These deposits are the focus of our studies.

Large-magnitude strike-slip faulting on the Altyn Tagh fault initiated in the Oligocene, as demonstrated by previous workers in the Tarim and Qaidam basins (Bally et al. 1986, Hanson 1999, Rumelhart 1999). Differential offsets on Late Oligocene – Early Miocene strike-slip basins along the Altyn Tagh fault also demonstrate progressive deformation on the Altyn Tagh fault, and suggest that most strike-slip (~310 km of 375±25 km in the central-eastern segment of the Altyn Tagh fault) occurred by the end of the early Miocene (Yue et al. 2001, 2004, Ritts et al. 2004). The older piercing points from the Oligocene-Early Miocene Xorkol basin that demonstrate this early phase of rapid, high-magnitude slip are age-correlative with fine-grained rocks in the footwall of the Northern Altyn Tagh reverse fault (Ritts et al. in press), fine-grained rocks in the footwall and hanging wall of the North Qilian thrust fault (Bovet et al., in review) and fine-grained rocks proximal to the Kunlun Shan and Qilian Shan in the Qaidam basin. These relationships are interpreted to indicate that significant crustal shortening and surface uplift in the Altun Shan, Kunlun Shan, and Qilian Shan did not accompany this Oligocene – earliest Miocene rapid slip on the Altyn Tagh fault.

Late Early to mid-Miocene strata throughout the region have a rapid transition to massive, boulder conglomerate sections; these lithologies continue to be dominant in the Miocene-Quaternary section. In all cases, these conglomeratic sections contain sediment derived locally from adjacent mountain ranges, have paleocurrents directions that are strongly transverse to these ranges and display proximal to distal gradients moving away from these ranges. These characteristics are indicate that these conglomeratic sections are coeval with shortening, surface uplift, and exhumation of the Altun Shan, Qilian Shan, and Kunlun Shan. The age of initiation of conglomeratic sedimentation is difficult to precisely define in some sections, but throughout the study region it can be bracketed to Miocene, and where more precise determinations are possible, it ranges from 18-11 Ma. In sections along the Altyn Tagh fault, this change to conglomeratic deposition overlies older strata that comprise large-offset piercing points on the Altyn Tagh fault. Furthermore, in the Xorkol, Aksay, Xorkol Pass, and Mangnai areas, these Neogene conglomerates have small or no offset from their source terranes on the opposite wall of the Altyn Tagh fault. Thus, piercing points in multiple post-Early Miocene basins along the Altyn Tagh fault demonstrate that the rate of strike-slip dramatically decreased after the Early Miocene, concomitant with initiation of shortening in the Qilian Shan, Kunlun Shan and Altun Shan.

Neogene conglomeratic deposition is dominated by waterlain facies, similar to the energetic river systems flowing from the Altun Shan, Kunlun Shan and Qilian Shan today. Furthermore, these conglomerates are interbedded with eolian deposits in some sections, particularly in the southern Tarim basin, suggesting that the modern depositional systems and climatic regime was fully established by mid-Miocene time.

We interpret this succession of depositional styles to reflect the evolving structural regimes on the northern margin of the Tibetan Plateau. Pre-Oligocene tectonic quiescence is suggested by the lack of Paleocene-Eocene strata in the region, and modeled slow-cooling from thermochronologic data (Sobel et al. 2001, Ritts et al. in press). Rapid, large-magnitude strike-slip faulting on the Altyn Tagh fault initiated in the Oligocene and continued into the Early Miocene, synchronous with shortening in the southern and central Tibetan Plateau (Cyr et al. 2005, Graham et al. 2005). Strike-slip faulting on the Altyn Tagh fault slowed dramatically with the mid-Miocene initiation of shortening in the fold-thrust belts of the northern Tibetan Plateau, the Qilian Shan, Kunlun Shan and Altun Shan. This mid-Miocene initiation of crustal shortening and slowing of strike-slip faulting, represents the timing of major surface uplift and exhumation on the northern margin of the Tibetan Plateau and establishment of the present topographic front of the Plateau. We further suggest that this sequence of structural events indicates northward growth of the Tibetan Plateau through a process where strike-slip deformation accommodated plate-like lateral extrusion of the northern plateau in the Oligocene and Early Miocene, concomitant with crustal shortening and construction of topography in the southern and central Tibetan Plateau, followed by propagation of distributed crustal shortening, surface uplift into the northern Tibetan Plateau region in the mid-Miocene, and slowing of slip on the Altyn Tagh fault.

References

Bovet PM, BD Ritts, G Gehrels, OA Abbink, BJ Darby and J Hourigan. Evidence of Miocene crustal shortening in the North Qilian Shan from Cenozoic stratigraphy of the western Hexi Corridor, Gansu Province, China. *American Journal of Science* (in review)

Cyr AJ, BS Currie and DB Rowley. 2005. Geochemical evaluation of Fenghuoshan Group lacustrine carbonates, north-central Tibet: Implications for the paleoaltimetry of the Eocene Tibetan Plateau. *Journal of Geology* 113: 517-533

Graham SA, P Chamberlain, Y Yue, BD Ritts, AD Hanson, TW Horton, JR Waldbauer, MA Poage and X Feng. 2005. Stable isotope records of Cenozoic climate and topography, Tibetan Plateau and Tarim basin. *American Journal of Science* 305:101-118

Hanson. 1999. *Organic geochemistry and petroleum geology, tectonics and basin analysis of the southern Tarim and northern Qaidam basins, northwest China.* Ph.D. dissertation. Stanford University, Stanford, 388 p

Ritts BD, YJ Yue and SA Graham. 2004. Oligocene-Miocene tectonics and sedimentation along the Altyn Tagh fault, northern Tibetan Plateau: Analysis of the Xorkol, Subei, and Aksay basins. *Journal of Geology* 114 (2)

Ritts BD, YJ Yue, SA Graham, ER Sobel, OA Abbink and Stockli D. From Sea Level to High Elevation in 15 Million Years: Uplift History of the Northern Tibetan Plateau Margin in the Altun Shan, *American Journal of Science* (In press),

Rumelhart PE. 1999. *Cenozoic basin evolution of southern Tarim, northwestern China: Implications for the uplift history of the Tibetan Plateau.* Ph.D. dissertation. Los Angeles, University of California. 268 p

Yue, YJ, BD Ritts and SA Graham. 2001. Initiation and long-term slip history of the Altyn Tagh fault. *International Geological Review* 43 (12): 1087-1093

Yue, YJ, BD Ritts, SA Graham, JL Wooden, GE Gehrels and Z Zhang 2004. Slowing extrusion tectonics: Lowered estimate of the post-Early Miocene slip rate along the Altyn Tagh fault. *Earth and Planetary Science Letters* 217: 111-122