Fault Histories of the Northeastern Tibetan Plateau Margin: Geodynamic Implications of Far-Field Deformation During Continental Collision

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The distribution of faulting with respect to the collisional plate boundary provides important geodynamic constraints. First, the "bulk strain rate" of the continental crust or lithosphere can be derived by the plate convergence rate divided by the distance over which faulting is distributed. Second, changes in the type or rate of faulting at the plateau perimeter may indicate how gravitationally-derived stresses originating from the interior of Tibet have evolved as a function of time. We review the chronology of fault histories in northeastern Tibet, largely derived from new and recently published low-temperature thermochronometry data, and with additional resources derived from the published literature. The northeast margin of the plateau is a key locality for understanding the longevity of faulting and subsequent changes to faulting patterns. The strike of this plateau margin is perpendicular to convergence and allows us to consider a two-dimensional model of bulk plateau strain. This margin is also relatively uncomplicated compared to western Tibet where large strength heterogeneities exist and undoubtedly influence the distribution of faulting.

Low-temperature thermochronometry ages from across northeastern Tibet range from Jurassic to late Miocene time, which suggests that the overall erosion magnitude is less than a few kilometres and that entire Cenozoic thermal histories are commonly preserved in vertical elevation sample profiles. Ages from fault blocks show accelerated middle-Eocene to Oligocene erosion rates that are interpreted as thrust fault initiation near collision time (Clark and others, 2010). Collision-age faulting is significant because it demonstrates that the northern perimeter of the plateau has changed little since collision began. A stationary northeastern perimeter to the plateau effectively implies that the orogen has grown smaller in north-south extent with time. By extrapolating the relationship between plate convergence rate and the north-south extent of deformation, we evaluate the bulk strain rate of Tibet that has evolved since collision began. Using recently published plate motions of India with respect to Eurasia over the last 70 Myr, we show that exponentially decreasing convergence rates can be related to the narrowing of the orogen such that the average strain rate across Tibet remains constant and is consistent with modern strain rates derived from geodetic values. Constant strain rate is an unexpected finding that implies a previously unrecognized link between far-field deformation, rheology and plate motions in convergent continental settings.

In addition to thrust faulting occurs within approximately 10 Myr of collision, we also identify a major kinematic change in faulting pattern that develops or evolves by at least mid-Miocene time. In contrast to the few, relatively continuous faults and broad basins that characterize the early Cenozoic fault history, the Miocene and younger period is dominated by the appearance of new faults that are more diverse in strike orientation and sense of slip, and are more closely spaced and discontinuous. These new structures are bound by two major left-lateral strike slip faults (Kunlun and Haiyuan faults) and possibly relate to the transfer of motion between them (Duvall and Clark, 2010). A change in faulting style in northeastern Tibet correlates with a dramatic decrease in fault slip rate of major strike-slip faults (Ritts and others, 2008), initiation of new fault systems (Blisniuk and others, 2001; Wang and others, 1998), expansion of eastern Tibet by lower crustal flow (Kirby and others, 2002; Clark and others, 2005; Ouimet and others, 2010) and propagation of faulting into the eastern Himalayan foreland (Clark and Bilham, 2008). The kinematic change in northeastern Tibet in Miocene time potentially relates to gravitationally derived stresses from central Tibet that initiates lower crustal flow or changes in GPE due to mantle foundering (Lease and others, in review).

Despite a dramatic change in the style and orientation of faults since Miocene time, the northeast perimeter of the plateau changes by only a modest amount. Faulting expands to a region 150 km north and east of where deformation had previously occurred. A stationary boundary that is established at collision time is not easily explained by existing indenter models of continental convergence into a uniform lithosphere and may be better described by considering the role strength heterogeneities in the continental lithosphere (Dayem and others, 2009) or basal tractions induced by small-scale mantle flow resulting from sinking high-density bodies. Under some circumstances, basal tractions may also contribute significantly to plate motion where known contributions from edge tractions are insufficient.

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