# The Uplift of Mountain Chains along the Northern and Eastern Margins of the Tibetan Plateau

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The first-order feature of the Tibetan Plateau is its relative flat interior and rugged margins. Mountain chains with elevation higher than the plateau interior constitute the plateau margins, including the Himalaya along its southern margin, the Karakorum along its western margin, the Altyn Tagh and Qilian Shan along its northern margin, and the Longmen Shan and Hengduan Shan along its eastern margin. Their rugged geomorphology and intense active tectonics show that these mountain chains have been actively deforming in late Cenozoic time, and are manifestations of the upward and outward growth of the Tibetan Plateau. Given their size and elevation, these mountain chains are important in environmental change and natural hazard occurrence in continental Asia.

Formation of high mountains is always associated with active deformation. The growth of the Altyn Tagh mountains is controlled by the Altyn Tagh fault, dominated by left-lateral strike-slip with a minor component of crustal shortening. Active tectonics in the Qilian Shan are characterized by partitioning of oblique convergence into left-lateral strike-slip faulting along the range-crest (the Haiyuan fault) and crustal shortening across the entire range especially along both its range-fronts. Shortening near the ends of major strike-slip faults also contributes to uplift in parts of the ranges in the northern margin of the Tibetan Plateau. The strike-slip faults in the northern margin of the plateau redistribute crustal thickness, accommodate regional oblique convergence, and reconcile inhomogeneous deformation. The Longmen Shan fault zone is predominantly a convergent boundary with a right-lateral strike-slip component. The co-seismic high-angle oblique reverse faulting and the uplift associated with the 2008 Wenchuan earthquake serve as a "snap-shot" of the style of late Cenozoic deformation of the Longmen Shan in the eastern margin of the Tibetan Plateau, and explain the presence of steep relief (>4000 m) with no coeval foreland subsidence. Formation of the north-south trending mountain ranges in Yun'nan Province (Hengduan Shan, or Longitudinal mountains) may be controlled by active north-south trending strike-slip faults. Outward flow of Tibet's crustal material and clockwise rotation around the Eastern Himalaya syntaxis may have caused north-south trending, left-lateral strike-slip motion in the Hengduan Shan region. The styles of late Cenozoic deformation in these mountain chains represent patterns of outward growth of the Tibetan Plateau and provide information on the geodynamics of continental deformation.

Although the onset of Cenozoic deformation in these mountain chains can be traced back to immediately after the collision between India and Eurasia, the late Cenozoic (14-6 Ma) appears to be the major period when uplift accelerated so that these mountains attained their current elevations to become significant geomorphic features. The initiation of mountain building differs from one mountain to another within this time period. Onset of uplift of the Altyn Tagh appears to be at 7-10 Ma. In the Qilian Shan and Qingling region, the exhumation started from 14 Ma to 6 Ma, and seems to propagate northeastward. Rapid exhumation in the Longmen Shan is reported to be from 5-12 Ma. Dating of rapid incisions of major rivers in the Hengduan Shan suggests major exhumation from 9-13 Ma. Thus, the northern and eastern margins of Tibetan Plateau appear to have grown outward and upward from 14-6 Ma.

The outward growth of the plateau, acceleration of tectonic deformation, and formation of mountain chains along the margins of Tibetan Plateau requires a change in the geodynamic framework that drives tectonic deformation of Asia. How this change is caused is not yet understood, but may relate to a slowing of relative motion between India and Eurasia, convective removal of Tibet's mantle lithosphere, and lower-crustal flow outward from the plateau interior. The change in driving forces may have triggered outward flow of the lower-crustal material of the Tibetan Plateau northward and eastward, that in turn caused outward growth and formation of mountain chains in the northern and eastern margins of the Tibetan Plateau.

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