Construction of the Tibetan Plateau by Distributed Lithospheric-Scale Shortening: Evidence from Deep Seismic-Reflection Profiling across Northeastern Tibet

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The northeastern corner of the Tibetan plateau south of Lanzhou has been interpreted as one of outlets of middle-crustal flow sourced from the high-altitude central Tibetan plateau. To test this hypothesis, a 240-km long north-south deep seismic-reflection profile was obtained from Tonggor to Hezuo along longitude of ~103°E across northeastern Tibet. The profile traverses the Songpan-Ganze terrane, the eastern segment of the active left-slip Kunlun fault, and the Kunlun-Qaidam terrane. Major structures in the Songpan-Ganze terrane are isoclinal folds in Triassic strata formed during the latest Triassic closure of the Paleo-Tethys ocean(s) and younger Cenozoic thrusts (mostly south-directed) placing Triassic strata over Tertiary basin fill. The structures in the Kunlun Qaidam terrane north of the Kunlun fault are marked by the appearance of two large anticlinoria cored by Paleozoic and locally Proterozoic units flanked by Paleogene strata. This relationship indicates that their formation occurred in Cenozoic. The Kunlun fault marks the boundary between the two terranes and has developed via reactivation of the Paleo-Tethys suture zone. Our detailed examination of the seismic profile assisted by deep-well data (> 6 km in the Songpan-Ganze terrane) has revealed that the Moho is offset by the vertical Kunlun fault zone for ~10 km. The Moho is also offset by a series of low-angle thrusts with total shortening on the order of at least 10s km along the profile. The Songpan-Ganze terrane consists of four structurally distinctive sequences bounded by major low-angle thrusts. They are from the bottom to the top (1) a highly reflected and well laminated lower crust that exhibits three prominent hanging-wall cutoffs, indicating that the section has been duplicated by discrete thrust shear zones, (2) a thickly laminated but internally folded section in the middle crust, (3) a thrust triangle zone tapering southward lies in the lower part of the upper crust, and (4) a highly folded section corresponding to surface exposure of Triassic flysch complexes is observed in the uppermost part of the section. We interpret sequence (3) as Proterozoic-Paleozoic passive margin sequence of the South China block and sequences (1) and (2) as its basement equivalent to the Pengguan high-grade metamorphic complex in the Longmen Shan to the east. For the Kunlun-Qaidam terrane, two main lithologic units can be recognized in the seismic reflection profile: the relatively transparent basement with short and discontinuous reflectors and its cover sequence with well-laminated and continuous reflectors. The main structures across this terrane are two large wedge systems cored by the two large anticlinoria exposed the northern and southern margins of the terrane along our traverse. The southern thrust wedge tapers northward whereas the north thrust wedge tapers southward. As a result of this structural configuration, a large synclinorium is developed between the two wedges. Internally, each thrust wedge comprises multiple thrust duplex systems and smaller wedges.

The total amount of shortening across the 130-km segment of the profile is at least 90 km. We tentatively suggest that this amount of shortening was entirely created in the Cenozoic rather than in the Triassic, as the style of Triassic deformation is distinctively different from that of the Cenozoic: the former is characterized by tight to isoclinal folds whereas the latter by flat-ramp thrusts that cut and duplicate the older folded sequences. The presence of discrete shear zones offsetting the Moho and duplicating lower-crustal sections on both sides of the Kunlun fault suggests that channel flow and continental subduction are implausible mechanisms for the development of the northeastern Tibetan plateau. Instead, distributed shortening of the entire lithosphere during Cenozoic India-Asia collision is the most likely process that has generated the northeastern Tibetan plateau.

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