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Anatomy and crustal evolution of the central Lhasa terrane (S-Tibet) revealed by investigations in the Xainza rift

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The present-day appearance of the Himalayan-Tibetan orogen is the result of ongoing northward translation of the Indian subcontinent. Terrane amalgation, subduction of oceanic lithosphere during closure of the Neo-Tethys, and the final hard-collision of India with Asia resulted in crustal shortening, extensive magmatism, and late-stage rifting across the uplifted Tibetan plateau. This study presents zircon LA-MC-ICPMS U-Pb and zircon and apatite (U-Th)/He data from the central Lhasa terrane (Xainza rift) providing new insights into the evolution of the central Lhasa terrane from subduction and collision related crustal thickening to initiation of E-W extension.

The Xainza rift, terminated by the right-lateral Gyaring-Co fault in the north and the Indus Yalu Suture Zone (IYSZ) in the south, comprises the following main tectono-stratigraphic units. (1) WNW-trending thrust sheets composed of Paleozoic limestone and low-grade slate that preserve ductile fabrics pre-dating extensive Gangdese magmatism. (2) Voluminous granitic to granodioritic plutonic rocks and associated rhyolitic to andesitic volcanic rocks dominate the central Lhasa terrane crustal section exposed along rift-bounding normal faults within the Xainza rift. Zircon LA-MC-ICPMS U-Pb data define two distinct episodes of plutonism and coeval volcanism dated at 129-132 Ma in the northern and central part of the Xainza rift and 50-60 Ma in both the northern and southern portions of the rift. (3) A Miocene granite, exposed as a $\sim$30 km long exhumed extensional fault block within the massive southern portion of the Gangdese Batholith, yielded a zircon U-Pb age of $\sim$14 Ma.

The structural development of the central Lhasa terrane is characterized by the following major tectonic events. (1) N-S directed shortening related to the early Cretaceous Lhasa-Qiangtang collision that resulted in large-scale folding, thrusting, and low-grade metamorphism of Paleozoic sediments. Following a long period of crustal growth by extensive magmatism, (2) initiation of rift systems perpendicular to the older structural grain reshaped the central Lhasa terrane. Detailed low-temperature zircon and apatite (U-Th)/He thermochronological studies elucidate the initiation and timing of exhumation of the rift flanks. Zircon (U-Th)/He data from the northern portion of the rift yielded middle Miocene ages indicating an early phase of rifting, while apatite (U-Th)/He ages from samples collected along normal faults throughout the rift reveal a regional episode of accelerated exhumation in the late Miocene (6-10 Ma), as do zircon (U-Th)/He ages from the southern portion of the Xainza rift that has experienced large-magnitude extension.

Based on integrated structural and thermochronometric constraints, we propose that N-S directed crustal shortening in the central Lhasa terrane resulted in early Cretaceous Lhasa-Qiangtang thin-skinned thrust tectonics accompanied by low-grade metamorphism. Post-kinematic granite emplacement and volcanic activities mark the end of this shortening event. After a period of magmatic quiescence, late Cretaceous to early Cenozoic arc magmatism and crustal growth dominated the Lhasa terrane driven by northward subduction of the Neo-Tethys oceanic crust. Slab rollback and influx of hot asthenosphere beneath the Lhasa terrane is thought to have triggered extensive arc magmatism and volcanism throughout the southern and central Lhasa terrane. Neo-Tethyan convergence culminated in hard-collision of India and Asia followed by underplating of Indian lithosphere beneath the Lhasa terrane. There is no evidence of Neogene N-S shortening within the Xainza rift suggesting that ongoing northward translation of India was predominately accommodated by thrusting at the margins of the plateau and within the Himalayas. Consistent with other investigations, we propose that E-W extension in the Lhasa terrane started as early as the middle Miocene. This middle Micoene rift pulse is likely responsible for the latest magmatic event at $\sim$14 Ma within the Gangdese Batholith. The modern rift morphology and structural grain is dominated by a second, Pliocene rifting episode that is linked kinematically to dextral strike-slipe faulting and to a transition in

the Tibetan strain field. Although our dataset cannot explain when the Tibetan plateau reached its maximum elevation, the onset of rifting in the middle Miocene probably represents a minimum estimate of plateau uplift cessation.