

Detection of a widespread mantle component of ^3He in thermal springs of Lhasa Block and Tethyan Himalaya, eastern Tibet: evidence for roll-back of the Indian-Asian mantle suture south of the Yarlung suture zone, and asthenospheric upwelling beneath the Lhasa block

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Our Sino-US collaborative study of Xizang thermal springs and their noble gases has thus far sampled 100 separate springs for $^3\text{He}/^4\text{He}$ analyses, including 33 new measurements discussed here. Although eastern Tibet, 88–93°E has historically seen the densest $^3\text{He}/^4\text{He}$ analyses in Tibet due to the relatively simple access, this sampling was focussed on the active geothermal fields and springs in the Yangbajain-Gulu rift zone, with only three reliable air-corrected values published from outside this rift, and no analyses from south of the Yarlung Tsangpo suture. Here we focus on extending the distribution of sampled springs into regions clearly outside the Neogene rift systems, and south into the Tethyan Himalaya.

Observations of mantle contributions to ^3He at Earth's surface require incipiently melting mantle at depth to continuously release ^3He into the crust faster than the ^3He signal can be overwhelmed by radiogenic production of ^4He . Cratonic Indian mantle that is far colder than its melting temperature cannot be a source of ^3He , so mantle-sourced ^3He in Tibet must come from hotter Tibetan mantle or asthenosphere. Crustal helium (dominated by radiogenic ^4He) has a $^3\text{He}/^4\text{He}$ ratio of $0.02 \cdot R_A$ (R_A is the atmospheric $^3\text{He}/^4\text{He}$ ratio), whereas upper-mantle helium (enriched in primordial ^3He) has the value $8 \cdot R_A$. Any measured $^3\text{He}/^4\text{He}$ ratio after correction for atmospheric contamination (denoted R_C) $> 0.1 \cdot R_A$ is considered to have an unequivocal mantle component.

All previously studied springs within the Yangbajain-Gulu rift zone have $^3\text{He}/^4\text{He}$ ratios $0.1 \leq R_C/R_A \leq 0.9$, as far south as 30°N, just 90 km north of the Yarlung Zangbo Suture, leading to the claim that the “mantle suture” (northern limit of Indian lithosphere at the Moho, southern limit of incipiently melting Asian mantle at the Moho) must be south of 30°N. This location is controversial because many seismologists place the mantle suture at 31–33°N, encouraging an alternative explanation that a tear in the subducting Indian plate along the line of the Yadong-Gulu rift permits asthenospheric upwelling and transfer of ^3He into the Tibetan crust. Our new data show a single tear is not a good explanation, because we measure unequivocal mantle contributions of ^3He far outside the rift zone, for example within the Gangdese batholith in Lhasa (measurements of $R_C/R_A = 0.14$ and 0.70), and also close to the Banggong suture ($R_C/R_A = 0.25$ and 0.88 85 km northeast of Nagqu). However, we also extend the region of elevated R_C/R_A significantly further south, to the Yarlung Zangbo river along the line of the Yadong Gulu rift ($R_C/R_A = 0.60$), and south of the suture (Yalaxiangbo Dome: $R_C/R_A = 0.57$). With our current spatial coverage, the southern limit of mantle contributions to surface thermal springs trends east-southeast, from 50 km north of the Yarlung Tsangpo in the PumQu-Xainza graben to 100 km south of the Yarlung Tsangpo in the Cona-Sangri graben.

Our widespread observation of ^3He enrichment, now across 10^5 km^2 of eastern Tibet, is convincing evidence that the India-Asia mantle suture (northern limit of Indian lithosphere at the Moho, equivalently

southern limit of incipiently melting Asian mantle at the Moho) must lie close to and in places south of the Yarlung Zangbo suture, and that even if Indian crust is underthrust north of the suture its subjacent lithospheric mantle has rolled back or delaminated. We believe our new results, combined with alternate interpretations of seismic common-conversion point receiver-function profiles, help address the long-standing controversy about the northern limit of subducting India beneath eastern Tibet.

DEEP-2018