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Episodic Crustal Anatexis in the Eastern Himalayan Syntaxis: A Shift in Melting Mechanisms from Syn- to Post-collision

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Crustal anatexis governs continental differentiation and the rheological evolution of orogenic belts. Crustal melting mechanisms vary between syn- and post-collisional stages, reflecting changes in fluid availability, thermal structure, and tectonic regime, yet their temporal evolution remains incompletely understood. Here we present Cenozoic migmatites from the Nyingchi area of the Eastern Himalayan Syntaxis (southeastern Tibet). Integrating petrography, garnet major- and trace-element profiles, zircon and monazite U–Th–Pb dating with trace elements, and phase-equilibrium modelling, we reconstruct the P–T–t evolution and evaluate temporal changes in crustal melting during the India–Asia collision.

Zircon and monazite U–Th–Pb dating reveals two discrete anatectic episodes at ca. 49 Ma and ca. 25 Ma. Garnet records three growth stages (Grt I–III) with distinct zoning and sharp compositional discontinuities. Morphological features, inclusion assemblages, and compositional systematics indicate that Grt I and Grt II are peritectic garnet formed during two separate melting events, whereas Grt III formed during cooling through back-reactions between garnet and anatectic melt. Garnet trace-element signatures, coupled with zircon and monazite ages, link Grt I to the ~49 Ma event and Grt II–III to the ~25 Ma event, indicating contrasting melting mechanisms.

Phase-equilibrium modelling indicates that the older (~49 Ma) event occurred in collision-thickened lower crust at 760–800 °C, 9.0–10.5 kbar (geothermal gradient ~18–23 °C/km), dominated by dehydration reactions involving biotite and muscovite breakdown, with localized hydration melting. In contrast, the younger (~25 Ma) event took place at ~790–845 °C and 7.2–8.4 kbar, yielding a hot geothermal gradient of ~28–35 °C/km, consistent with lower-pressure melting under an extensional or lithospheric thinning regime. ~25 Ma monazite shows lower Rb/Sr and higher Sr–Ba than the ~49 Ma population, implying enhanced feldspar participation and a more H_2O-rich hydrating melting.

Given the low permeability of the deep crust, the ~25 Ma hydration melting was likely promoted by localized “flux enhancement,” whereby fluids released from hydrous layers were channeled into shear zones and coupled with heat input from lithospheric thinning and asthenospheric upwelling. These results document a transition from syn-collisional dehydration melting to post-collisional hydration melting in the Eastern Himalayan Syntaxis, providing new insights into melt-production pathways and Himalayan tectono-thermal evolution.