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Presence of ca. 43 Ma highly fractionated and normal calc-alkaline granites first identified in the Gangdese Batholith, southern Tibet

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The Gangdese Batholith in southern Tibet has long been linked with the subduction of Neo-Tethyan oceanic lithosphere and subsequent India-Asia collision. However, the specific processes of magmatic evolution and petrogenesis of the batholith remain poorly constrained because most existing studies have focused on its geochronological framework. New integrated whole-rock major and trace element, zircon U-Pb age, and zircon Hf isotopic data of granites from Dajia in the western Gangdese Batholith, southern Tibet establish the presence of highly fractionated syenogranite (HFS) and normal calc-alkaline monzogranite (NCM). One syenogranite sample has been dated by LA-ICP-MS zircon U-Pb method to be 43.9 $\pm$ 0.3 Ma and three monzogranite samples yielded ages of 42.6 $\pm$ 0.3 Ma, 42.7 $\pm$ 0.4 Ma, and 43.6 $\pm$ 0.3 Ma, representing the late-phase magmatism of the Gangdese Batholith. Six NCM samples display SiO_2 of 69-72 wt.%, K_2O of 4.9-5.5 wt.%, and Na_2O of 3.2-3.8 wt.%, with differentiation index (DI) in the range of 84-93. These rocks are enriched in Rb, Th, U, and LREE and depleted in Ba, Nb, Sr, P, and Ti, with $(La/Yb)_N$ = 18.1-26.9 and Eu/Eu* = 0.6-0.83. Eight HFS samples are characterized by high SiO_2 (75-78 wt.%) and DI (95-97), and significant negative Eu anomalies (Eu/Eu* = 0.27-0.70), although K_2O (4.8-5.3 wt.%) and Na_2O (3.2-3.6 wt.%) contents and $(La/Yb)_N$ (12.5-27.2) ratios are comparable to those of the NCM samples. These HFS samples display marked concave-upward middle rare earth element (MREE; Gd-Ho) patterns that are not observed in the NCM samples. The NCM and HFS samples have similar zircon Hf isotopic compositions with zircon ε_{Hf}(t) of -5.6 to +6.3 and -1.6 to +4.6, respectively. Such isotopic compositions, together with low heavy REE and Y abundances, indicate that both the NCM and HFS samples were most likely derived from partial melting of the thickened juvenile crust beneath the southern Lhasa subterrane with varying contributions from ancient continental crust material. The absence of fractionation trends between the NCM and HFS samples (e.g., SiO_2 vs. Sc and SiO_2 vs. Dy/Yb) suggests that the HFS samples with concave-upward MREE patterns can be interpreted as resulting from partial melting of basaltic lower crust leaving an amphibole-rich residuum followed by significant fractional crystallization of feldspar, plagioclase and apatite. The presence of HFS with low heavy REE and Y (6.2-15.3 ppm) abundances identified for the first time in the Gangdese Batholith corroborates that the southern Lhasa crust had already been thickened by ca. 43 Ma. High whole-rock zircon saturation temperatures (815˚C-869˚C) for the NCM samples suggest high heat supply likely associated with rising asthenospheric flow in response to post-collision breakoff of the Neo-Tethyan oceanic lithosphere.