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A Transect Across the Greater Himalayan Sequence of Bhutan: Evidence for a Minimum of 10 Ma of Ductile Flow Between the Outer South Tibetan Detachment and the Main Central Thrust

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ABSTRACT: Unique features of the Bhutan Himalaya are klippen of Tethyan sediments that overlie sillimanite and kyanite gneisses of the Greater Himalayan Sequence (GHS). The contact is strongly sheared, and referred to as the Outer South Tibetan Detachment (O–STD). Five such klippen are preserved in Bhutan and give insight into the Miocene displacement (ca. 24-11 Ma) of the STD system and on the evolution of the uppermost GHS. The base of the klippen are characterized by strongly sheared Grt-Bt±St±Sil schists of the Chekha Formation that appear to grade continuously upward into the black slates and weakly– to unmetamorphosed rocks of the Tethyan Sedimentary Sequence (TSS). Leucogranites intrude the Chekha Fm and the GHS in the vicinity of the contact, but not the TSS.

New metamorphic, structural and geochronologic data from the western side of the Tang Chu klippe show that deformation and metamorphism within the Chekha Fm. were underway prior to 17.6 Ma, and that ductile shearing clearly overprints peak metamorphic mineral assemblages and continued until after 14 Ma. These data, when combined with previously reported data from adjacent klippen and the Main Central Thrust Zone to the south, provide a record of fairly continuous ductile flow of the GHS between 25-23 Ma and 13-11 Ma, at which point displacement transfers north of the klippen, to the Kakhtang thrust and the Inner-STD.

Samples for this study were collected along a 10 km traverse and include four samples of Chekha Fm. and two samples of GHS collected across an ~ 80 m structural section that straddles the O-STD. The top of the interval starts in the Chekha Fm. and is characterized by the assemblage Grt-Bt-St, with a peak temperature near 600 °C. The base of the Chekha Fm. preserves Grt-Bt-Ms, with minor Sil, and peak temperatures near 650 °C; no evidence of partial melting is observed. The GHS samples are characterized by Grt-Bt-Ms-Sil and were partially melted. Peak metamorphic temperatures are estimated to be 650-750 °C. No pressure break is observed across the O-STD, and all peak temperatures correspond to a pressure of 6–7 kbar. In-situ, monazite SHRIMP U-Pb ages for the Chekha Fm. range from about 16.58 Ma ± 0.22 Ma (2σ) at the top of the interval to about 17.58 Ma ± 0.47 Ma (2σ) near its base. Apparent ages from monazite in the GHS range from 21.0 Ma ± 0.7 Ma (1σ) to 13.9 Ma ± 0.4 Ma (1σ).

Deformation outlasts metamorphism, as indicated by pre– to syn–kinematic porphyroblasts overprinted by shear bands. Samples from the Chekha Fm. show top-to-north extensional displacement at the top of the interval and conjugate top-to-north and top-to-south shearing indicative of flattening at the base. The GHS samples show dominantly top-to-south shearing overprinted by minor top-to-north shearing. The simultaneous displacement across the GHS and O-STD, the compression of isotherms, and the absence of a discrete pressure break across the O-STD are consistent with a model of ductile flow and extrusion.