Metamorphic and Structural Discontinuities in the Greater Himalayan Sequence, Karnali Valley, West Nepal

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Tectonometamorphic domains along the Himalayan front should ideally be separated by distinctive and diagnostic structural and metamorphic discontinuities that can be quantitatively tested along the strike of the orogen. Although previous workers have mapped the Greater Himalayan sequence (GHS) in structural contact above the Lesser Himalayan sequence (LHS) along the Main Central thrust (MCT) in the Karnali valley of northwestern Nepal (Murphy and Copeland, 2005; Robinson and others, 2006), the region lacks comprehensive metamorphic, microstructural, and geochronological data that are essential to differentiate between the two tectonometamorphic packages.

We present new results of detailed mapping, quartz petrofabric data, vorticity estimates, and thermobarometric estimates that document two discontinuities in strain and metamorphism within the previously defined GHS and LHS. The lower 'structural' discontinuity juxtaposes a pervasively sheared sequence of mid- to high-grade metamorphic rocks that exhibit top-to-the-south shear sense above low-strain rocks that preserve polydeformational features and primary sedimentary structures. The structurally higher 'metamorphic' discontinuity is characterized by up section changes from: (1) increasing to decreasing metamorphic pressures at peak metamorphic temperature, (2) preservation to destruction of prograde garnet zonation, and (3) a single metamorphic event associated with top-to-the-south directed deformation into polymetamorphic and polydeformational assemblages. These two discontinuities separate three tectonometamorphic domains, which correspond from low to high structural levels to: (1) the Lesser Himalayan sequence, (2) the lower Greater Himalayan sequence (GHS_L), and (3) the pervasively migmatitic upper Greater Himalayan sequence (GHS_U).

The structural discontinuity is defined based on the change up structural section from low-strain units into high-strain pervasively sheared units that exhibit top-to-the-south directed deformation observed from field observations, microstructural analysis, quartz petrofabrics, and vorticity analysis. Asymmetric quartz c-axis petrofabrics between the structural and metamorphic discontinuities indicate top-to-the-south directed deformation. The opening angles of quartz c-axis girdles (e.g. Law and others, 2004) constrain temperatures to 430°C at lower structural levels just above the structural discontinuity to >630°C immediately beneath the metamorphic discontinuity. Chessboard extinction within quartz from most specimens above the metamorphic break indicate deformation temperatures >630°C.

Vorticity estimates using the rigid clast method (e.g. Law and others, 2004) suggest nearly equal contributions of pure and simple shear in the GHS_L. The simple shear component of deformation reaches a maximum of ~65 % in the vicinity of the metamorphic break and decreases structurally downwards to a minimum of 40% at the lowest structural levels just above the LHS. The simple shear component also decreases structurally upwards to a minimum of 45% approximately 4 km structurally above the metamorphic break. Beneath the structural break, the preservation of sedimentary features and polyphase deformation indicate the rocks are not pervasively sheared.

The GHS_L contains garnet- through kyanite-grade rocks. Peak metamorphic assemblages are developed during south-directed deformation as evidenced by spiral and sigmoidal inclusion trails in garnet and staurolite. The GHS_U preserves a polymetamorphic history with peak metamorphic assemblages that exhibit complex timing relationships with south-directed deformation. Sillimanite-grade specimens collected above the metamorphic break commonly contain leucosome pods with relict kyanite blades, indicative of crystallization in the kyanite field. These same specimens contain strongly developed north-plunging lineations defined by fibrolitic sillimanite that, in conjunction with sigma porphyroblasts, C-C'-S fabrics, and mica fish, suggest south-directed transport in the sillimanite stability field.

In the GHS_U, sillimanite-grade migmatitic paragneisses and orthogneisses preserve peak metamorphic temperatures of 650-720°C at 5-10 kbar (THERMOCALC, v. 3.30). Peak metamorphic temperatures remain constant and pressures at peak temperatures decrease gradually up structural section from 10 kbar to 5 kbar. In the GHS_L garnet- to kyanite-grade meta-pelitic schists record peak metamorphism temperatures of 570-640°C at 7.5-10.0 kbar. Peak metamorphic temperatures systematically increase up structural section coincident with an inverse Barrovian field gradient, ranging from biotite- through kyanite-grade. Calculated pressures at peak temperatures gradually increase up section from 6 kbar in the structurally lowest garnet zone, reaching a maximum of 10 kbar at the top of the GHS_L, which roughly coincides with the kyanite-in isograd. Peak metamorphic temperatures in the GHS_L overlap with deformation temperatures obtained from quartz c-axis opening angles and the operating temperatures of the observed dynamic recrystallization mechanisms of quartz and feldspar.

The integration of metamorphic and microstructural data indicate three distinct tectonometamorphic domains, from low to high structural levels: (1) a low-grade weakly strained unit (LHS), (2) a pervasively sheared mid-to-high grade package with top-to-the-south directed deformation and peak-metamorphic temperatures coinciding with calculated deformation temperatures (GHS_L), and (3) a pervasively sheared high-grade migmatitic unit with a polymetamorphic history (GHS_U). Observations from the GHS_U are consistent with the model of the southward ductile extrusion of the GHS from mid-crustal depths that is defined by early high-P (kyanite-bearing) assemblages overprinted by syn-deformational high-T and mid-P (sillimanite-bearing) assemblages. Structural and metamorphic data from the GHS_L are consistent with that from central Nepal (Larson and others, 2010). The GHS_L is interpreted to represent either a series of ductilely-deformed and accreted slices beneath a southward extruding channel, or alternatively, the incorporation of material into the channel as its lower boundary migrated structurally downwards with time. This regime is manifested metamorphically by peak assemblages temporally coinciding with simultaneous crustal thickening and south-directed deformation within the MCT zone. Below the structural discontinuity, primary structures and greenschist-facies metamorphism are preserved, along with an absence of pervasive shearing, consistent with the LHS below the MCT as defined by Searle and others (2008).

Microstructural and metamorphic data from this study present a temporal 'snapshot' of the complex interplay between deformation and metamorphism at the transition zone between the LHS and GHS and strongly negates the premise that a single discrete thrust fault separates the two in the Karnali valley of western Nepal. The characterization of three tectonometamorphic units separated by two discontinuities in strain and metamorphism in west Nepal indicates the need to reassess the LHG-GHS transition in regions where they are mapped as separated by a single discrete fault.

References

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