Recognition of the South Tibetan Detachment in the Karnali klippe, western Nepal: implications for emplacement of Himalayan external crystalline nappes

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The Himalayan external crystalline nappes are traditionally viewed as a series of Greater Himalayan Sequence (GHS) klippen carried southward on the Main Central Thrust (MCT) (Ganser, 1964), and therefore represent the southernmost exposure of the metamorphic core. Larson et al. (2010) have recently proposed that a transition exists from older mid-crustal ductile flow in the hinterland to younger thrust-fold wedge deformation propagating into the foreland. The style and timing of deformation and metamorphism in the external klippen could therefore highlight this postulated transition. In contrast, an alternative tectonic model states that the South Tibetan Detachment (STD) and the MCT merge in southern Nepal, which implies a tectonic wedge geometry for the GHS (Yin, 2006; Webb et al. 2007, 2011). If the GHS is a tectonic wedge, external klippen are consequently crucial locations to study the geometrical relationships between the MCT and STD.

Our study is located at the eastern termination of the Almora-Dadeldhura klippe in western Nepal, which was originally investigated by Frank and Fuchs (1970), Arita et al. (1984) and Hayashi et al. (1984). More recently, from observations on the northern flank of the Karnali klippe, He (2013) proposed that the MCT and the STD merge at depth, thus suggesting a tectonic wedge geometry. This interpretation, however, warrants complementary data from the southern flank of the klippe. Consequently, one of the main objectives of our study is to investigate both the northern and southern flanks of the klippe and assess the relationships between the MCT and the STD. Our mapping was carried out along a ~125 km long transect from Jumla to Dailekh in a section of the klippe commonly referred to as the Karnali klippe (e.g. Upreti and LeFort, 1999; Johnson, 2005). This area occupies an intermediate geographic position between the typical homoclinal exposure of the GHS to the north and the southernmost crystalline klippen.

The Karnali klippe is an east-west trending synform defined at the base by a ~2 km thick folded top-to-the-southwest reverse-sense shear zone. Greenschist to amphibolite metamorphic-facies rocks consist of abundant granitic orthogneiss with common metapelite and local calcsilicate gneiss, quartzite and meta-arenite. The metamorphic field gradient increases from biotite grade near the basal shear zone to kyanite grade in the upper structural levels. On the southwestern flank, however, a decrease to staurolite grade is observed towards the top-bounding shear zone. The metamorphic rocks record both coaxial and top-to-the-southwest non-coaxial strain. Quartz deformation textures suggest temperatures of deformation in excess of 500 °C. In contrast, the structurally highest levels of the klippe exposes a ~1 km thick top-to-the-northeast shear zone that separates footwall metamorphic units from lower greenschist facies to subgreenschist sedimentary rocks in the hanging wall. This shear zone corresponds to a drastic change in lithology and break in metamorphic grade; above it, rocks vary structurally upwards from calcareous meta-arenite to micaceous crystalline limestone and silty laminated limestone. Quartz deformation textures suggest that temperatures of deformation decrease rapidly from >500 °C in the lower part of the top-to-the-northeast shear zone to 400 °C in its upper part. Calcite twining types in the upper part of the shear zone suggest temperatures of deformation >250 °C, whereas the weakly metamorphosed limestone above the shear zone was likely deformed at lower temperatures around 150-200 °C.

We correlate the amphibolite metamorphic-facies units of the Karnali klippe with the GHS, which is exposed less than 20 km northeast of Jumla, on the basis of lithologic and metamorphic similarities. The sedimentary rocks at the structurally highest levels are tentatively correlated with the Cambro-Ordovician Tethyan sedimentary sequence (TSS) 'Yellow marble' (Robinson et al. 2006) and phyllite, quartzite and

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marble (Murphy and Copeland, 2005) in western Nepal, and to the Annapurna-Yellow-Larjung Formation (Colchen et al. 1981, 1986) in central Nepal. This interpretation implies that the basal top-to-the-southeast shear zone represents the MCT and the top-to-the-northeast shear zone is the STD. The presence of the STD on the north and west flanks of the folded TSS and the presence of GHS rocks southwest of the TSS contradicts conclusions that the STD and the MCT merge at depth in the core of the klippe (He, 2013), and therefore weakens the argument for tectonic wedging in western Nepal. The geology of the Karnali klippe is similar to that of the Dadeldhura klippe in far western Nepal (Antolín et al. 2013). Although both klippen expose medium to high metamorphic grade rocks bounded by a lower top-to-the-southwest shear zone and an upper top-to-the-northeast shear zone with low metamorphic grade rocks at the highest structural levels, lithological correlation between the two klippen is uncertain. Metapelitic rocks are near absent in the metamorphic part of the Dadeldhura klippe, where slate and phyllite comprise the structurally highest units. In contrast, metapelitic rocks are common in the metamorphic part of the Karnali klippe and carbonate rocks comprise the structurally highest units. The lithologic differences between the Dadeldhura and Karnali klippen could be a reflection of lateral protolith variation, contrasting structural levels of the TSS cut by the STD (e.g. Searle and Godin, 2003), or the fundamental and independent nature of the Dadeldhura and Karnali klippen (e.g. Upreti and LeFort, 1999).

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