The Tso Morari Nappe of the Ladakh Himalaya: formation and exhumation

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The Tso Morari Nappe is one of the North Himalayan nappes and is characterized by ultra-high pressure metamorphic rocks. It is composed of graywackes, slates, sandstones and dolomites of the Upper Haimantas and Karsha formations (Vendian-Cambrian). It includes also metabasites. The Tso Morari anatectic granite is dated at 479 Ma (Ordovician, Girard and Bussy 1999) and is intrusive in the Haimantas and Karsha formations. It contains basic dikes, perhaps in part cogenetic. The Tso Morari Nappe is characterized by high to ultra-high pressure metamorphic paragenesis (de Sigoyer at al. 1997, Mukherjee and Sachan 2001) dated at 53 Ma (Leech et al. 2005). Eclogites are absent of the surrounding units. Static eclogite facies crystallization preserves folded boudins of metabasites in the Tso Morari granite. These structures predate the HP metamorphism and can be interpreted as deformation of cogenetic dikes in relation with the Tso Morari granite intrusion. Only sparse deformational structures can be attributed to the ultra-high pressure event.

The main schistosity S1 is associated to an E-directed stretching lineation L1 with top-E shear indicators. In general, this is a strong deformation dominated by mylonitic structures. Strain is however heterogeneous and relatively large area of massive, non-deformed granite can be observed. This deformation is related to mineral assemblages of the amphibolite facies attesting a pressure drop and a temperature increase. It is interpreted as associated to the nappe extrusion. A younger deformation D2 is characterized by a N-S trending stretching lineation L2 with top-S shear indicators. This deformation is developed at the upper part of the Tso Morari nappe and can be found in the higher Tertaogal and Mata nappes. It has been observed also at the front of the North Himalayan nappes in the Lingti Valley (Epard and Steck 2004). It is interpreted as related to an early phase of north-directed underthrusting of the Tso Morari Nappe below the Tetraogal and Mata nappes. This is coherent with the early N movement of India below Asia (Patriat and Achache 1982). The D2 deformation is superimposed by the D3, L3 deformation with top-SW shear indicators. It is associated to the main phase of North Himalayan nappes emplacement and is a shared structure in the North Himalayan nappe stack. Barrovian regional metamorphism is coeval to the extrusion of the Tso Morari Nappe and its incorporation into the North Himalayan nappe stack. It reaches amphibolite facies in most area of the Tso Nappe except the eastern part, close to the colder rocks of the Indus Suture Zone where it reaches only higher greenschist facies. This is due to a more rapid extrusion of this part of the nappe and is responsible for the first warping of the Tso Morari Nappe (Schlup et al. 2003). This first warping has been emphasized by NE verging backfolding already described by Steck et al. (1998) and also by structures related to neotectonics. The superposition of these structures leads to the present day dome structure. These tectonic structures are compatible with a late, NW-SE striking dextral shear zone, parallel to the Indus Suture Zone. They consist in large E-W trending, en-echelon, open folds as well as N-S striking normal faults. Additional new structural and metamorphic data, as well as a compilation of the published data on the Tso Morari nappe can be found in Epard and Steck (2008).

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