Petrology and geochronology of eclogitic and retrograde micas from Tso Morari UHP Complex, Ladakh Himalaya

Igor M Villa[1,2*], Julia de Sigoyer[3] and Stéphane Guillot[4]

[1] *Universität Bern, 3012 Bern, SWITZERLAND*
[2] *Università di Milano Bicocca, 20126 Milano, ITALY*
[3] *ENS-CNRS, Labo. Géologie, 75005 Paris, FRANCE*
[4] *CNRS-Université Grenoble 1, 38031 Grenoble, FRANCE*
[*] *For correspondence, email: igor@geo.unibe.ch*

The Tso Morari UHP Complex in Ladakh (NW Himalaya) recorded the very early evolution of the Himalayan range. Based on sedimentological and geochemical arguments the Tso Morari Complex can be related to the polymetamorphic Indian continental margin. Dating its UHP metamorphic peak and its retrogression allow to discus the geometry of the subduction zone, the geometry of the Indian margin before the collision, and the exhumation processes of UHP complex.

The Tso Morari UHP complex consists of coesite-bearing meta-crustal rocks (mostly metagranites and a thin metasedimentary cover). The eclogitic paragenesis proper is coesite-garnet-omphacite-quartz-phengite-rutile, in metabasic rocks, and garnet-jadeite-chloritoid-phengite in metapelitic rocks.

The age of peak metamorphism was established to be near 55 Ma by multichronometry (de Sigoyer et al. *Geology* 28 2000). Successive zircon SHRIMP dating refine the age of peak metamorphism close to 53 Ma (Leech et al. EPSL 234: 2005) or close to 49 Ma (O'Brien, EPSL 245: 2006).

Among the findings by de Sigoyer et al. (2000) were the observation of an amphibolitic paragenesis on the exhumation path, and of a subsequent greenschist facies retrogression, which both constrained a P-T-t path.

The 39Ar-40Ar analysis of the micas in the different rock types of the Tso Morari Complex can give decisive understanding on the processes that affected the UHP rocks. Here we focus on the amphibolite/greenschist parageneses.

The greenschist facies retrogression reactions are dated at 30-31 Ma in the southern part of the Tso Morari massif. Greenschist facies rocks are pervasively recrystallized, and biotite (not an eclogitic mineral in the metapelitic rocks) can be used as an index mineral for the chemically open-system recrystallization. Biotite-bearing metapelites have low-Si muscovites (Si $<$ 3.1 apfu), again showing that the high-Si HP phengites were recrystallized. One such sample, LK93-42, gave a "plateau" at 30.6 $\pm$ 0.4 Ma, with a noticeable age increase in the high-temperature steps. This age increase correlates with the Ca/K and Cl/K ratios and therefore, following Villa (Lithos, 55: 2001), we presumed that it consisted of a heterochemical mixture of more than one white mica generation. Electron microprobe analyses confirmed that high-Si and low-Si mica grains were present. The separate was therefore subjected to density separation, and a light (L) and a heavy (H) fraction were analyzed both by 39Ar-40Ar and by electron microprobe. The two age spectra were found to be remarkably different. LK93-42H was almost flat, with an age of 30.6 Ma. LK93-42L on the other hand had a much more pronounced high-temperature age discordance, with high-temperature steps up to ca. 40 Ma. The Cl/K and Ca/K indicators of heterochemical contaminants were much higher for –L than for –H. The straightforward explanation is that the different white mica generations were physically separated. Indeed, the BSE images show that the L fraction contains about 10% pure low-Si muscovite and 90% grains containing Si-rich phengite inclusions. The H fraction consists of about 66% pure muscovite grains and only 34% inclusion-bearing grains. We are forced to identify the eclogite and/or amphibolite facies (older) HP phengite relics as the carriers of inherited 40Ar.

The amphibolite facies event is well constrained by multichronometry to have occurred at 47 $\pm$ 3 Ma (De Sigoyer et al. 2000). The amphibolite-facies, intermediate pressure (ca. 10 kbar) phengite samples (Si $>$ 3.3 apfu) mostly give discordant age spectra ranging from Eocene to Early Cretaceous; ages never cluster towards what could be viewed as a well-defined age estimate. Moreover, the Cretaceous ages conflict with the other Eocene ages for the amphibolite facies retrogression. It is a very common observation (Di Vincenzo et al. J Petrol 145: 2004) that eclogitic white micas can preserve inherited 40Ar contained in pre-eclogitic relics. In our case, minor inheritance of a very much older mica population can easily bias young phengites to a significant extent. It can be easily detected, fortunately, by the same Ca/Cl/K-age diagrams that successfully unravelled the greenschist-facies mixture. Most samples show Cl/K and/or Ca/K clusters, but never simple binary mixing, indicating that the pre-eclogitic mica relics were themselves heterogeneous. BSE mapping will examine this possibility.

In conclusion, the Tso Morari Complex consists of rocks that record different peak and retrograde reactions. The combination of petrology and geochronology allows the self-consistent reconstruction of its tectonic history. Its exhumation from $>$ 27 to ca. 10 kbar occurred "quickly" before ca. 47 Ma, at a minimum average rate of (17 $\pm$ 2 kbar)/(4 $\pm$ 4 Ma). Subsequent exhumation to greenschist facies (ca. 4 kbar) was almost one order of magnitude slower, at a rate of 6 kbar/16Ma.