P-T-t evolution of the Himalayan metamorphic core in the Mugu Karnali transect (Central Himalaya): preliminary data based on calculations of pseudosections

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P-T paths for rocks from the metamorphic core of the Himalayan Belt are important sources of information for testing models of mountain building processes and exhumation models for deep-seated rocks in the Himalaya. This testing is hampered by the possible underestimation of metamorphic "peak" condition based on classical geothermobarometry on high-grade samples [1, 2]. Moreover, "peak" P-T data alone cannot discriminate between different models without the knowledge of the timing of the corresponding processes [3].

In this contribution we present new P-T data of selected samples from different structural positions along a transect within the Greater Himalayan Sequence (GHS) in the Mugu Karnali valley (Western Nepal, Central Himalaya). *In situ* U-(Th)-Pb monazite geochronology allowed to assess the difference in timing of nearly peak metamorphic conditions along the transect.

P-T data have been obtained from equilibrium assemblage diagrams (EADs, often referred as pseudosections) [2], which were constructed with the software PERPLE_X [4] and the internally consistent thermodynamic dataset (and updates) of [5] in the MnNCKFMASHT(O) system. These diagrams were contoured by various isopleths related, e.g., to the content of molar fractions of garnet components. The variation of the effective bulk composition (EBC) due to garnet growth was accounted (where necessary) with the method of [6]. Whereas EBC variation has a small effect on the P-T conditions at which early minerals formed (e.g. staurolite-in, except for garnet-in) it has, in our samples, a dramatic effect on the P-T position of the intersection of garnet rim isopleths. The influence on P-T estimates by the assumption of a fixed oxidation state of iron, was tested through the construction of a set of P-T (at different X_{Fe}) and T-X_{Fe} EADs.

The Mugu Karnali transect is a natural cross-section through the Himalaya, where few information were available until today [7]. In this transect, following [8, 9], the GHS is subdivided in two portions: (i) the lowermost one (GHS_L) where an inverted metamorphic sequence from biotite up to kyanite (locally anatectic) gneiss is exposed, and (ii) an uppermost part (GHS_U) mainly made of sillimanite to cordierite migmatitic gneisses (with few kyanite relicts), leucogranitic intrusions and few calcsilicate marbles. These two portions are separated by a top-to-the SW tectono-metamorphic discontinuity, named Mangri Shear Zone (MSZ) [9].

A MSZ footwall paragneiss sample from the GHS_L shows a prograde garnet growth from ~500°C, ~0.60 GPa (close to garnet-in curve) to ~590°C, ~1.10 GPa. During the decompression (and heating) stage kyanite and staurolite growth and garnet resorption occurred at ~650°C, ~0.80 GPa.

In hanging-wall mylonites of the GHS_U porphyroclastic garnet preserves little memory of the prograde path. Garnet rim isopleths and matrix minerals intersect at ~700°C, ~0.70 GPa, and suprasolidus conditions. A previous, higher P stage (~1.10 GPa, ~600°C) is testified by the composition of large white-mica cores.

Textural geochronology by *in situ* analysis of U-(Th)-Pb in monazite can help to place a time constraint in the P-T evolution [10]. Linking microstructural positions and Y+HREE compositions of monazite [10] a diachronism in the age of both metamorphism and shearing has been revealed. In the time span older than 18 Ma, while the MSZ hanging-wall samples underwent exhumation (high Y monazite rims), the footwall samples where still in the underthrusting stage (core to mantle low in Y at 21-17 Ma) [9]. In the footwall, retrograde high Y monazite rims [10] are younger at 15-13 Ma [9].

Structurally upwards, just few meters below the very low-grade marble of the Tethyan Sedimentary Sequences, a tiny outcrop of cordierite (coronae on staurolite)-garnet-gedrite gneiss was detected. These rocks, with no macroscopic evidence of *in situ* partial melting, are ductilly sheared by the South Tibetan Detachment System. The cordierite-garnet-gedrite gneiss is laterally correlated with muscovite-bearing (gedrite absent) gneiss of very similar texture, referred as North Col Formation (NCF) reported in [11].

EAD analyses for these rocks reveal a prograde heating path from 590°C up to 725°C at constant pressure of 0.55 GPa which can fit the textural relationships and the composition of the mineral phases. A T-XH_2O EAD shows that almost all water is lost by mica breakdown (5.5 wt%. to <2 wt%) during the heating path. In order to explain the modal amount of late, fabric cross-cutting, chlorite an input of external water-rich fluids, probably from crystallizing dikes, is necessary.

No direct geochronological constraints are at present available for these samples. If the spatial correlation with the NCF of [11] is correct, an age ≥ 23.5 Ma is likely for their metamorphism.

It is important to stress that in both upper and lower portions of the GHS typical Barrovian minerals (e.g. staurolite and sillimanite) grew during the decompression part of the P-T path, in agreement with microstructural observation (blastesis/deformation relationships). The nearly isobaric heating path of NCF samples, could be related, in the more fertile protoliths, to the genesis of cordierite/andalusite-bearing two-mica leucogranite as recently proposed by [14,15].

Our new data support the recent findings, based on multidisciplinary investigations, that the GHS has, at least in some places of the Himalaya, a complex and not uniform (in space and time) tectono-metamorphic history [3, 9, 10, 12, 13]. Any recent and future exhumation model for the GHS has to take into account the new P-T-t-D data and geochronological observations [e.g. 3, 9,10, 11, 12, 13].

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