

PHASE PETROLOGY OF POLYMETAMORPHIC METASEDIMENTARY ROCKS (SILVRETTA THRUST SHEET, EASTERN ALPS)

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Thermobarometry in polymetamorphic rock may result into meaningless results if some necessary conditions are not taken into consideration:

0) Values defined by thermobarometers should be a-priori related to process (the best is mineral growth of course) in an objective and unique way.

1) Chemical compositions of the minerals involved in the thermobarometric calculation represent equilibrium conditions at one time that is the same for all the phases. Kinetics may be considered but it implies many and poorly understood processes. Isotopic investigations may also help to validate equilibrium hypothesis. Unluckily isotopic disequilibrium (on the contrary to thermodynamic disequilibrium) cannot be responsible for recrystallization and a simple comparison of equilibrium-disequilibrium between isotopic and major chemical elements systems is not possible.

2) One single thermobarometer is not enough to define P-T-X conditions, and the other independently calibrated thermobarometers should be in first approximation consistent.

The following limitations should also be considered before application of thermobarometry:

3) In experimental calibrations a buffer mineral assemblage is present. In polymetamorphic rocks the equilibrium assemblage is hard to define because of several phase relics (the direction in the reaction path can still be defined because a stable assemblage cannot be replaced by an unstable one).

4) Thermobarometry is subject to errors due to poorly constrained activity models and rock forming minerals are usually multicomponent systems with structural complications. Thermobarometry often oversimplifies minerals to Fe/Mg or other simple ratios.

5) Experimental calibrations are usually done at P-T conditions quite far from normal metamorphic conditions and therefore extrapolations are required.

In the Silvretta basement, points 0 to 3 are severe boundaries for using thermobarometry since micas, garnet and staurolite are in textural disequilibrium and grew at different time. Point 4 introduces some problems with micas and staurolite.

On the other hand, it is possible to investigate metamorphic rocks by first principles using the Gibbs free energy minimization approach. The theoretical framework describing chemical equilibrium in a closed system was already developed by J.W. Gibbs over a century ago, and recently a few Earth scientists started to work in this field. The development of internally consistent thermodynamic databases allows to calculate the apparent Gibbs free energy of many minerals, and therefore, multicomponent phase equilibria can be investigated. Merits and pitfalls of the Gibbs free energy minimization approach will be discussed elsewhere.

The minimization of the total Gibbs free energy is done using DOMINO by de Capitani (University of Basel) and a P-T-X grid of a simplified paragneiss and micaschist including isopleths and isochines is produced starting from their bulk chemical composition. The volu-

me and composition of minerals estimated to be inert (like armoured relics) have been estimated and therefore the bulk chemical system has been modified. Different approaches were already followed by FREI et al. (1995) and PROSPERT & BIINO (1996).

The results of our investigation with DOMINO show:

- 1) The (Carboniferous) P-T-t path is anticlockwise and differs from P-T-t paths proposed by other authors. These P-T-t paths were probably based on mixing different assemblages and using partially reset phases. It is interesting to stress that PTAX (University of Bern) defined the same anticlockwise path.
- 2) Maximum temperature (ca. 550 °C) is constrained by the stability of staurolite and muscovite. After temperature climax or close to it, pressure increases quasi-isothermally to P_{max} of ca. 0.5-0.6 GPa. The absence of margarite and the staurolite destabilization into andalusite define the retrograde path. The path is in full agreement with fluid inclusion data (PROSPERT & BIINO this volume).
- 3) Micas formation prevent the nucleation of Al₂SiO₅ at middle pressure and temperature in semipelitic chemical system. This is in agreement with our previously done interpretation of microstructural relationships. This information and the sequence of stable assemblages were not acquired using PTAX.
- 4) In the considered P-T-X space Al₂SiO₅ are not stable in paragneiss as observed in the field and thin section
- 5) The formation of staurolite in a small T field explains the limited variation in chemical composition observed in staurolite.
- 6) The possibility to define where a mineral is forming allows to test the validity of results by DOMINO with microstructural information.

Metamorphic petrology investigates rocks as a chemico-physical system to give information that should be integrated with tectonic and geochronological data in order to reconstruct the evolution of rock units. It may happen that the P-T-X data can be defined with large errors and the evolution model is not severely affected. Indeed, this investigation evidences that only precise P-T-X values allow to discriminate between different geodynamic models and reliable petrologic approaches are needed. We suggested that the prograde temperature path is related to erosion of the subcontinental lithospheric mantle and magmatic underplating of basaltic melts like in the Ivrea-Verbano zone. Subsequent increase in pressure, culminating in P_{max}, may be caused by the emplacement of nappe(s) and/or of magmatic rocks on top of the Silvretta basement. The Variscan evolution was confined to 20 Ma. At the end of the Variscan cycle extensional structures coincide with exhumation. These structures may be related either to large scale extensional tectonics or to more local events.

FREI, R., BIINO, G. G. and PROSPERT, C. (1995): Dating a Variscan pressure-temperature loop with staurolite. - *Geology*, **23**, p. 1095-98.

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