MITT.ÖSTERR.MINER.GES. 148 (2003)

PETROLOGIC EVALUATION OF HIGH-PRESSURE ROCKS: STATE OF THE PROBLEM, MEANS OF SOLUTION

A. Proyer

Institut für Mineralogie und Petrologie
Universität Graz, Universitätsplatz 2, A-8010 Graz, Austria

In the petrologic evaluation of high-pressure rocks we face the problems common to all rocks plus some additional ones that become flagrant at high pressures. It all comes under the heading: "What do we want to know?" – e.g. a P-T path, versus "What can we know?" – What is preserved, and which of the preserved features are diagnostic for a particular stage in the evolution of a rock? The recent years have brought an improved understanding of what preservation means, and we have learned more about the diagnostic values of minerals, textures or mineral chemical peculiarities, particularly in high- and ultrahigh-pressure rocks.

Preservation has little to do with themodynamics, but everything to do with kinetics. It depends on a variety of factors, the most decisive being definitely the presence of a fluid. It plays a triple role: It is always important as a catalyst of reactions and as a transport medium, and it may also be required as a reactant for further reactions to occur. Its disappearance from the rock due to its mobile character has thus been regarded as the most influential factor to stop reactions and freeze in assemblages that can later be sampled and examined.

Consequently, the main thermodynamic foothold on any preservation discussion is dehydration (devolatilization) reactions. They tell us when – in theory, i.e. under equilibrium conditions – dehydration will occur. In the past, these phenomena have been discussed maily in the context of (idealized) univariant reactions and their corresponding field isograds.

The new NKFMASH grid for metapelites (PROYER, in press), for example has enabled us to discuss preservation of HP-assemblages in a really large P-T range, with realistic bulk compositions, whereas for metabasites and other rock types the variance is usually too high, and the number of useful univariants or even invariant points too small for such an approach. A much more thorough and detailed method is that of contoured pseudosections for particular samples/bulk compositions. A series of recent papers shows the advantages and drawbacks of this method, but its potential is enormous. In fact, we can now precisely define, what we mean by "peak conditions of metamorphism" along a given P-T path, i.e. those conditions that are preserved by a rock, and it is almost never the T- or P-peak of that path. This tool is currently developed even further to describe fluid-absent conditions, also below the solidus.

The ideal sample records just one set of P-T conditions, at which it was perfectly equilibrated and then frozen in. However, at low to medium metamorphic grades, in the greenschist and amphibolite facies, several minerals can be zoned or vary in composition, either irregularly or depending on their textural position. Garnet, plagioclase, muscovite and amphibole are typical examples for such a behaviour. Furthermore, overprinting relationships, where a peak metamorphic assemblage is replaced along fluid pathways or in certain domains by a younger assemblage and older phases are affected by resorption and zoning, are quite common in rocks. There have been many efforts in the past to utilize such phenomena to derive more than one point for a P-T path (KRUHL, 1993; SCHULZ, 1994; CARSWELL, 1999). These efforts have been quite enlightening, both by their successes and failures. A reasonable interpretation of textures and a flawless application of phase petrologic laws are vital to establish, if it is possible to derive P-T conditions in such cases or not. Even though deriving P-T paths from a single specimen is troublesome, the obvious solution of using several samples from the same outcrop area which differ in equilibration stage or bulk composition, has not found a wide application by petrologists. In this case, problematic overprinting relationships may and in most cases will exist on an outcrop scale.

Facing the problem of preservation of the bulk mineral assemblage, particularly for rocks with a high- and ultrahigh-pressure history, geologists have turned more and more to those traces of early stages that are preserved on a micro-scale: inclusions of index minerals like omphacite, coesite or diamond in refractory hosts (mainly zircon) and diagnostic mineral compositions, either preserved directly (as inclusions) or indirectly (exsolution textures).

Experimental petrology plays a very important role as it provides a lot of hints about which phases can be expected at extreme pressures. At ultrahigh pressures, geothermobarometry in a classical sense is virtually impossible, not only because most phases have reequilibrated at lower P-T conditions, but also because the properties of solid solutions and fluids in complex bulk compositions are basically unknown. Experiments with simplified but also with common pelitic or metabasic bulk compositions can provide important constraints on the range and nature of solid solution in phases like garnet, clinopyroxene and others, which may become useful first-order geothermobarometers (e.g. ONO et al., 1998). However, experimental work with this purpose in mind is still in its very beginnings.

The speed of exhumation of HP and UHP rocks is a major issue in the geological community. The traditional approach of applying a number of isotopic systems to get several constraints on the exhumation path has been refined, but the absolute ages have statistical error which are at least one order of magnitude greater than those of "durations" calculated from diffusion profiles, mostly in garnet, using recently developed "geospeedometry" programs (e.g. PERCHUK et al, 1999; DACHS & PROYER, 2002)

Finally, even the most classical approach of deriving P-T conditions for eclogites is hampered by unforeseen difficulties, when it comes to UHP conditions. Omphacite incorporates significant amounts of a Ca-eskola molecule $Ca_{0.5}[]_{0.5}AlSi_2O_6$, which introduces vacancies and makes it impossible to calculate Fe^{3+} from the formula. Garnet-omphacite temperatures can be wrong by up to 150°C, if no independent value for Fe^{3+}, e.g. from Mössbauer spectrometry, is known.

References

CARSWELL, D. A. & ZHANG, R. Y. (1999): Petrographic characteristics and metamorphic evolution of ultra-high-pressure eclogites in plate-collision belts. - Int. Geol. Review 41: 781-798.

DACHS, E. & PROYER, A. (2002): Constraints on the duration of high-pressure metamorphism in the Tauern Window from diffusion modelling of discontinuous growth zones in eclogite garnet. - J. metamorphic Geol. 20: 769-780.

KRUHL, J. (1993): The P-T-d development at the basement-cover boundary in the north-east Tauern Window (Eastern Alps): Alpine continental collision. - J. Metamorphic Geol. 11: 31-47.

ONO, S. (1998): Stability limits of hydrous minerals in sediment and mid-ocean ridge basalt compositions; implications for water transport in subduction zones. - J Geophys. Res. B:103/8:18, 253-18, 267.

PERCHUK, A., PHILIPPOT, P., ERDMER, P. & FIALIN, M. (1999): rates of thermal equilibration at the onset of subduction deduced from diffusion modelling of eclogitic garnets, Yukon-Tanana terrane, Canada. - Geology, 27, 531-534.

PROYER, A. (2003): Metamorphism of pelites in NKFMASH - a new petrogenetic grid with implications for the preservation high-pressure rocks during exhumation. - J. Metamorphic Geol. (in press).

SCHULZ, B. (1993): P-T-deformation paths of Variscian metamorphism in the Austroalpine basement: controls of the geothermobarometry from microstructures in progressively deformed metapelites. - SMPM 73: 301-318.