THE METAMORPHIC DEVELOPMENT IN DIFFERENT FUNDAMENTAL UNITS OF THE BOHEMIAN MASSIF: MONO-, MULTI- AND POLY-PHASE HISTORIES

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The Bohemian Massif is well known as one of the classic areas in which to study regional low pressure metamorphism. Interestingly, the same outcrops that provide well preserved low pressure ($\leq$ 5 kbar) metamorphic rocks - commonly migmatitic cordierite-sillimanite-K feldspar metapelitic gneisses also sometimes yield rock samples containing evidence for high ($\geq$ 10 kbar) and very high ($\geq$ 25 kbar) pressure metamorphism such as eclogites, garnet peridotites and high pressure granulites (see O'BRIEN & CARSWELL 1993, for a detailed review). Have the low pressure rocks also experienced the high pressure conditions only to undergo complete recrystallisation during exhumation? Have the high pressure rocks had a substantial history outside their present hosts and only come into contact with their present neighbours during later thrusting/faulting? These are important questions we must answer if we really want to decipher the complex series of events involved in continent-continent collision. A useful way to subdivide the metamorphic rocks is to determine if they underwent mono-, multi- or poly-phase metamorphism: monophase being due to a single tectonometamorphic event; multiphase caused by reactivation at (a) later stage(s) of the same overall orogenic cycle and polyphase the result of reactivation during a separate event with a significant time interval between.

The high grade crystalline core of the Bohemian Massif, the Moldanubian Zone, is flanked to the north by the generally lower grade Saxothuringian Zone with the fault-bounded Bohemicum positioned between these two: all are cut by late Variscan granites. In the Moldanubian Zone a monotonous migmatitic metapelitic series with occasional more variegated (marble, orthogneiss, amphibolite, quartzite) series dominates. Metamorphism here is of low pressure-high temperature type in places with regional isograds and garnet zoning supporting a model of a mono-phase low pressure event (e.g. BLÜMEL, 1990). Enigmatic relics of garnet, staurolite and kyanite from scattered localities could be interpreted as remnants of an earlier higher pressure stage i.e. indicating a multistage evolution. Alternatively they may be part of a much earlier, perhaps Cadomian, medium pressure event thus making them polyphase metamorphic rocks. In this respect it is instructive to look to the western margin of the Bohemicum where regional isograds in staurolite$\pm$kyanite-bearing metapelites are cut and overprinted in the contact aureole of lower Palaeozoic plutons. If the medium pressure relics in the Moldanubian gneisses are also old then linking the P-T conditions for the different stages as for a multiphase history when in fact a polyphase evolution was appropriate, seriously misrepresents the true path followed. Migmatisation could thus be the product of isobaric heating rather than decompression at high temperature.

A further subdivision in the Moldanubian Zone, the Gföhl Nappe, comprises predominantly felsic high pressure granulites enclosing bodies of garnet peridotite that include bodies of garnet pyroxenite. Phase relations and reaction textures in the acid granulites from Lower Austria allow distinction between an early high pressure (ca. 16 kbar, 1000 °C) stage characterised by the presence of ternary feldspar and kyanite and a secondary medium pressure stage (ca. 6.5 kbar, 725° C) with considerable development of biotite, plagioclase, sillimanite and also orthopyroxene (CARSWELL & O'BRIEN, 1993): in some locations the reaction sequence has continued into the low pressure cordierite field.

Ultramafic rocks from the same area retain relics of an early high temperature stage with aluminous pyroxenes (in rare cases) followed by a very high pressure (> 30 kbar) stage before partial recrystallisations at conditions directly comparable with those for reactions in their host granulites (CARSWELL, 1991). This multistage metamorphic history is repeated in the granulite massifs within the Saxothuringian Zone (Granulitgebirge, Sowie Gory): an unusual coincidence or was there originally a connection between these now widely scattered units?

Eclogites and other garnet-clinopyroxene rocks occurring in gneiss units not connected to acid granulites or garnet peridotites are found within the Moldanubian Zone, Saxothuringian Zone and even at the western margin of the Bohemicum in the Mariánské Lázně Complex (O'BRIEN, 1994). In each occurrence the prograde evolution of the eclogites as well as multiple discrete breakdown stages are discernible with one or more of the breakdown stages having been at conditions above 10 kbar. Thus not only the peak pressure transformation but even the early breakdown took place at conditions considerably different from those recoverable from the vast majority of the gneisses hosting eclogites. Generally, high temperature overprints are found for eclogites of the Moldanubian Zone (cf O'BRIEN & VRÁNA, this volume) whereas lower temperature evolutions are the norm for those from the Saxothuringian realm (e.g. W. Erzgebirge, Münchberg Massif). However, some areas of the Saxothuringian Zone also contain high temperature eclogites (Central Erzgebirge, Śnieżnik). These differences suggest a convergent metamorphism for these rock types and imply that even if the units bearing the high pressure rocks are allochthonous, these units are themselves composite bodies assembled from rocks with different pressure-temperature trajectories.

The rocks with multistage metamorphic evolutions are the only ones that can yield information on the processes, and the rate of change of these processes, that led to their preservation and their exhumation. They tell us about episodic changes and transient conditions in collision belts and are the only witnesses that we have of these ancient orogenies. We must always be cautious, however, and bear in mind the possibility that the rocks have endured separate metamorphic cycles. In such cases the joining of equilibration fields defined by different mineral assemblages does not form a true P-T-t path and thus may result in the determination of spurious cooling and uplift rates.

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ECLOGITES WITHIN THE MONOTONOUS SERIES OF THE BOHEMIAN MASSIF: EXAMPLES FROM SOUTH BOHEMIA AND LOWER AUSTRIA

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In the southern Bohemian Massif high pressure mafic and ultramafic rocks (eclogites, garnet peridotites and garnet pyroxenites) are generally found within the acid granulite massifs. However, small bodies of overprinted eclogites, garnet pyroxenites and spinel peridotites are also known from the outcrop area of the Monotonous Series migmatitic cordierite-sillimanite-K-feldspar gneisses.

In Lower Austria blocks of overprinted eclogite are recorded from the Ostrong Unit in the area between Nussendorf and Prinzendorf, NNW of Ottenschlag and around Sallingberg (all map sheet 36, Ottenschlag) and close to the Rastenberger Granodiorite at Gutenbrunn (sheet 19, Zwettl). The majority of sampled metaeclogites once contained the high pressure assemblage garnet + omphacite + quartz + rutile + kyanite ± (clino)zoisite. All have suffered a major static recrystallisation at lower pressure conditions with the most prominent having occurred at granulite facies conditions. Garnet was replaced by very fine-grained intergrowths of orthopyroxene + spinel + calcic plagioclase; omphacite broke down to produce a symplectitic intergrowth of diopside + sodic plagioclase + orthopyroxene ± amphibole; former kyanite domains consist of almost opaque aggregates of tiny grains or needles of spinel ± corundum ± extremely Al-rich sapphirine set in anorthite; (clino)zoisite is pseudomorphed by aggregates of anorthite dusted by tiny Fe oxides; quartz has thick coronas of orthopyroxene (especially close to garnet) and rutile has been mostly replaced by ilmenite. In some metaeclogites all the primary phases (except quartz) have been totally replaced but with the original texture of the rock completely preserved thus confirming the static nature of the overprint. In less aluminous (kyanite ± zoisite-free) samples symplectites after omphacite are very fine-grained and contain small rounded aggregates (spots) comprising a core of orthopyroxene and a rim of clinopyroxene of a third composition.