Metamorphic and Structural Evolution of the Moldanubian Lower Crust – An Example of the Strážek Moldanubicum

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The major objective of our research was to study the relationship between lower crust of the orogenic root and the juxtaposed middle-crustal rocks. We used both field structural investigations and petrological analysis of main lithologies to decipher the exhumation history of the lower crust. The studied area is situated at the eastern limit of the internal orogenic domain of the Bohemian Massif. Here, two crystalline complexes with different grade of metamorphism meet along the major tectonic boundary. The Strážek Moldanubicum (SM) is represented by acid granulites and granulitic gneisses associated with the migmatized Gföhl gneisses, amphibolites, ultramafic rocks and durbachitic intrusions. This unit is thrust over metasediments, orthogneisses and migmatites of the Svratka Crystalline Complex (SCC).

Two dominant sets of structures can be observed in the area. The early S_1 foliation in granulites is represented by flattened quartz ribbons and partly also by preferred orientation of biotite. The S_1 foliation is subvertical and strikes mostly in N-S direction. The L_1 stretching lineation is represented by elongate quartz and quartz-feldspar aggregates it plunges to the S-SE under moderate angles. Sills of durbachites parallel to the S_1 fabric were observed at several localities. The D_1 fabric is overprinted by S_2 planar system which is either penetrative or developed as discrete ductile shear zones. It crosscuts the S_1 at high angles. The S_2 fabric is generally oriented to the SW and becomes progressively steep close to the contact with the underlying SCC. As in the case of the S_1 foliation, we have also observed durbachites within the S_2 shear zones.

So far, we have studied metamorphic conditions of granulites from two distinct localities in the Strážek Moldanubicum––the Loučka–Bobrůvka river valley and the Libochovka river valley. These are typical acid granulites with mineral parageneses consisiting of Grt-Ky-Sill-Bt-Hc-Plg-Kf-Qtz. We have observed succession of stable mineral assemblages, which can be defined as follows. 1) The stable mineralogy in several samples from granulites with subvertical fabric (interpreted as S_1) is represented by Grt-Ky-Bt-Plg-Kf-Qtz. 2) More often, the granulite samples show extensive conversion of kyanite to sillimanite, thus suggesting stabilization of the assemblage Grt-Sill--Bt-Plg-Kf-Qtz. 3) In a few samples we observe crystallization of hercynite suggesting discontinuous reaction Grt + Sill = Hc + + Bt. 4) A complete retrogression of Grt-bearing mineral assemblages can be observed in samples from the S_2 shear zone. The resulting mineralogy comprises only Bt-Plg-Kf-Qtz.

These preliminary structural and petrological data can be interpreted as a polyphase exhumation of lower-crustal rocks. As the D_1 fabric is developed exclusively in the SM, we suppose that this event reflects compressional event deep in the lower crust. The observed D_2 fabric reflects transition from vertical extrusion into thrusting of lower-crustal rocks over middle crust of the SCC. This flat thrusting occurred in middle to shallow level of the crust but under high temperature conditions. We assume that durbachite magma exploited the early D1 fabric for vertical ascent parallel to the main anisotropy. It is likely but not satisfactorily proved that durbachites also intruded late S_2 surfaces.

Rare-Element Nb-Ta-W Mineralization of the Tin-Bearing Spiš-Gemer Granites, Eastern Slovakia

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The Spiš-Gemer granites, SGG (Uher and Broska 1996) represent several small intrusions outcropping in western and southeastern part of the Gemericum Superunit, one of the principal Paleozoic-Mesozoic units of the Central Western Carpathians. They gained an increased attention due to their clearly different composition if compared to the other West-Carpathian granites as well as their potential genetic relationship with numerous hydrothermal siderite-sulphide and stibnite deposits of the Gemericum Superunit (Grecula Ed. 1995 and references therein). Moreover, SGG showed features of tin-bearing intrusions, locally with zonal structure containing (from bottom to the roof) two-mica, tourmaline, albite-Li-mica-topaz (Li-F) granites (or muscovite-topaz leucogranites), albitites and greisens in granite cupolas, with disseminated rare-element Nb-Ta-W mineralization in Dlhá Valley, Hnilec and Poproč localities (Malachovský et al. 1983; 1992a,b – in Grecula Ed. 1995).

Ferrocolumbite to manganocolumbite are the most widespread Nb-Ta phases of SGG, they form euhedral to anhedral, up to 0.4 mm large crystals in rock-forming minerals, often with cassiterite and Nb-Ta rutile. Ferrocolumbite occurs predominantly in various granite types, manganocolumbite is typical mainly of greisens (Dlhá Valley). Ferrocolumbite and manganocolumbite show oscillatory zoning often corroded by younger irregular zones along the margins of crystals. Generally, an increase in Ta and W from centre to rim of the crystals was detected. Moreover, upper greisen and albitite parts of the granite cupola are often enriched in Mn and Ta in comparison to the lower granite parts. Columbite-group minerals show atom. Ratio Mn /(Mn + Fe) = 0.06 – 0.85, Ta / (Ta + Nb) = 0.04 – 0.42; elevated W and Ti contents (up to 13 wt.% WO_3 and 7 wt.% TiO_2) are characteristic.

W-rich ixiolite represents a disordered columbite-group phase with 19–31 wt.% WO_3. The mineral forms strongly inhomogeneous, up to 0.3 mm large grains. W-rich columbite/ixiolite compositions are characteristic of tin-bearing rare-element granites as documented in the Cínovec granite cupola (Johan and Johan 1994).

A phase with stoichiometry analogous to qitianlingite (?), $(Fe,Mn)_2(Nb,Ta)_2WO_{10}$ (Yang et al. 1985), containing 32–39 wt.% WO_3, Mn /(Mn + Fe) = 0.26–0.39 and Ta /(Ta + Nb) = = 0.05–0.35, forms rare, max. 15 µm large probably exsolution lamellae in intergrowths with Wrich columbite/ixiolite and Nb,Ta-rich ferberite in Dlhá Dolina, Hnilec and Poproč Li-F or muscovite-topaz granites. However, the phase possibly represents a strongly W-rich columbite or ixiolite member (cf. Johan and Johan 1994).

Minerals of the wolframite series; ferberite, rarely hübnerite (Mn/(Mn + Fe) = 0.19–0.56), occur as platy crystals and fan aggregates, 0.1 mm to 2 cm in size, in Li-F granites and quartz veins in greisens. In some cases, ferberite is intergrown with other afore-mentioned W,Nb,Ta-rich phases and show increased Nb contents (7–22 wt.% Nb_2O_5), up to an intermediate phase between wolframite and columbite/ixiolite composition ("?-phase").

Niobian and tantalian rutile (ilmenorutile and strüverite) forms 30–50 µm anhedral, strongly zonal crystals in Li-F granites and albitites; it contains up to 7 wt % WO_3, 30 wt % Nb_2O_5 and 22 wt % Ta_2O_5; Ta/(Ta + Nb) = 0–0.58.

Cassiterite, the most common ore mineral of the mineralization, contains only up to 1.2 wt % Nb_2O_5 and 2.2 wt.% Ta_2O_5. Locally, tiny ferrocolumbite inclusions occur in cassiterite.

Microlite to uranmicrolite forms inhomogeneous subhedral grains, max. 0.2 mm large, in the Dlhá Valley albitites and greisens. Locally, it is rimmed by ferrocolumbite. Microlite contains 5–7 wt.% UO_2 and < 1 wt.% TiO_2, uranmicrolite shows 20-24 wt.% UO_2 and 5–9 wt.% TiO_2. For both species: Ca » Na (< 0.5 wt.% Na_2O) and Ta/(Ta + Nb) = 0.70–0.89.

A complex Y-HREE-Nb-Ta oxides, the most probably polycrase-(Y) and uranopolycrase were detected as up to 50 µm irregular grains in silicified phyllite and in quartz albitite vein from exocontact aureole of the Dlhá Valley granite. They contain 7–15 wt.% Y203, < 8 wt.% HREEZOa (mainly Dy and Yb), 12–23 (polycrase-(Y)) or 29–31 wt.% U_2O_2 (uranopolycrase), 18–29 wt.% TiO_2 and max. 5 wt.% WO_3; Ta/(Ta+Nb) = = 0–0.31.

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Depositional Systems and Sequence Stratigraphy of Coarse-Grained Deltas in a Shallow-Marine, Strike-Slip Setting: the Bohemian Cretaceous Basin, Czech Republic

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Coarse-grained, Gilbert-type deltas showing a varying degree of reworking of foresets by basinal currents, were the dominant depositional system in Bohemian Cretaceous Basin during the Turonian through Early Coniacian times. The progradation of the deltaic packages, earlier interpreted as large-scale subaqueous dunes, shelf ridges, or subaqueous fault-scarp "accumulation terraces", was controlled by high- and low-frequency, relative sea-level changes in a relatively slowly subsiding, intracontinental strike-slip basin. End-member types of the Bohemian Cretaceous coarse-grained deltas are deep-water deltas, characterized by thick (50–80 m) foreset packages with steep (10–30°) foresets, and shallow-water deltas, which deposited thin (less than 15 m) packages with foresets typically between 4 and 10°. The differences in thickness and foreset slope angle were controlled dominantly by the accommodation available during progradation. The depositional regime of the deltas was governed (i) by the fluvial input of abundant sand bedload, with a minor proportion of gravel, (ii) gravity flows caused most likely by liquefaction of the upper part of the unstable foreset slope, and (iii) by migration of sandy bedforms on the foreset slopes. The bedform migration was driven by unidirectional currents of possible tidal origin. Individual foreset packages represent systems tracts, or parts of systems tracts, of depositional sequences. A variety of stacking patterns of high-frequency sequences exist in the basin, caused by low-frequency relative sea-level changes as well as by local changes in sediment input. Because of generally low subsidence rates, fluvial or beach topset strata were not preserved in the cases studied. The absence of preserved fluvial facies, which has been one of the main arguments against the fluvio-deltaic origin of the sandstone bodies, is explained by erosion of the topsets during transgression and their reworking into coarse-grained lags of regional extent covering ravinement surfaces.