Shallow Reflection Seismic Prospecting of the Kurovice Klippe (Magura Flysch) and its Structural Interpretation

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Shallow high-resolution reflection seismics measurements were carried out at section MS-KB-1/98 across the central part of Kurovice limestone klippe of the Upper Jurassic/Lower Cretaceous age. The Kurovice Klippe consists of turbiditic limestones and marlstones and belongs to Magura Group of nappes (partial RaPa nappe).

The principle of shallow high-resolution reflection seismics is based on generation of seismic energy in shallow boreholes (till 1 m) and registration of reflected waves by a set of geophone groups. Natural frequency of geophones was 40 Hz, groups spacing 10 m and CMP intervals for the given solution was 5.0 m.

The main output of this seismic measurement is the final set of time section at the scale 1 : 5000. The range of time sections is given by the measurement method and is 950 ms two-way travel time.

Older seismic logging measurement results from the well TlumaPov-1 (approx. 1 km to the west from section MS-KB-1/98) were used for the time-to-depth conversion. From this conversion, the depth penetration of the measurement is about 1500 m.

Interpretation of seismic section MS-KB-1/98 is based on space analysis of the wavefield, which scans frequency and shape differences in the signal. This allows to divide the seismic section by different echogenity of the wavefield.

The main task of the interpretation of seismic section M-KB-1/98 was to define the structure of the Kurovice klippe. For this purpose, GPR measurements on section 1 were also used and added to the uppermost part of the seismic section.

The body of Kurovice limestones itself is manifested by distinct group of oblique reflections on seismic section MS-KB-1/98, dipping southwest and reaching a depth of about 400 m from the surface. Turning of the lower part of Kurovice klippe to the northwest is interpreted at a depth of 400 - 500 m. Its base is interpreted at a depth of about 800 m, i.e. at the level of -500 m a.s.l. At that level the lower boundary of the Soláb Formation is interpreted, too, representing the base of the Magura Flysch.

We suppose that the turning of lower part of Kurovice klippe is caused by the strike-slip tectonics, the manifestation of which can be followed in the deeper parts of the seismic section, too. The main fault of the tree-formed structure coincides with the northwestern edge of the upper part of the Kurovice limestones.

Assumption of the left-handed strike-slip along the main thrust surface of the Magura Flysch is supported by the existence of a positive structure (elevation) in the crystalline basement immediately below the main thrust surface. This structure is well recorded in the regional seismic section 231/78.

Geophysical survey shows that the Kurovice klippe is a rather complicated tectonic structure formed in the front of the Magura Flysch. Frontal contact of the Soláň and Ždánice units (Outer Flysch) is irregular and can be generally assumed as vertical with the thickness of about 800 m. In the area of the main thrust surface, a distinct strike-slipe fault is manifested with numerous deformations of geological units. According to the surface correlation of geophysical indications, the northeastern edge of the Kurovice klippe is limited by E-W-striking tectonics.

Interplay between Assimilation, Fractional Crystallization and Magma Mixing – the Story of the high-K calc-alkaline Kozárovice Intrusion, Central Bohemian Pluton

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The Kozárovice granodiorite is a typical representant of the high-K calc-alkaline Blatná suite, demonstrating processes of general importance not only to the petrogenesis of this part of the Central Bohemian Pluton, but also Hercynian calc–alkaline granitoids in general.

Harker plots for the granodiorite show strong negative correlations between SiO_2 and FeO*, MnO, MgO, CaO and TiO_2, that, if interpreted on the basis of a fractional crystallization model, point to fractionation dominated by ferromagnesian phase(s) and plagioclase. Least-squares modelling implies that the whole compositional spectrum could have been derived by up to 45% fractional crystallization of 35–42% amphibole, 28–33% plagioclase, 7–13% K-feldspar and 13–22% biotite; and this is in line with modelling using LILE and REE data.

The Kozárovice granodiorite is associated with K-rich pyroxene-bearing monzonitic rocks (Zalužany monzonite and Lučkovice melamonzonite–monzogabbro). In a quarry SE of Kozárovice small bodies of biotite–amphibole quartz monzonite occur that are net-veined and broken into microgranular mafic enclaves at the contact with the granodiorite. Hornblendes in both of these rocks enclose resorbed relics of biotite flakes. This texture can be explained either by a decrease in a_{SiO2} or an increase in a_{plag} of the melt, possibly due to its sudden basification (Castro, 1993). Both rocks also contain nearly monomineralic amphibole clots, the shapes of which often resemble those of pyroxene phenocrysts. In the quartz monzonite, quartz and K-feldspar form large oikocrysts; apatite is long prismatic or acicular.

The plagioclase of the quartz monzonite frequently shows discontinuous zoning (the terminology used follows that of Wiebe, 1968). Relatively large andesine ($An_{34–43}$) cores with oscillatory zoning are common and are overgrown by calcic andesine–labradorite spikes (surges in An content, up to An_{56}) and normally zoned oligoclase–andesine rims ($\rightarrow An_{26}$). Some lath-shaped crystals of oligoclase–andesine ($An_{28–32}$), may be unzoned while crystals with andesine–labradorite cores ($An_{46–60}$) are overgrown by sodic, normally zoned rims ($\rightarrow An_{26}$). The plagioclase of the granodiorite may be unzoned oligoclase–andesine, or consists of crystals with andesine–labradorite cores ($An_{42–51}$) overgrown by normally-zoned oligoclase rims (An_{28-29}); narrow calcic spikes or slight reversals in the zoning are scarce.
These textures can be explained - in agreement with the major- and trace-element based mixing tests - by mingling of granodioritic and monzonitic magmas. The acid magma chamber was invaded by basic magma and, especially close to the contact, partly crystallized plagioclases were exchanged. In the monzonite, sodic cores (early-formed crystals captured from the granodiorite) were overgrown by calcic spikes. In addition, the strong undercooling of the basic magma triggered the nucleation of numerous lath-shaped plagioclases, some with calcic cores. After thermal re-adjustment crystallization proceeded relatively slowly. The spikes graded into normally-zoned oligoclase–andesine rims and quartz and K-feldspar oikocrysts developed. In the granodiorite most of the plagioclase crystals are normally-zoned sodic andesine–calcic oligoclase, but those with partly resorbed calcic cores overgrown by normally-zoned sodic rims represent crystals locally captured (together with pyroxene, now amphibole) from the monzonitic magma. Even more complex zoning patterns represent repeated exchange between the two magmas possibly resulting from vigorous convection caused by instability following the influx of hot basic magma.

The Sr–Nd isotopic composition of the Blatná suite documents an important role for open–system processes. A mixing model involving monzonitic and evolved granodioritic magmas can account for the observed $^{87}Sr/^{86}Sr_i$–epattern. However, in a 1/Nd–e plot, the Kozárovice and Blatná intrusions form independent, curved trends. Binary mixing and conventional assimilation and fractional crystallization (AFC) in which *r* (the rate of assimilation/fractional crystallization) and *D* (the bulk distribution coefficient) are constant ought to produce linear trends. The curvature observed can be explained by changing either *D* or *r* in the course of AFC (Powell, 1984). For the Kozárovice intrusion, the most feasible of the models tested assumes an increase in D_{Nd} ($1.3 \rightarrow 4.5$ for $r = 0.5$ and a typical Moldanubian paragneiss as a contaminant).

Taken together, the petrography and geochemistry of the Kozárovice intrusion reflect open system processes, probably AFC with variable D_{Nd}. Interaction with monzonitic magmas, at least locally, played an additional important role.

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On the Applicability of Theoretical Models of the Motion of Crystals in Viscous Magma

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There are two basic models that can be applied to the study of crystals in viscous magma. The model of March (1932) considers passive markers that move like lines or planes in a deforming matrix. Historically older and more sophisticated is the model of Jeffery (1922). It is in fact a side product in Jeffery‘s generalisation of Einstein‘s approach to the study of the increase of viscosity caused by a suspension of rigid particles, and it is based on the solution of Stokes flow around a rigid ellipsoid. From the sixties, both models have been widely used by geologists for modelling of the development of shape-preferred orientation (SPO) and for the estimation of geometry of flow, especially in igneous rocks. In our contribution we review the basic theoretical properties of both Jeffery and March model, discuss limits of their applicability and show examples of their use.

The advantage of both models is that we can trace a development of a preferred orientation during progressive deformation of a hypothetical geologic body, together with the parameters of strength and symmetry of the fabric. Moreover, if we consider crystals as carriers of magnetism we can evaluate the corresponding AMS. A typical application of these models then proceeds as following. We collect structural data (finite strains, orientation of lineation and foliation, preferred orientations of particular objects and sets or subsets of crystals measured by optical goniometer, AMS measurement) and construct a pre-