Syn-exhumation of the Devonian Basin System in the Bohemian Massif: Geochronological and Geochemical Evidence of the Eo-Variscan Orogen

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The northern Bohemian Massif displays remnants of Middle and Upper Devonian sedimentary sequences and includes: the Świebodzice sequence (Porębski, 1997); the autochthonous Bardo Mountain rock complex (Wajsprych, 1995); the Itrava unit of the Jested Mountains; the siliciclastic Hradec Kralove area; the Rychmburk greywackes of the Hlinsko zone (Pitra et al., 1994); the siliciclastic Mohelnice Paleozoikum sequence (Hladil et al., 1999); the Srbsko Formation of the Barrandien basin (Strand, 2002); and the coarse-grained siliciclastic Rozmital sequence, southeastern from Prague.

All the mentioned sequences are made of immature sediments dominated by turbidites and present weak or no metamorphism. With the exception of the Mohelnice Paleozoicum sequence they are located within the Bohemian zone, which according to the traditional tectono-stratigraphic zonation belongs to the Moldanubian zone, in the Bohemian Massif. Gravity-driven processes are a common feature for all the basins associated with these sequences.

Petrographic features of these sediments include: (A) variable occurrences of lithic volcanic grains with different metamorphic grades including HP; (B) basite and ultrabasite grains; (C) carbonate grains, commonly Frasnian biolitithes, either metamorphic or non metamorphic; (D) intra-formational siliciclastic grains; (E) basic to acidic magmatic grains; and (F) greenschist to high-grade metamorphic rock fragments. These features strongly support an orogenic uplift as the source of the detrital material in these deposits.

Five sedimentary samples from the Mohelnice Formation have been analyzed for trace element content as shown in figure 1: (1) phyllitised Givetian carbonate shales; (2) hemipelagic Famennian Trnavka shale; (3) turbidite Visean greywacke; (4) subvolcanic spilitic pebble; and (5) Mirov greywacke pebble. All samples show the same REE profile when normalized to PA-UCC reference values, except for sample (3 – triangles). Samples (1) and (2) display positive Ce anomaly and are depleted in LREE and enriched in HREE, whereas samples (4) and (5) – squares, are depleted in all REE due to a dilution effect of the carbonate and silica content. Sample (3) presents a negative Ce anomaly and a positive slope from La to Lu.

The Ce anomaly in sample (3) has been interpreted as the result of a lack in monazite content. Negative Eu anomaly is a systematic feature and results from intracrustal geochemical differentiation; Gd_n/Yb_n varies from 2.09 to 1.57; Th/Sc versus Zr/Sc covaries sympathetically; Th/Sc ranges from 0.19 to 0.58, strongly contrasting with an average value of 0.97 for PA-UCC; and Zr and Hf are depleted but not fractionated, which is consistent with heavy mineral sorting during transport. Monazites from pebbles of the Mirov greywacke lack Gd. These monazites are different in composition and C1-normalized REE pattern from the detrital monazites from the Carboniferous Upper Silesia foreland basin. Differences in monazite composition support the hypothesis that the Eo-Variscan Orogen could not have been the source terrain for the Carboniferous foreland deposits. The Mohelnice Basin is being promoted as an independent feature of a late orogenic extensional collapse.

A synchronous onset of diastrophic sedimentation is supported, despite a different time frame for all the mentioned basins' formation and their diverse tectono-sedimentary history. Biostratigraphic data support late Givetian age for the onset. Cooling ages on detrital micas show a narrow time-span of ~382 Ma for the exhumation of these orogenic complexes (e.g. Schneider et al., 1999, J. Otava and present authors unpublished data), which

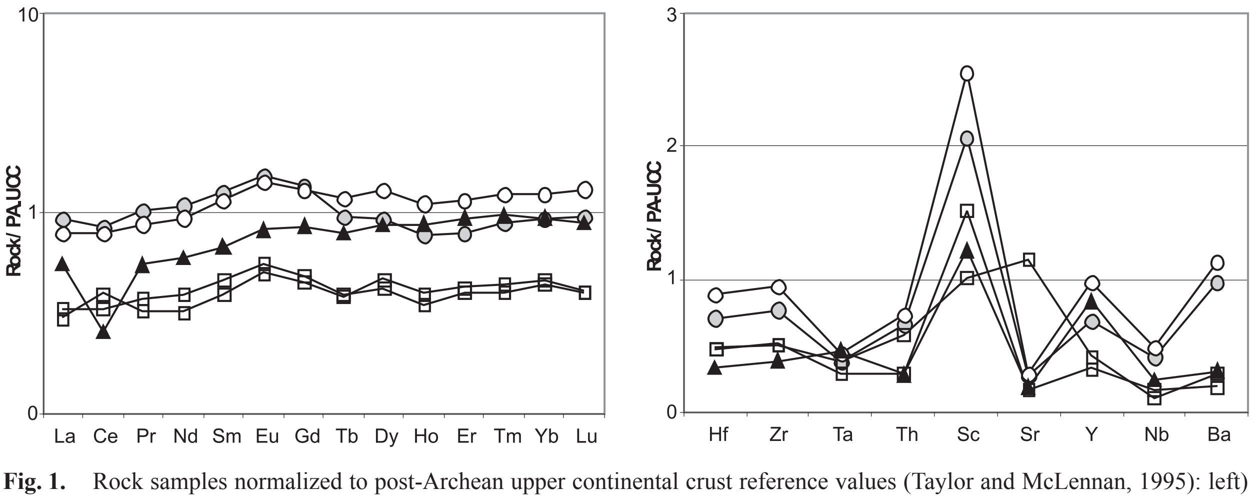

Fig. 1. Rock samples normalized to post-Archean upper continental crust reference values (Taylor and McLennan, 1995): left) display a consistent close to flat parallel trend with a positive Eu anomaly for all the samples but (3); right) view of the positive Sc anomaly and Hf-Zr systematics.

indicates a short time-break between the tectono-thermal event and the beginning of the diastrophic sedimentation. This data indicates a high rate for the exhumation process and its synchronous onset across the Bohemian Massif. The orogenic complexes studied were related to the Eo-Variscan tectono-thermal event that included HP metamorphism.

All the associated basins with the sequences mentioned above were formed independently from the main Moravo-Silesian Sudetian foreland basin, opposite to the hinterland, late orogenic collapse basin system, of early Bretonian phase (Hartley and Otava, 2001).

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PolyLX – the MATLAB™ Toolbox for Quantitative Analysis of Microstructures

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The textural analysis is a powerful, but underused tool of petrostructural analysis. This technique can answer some questions dealing with surface energies, grain nucleation, grain growth and duration of metamorphic and magmatic cooling events as long as appropriate thermodynamical data for studied mineral exist. This technique also allows systematic evaluation of degree of preferred orientations of grain boundaries in conjunction with their frequencies. This may help to better understand the mobility of grain boundaries and precipitations or removal of different mineral phases.

The quantitative textural analysis concerns detailed and precise description of grain sizes, grain shapes, grain boundaries as well as preferred orientations of grain and grain boundaries. We introduce a new open platform, object-oriented MATLAB™ toolbox PolyLX providing several core routines for data exchange, visualization and analysis of microstructural data, which can be run on any platform supported by MATLAB™.

Grain and grain boundary shape: Shape is extremely difficult property to measure, or even to define in a precise manner. Perhaps this is why there are so many proposed shape measures, none of which has been proved as entirely satisfactory. A shape measure should possess several desirable properties. Obviously, objects with different shapes should yield different measures, and similarly shapes should yield similar values regardless of the size or orientation of the object. Unfortunately, a shape measure possessing these properties may be a chimera; it has been proven that no single measure can be unique to only one shape. Therefore, there is a wide spectrum of single value measuring methods available in PolyLX toolbox.

Grain and grain boundary preferred orientation: To obtain data of preferred orientation, several techniques are implemented in PolyLX toolbox. The most general one is method of analysis matrix of inertia. This method can be applied on individual grains or boundaries as well as on a set of grains or grain boundaries. In latter case, the result is weighted by size of objects, which is welcome in specific tasks and differs from the results obtained from orientation analysis based on histograms (rose diagrams) or Fisher distribution. Another group of routines using approach of direction dependent projection of grain or grain boundaries (PAROR, SURFOR and PARIS) and advertised by Pannozo (1983) are fully implemented.

Spatial statistics: One of the most important aspects of quantitative texture analysis is description of spatial characteristics of grains or grain boundaries. PolyLX contains several routines dealing with spatial distribution of grains or grain boundaries (grain density method, nearest neighbour analysis, spatial pattern index) or evaluating deviation from random distribution (contact frequency and contact area methods).

Crystal size distributions: PolyLX offers implementation of method to construct the CSD plots using technique described by Peterson (1996).

Strain analysis: Several techniques to estimate strain are available. Classical ones as Rf/f, centre-to-centre method and Harvey and Fergusson (1981) as well as some of their recent modifications like DTNNM (Mulchrone, 2000) or area weighted Rf/f are implemented.