GEOCHEMISTRY AND GEODYNAMIC SETTING OF THE PERMIAN VOLCANISM IN THE WESTERN CARPATHIANS: A REVIEW

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Abstract: Upper-Carboniferous-Permian volcanic rocks of the Western Carpathians vary in composition from basalts to rhyolites. They occur as a part of volcano-sedimentary complexes or as clasts in Cretaceous and Palaeogene conglomerates in various tectonic units of the central and inner Western Carpathians. The volcanic rocks are geochemically closed to subduction-related high-K calc-alkaline magmatic association and originally were probably generated in a magmatic arc, which was evolving to the back-arc rifting.

Key words: Permian, Western Carpathians, volcanism, calc-alkaline, magmatic arc

Permian volcano-sedimentary complexes as a constituent of nappes and tectonic slices are incorporated into the recent geological structure of the central and inner Western Carpathians. They represent only fragments of a former originally spacious terrain, which was created on an older basement and subsequently underwent intensive denudation and multiple tectonic destruction related to nappe-forming processes. Stratigraphic position as well as the age of volcanic rocks of these complexes is poorly constrained. It seems to be most probable that formation of the terrain started in Upper Carboniferous and operated continually up to Lower Triassic. Preserved Permian complexes appear to be basinal accumulations formed due to combination of extensive clastic material transport and intensive volcanic activity in subaerial or subaqual sedimentary environment (Vozárová & Vozár, 1988). Volcanic rocks formed usually significant portion of the transported clastic material probably as a consequence of great depth of volcanic cover combined with steep topography. The extensive recycling of the volcanogenic material was connected not only with Permian volcanic activity but also with later (Cretaceous, Palaeogene) destruction of nappe stacks containing Permian complexes.

Material of destructed nappes was deposited in sedimentary basins partly preserved in the geological structure of the Pieniny Klippen Belt (PKB) and the central Western Carpathians.
Permian volcanic, subvolcanic and intrusive rocks then occur as: (1) bodies and clasts in the Permian volcano-sedimentary complexes, (2) veins, necks and small intrusive bodies in the Pre-Permian rock complexes and (3) recycled material (clasts) in the Cretaceous and Palaeogene conglomerates. Permian age of rhyolite bodies (olistoliths?) in the Lower Triassic on the base of the Silicic Unit and in the Jurassic of Meliatic Unit cannot be fully excluded too. Magmatic mineral associations are seldom preserved in the Permian volcanic rocks. All these rocks experienced metamorphic alteration in the low-pressure-low temperature (LP/LT) conditions (prehnite-pumpellyite to greenschist facies) but also high-pressure-low temperature (HP/LT) metamorphosed volcanic rocks as pebbles of the Cretaceous conglomerates of PKB have been found. Only Permian rocks at the south border of the Veporic Unit underwent high-grade metamorphic alteration in the kyanite to silimanite zone conditions.
Wide variability of petrographic types from basalts to rhyolites has been found among the Permian volcanic rocks in the Western Carpathians, which is reflected also by chemical composition (Fig. 1). Generally subalkalic character and calc-alkaline affinity are typical for these volcanic rocks. Small declines from calc-alkaline differential trend could be explained by subsolidus alteration (strong enrichment in K or Na) eventually by the specific low-pressure fractionation in magma chambers (increased concentrations of Ti and P).
Basalts to basaltic andesites have been found in the Krompachy Group (Gemeric Unit), in the Revúca Group and Predná Hora Formation (Fm.; Veporic Unit) and as highly dominated petrographic type – in the Malužiná Formation (Hronic Unit). Their analogues occur as pebbles in the Cretaceous and Palaeogene conglomerates of the PKB, Krížna Nappe and cover units of crystalline complexes. Large petrographic variability of basalts and basaltic andesites seems to be caused by: (1) magmatic fractionation, (2) crystallization rate and (3) subsolidus alteration. Basaltic rocks with (1) aphyric, (2) porphyritic and (3) glomeroporphyritic textures have been found. Phenocrysts were originally composed mostly by plagioclase, less frequently also by clinopyroxene and olivine. All these rocks are geochemically close to high-K calc-alkaline basalts and basaltic andesites (Fig. 2; Fig. 3). Their REE normalized patters indicate differentiated enrichment LREE /HREE combined also with the extra enrichment in LREE (La_N/Yb_N=2.30-8,63; Fig. 4). Negative Eu-anomalies (Eu/Eu*=0,66-1,02) most probably reflect of plagioclase fractionation, whereas variability in total amount of REE (La_N=45.41-137,13) and some compatible elements as Cr, V, Sc could be controlled by fractionation of major mineral phases.

Andesites to dacites are known from the Krompachy Group (Gemeric Unit), Vyšná Boca Fm. (Hronic Unit), Predná Hoľa and Brusno Fms.(Veporic Unit) as well as from the conglomerates of the PKB, Krížna Nappe and cover units of crystalline complexes. They form effusive and extrusive types as well. Mostly porphyritic texture originally with plagioclase and less frequently also with pyroxene, biotite and quartz phenocrysts is typical for these rocks. Some of andesites and dacites display coherent major and trace element concentrations with most basalts and basaltic andesites. Their REE patterns are similar to basalts (Fig. 5) but with difference total REE concentrations (La_N= 80.17-143.46) and more significant LREE enrichment (La_N/Yb_N= 4.51-6.25). Other andesites and dacites from the Gemeric and Veporic Units as well as from the conglomerates of the PKB seems to be more enriched in LREE or display different fractionation of HREE.

Rhyolitic rocks appear to be the most widespread type of volcanic rocks practically for all Permian volcano-sedimentary formations of the Western Carpathians except of the formations in the Hronic and Veporic Units. Both effusive and extrusive forms occur together. Although porphyritic varieties are most common, glassy rhyolites with perlitic texture and ignimbrites have been found as well. Texturally most variable rhyolitic rocks are concentrated in the Cretaceous conglomerates. Phenocrysts in rhyolites are formed by plagioclase, K-feldspar, quartz, biotite and amphibole in variable proportions. Geochemical characteristics of rhyolites are close to rhyolites of high-K calc-alkaline series (Fig. 6). Their normalized REE patterns are more variable in comparison to basic or intermediate volcanic rocks (La_N/Yb_N= 6.24-17.80; La_N= 62.02-397.62) with distinctive Eu-anomaly (Eu/Eu*= 0.06-0.46). No geochemical differences appear to exist between Permian rhyolites and those rhyolites from Lower Triassic sediments of the Silicic Unit (cf. Uher et al., 2002).

During the Permian magmatic activity in the Western Carpathians were produced except volcanic rocks also small granitic intrusions with A-type or S-type affinity located in the Gemeric Unit and in the southern part of the Veporic Unit (Uher & Broska, 1996; 1999). Their intrusive and subvolcanic analogues were found in Cretaceous conglomerates of the PKB.

High-K calc-alkaline affinity of the Permian volcanism in the Western Carpathians indicates their generation in the subduction-related geodynamic setting – in the magmatic arc of an ensialic island arc or active continental margin. Highly explosive character of the Permian volcanism indicated by widespread pyroclastic rocks and ignimbritic textures supports such interpretation. Subduction in the Carboniferous-Permian time is recorded also through obducted oceanic crust relics preserved in the Carboniferous Črmeľ-Ochtiná and Zlatník Fms.

of the Gemeric Unit (Ivan, 1996; 1997). Application of the magmatic arc evolution model by Lawton & McMillan (1999) allows us to speculate that the origin of Permian complexes of the Western Carpathians could be related to the evolved stage of its evolution characterized by widespread acid volcanic activity and initiation of the extensional basin formation accompanied by linear eruption of the calc-alkaline basaltic magma. Malužiná Fm. (Permian of Hronic Unit) could be considered as a relic of such basin. Permian formations located to the south of this formation do not contain any clastic material derived from high-grade metamorphosed crystalline complexes. Late stage of magmatic arc evolution related to the retreat of subducting slab appears to take place in the Late Permian. Basalts with OIB signature occurring recently as olistoliths tectonically incorporated into Late Permian evaporites on the base of the Silica Nappe (cf. Horváth, 2000) were probably generated at the beginning of this stage. Further evolution led to the back-arc rifting and the Meliata Ocean basin opening (Ivan, 2002). During the Upper Jurassic subduction of the Meliata Ocean slab (150-160 Ma, e.g. Dallmayer et al., 1996) also some Permian volcanic rocks were pulled down into subduction zone and metamorphosed in HP/LT conditions. Due to following collision and further involving in younger tectonic processes was the Permian magmatic arc finally destructed and incorporated into the Lower Cretaceous nappe pile. The denudation of this nappe pile served as a source of the clastic material for the Upper Cretaceous conglomerates in the PKB – most complete source of the Permian volcanic rocks including its HP/LT derivates (Plašienka, 1997; Ivan et al., 1999)

Permian volcanism with petrographic and geochemical features analogical to the Western Carpathian one has been found also in the Sardinia, Ligurian and Southern Alps (Barth et al., 1993; Cortesogno et al., 1998) and indicate common evolution of these areas in a magmatic arc related to the subduction of the Paleotethys Ocean (Stampfli, 2000).

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Fig. 1: Classification diagram Zr/Ti vs. SiO_2 (Winchester & Floyd, 1977 for the Permian volcanic rocks of the Western Carpathians. Explanations: PPKB-c – conglomerate of the peripheral part of the Pieniny Klippen Belt; KP-c – Kľuknava Palaeogene conglomerate; R-rhyolite

Fig. 2: Diagram Hf/3-Th-Ta (Wood, 1980) for the Permian basalts and basaltic andesites of the Western Carpathians. Explanations: see Fig. 1, N-MORB – normal mid-ocean ridge basalt, E-MORB – enriched mid-ocean ridge basalt, OIB – alkali oceanic island basalt

Fig. 3: Diagram Ta/Yb vs.Th/Yb (Pearce et al., 1981) for the Permian basalts and basaltic andesites of the Western Carpathians. Explanations: see Fig. 1, thick line with three crosses – mantle array with the positions of mean composition of N-MORB, E-MORB and alkali OIB

Fig. 4: Chondrite normalized REE patters for the Permian basalts and basaltic andesites of the Western Carpathians. Normalization after Sun and McDonough (1989). Explanations: see Fig.1

Fig. 5: Chondrite normalized REE patters for the Permian andesites and dacites of the Western Carpathians. Normalization after Sun and McDonough (1989). Explanations: see Fig.1

Fig. 6: Diagram Zr vs. Nb (Leat et al., 1986) for the Permian rhyolites of the Western Carpathians. Explanations: see Fig. 1; concentration lines 350-700 ppm Zr discriminate between subalkaline and peralkaline rhyolites, Zr/Nd ratio lower than 10 when Zr concentration is higher than 500 ppm is typical for peralkaline rhyolites unrelated to subduction processes

Fig. 7: Chondrite normalized REE patters for the Permian rhyolites of the Western Carpathians. Normalization after Sun and McDonough (1989). Explanations: see Fig.1

Fig. 1.

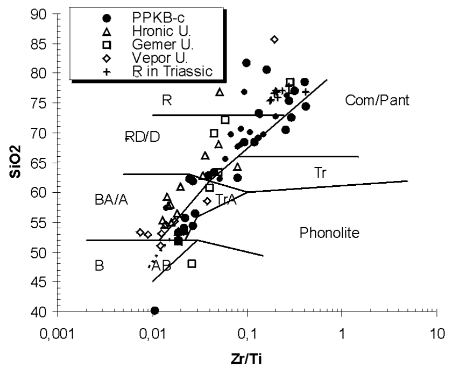


Fig. 2.

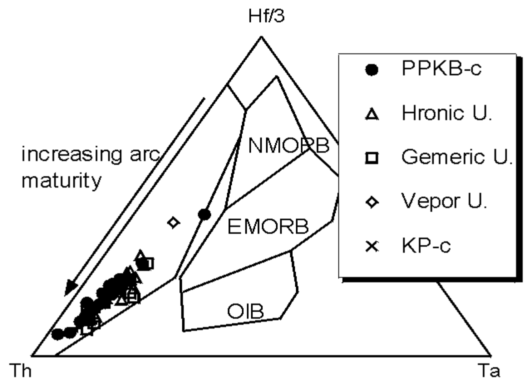


Fig. 3.

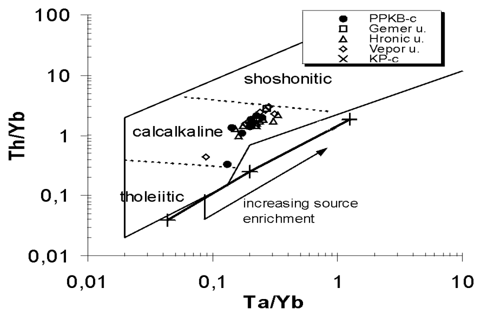


Fig. 4.

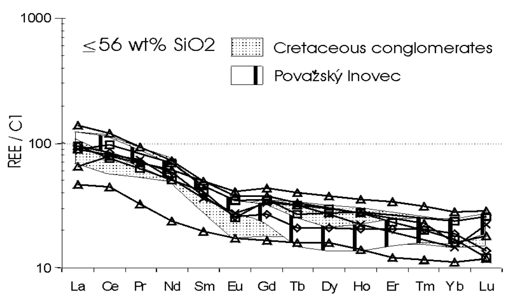


Fig. 5.

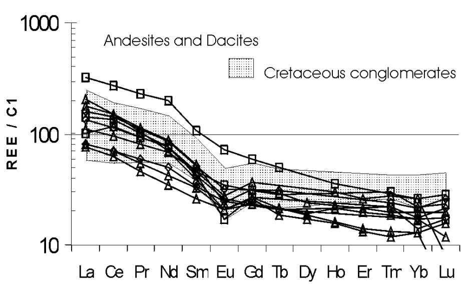


Fig. 6.

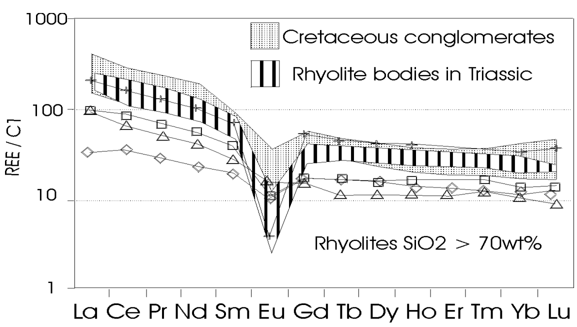
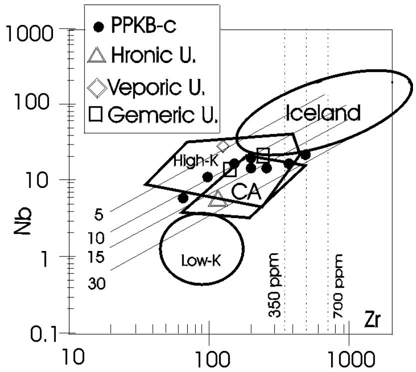


Fig. 7.



PPKB-c
Hronic U.
Veporic U.
Gemeric U.
Iceland
High-K
CA
Low-K
5
10
15
30
350 ppm
700 ppm
Nb
Zr
1000
100
10
1
0.1
10
100
1000