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# U/Pb DATING OF ZIRCONS OF POSTOROGENIC ACID METAVOLCANICS AND METASUBVOLCANICS: A RECORD OF PERMIAN-TRIASSIC TAPHROGENY OF THE WEST-CARPATHIAN BASEMENT

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**Abstract:** The Permian and/or Triassic ages (278–216 Ma) of subalkaline postorogenic acidic metavolcanics and metasubvolcanics, in the contact area between the Tatric and Veporic Zones, correspond to early Alpine taphrogeny of the West-Carpathian basement in the area of a large (Pohorelá) normal detachment fault/shear zone.
The dated complexes are mostly represented by Permian bimodal subalkaline volcanics, often surrounded by pyroclastics and accompanied by subvolcanic bodies indicating transtensional, narrow, temporary active furrows above deep-seated shear zones. They reflect a continental rifting phase (taphrogeny) of the southern parts of the central West-Carpathian basement belonging to a Paleotethys or Cimmerian passive margin of the Meliata (-Vardar-Hallstatt) oceanic basin.

**Key words:** Western Carpathians, Tatro-Veporic Zone, zircon U/Pb isotope dating, acidic subalkaline metavolcanics and/or metasubvolcanics, anorogenic setting, taphrogeny, Permian-Triassic.

## Introduction

Basic information about granite porphyries of the supposed Permian age can be found on the general map of the ČSSR 1: 200,000 (sheet of Banská Bystrica) in the Ľubietová and Kraklova zones of the Veporic Unit (Zoubek in Maheľ et al. 1964, 1968). Similar rocks were designed as leptites (Krist 1976, 1977; Krist et al. 1986) in the Kráľová hoľa Veporic Zone further south.

Detailed geological-petrographical and geochemical research of the low-grade metamorphic acidic and basic volcanics, tuffs and accompanying metasediments enabled us to separate and define a new Jánov Grúň Complex (Miko 1981; Miko & Korikovsky 1994) of the supposed Devonian-Early Carboniferous age (according to palynological features: Planderová & Miko 1977).

Different lithology and a metamorphic gap between the Jánov Grúň Complex and the surrounding medium-grade Hron Complex (Klinec 1966) prove a tectonic relationship between these complexes, where the former complex was considered to be a product of diaphtoritization of the latter (Zoubek in Maheľ et al. 1964; Kamenický 1977).

$^{40}Ar/^{39}Ar$ dating of the cleaved whole-rock phyllite (meta-felsic volcanic rock) from the Jánov Grúň Complex recorded a plateau age of 86.1 ± 0.4 Ma (Dallmeyer et al. 1993). This age was interpreted as closely dating the crystallization of the constituent metamorphic white mica. All other obtained ages are Variscan in the Supratatric basement area (Dallmeyer et al. 1993, 1994; Maluski et al. 1993). From this point of view Devonian age of the Jánov Grúň Complex appears to be questionable.

Permian to Triassic U/Pb age-data for the granite porphyries and the dacites were not influenced by the Alpine recrystallization, which adjusted only the Rb/Sr and K/Ar isotope data of the host rocks (Cambel et al. 1990; Bibikova et al. 1990; Krist et al. 1992).

These new isotope age data of metavolcanics and metasubvolcanics clarify the timing of late Variscan/early Alpine transition period in the central Western Carpathians.

The aim of presented paper is to document the age of volcanic and subvolcanic postorogenic bodies that intruded into different basement complexes thus representing post-metamorphic post-Variscan members. The emplacement of post-orogenic vein bodies was enhanced by the early Alpine (since Early Permian) taphrogeny of the Variscan basement.

## Geological position of dated volcano-sedimentary complexes

The Jánov Grúň Complex (Miko 1981) and its analogies (Kraklova Formation, Korikovsky & Miko 1992) are exposed in the imbrication structures of the basement in the contact

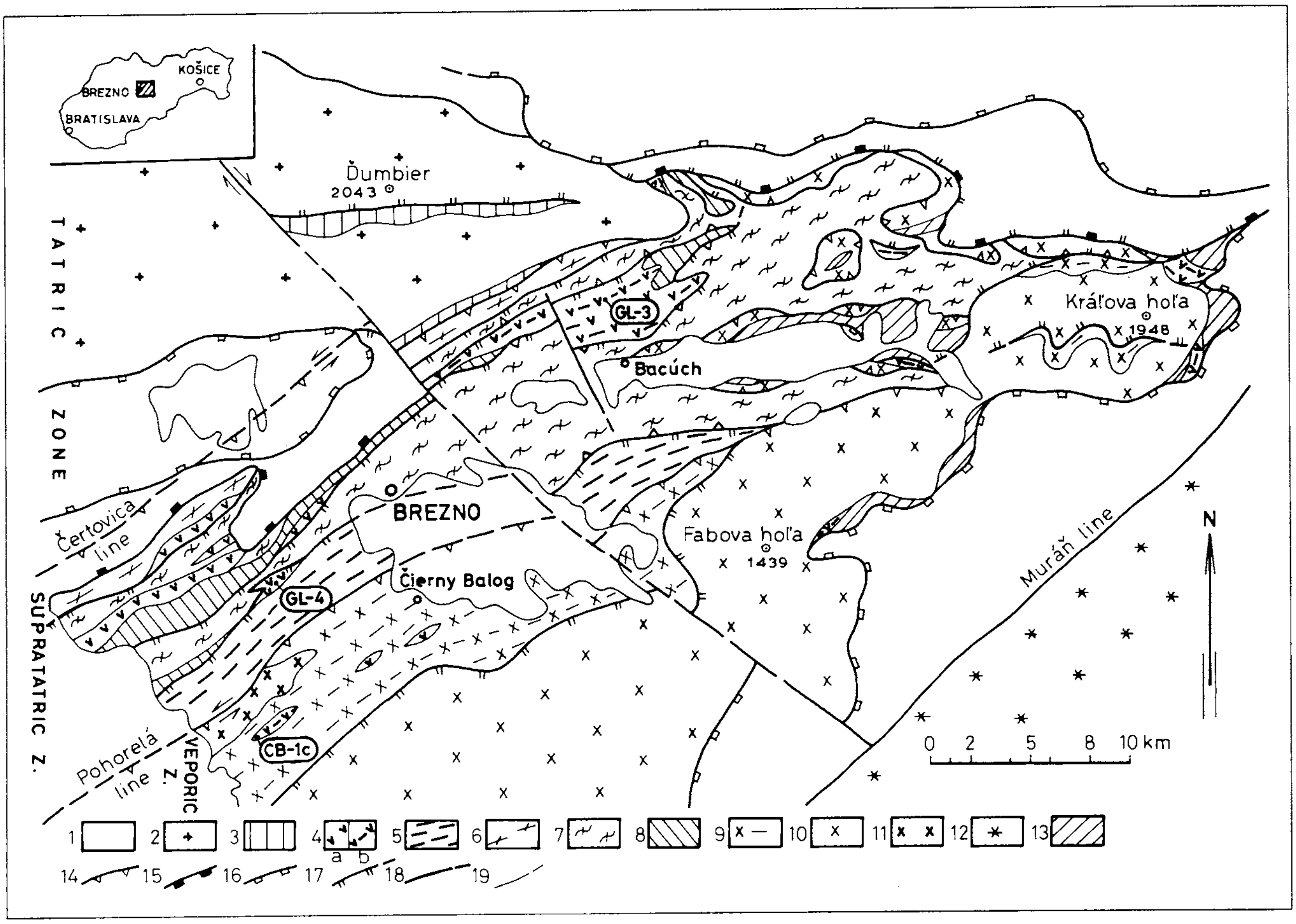

**Fig. 1.** Cretaceous tectonic structure of the Tatro-Veporic basement and cover complexes (Putiš 1995) with subalkaline (A-type) Permian/Triassic volcanics and subvolcanics. **1** — Tertiary rocks, **2** — Tatric crystalline basement complexes, **3** — Tatric (Permian-Cretaceous) cover complexes, **4** — Permian (/Triassic) low-grade volcano-sedimentary complexes: a — subvolcanic vein bodies, b — volcanics accompanied by pyroclastic and terrestrial sedimentary rocks (mostly Bacuch-like Formation), **5** — Late Carboniferous ? metasediments (the Kraklova Formation), **6** — Ľubietová medium/high-grade crystalline complex (Early Paleozoic ?), **7** — Hron medium-grade crystalline complex (Early Paleozoic ?), **8** — anchi-to low-grade Permian-Cretaceous cover of the Supra-Tatric (North-Veporic) crystalline basement complexes, **9** — Čierny Balog medium/high-grade crystalline complex (Early Paleozoic ?), **10** — Late Carboniferous-Permian granites to tonalites of the Vepor pluton, Cretaceous low-grade granite-mylonites, **11** — Hrončok Granite (Permian, Cambel et al. 1990, Rb/Sr data), Cretaceous low-grade granite-mylonites, **12** — undivided South-Veporic crystalline basement, **13** — low-grade Permian-Triassic cover of the Veporic basement, **14** — main mid-Cretaceous thrusts and transpressions, **15** — Krížna Mesozoic Nappe, **16** — Choč and Muráň higher Mesozoic Nappes, **17** — internal thrusts, **18** — fault, or a tectonic boundary, **19** — primary geological boundary.

area between the Tatric and Veporic (mid-Cretaceous) Zones of the central Western Carpathians (Fig. 1).

The studied (Permian and/or Triassic) volcanics, subvolcanics and pyroclastics were tectonically incorporated into three different Variscan medium/high-grade basement complexes: into the Ľubietová Complex (Zoubek in Maheľ et al. 1964, 1968), into the Hron Complex (Klinec 1966; Putiš 1989) and into the Čierny Balog Complex (Krist 1976, 1977; Putiš 1995), as a direct or an independent part of their Permian-Mesozoic autochthonous cover sequences. The basement complexes have been incorporated into late Variscan nappe structure (Putiš 1992, 1993) before intrusion of Permian volcanics. The subvolcanic bodies cut regional-metamorphic foliation of the surrounding crystalline basement complexes. In other places there are acidic volcanics accompanied by acidic tuffs and the basic volcanics with tuffs as well, indicating their formation in narrow temporary active transtension furrows.

The subvolcanic vein bodies appear to be younger than the different types of late Variscan granites-to-tonalites in the area of question (Bibikova et al. 1990, according to U/Pb data, or Cambel et al. 1990, according to Rb/Sr data). Such a relationship can be possibly seen even in field (in the middle part of the Kamenistá dolina Valley and at the beginning of the Podtajchova dolina Valley), where synkinematic coarse-grained orthogneiss-like (Hrončok type) granitic bodies are cut by pale veins of metasubvolcanics. A similar situation was found in the Ľubietová Zone a few kilometres to the N.

Alpine metamorphic recrystallization of Permian volcano-sedimentary complex and mylonitization (phyllonitization) of the host crystalline rocks is bound to originally early Alpine extension (Pohorelá normal detachment) fault/shear zone, later transformed into a thrust/transpression zone during mid-Cretaceous collision of the Tatric and Veporic structural units. Tectonic cover was mainly represented by the thrust Veporic crystalline basement complexes. The Late Cretaceous-Early Paleogene extension (unroofing) of the Veporic structural unit revealed deeper parts of the fault/shear zones with the strongly mylonitized basement rocks in biotite and garnet zone conditions, with a perfect ductile behaviour of quartz and that a semiductile of feldspars (Putiš 1991, 1993). Cretaceous mylonitization of the basement rocks (Dallmeyer et al. 1993) was connected with the prograde Alpine metamorphism of the Permian/Mesozoic cover rocks, incl. the Permian/Triassic volcanic/subvolcanic bodies and surrounding pyroclastics and terrestrial clastics, mostly in biotite-garnet zone conditions.

## Petrography of metavolcanic/metasubvolcanic rocks

Three characteristic types of acidic K-Na volcanic and subvolcanic rocks of the north-western Veporské vrchy Mts. were selected for U/Pb zircon dating. The location of the dated samples is presented in Fig. 1. The grade of metamorphic recrystallization of all volcanic rocks is identical and mainly corresponds to biotite zone conditions (360-400 °C). According to phengite geobarometer, the pressure at 600 MPa was estimated.

There are, however, a lot of leucocrate granite-gneiss bodies with newly formed (Alpine) grossularite-rich garnet in the Čierny Balog area. Some garnet grains have still preserved magmatic cores composed of 62-63 % of almandine, 13-27 % of spessartine, 7-8 % of grossularite and 7-8 % of pyrope. They have Ca-rich rims composed of 49-54 % grossularite, 32-37 % of almandine, 12-14 % of spessartine and 0-1 % of pyrope. Such newly formed garnets (often idiomorphic) are also present in host crystalline rocks (especially in albitized plagioclase in both mylonitized gneisses and amphibolites) that apparently subjected Alpine recrystallization (Putiš 1993).

The metagranite porphyry (quartz metaporphyry) (GL-4) forms a cross-cutting stock of 100 m width and 1 km length placed in chlorite-muscovite phyllites and metasandstones of the Kraklova Formation (Korikovsky & Miko 1992) in the Kamenistá dolina Valley. Microtexture of the granite porphyry is subvolcanic and comprises quartz and feldspar phenocrysts. The magmatic biotite is fully replaced by fine-grained metamorphic biotite. A mesostasis of these rocks transformed then into a fine-grained aggregate of a phengite, K-feldspar, albite and quartz.

The metarhyodacite (GL-3) is a dyke 0.6 m thick, crosscutting the chlorite-muscovite phyllites, metasandstones and metavolcanoclastic rocks of the Jánov Grúň Complex (Miko 1981) in the Bacúch area. The microtexture of the rock is volcanic and contains the quartz phenocrysts, sometimes K-feldspars and brown magmatic biotite which is partly replaced by the pale-brown metamorphic biotite and leucoxene. The microgranular recrystallized but not schistosed mesostasis consists of newly-formed albite, K-feldspar, quartz, phengite and calcite. The grade of metamorphic recrystallization of the metavolcanics (the Jánov Grúň Formation) and the surrounding metasedimentary rocks (the Kraklova Formation) of the Jánov Grúň Complex is always the same.

The metarhyodacite porphyry (CB-1C) forms a small dyke 7 m thick, surrounded by restricted amounts of acidic metatuffs and metatuffites. In the same area these subvolcanics crosscut the ortho- and paragneisses and garnet amphibolites of the Čierny Balog Complex of unknown age. Metarhyodacite porphyry has the subvolcanic granophyric microtexture comprising the prismatic phenocrysts of K-feldspars and plagioclase replaced by metamorphic Na-poor K-feldspar and albite. The fine-grained mesostasis evolved into schistose phengite-biotite-albite-K-feldspar-quartz aggregates. The grade of metamorphic recrystallization of rhyodacite porphyry is much less than that of the surrounding gneisses and amphibolites, and it corresponds to the biotite zone conditions. A part of veins has character of metaaplitoids. The Alpine metamorphic overprint (diaphtoresis) of the crystalline complexes is equal (biotite zone), or even higher (biotite-garnet zone) to prograde metamorphism of Permian/Triassic volcano-sedimentary complex.

## Methodological approach and results of the U/Pb geochronological dating

Geochronological determinations were performed in the Institute of Precambrian Geology and Geochronology (Russian Academy of Sciences, St. Petersburg) on a Finnigan MAT 261 8-collector masspectrometer in static mode.

Zircons were extracted from crushed rock samples with heavy liquid and magnetic separation techniques. Handpicked aliquots of zircon were analyzed following the method of Krogh (1973). The total blanks were 0.05-0.1 ng Pb and 0.005 ng U. An air-abrasion treatment of the zircon was performed on the basis of Krogh (1982) technique, modified by coating the abrasive walls with epoxy impregnated with diamond powder.

The Pb Dat and ISOPLOT programs by Ludwig (1991a, b) were used for uncertainties and correlations of U/Pb. Ages were determined using the decay constants given by Steiger & Jäger (1976). All errors are reported at the 2 level. Corrections for common Pb were made using values of Stacey & Kramers (1975).

**Metarhyodacite porphyry** (Sample No. CB-1C, Location: 15 km SW of Brezno, Kamenistá dolina Valley, a quarry at the Čierny potok gamekeepers' cottage).

The zircon grains are prismatic, idiomorphic, transparent or nebulous, hyacintic in habit, pink-brown in this sample. Magmatic zoning and minor amount of microinclusions are recognized in the outer parts of the crystals. The range of crystal sizes are 40-250 μm. Zircons have a length/width ratio of 1.5-2.5. Two size fractions of zircons (-60+40 μm and -154 +135 μm) were recorded from the sample and analysed (No. 1, 2; Tab. 1) and one (+100 μm) was abraded (No. 3, Tab. 1) which resulted in a substantial increase in concordance (Fig. 2). The discordia for three points yielded an upper intercept age of 278 ± 11 Ma, and a lower intercept of 37 ± 20 Ma; MSWD = 0.85.

**Metarhyodacite** (Sample No. GL-3, Location: 15 km NE of Brezno, Kršková dolina Valley, 1 km NW of the topogr. point 713.1, the Bacúch Formation).

The zircon population of sample No. GL-3 mainly consists of semi-transparent or translucent unzoned idiomorphic, prismatic, pink-yellow crystals of hyacinth habit with sharp dipyramidal terminations. Opaque inclusions are common in the central and outer parts of the grains. The range of crystal size is 40-300 μm. Zircons have a length/width ratio of 1.0-4.5. Remnant core patches are present in a small number of grains (10 %) from the size fraction +100 and they could represent older inherited zircon.

Four hand picked zircon size fractions from sample No. GL-3 were analyzed (Tab. 2). All the data points are discordant, three points (fractions -45 μm, -80 + 60 μm and -135 + 100 μm;

**Table 1:** U/Pb isotopic data for zircons from a metarhyodacite-porphyry of the Čierny Balog area: sample No. CB-1C (Fig. 2).

| No. | Fraction size (µm) | Fraction weight (mg) | Pb (ppm) | U (ppm) | Atomic ratios | | | | | Age (Ma) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $^{206}Pb/^{204}Pb^a$ | $^{207}Pb/^{206}Pb^a$ | $^{208}Pb/^{206}Pb^a$ | $^{206}Pb/^{238}U^b$ | $^{207}Pb/^{235}U^b$ | $^{207}Pb/^{206}Pb$ |
| 1 | -60+40 | 1.08 | 331 | 1057 | 853.7 | 0.0685 | 0.2000 | 0.0280 | 0.1987 | 258±2 |
| 2 | -154+135 | 1.19 | 458 | 1347 | 1352 | 0.0622 | 0.01915 | 0.0311 | 0.2207 | 263±3 |
| 3 | +100 | 0.50 | 60.3 | 758 | 67.69 | 0.2676 | 0.6853 | 0.0343 | 0.2443 | 272±10 |

[a] Data corrected for blank.
[b] Data corrected for blank and common lead.
[c] Residue of zircon after air abrasion in weight %.

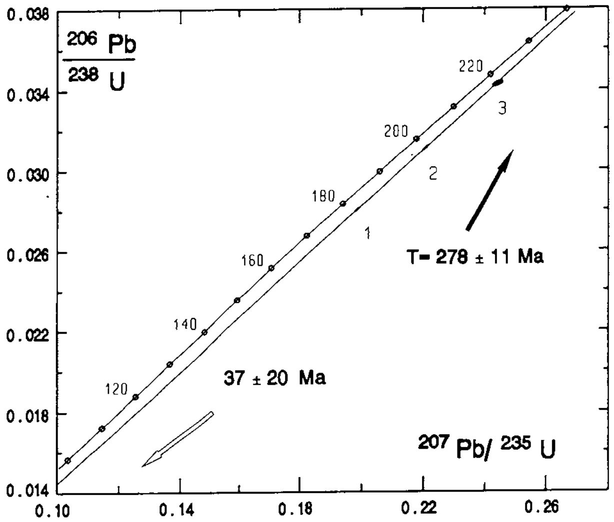

Fig. 2. U/Pb concordia diagram for sample CB-1C. Error ellipses shown are calculated according to Ludwig (1991b).

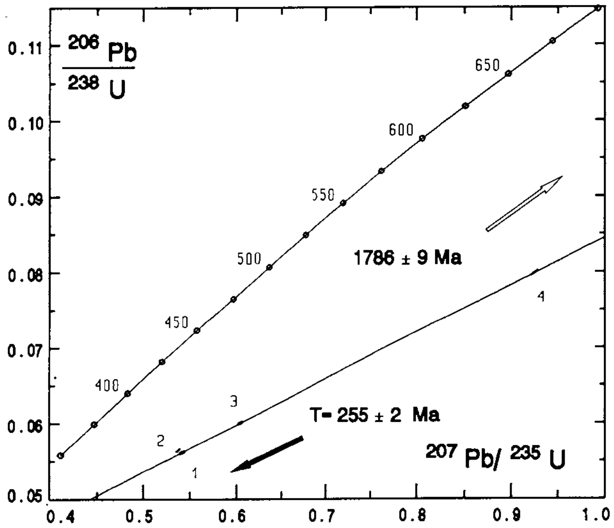

Fig. 3. U/Pb concordia diagram for sample GL-3. Error ellipses shown are calculated according to Ludwig (1991b).

Nos. 1, 3, 4; Fig. 3) defining a discordia which intersects the concordia curve at 1786 ± 9 Ma and 255 ± 2 Ma (MSWD = 0.23). The data point for zircons -60 + 44 µm size fraction deviates from discordia and can be correlated with the presence of significant amounts of inclusions in the grains.

**Metagranite porphyry** (Sample No. GL-4, Location: 8 km SW of Brezno, Kamenistá dolina Valley, the Kraklova Formation).

The zircon population of this sample is made up of a euhedral, prismatic or needle shaped, pale pink transparent grains, hyacinth in habit, with high birefringence. The range of crystal size is 30-250 µm. Zircon grains have a length/width ratio of 1.5-5.0, rarely 5.0-7.0. Zoning is recognized, opaque rounded and needle shaped inclusions are common. A minor amount of grains (no more than 20 %) from size fraction +100 µm contain remnants of relict cloudy patches in the central part of the crystals which could represent older inherited zircon.

Zircon analyses were made on four size fractions of idiomorphic and transparent grains (Tab. 3, Nos. 1-4). Then one aliquot (-100 µm) was subjected to preliminary acid treatment (Tab. 3, No. 5). Zircon powder was treated with 35% HF and 68% $HNO_3$ at 220 °C during two hours. Then, the dissolved parts of the zircon were carefully removed by repeated interaction with concentrated HCl, and zircon residues were analysed. On a concordia plot, all data points are discordant (Fig. 4). A discordia line, constructed for these points, has an upper intercept with the concordia that corresponds to an age 1094 ± 71 Ma and a lower intercept at 216 ± 5 Ma (MSWD = 5.5).

## Interpretation of the U/Pb isotope data and tectonic implications

The morphological forms of the zircon grains of all three samples are proper to a magmatic origin. The data points of sample No. GL-4 (metagranite porphyry) are distributed near the lower intercept of discordia (Fig. 4). In addition, the analysed zircons from size fraction +100 µm which is enriched in inherited zircon are mostly plotted far from the lower intercept of the discordia. Similar data point distributions were found for sample No. GL-3 (metarhyodacite) (Tab. 2, Fig. 3). Taking into account the igneous origin of the studied zircons, it can be assumed that the ages generated by the lower intercepts correspond to the periods of formation. In this case the upper-intercept ages may reflect the ages of the inherited zircon grains (= age of a remelted Proterozoic protolith). Thus the U/Pb data on the zircon grains from metagranite-porphyry of the Kraklova Formation (sample No. GL-4) and from metarhyodacite of the Jánov Grúň Formation (sample No. GL-3) allowed us to interpret the ages 216 ± 5 and 255 ± 2 Ma as the time of their magmatic emplacement. The lower intercept defined by the discordia and plotted for the magmatic zircons of sample No. CB-1C (metarhyodacite porphyry) is close to zero (Fig. 2). Anyway, the age of 278 ± 11 Ma yielded for the upper intercept of discordia, corresponds to the emplacement time of the metarhyodacite porphyries. The magmatic emplacement of the volcanics spans from 278 Ma to

**Table 2:** U/Pb isotopic data for zircons from a metarhyodacite of the Bacúch area (the Jánov Grúň Complex, the Bacúch Formation): sample No. GL-3 (Fig. 3).

| No. | Fraction size | Fraction weight | Pb | U | Atomic ratios | | | | | Age (Ma) |
|---|---|---|---|---|---|---|---|---|---|---|
| | (μm) | (mg) | (ppm) | (ppm) | $^{206}Pb/^{204}Pb^a$ | $^{207}Pb/^{206}Pb^a$ | $^{208}Pb/^{206}Pb^a$ | $^{206}Pb/^{238}U^b$ | $^{207}Pb/^{235}U^b$ | $^{207}Pb/^{206}Pb$ |
| 1 | -45 | 0.29 | 53.5 | 841 | 504.7 | 0.0981 | 0.1844 | 0.0561 | 0.5416 | 927±8 |
| 2 | -60+44 | 1.03 | 45.7 | 750 | 979.1 | 0.0836 | 0.1501 | 0.0564 | 0.5370 | 900±2 |
| 3 | -80+60 | 1.67 | 48.0 | 681 | 425.7 | 0.1063 | 0.2004 | 0.0600 | 0.6042 | 1013±5 |
| 4 | -135+100 | 0.75 | 55.3 | 643 | 1175 | 0.0959 | 0.1413 | 0.0798 | 0.9247 | 1294±1 |

[a] Data corrected for blank.
[b] Data corrected for blank and common lead.

**Table 3:** U/Pb isotopic data for zircons from a metagranite-porphyry of the Kraklova area (the Kraklova Formation): sample No. GL-4 (to Fig. 4).

| No. | Fraction size | Fraction weight | Pb | U | Atomic ratios | | | | | Age (Ma) |
|---|---|---|---|---|---|---|---|---|---|---|
| | (μm) | (mg) | (ppm) | (ppm) | $^{206}Pb/^{204}Pb^a$ | $^{207}Pb/^{206}Pb^a$ | $^{208}Pb/^{206}Pb^a$ | $^{206}Pb/^{238}U^b$ | $^{207}Pb/^{235}U^b$ | $^{207}Pb/^{206}Pb$ |
| 1 | -40 | 0.89 | 53.4 | 1289 | 963.4 | 0.0685 | 0.1949 | 0.0374 | 0.2755 | 346±3 |
| 2 | -50 | 0.74 | 35.2 | 839 | 550.9 | 0.0808 | 0.2002 | 0.0372 | 0.2799 | 393±57 |
| 3 | -85+50 | 1.76 | 35.3 | 851 | 1339 | 0.0650 | 0.1634 | 0.0388 | 0.2901 | 379±3 |
| 4 | +100 | 0.53 | 25.2 | 529 | 877.8 | 0.0748 | 0.1287 | 0.0455 | 0.3661 | 544±3 |
| 5 | $-100^c$ | 1.71 | 26.6 | 597 | 5388 | 0.0599 | 0.0914 | 0.0451 | 0.3564 | 503±35 |

[a] Data corrected for blank.
[b] Data corrected for blank and common lead.
[c] Residue of zircon after acid treatment.

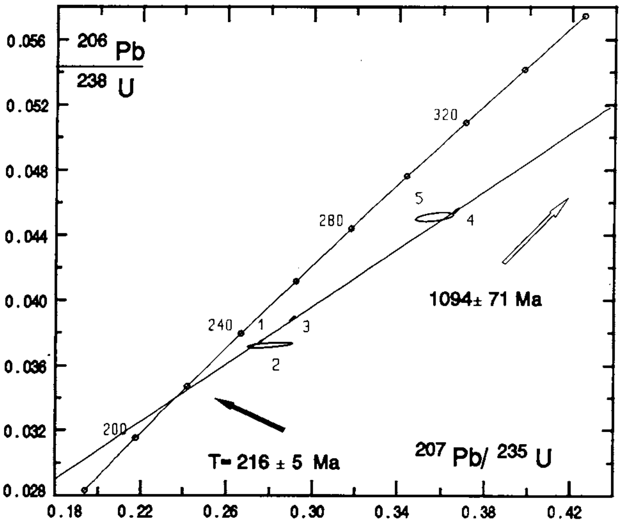

**Fig. 4.** U/Pb concordia diagram for sample GL-4. Error ellipses shown are calculated according to Ludwig (1991b).

216 Ma, which suggests a long-term magmatic/volcanic activity with different source rocks (1786 Ma and 1094 Ma).

The emplacement of the volcanics/subvolcanics is concentrated into a wide zone of the Pohorelá detachment fault/shear system of lithospheric significance (Putiš 1991, 1992, 1993; Tomek 1993), separating the Cimmerian mobile belt in the south from the European platform already during the Permian/Triassic period, or the zone dominated by Triassic (-Jurassic) extension (S of the Pohorelá shear zone) from that of a general Jurassic-Cretaceous extension (N of the Pohorelá shear zone).

The early Alpine extension process (taphrogeny) was obviously connected with mantle upwelling and melting of deep-seated protoliths which enhanced the emplacement of the subalkaline volcanic bodies into the upper crust along the normal detachment faults. Precambrian protoliths might have come from remobilized pan-African basement which was incorporated into late Variscan pile of the basement nappes (Putiš 1992 — Fig. 2).

The studied postorogenenic types of volcanic-subvolcanic rocks fit quite well into the framework of a magmatic-type anorogenic setting (Pupin 1980, see Fig. 5 ex Krist et al. 1986; Bonin 1990). Small Hrončok granite bodies (265 Ma, Rb/Sr, Cambel et al. 1990) in the same area were ascribed to an A-type granite (Broska et al. 1994; Petrík et al. 1994) and the Permian/Triassic subalkaline volcanic activity appears to be a continuation of an anorogenic plutonic activity.

The Pohorelá shear zone s.l. was active since the Late Carboniferous (since late Variscan postorogenic collapse, Putiš 1995) and was infilled by a few phases of granitoid magmatism: the older one is represented by a sheet-like body of the Vepor pluton, composed of tonalites (303 ± 2 Ma, U/Pb) and porphyric granites to granodiorites (285 ± 5 Ma) (Bibikova et al. 1990) of the I- (tonalite) and I-S-type (porpyric granite) (Petrík et al. 1994), followed by an A-type Hrončok granite intrusion (Broska et al.1994) (265 Ma, Rb/Sr) and then by A-type subalkaline volcanics/subvolcanics (278-216 Ma).

## Conclusions

1 — U/Pb dating of low-grade metamorphosed acid volcanics/subvolcanics confirmed their Permian (samples CB-1C, GL-3) and/or Triassic (sample GL-4) ages. The melted source

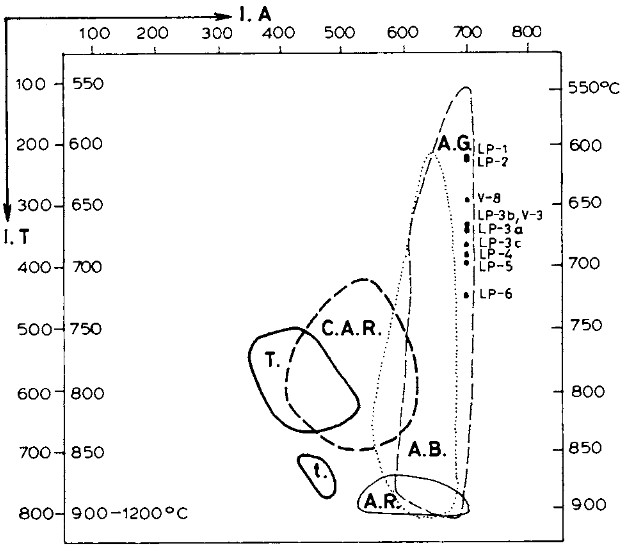

**Fig. 5.** Position of the projection points of the zircon populations of the studied metavolcanic/metasubvolcanic rocks, in fields of some volcanic and granitoid rocks, constructed after Pupin (1980). **T** — tonalites, **t** — trachyandesites, **C.A.R.** — calcalkaline rhyolite series (orogenic), **A.R.** — alkaline rhyolite series (anorogenic), **A.B.** — alkaline basalts, **A.G.** — alkaline and hyperalkaline syenites and granites (anorogenic). Lp and V metavolcanic rocks samples position, according to Krist et al. (1986): V-3 (=CB-1C, in this paper), V-8 (close to CB-1C), Lp-2,3,4, 5,6 (from bodies NE of CB-1C, S of Čierny Balog).

rocks of the volcanics/subvolcanics belong to the continental crust of Precambrian age according to the dated magmatic zircon cores relics at 1786 and 1094 Ma. The surrounding pyroclastic and sedimentary rocks (the Bacúch Formation and the Kraklova Formation) metamorphosed in comparable conditions appear nearly the same age. Part of the sedimentary rocks can be relatively older-Upper Carboniferous (?) (the Kraklova Formation) cut by Permian subvolcanic bodies.

2 — Consequently, at least two different types of Permian sedimentary-magmatic/volcanic complexes can be distinguished in the central Western Carpathians:

The first type is represented by Permian, mostly bimodal subalkaline volcanics, often surrounded by pyroclastics and accompanied by subvolcanic bodies. Part of the subvolcanic bodies occurs outside the Permian complex and cuts the Variscan crystalline basement structures. These complexes are interpreted as indicators of an early Alpine (Early Permian-Triassic) transtensional process and the development of narrow, temporary active furrows above deep-seated fault/shear zones of the lithosphere. They reflect a continental rifting phase (taphrogeny) of the southern parts of the central West-Carpathian basement, indicating a Paleotethys or Cimmerian passive margin realm (Putiš 1991; Plašienka 1991; Kozur 1991).

There are some similarities to bimodal volcanics of previous Permian complex in other Tatro-Veporic regions (Predná hoľa Complex, and Permian complexes of the Považský Inovec, Tribeč and Malá Fatra Mts.).

The second type is represented by Permian complexes which formed in molasse-type basins and in depressions filled up with dominantly clastic sedimentary rocks and synsedimentary bodies of rhyolites and tuffs, probably Late Permian in age. In the Tatric-Veporic boundary zone, such a sequence could represent Permian Ľubietová Complex (Vozárová & Vozár 1988).

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