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From subduction to collision: Genesis of the Variscan granitic rocks from the Tatric Superunit (Western Carpathians, Slovakia)

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Abstract: Granitic rocks from the core mountains of the Tatric Superunit (Western Carpathians, Slovakia) were dated by means of the sensitive high-resolution ion microprobe (SHRIMP) zircon U–Th–Pb method. The dated granitic rocks yielded a broad interval of the Concordia ages from 365±5 Ma to 332±3 Ma and largely invalidated the former hypothesis of a duality/antagonism in emplacement ages of the Variscan S- and I-type granites (Mississippian vs. Pennsylvanian) in the Central Western Carpathians (CWC). Generally, the obtained magmatic ages cluster in two separate intervals reflecting different stages of orogeny. The older, Famennian–Tournaisian event (365–350 Ma) was related to subduction of the Rheic Ocean, whereas the younger, mostly Visean event (348–332 Ma) was associated with collisional melting. The Th/U ratios of analysed zircons are compatible mainly with their magmatic origin (Th/U>0.2), while the lower ones (Th/U<0.1) in some zircons can indicate competition for Th with monazite and allanite, commonly present in the analysed granitic rocks. The new dating confirmed common zircon inheritance in Western Carpathian granites with inherited zircon cores showing the Neo-Archean to Paleo-Proterozoic (2800–1690 Ma) and Ediacaran to Late Ordovician (623–448 Ma) ages. The lack of any significant differences in magmatic/emplacement ages and the common "dirty" or hybrid character of both I- and S-type granites in the CWC indicate that the melted, often mixed sources and/or subsequent modification by hybridization and assimilation processes were mostly responsible for their general "alphabetic" designation (I-/S-type).

Keywords: Western Carpathians, core mountains, genesis, granitic rocks, SHRIMP dating, zircon.

Introduction

Granitic rocks – felsic plutonic rocks that crystallized from magma – represent an important constituent of continental crust and their origin may result from fractionation of mantle-derived basaltic magmas or partial melting of different crustal protoliths in contrasting pressure–temperature conditions, either water-fluxed or fluid-absent (Janoušek et al. 2020). Granitoids can originate in various geodynamic settings; however, most of the granitic rocks were generated at the subduction- and collision-controlled processes (Pitcher 1987, 1992; Bonin 1990; Clarke 1992; Bonin et al. 2020).

A typical feature of the Variscan (Hercynian) Orogeny in Europe was a production of widespread and voluminous felsic igneous rocks during its long-lasting evolution from the Late Devonian to the Early Permian. The granitic rocks form a significant component of the basement in the Western Carpathians (WCB) in the territory of Slovakia. The geodynamic evolution of the WCB was comparable to the other parts of the Variscides in Western and Central Europe, such as the Iberian Massif, French Massif Central, and Bohemian Massif. The polyorogenic Variscan history was characterized by docking and collision of various terranes and/or blocks that mostly originated at the Gondwanan margin, resulting in multistage tectonic evolution with large-scale nappe and strike-slip tectonics (e.g. Badham 1982; Schulmann et al. 2014). The Variscan basement of the Tatric Superunit (or Tatricum) is largely composed of the Variscan granitic rocks in the majority of the so-called core mountains (CM), whereas the metamorphic rocks of various origins predominate over granites only locally at the present erosional level (Kohút & Janák 1994; Poller et al. 2000a, 2001a; Broska & Uher 2001; Putiš et al. 2009).

A general paradigm concerning the age of the two principal Meso-Variscan granitic suites was accepted in the Central Western Carpathians (CWC) during the last decade of the XXth Century. The Early Carboniferous S-type granitic series and the Late Carboniferous I-type granitic series were identified in the CWC on the basis of their mineralogy, petrology and/or conventional (multigrain) zircon U–Pb ages (Cambel & Petrík 1982; Cambel & Kráľ 1989; Petrík & Broska 1989, 1994; Bibikova et al. 1990; Petrík & Kohút 1997; Broska & Uher 2001; Petrík et al. 2001; Finger et al. 2003). In the Malé Karpaty Mts., however, newer U–Th–Pb zircon SHRIMP data ruled out any significant gap between these two granitic series and suggested their synchronous crystallization at 355–347 Ma (Kohút et al. 2009). Soon thereafter, increasing number of modern in situ U–Th–Pb zircon determinations by the SHRIMP, SIMS and/or LA ICP-MS techniques extended the age range of the Tatric Superunit Variscan granitic rocks to 367–332 Ma (Kohút et al. 2010; Burda et al. 2013a, b, 2020; Gaweda et al. 2016; Broska & Svojtka 2020). Broska et al. (2013) revealed the I-type granite ages of 364–358 and interpreted them as a result of Paleotethys subduction related magmatism in the Galatian terrane. Broska & Svojtka (2020) presented the Visean age of the Malá Fatra Mts. granites as a product of collisional event, similarly to the indications of collisional granites in the Tribeč Mts. (Broska & Petrík 2015). The aim of the current study is to present the SHRIMP U–Th–Pb zircon dating results from other core mountains granitic plutons, and discuss their geotectonic significance for genesis of the Tatric Superunit granitoids.

Geological setting

The Central Western Carpathians are traditionally subdivided into three main crustal-scale superunits; from bottom (north) to top (south) these are: the Tatric (or Tatricum), Veporic, and Gemeric superunits (Fig. 1). The CWC units were individualized and deformed dominantly by the Cretaceous, pre-Coniacian tectonic processes, commonly termed the Paleo-Alpine allochthonous tectonics. The Tatric Superunit includes core mountains in western and northern Slovakia (namely: Malé Karpaty Mts., Považský Inovec Mts., Tribeč Mts., Strážovské vrchy Mts., Žiar Mts., Malá Fatra Mts., Veľká Fatra Mts., Vysoké Tatry Mts., Nízke Tatry Mts., Branisko Mts.) with a crystalline basement, and their Late Paleozoic and Mesozoic sedimentary autochthonous to para-autochthonous cover, that is overridden by the superficial thin-skinned nappe systems: the Fatric Unit (Krížna nappe) and the Hronic Unit (Choč nappe) (Andrusov 1968).

These core mountains represent mainly asymmetric, northward-tilted horst structures (ca. 40–50 km long and 15–20 km wide on average) resulting from Late Cenozoic uplift, and are surrounded by sediments of the Cenozoic basins. The Tatric pre-Alpine, generally Variscan crystalline basement was only slightly affected by the Alpine deformation and metamorphism; hence the Variscan structures and isotopic cooling ages are commonly preserved. The Variscan granitic rocks form backbones of the Tatricum core mountains, and intruded the variegated Lower Paleozoic crystalline basement consisting of two principal structural and lithological levels or étages (Kohút et al. in print).

The ***Lower étage*** (Cambrian to Silurian in age) is composed of a Leptynite–Amphibolite Complex (LAC) with remnants of retrogressed eclogites and meta-ultramafites, tonalitic gneisses, and sheared Cambro–Ordovician felsic magmatites – now orthogneisses. These meta-igneous rocks are intercalated with metamorphosed psammites/pelites (paragneisses) with rare carbonate (calc-silicate) lenses, and scarce black schists. The metamorphic conditions of this complex usually show 650–800 MPa and 600–780 °C (Hovorka & Méres 1991; Krist et al. 1992; Bezák et al. 1993; Janák & Lupták 1997) sometimes with characteristic widespread migmatization/granitization, whereas P–T conditions reached up to 1.2–2.5 GPa and 700–750 °C in the high-pressure (eclogite) remnants (e.g. Janák et al. 1996, 2020; Faryad et al. 2005, 2020; Moussallam et al. 2012).

The ***Upper étage*** is formed by typical Upper Silurian–Devonian volcano-sedimentary sequences composed of metagreywackes, phyllites, metabasites (epidote–actinolite amphibolites), black shales, lenses of calc-silicates, Fe and Pb–Zn (Lahn-Dill-type) mineralization, and scarce apatite-rich rocks. Their low-grade metamorphism reached greenschist

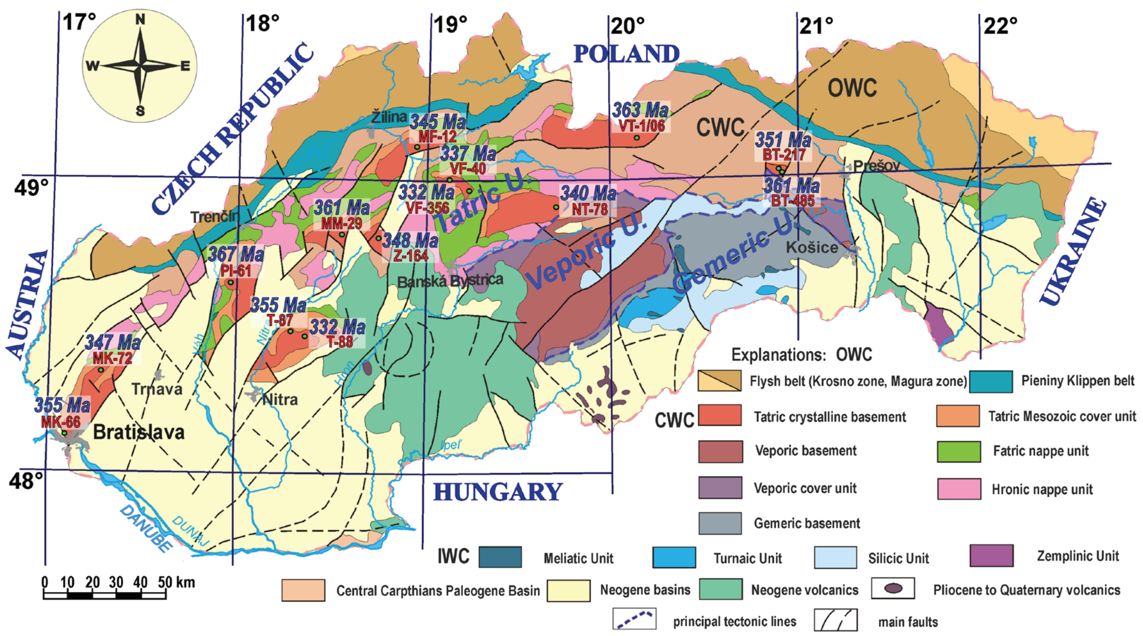

Fig. 1. Location of the granitic rocks from the Tatric Superunit (Western Carpathians, Slovakia) dated by means of the SHRIMP-II (VSEGEI, St. Petersburg). Results of the samples MK-66 and MK-72 were published by Kohút et al. (2009). *Explanations*: OWC — Outer Western Carpathians; CWC — Central Western Carpathians; IWC — Inner Western Carpathians.

facies only (below 350 MPa and 650 °C), and weak intrusive migmatitic zones are merely observed (Cambel in Buday et al. 1962; Krist et al. 1992; Ivan et al. 2001, 2007; Méres 2005; Kohút et al. 2006). The Lower and Upper structural étages are commonly in a normal mutual position in respect of the Variscan tectonics, albeit overturned stacking has been documented as well.

The following text contains common granitic petrology and geochemistry characteristics in terms of the I-/S-type classification (Chappell & White 1974; White & Chappell 1983) to simplify communication among granitologists. The peraluminous two-mica granodiorites and granites often with gneissic xenoliths dominate the *S-type series*, whereas biotite tonalites to granodiorites are subordinate. The total REE contents of S-types are moderate with fractionated chondrite-normalized patterns and small depletions in Eu. The metaluminous to subaluminous biotite tonalites to granodiorites with scarce hornblende dominate in the *I-type series*, while muscovite–biotite granodiorites to granites are less frequent. Lower silica contents coincide with elevated concentrations of trace elements such as Sr, Ba, Zr and LREE. The presence and composition of mafic microgranular enclaves (MME) indicate an interaction with gabbroic–dioritic, mantle-derived or lower crustal melts (see reviews of Petrík & Broska 1989; Petrík & Kohút 1997; Petrík et al. 2001; Kohút 2014). For the common S-types, isotopic characteristics (Sr, Nd, Pb, Hf, O, S and Li) document an origin by crustal anatexis of metasedimentary material with minor contributions from mantle-derived melts. In contrast, the I-types originated by melting of predominantly mafic/felsic lower crustal protoliths with contributions from the subcontinental lithospheric mantle (SCLM) (Kohút et al. 1999, 2001; Poller et al. 2001a, 2005a, b; Kohút & Recio 2002; Kohút & Nabelek 2008; Magna et al. 2010; Kohút 2014).

Studied samples

One or two representative granitic rock samples from each CM were selected for this study to cover spatial, temporal, petrographic and typological variability of the Variscan granites from the Tatric Superunit, complementing the previous work on Malé Karpaty granites of Kohút et al. (2009). On the basis of these criteria, the following samples have been chosen (Fig. 1; location in Appendix):

PI-61 – garnet-bearing biotite–muscovite granite, the Považský Inovec Mts. *("S-type");*
MM-29 – muscovite–biotite granite (+garnet), the Strážovské vrchy Mts. *("S-type");*
MF-12 – biotite granodiorite, the Malá Fatra Mts. *("I-type");*
VT-1/06 – biotite tonalite, the Vysoké Tatry Mts. *("I-type");*
BT-217 – muscovite–biotite granite, the Branisko Mts. *("S-type");*
BT-485 – biotite tonalite (±hornblende), the Branisko Mts. *("I-type");*
T-87 – biotite granodiorite, the Tribeč Mts. *("S-type");*
T-88 – biotite tonalite (+titanite), the Tribeč Mts. *("I-type");*
Z-164 – muscovite–biotite granite, the Žiar Mts. *("S-type");*
VF-40 – biotite–muscovite granite, the Veľká Fatra Mts. *("S-type");*
VF-356 – biotite tonalite, the Veľká Fatra Mts. *("I-type");*
NT-78 – biotite granodiorite – "Ďumbier type" the Nízke Tatry Mts. *("I-type").*

The examples of typical granitic textures of the studied samples are presented in the photo-table (Fig. 2).

Analytical methods

The heavy-mineral separation of accessory zircon crystals was conducted by the standard separation procedure (crushing, sieving, gravitation density separation by using Wilfley table, heavy liquid – bromoform, electro-magnetic, and hand-picking). Euhedral transparent crystals of zircon, usually 100 to 350 μm in size, were selected for dating. The grains were mounted in epoxy, polished, and imaged optically as well as by the cathodoluminescence (CL) and back-scattered electron (BSE) detectors attached to an electron microscope (CamScan MX 2500S with CLI/QUA 2 detector; located at VSEGEI laboratory) to reveal the internal structure for analytical spot positioning (Fig. 3). The highest quality zircon crystals in the given rock sample were selected for measurement. Fractures, impurities and mineral inclusions were avoided.

In situ U–Th–Pb analysis was performed by using the SIMS SHRIMP-II apparatus, the high-resolution five-collector secondary ion mass-spectrometer (ion microprobe) of ASI (Australian Scientific Instruments) at the Centre of Isotopic Research (CIR) at the A.P. Karpinsky All-Russian Geological Research Institute (VSEGEI), St. Petersburg, Russia. The results were acquired with a secondary electron multiplier in peak-jumping mode, following the standard procedure of Williams (1998), Larionov et al. (2004). A primary O_2^- beam with 2 to 3 nA ion current produced approximately 25×20 μm elliptic analytical craters. Typical mass-resolution at 254 AMU (^{238}UO) was M/ΔM > 5000 (1 % valley) and this enabled resolution of isobaric interferences. One-minute rastering over an approximately 65×50 μm rectangular area was then employed before each analysis to remove gold coating and any surface Pb contamination. The following ion species were measured in the sequence: $^{196}(Zr_2O)$–^{204}Pb–background (~204 AMU)–^{206}Pb–^{207}Pb–^{208}Pb–^{238}U–^{248}ThO–^{254}UO with integration times ranging from 2 to 30 seconds. Four cycles for each analysed spot were acquired, and each fourth measurement was made on the standard zircon: TEMORA (Black et al. 2003) or 91500 as a secondary reference (Wiedenbeck et al. 1995). The raw data were processed by SQUID v1.13a (Ludwig 2005a) and ISOPLOT/Ex 3.22 (Ludwig 2005b) software with decay constants of Steiger & Jäger (1977) and common lead corrected using measured ^{204}Pb/^{206}Pb and model values of Stacey & Kramers (1975). The ages for the samples with a complex multi-stage evolution were processed by the ISOPLOT "Unmix Ages" tool in order to distinguish the main age groups. The Concordia diagrams show that almost all measured spots yield concordant ages. The 10–13 spots from 7–10 different zircon grains on each rock-sample were analysed, and the resulting ages with 2σ errors are shown in Figures 4 and 5. The measured isotope data are summarized in Table 1 with individual uncertainties quoted as 1σ. Further details concerning measurement and age calculations can be found in Larionov et al. (2004) and Putiš et al. (2009).

Results

The SHRIMP zircon dating of the Tatric Superunit CM granitic rocks reveals a rather long interval of spot ages spanning more than 70 Myr from the Late Devonian to Late Carboniferous. These ages can be associated with the Variscan metamorphic/magmatic processes for the majority of analysed points. Besides this Variscan zircon population, the identified zircons included sporadic Neo-Archean to Paleo-Proterozoic (2800–1690 Ma), and Neo-Proterozoic (*Ediacaran*) to Late Ordovician (623–448 Ma) inherited crystal cores, and Triassic to Jurassic (238–152 Ma) zircon rims (Fig. 3; Table 1). The Th/U ratio of zircon grains has been used as a geochemical indicator to determine a zircon origin and growth environments, distinguishing the likely metamorphic and magmatic zircons (Schaltegger et al. 1999; Rubatto 2002; Hoskin & Schaltegger 2003; Hartmann & Santos 2004; Yakymchuk et

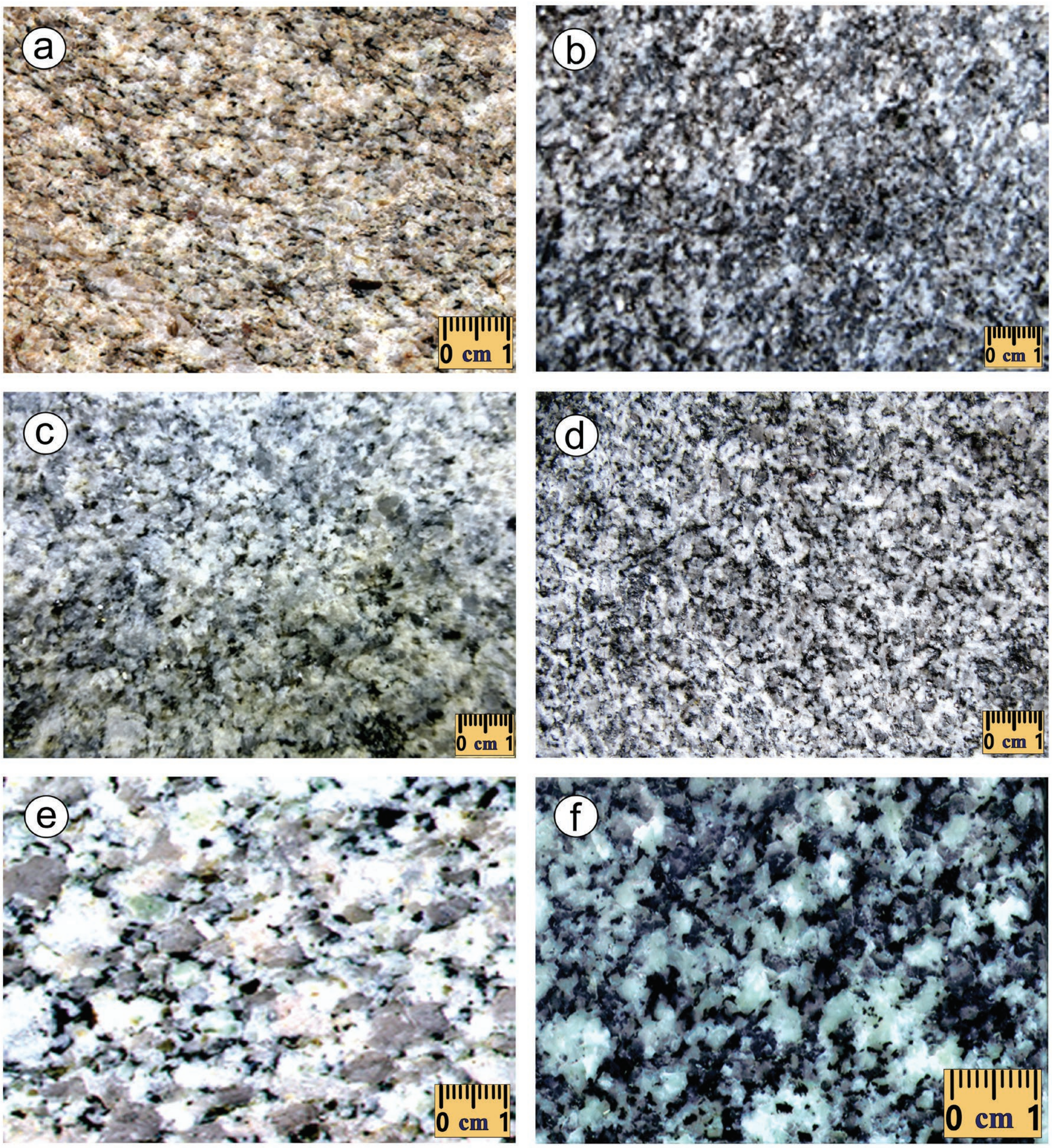

Fig. 2. Examples of typical textures of the dated samples: **a** — PI-61, biotite granite; **b** — VT-1/06, biotite tonalite; **c** — Z-164, muscovite–biotite granite; **d** — NT-78, biotite granodiorite; **e** — VF-40, two mica granite; **f** — T-88, biotite tonalite. See detailed location in Appendix.

Fig. 3. Cathodoluminescence images of selected dated zircons with the location of analysed spots and the results of the SHRIMP zircon U–Th–Pb dating ($^{206}Pb/^{238}U$ age in Ma).

al. 2018). A low Th/U ratio, lower than 0.1, has been considered indicative of metamorphic zircon (Rubatto 2002; Yakymchuk et al. 2018) whereas Th/U ratios exceeding 0.2 are taken as representing growth from a melt (Schaltegger et al. 1999; Hartmann & Santos 2004). The Variscan zircons of this study show Th/U ratios indicating mainly a magmatic origin, but partly decreased Th/U ratios may hint at metamorphic derivation (Fig. 6) although without any age systematics. Moreover, it is important to note that lower Th/U in zircons can also indicate an open-system behaviour, or competition for Th with other high-Th minerals, such as monazite or allanite, during their crystallization from magma. On the other

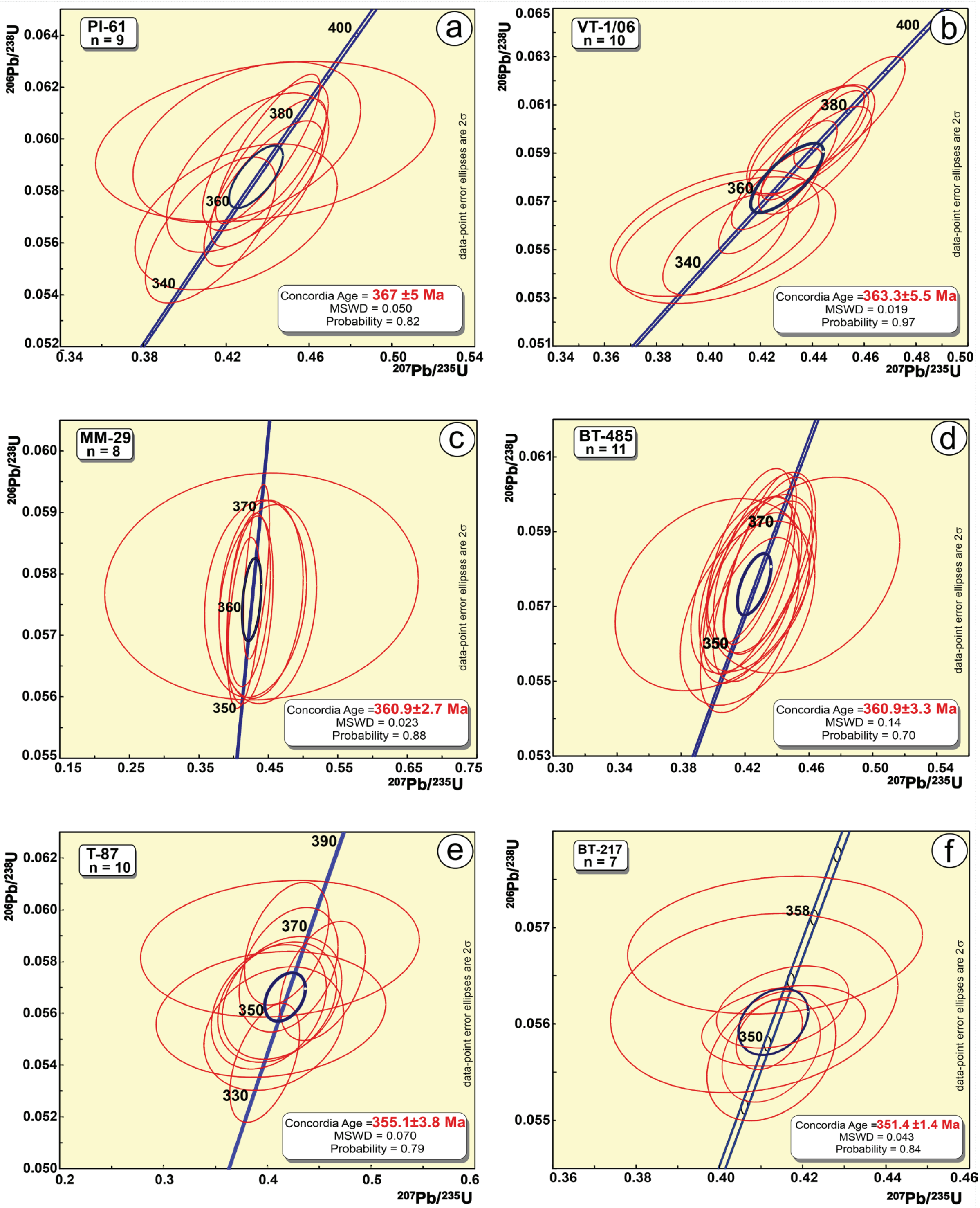

Fig. 4. U–Pb Concordia diagrams for the studied samples.

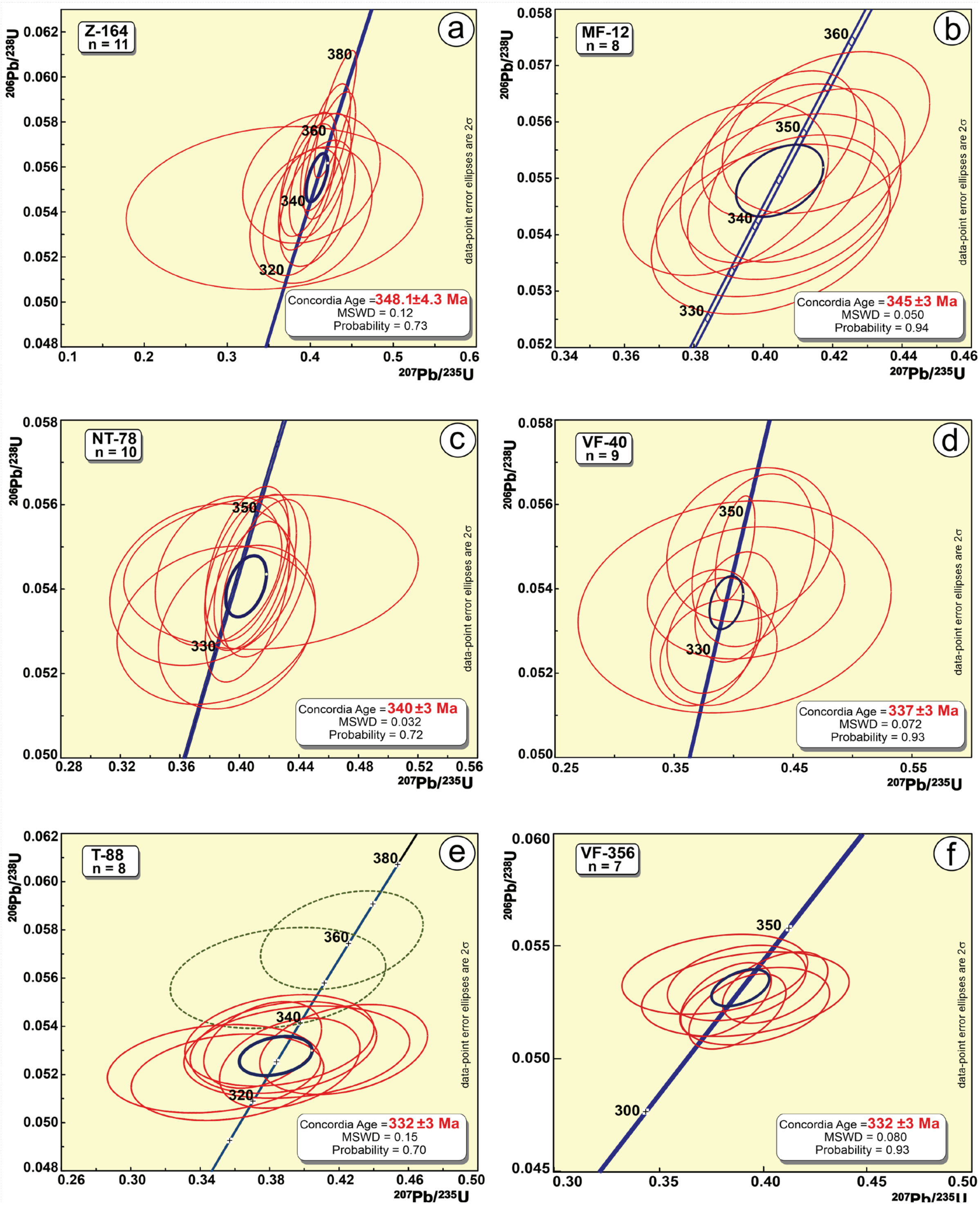

Fig. 5. U–Pb Concordia diagrams for the studied samples.

hand, an elevated Th/U ratio can reflect open-system behaviour, or vying with high-U minerals (e.g. xenotime).

The obtained Concordia ages fall in a broad interval from 367±5 Ma to 332±3 Ma. Obviously it was not one long lasting magmatic event, but the resultant Concordia ages form three distinct populations corresponding to the three discrete melting/crystallization episodes. These are namely: (a) ***older*** (Late Devonian–Famennian) – shown by Concordia ages between 367 and 360 Ma; (b) ***middle*** (Early Mississippian–Tournaisian) – 355–345 Ma; and (c) ***younger*** (Middle Mississippian–Visean) – 340–332 Ma (Fig. 7). Although there are 12+2 (Kohút et al. 2009) dated granitic samples only (Fig. 1), each Concordia age is calculated from 7–11 spot results (Figs. 4, 5; Table 1); however, some of the presented Concordia plots can contain a mixture of spot ages from two Variscan granitic events/populations.

Table 1: SHRIMP U–Th–Pb zircon data from the analysed samples in this study.

Spot	% $^{206}Pb_c$	ppm U	ppm Th	Th/U	$^{232}Th/^{238}U$	ppm $^{206}Pb^*$	(1) $^{206}Pb/^{238}U$ Age		(1) $^{238}U/^{206}Pb^*$	±%	(1) $^{207}Pb^*/^{206}Pb^*$	±%	(1) $^{207}Pb^*/^{235}U$	±%	(1) $^{206}Pb^*/^{238}U$	±%	err corr
PI-61_2.2	0.66	775.3	158.0	0.20	0.21	25.3	238.9	±4.6	26.48	2	0.0525	3.2	0.273	3.8	0.03776	2	0.527
PI-61_3.2	0.55	814.6	245.0	0.30	0.31	34.6	309.3	±6.0	20.34	2	0.0543	2.8	0.368	3.4	0.04915	2	0.577
PI-61_1.1	0.13	242.2	84.7	0.35	0.36	11.8	354.3	±7.0	17.7	2	0.053	2.4	0.412	3.1	0.0565	2	0.652
PI-61_5.2	0.70	464.1	196.7	0.42	0.44	22.9	357.4	±7.0	17.54	2	0.054	4.2	0.425	4.7	0.057	2	0.430
PI-61_4.1	0.10	758.2	212.9	0.28	0.29	37.8	362.9	±7.0	17.27	2	0.05486	1.8	0.438	2.7	0.0579	2	0.737
PI-61_8.1	0.08	455.7	162.1	0.36	0.37	23.0	367.7	±7.1	17.03	2	0.05441	1.7	0.44	2.6	0.0587	2	0.766
PI-61_3.1	0.24	208.6	85.5	0.41	0.42	10.5	367.8	±7.6	17.03	2.1	0.0532	3	0.43	3.7	0.0587	2.1	0.575
PI-61_2.1	0.06	509.4	264.0	0.52	0.54	26.0	371.6	±7.1	16.85	2	0.0536	2	0.439	2.8	0.0593	2	0.700
PI-61_6.1	0.04	975.9	245.8	0.25	0.26	50.0	373.3	±7.1	16.77	2	0.05354	1.2	0.44	2.3	0.0596	2	0.845
PI-61_7.1	0.44	195.4	66.0	0.34	0.35	10.1	374.9	±7.7	16.7	2.1	0.0521	4.8	0.43	5.2	0.0599	2.1	0.405
PI-61_5.1	1.89	258.9	90.2	0.35	0.36	13.6	375.1	±7.7	16.68	2.1	0.0531	7.3	0.439	7.6	0.0599	2.1	0.276
VT-1/06_1.1	0.11	1485	19	0.01	0.01	77.5	379.8	± 5.8	16.48	1.6	0.0543	1.1	0.4544	1.9	0.06069	1.6	0.808
VT-1/06_2.1	0.03	1342	15	0.01	0.01	68.4	371.5	± 5.6	16.86	1.6	0.05382	0.98	0.4403	1.8	0.05933	1.6	0.846
VT-1/06_3.1	0.00	1038	201	0.19	0.20	50.9	357.5	± 5.5	17.54	1.6	0.0539	1.1	0.4238	1.9	0.05703	1.6	0.815
VT-1/06_4.1	0.18	1312	63	0.05	0.05	67.2	372.7	± 5.7	16.8	1.6	0.05346	1.5	0.4387	2.1	0.05951	1.6	0.729
VT-1/06_5.1	0.01	1313	686	0.52	0.54	617	2813	± 35	1.828	1.5	0.18467	0.44	13.93	1.6	0.547	1.5	0.961
VT-1/06_5.2	0.29	3366	52	0.02	0.02	168	364.1	± 5.6	17.21	1.6	0.05359	1.1	0.4293	1.9	0.05809	1.6	0.819
VT-1/06_6.1	0.41	2812	415	0.15	0.15	142	367.8	± 5.5	17.03	1.5	0.0545	1.3	0.4412	2	0.05871	1.5	0.768
VT-1/06_7.1	0.36	2242	71	0.03	0.03	115	373.1	± 5.6	16.78	1.6	0.0535	1.7	0.439	2.3	0.05958	1.6	0.678
VT-1/06_8.1	0.00	99	45	0.45	0.47	4.72	349.2	± 6.5	17.97	1.9	0.0524	3.6	0.402	4.1	0.0557	1.9	0.470
VT-1/06_8.2	–	95	42	0.45	0.46	4.5	347.4	± 6.6	18.06	1.9	0.0532	3.8	0.406	4.2	0.0554	1.9	0.456
VT-1/06_9.1	1.23	3284	385	0.12	0.12	130	286.2	± 4.4	22.03	1.6	0.0519	2.7	0.325	3.1	0.0454	1.6	0.496
VT-1/06_10.1	0.86	21	9	0.43	0.44	1.83	623	± 16	9.86	2.7	0.058	9.4	0.811	9.8	0.1015	2.7	0.272
VT-1/06_10.2	0.67	2455	77	0.03	0.03	117	346.6	± 5.3	18.1	1.6	0.0534	1.9	0.4068	2.4	0.05524	1.6	0.638
MM-29_1.1	1.11	4125	157	0.04	0.04	206	361.1	± 4	17.36	1.1	0.0543	6.9	0.432	7	0.05762	1.1	0.164
MM-29_2.1	0.38	838	477	0.57	0.59	66.6	568.2	± 6.5	10.85	1.2	0.0593	3.6	0.753	3.8	0.0921	1.2	0.316
MM-29_3.1	0.22	2600	25	0.01	0.01	129	359.9	± 3.8	17.42	1.1	0.0535	3	0.424	3.2	0.05742	1.1	0.337
MM-29_4.1	0.68	2213	23	0.01	0.01	110	360.9	± 3.5	17.36	1	0.0532	2.8	0.423	3	0.05759	1	0.337
MM-29_5.1	13.59	2382	33	0.01	0.01	138	365	± 4.8	17.17	1.4	0.057	21	0.455	21	0.05825	1.4	0.064
MM-29_6.1	0.25	2037	60	0.03	0.03	100	358.6	± 3.5	17.48	0.99	0.0526	2.1	0.4151	2.3	0.05721	0.99	0.427
MM-29_7.1	0.93	681	883	1.30	1.34	51.3	537	± 5.9	11.51	1.1	0.0573	6.1	0.686	6.2	0.08687	1.1	0.183
MM-29_7.2	2.50	1247	16	0.01	0.01	63.3	360.8	± 4	17.37	1.2	0.0567	6.3	0.45	6.4	0.05757	1.2	0.181
MM-29_8.1	2.93	115	110	0.95	0.98	9.11	551	± 10	11.21	2	0.0589	15	0.72	15	0.0892	2	0.129
MM-29_8.2	0.53	810	5	0.01	0.01	40.3	361	± 4	17.36	1.1	0.0554	5.5	0.44	5.6	0.0576	1.1	0.203
MM-29_9.1	0.25	2870	28	0.01	0.01	143	363.7	± 3.5	17.23	10	0.0541	1.5	0.4329	1.8	0.05804	10	0.564
BT-485_1.1	0.12	265	18	0.07	0.07	13.3	364.5	±6	17.19	1.7	0.0539	2.5	0.432	3	0.05817	1.7	0.562
BT-485_1.2	0.32	193	111	0.58	0.59	9.46	356.3	±6.1	17.6	1.8	0.0538	3.7	0.422	4.1	0.0568	1.8	0.434
BT-485_2.1	0.09	308	247	0.80	0.83	15.2	361.2	±5.9	17.35	1.7	0.0539	3.1	0.428	3.5	0.05763	1.7	0.480
BT-485_2.2	0.00	294	142	0.48	0.50	14.6	360.8	±5.9	17.37	1.7	0.0532	2.2	0.423	2.8	0.05757	1.7	0.613
BT-485_3.1	0.00	671	690	1.03	1.06	33.6	365.1	±5.7	17.16	1.6	0.05347	1.4	0.4296	2.1	0.05827	1.6	0.748
BT-485_3.2	0.42	144	36	0.25	0.26	7.18	362.5	±6.5	17.29	1.9	0.0575	5.2	0.459	5.5	0.0578	1.9	0.335
BT-485_4.1	0.23	330	209	0.63	0.65	16.4	360.9	±5.9	17.37	1.7	0.053	2.9	0.421	3.4	0.05758	1.7	0.497
BT-485_4.2	–	324	32	0.10	0.10	16.1	364.1	±5.9	17.21	1.7	0.0542	2	0.434	2.6	0.05809	1.7	0.638
BT-485_5.1	0.57	148	71	0.48	0.50	7.31	359.3	±6.4	17.45	1.8	0.0504	6.1	0.398	6.4	0.0573	1.8	0.287
BT-485_6.1	0.12	274	73	0.27	0.27	13.3	354.3	±5.8	17.7	1.7	0.0543	2.5	0.423	3	0.0565	1.7	0.568
BT-485_7.1	0.00	227	116	0.51	0.53	11.2	359.8	±6	17.42	1.7	0.0545	2.4	0.431	2.9	0.05741	1.7	0.584
BT-485_8.1	0.08	395	342	0.87	0.90	19.8	365.5	±5.9	17.14	1.6	0.0525	2	0.423	2.6	0.05834	1.6	0.634
BT-485_9.1	0.19	517	524	1.01	1.05	25.5	358.8	±5.7	17.47	1.6	0.0536	2.5	0.423	3	0.05723	1.6	0.543
T-87_1.1	3.65	317	140	0.44	0.46	24	525.3	±9.8	11.78	1.9	0.0549	16	0.64	16	0.0849	1.9	0.123
T-87_2.1	0.17	724	380	0.52	0.54	35.7	358.9	±5.7	17.47	1.6	0.0574	3.3	0.453	3.7	0.05725	1.6	0.442
T-87_3.1	0.66	496	287	0.58	0.60	24.7	361.5	±6	17.33	1.7	0.0529	4.3	0.42	4.6	0.05769	1.7	0.368
T-87_3.2	1.21	385	183	0.48	0.49	18.9	352.8	±6	17.78	1.7	0.0518	5.4	0.401	5.6	0.05625	1.7	0.309
T-87_4.1	1.00	538	251	0.47	0.48	26.4	354.9	±5.9	17.67	1.7	0.0531	5.4	0.414	5.7	0.0566	1.7	0.301
T-87_4.2	1.24	450	183	0.41	0.42	22.1	353.9	±5.8	17.72	1.7	0.0526	5.5	0.409	5.7	0.05643	1.7	0.294
T-87_5.1	0.84	922	617	0.67	0.69	46.9	367.7	±5.9	17.04	1.6	0.0517	3.6	0.419	4	0.05869	1.6	0.417
T-87_6.1	0.94	831	524	0.63	0.65	39.9	347.6	±6	18.05	1.8	0.0532	6.5	0.406	6.8	0.05541	1.8	0.260
T-87_7.1	1.23	523	297	0.57	0.59	26.6	366.7	±6.6	17.08	1.9	0.0507	14	0.409	14	0.0585	1.9	0.132
T-87_8.1	2.76	379	131	0.35	0.36	18.7	351.2	±6.1	17.87	1.8	0.0523	11	0.403	11	0.05596	1.8	0.158
T-87_9.1	0.84	734	259	0.35	0.36	34.4	339.6	±5.7	18.49	1.7	0.0533	3	0.397	3.5	0.05409	1.7	0.503
BT-217_1.1	0.23	372	26	0.07	0.07	18.2	356.2	±1.8	17.6	0.51	0.0528	3.5	0.413	3.5	0.05682	0.51	0.147
BT-217_2.1	1.55	1843	53	0.03	0.03	116	448.7	±1.2	13.869	0.28	0.0574	2.2	0.571	2.2	0.07209	0.28	0.125
BT-217_2.2	–	1917	42	0.02	0.02	92	350.6	±0.9	17.892	0.27	0.05346	0.74	0.412	0.79	0.05589	0.27	0.336
BT-217_3.1	0.47	219	61	0.28	0.29	15	492.9	±2.9	12.583	0.62	0.0569	3.9	0.624	4	0.07947	0.62	0.156
BT-217_3.2	–	491	11	0.02	0.02	23.5	349.2	±1.7	17.963	0.5	0.05374	1.5	0.4125	1.5	0.05567	0.5	0.323
BT-217_4.1	0.26	1447	35	0.02	0.02	72.9	366.6	±1	17.088	0.29	0.05473	1.6	0.4416	1.7	0.05852	0.29	0.174
BT-217_4.2	0.28	347	374	1.08	1.11	16.6	349.6	±2	17.95	0.6	0.0537	4.6	0.413	4.6	0.05572	0.6	0.130
BT-217_5.1	0.04	644	42	0.07	0.07	166	1689.3	±7	3.338	0.47	0.15436	0.41	6.376	0.62	0.2996	0.47	0.754
BT-217_5.2	0.31	378	9	0.02	0.02	18.3	352.6	±2.3	17.79	0.68	0.0527	3.4	0.408	3.4	0.05622	0.68	0.196

Table 1 (continued)

Spot	% $^{206}Pb_c$	ppm U	ppm Th	Th/U	$^{232}Th/^{238}U$	ppm $^{206}Pb^*$	(1) $^{206}Pb/^{238}U$ Age		(1) $^{238}U/^{206}Pb^*$	±%	(1) $^{207}Pb^*/^{206}Pb^*$	±%	(1) $^{207}Pb^*/^{235}U$	±%	(1) $^{206}Pb^*/^{238}U$	±%	err corr
BT-217_6.1	0.76	156	60	0.39	0.40	7.61	352.5	±3.6	17.79	1	0.0541	7.4	0.419	7.5	0.0562	1	0.139
BT-217_7.1	–	570	52	0.09	0.09	27.4	350.6	±1.5	17.894	0.43	0.05389	1.5	0.4152	1.5	0.05589	0.43	0.285
Z-164_10.2	0.57	87	53	0.61	0.63	4.03	338.2	±7.6	18.56	2.3	0.054	7.1	0.401	7.5	0.0539	2.3	0.307
Z-164_3.1	0.42	164	31	0.19	0.19	7.63	339.1	±7.1	18.51	2.1	0.0525	4.5	0.391	5	0.054	2.1	0.429
Z-164_2.2	2.09	41	20	0.49	0.51	1.97	339.3	±9.6	18.49	2.9	0.048	22	0.357	22	0.0541	2.9	0.132
Z-164_5.1	0.26	218	52	0.24	0.25	10.2	341.4	±7	18.39	2.1	0.0545	4	0.409	4.5	0.0544	2.1	0.463
Z-164_4.1	0.15	242	241	0.99	1.03	11.5	345.8	±7	18.14	2.1	0.0521	2.9	0.396	3.6	0.0551	2.1	0.583
Z-164_7.1	1.49	287	152	0.53	0.55	13.9	348.2	±7.2	18.01	2.1	0.0525	8.1	0.401	8.4	0.0555	2.1	0.252
Z-164_6.1	0.20	468	165	0.35	0.37	22.4	349.0	±6.9	17.98	2	0.0537	3.1	0.412	3.7	0.0556	2	0.548
Z-164_8.1	0.19	452	313	0.69	0.72	21.6	349.3	±6.9	17.96	2	0.0518	2.9	0.397	3.5	0.0557	2	0.576
Z-164_2.1	0.20	331	19	0.06	0.06	16.1	354.4	±7	17.69	2	0.0543	2.2	0.423	3	0.0565	2	0.677
Z-164_1.1	0.14	318	159	0.50	0.52	15.5	356.6	±7	17.58	2	0.0533	2.1	0.418	2.9	0.0569	2	0.688
Z-164_9.1	0.07	834	26	0.03	0.03	41.8	365.6	±7	17.14	2	0.05347	1.4	0.43	2.4	0.0583	2	0.820
Z-164_10.1	8.05	95	10	0.10	0.10	5.82	410.0	±11	15.19	2.8	0.057	26	0.51	26	0.0656	2.8	0.106
MF-12_2.1	0.27	610	205	0.34	0.35	26.1	312.5	±3.7	20.13	1.2	0.0537	3.4	0.368	3.6	0.04966	1.2	0.339
MF-12_.5.1	0.34	457	28	0.06	0.06	21.3	339.6	±3.8	18.48	1.1	0.0539	3.3	0.402	3.5	0.0541	1.1	0.325
MF-12_.4.1	0.26	1294	301	0.23	0.24	60.7	342.1	±3.2	18.35	0.96	0.0542	2.8	0.407	2.9	0.05449	0.96	0.329
MF-12_1.1	0.3	447	105	0.23	0.24	21	342.2	±4.0	18.34	1.2	0.0538	3.3	0.404	3.6	0.05452	1.2	0.341
MF-12_3.1	0.3	776	356	0.46	0.47	36.7	344.1	±3.8	18.24	1.1	0.0515	2.9	0.389	3.1	0.05481	1.1	0.368
MF-12_2.2	0.1	410	71	0.17	0.18	19.4	345.5	±3.8	18.16	1.1	0.0543	2.6	0.413	2.8	0.05505	1.1	0.408
MF-12_6.1	0	343	68	0.20	0.2	16.2	345.7	±4.0	18.15	1.2	0.0532	2.6	0.404	2.8	0.05509	1.2	0.415
MF-12_3.2	0.14	1393	410	0.29	0.3	66.7	348.9	±3.2	17.98	0.95	0.0528	2	0.405	2.2	0.05561	0.95	0.424
MF-12_7.2	0.38	675	246	0.36	0.38	32.5	350.1	±3.6	17.92	1	0.0543	2.7	0.418	2.9	0.05581	1	0.36
MF-12_7.1	0.06	2869	1068	0.37	0.38	143	362.7	±3.1	17.28	0.89	0.0536	1.1	0.428	1.5	0.05788	0.89	0.615
NT-78_8.2	0.63	600	431	0.72	0.74	27.4	333.5	±5	18.83	1.5	0.0544	5.2	0.398	5.4	0.05310	1.5	0.28
NT-78_3.1	0.82	362	159	0.44	0.46	16.5	333.8	±5	18.82	1.4	0.0525	6.9	0.384	7.1	0.05315	1.4	0.20
NT-78_5.2	0.00	351	205	0.58	0.60	16.2	337.2	±5	18.62	1.4	0.0547	2.5	0.405	2.8	0.05370	1.4	0.51
NT-78_2.1	0.52	334	150	0.45	0.46	15.5	339.7	±5	18.48	1.4	0.0503	6.6	0.375	6.8	0.05411	1.4	0.21
NT-78_6.1	0.00	349	152	0.44	0.45	16.3	340.6	±5	18.43	1.4	0.0558	2.6	0.418	2.9	0.05426	1.4	0.48
NT-78_5.1	0.00	377	156	0.41	0.43	17.6	341.2	±5	18.40	1.4	0.0541	2.5	0.405	2.9	0.05436	1.4	0.47
NT-78_8.1	0.00	384	288	0.75	0.77	18	341.5	±5	18.38	1.4	0.0571	10.0	0.428	10.1	0.05440	1.4	0.14
NT-78_7.1	0.00	402	167	0.42	0.43	18.8	341.6	±5	18.38	1.4	0.0547	2.4	0.411	2.8	0.05442	1.4	0.50
NT-78_1.1	0.32	907	437	0.48	0.50	42.4	341.7	±4	18.37	1.3	0.0514	4.3	0.386	4.5	0.05443	1.3	0.30
NT-78_4.1	0.00	363	91	0.25	0.26	17	342.7	±5	18.31	1.4	0.0538	2.5	0.405	2.8	0.05460	1.4	0.49
VF-40_2.2	2.07	2401	320	0.13	0.14	111	329.8	±3.1	19.04	0.98	0.0536	5.1	0.388	5.2	0.05249	0.98	0.189
VF-40_2.1	0.64	553	43	0.08	0.08	25.3	331.9	±4.0	18.92	1.2	0.0516	4.8	0.376	4.9	0.05284	1.2	0.253
VF-40_7.1	0.64	1054	25	0.02	0.02	48.2	332.3	±3.4	18.9	1.1	0.0526	4.1	0.384	4.2	0.05290	1.1	0.250
VF-40_5.2	1.09	1686	10	0.01	0.01	78.5	336.4	±3.3	18.66	1.0	0.0544	3.4	0.402	3.5	0.05357	10	0.284
VF-40_4.1	2.01	136	40	0.29	0.30	6.4	336.4	±6.3	18.66	1.9	0.0543	13	0.401	13	0.05360	1.9	0.143
VF-40_3.1	4.21	1025	34	0.03	0.03	49.6	338.5	±3.9	18.53	1.2	0.0552	8.2	0.411	8.3	0.05391	1.2	0.144
VF-40_6.2	0.32	202	54	0.27	0.28	9.52	343.2	±5.1	18.29	1.5	0.0553	4.8	0.417	5.1	0.05468	1.5	0.303
VF-40_1.2	0.19	2681	25	0.01	0.00	127	344.9	±3.1	18.2	0.93	0.0530	1.4	0.401	1.7	0.05495	0.93	0.548
VF-40_6.1	0.93	351	63	0.18	0.19	16.8	345.4	±4.6	18.16	1.4	0.0545	6.8	0.414	6.9	0.05505	1.4	0.197
VF-40_5.1	0.37	461	215	0.47	0.48	30.9	481.8	±5.4	12.88	1.2	0.0556	3.5	0.595	3.7	0.07761	1.2	0.312
VF-40_1.1	0.00	284	109	0.38	0.40	123	2639	±23	1.977	1.1	0.1877	0.56	13.1	1.2	0.50600	1.1	0.883
T-88_1.1	0.69	454	177	0.39	0.40	20.2	326.1	±4	19.27	1.4	0.0497	6.2	0.356	6.4	0.05189	1.4	0.22
T-88_6.1	0.87	441	115	0.26	0.27	19.8	328.3	±5	19.14	1.4	0.0483	7.1	0.348	7.2	0.05224	1.4	0.20
T-88_8.2	0.20	1067	529	0.50	0.51	48.1	329.7	±5	19.06	1.5	0.0541	4.0	0.392	4.2	0.05247	1.5	0.34
T-88_5.1	0.69	348	156	0.45	0.46	15.8	332.5	±5	18.89	1.5	0.0542	6.6	0.396	6.7	0.05293	1.5	0.22
T-88_7.1	−0.39	448	187	0.42	0.43	20.4	333.1	±5	18.85	1.4	0.0578	4.4	0.423	4.7	0.05304	1.4	0.31
T-88_6.2	0.44	351	133	0.38	0.39	16	333.7	±5	18.82	1.5	0.0530	5.5	0.388	5.7	0.05312	1.5	0.26
T-88_4.1	0.25	561	304	0.54	0.56	25.6	334.3	±4	18.79	1.4	0.0512	3.4	0.376	3.7	0.05323	1.4	0.37
T-88_3.1	0.26	311	86	0.28	0.29	14.3	335.5	±5	18.72	1.5	0.0524	5.6	0.386	5.8	0.05342	1.5	0.25
T-88_2.1	0.49	434	124	0.29	0.30	20.9	351.3	±5	17.85	1.5	0.0498	6.4	0.385	6.6	0.05601	1.5	0.23
T-88_8.1	0.22	1494	663	0.44	0.46	73.9	360.9	±5	17.37	1.4	0.0531	4.3	0.422	4.5	0.05758	1.4	0.32
VF-356_1.1	6.07	4492	427	0.10	0.10	92.6	152.9	±12	41.67	8.1	0.1040	57.0	0.344	57.6	0.02400	8.1	0.14
VF-356_7.1	0.59	2339	928	0.40	0.41	66.2	209.0	±3	30.34	1.2	0.0523	6.8	0.238	6.9	0.03295	1.2	0.18
VF-356_6.2	0.00	529	118	0.22	0.23	23.6	327.0	±4	19.22	1.3	0.0535	2.2	0.384	2.5	0.05203	1.3	0.52
VF-356_7.2	0.17	430	181	0.42	0.44	19.3	328.8	±4	19.11	1.4	0.0544	3.4	0.392	3.7	0.05233	1.4	0.37
VF-356_4.1	0.23	1663	521	0.31	0.32	75.1	330.4	±4	19.02	1.3	0.0521	2.0	0.378	2.4	0.05259	1.3	0.53
VF-356_2.2	1.05	1004	338	0.34	0.35	45.6	332.0	±5	18.92	1.4	0.0531	5.1	0.387	5.3	0.05286	1.4	0.27
VF-356_3.1	0.24	1292	495	0.38	0.40	59	333.9	±4	18.81	1.2	0.0549	2.2	0.402	2.6	0.05316	1.2	0.49
VF-356_5.1	0.30	730	165	0.23	0.23	33.5	335.2	±4	18.74	1.3	0.0520	3.3	0.383	3.5	0.05337	1.3	0.37
VF-356_6.1	0.52	597	193	0.32	0.33	27.6	337.6	±4	18.60	1.3	0.0502	4.7	0.372	4.9	0.05376	1.3	0.27
VF-356_2.1	0.49	1126	197	0.18	0.18	59.5	384.9	±4	16.25	1.1	0.0583	2.6	0.495	2.8	0.06152	1.1	0.41

Errors are 1-sigma; Pb_c and Pb^* indicate the common and radiogenic portions, respectively.
Error in Standard calibration was 0.54 % (not included in above errors but required when comparing data from different mounts).
(1) Common Pb corrected using measured ^{204}Pb.

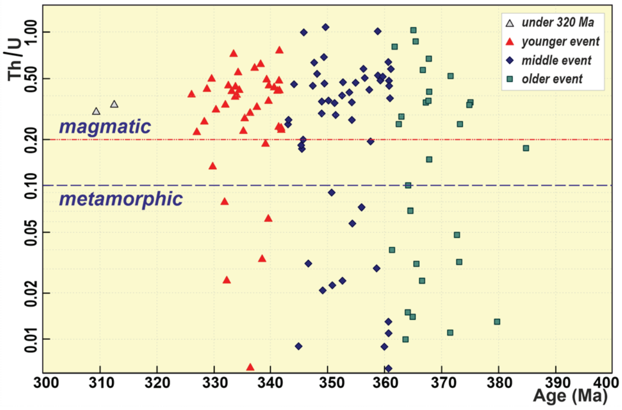

Fig. 6. Plot of Th/U ratios versus ^{206}Pb/^{238}U age (Ma).

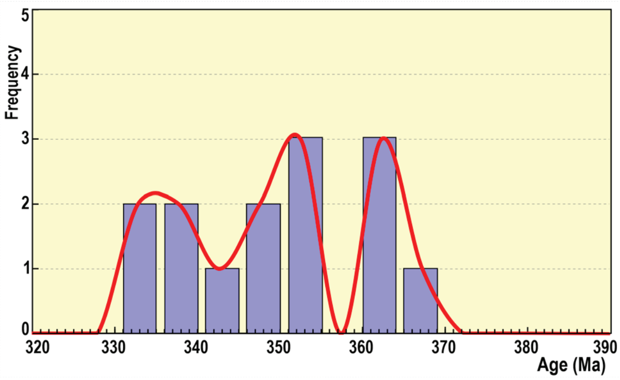

Fig.7. Frequency histogram of the Concordia ages from the Tatricum core mountains granitic rocks.

Discussion

Critical assessment of the pre-existing geochronological information

The Carboniferous age of the CWC granitic rocks from the Tatricum core mountains was first recognized by Uhlig (1897), who deduced that the granites have to be younger than the intruded country-rock Devonian metamorphic complexes, and older than the Permian strata containing granite pebbles. This assumption was confirmed by Kantor (1959) in the modern era on the basis of K–Ar dating, and later by extensive use of Rb–Sr isochron dating with whole-rock isochron ages between 393±6 Ma and 300±10 Ma (see review of Petrík & Kohút 1997).

In early 1990's, the conventional (multigrain) zircon U–Pb dating, mostly done in Russian labs, introduced the so far commonly accepted I-/S-type bimodality in the CWC. The S-type granodiorites and granites have shown the older ages (355–350 Ma), whereas the I-type tonalities and granodiorites gave significantly younger ages (310–303 Ma) (e.g. Bibikova et al. 1988, 1990; Broska et al. 1990).

The first single-grain cathodoluminescence (CL) controlled zircon and monazite dating by TIMS partly confirmed this duality giving ages of 365–340 Ma (S-types) and 314–304 Ma (I-types) from the Veľká Fatra Mts. and Tatry Mts. (Kohút et al. 1997; Poller & Todt 2000; Poller et al. 2000a, b, 2001b). However, synchronous using of SIMS (IMS Cameca 1270, Nancy) and SHRIMP facilities (Canberra, and Perth) brought the first U–Th–Pb zircon age results from the CWC granites that did not fit this paradigm: 337±9 Ma (S-type two-mica granite, Veľká Fatra Mts.), 351±4 and 342±5 Ma (I-type biotite granodiorites to tonalites, Tatry Mts.) (Poller et al. 2000b, 2001b). Similarly, Early Mississippian ages were obtained from the Veporic Superunit – Kráľová Hoľa granites (e.g. 356±10 and 359±6 Ma, Gaab et al. 2005). Pilot using of SHRIMP II instrument in St. Petersburg have revealed nearly synchronous age of a typical S-type granite 355±5 Ma and I-type tonalite 347±4 Ma from the Malé Karpaty Mts. (Kohút et al. 2009).

Subsequently, Broska et al. (2013) published dating results of I-type granitic rocks using the NORDSIM (Stockholm) facility from the Tatric and Veporic superunits of the CWC. Four samples from the Tatric CM of the Tribeč Mts. yielded ages corresponding to the Famennian–Mississippian boundary (367–358 Ma), while the "Ďumbier type" tonalite and "Prašivá type" granodiorite of the Nízke Tatry Mts. yielded nearly coeval ages of 356–353 Ma respectively, like the Veporic Sihla tonalite showing age 357 Ma.

General progress in geochronology with application of the Laser Ablation Multi-Collector Inductively-Coupled Plasma Mass Spectrometry (LA-MC-ICP-MS) U–Pb zircon dating brought new insights into the evolution of granitoids from the Tatry Mountains. Polish friends in collaboration with Austrian and Irish colleagues presented a lot of high-quality data from various granitic rocks of the Západné and Vysoké Tatry (Western & High Tatra) Mts. According to these results, the generation and emplacement of the so-called "*older granitoids*" occurred at 370–355 Ma in the Western Tatra Mts. (Burda et al. 2011, 2013a; Gaweda et al. 2016), whereas melting and crystallization of the so-called "*younger granitoids*" predominating in the High Tatra part took place at ca. 350–330 Ma ago (Burda et al. 2013b; Gaweda et al. 2016).

Recently, Burda et al. (2020) published an interesting detailed dating study from a single sample from the Chopok peak (the Nízke Tatry Mts., Tatricum CM). The authors described this so-called Chopok granite as an atypical 'cold' granite that originated during an Early Ordovician (475.8±3.3 Ma) magmatic event. Subsequently, the sample recorded only the Early Carboniferous (ca. 352 Ma) metasomatism, and the Permo–Triassic (ca. 255 Ma) low-T fluid dissolution/reprecipitation processes. The essential message of their study is that Chopok granite did not reach magmatic conditions (suspension of crystals in liquid) during the Variscan Orogeny.

Since Uhlig's (1897) holistic approach, it is obvious that majority of Tatricum CM granitic rocks are Variscan magmatic products that were generated and emplaced mainly during the Carboniferous. Naturally, the so-called "Ďumbier granitic pluton" of the Nízke Tatry Mts. is not an exception (Biely et al.

1992, 1997). Burda et al. (2020) correctly recognized their sample as an analogue of the "Chopok granite" (Petrík 2000), closely matching the Králička-type granite (Petrík 2000; Kohút & Nabelek 2008). The leucocratic Králička granite occurs often within the orthogneisses belt and it is generally believed to have been formed by partial melting of the orthogneisses (Zoubek 1951). The CWC orthogneisses have Cambro–Ordovician (497–470 Ma) proto-magmatic ages (Putiš et al. 2009). Generally, the granitic rocks from the Chopok peak area (see the map of Biely et al. 1992) belong to the Ďumbier type *sensu* Koutek (1931). This type was originally characterized as medium- to coarse-grained, dark grey, biotite granodiorite to tonalite with an equigranular and locally slightly anisotropic fabric, containing sporadic metamorphic host-rock xenoliths.

The Variscan ages of the Ďumbier granitic pluton were determined by various methods. For instance, Kantor (1959), Kantor et al. (1984) presented K–Ar muscovite and biotite cooling ages (341–316 Ma), while the Rb–Sr whole-rock isochron by Bagdasaryan et al. (1985) indicated a possible magmatic homogenization at 365–362 Ma ago. However, the first multigrain monazite U–Th–Pb dating brought a somewhat younger age of 330±20 Ma (Bojko et al. 1974), which was confirmed by single grain zircon CL-controlled TIMS dating with an age of 330±10 Ma (Poller et al. 2001a) from the Chopok area. Later, Putiš et al. (2003) postulated an age of the Ďumbier type granites at 343 ± 3 Ma by means of the conventional zircon U–Th–Pb dating. On the other hand, Broska et al. (2013), using SIMS documented the Early Mississippian (Tournaisian) age of the Ďumbier biotite tonalite (356±2 Ma) and Prašivá biotite granodiorite (353±3 Ma) as the subduction related magmatic products. Reviewing the ages of the magmatic/hydrothermal processes related to granitic magmatism in the Nízke Tatry Mts. it is impossible to omit recent molybdenite Re–Os ages of 352±3 Ma and 351±3 Ma (Majzlan et al. 2020). Keeping in mind all above, it is obvious that the Ďumbier granitic pluton is a classic Variscan composite pluton with a long-term history. Its structural and textural features as well as whole-rock chemical compositions document common hybridization, imperfect homogenization, partial fractionation and local high-/low-temperature fluid/hydrothermal activity (Petrík & Broska 1994; Petrík & Kohút 1997; Kohút et al. 1999; Broska & Uher 2001; Petrík et al. 2001; Kohút & Nabelek 2008; Broska & Petrík 2015; Maraszewska et al. 2020). The so-called "Chopok granite" in this context can be seen as a roof pendant that was only incompletely homogenized and incorporated into the new anatectic magma by the surrounding Ďumbier-type granite in Early Mississippian times.

General implications of the newly determined age data

In general, partial assimilation of country rocks is a usual feature of the Variscan CWC granitic rocks, and due to imperfect assimilation and/or homogenization processes these granites often have "dirty" or hybrid character which is common for the apical zones of granitic plutons (Petrík & Kohút 1997; Broska & Uher 2001; Petrík et al. 2001; Kohút 2014). Zircon inheritance documenting relatively fast crustal magma generation, Zr-rich protoliths and/or partial melting at low temperature, is commonly documented within the CWC granitic rocks (Poller et al. 2000a, b, 2001b, 2005b; Poller & Todt 2000; Gaab et al. 2005; Kohút et al. 2009; Broska et al. 2013).

Generally, it is supposed that igneous systems crystallize in less than 10 Myr, including even the longest-lived granitic plutons and batholiths (Miller et al. 2007; Schaltegger & Davies 2017). The post-emplacement crystallization and cooling of felsic intrusive rocks at mid-crustal levels may take 700–600 kyr (e.g. Samperton et al. 2017). Zircons crystallizing during incipient cooling of the magmas are entrained into the ascending melts, which are emplaced and rapidly solidified in the upper crust, and fractional crystallization and hybridization in the lower-to-middle crust, ascent into the upper crust and solidification do not last longer than 200 kyr (Broderick et al. 2015). The zircon U–Pb ages suggest injection of small melt batches into the upper crust, emplacement and crystallization within no more than 10 kyr (Chelle-Michou et al. 2014), eventually building large plutons by sequential accretion over millions of years.

Currently, there are more than 80 modern high quality data timing the Variscan granite magmatism in the Tatric Superunit of the CWC (see Supplementary Table S1). These age results, like the data from this study, indicate a long duration of the Variscan granitic magmatism (from ca. from 370 to 330 Ma: Fig. 8).

However, these U–Th–Pb zircon data exclude any significant time gap between the two granitic suites (I-/S-types) postulated in the past within the CWC, and indicate rather their coeval origin as a consequence of primary difference in sources, melting conditions, hybridization and assimilation processes throughout various periods of the Variscan Orogeny.

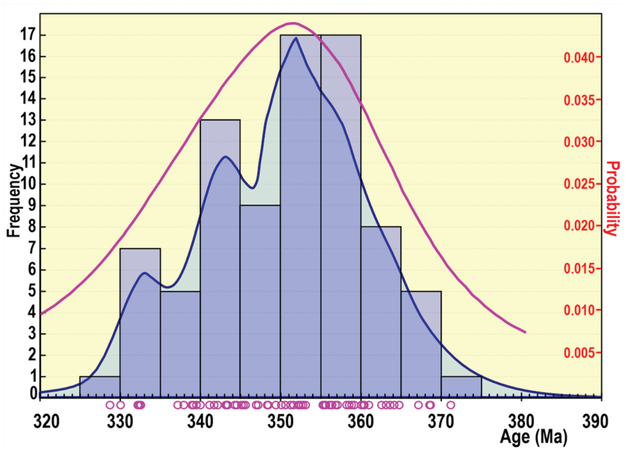

Fig. 8. Combined Frequency & Probability density plot using AgeDisplay (blue; Sircombe 2004) and Kernel density plot (KDP – violet colour) from all the available age data of the CWC granitic rocks. See Supplementary Table S1 for the underlying data.

Naturally, these granitic rocks have recorded evolution over several phases of the Variscan Orogeny in the CWC. Gabbroic rocks with the ages between 374 and 371 Ma were witnesses of an initial magmatic activity during oceanic subduction within a magmatic arc (Putiš et al. 2009). These mafic igneous products were followed by first hybridized granitic I-/S-types showing ages of ca. 370–365 Ma, and latter progressively succeeded by an additional granitic pulse at ca. 355–350 Ma, reflected by a peak in Probability density plot (PDP) at ca. 352 Ma (Fig. 8). Because of missing exact modern data on duration of subduction in the CWC metamorphic basement, the original assumption of the Breton Phase lasting till the end of the Devonian (ca. 360–355 Ma – Stille 1920, 1951) is generally accepted. Recently, Gaweda et al. (2018) presented multi-mineral (zircon, titanite and apatite) integrated U–Th–Pb dating study from the metamorphic basement of the Western Tatra Mts., proposing a metamorphic climax at 352–347 Ma and contemporaneous anatexis due to rapid exhumation.

As the subduction ceased, a short period of tectonic quiescence followed (mirrored by minimum at ~347 Ma in the PDP; Fig. 8). Contraction continued with imbrication of the continental crust due to continental collision. Thermal relaxation resulted in the rise of temperatures in lower parts of the collided complex leading to anatexis within its high-grade migmatitic core. This migmatitic core was subsequently intruded by the high-heat production granites that must have been derived from a previously radioelement-enriched source (Pitcher 1987; Sawyer et al. 2011; Bea 2012; Moyen 2020).

Tectonic crustal thickening with attendant shear heating triggered low-temperature, "wet" melting of the largely psammitic to pelitic rocks within the hanging wall, and a high-temperature, "dry" melting of the gneissic rocks within the foot wall. Most of the CWC basement meta-sedimentary rocks of the ***Lower étage*** (Kohút et al. in print) had their origins in the Rheic Ocean. The majority of the Lower étage mafic and felsic meta-igneous rocks accordingly show Cambrian–Silurian protoliths. However, the Devonian ***Upper étage*** volcanic-sedimentary rocks were deposited in a different realm, possibly the Rhenohercynian Basin, and never experienced a high-grade overprint. Prolonged convergence of various terranes (continental ribbons) occurring in the Carboniferous by way of continent–continent collision, forced in some places by large scale strike-slip tectonics, led finally in juxtaposition and/or mutual thrusting of the Rheic Ocean and Rhenohercynian Basin rock complexes in the Visean time in the CWC (Kohút et al. in print). Although the lithological, structural, metamorphic and age characteristics of these two CWC basement étages (Lower and Upper) display significant differences, their zircon age spectra record common indications of the Cadomian/Avalonian basement provenance (Kohút et al. in print).

The Paleozoic Variscan orogenic cycle culminated in the CWC between 345 and 335 Ma with a Himalayan-type collision with crustal thickening accompanied by voluminous intrusions of the younger collision-related granitic rocks having typical S-type and/or hybrid S/I-type granitic character. The peak at ca. 342–340 Ma (Fig. 8), representing probably the main period of the collisional granites production/emplacement, was in part accompanied by intrusions of dioritic syn-plutonic dykes (see Supplementary Table S1). On the other hand, some authors invoked local imprint by hydrothermal fluids released from collisional Visean granodiorites upon the older subduction-related granitic rocks (Uher et al. 2019; Broska & Svojtka 2020). If someone has a problem with the second, younger collision-related magmatic event at ca. 337–332 Ma in the CWC, it is important to note that the structural, textural, geochemical (including isotopic) characteristics and/or zircon CL images (Figs. 2, 3) suggest a magmatic, rather than metasomatic, origin of this younger granitic suite. Naturally, fluid alteration/oxidation during late- to post-magmatic stages was identified for part of these tonalite–granodiorite (I-type) rocks (Broska et al. 2007; Broska & Petrík 2015; Petrík 2019). However, recycling of zircon antecrysts during successive magmatic injections seems the primary cause of the modest age dispersion of concordant zircon ages, and is compatible with progressive growth of a large, long-lived, crystal mush body (Miller et al. 2007).

Comparison with other Variscan granitoid provinces in Western and Central Europe

The timing of partial melt formation during an orogenic cycle depends on the crustal composition, as well as on the thermal and tectonic state within the orogen (White & Chappell 1983). The Variscan granitic rocks form an important crustal component within the European pre-Alpine basement (Bonin et al. 1993; Finger et al. 1997; Schaltegger 1997; Schermaier et al. 1997; Bea et al. 1999; Bussy et al. 2000; Žák et al. 2014; Laurent et al. 2017; Janoušek 2019). Generally, the Variscan granitoids of Central Europe were subdivided into five geotectonic and genetic groups: **(1)** Famennian to Early Visean (ca. 370–340 Ma) "Cordilleran" I-type granitoids reflecting a magmatic-arc setting; **(2)** Early Visean (ca. 340 Ma), deformed S-type granite/migmatite associations formed during syn-collisional and/or nappe stacking period; **(3)** Late Visean and early Namurian (ca. 340–310 Ma) S-type and high-K, I-type granitoids formed probably as a consequence of post-collisional extension and mafic magmatic underplating; **(4)** Post-collisional, epizonal I-type granodiorites and tonalites (ca. 310–290 Ma) related to the renewed subduction and/or to extensional slab melting; **(5)** Late Carboniferous to Permian (ca. 300–250 Ma) leucogranites resembling sub-alkaline A-type granites (Finger et al. 1997; Schermaier et al. 1997).

However, within the intra-Alpine Variscides mainly I- and S-types predominate with ages between 334±3 and 290±10 Ma representing groups **3** and **4** above, and sporadically the Permian granites from group **5** (e.g. Schaltegger & Corfu 1992; Finger et al. 1997; Schermaier et al. 1997). On the other hand, the hypothetical Cetic Massif (studied only by means of its exotic boulders and pebbles from the Mesozoic to Eocene sediments of the Ultrahelvetic and the Rheno-Danubian flysch nappes, which can be found between Vienna and Salzburg), and sheared granitoids from the Seckau Complex (forming the southern part of the Variscan European Belt in the Eastern Alps) show proto-magmatic ages between 365±11 and 331±10 Ma (Mandl et al. 2018; Finger et al. 2019).

It is worth noting that the high-precision U–Th–Pb zircon and monazite dating from the Western Alps in the Aiguilles Rouges Mont Blanc area (External Crystalline Massifs) demonstrate three short-lived bimodal magmatic pulses: **(1)** the early 332±2 Ma for Mg–K Pormenaz monzonite and associated 331±2 Ma peraluminous Montees Pelissier monzogranite, **(2)** the 307±2 Ma peraluminous (cordierite-bearing) Vallorcine and Fully intrusions, and **(3)** the 303±2 Ma for high Fe–K Mont Blanc syenogranite. The identification of the synplutonic gabbro dykes within a migmatitic granodiorite with an age 307±2 Ma has great importance for proving direct (asthenospheric?) mantle involvement during the Late Carboniferous Variscan Orogeny in Europe (Bussy et al. 2000).

The Variscan Bohemian Massif, representing a typical example of a large hot orogen in Central Europe, was intruded by voluminous and compositionally diverse, mostly granitic plutons. These plutons yield unique insight into the composition of the orogenic lower/middle crust and its development in both space and time. Their evolution in the orogenic root (Moldanubian Zone) can be presented in the form of a sequence of six petrogenetic suites (Holub et al. 1997; Janoušek et al. 2000; Žák et al. 2014; Janoušek 2019): **(1)** *Normal-K calc–alkaline (Sázava) suite* – recording transpression along NW contact of the Central Bohemian Pluton – is represented by gabbros, diorites, tonalites, granodiorites and trondhjemites of the arc-related magmatic setting having an age of ca. 375–355 Ma; **(2)** *High-K calc–alkaline (Blatná) suite* – recording the onset of exhumation of the Moldanubian orogenic root – (Amp) Bt granodiorites, products of mixing/mingling of felsic crustal magma with moderately enriched mantle melts at ca. 345 Ma; **(3)** *(Ultra-) potassic (Čertovo bremeno) suite* – is characterized by syn- or post-tectonic intrusions and dyke swarms, most typically the strongly Kfs-phyric durbachite suite rich in mafic enclaves that have originated from primary ultra-K magmas derived from lithospheric mantle contaminated by felsic crust that subsequently mixed with leucogranitic melts ca. 343–335 Ma ago; **(4)** *Porphyritic biotite granite suite* – dominated by strongly Kfs-megacrystic Weinsberg-type biotite granites that were probably generated by partial melting of heterogeneous lower crust ca. 331–323 Ma ago; **(5)** *Peraluminous two-mica granites (Eisgarn suite)* with Crd and magmatic And that originated by dehydration melting of metasediments ca. 328–326 Ma ago; **(6)** *Post-tectonic tonalite–granite (Freistadt) suite* – the late metaluminous, calc–alkaline tonalites to granites, intruding mostly the older granitoids of the Weinsberg suite, originated by partially melting of metatonalitic lower crust at ca. 316–300 Ma.

Neoteric U–Th–Pb dating using zircon and monazite from the southern Black Forest has discarded the former hypothesis of a Devonian emplacement, and suggested Visean (340–332 Ma) magmatic age of granitic rocks (Schaltegger 1997).

Granitic bodies of the Central and Southern Vosges Mts. can be assigned to two major Carboniferous magmatic events: **(a)** Visean Mg–K event (345–336 Ma) and **(b)** younger S-type event (329–322 Ma). The differences between these groups are explained by a geodynamic scenario and magma sources; that is, melting of the metasomatized lithospheric mantle yielding Mg–K magmas interacting with a mature crustal material in deep subduction, and mixed crustal sources (paragneisses and/or immature felsic–intermediate meta-igneous rocks) during collisional stages (Tabaud et al. 2015).

Zircon and monazite U–Th–Pb ages from the eastern French Massif Central imply a long-lasting (~40 Myr) period of crust- and mantle-derived magmatism, as is reflected by the coeval emplacement of granites between 337.4±1.0 and 298.9±1.8 Ma, and high Mg–K suite (vaugnerites) between 335.7±2.1 and 299.1±1.3 Ma (Laurent et al. 2017).

The generation of the crustal granitoids on a batholithic scale took place from ca. 330 Ma to ca. 290 or 340–280 Ma, during the main extensional period in the Iberian Massif (Bea et al. 1999; Ribeiro et al. 2019). Gutiérrez-Alonso et al. (2011) linked post-orogenic magmatism with Iberian orocline-driven lithospheric thinning/delamination and divided the 25 Myr of post-orogenic magmatism (310–285 Ma) into four events: **(1)** oroclinal bending began at 310–305 Ma resulting in lithospheric thinning and asthenospheric upwelling in the outer arc of the orocline accompanied by production of mantle and lower crustal melts; **(2)** between 305 and 300 Ma, melting continued under the outer arc of the orocline (Central Iberian Zone) and mid-crustal melting was initiated. Simultaneously, the lithospheric root beneath the inner arc was thickened due to progressive arc closure; **(3)** between 300 and 292 Ma, sinking of the lithospheric root has been followed by melting in the lithospheric mantle and in the lower crust beneath the inner arc due to the asthenosphere upwelling; **(4)** cooling of the lithosphere between 292 and 286 Ma resulted in a drastic attenuation of lower crustal high-temperature melting.

A brief overview of the Variscan granitic ages throughout the European realm presented above demonstrates a complex interplay between crustal and mantle tectonic processes in genesis of these felsic igneous rocks over a long period from ca. 370 Ma to 285 Ma and, in some cases, even up to 250 Ma, as was presented by Bonin (2008). Interestingly, the distribution of these magmatic/emplacement ages indicates an apparent trend in the Variscan Orogen, with progressively younger granite ages going from East to West, although Schulmann et al. (2014) assumed rather a rejuvenation of the Variscides from North to South, and/or presence of two orogenies, the older mostly preserved in Central–Eastern Europe, and the younger that has overprinted much of Southern Europe. Data presented in this study give evidence mainly for the early stages of the Variscan granite-forming processes in the Tatric Superunit CM. However, Permian A-type granites are known from contact zone between the Veporic and Gemeric superunits, and specialized ore-bearing S_s-type granites are documented within the Gemeric Superunit of the CWC (Kubiš & Broska 2010; Broska & Kubiš 2018; Ondrejka et al. in review).

Obviously, the older group of granitic rocks dated at ca. 370–350 Ma had origins related to subduction, whereas the younger group (348–332 Ma) was associated with syn-collisional melting. The studied granitic rocks have mainly hybrid character inherited from their sources consisting of a mixture of the lower crustal felsic and mafic metaigneous rocks with addition of the meta-psammites and meta-pelites and/or slight admixture of mafic melts derived from the SCLM. These granitoids form mainly composite plutons with several magma pulses and locally normally zoned plutons as well; however, more dating and isotopic (Sr, Nd, Pb, Hf, O, S, Li etc.) data are needed for their proper understanding. This task remains for future research.

Conclusions

The SHRIMP zircon U–Th–Pb dating of the Tatric Superunit core mountains granitic rocks provided a broad interval of individual spot ages from the Late Devonian to Late Carboniferous (more than 70 Myr) yielding Concordia ages ranging from 365±5 Ma to 332±3 Ma. There is no temporal difference between the studied I-/S-type granitic rocks, and both groups show common inheritance with Neo-Archean to Paleo-Proterozoic (2800–1690 Ma) and Neo-Proterozoic (Ediacaran) to Late Ordovician (623–448 Ma) inherited (restitic) zircon cores. The Variscan zircons of this study have mainly Th/U>0.2 suggesting a magmatic origin, whereas partly lower ones (Th/U<0.1) suggest competition for Th with other high-Th minerals such as monazite or allanite. The Rheic Ocean subduction (365–350 Ma) and collision-related (348–332 Ma) granitic magma producing periods have been identified in the Tatric Superunit core mountains of the Central Western Carpathians. These two distinct, quasi-independent orogenic events reflect a radical change in geotectonic setting but a more or less continuous Variscan Late Devonian (Famennian) to Early Carboniferous (Visean) crustal evolution. However, it is important to note a common hybrid character of both the studied I-/S-types granitic suites. This is mostly a consequence of melting of variegated sources and/or imperfect hybridization and assimilation processes.

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Appendix

Sample locations

Sample	Petrography	CM	Locality	Longitude	Latitude	Altitude (m a.s.l.)
PI-61	*Bt–Ms Gr*	PI	Striebornica, nat. o.	48°35'54.57"	17°54'28.53"	273
MM-29	*Ms–Bt Gr*	SV	Poruba Valley, quarry	48°50'21.84"	18°34'09.06"	533
MF-12	*Bt GD*	MF	Šútovský potok, nat. o.	49°10'27.06"	19°04'44.92"	687
VT-1/06	*Bt T*	VT	Velická Valley, nat. o.	49°09'47.38"	20°09'17.44"	1882
BT-217	*Ms–Bt Gr*	Br	Patria ridge, nat. o.	49°00'53.30"	20°54'03.40"	905
BT-485	*Bt T*	Br	Kanné Valley, nat. o.	49°00'48.81"	20°54'42.31"	869
T-87	*Bt GD*	Tr	Krnča, road cut	48°31'32.00"	18°15'43.00"	353
T-88	*Bt T*	Tr	Zlatno Valley, nat. o.	48°28'53.00"	18°17'57.00"	715
Z-164	*Ms–Bt Gr*	Z	Veľká Valley, nat. o.	48°49'27.03"	18°46'27.30"	590
VF-40	*Bt–Ms Gr*	VF	Vyšná Krivá, nat. o.	49°01'22.15"	19°11'29.01"	1035
VF-356	*Bt T*	VF	Vyšné Matejkovo, quarry	48°59'47.22"	19°15'03.59"	812
NT-78	*Bt GD*	NT	Nižná Boca, nat. o.	48°56'17.16"	19°45'43.22"	1069

Explanations: **CM** – core mountains - **PI** – Považský Inovec Mts., **SV** – Stražovské Vrchy Mts., **MF** – Malá Fatra Mts., **VT** – Vysoké Tatry Mts., **Br** – Branisko Mts., **Tr** – Tribeč Mts., **Z** – Žiar Mts., **VF** – Veľká Fatra Mts., **NT** – Nízke Tatry Mts.; ***Bt*** – biotite, ***Ms*** – muscovite, ***Gr*** – granite, ***GD*** – granodiorite, ***T*** – tonalite; **nat. o.** = natural outcrop.

Supplement

Table S1: The available ages of the Variscan granites from the Central Western Carpathians. *Explanations*: **Gr_S-type** + **Gr_I-type** – conventional assignment of granite types according White & Chappell (1974); **SHRIMP** – Sensitive High Resolution Ion Micro-Probe; **Conv_Multigr** – conventional multigrain dating; **TIMS** – Thermal Ionization Mass Spectrometry; **CLC TIMS** – cathodoluminescence-controlled single-grain TIMS dating; **SIMS** – Secondary-Ion Mass Spectrometry; **LA-ICP-MS** + **LA-MC-ICP-MS** – Laser-Ablation (Multi-Collector) Inductively-Coupled Plasma Mass Spectrometry; **N-TIMS** – Negative Thermal Ionization Mass Spectrometry; **CA** – Concordia age; **LI** – Lower intercept; **UI** – Upper intercept; **Kober M** – "Kober method": direct evaporation dating on TIMS (Kober 1987).

Sample	Mts.	Rock type	Mineral	Method	CA / UI vs. LI	Publication	Laboratory	Age (Ma)
MK-66	Malé Karpaty	Gr_S-type	zircon	SHRIMP	CA	Kohút et al. (2009)	St. Petersburg	355.4 ± 4.7
MK-72	Malé Karpaty	Gr_I-type	zircon	SHRIMP	CA	Kohút et al. (2009)	St. Petersburg	346.8 ± 4.1
PI-61	Považský Inovec	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	367 ± 5
MM-29	Stražovské vrchy	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	360.9 ± 2.7
MF-12	Malá Fatra	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	345 ± 3
VT-1/96	Vysoké Tatry	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	363.3 ± 5.5
BT-217	Branisko	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	351.4 ± 2.4
BT-485	Branisko	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	360.9 ± 3.3
T-87	Tribeč	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	355.1 ± 3.8
T-88	Tribeč	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	332 ± 3
Z-164	Žiar	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	348.1 ± 4.3
VF-40	Veľká Fatra	Gr_S-type	zircon	SHRIMP	CA	this paper	St. Petersburg	337 ± 3
VF-356	Veľká Fatra	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	332 ± 3
NT-78	Nízke Tatry	Gr_I-type	zircon	SHRIMP	CA	this paper	St. Petersburg	340 ± 3
ZT-26/09	Západné Tatry	Gr_I-type	zircon	SHRIMP	CA	Kohút & Siman (2011)	St. Petersburg	358.7 ± 6.2
Z-117	Ziar	Gr_S-type	zircon	SHRIMP	CA	Kohút (2015)	St. Petersburg	332 ± 2
RAO-4/91	Ziar	Gr_S-type	zircon	SHRIMP	CA	Kohút (2015)	St. Petersburg	332.3 ± 2.1
M-9	Nízke Tatry	Gr_S-type	monazite	Conv_Multigr	CA	Bojko et al. (1974)	Kiev	330 ± 20
KV-3	Veporic Unit	Gr_S-type	zircon	Conv_Multigr	LI	Bibikova et al. (1988)	Moscow	350 ± 5
VG-1-6	Veporic Unit	Gr_S-type	zircon	Conv_Multigr	LI	Michalko et al. (1998)	Espoo	345 ± 8
DS-1	Malá Fatra	Gr_I-type	zircon	Conv_Multigr	UI	Shcherbak et al. (1990)	Kiev	353 ± 5
V-94	Stražovské vrchy	Gr_S-type	zircon	TIMS	Kober M	Kráľ et al. (1997)	Heidelberg	356 ± 9
DUM-1	Nízke Tatry	Gr_I-type	zircon	TIMS	LI	Putiš et al (2003)	St. Petersburg	343 ± 3
VF-43	Veľká Fatra	Gr_S-type	zircon	CLC_TIMS	UI	Kohút et al. (1997)	Mainz	356 ± 25
UP-1023	Západné Tatry	Gr_S-type	zircon	CLC_TIMS	LI	Poller et al. (2000a)	Mainz	347 ± 14
UP-1036	Západné Tatry	Gr_S-type	zircon	CLC_TIMS	UI	Poller et al. (2000a)	Mainz	357 ± 13
UP-1040	Západné Tatry	Gr_S-type	zircon	CLC_TIMS	LI	Poller et al. (2000a)	Mainz	363 ± 11
UP-1016	Vysoké Tatry	diorite	zircon	CLC_TIMS	UI	Poller & Todt (2000)	Mainz	341 ± 5
UP-1052	Vysoké Tatry	Gr_S-type	zircon	CLC_TIMS	LI	Poller & Todt (2000)	Mainz	332 ± 5
UP-1088	Nízke Tatry	Gr_I-type	zircon	CLC_TIMS	CA	Poller et al. (2001a)	Mainz	330 ± 10
VF-639	Veľká Fatra	Gr_S-type	monazite	CLC_TIMS	CA	Kohút et al. (1997)	Mainz	340 ± 2
UP-1037	Veľká Fatra	Gr_S-type	zircon	SIMS	CA	Poller et al. (2000b)	Nancy	339 ± 9
UP-1044	Vysoké Tatry	Gr_I-type	zircon	SHRIMP	CA	Poller et al. (2001b)	Canberra	351 ± 4
UP-1053	Vysoké Tatry	Gr_I-type	zircon	SHRIMP	CA	Poller et al. (2001b)	Perth	342 ± 5
02GA14	Veporic Unit	Gr_I-type	zircon	SHRIMP	CA	Gaab et al. (2005)	Canberra	356 ± 10
02GA17	Veporic Unit	Gr_I-type	zircon	SHRIMP	CA	Gaab et al. (2005)	Canberra	359 ± 6
T-22	Tribeč	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	358 ± 3
T-60	Tribeč	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	367 ± 3
T-63	Tribeč	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	364 ± 2
T-70	Tribeč	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	360 ± 3
NTBS-1	Nízke Tatry	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	356 ± 2
NTBS-2	Nízke Tatry	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	353 ± 3
Sihla-1	Veporic Unit	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	357 ± 2
CH-2K2	Veporic Unit	Gr_I-type	zircon	SIMS	CA	Broska et al. (2013)	Stockholm	357 ± 3
MF-DS	Malá Fatra	Gr_I-type	zircon	LA-ICP-MS	CA	Broska & Svojtka (2020)	Prague	353 ± 3
MF-DS (y)	Malá Fatra	Gr_I-type	zircon	LA-ICP-MS	CA	Broska & Svojtka (2020)	Prague	342 ± 3
MF-S	Malá Fatra	Gr_S-type	zircon	LA-ICP-MS	CA	Broska & Svojtka (2020)	Prague	342 ± 3
JBL-1	Západné Tatry	Gr_S-type	zircon	LA-MC-ICP-MS	CA	Burda & Gaweda (2009)	Vienna	359.1 ± 1.2
SP2	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2011)	Vienna	368.5 ± 7.7
WM-a	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2013a)	Vienna	350.5 ± 4.7
WM-b	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2013a)	Vienna	337.8 ± 5.9
CS	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2013a)	Vienna	345.3 ± 6.3
G-1	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2013b)	Vienna	371 ± 6
G-2	Západné Tatry	Gr_S-type	zircon	LA-MC-ICP-MS	CA	Burda et al. (2013b)	Vienna	350 ± 4.7

Table S1 (continued)

Sample	Mts.	Rock type	Mineral	Method	CA / UI vs. LI	Publication	Laboratory	Age (Ma)
Cho-1	Nízke Tatry	Gr_S-type	zircon	SIMS	CA	Burda et al. (2020)	Beijing	**352.6 ± 2.5**
HTG	Vysoké Tatry	Gr_I-type	apatite	LA-ICP-MS	LI	Gaweda et al. (2014)	Dublin	**339.5 ± 4.4**
GDG	Západné Tatry	diorite	apatite	LA-ICP-MS	LI	Gaweda et al. (2014)	Dublin	**338.8 ± 5.3**
WTC	Západné Tatry	Gr_S-type	apatite	LA-ICP-MS	LI	Gaweda et al. (2014)	Dublin	**344.3 ± 2.8**
KOS	Vysoké Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Gaweda et al. (2016)	Vienna	**368.3 ± 9.4**
WG	Západné Tatry	Gr_S-type	zircon	LA-MC-ICP-MS	CA	Gaweda et al. (2016)	Vienna	**364.7 ± 5.3**
RP	Západné Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Gaweda et al. (2016)	Vienna	**360.2 ± 5.5**
LOM	Vysoké Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Gaweda et al. (2016)	Vienna	**355.2 ± 8.2**
WPP	Vysoké Tatry	Gr_I-type	zircon	LA-MC-ICP-MS	CA	Gaweda et al. (2016)	Vienna	**345.6 ± 3.7**
R-1	Západné Tatry	pegmatite	apatite	LA-ICP-MS	LI	Gaweda et al. (2016)	Dublin	**328.6 ± 2.4**
DNT-1	Nízke Tatry	diorite	zircon	SHRIMP	CA	Uher et al. (2011)	St. Petersburg	**350 ± 2.4**
DMK-18	Malé Karpaty	diorite	zircon	SHRIMP	CA	Uher et al. (2011)	St. Petersburg	**353 ± 2.3**
MM-5	Malé Karpaty	diorite	zircon	SHRIMP	CA	Uher et al. (2011)	St. Petersburg	**341.6 ± 2.4**
ZK-79	Nízke Tatry	Gr_I-type	titanite	SHRIMP	CA	Uher et al. (2019)	Warsaw	**343.1 ± 6.8**
ZK-83	Veporic Unit	Gr_I-type	titanite	SHRIMP	CA	Uher et al. (2019)	Warsaw	**351.0 ± 6.5**
Sih-1	Veporic Unit	Gr_I-type	titanite	SHRIMP	CA	Uher et al. (2019)	Warsaw	**344.0 ± 5.9**
ZK-12	Veporic Unit	Gr_I-type	titanite	SHRIMP	CA	Uher et al. (2019)	Warsaw	**337.9 ± 6.1**
SAS-6/06	Veporic Unit	Gr_I-type	zircon	SHRIMP	CA	Putiš et al. (2009)	St. Petersburg	**349.9 ± 4.4**
Vsi-1	Veporic Unit	Gr_I-type	zircon	SHRIMP	CA	Putiš et al. (2009)	St. Petersburg	**355.7 ± 3.7**
Pezinok-Stupy	Malé Karpaty	Gr_S-type	zircon	SHRIMP	CA	Putiš et al. (2009)	St. Petersburg	**352.3 ± 1.8**
Pezinok-Stupy	Malé Karpaty	Gr_S-type	zircon	SHRIMP	CA	Putiš et al. (2009)	St. Petersburg	**343.2 ± 2.1**
Zel-1/z	Nízke Tatry	diorite	zircon	LA-ICP-MS	CA	Spišiak unpublished	Dublin	**362.4 ± 2.9**
Zel-1/a	Nízke Tatry	diorite	apatite	LA-ICP-MS	LI	Spišiak unpublished	Dublin	**358.4 ± 2.8**
T-1	Západné Tatry	pegmatite	molybdenite	N-TIMS	Re-Os	Mikulski et al. (2011)	Fort Collins	**350 ± 1**
D-602	Nízke Tatry	pegmatite	molybdenite	N-TIMS	Re-Os	Majzlan et al. (2020)	Prague	**352 ± 3**
MZ-1	Nízke Tatry	pegmatite	molybdenite	N-TIMS	Re-Os	Majzlan et al. (2020)	Prague	**351 ± 3**
D-1	Nízke Tatry	pegmatite	molybdenite	N-TIMS	Re-Os	Kohút & Stein et al. (in prep.)	Fort Collins	**348.3 ± 1.3**
D-2	Nízke Tatry	pegmatite	molybdenite	N-TIMS	Re-Os	Kohút & Stein et al. (in prep.)	Fort Collins	**349.2 ± 1.3**
PT-45/271	Malé Karpaty	pegmatite	molybdenite	N-TIMS	Re-Os	Kohút & Stein et al. (in prep.)	Fort Collins	**356.7 ± 2.6**

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Supplementary Table S1 is available online at http://geologicacarpathica.com/data/files/supplements/GC-72-2-Kohut_Suppl_Table_S1.xlsx.