^{40}AR/^{39}AR STEP-HEATING DATING OF PHLOGOPITE AND AMPHIBOLE MEGACRYSTS FROM ŽELEZNÁ HŮRKA (EISENBÜHL), CHEB BASIN, CZECH REPUBLIC

M.J. Timmerman[1], L. Krmíček[2; 3], M.A. Ziemann[1] and M. Sudo[1]
[1] Institut für Erd- und Umweltwissenschaften, Universität Potsdam, Karl-Liebknecht-Strasse 24-25, Haus 27, D-14476 Potsdam-Golm, Germany; [2] Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, Veveří 95, CZ-602 00 Brno, Czech Republic; krmicek.l@fce.vutbr.cz; [3] Institute of Geology, v.v.i., Czech Academy of Sciences, Rozvojová 269, CZ-165 02 Prague 6, Czech Republic.

Stretching of Variscan crust in western Bohemia (Czech Republic and Vogtland, Germany) started in the Late Cretaceous and ultimately resulted in the formation of the 300 km long and 50 km wide, fault-bounded Ohře/Eger Rift. Extension-related and mantle-derived volcanism and its derivatives started at c. 80 Ma, peaked in the Eocene to Miocene (42–16 Ma) and lasted until 300,000 years ago [1,2 and references therein]. In the Cheb Basin in the western part of the Eger Rift, extension resulted in the formation of spatially associated small eruptive centres, mineral water springs, large-scale emanations of deeply sourced carbon dioxide as CO_2-rich gas or mineral waters from mofettes, higher heat flows and the occurrence of episodic clusters of small magnitude earthquakes [3-5], the latter attributed to fluids and gases released from crystallizing mafic magmas moving rapidly upwards along deep-seated faults [6].

The youngest (Pleistocene) volcanic eruptions in the Cheb Basin were explosive, mafic, silica-undersaturated and of small volume, forming maars and scoria vents such as those at Železná hůrka (Eisenbühl), Mýtina and Komorní hůrka (Kammerbühl). In early 2015, a further young, probably 200,000 years old maar was discovered near Neualbenreuth in Germany, just 1 to 2 km south of the known maars in the Czech Republic. More young volcanic centres are suspected in the same general area and geophysical studies are underway (May 2017).

The scoria vent at Železná hůrka and tephra at Mýtina are long known to contain xenoliths of ultramafic rocks (mostly wehrlites, clinopyroxenites, and hornblendites with cumulate textures), of middle and upper crustal wall rocks, and megacrysts of olivine, clinopyroxene, amphibole and phlogopite [7 and references therein]. Olivine phenocrysts and a clinopyroxene megacrysts from Železná hůrka and Mýtina have $^{3}He/^{4}He$ R_a values typical for xenoliths from European subcontinental mantle (6–7 R_a) and very similar to those for fluids presently emitted from the CO_2-rich mofettes in the Cheb Basin [8].

Generally, K–Ar and $^{40}Ar/^{39}Ar$ dating of young mafic pyroclastic rocks is problematic due to their low age and the low to intermediate potassium contents (hence low ^{40}Ar content) and alteration, often resulting in widely varying groundmass K–Ar ages with large analytical uncertainties, and often anomalously young ages due to alteration-related ^{40}Ar loss. In contrast, anomalously old ages may result from incorporation of excess argon into the mafic parent melt by heat-induced degassing of old, K-rich (thus ^{40}Ar rich) country rocks. In addition, fine-grained and/or glassy material such as tuffs may also suffer from ^{39}Ar loss during neutron activation prior to $^{40}Ar/^{39}Ar$ dating ("recoil"), also resulting in anomalously old ages.

Šibrava & Havlíček (1980) reported K–Ar ages for volcanic rocks from Železná hůrka and Komorní hůrka that range widely between 260 ka and 1 Ma [9]. For this reason, several other methods have been employed to directly or indirectly obtain crystallization ages for the maars and diatremes in the Cheb Basin (see Table). Apatite fission track, alpha-recoil track, electron spin resonance, thermoluminescence, K–Ar, $^{40}Ar/^{39}Ar$ step-heating and $^{40}Ar/^{39}Ar$ single grain total fusion dating have been employed on material as different as apatite and quartz from xenoliths, magmatic groundmass and phlogopite phenocrysts and megacrysts.

We report $^{40}Ar/^{39}Ar$ step-heating ages for a phlogopite and an amphibole megacryst collected as loose material from the Železná hůrka outcrop. Phlogopite megacrysts Eb-2 yielded a 631 ± 53 ka (1 sigma) plateau age for 8 gas fractions comprising 91% of the ^{39}Ar released. The inverse isotope correlation age for the plateau-defining gas fractions is somewhat younger at 435 ± 108 ka with an $^{40}Ar/^{36}Ar$ intercept ratio of 305 ± 5, slightly higher than that of air ($^{40}Ar/^{36}Ar$ = 295.5). In contrast, step-heating dating of amphibole megacryst Eb-1 did not yield a plateau age due to the release of an unexpectedly large amount of Ar (48% of the ^{39}Ar released) during fusion at the highest experimental temperature. The total gas age is 1.55 ± 0.02 Ma and a 1.53 ± 0.02 Ma weighted-mean age can be calculated for 7 gas fractions comprising 53% of the ^{39}Ar released.

We assume the **435 ± 108 ka** phlogopite inverse isotope correlation age to date the volcanism at Železná hůrka, which would make it c. 100 ka older than that of nearby Mýtina maar. The approximately 1 Myr older apparent age of the amphibole from Železná hůrka needs to be confirmed, but if applicable, could indicate earlier fractionation at deep crustal levels of the same mafic parent melt that produced the younger phlogopite megacrysts during an advanced stage of fractionation.

References:

[1] Kämpf H. et al. (1993) *Z geol Wiss* **21**, 117-134. [2] Ulrych J. et al.. (2013) *Lithos* **123**, 133–144. [3] Dahm T. et al. (2016) *Sci Drilling* **16**, 93–99. [4] Bräuer K. et al. (2014) *J Geophys Res* **119**, 5613–5632. [5] Nickschick T. et al. (2015) *Int J Earth Sci* **104**, 2107–2129. [6] Mullick N. et al. (2015) *Tectonophys* **647–648**, 105–111. [7] Geissler W.H. (2005) Dissertation, Freie Universität Berlin. *GeoForschungszentrum Potsdamn, Scientifical Technical Report* **STR05/06**, 152 pp. [8] Niedermann S. et al. (2005) *Abstracts ICGG8, 2-8 Oct 2005, Sicily, Italy*. [9] Šibrava V. & Havlíček P. (1980) *Věst Ústř Úst geol* **55**, 129-150. [10] Todt W. & Lippolt H.J. (1975) *J Geophys* **41**, 43–61 [11] Gögen K. & Wagner G.A. (2000) *Chem Geol* **166**, 127–137. [12] Woda C. et al. (2001) *Quat Sci Rev* **20**, 993-998. [13] Wagner G.A. et al. (2002) *Z geol Wiss* **3**, 191-200. [14] Mrlina J. et al. (2007) *Z geol Wiss* **35**, 213–230.

	^{40}Ar/^{39}Ar SH	**^{40}Ar/^{39}Ar TF**	**K-Ar**	**AFT**	**ART**	**ESR**	**TL**
Železná hůrka	435 ± 108 ka (V) (6) 1.53 ± 0.02 Ma (V) (7)				300 ± 60 (I) (2)	733 ± 70, 585 ± 62, 537 ± 20 (II)	517 ± 86, 367 ± 123 (III)
Komorní hůrka			2.0 ± 1.8 Ma (I)(1)			285 ± 33, 751 ± 61, 769 ± 79 (II)	881 ± 114, 497 ± 58 (III)
Mýtina	253 ± 36 (IV) (4)	299 ± 20 (IV) (5)		365 (III) (3)			

Radiometric ages for the Pleistocene volcanic centres in the Cheb Basin of the Eger Rift. Ages given in ka, except (1) and (7). Abbreviations for dating methods: AFT = apatite fission track, ART = alpha-recoil track (quartz), ESR = electron spin resonance (quartz), TL = thermoluminescence (quartz), SH = step-heating, TF = single grain total fusion. Remarks: (1) – olivine nephelinite groundmass; (2) – phlogopite megacryst; (3) – apatite from hornblendite xenolith, age average; (4) – plateau age for nine gas fractions, phlogopite phenocrysts; (5) – age average for phlogopite phenocrysts; (6) – inverse isotope correlation age, phlogopite megacryst; (7) – weighted-mean age for 7 gas fractions, amphibole megacryst. Sources: (I) – Todt & Lippolt (1975); [10]; Gögen & Wagner (2000) [11]; (II) - Woda et al. (2001) [12]; (III) - Wagner et al. (2002) [13]; (IV) - Mrlina et al. (2007) [14]; **(V) this study.**