Journal of Volcanology and Geothermal Research 198 (2010) 275–287

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

U–Th–Pb geochronology of zircon and monazite from syenite and pincinite xenoliths in Pliocene alkali basalts of the intra-Carpathian back-arc basin

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ARTICLE INFO

Article history:
Received 11 May 2010
Accepted 6 September 2010
Available online 16 September 2010

Keywords:
maar
alkali basalt
syenite
pincinite
zircon
monazite
Western Carpathians

ABSTRACT

Phreatomagmatic eruptions in the Lučenec Basin in Slovakia ejected fragments of igneous rocks of unknown age and ranging in composition from gabbro to syenite and orthopyroxene granodiorite – pincinite. Two kinds of syenites with different Fe^{3+} contents composed of anorthoclase and interstitial metaluminous trachyte-to-alkali rhyolite glass represent the final products of alkali basalt differentiation at depths of 10 and 15–18 km. Pincinite composed of plagioclase, quartz, orthopyroxene, ilmenite and interstitial peraluminous dacite glass is a quenched supersolidus anatectic melt formed at the depth of 17–20 km by high-temperature dehydration melting of biotite-bearing gneissic protolith.

Zircon from pincinite and syenite, and monazite from syenite were dated using excimer laser ablation ICP-MS. The obtained ages cluster at 5.8 ± 0.1 and 5.4 ± 0.1 Ma, thus corroborating the genetic link between the two rock-types and constraining the residence time of at least 300 ± 100 ka of the parental basalt in the deep crustal magma storage zones. The inferred ages overlap the Upper Miocene–Pliocene boundary, and are considerably younger than spatially associated basaltic lava flows dated using the K/Ar method. Consequently, the fluviolacustrine Poltár Formation overlying the maar structure must have sedimented during the Pliocene and not during the Upper Miocene (Pontian) as previously assumed.

1. Introduction

Alkali basalt volcanism in the Carpathians is commonly interpreted as a “within-plate” post-collision association formed by decompression-related partial melting of the depleted asthenosphere (Downes et al., 1995; Dobosi et al., 1995; Konečný et al., 1995, 2002; Pécskay et al., 2006). Small isolated monogenetic volcanic centres originated throughout the whole intra-Carpathian back-arc basin system due to a post-rift thermal subsidence post-dating a Miocene Alpine-type subduction which was triggered by the collision of Alcapa and Tisia microplates with the European platform (Konečný et al., 2002; Seghedi et al., 2004).

Intra-Carpathian alkali basalts commonly contain fragments and nodules of igneous rocks covering the compositional range from clinopyroxene-dominated gabbroic cumulate (Dietrich and Poultidis, 1985; Embey-Isztin et al., 1990; Huraiová et al., 1996; Zajacz and Szabó, 2003) to K-feldspar-dominated syenite (Huraiová et al., 1996; Hurai et al., 1998). The Pinciná maar in southern Slovakia is unique in this context (Fig. 1), where phreatomagmatic eruptions ejected gabbro, syenite and glassy orthopyroxene granodiorite–tonalite (pincinite) xenoliths up to 50 cm in diameter. All these rock types occur as fragments, sometimes enclosed in basaltic bombs, in the same horizon of lapilli tuffs deposited in the maar rim. Isotopic signatures, trace element abundances and fluid inclusions showed that the gabbro and syenite originated due to a polybaric fractional crystallisation of alkali basalt (Hurai et al., 1998). Two compositionally different types of the pincinite were interpreted as quenched supersolidus anatectic melts formed around basaltic magma storages at depths of 10–11 and 17–20 km by dehydration melting of the biotite-quartz-feldspar-bearing crust (Huraiová et al., 2005). Chemical U–Pb–Th dating of restitic monazite isolated from the pincinite proved the Variscan (Upper Carboniferous) age of the gneissic protolith (Huraiová and Konečný, 2006).

Chronology of the alkali basalt volcanism in central and southern Slovakia was well-documented using K/Ar whole rock age determination from 39 lava flows, necks and dykes (Vass et al., 2007 and references therein). A total of 3 volcanic cycles subdivided into 7 volcanic phases cover the interval from the Late Pannonian (8.3 Ma) to the Quaternary (0.25 ± 0.12 Ma). The ages of maars, cinder and spatter cones have been inferred from superposition of sedimentary basin deposits, or from spatial relationship with lava flows and dykes dated by the K/Ar method. However, the ages of the deep crustal basaltic magma storages remain unknown. The newly formed monazite from syenite and pincinite xenoliths from the Pinciná maar yielded electron microprobe U–Pb–Th ages scattered between zero and 70 Ma (Huraiová and Konečný, 2006).

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doi:10.1016/j.jvolgeores.2010.09.012

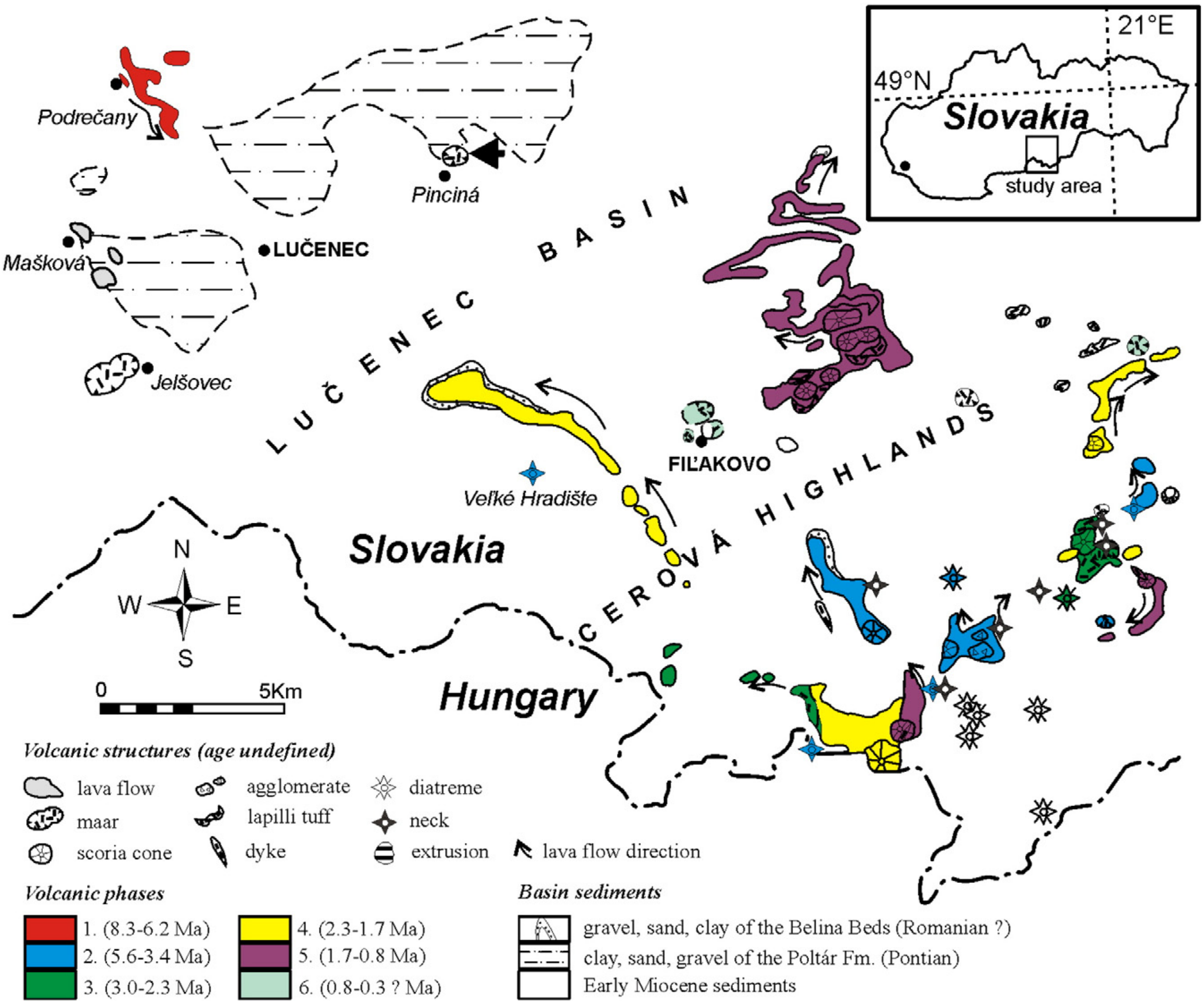

Fig. 1. Geological situation in the study area with volcanic phases as indicated by K/Ar whole rock and isochron dating of basalts (Vass et al., 2007). Location of the Pinciná maar is designated by the thick arrow.

According to geochemical indicators and textures, abundant intergranular glass and glass pockets in syenite and pincinite were interpreted as quenched supersolidus melt present in the xenoliths prior to entrainment in the alkali basalt (Hurai et al., 1998; Huraiová et al., 2005). Assuming that this is correct, the age of the igneous xenoliths would not differ too much from that of the host basalt, thereby defining also the lower age limit of the phreatomagmatic eruption and the associated fluviolacustrine sediments. Moreover, an age overlap of the newly formed magmatic zircon in the syenite and pincinite xenoliths would provide compelling evidence for the partial melting of the crust triggered by the basaltic magma underplating. To solve these issues, zircon and monazite crystals recovered from the syenite and pincinite xenoliths were studied using the U–Th–Pb system measured by the LA-ICP-MS dating method. During the last decade, this technique became an efficient, fast and reliable geochronological tool even for very young Holocene minerals (e.g. Jackson et al., 2004; Cocherie et al., 2009; Paquette and Mergoil-Daniel, 2009).

2. Analytical methods

A total of four syenite and pincinite xenoliths, weighing from 0.5 to 2 kg, were crushed and sieved, and the 0.2–0.5 mm volume fraction was further reduced by flow separation in water. The heavy fraction obtained was dried and gravitationally separated to light and heavy fractions in bromoform ($CHBr_3$). Zircon and monazite crystals were handpicked under binocular microscope from the heavy diamagnetic fraction and these were mounted in a 1 in. diameter disk of epoxy resin and polished until the crystals were exposed on the surface. Grain mounts were cleaned in an ultrasonic bath and coated with graphite for electron microprobe analysis and imaging.

The chemical composition of zircons was determined using a Cameca SX-100 electron microprobe at the Geological Survey, Bratislava, Slovakia, with an accelerating voltage of 15 keV, a beam current of 20 nA and a beam diameter of 5 μm.

For zircon analysis, calibration was made using the following natural and pure synthetic compounds (detection limits in parentheses): apatite (300 ppm P), ThO_2 (640 ppm Th), UO_2 (800 ppm U), YPO_4 (600 ppm Y), $ZrSiO_4$ (980 ppm Zr and 480 ppm Si), $YbPO_4$ (1400 ppm Yb), $ErPO_4$ (2000 ppm Er), $HoPO_4$ (1900 ppm Ho), $GdPO_4$ (1000 ppm Gd), $EuPO_4$ (1400 ppm Eu), $SmPO_4$ (1000 ppm Sm), $CePO_4$ (1000 ppm Ce), $LaPO_4$ (1000 ppm La), HfO_2 (1800 ppm Hf).

The chemical composition of monazite was measured by using a 2–3 μm beam diameter, 15 kV and 80–150 nA excitation conditions, with 165 s counting time for Pb, Th, U, Y and 25 s for the remaining elements. The microprobe was calibrated against the following standards (first order element lines and crystals used are shown in parenthesis): PbS (Mα, LPET), UO_2 (Mβ, LPET) ThO_2 (Mα, LPET), YPO_4