Petrology and age of Kozhuh volcano, SW Bulgaria

Петрология и възраст на вулкана Кожух, Югозападна България

***Stoyan Georgiev*[1]*, Peter Marchev*[1]*, Valentin Grozdev*[1]*, Albrecht von Quadt*[2]*, Irena Peitcheva*[1, 2]**
***Стоян Георгиев*[1]*, Петър Марчев*[1]*, Валентин Гроздев*[1]*, Албрехт фон Квадт*[2]*, Ирена Пейчева*[1, 2]**

[1] Geological Institute, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria;
E-mail: kantega@abv.bg; pmarchev@geology.bas.bg
[2] Institute of Isotope Geochemistry and Mineral Resources, ETH-Zurich, 8092 Zurich; E-mail: albrecht.vonquadt@erdw.ethz.ch

Key words: Struma valley, Miocene volcanic activity, petrology, U-Pb zircon age.

Introduction

Kozhuh volcano and the volcanic rocks in the Neo Petritsi area (Slavianka M[t]) crop out along the Bulgarian-Greece border and represent the only known "young" volcanic event in the Struma Valley graben. The rocks of Kozhuh volcano have been considered to be Pliocene in age (Petrov, 1960). However, recent K/Ar age determinations (Pecskay et al., submitted) and identical Ar/Ar ages for the Neo Petritsi (Elefteriadis, Staikopoulos, 1997), suggest that the volcanic rocks are of Miocene age. Although the age seems to be well-constrained, no detailed petrological studies have been carried out on the rocks. Here we provide the first geochemical, isotope and mineral chemistry data of the volcanic rocks, along with new precise U-Pb LA-ICP-MS zircon data from Kozhuh dome.

Geological setting

The Kozhuh "extinct volcano" is mentioned for the first time by Bonchev in 1920, but the geology of the volcano and the mineral springs at its vicinity have been studied much later by Petrov (1960).

According to Dinter and Royden (1993), the Struma Valley can be considered as a detachment area due to the primary contact between Neogene sediments and the underlying metamorphic and igneous rocks. This view has been disputed by Zagorchev (1992) who considers the Struma valley as a rift (graben) system resulting from the extensional neotectonic development in SW Bulgaria.

Volcanic rocks form an N–S elongated cryptodome intruded in the high-grade metamorphic rocks of the Ograzhden unit and the Neogene sediments around the volcano. The Struma River has eroded a semicircular-like depression in the eastern side of the dome that can be described as an erosional caldera.

Analytical methods and sampling

In total, three samples have been collected: two from the base and one from the top of the dome. Major elements were determined on fused pellets using a Philips PW2400 spectrometer at the University of Lausanne and ETH-Zurich. Trace elements were determined by solution ICP-MS at Washington State University and by LA-ICP-MS at ETH-Zurich. Mineral composition was determined using a JEOL 870 SUPERPROBE at the University of Florence. U-Pb age determinations of the zircons and whole-rock $^{87}Sr/^{86}Sr$ ratios were obtained in ETH-Zurich using a LA-ICP-MS setup and a Triton TIMS respectively.

Petrography and whole rock composition

The rocks are composed of phenocrysts of amphibole, biotite, plagioclase, sanidine in a groundmass of plagioclase, biotite, amphibole and sanidine microlites and accessories apatite, zircon and magnetite.

The analyzed samples show relatively constant SiO_2 contents ranging from 67.3 to 68.0 wt.%. The rocks are high alkaline with total alkalies 7.9–8.4 wt.% and K_2O/Na_2O ratio 1.04–1.3, with the highest ratio found in the sample from the top of the dome. They show high contents of LILE and steep LREE and MREE and almost flat HREE chondrite-normalised patterns. The Eu anomaly is 0.91–0.98. In accordance with its high K content, the sample from the top of the dome shows enrichment in almost all trace elements, particularly in the fluid compatible elements Cs, Th and Rb. On a primitive-mantle normalized diagram, the rocks show typical subduction-related signature with Nb, Ta minimum and Pb maximum. The $^{87}Sr/^{86}Sr_i$ ratio of 0.70643 shows intermediate values between mantle and continental crust.

Geochronology

Analyzed 10 zircon points delineate 2 narrow mean $^{206}Pb/^{238}U$ age intervals: a core of 13.47±0.28 Ma and rim of 12.11±0.57 Ma. We interpret the older age as the result of early stage crystallization of a cogenetic magma, whereas the second one reflects the time of crystallization of the dome. This age is within the error of the $^{40}Ar/^{39}Ar$ age of 11.87± 0.11Ma, obtained from the sanidine of Neo Petrisi (Elefteriadis, Staikopoulos, 1997) and 12.4–12.2 Ma, obtained from plagioclase and biotite from Pesckay et al. (submitted). Most of the crystals are free of inherited cores except one crystal yielding much older ages ~ 250 Ma, similar to the age of Igralishte pluton (Peytcheva et al., in press) suggesting assimilation of basement rocks.

Mineral chemistry and temperature of crystallization

Plagioclase represents the dominant mineral phase. It shows well expressed zonation with core and outer rim having similar compositions (An_{27}), and a more calcic intermediate zone (An_{35}).

Sanidine (Or_{58-63}) is characterized by very high BaO contents varying from 6.0 wt.% in the core down to 3.0 wt.% in the rim of the phenocrysts. Groundmass sanidine has BaO ~4.9 wt.%.

Amphibole is totally altered, replaced by iron dust and carbonate.

Biotite forms euhedral, rarely embedded, crystals. It shows thin opacitized rim, consisting of Fe-Ti oxides. Biotite is slightly reversely zoned with less Mg-rich (Mg# 57.7) core and more Mg-rich outer rim (Mg# 60.3), accompanied by a slight decrease of fluorine from 1.20 to 0.90. In addition, biotite is characterized by high BaO of ~2 wt.%.

Titanium magnetite forms microphenocrysts with TiO_2 content up to 8.5 wt.% and minor MgO and MnO.

Apatite is an ubiquitous accessory mineral. It is characterized by high fluorine (~3.9 wt.%) and very low chlorine content (0.05 wt.%).

The results from ternary-feldspar thermometry are controversial because of the high Ba content in the sanidine. Using the method of Fuhrman and Lindsley (1988), the temperatures are at the range of 570–695 °C. The two-feldspar thermometer of Putirka (2008) yields a temperature range of 890–960 °C but it does not take in account the Ba content. We think that a temperature of less than 900 °C is most probable.

Discussion

The high SiO_2 content of the investigated trachydacites can be explained by: 1) fractionation from a more mafic magma; or 2) melting of a crustal source. The absence of more mafic rocks in the volcano seems to favour the second hypothesis. However, the trace element chemistry of the trachydacite contradicts the crustal source melting scenario. Crustal rocks of such high contents of Pb, and particularly Sr and Ba, are not known and the measured $^{87}Sr/^{86}Sr_i$ ratio of 0.70643 in the Kozhuh rocks is too low to be the result of direct melting of silicic crustal rocks which have $^{87}Sr/^{86}Sr_i > 0.710$. We believe, that the Kozhuh rocks more likely formed by crustal assimilation and fractionation of a mantle-derived magma. Such a process is confirmed by findings of inhereted zircons with Upper Permian–Lower Triassic ages.

Acknowledgements: We thank Orlando Vaselli for the assistance in microprobe analyses and Fabio Caponi for the XRF analyses. The isotope analyses are supported by SCOPES-Project No. IZ73Z0–128089.

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