Visoka Elha paleovolcano – an example for adakite-like rhyolite formation that postdates the Late Alpine collisional tectonics in the Balkanides

Палеовулканът Висока Елха – пример за формиране на адакитоподобни риолити, последващи късноалпийската колизионна тектоника в Балканидите

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Introduction

The Visoka Elha paleovolcano crops out in Lozen Mountain, near to Kokalyane village (in the vicinities of Sofia). It represents deeply eroded acid volcano with epiclastic aprons of volcanoclastic sediments − a product of debris flows (mudflows) and alluvial fans (Muszynski, 1980; Nemec, Muszynski, 1984 and reference therein). The rocks are intruded in low grade phylites and diabases, high-grade methamorphic rocks and Upper Cretaceous volcanics of the West Srednogorie Zone and are covered by Neogene sediments. Although it is quite near to Sofia, the last comprehensive petrology and geochemistry studies of the rocks are achieved by the latter researchers and after that it is mentioned only in regional interpretations. Here we provide new geochemical, isotope and petrology data of the volcanic rocks, along with U-Pb LA-ICP-MS geochronology and zircon population analysis. The aim is to constrain better the sources and time of magma generation along with geodynamic implications.

Analytical methods and sampling

Major and trace elements are determined on fused pellets using a Philips PW2400 XRF spectrometer (at ETH–Zurich) and LA-ICP-MS (at GI–BAS, Sofia). In-situ U-Th-Pb age dating of the zircons is made applying the LA-ICP-MS method (GI–BAS). The whole-rock $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios are obtained after a chromatographic cleaning procedure applying ID-TIMS techniques (TritonPlus analyses at ETH-Zirich), and the $^{176}Hf/^{177}Hf$ ratios of zircon zones/grains are achieved by spatial controlled in-situ LA-MC-ICP-MS (at ETH–Zurich). The mineral chemistry is determined by SEM-EDS JEOL JSM–6610LV (University of Belgrade).

Petrography

The rocks are composed of phenocrysts of plagioclase, biotite and hornblende set in a groundmass of micro grained aggregate and microlites of the same minerals. Neither sanidine nor quartz is observed in the porphyry assemblage. Perlite is found as rock fragments in the volcaniclastic deposits (Muszynski, 1980). The accessory minerals are presented by zircon, apatite and magnetite.

Plagioclase ($An_{53–30}$) represents the dominant mineral phase. It shows well expressed oscillatory zoning. Some of the crystals display reverse zoning with acid core (An_{40}) and basic outer rim (An_{53}) with sieve texture. This can be referred to mixing process.

Biotite forms euhedral, rarely embedded in the plagioclase, crystals. Some crystals shows thin opacitized rim, consisting of Fe-Ti oxides while others are strongly opacitizied and are determined as phlogopite with (Mg# 82). The latter can represent xenocrysts from the lower crust or more maffic Upper Cretaceous (?) lithologies.

Horblende forms prismatic crystals that are strongly opacitized and oxidized. This probably is due to fast ascend from deeper levels and decompression.

Whole rock geochemistry

The analyzed samples show relatively constant SiO_2 contents ranging from 69.7 to 72.9 wt.%. The rocks are medium-K calk-alkaline with total alkalis of 7.2–7.8 wt.% and K_2O/Na_2O ratio 0.81–1.05. The rocks exhibit geochemical adakite-like features with high Sr (550–795 ppm), high Sr/Y (86–100), low Y (6.4–8) and low HREE. On the primitive-mantle normalized diagram, they show enrichment of LILE, U, Th and Pb, high depletion of HFSE and HREE. Nb, Ta, P and Ti show a minimum and Pb – a maximum. The chondrite normalized REE patterns show enrichment of LREE, negligible negative Eu anomaly (0.85–0.92) and high fractionation of HREE with $(La/Yb)_N$ in the range of 71–102, implying that the garnet was stable in their source during the partial melting. The $^{87}Sr/^{86}Sr_i$ ratio of 0.70565–0.70579 and εNd_i –2.16 to –2.44 shows intermediate values between mantle and continental crust.

Geochronology and zircon population analysis

The Visoka Elha rhyolite is dated at 32–38 Ma by K-Ar method on whole rock and mineral separates (Muszynski, 1980). We studied zircon population of one sample from the quarry near to Visoka Elha summit. The Concordia U-Pb LA-ICPMS age of the rhyolite is determined at 40.38 ± 0.48 Ma. The inherited zircons define two main clusters with Campanian (72.4 ± 0.52 Ma, 5 grains) and Maastrictian (68.16 ± 0.34 Ma, 13 grains) ages. The own autocrystic zircons are rare and are presented by corroded (rounded) fragments of oscillatory zoned short prismatic crystals and one medium prismatic grain. They are presented wholly by single zircons and are not observed as a periphery of the xenograins. The Cretaceous xenozircons of the both populations are long prismatic with well defined magmatic oscillatory zoning and some of the edges of the pyramids are rounded probably by magmatic corrosion. The εHf_i of the autocrystic magmatic zircons of Visoka Elha rhyolite are in the range of –0.33 to +0.95 which are intermediate values between mantle and continental crust. The Cretaceous xenocrysts have more mantle affinity with εHf_i in the range of +1.96 to +5.36. The Ti-in-zircon temperature of the autocrystic zircons is in the range of 700−730 °C. Most probably the autocrystic zircons are crystalised in deeper crustal levels and after that the melt has ascended fast to the surface and assimilated the Cretaceous rocks.

Geodynamic implications

During the Late Cretaceous (94–68 Ma, with gradual rejuvenation from north to south) a wide spread magmatic activity referred to north directed subduction with slab-rollback and retreat has proceeded. After that follows a magmatic gap which probably is due to the Late Alpine collisional tectonics in Stara Planina Mountain and Rhodopes. The resumption of the magmatic activity began in the Lower to Middle Eocene when granitoid intrusions are formed in the Rhodopes and volcanic/subvolcanic rocks are found in the Visoka Elha and Tran region. The continuation of the Middle Eocene magmatism to the east can be traced through the Pontides in Turkey where intermediate to acid rocks are found and to the west in Serbia – the East Serbian basanites (Cvetković et al., 2004). Adakitic features are traditionally referred to melting of the oceanic eclogite slab in subductional setting. However, numerous recent studies propose different mechanisms of generation of adakitic melts such as partial melting of mafic lower crust which is consistent with the results of basalt melting at high pressure where garnet is a stable and residual phase (Castillo, 2006 and reference therein). Adakite-like features of Middle Eocene age are recognised in the Tran plagio-rhyodacites (Peytcheva et al, 2012) and after a revision of the geochemical data can be found in the Lower to Middle Eocene granites in the Rhodopes. Such characteristics are also wide spread in the Pontides (Karsli et al., 2010 and reference therein). The most probable scenario for generation of the Eocene Visoka Elha adakite-like rhyolite is due to either slab-break off or dellamination followed by mantle underplating which caused melting of mafic lower crust in extensional setting that postdates the Late Alpine contraction (collision) tectonics and continental crust thickening.

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