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Petrology of the 31.6 Ma Central Rhodope Perelik monotonous intermediate ignimbrite eruption

Peter Marchev[1], Raya Raicheva[1], Petyo Filipov[1], Rositsa Ivanova[1], Ioannis Baziotis[2]

[1] Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 24, 1113 Sofia;
E-mails: pmarchev@geology.bas.bg; raya@geology.bas.bg; p_philipov@geology.bas.bg; rossiv@geology.bas.bg
[2] Department of Natural Resources Management & Agricultural Engineering, Agricultural Univ. of Athens, Iera Odos 75, 11855, Athens, Greece; E-mail: ibaziotis@aua.gr.

Петрология на 31.6 млн. г. Централнородопска Перелишка ерупция от „monotonous intermediate“ игнимбрити

Петър Марчев[1], Рая Райчева[1], Петьо Филипов[1], Росица Иванова[1], Янис Базиотис[2]

Abstract. Volcanism during the Priabonian–Oligocene times (35–27 Ma) in the Rhodope Massif produced large volume of shoshonitic and calcalkaline lavas and three large volume silicic ignimbrites and fallout deposits. The youngest of these ignimbrites, named here as Perelik ignimbrite (PI), consists of three areas, previously described as three separate ignimbrite units, namely Bratsigovo-Dospat, Perelik and Kotili-Vitina. The ~300 m thick ignimbrites cover an area of 700 km^2, 220 km^2 and 350 km^2, respectively. Our study demonstrates that these ignimbrites have identical ages of ~31.6 Ma and mineral and chemical compositions and are parts of a single large eruption. Based on these data, we suggest that the original areal coverage was much larger, possibly 3000 km^2, with magma volume of ~1000 km^3. These results classify the Perelik eruption as one of the largest European Oligocene supereruptions These ignimbrites have notably high phenocrystal content (40–50%) and are a relatively homogeneous chemical composition, which are characteristics features of the 'monotonous intermediate' ignimbrites. Here, we provide petrographic observations, and chemical and isotopic (Sr, Nd) analyses to explain the P-T conditions of crystallization of these ignimbrites.

Keywords: Rhodope Massif, supereruption, monotonous intermediate ignimbrite.

Introduction

Paleogene (Priabonian–Rupelian, 35–27 Ma) volcanism in the Rhodope Massif produced large volumes of high-K calcalkaline and shoshonitic intermediate and silicic magmas and subordinate basic lavas (Harkovska et al., 1989; Yanev et al., 1998). The silicic rocks comprise numerous lava flows and three major large-volume pyroclastic flows (ignimbrites) and fall out deposits, estimated at several 1000s km^3 total volume (Marchev et al., this volume). Erupted within 2 Ma, these products form an ignimbrite flare-up episode. Three of the eruptions, described in the Eastern Rhodopes as First, Second and Third acid volcanism, have been used as valuable stratigraphic markers (Ivanov, 1960; Goranov, 1960; Yanev et al., 1998). The first two eruptions are sourced from the Eastern Rhodopes, whereas the source of the third one is not well constrained.

This study focuses on the largest ignimbrite eruption in the Central Rhodopes, which consist of three large scattered remnants of strongly welded crystal-rich rhyodacites, formally known as Bratsigovo-Dospat, Perelik and Kotili-Vitina (Harkovska

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et al., 1998, and references therein). For simplicity, we refer to the composite ignimbrite as the "Perelik ignimbrite" (PI). Marchev et al. (this volume) show that the rocks from the three localities and their proximal and distal fall deposits in central, southern and southeasten Europe are coeval, clustering at ~ 31.6 Ma, and concluded that it is a supereruption. In this work, we provide petrological and geochemical data for the ignimbrite in order to constrain its P/T conditions of crystallization.

Perelik Eruption

The PI eruption products cover substantial parts of the Central Rhodope Massif. The Bratsigovo-Dospat, Perelik and Kotili-Vitina localities cover ~700 km^2, 220 km^2 and 350 km^2, respectively. Using an average thickness of ~300 m Harkovska et al. (1989) calculated their volumes at 200 km^3, 65 km^3 and 105 km^3, respectively. Owing to the thickness uncertainty and space distribution, erosion and the lack of data about the presence of caldera, the exact coverage and magma volume can only be approximately calculated. However, based on the identity of the 3 localities and the space between them, we suggest that the original space coverage of the ignimbrite was at least ~3000 km^2 and reconstructed magma volume ~1000 km^3.

Textural and petrographic variations of the ignimbrite

The ignimbrite is characterized by uniform, lava-like appearance and high crystal contents (this study; Harkovska et al., 1998 and references therein). The ignimbrite is welded to highly welded, which explains its lava-like appearance. Such large volume, high crystal-rich and compositionally constant ignimbrites of dacitic to rhyodacitic composition, have been referred by Hildreth (1981) as "monotonous intermediates". Their typical representatives are the large ignimbrites in South America (e.g., Grocke et al., 2017, and references therein) and North America, including the largest known on Earth crystal-rich ignimbrites of the Fish Canyon tuff (Bachmann et al., 2002, and references therein).

The ignimbrite shows well-expressed structural zonality. The base of the ignimbrite is represented by basal vitrophyre with numerous fiamme and lithic fragments from the Rhodope metamorphic basement rocks. The thick middle part is composed of massive devitrified ignimbrites with fiamme and pumice, and the uppermost part, where preserved, consists of glassy ignimbrites, similar to the basal vitrophyres (Katskov, 1981; Elefteriadis, 1995; Harkovska et al., 1998). Three main types of juvenile clasts are present throughout the Perelik ignimbrite: ellipsoidal (flattened) or rarely rounded coarser-grained high crystalline mush xenoliths, usually with removed crystals, and brown and white in colored pumice populations.

Sampling and analytical methods

The ignimbrite has been sampled from outcrops in the Bratsigovo-Dospat, Smolian and Vitina-Poliana areas. Whole-rock major elements were measured using ICP-AES method in Akvatest lab, Sofia. Major element composition of the minerals and matrix glass was analysed using microprobes in the University of Florence, University of Belgrade and the Agricultural University of Athens. Strontium and Nd isotopes have been measured in two laboratories: at ETH Zurich using a Thermo Scientific Triton TIMS and Nu Instruments Nu Plasma II MC-ICP-MS and at the University of Geneva on a multicollector Finningan MAT 262 thermal ionization mass spectrometer in semidynamic mode. Three analyses are taken from Harkovska et al. (1998).

Petrology and chemistry

The silica content of the whole-rock compositions varies between 68.0–75 wt % but most analyses cluster between 70 and 73 wt % and the rocks can be classified as low-silica rhyolites. The K_2O varies between 4.7–5.5 wt %, the sum of alkalies between 8.0–8.4 wt %. The composition of the interstitial glass is more silica rich SiO_2 in the range 78.96–79.11 wt %, and K_2O 5.25–5.5 wt %.

The PI is characterized by a uniform mineral assemblage. The rock is strongly porphyritic with a total volume of the phenocrysts ~40–50%. Plagioclase is 20–30%, with prevailing core to rim variations in the range An_{49} to An_{20} with single crystals showing calcic cores (An_{84-77}); sanidine 20–30%, with more potassic cores (Or 75–76) and outer zones Or 67.5, quartz 30–40%, biotite 5–10% with Mg# varying from 60–58 in the cores to 63.4–63.0. Most amphiboles are low Al (7.3–6.29 wt %) Mg hornblende) with Mg# range from 66 to 62, with single high-Al (11 wt %) Mg hastingsite. Clinopyroxene is rare with Mg# 80.8–72.8. The most abundant accessory minerals are apatite, allanite, titanite and opaques (magnetite and ilmenite).

Mineral equilibria and physico-chemical conditions of crystallization

Based on the amphibole geobarometer of Ridolfi et al. (2010), the low Mg hornblende in the PI yields pressures between 119 and 83 MPa with one high-Al Mg hastingsite giving a higher pressure of 290 MPa. These values correspond to a range of crystallization depths ~4–2.5 km and ~6 km, respectively, in continental conditions. The thermometer of Ridolfi (2010) gave temperature of crystallization for the Mg hornblende 869–796 °C and slightly higher (~905 °C) for the Mg-hastingsite. The two-feldspar geothermometer of Putirka (2008) yields lower temperatures, ranging from 800–720 °C using the equations 27a and 27b. Based on the amphibole hygrometer of Ridolfi et al. (2010), the H_2O contents in PI varies between 5.4 and 3.7 wt %. The total fO_2 is estimated in the range ΔNNO +1.8 – +3.6.

Isotopic composition

The initials Sr and Nd isotopic compositions for the Bratsigovo-Dospat samples (0.70883–0.7094; Nd –4.5 –6.5) and Perelik samples (Sr – 0.70891–0.70974; εNd –5.3) display comparatively narrow ranges. Sr isotope ratios rom an older paper for Kotili-Vitina are slightly lower (0.7077–0.70852; Elefteriadis et al., 1995).

Preliminary discussion on the origin of the ignimbrite

The genesis of the ignimbrite will be discussed in details elsewhere. Here we point out only some of their most important geochemical characteristics, which can be used for preliminary conclusions. The high-SiO_2, K_2O/Na_2O, low CaO, MgO, TiO_2 of the PI indicate a relatively evolved magma, but they are not diagnostic of any specific mechanism of magma genesis. More informative for the origin of the magmas are their Sr and Nd isotopes. The less radiogenic $^{87}Sr/^{86}Sr$ (0.70883–0.70974) and more radiogenic Nd (–4.5 –6.5) composition of the ignimbrites compared to the local Rhodope basement ratios (Sr_i 0.707–0.730; εNd –4.9 –11; Marchev et al., 2022) exclude their pure crustal melting and is more consistent with the fractionation of crustally contaminated more mafic magmas.

Conclusions and questions

The age (31.6 Ma), petrological and isotopic study demonstrates that the separate localities of the ignimbrite are coeval and the youngest among the large Rhodope eruptions. Their high (40–50%) phenocryst content, mineral and chemical homogeneity, and the large volume are characteristics of the 'monotonous intermediate' ignimbrites, whose origin and driving eruptions processes are the subject of animated discussion. Comparison with the distal tuff deposits of the eruption (Marchev et al., this volume) shows that it is the likely source of the Third acid volcanism. An unresolved question for the PI is the lack of caldera related to the eruption. Normally, such large volume eruptions require sufficiently large calderas as a source. However, the only evidence for the presence of a caldera in the PI has been proposed in the SW part of Bratsigovo-Dospat area on the basis of gravity data (Katskov, 1987 and references therein). The size of this caldera, however, is too small for such a large eruption. Katskov (1981) and Kackov (1987) suggests that the ignimbrites derived from wide 120 and 160–180° open fractures (faults) and single volcanic centers located on them, which is supported by numerous ignimbrite-like dykes in the Perelik and Bratsigovo-Dospat ignimbrites. Such fed-fractured ignimbrites have also been described by Aguirre-Díaz and Labarthe-Hernández (2003) and Sieck et al. (2021) in Sierra Madre, Mexico. Future studies on the ignimbrite are necessary to clarify the unresolved question of their origin.

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References

Aguirre-Díaz, G. J., G. Labarthe-Hernández. 2003. Fissure ignimbrites: fissure-source origin for voluminous ignimbrites of the Sierra Madre Occidental and its relationship with Basin and Range faulting. – *Geology*, 31, 9, 773–776; https://doi.org/10.1130/G19665.1.

Bachmann, O., M. A. Dungan, P. W. Lipman. 2002. The Fish Canyon magma body, San Juan volcanic field, Colorado: rejuvenation and eruption of an upper-crustal batholith. – *J. Petrol.*, 43, 8, 1469–1503; https://doi.org/10.1093/Petrology/43.8.1469.

Elefteriadis, G. 1995. Petrogenesis of the Oligocene volcanics from the Central Rhodope massif (N. Greece). – *European J. Mineralogy*, *7*, 5, 1169–1182; https://doi.org/10.1127/ejm/7/5/1169.

Goranov, A. 1960. Lithology of the Paleogene deposits in a part of the Eastern Rhodopes. – *Trudove varhu Geologiata na Bulgaria, Seria Geohimia y Polezni Izkopaemi*, 1, 259–310 (in Bulgarian with English abstract).

Grocke, S., S. L. de Silva, P. J. Wallace, E. Cottrell, A. Schmitt. 2017. Catastrophic caldera-forming (CCF) monotonous silicic magma reservoirs: Constraints from volatiles in melt inclusions from the 3·49 Ma Tara Supereruption, Guacha II caldera, SW Bolivia. – *J. Petrol.*, *58*, 11, 2115–2142; https://doi.org/10.1093/petrology/egy003.

Harkovska A., P. Marchev, Ph. Machev, Z. Pecskay. 1998. Paleogene magmatism in the Central Rhodope area, Bulgaria — a review and new data. – *Acta Vulcanol.*, *10*, 199–216.

Harkovska, A., Y. Yanev, P. Marchev. 1989. General features of the Paleogene orogenic magmatism in Bulgaria. – *Geologica Balc.*, *19*, 1, 37–72.

Hildreth, W. 1981. Gradients in silicic magma chambers: Implications for lithospheric magmatism. – *J. Geophys. Res, Solid Earth*, *86*, B11, 10153–10192; https://doi.org/10.1029/JB086iB11p10153.

Ivanov, R. 1960. Magmatism in the East Rhodope Paleogene depression. Part I. *Travaux sur la Géologie de Bulgarie.*

Série de Géochimie et des Gîtes Métallifères et Non-Métallifères, 1, 311–387 (in Bulgarian with German abstract).

Kackov, N. 1987. Reconstruction des Paleovulkanismus im Bracigovo-Dospater Vulkanitmassiv (Bulgarien). – *Zeitschr. Angewandte Geol.*, 33, 175–179.

Katskov, N. 1981. Bratzigovo-Dospat volcanic massif. – In*: Paleogene Volcanism in Mesta Graben, Central and Eastern Rhodopes*, 33–40.

Marchev, P., R. Raicheva, S. Georgiev, I. P. Savov, D. Jelev. 2022. Formation of ultrapotassic magma via crustal contamination and hybridization of mafic magma: an example from the Stomanovo monzonite, Central Rhodope Massif, Bulgaria. – *Geol. Mag.*, *159*, 1, 81–96; https://doi.org/10.1017/S0016756821000868.

Marchev, P., R. Raicheva, P. Filipov, B. Jicha, R. Spikings, R. Ivanova, O. Bachmann, M. Guillong, A. Okay. 2023. $^{40}Ar/^{39}Ar$ and U-Pb age correlations of the large Rupelian Rhodope Massif eruptions with airfall tuffs in SE, S and Central Europe. – *Rev. Bulg. Geol. Soc.*, *84*, 3 (Geosciences 2023), this volume.

Putirka, K. D. 2008. Thermometers and barometers for volcanic systems. – *Rev. Mineral. Geochem.*, *69*, 1, 61–120; https://doi.org/10.2138/rmg.2008.69.3.

Ridolfi, F., A. Renzulli, M. Puerini. 2010. Stability and chemical equilibrium of amphibole in calc-alkaline magmas: an overview, new thermobarometric formulations and application to subduction-related volcanoes. – *Contrib. Mineral. Petrol.*, *160*, 45–66; https://doi.org/10.1007/s00410-009-0465-7.

Sieck, P., P. Dávila-Harris, R. A. López-Doncel, J. Almaguer, A. Aguillón-Robles, K. Wemmer, R. Guevara. 2021. Voluminous Paleogene volcanism in the southern Mesa Central, Mexico: Unravelling the fissure-fed origin of rhyolitic ignimbrites of the Villa Garcia-Loreto Volcanic Complex. – *J. Volcanol. Geotherm. Res.*, *415*, 107252; https://doi.org/10.1016/j.jvolgeores.2021.107252.

Yanev, Y., F. Innocenti, P. Manetti, G. Serri. 1998. Upper Eocene-Oligocene collision-related volcanism in eastern Rhodopes (Bulgaria) – Western Thrace (Greece): Petrogenetic Affinity and Geodynamic Significance. – *Acta Vulcanol.*, *10*, 2, 279–292.