Sources and evolution of Late Cretaceous magmatism in Eastern Srednogorie, Bulgaria: constraints from petrology, isotope geochemistry and geochronology

Източници и еволюция на къснокредния магматизъм в Източното Средногорие, България: петроложки, изотопно-геохимични и геохроноложки данни

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Eastern Srednogorie is the easternmost part of the Apuseni-Banat-Timok-Srednogorie (ABTS) magmatic belt in Southeastern Europe, which provides a unique opportunity to study processes of primitive magma formation and evolution in arc environments. Located between the richly mineralized Central Srednogorie zone to the west and the Black Sea to the east, this zone represents the possible link of the ABTS belt with the Pontide magmatic belt in Turkey. The knowledge for the time evolution of Eastern Srednogorie zone is therefore crucial for the understanding of the geodynamics of the area.

The Late Cretaceous magmatism in Eastern Srednogorie is abundant and extremely diverse in composition covering a wide range from ultramafic volcanics to granites. In contrast to other parts of the belt, relatively mafic lavas predominate here. Three magmatic regions are distinguished within Eastern Srednogorie from south to north: Strandzha, Yambol-Burgas and East Balkan. Systematic differences exist between these magmatic regions, namely the increased alkalinity of samples from the Yambol-Burgas region in the middle. Despite of the large volume and intriguing composition of the magmatism, Eastern Srednogorie has remained relatively understudied compared to adjacent parts of the ABTS belt.

In order to constrain the sources and the evolution of the magmatism, we conducted a large number of whole-rock major and trace element analyses of volcanic and intrusive rocks from this zone, combined with Sr and Pb isotope analyses of key samples. All rocks display clear subduction like signature of their trace elements patterns, particularly the enrichment in large ion lithophile elements and light rare earth elements relative to high field strength elements. A distinct primitive nepheline-normative ankaramite magma type is recognized among the mafic volcanic rocks from Yambol-Burgas region. Lower crustal clinopyroxene and amphibole cumulates carried to the surface as xenoliths in a mafic dike are a possible source for the ankaramite formation.

Thermodynamic modeling of the melting process suggests that low degrees of batch melting of a clinopyroxene rich, amphibole containing source similar to the cumulates, at 1 GPa, temperatures of 1240–1300° C, oxidized conditions and water content of 0.2 wt% reproduces accurately most of the observed major and trace element characteristics of the studied ankaramites. Underplating of lherzolite melts at the crust/mantle boundary in an extensional environment as a response of slab-roll back provides the necessary heat to melt lower crustal cumulates and explains part of the geochemical peculiarities of the magmatism. Fractional crystallization of mainly clinopyroxene, plus olivine and Fe-Ti oxides from the ankaramitic magma in deep (8 kb) magma chamber produced most of the observed range of basalts and basaltic andesites in Eastern Srednogorie. The more evolved andesitic varieties were probably formed by crystallization at lower temperatures in lower pressure magma chambers. Whole rock Sr and Pb isotopes indicate a larger degree of assimilation of basement rocks by the Late Cretaceous magmas in Strandzha compared to Yambol-Burgas region.

Detailed high-precision zircon U-Pb geochronology conducted in this study constrains the time evolution of the Cretaceous magmatism and also provides crucial information for age of the basement rocks and their assimilation from the Late Cretaceous magmas. The first evidence for the Late Cretaceous magmatic activity comes from the northernmost region (East Balkan), where shallow intrusive and volcanic rocks were formed at ca. 90 Ma, based on stratigraphic relations. With time, the magmatism shifted to the south and several intrusions crystallized in Strandzha region at ca. 86 Ma. Evidence for these 90 and the 86 Ma events are not detected in the central Yambol-Burgas region. The abundant magmatism in this region commenced at ca. 81 Ma and lasted till ca. 78 Ma, with some indications for slightly younger ages. This peak of the magmatic activity partly overlaps with the formation of numerous intrusions in Strandzha region to the south between 81 and 78 Ma.

The age of several granitic rocks from the basement of Eastern Srednogorie is determined as Permian/Carboniferous (~ 275–300 Ma). The significant presence of inherited zircon grains with such ages in the Late Cretaceous rocks from East Balkan and Strandzha regions implies that similar rocks were assimilated by the Cretaceous magmas. In contrast, the rocks from the intermediate Yambol-Burgas region record mostly Ordovician (~ 460 Ma) or older inherited ages, suggesting a different basement between these regions and/or different depths of magma formation and storage.

The magmatic ages and the geochemical data are compared to the adjacent Central Srednogorie zone, and integrated into a model for the geodynamic evolution of Eastern Srednogorie. Our model involves a southward retreating slab and related arc magmatism which formed the ~ 90 Ma calc-alkaline to high-K shallow intrusions and volcanics in the north (East Balkan) and large 87–78 Ma old mid-crustal tholeiitic, calc-alkaline and high-K intrusions in the south (Strandzha). Subduction roll-back, combined with processes of widening of the Black Sea basin led to the formation of the Yambol-Burgas intra-arc rift basin which separated East Balkan from Strandzha region. The crustal thinning led to decompression and increased heat flow, which facilitated large–scale melting of lower crustal amphibole containing wherlites to produce primitive ankaramites in Yambol-Burgas region. Mixing of the ankaramitic melts with subduction-derived magmas from the mantle wedge, followed by subsequent fractional crystallization and assimilation of basement material produced the observed range of the magmatism. The main phase of the intra-arc rift magmatism was from 81 till 78 Ma. The following compression led to crustal shortening, deformation and northward thrusting, responsible for the present-day structure of Eastern Srednogorie zone.