AN ACROSS-ARC PETROLOGICAL TRANSECT TROUGH THE CENTRAL SREDNOGORIE LATE-CRETACEOUS MAGMATIC CENTERS IN BULGARIA

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Introduction

Magmatic rocks of Late Cretaceous age from the Central Srednogorie in Bulgaria reveal marked variations in their geochemistry, which do not correspond to the classical across-arc regularities. The present study is focused on the common features of the magma evolution paths of several ore-magmatic centers: Elatsite, Chelopech, Medet, Assarel, Elshitsa and Capitan-Dimitrievo. We made an attempt to put together all available up-to-now published, reported and new-obtained our data, devoted to this magmatism, because we feel that, in spite of the many publications regarding the geology, tectonics and the ore mineralizations, this region is still lacking up-to-date generalizations of its petrology and geochemistry. Comparing the petrographical diversity, the rock-forming mineralogy, geochemical variations and magma evolution paths, we will demonstrate a sort of a petrological transect.

Petrology

The plutonic and volcanic rocks contain mainly plagioclase, clinopyroxene, amphibole, biotite, quartz and orthoclase, all of them analyzed by micro-probes. Sharp increasing of the anorthite composition in some of the intermediate zones is occasionally a particular feature of the plagioclases, as well as the occurrence of reverse zoning together with the normal one. In most of the samples the amphibole is the dominant mafic phase. Its zoning is not systematic, but the reverse variation is more common than the normal one. The vast majority of the clinopyroxenes record crystallization from a liquid comparable to the gabbro magma, but in some pyroxene grains from Capitan-Dimitrievo center there are small crystals, bearing traces of multiple replenishment events in the magma chamber. The existence of abundant mafic enclaves with chilled margins, cumulative packets of mafic minerals together with the occurrence of minerals in disequilibria with the evolved magma support magma-mingling and magma-mixing processes leading to the formation of many transitional petrographic varieties.

Pressure calculations (Johnson and Rutherford, 1989) cluster in two levels of crystallization, corresponding to depths of approximately 10-12 km and 15-20 km. The deepest crystallization conditions are recorded for the mafic enclaves, ore-related dykes in Elatsite, basaltic andesites in Assarel and for the mafic dykes in Capitan-Dimitrievo.

Geochemistry

The geochemistry is based mainly on the large recently presented (Stoykov et al., 2002; von Quadt et al., 2002; Kamenov et al., 2003; Zartova et al., 2004) or unpublished new data sets compiled by the authors.

On the TAS diagrammes the igneous rocks of the individual magmatic centers plot on continuous trends, usually in saturated suite and in some of the centers also in oversaturated one. The peculiar evolution from intermediate to more basic stages is a common characteristic for most of the centers, but it is complicated by fractional crystallization and mixing between more primitive and evolved magmas. Typical calc-alkaline serial trend is established only in the middle of the transect (Elshitsa pluton mainly and partly in Assarel center). Going to the north (Chelopech and Elatsite centers) and to the south (Capitan-Dimitrievo pluton) high-K calc-alkaline and even shoshonitic serial trends prevail. The bilateral decreasing of the general alkalinity of the magmas directed to the central part of the transect is a remarkable compositional new-revealed geochemical feature.

The chondrite-normalized REE-patterns are generally very similar, suggesting common genetic relationship. All patterns resemble closely those of the typical island-arc magmas. In contrast to the data published before, most of the patterns do not show negative Eu-anomalies.

The multi-element MORB-normalized plots are also typical for the subduction-related magmas. The only case of a distinct Sc-enrichment relative to the adjacent elements and relative to MORB was found in Elshitsa gabbro. A specific geochemical peculiarity of the Elshitsa gabbro is also the lack of Zr-anomalies, in respect to Hf and the weakest Ti-anomalies in comparison with the patterns from the other centers. One of the strongest Sr-depletions for the rocks in the transect is again noted for Elshitsa granites.

Important chemical argument for magma-mixing, in addition to the petrographical and mineralogical features is its ability to explain some trace element concentrations in excess to those predicted by crystal fractionation. Binary mixing behaviour is internally consistent with the REE and trace element characteristics of the basic and acid rock varieties within the transect. Magma-mixing is especially well expressed chemically in Elshitsa (Ivanov et al., 2001) and Capitan-Dimitrievo (Kamenov et al., 2003) centers. It is also clear from the REE- and MORB-normalized patterns that mixing only is not viable in explaining the geochemical variations among the hybrid varieties. Some of the HREE, MREE, and HFSE owe their distribution to some combination between magma-mixing and fractional crystallization (MFC process).

Sr- , Nd- , Pb- and Hf isotope tracing on whole rocks and

minerals suggest a mixed crust-mantle origin of the parental magmas. The ε-$Hf_{T\text{-}90}$ of the concordant zircons (+0.2 to –3.2) reveals mantle source of the magmas, mixed in different degrees with crustal materials. The crustal contribution is indicated by moderately radiogenic Pb. The reducing of the radiogenic components to younger centers southward is a result, probably of the reducing of the crustal material, assimilated in the magmas.

MORB-normalized extended patterns for the most primitive samples have been constructed to distinguish between different classes of compatible and noncompatible elements, using the method of Pearce and Parkinson (1993).

Discussion and conclusions

The main conclusion out of these patterns is that contrary to the usual geochemical across-arc zonality in the island arcs, a decrease of the incompatibility of the slab-derived components directed to the central part of the transect (from Assarel and Capitan-Dimitrievo to Elshitsa) is established. In contrast, the compatibility of the moderate compatible elements and the very high compatible Fe-related elements (Sc, Mg, Cr, Ni, etc.) also decreases in the same direction. A fertile MORB mantle source (FMM) is deduced from the geochemistry data for the whole transect. Our data support the idea that the magma source contained hornblende, phlogopite, apatite, rutile and spinel to the usual lherzolitic minerals in the mantle. All FMM-normalizations are concordant with derivation of the magmas from a metasomatized mantle.

Important point is that the geochemistry of the samples from the transect agrees with low degree melting for the samples from Capitan-Dimitrievo and Assarel, but directs to clearly higher melting degree for Elshitsa center samples. The deduced conditional degrees of melting are as follows: Capitan-Dimitrievo ~ 5-15 %, Assarel ~ 15-20 % and Elshitsa ~ 20-25 %. We assume that the strike-slip Iskar-Yavoritza shear zone (Ivanov et al., 2001) known to pass just in the middle part of the transect (around Elshitsa center) stimulated this higher degree of partial melting of the source there. Having in mind that not more than 10 % of this melting is due to fluid addition to the source, the rest of this estimated value is caused by decompression. Obviously, this zone is one of the reasons for the geochemical peculiarities there – higher melting degree, unique calc-alkaline character, extensive evidences of magma-mingling and magma-mixing, specific geochemical features.

The applied tectonic discriminations supplement additionally the conclusions from the geochemistry for continental-margin subduction-related setting. Most of the samples generally plot in the continental-arc potassic fields, although there is some overlapping with ocean-floor fields (late oceanic-arc) for some of the basic rocks from Elshitsa and Capitan-Dimitrievo centers. The abundances of some HFSE classify the samples also mainly in the subduction-related settings.

The preservation of volcanic rocks in the northern and central parts of the transect is consistent with the interpretation that progressively deeper crustal levels are preserved from north to the south in the arc system of the area.

The recently performed high-precision U-Pb single zircon dating in the area of the transect evidenced that the magmatic activity started in the north at 92.1 Ma and finished in the south at 78.7 Ma. This temporal southward migration of the magmatism is just opposite to the typical across-arc zonality. We suggest that it is related to a slab roll-back process.

The simplified model in Fig. 1 highlights some of our new-obtained data and their explanation. Changes in the geometry during the subduction (slab steepening) could produce the described temporal regularities. Because of the fact that the slab in Late Cretaceous time was still hot enough, only stretching in the middle part of the transect is perceived. The logical implication out of this inference is that a continental rift genesis and therefore a slab-window of the magmas in the transect is not supported by the new geochemical data presented here.

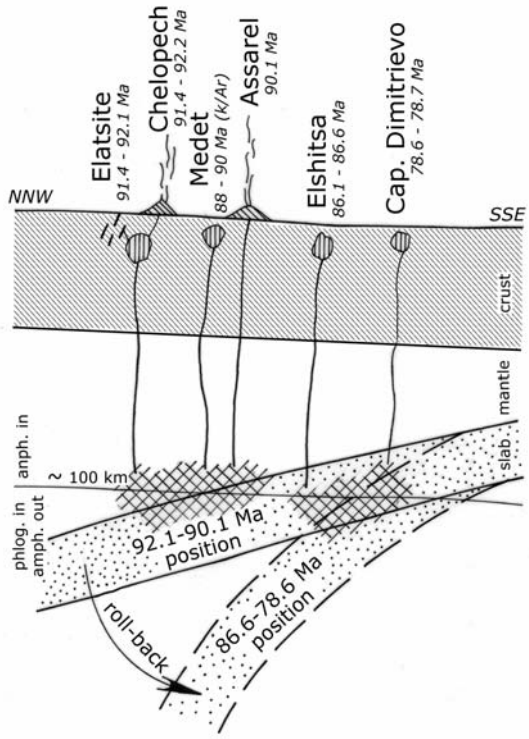

Fig. 1. Cartoon presenting the slab roll-back model for the studied transect of the Central Srednogorie.

References

Ivanov J, B. Henry, D. Dimov, N. Georgiev, D. Jordanova, N. Jordanova. 2001. New model for Upper Cretaceous magma emplacement in the southwestern parts of Central Srednogorie – petrostructural and AMS data. - *Romanian J Mineral Deposits* 79 ABCD-GEODE 2001 Romania, Abstract volume: 60-61

Kamenov B. K., A. von Quadt I. Peytcheva. 2003. Capitan-Dimitrievo pluton in Central Srednogorie, Bulgaria: Mineral chemistry, geochemistry and isotope evidence for magma-mixing origin. - *Geochemistry, Mineralogy and Petrology*, Sofia 40:21-53

Pearce J. A., I. J. Parkinson. 1993. Trace element models for mantle melting: application to volcanic arc petrogenesis. In: Prichard HM, T. Alabaster, N. B. W. Harrison, C.R. Neary (eds) *Magmatic Processes and Plate tectonics.* Geological Society of London, Special Publication, 76, 373-403

Stoykov S, Y. Yanev, R. Moritz, D. Fontignie. 2003. Petrology, Sr- and Nd- isotope characteristic of the Late Cretacepous magmatic rocks from south-eastern Etropole Stara planina, Srednogorie magmatic zone. - *Jubillee collection "50 years Mining and Geologcial University, Sofia"*: 161-166

Von Quadt A, I. Peytcheva, B. Kamenov, L. Fanger, C.A. Heinrich, M. Frank. 2002. The Elatsite porphyry copper deposit in the Panagyurishte ore district, Srednogorie zone, Bulgaria: U-Pb zircon geochronology and isotope-geochemical investigations of magmatism and ore genesis. In: D.J. Blundell, F. Neubauer, A. von Quadt (eds): *The Timing and Location of Major Ore Deposits in an Evolving Orogen.* Geological Society of London Special Publications 204:119-135

Zartova A, R. Nedialkov, R. Moritz. 2004. Petrology of the magmatism of the Assarel porphyry copper deposit (in this volume)