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PETROCHEMICAL FEATURES OF THE LATE ALPINE LATE EXTENSIONAL MAGMATISM IN THE EASTERN RHODOPES

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ABSTRACT. During the Paleogene the Rhodope massif was affected by extensional processes that produced a number of metamorphic core complexes (domes). The East Rhodope depression formed between the Central Rhodope dome and Harmanli block. It was an area of intensive magmatism mainly of volcanic facies. Subvolcanic bodies and dikes intruded also the metamorphic core complexes outside the depression. According to K_2O content, the magmatic rocks of the East Rhodope depression belong to the high-potassic calc-alkaline and shoshonitic series. Single analyses of some magmatic complexes plot also in the field of the calc-alkaline and potassic-subalkaline series. Rocks of the shoshonitic series dominate along the peripheral parts of the Rhodope massif, in the Northeastern Rhodope and Zlatoustovo depressions. In Momchilgrad depression, located between the Central Rhodope and Byala Reka domes, rocks of the high-potassic – calc-alkaline series prevail.
Key words: magmatism, magmatic groups and complexes, petrochemistry, metallogenic specialization.

ПЕТРОХИМИЧНИ ОСОБЕНОСТИ НА КЪСНОАЛПИЙСКИЯ МАГМАТИЗЪМ В ИЗТОЧНИТЕ РОДОПИ

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РЕЗЮМЕ. Родопският масив през палеогена е подложен на екстензия. В резултат се формират редица ядрени комплекси (куполи). Между Централнородопския и Белоречкия купол и Хармалийския блок се формира Източнородопското понижение. То е арена на интензивен магматизъм, проявен преимуществено във вулкански фациес. Субвулкански тела и дайки са внедрени и извън понижението в метаморфните ядрени комплекси. Според съдържанието на K_2O магматичните скали в Източнородопското понижение се отнасят към висококалиево-калциевоалкалната и шошонотовата серия. Отделни анализи на някои магмени комплекси попадат в полетата на калциевоалкалната и калиевосубалкалната серия. По периферията на Родопския масив, в Североизточнородопската и Златоустовската депресия, преобладават скалите от шошонитовата серия. В Момчилградската депресия, разположена между Централнородопския и Белоречкия купол на Родопския масив, доминират скалите от висококалиево-калциевоалкалната серия.

Geological setting

After the end of the Late Cretaceous, the Rhodope massif was affected by extension and as a result metamorphic core complexes formed (Иванов, 2000). In the initial stages of extension (end of Late Cretaceous – Eocene), granitoid intrusions were emplaced. In the interval Paleocene-Oligocene, several depressions formed between the core complexes (domes) or around their periphery. The depressions were areas of intensive late extensional magmatism of dominantly volcanic facies (Eocene – Oligocene).

The Momchilgrad depression is located in the Eastern Rhodopes, between the Central Rhodope, Byla Reka and Kessebir core complexes. The respective magmatic rocks are assigned to the Dambala magmatic group further subdivided into Putocharka intermediate subgroup, Zdravets silicic subgroup and Pcheloyad dike complex (Georgiev, Miovanov, 2003a).

The Northeastern Rhodope depression is situated between the Central Rhodope core complex and Harmanly block. The magmatic rocks of the depression are subdivided into Sarnitsa intermediate group and Chamdere silisic group with Tri mogili dike complex (Georgiev, Milovanov, 2004).

The Zlatoustovo depression extends between Byala Reka core complex and Harmanli block. The respective magmatic rocks are subdivided into Madzharovo latite complex and Zlatoustovo silicic group (Fig. 1).

The three depressions join in the area of Kardzhali and together form the Eastern Rhodope Paleogene depression (Иванов, 1960). The magmatic rocks in the area of Kardzhaly are assigned to the Kardzhali silicic group.

The magmatic rocks in the metamorphic framework of the Eastern Rhodope Paleogene depression, which are emplaced in Byala reka and Kessebir core complexes, are defined as Byala Reka magmatic group. It comprises subvolcanic bodies and dikes of rhyolites and basalts.

The distribution of the magmatic groups is spatially limited within definite geographic regions. The magmatic rocks are products of a relatively independent evolution of different peripheral magma chambers of intermediate and acid composition and have a common mantle origin.

State of the problem

Data on the petrochemical composition of the magmatic rocks in the Eastern Rhodopes have been published in many papers

(Ivanov, 1963, 1978; Marchev et al., 1985; Yanev et al., 1989). In most cases these are single analyses from limited regions or from specific varieties. A large part of the analyses has been summarized by Yanev et al. (1998). According to these authors the volcanism is of orogenic affinity and covers the petrochemical range of the CA, HKCA, SH and HKTR (UK) series. They demonstrate that the K_2O content increases in the intermediate volcanics of phase IIA (= II-nd intermediate volcanism of Иванов, 1960) and decreases from north (Borovitsa volcanic region) to south (Momchilgrad-Arda volcanic region). This is interpreted as a result of the increasing depth of primary magma generation in northern direction – in the zone of lithospheric delamination inheriting a subduction zone (Yanev et al., 1995; 1998).

Data

As a result of the new 1:25 000 geological mapping of the Eastern Rhodopes during the last decade, many new data about the distribution of the magmatic rocks and their petrochemistry were collected (unpublished reports by Нафтали et al., 1994; Георгиев et al., 1995, 1996, 1997, 1998, 1999, National Geological Archive).

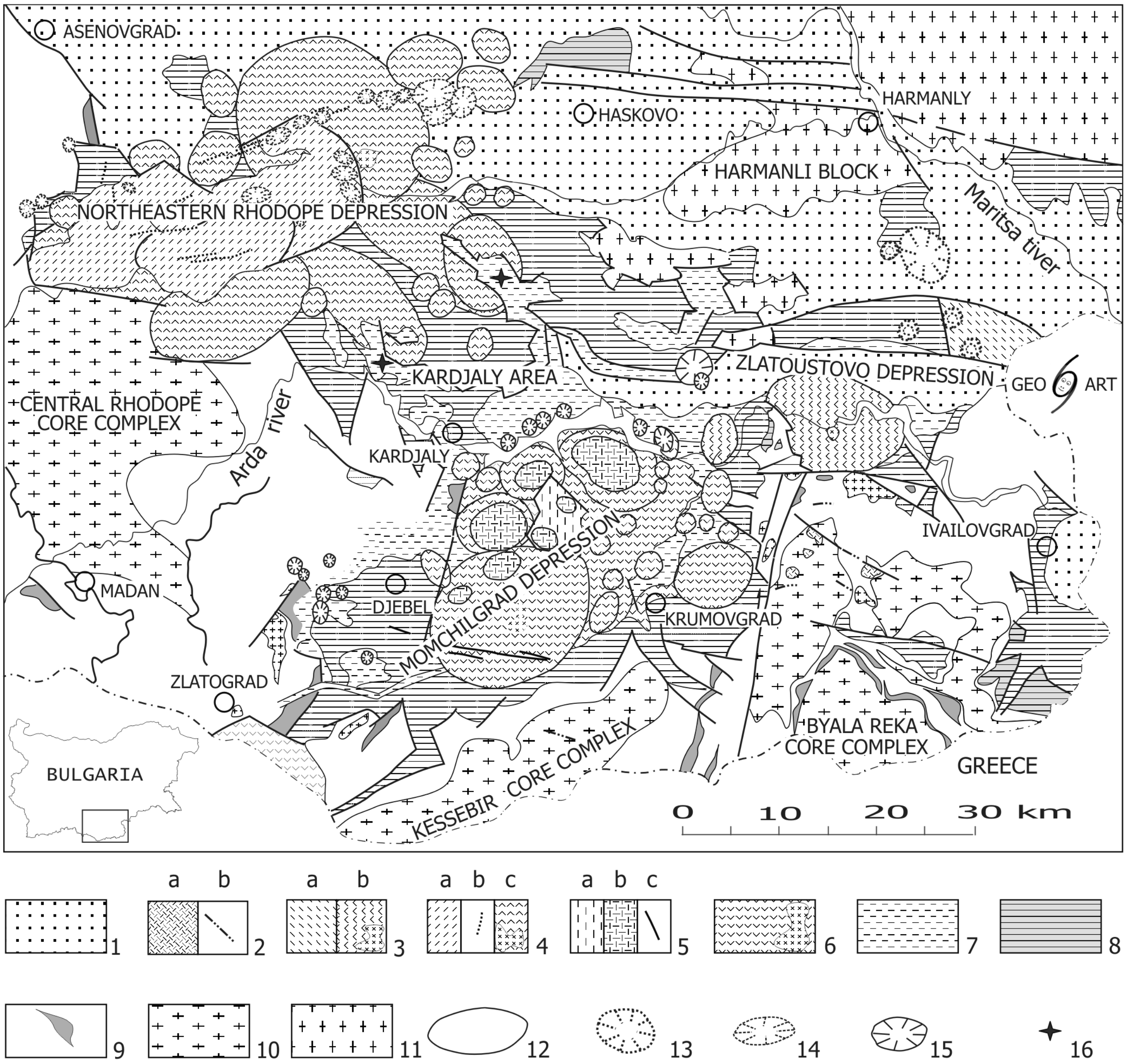

Fig. 1. Geological map of the Eastern Rhodopes. 1– Neogene-Quaternary deposits; 2– rhyolite bodies (a) and dikes (b) of Byala reka group; 3– tuffs of the Zlatoustovo acid group (a) and Madzharovo intermediate group with monzonitoid intrusion (b); 4– tuffs of the Chamdere acid group (a), dikes of Tri mogili complex (b) and Sarnitsa acid group with monzonitoid intrusion (c); 5– tuffs (a) and effusive rocks (b) of the Zdravets acid subgroup and dikes of the Pcheloyad complex (c); 6- Putocharka intermediate subgroup with monzonitoid intrusion; 7– tuffs of the Kardzhali acid group; 8– Mesozoic greenschist rocks; 9– "variegated" metamorphic complex; 10– migmatic metamorphic complex; 11– Harmanli block metamorphic rocks; 12– volcanic cones; 13-15– extrusions of Zlatoustovo (13), Chamdere (14) and Kardzhali (15) acid groups; 16– explosive vent of the Kardzhali acid group

The present work is based on 216 new silicate analyses from the geological mapping that include all varieties of the late extensional Paleogene magmatic rocks. The silicate analyses were done by Eurotest Ltd. The analyses from Momchilgrad depression have been published by Georgiev, Milovanov (2003b). The rest will be published in a discussion on the petrochemistry of magmatic groups in selected regions. Here we discuss the general petrochemical trends in the Eastern Rhodopes.

The petrochemical diagrams in this paper are based entirely on analyses of the authors. Correlation of other published analyses with our subdivision of magmatic rocks is not always possible. Furthermore we think that construction of diagrams based on data from different laboratories seems to be not quite correct.

Results

The individual regions in the discussed area exhibit certain differences in the chemical composition of the magmatic rocks both wit respect to SiO_2 and the other oxides.

SiO_2 content

The largest range in the SiO_2 variation is established in Byala reka region (dome) – 48,0 – 74,4%. There, however, only the end members are present – basalts and rhyolites.

Among the depressions, the largest SiO_2 difference is recorded in the Northeastern Rhodope depression – 48,0-76,8 %. In Momchilgrad depression, it varies from 53,5 to 75,0 % and in Zlatoustovo depression – from 55,0 to 80,0 %. The smallest interval in the SiO_2 distribution is noted in Kardzhali region (Kardzhali silicic group) - 62,1- 79,9 % (Table 1).

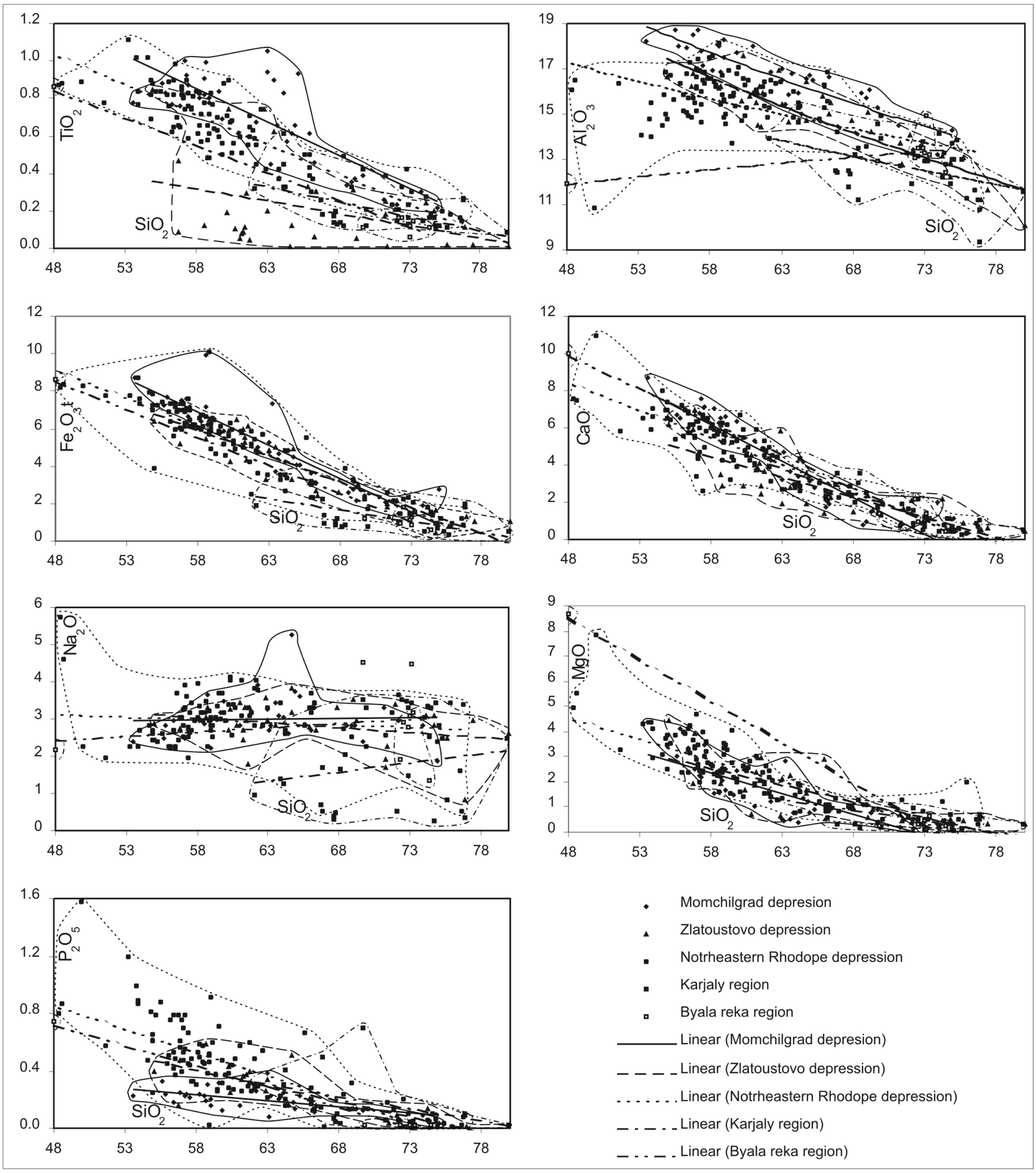

Fig. 2. Variation diagrams of the main oxides

Content of other major oxides

The distribution of TiO_2, Al_2O_3, Fe_2O_3, CaO, MgO and P_2O_5 shows similar features (Fig. 2). All of these oxides decrease with increasing SiO_2 content. However, there are some specific trends in individual regions and magmatic groups.

The Zlatoustovo depression (mainly the Madzharovo latite complex), and the Kardzhali and Byala reka regions are characterized by lower TiO_2 content.

All regions and magmatic groups show relatively close values and uniform decrease in the Al_2O_3 content with increasing SiO_2. The Byala reka region (group) and Sarnitza intermediate group are an exception - Al_2O_3 slightly increases with increasing SiO_2.

The distribution of CaO, MgO and P_2O_5 is monotonous in all regions and magmatic groups, their content uniformly decreasing with increasing SiO_2. Only the basic varieties from Byala reka group differ with higher MgO content, and the intermediate Sarnitsa group – with higher values of P_2O_5.

Na_2O exhibits an “inert” behavior with contents varying around 3%. Only the Kardzhali region (group) is characterized by lower contents and Na_2O increases with increasing SiO_2.

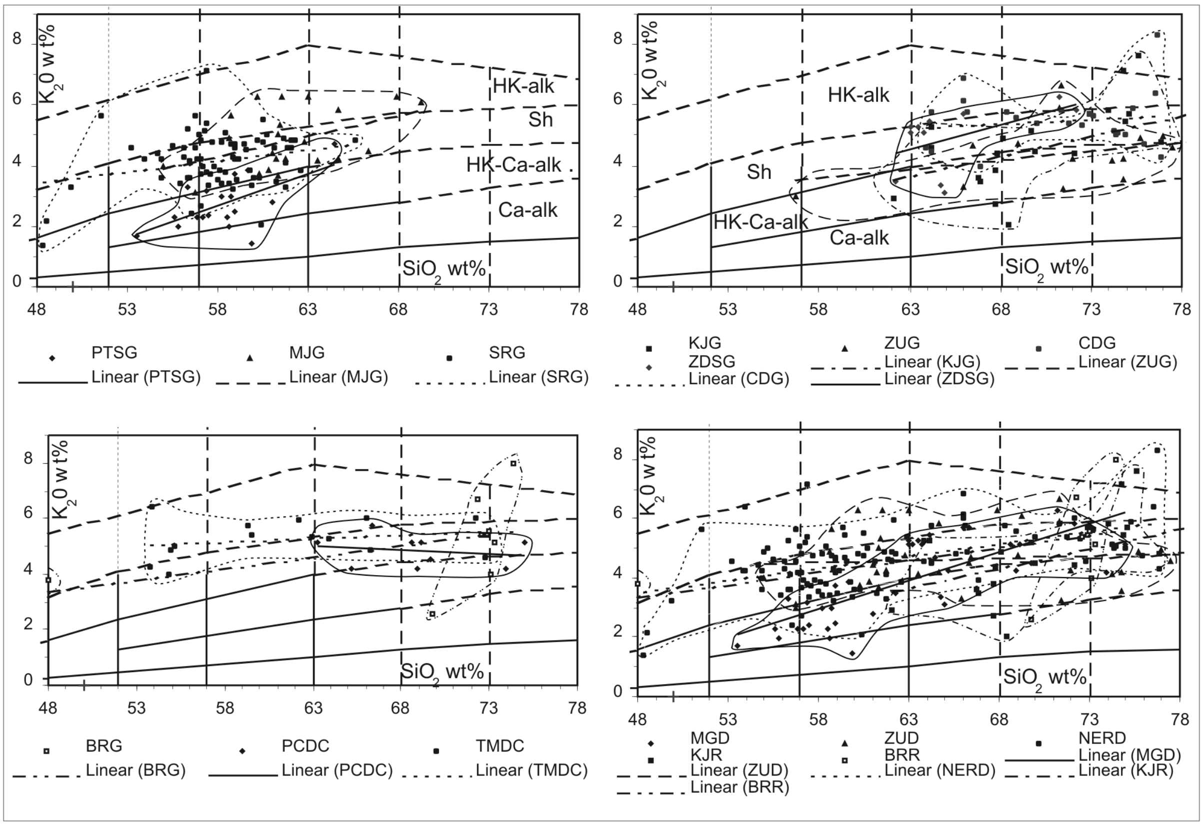

Fig. 3. K_2O/SiO_2 diagram (after Peccerilo & Tejlor, 1976; Dabovsky et al., 1991). PTSG – Putocharka subgroup; MJC – Madzharovo complex; SRG – Sarnitsa group; KJG – Kardzhali group; ZUG – Zlatoustovo group; CDG – Chamdere group; ZDSG – Zdravets subgroup; BRG – Byala reka group; PCDC – Pcheloyad dike complex; TMDC – Tri mogili dike complex; MGD – Momchilgrad depression; ZUD – Zlatoustovo depression; NERD – Northeastern Rhodope depression; KJR – Kardzhali region; BRR – Byala reka region

K_2O/SiO_2 ratio

On the K_2O/SiO_2 diagrams most analyses plot in the field of the SH series (Fig. 3). A large number of analyses plot also in the fields of the HKTR (UK) and HKCA series and single samples – in the field of the CA series. The trend line of the analyses of all magmatic groups lies entirely in the field of the SH series.

Among the silicic magmatic groups, the K_2O content is highest in Madzharovo Chamdere group. The analyses plot in the fields of the SH and HKTR series. Most analyses from Kardzhali and Zlatoustovo group lie in the fields of the SH and HKCA series.

Among the late dike complexes, the K_2O content is highest in Tri mogili complex and the analyses plot in the field mainly of the HKTR series. The analyses of Pcheloyad complex lie in the field of the SH series. The analyses of Byala reka group are characterized by a wide range of K_2O variation and plot in the interval from the HKCA to HKTR series.

The rocks of the Northeastern Rhodope depression (Sarnitsa and Chamdere group, including also Tri mogili dike complex) are characterized by the highest K_2O content. The analyses of these rocks plot mainly in the fields of the SH and HKTR series. The K_2O trend lines of the rocks from the Northeastern Rhodope depression lie entirely in the field of the SH series.

The rocks of Momchilgrad depression and Kardzhali region are characterized by the lowest K_2O values. The analyses of Dambala and Kardzhali group plot mainly in the fields of the HKCA and SH series. The more basic varieties lie in the field of the HKCA series and the silicic ones – in the field of the SH series.

According to SiO_2 content the rocks of Zlatoustovo depression occupy an intermediate position. The analyses plot mainly in the field of the SH series. A considerable number of analyses plot both in the fields of the HKTR (Madzharovo complex) and the HKCA series (Zlatoustovo complex). The trend of the K_2O content in Zlatoustovo depression lies mainly in the field of the SH series and only the most silicic varieties plot in the field of the HKCA series.

(Na_2O+ K_2O)/SiO_2 ratio

The (Na_2O+ K_2O)/SiO_2 diagram shows similar features (Fig. 4). They can be explained by the relatively monotonous values of the Na_2O content (Fig. 2).

The highest total alkalinity is related to the rocks of the Northeastern Rhodope depression. Almost all analyses plot in the fields of the alkaline varieties – trachyandesite basalts, trachybasalts and trachydacites for Sarnitsa group, trachydacites and rhyolites for Chamdere group and trachyandesite basalts, trachybasalts, trachydacites and rhyolites for Tri mogili dike complex.

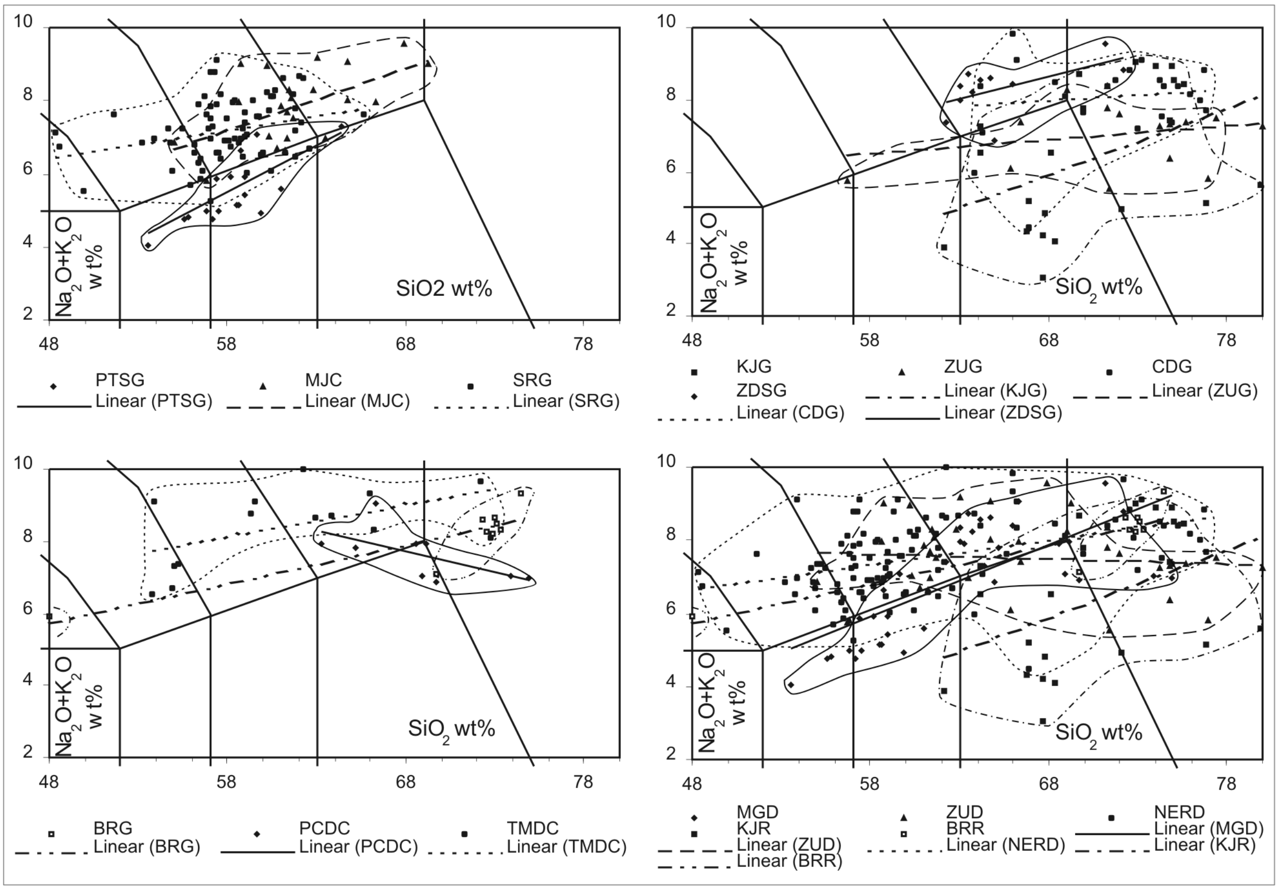

Fig. 4. (Na_2O+ K_2O)/SiO_2 diagram (after Le Maitre, 1976). Key is same as in Fig. 3

In Momchilgrad depression, the intermediate rocks are characterized by lower total alkalinity and plot in the fields of the subalkaline varieties, and the silicic varieties – by higher total alkalinity and plot in the fields of the alkaline varieties. The analyses from the intermediate Putocharka subgroup of Dambala group plot in the field of the andesitic basalts and andesites, less commonly trachyandesites. The analyses from the silicic Zdravets group lie mainly in the field of trachydacites and less commonly of the rhyolites. The analyses of Pcheloyad dike complex plot in the field of the trachydacites, dacites and rhyolites.

An opposite tendency is established in Zlatoustovo depression – the intermediate varieties are characterized by higher total alkalinity, and the silicic ones – by lower. The analyses from Madzharoco complex plot in the fields of the trachyandesites and the trachydacites and those from the Zlatoustovo group – in the field of the dacites and rhyolites.

The varieties of Kardzhali group, similarly to Zlatoustovo group, are characterized by lower total alkalinity. They are defined as dacites and rhyolites.

The basic varieties of Byala reka complex are defined as absarokites and the acid ones – as rhyolites.

Discussion

The data obtained are consistent with the concepts about the HKCA and SH seriality of the volcanism in the Eastern Rhodopes (Harkovska et al., 1989; Yanev et al., 1998; Georgiev & Milovanov, 2003). SH seriality prevails as a whole. Nevertheless, different tendencies can be detected in individual regions.

The Northeastern Rhodope and Zlatoustovo depressions show very similar petrochemical features. The trend lines of the K_2O content are located entirely within the field of the SH series. On the TAS diagrams, the Na_2O+ K_2O trends plot mainly in the field of the alkaline series.

The petrochemical features of Momchilgrad depression and Karzhali regions are also very close. The K_2O trends of the more basic varieties lie in the field of the HKCA series whereas the silicic ones plot in the field of the SH series. On the TAS diagrams, the Na_2O+ K_2O trends are within the field of the subalkaline series or around the boundary between the alkaline and subalkaline series. This tendency is better expressed in the rocks from Kardzhali region due to the lower Na content.

There are also some specific features in the petrohemical behavior of intermediate and silicic magmatic groups and complexes.

The intermediate magmatic groups and complexes of Sarnitsa group and Madzharovo complex show higher alkalinity and the trend lines of the K_2O content lie entirely in the field of the SH series whereas the Na_2O+ K_2O trend plots within the alkaline series. The Putocharka subgroup of Dambala group is characterized by lower alkalinity and the K_2O trends lie entirely in the HKCA field whereas the Na_2O+ K_2O trend plots in the field of the subalkaline series. There is a well-expressed tendency toward decreasing alkalinity from NNE to SSW, i. e. from the periphery of the Rhodope massif (Northeastern Rhodope and Zlatoustove depression) to its internal parts (Momchilgrad depression).

The silicic magmatic groups exhibit somewhat different tendencies. The alkalinity is highest in Chamdere and Zdravets subgroup of Dambala group. The trends of the K_2O content plot entirely in the field of the SH series and those of Na_2O+ K_2O – in the field of the alkaline series. Kardzhali and Zlatoustovo groups are characterized by lower alkalinity and the K_2O trend lines plot entirely in the HKCA field and those of Na_2O+ K_2O – in the field of the subalkaline series. The silicic magmatic groups show a general tendency toward decreasing alkalinity from WSW to ENE, the lowest values being concentrated around Zlatoustovo fault.

The Byala reka group, related to the inner parts of Byala reka and Kessebir domes, is likewise characterized by higher alkalinity.

The presence of different series in the individual magmatic groups suggests specific environment for the origin of the parent magma (on the background of the general late extensional tectonic setting) or development of different intermediate magmatic chambers that produced the individual magmatic groups. Processes of fractional crystallization dominated during the later evolutional stages.

Metallogenic specialization

The different magmatic groups are characterized by specific metallogeny.

Mainly metallic deposits (Pb-Zn±Au-Ag; Mo, Sb, Mn) are paragenetically related to the intermediate magmatic groups. One quartz-gold-polymetallic ore field associates with each intermediate magmatic group – Spakhievo ore field with Sarnitsa group, Zvezdel-Pcheloyad ore field with Putocharka subgroup, Madzharovo ore field with Madzharovo complex.

Popsko quartz-gold-polymetallic and Chernichevo quartz-gold-polymetallic (with stibnite) ore fields are presumably related to unexposed monzoinitoid intrusive bodies. Occurrences of semi-pricious minerals (jasper, agate) are genetically associated with the intermediate magmatic groups.

Metallic deposits, which are related to silicic magmatism (Pb-Zn±Au-Ag, Lozen ore field and Sveta Marina deposit), are an exception and do not have any commercial significance. Mainly deposits of non-metallic raw materials (zeolites, perlite) associate with the silicic magmatic groups.

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