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METALLOGENY OF THE ZLATOUSTOVO VOLCANO-TECTONIC DEPRESSION (EASTERN RHODOPES)

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ABSTRACT
The Zlatoustovo volcano-tectonic depression originated during the Paleocene in the area around Zlatoustovo fault zone. This fault zone trends E-W and separates Harmanli and Southeastern Rhodopes blocks in the Eastern Rhodopes. The following structures, from north to south, are divided within the Zlatoustovo depression: Lozen depression, Ibredjeck horst, Bryagovo depression and Madjarovo step. Coal occurrences are related to Paleocene and Eocene terrigenous sediments. The volcanic activity started towards the end of the Priabonian and continued during the Oligocene. The volcanics belong to the high-K Ca-alkaline and shoshonitic petrochemical series. Initially, several acid volcanoes developed along the Zlatoustovo fault zone. Zeolite deposits are related to pyroclastic varieties in these volcanoes. Polymetallic ore mineralizations associate with Sveta Marina volcano. The Lozen Au-polymetallic ore field is connected, both spatially and genetically, to Lozen volcano. The Madjarovo latite volcano, centred by a monzonitoide intrusion, developed in the area of Madjarovo step. Stratified Mn ore occurrences associate with the initial stages of the evolution of this volcano. The Madjarovo Au-polymetallic ore field is related to the final stages. The ore deposits are epithermal, of low-sulfidation type, and mainly vein-like. Sb mineralizations are located in the SE periphery of the Zlatoustovo depression. Placer gold is found in the Neogene-Quaternary sediments in the Ibredjeck horst.

INTRODUCTION

Zlatoustovo volcano-tectonic depression is situated in the Eastern Rhodopes, in the border area between two blocks – Harmanli and Southeastern Rhodopes. These blocks are built up of high-grade metamorphic rocks intruded by pre-Paleogene granitoid plutons.

The closure of the Tethys ocean in Late Cretaceous-Paleogene times (Dabovski, 1991) was followed by collision between Eurasia and African plate fragments resulting in accretion of separate “exotic” fragments of the African plate (as for example Rhodopes, Sakar, Strandja, etc.) to the southern margin of Eurasia.

The Harmanli block is considered to be a part of the Sakar fragment (Boyanov, 1992, etc.), and the Southeastern Rhodopes block - an element of the Rhodopes fragment. The boundary between these two blocks is marked by the Zlatoustovo fault zone (Fig.1) Its general trend is E-W, turning to WNW only in the westernmost parts of the structure. The Late Alpine Zlatoustovo volcano-tectonic depression developed upon and around this fault zone. This depression has not been described as a uniform structure until now. In our scheme it includes the following second-order structures: Madjarovo step, Bryagovo depression, Ibregjeck horst, Stambolovo and Lozen depression (Boyanov, 1992, 1995). The Zlatoustovo depression partly coincides with the Madjarovo depression of Boyanov (1971). Later Boyanov (1995, etc.) limited the Madjarovo depression to a high-rank structure that spatially corresponds to the Madjarovo step in our scheme. To the west (in the area of the town of Kardjali), the Zlatoustovo depression integrates with the Northeastern Rhodopes and Momchilgrad depressions. To the east it extends to the Maritsa fault zone. To the north and south the Zlatoustovo depression is bordered by the uplifted basement of the Harmanli and Southeastern Rhodopes blocks, respectively.

GEOLOGICAL EVOLUTION

The formation of ***Zlatoustovo depression*** commenced probably during the Paleocene. The earliest sediments in the confines of the depressions are Biser breccia and Leshnikovo sandstone-conglomerate formation. The transgression continued during the Priabonian with deposition of breccia-conglomerate, coal-sandstone and marl-limestone units (Goranov, et al., 1992).

The volcanic activity started in the end of the Priabonian. Beli Plast rhyodacite, Zimovina rhyolite-rhyodacite, Mezek and Lozen rhyolite complexes (I acid volcanism) were the earliest volcanic sequences formed in Priabonian-Rupelian times.

Tuffs and tuffaceous limestones, referred to Beli Plast complex, were deposited to the west, around Zlatoustovo fault zone.

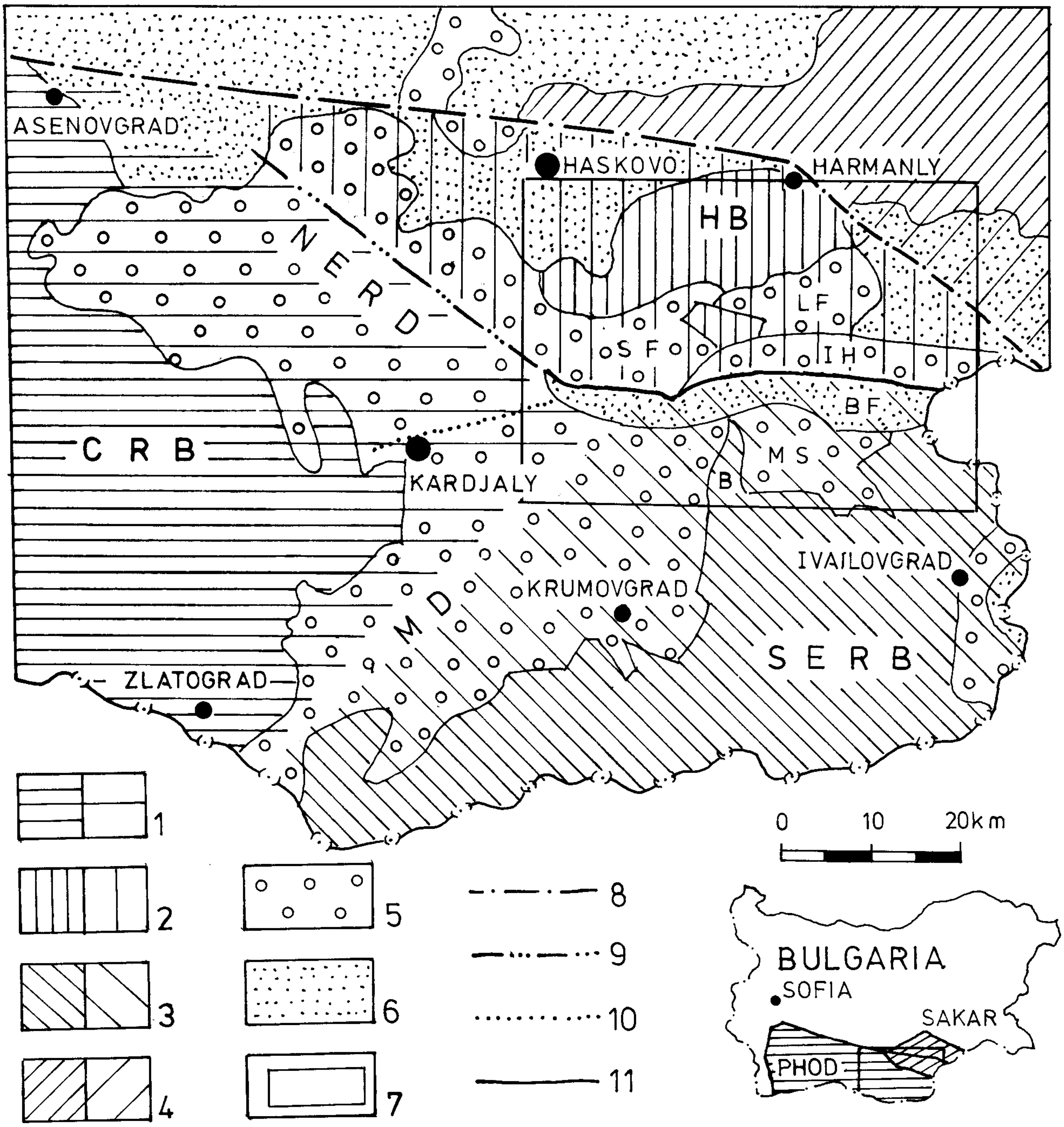

Figure 1. Generalised geological map of the Eastern Rhodopes (after Iovtchev et al., 1971, modified). 1 - Central Rhodopes block; 2 - Harmanli block; 3 - Southeastern Rhodopes block; 4 - Sakar block; 1a, 2a, 3a, 4a - surface exposures of the basement of the respective blocks; 5 - Paleogene sediments and volcanics; 6 - Neogene-Quaternary deposits; 7 - boundaries of the studied area1; 8 - Maritsa fault zone; 9 - Pchelarovo fault set; 10 - Ardino fault; 11 - Zlatoustovo fault zone.

Lyaskovets volcano, comprising the rocks of Zimovina complex, was formed in the westernmost parts of the Zlatoustovo depression.

Mezek complex is located in the easternmost parts of the Ibredjeck horst where together with acid tuffs some extrusive bodies were also formed.

The effusive rocks of Lozen complex build up Sveta Marina volcano in the Ibredjeck horst as well as Lozen volcano (Yanev, et al., 1975) situated within the Lozen depression.

Silen volcano, composed of the rhyolites of Perperek complex (II acid volcanism), is located in the western parts of Zlatoustovo depression. Some later phases of this volcano are established in the area of Lozen volcano. These are Cherna Mogila trachyrhyodacite and Planinets trachyrhyolite complexes (II and III acid volcanism) as well as some diorite-porphyrite bodies of Cherna Mogila complex that intrude the rocks of Lozen volcano.

Madjarovo volcano is located in the southern parts of the depression. It is formed of the rocks of Madjarovo latite complex (II intermediate volcanism). Intermediate tuffs, tuffites, and tuff-breccias interbedded with reef limestones were deposited during the earliest stages. Later followed eruptions of trachybasaltic andesites, various latites, trachydacites and quartz-trachytes. They form an elliptic volcanic edifice (17x11 km) elongated in WNW direction (Fig. 2). This large volcano associates with numerous smaller satellite and parasitic volcanic cones. In the vicinity of the town of Madjarovo, few relatively small intrusive bodies are also found (Mavrudchiev, 1959). They are probably parts of a larger intrusion, emplaced in the main magma conduit that fed the Madjarovo volcano. The volcanic cone is cut by numerous dykes of trachybasaltic-andesite, latiteandesite and latite compositions. Most of them are radial, but some are randomly oriented.

Valche Pole unit (of Oligocene-Miocene age) was deposited within the Bryagovo depression, and Ahmatovo Formation (Miocene-Pliocene) - in the Lozen depression.

METALLOGENY

Volcano-sedimentary zeolite deposits are related to the tuffs of the Beli Plast rhyodacite and, to a lesser extent, to the tuffs of the Mezek and Perperek rhyolite complexes. The zeolite-bearing bodies are stratum- or lens-like. These deposits, as well as the hosting tuffs, are located around the Zlatoustovo fault zone. In the western part of the depression, there are deposits of clinoptilolite (associated with chlorite, celadonite and montmorillonite) related to the pyroclastics of Beli Plast (Most and Rabovo deposits) and Perperek (Perperek deposit) complexes. In the area of Lyaskovets village, the tuffs of the Beli Plast complex are mordenitized and contain analcime and clinoptilolite (Djourova and Aleksiev, 1988). Mordenite-clinoptilolite zeolites, accompanied by erionite, analcime and stilbite, occur in acid tuffs of the Mezek complex in the eastern parts of the Ibredjeck horst (Ivanova, et al., 2001).

Sveta Marina lead-zinc deposit is closely associated with the volcano of the same name. The ore mineralizations form stratum- or lens-like bodies within the Priabonian sediments. The following stages of mineralization are recognised on the basis of the most important minerals (Breskovska and Gergelchev, 1988): 1) quartz-galena-sphalerite with minor pyrite and chalcopyrite; 2) quartz-barite-sulfosalts (with restricted distribution) – the sulfosalts are tetrahedrite and tennantite; 3) carbonate (also locally present) - calcite, dolomite. The authors, cited above, described also a stage of later sulfosalts, but they are represented by separate pyrite, galena and sphalerite crystals over carbonates and probably belong to the carbonate stage.

The Lozen lead-zinc ore field is related, spatially and genetically, to the Lozen rhyolite volcano. According to Breskovska and Gergelchev (1988), the ore bodies are of two types: shallowly dipping veinlet-disseminated ore mineralizations interbedded with sediments and volcanics; and fault-hosted steeply dipping vein-like bodies of veinlet-disseminated and vein type ore mineralizations. The ore-hosting rocks were affected by intensive hydrothermal alteration prior to the ore mineralization. The alteration in the upper parts of deposits is argillization (mainly montmorillonite), and in the lower levels it is of quartz-sericite type.

According to Breskovska and Gergelchev (1988), the ore mineralization was formed in three stages: 1) quartz-galena-sphalerite (or quartz-sulphide) – the productive stage, with pyrite and chalcopyrite as subordinate minerals; 2) quartz-barite with gold (of restricted distribution); and 3) carbonate (calcite, dolomite, ankerite) stage. According to Bogdanov (1983) the barite mineralization is later than the carbonate one. Concentric horizontal zonality in the spatial distribution of ore mineralization was described (Bogdanov, 1983): Cu-Pb-Zn mineralizations concentrate in the outermost parts, Pb-Zn – in the middle and Au-Ag mineralizations - in the outermost parts of the deposit.

Madjarovo *polymetallic and gold-polymetallic* ***ore field***. Veinlet-disseminated type copper-molybdenum mineralization of non-economic significance occurs within the monzonitoid bodies in Madjarovo volcano.

Polymetallic and gold-polymetallic ores are localized mainly in the inner (central) parts of the volcano (Gorno Pole, Arda, Momina Skala, Patronkaya, Gaberovo, Radonovsko, Harmankaya, Chatalkaya and Brusevtsi deposits). The ore bodies are of vein type, steeply dipping (70-90^{o}) and most of them are radial with respect to the Madjarovo volcano. They are located mainly within the volcanics and locally - in the sedimentary and metamorphic rocks from the basement of the volcano. Small metasomatic bodies are hosted in limestones.

The host rocks of the ore field rocks are affected by three temporal types of hydrothermal alterations: early pre-ore, pre-ore, and syn-ore. The first type is a regional propylitization of the volcanic rocks. Secondary quarzites (advanced argillizites) are also related to the first type. They form concentric zones around monzonitoid intrusions: the alterations in the inner parts are of argillizite type, propylites are established in the peripheries and the most intensively altered parts are converted to diaspor-bearing alunite-quartzites and zunyit-bearing diaspor-quartzites. Pre-ore metasomatics are restricted along faults and belong to the adularia-sericite type (Velinov and Nokov, 1991). The syn-ore alteration is represented by sporadic kaolinization and is poorly studied.

Various in number and composition stages of ore mineralization have been distinguished by different authors (Radonova, 1960; Atanasov, 1962; Kolkovski, 1971; Breskovska and Gergelchev, 1988). Our studies suggest five mineralization stages: 1) specularite-guartz with gold (productive for Au); 2) quartz-chalcopyrite (also productive for Au); 3) quartz-galena-sphalerite with pyrite and chalcopyrite as

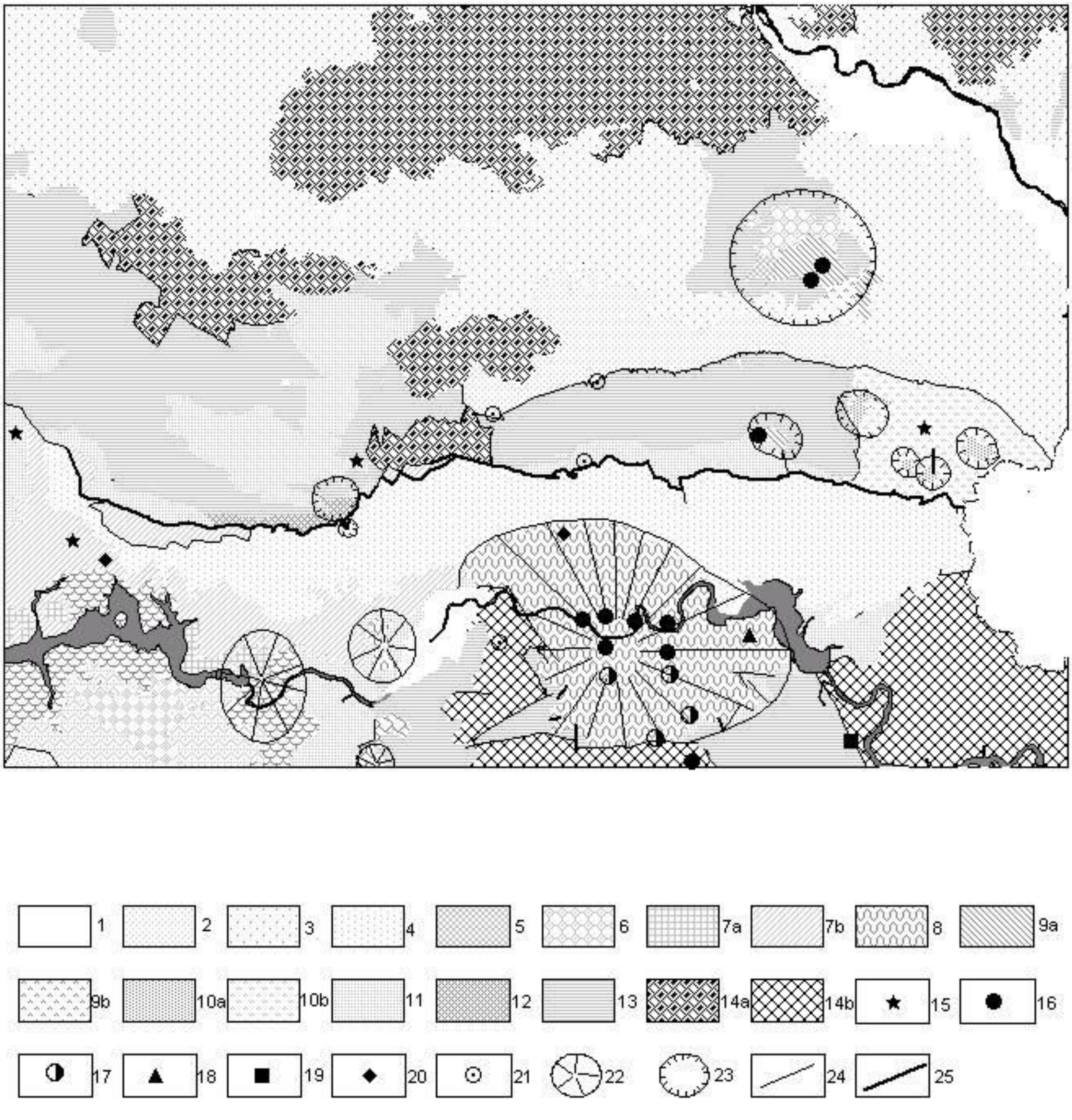

*Figure 2.. Metallogenic map of the Zlatustovo volcano-tectonic depression. Quaternary: 1- alluvium; 2- proluvium; Miocene-Pliocene: 3-Ahmatovo Formation; Oligocene-Miocene: 4-Valche Pole Formation; Oligocene: 5- Planinets trachyrhyolite complex; 6-Cherna Mogila trachyrhyodacite complex; 7-Perperek rhyolite complex: 7a- rhyolite; 7b- tuffs; 8-Madjarovo latite complex; Eocene-Oligocene: 9-Lozen rhyolite complex: 9a- rhyolite; 9b- tuffs; 10-Mezek rhyolite complex: 10a- rhyolite; 10b- tuffs; 11-Beli Plast rhyodacite complex - tuffs; 12- Zimovina rhyolite complex; Paleocen- Eocene: 13-Paleogene sedimentary complexes; 14-pre-Paleogene basement; Ore deposits: 15- Zeolite; 16- Polymetallic (Pb-Zn); 17- Gold-polymetallic; 18- Manganese (pyrolusite); 19-Antimony; 20-Weathering deposits (halloysite-kaolinite, kaolinite, psilomelane-pyrolusite); 21-Placer gold; 22-Volcanic cone of the Madjarovo volcano; 23-extrusive bodies; 24- fault; 25- Zlatoustovo fault zone; MV -Madjarovo volcano; LV -Liaskovo volcano; SV - Silen volcano; SMV - Sveta Marina volcano; MZV - Mezek volcano; LZV - Lozen volcano **Placer gold** is found both to the north and south of the Ibredjeck horst, in the areas of the villages of Tankovo, Zlatoustovo, Efrem, etc., and within the Lozen depression. They might have resulted from the destruction of the coarse-grained sediments that build up a large part of the horst. Au-bearing placers are identified along Bryagovska River and they could have formed at the expense of the gold dispersed in the metamorphic rocks exposed near by. Non of these occurrences is of economic significance.*

subordinate minerals (productive for Pb, Zn, and to some extent for Cu, Ag, and Au); 4) quartz-chalcedony-barite with Ag-sulfosalts and electrum (productive for Au); and 5) carbonate-quartz (locally present). In the surface parts of the ore field, the hydrothermal solutions produced minerals, typical of supergenic conditions (chalcophanite, wavellite and anglesite). This was probably caused by mixing of hydrothermal and rich in oxygen meteoric solutions.

A dome-like zonality in the distribution of ore mineralizations has been described around the main magmatic and ore-controlling structure - the vent of the Madjarovo volcano (Iliev, 1980). The predominating ore mineralizations in the inner and lower parts of the ore field are Pb-Zn, while Au-bearing dominate in the upper and peripheral parts of the deposit

Madjarovo ore field is related both spatially and genetically to the Madjarovo volcano. They have a common source in depth and both result from the evolution of one magma chamber.

Manganese (pyrolusite) ore occurrences (Borislavtsi and Kochash) form beds or networks of tiny veinlets in lava flows on the slopes of Madjarovo volcano. The gold-polymetallic Madjarovo ore field is also associated with this large volcano. The ore mineralizations are epithermal, of low-sulfidation type.

The Mareshnitsa antimony occurrence is situated to the southeast of the Madjarovo volcano. It is hosted in breccia-conglomerates of the Krumovgrad Group. The ore mineralization consists of quartz and stibnite as well as minor calcite, realgar, pyrite and pyrrhotite (Mladenova and LŸders, 2000). This mineralization, as usual in the Eastern Rhodopes, is located in the periphery of the depression. Its connection with the volcanism in not so clear and is, to a certain extent, hypothetical. As a more low-temperature mineralization, it seems to be formed at a greater distance from the volcanic edifices.

The halloysite-kaolinite deposit of Dolni-Glavanak, as well as some occurrences of this type (Topolovo, Topolovo-E and Borislavtsi) are related to weathering crusts formed upon the northern periphery of the Madjarovo volcano (Todorova, 1988). In the weathering zone of the tuffs of Perperek complex, kaolinite and psilomelane-pyrolusite mineralizations were formed. All of them are covered by sediments of the Valche Pole unit which contains coal occurrences.

CONCLUDING REMARKS

The cyclic evolution of the volcanism in the Eastern Rhodopes, that is believed to be a four-fold alternation of intermediate and acid phases (Ivanov, 1960, 1963; Harkovska, et al., 1989, etc.), is an idealised and abstract scheme. In fact, the magmatic activity usually evolved from intermediate to acid in the individual volcanic edifices. Several magmatic chambers with similar, but not contemporaneous development might have existed. Their activities overlapped in space and time and that is why their products at the surface overprint and interfinger laterally, creating the impression of a cyclic evolution. Thus, the idea of the existence of several alternating phases (I, II, etc.) of intermediate and acid volcanism is used here for the readers' convenience.

Only acid volcanism belonging to different phases occurred around the Zlatoustovo fault zone and in the northern parts of the Zlatoustovo depression where mainly zeolite deposits are localized. There, polymetallic ore mineralizations are of subordinate significance and their association with acid volcanics is a quite unusual case in nature. Mainly intermediate volcanism developed in the southern parts of the depression where Madjarovo Au-polymetallic ore field and some Mn mineralizations associate with the Madjarovo volcano. Sb mineralizations are also identified.

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