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ALPINE GEOTECTONIC EVOLUTION AND METALLOGENY OF THE EASTERN PART OF THE BALKAN PENINSULA

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ABSTRACT
Several consecutive stages are recognized in the Alpine evolution of the eastern part of the Balkan Peninsula. They are marked by different geotectonic settings: intracontinental rifting, ocean spreading, subduction, early collision, intracollisional rifting, late collision, late to postcollisional orogeny. The Strandja metallogenic zone and Kremikovtsi ore field developed during the intracontinental rifting stage. The ophiolite complex and related ore deposits in the Vardar metallogenic zone as well as the sedimentary iron ore deposits in the continental shelf were formed during the spreading stage. The Pirin-Rhodopian metallogenic zone was related to the early collisional granitoide plutons. The Apuseni-Banat-Timok-Srednogorie metallogenic zone was formed as a result of intracollisional rifting. The West Balkan metallogenic zone developed along the northern border of the intracollisional rift. The Transbalkan and Circum Black See metallogenic zones are related to the postcollisional orogeny.

INTRODUCTION

The eastern part of the Balkan Peninsula, with the exception of the Moesian platform, belongs to the Alpine-Himalayan tectonic belt. The Balkanide tectonic system developed in this territory along the northeastern continental margin of the Vardar paleoocean. The system is connected with the Pontides to the east and the Carpathians to the northwest. At the same time, the Balkanide system is conjugated to the west with the Dinaride system, which is related to the evolution of the Dinaride ocean.

In this paper, the Rhodopean and adjoining part of the Serbo-Macedonean regions are discussed in the framework of the Balkanide system, together with the strictly Balkanide structures (Stara Planina, Srednogorie).

Numerous plate tectonics models have been proposed to explain the Alpine evolution of the investigated territory [Dewey et al., 1973; Grubic, 1974, 1980; Bocaletti et al., 1974; Karamata, 1974; Hsu et al., 1977; Bogdanov et al., 1977; Popov, 1981, 1996; Robertson and Dixon, 1984; Boyanov et al., 1989; Dabovski, 1991; Dabovski et al., 1991; Gochev, 1991; Popov et al., 1997; and many others]. The new data suggest a new, more perfect model for the Alpine evolution of the Balkanide tectonic system, which is based on the Wilson's cycle. The successive development of numerous tectonic settings marks different stages of this evolution: intracontinental rifting; ocean spreading; subduction; early collision; intracollisional rifting; late collision; post-collisional orogeny.

The Alpine metallogeny of the eastern part of the Balkan Peninsula is characterized by a broad variety of genetic types of ore deposits. They were formed as a result of the consecutive development of different geotectonic settings and accompanying magmatic, sedimentary and metallogenic events. Several metallogenic zones can be distinguished: Strandja, Vardar, Pirin-Rhodopian, Apuseni-Banat-Timok-Se-rednogorie, West-Balkan, Trans-Balkan and Circum-Black Sea zones.

In the beginning of the Alpine evolution, the continental massifs of Europe (the Moesian platform) and Africa (Rhodopean, Serbo-Macedonian, Pelagonean etc. blocks) were acreted into a single continent as a result of Early Paleozoic subduction and Hercynian collision [Haydoutov, 1991]. This event is marked by the deposition of Upper Carboniferous-Permian epicontinental molasse deposits.

A quasi-platform setting was established in the investigated territory at the end of the Permian and beginning of the Triassic. It is indicated by low tectonic activity, flat relief as well as by the Lower Triassic continental and Middle-Upper Triassic carbonate deposits. The Alpine tectonic activization commenced in restricted regions and then gradually embraced larger territories.

INTRACONTINENTAL RIFTING SETTING AND RELATED MINERAL DEPOSITS

Intracontinental rifting is the first stage of the Alpine evolution. It developed mainly during the Triassic along the Pindos–Dinaride zone in the western part of the Balkan Peninsula. In this area it is marked by basalt-andesite-dacite, spilite-keratophyre and gabbro-diorite-granodiorite-granite complexes as well as by related Zn Pb, Cu, Ba, Fe, Mn etc. deposits of different type.

Greenschist facies Triassic basic volcanic rocks and associated terrigenous and carbonate deposits build up the Strandja allochthon. They reflect the intracontinental rifting processes in the southeastern part of the Balkan Peninsula. These rocks and related mineral deposits mark the development of the **Strandja Metallogenic Zone**. Only part of this zone is exposed at present. Several volcano-sedimentary copper-zinc-lead massive sulphide deposits of variable mineral composition (Kartsalevo, Raevo, Keremidoto, etc.) associate with the Triassic greenschists and metadiabases in this region. They are located in the confines of the ***Gramatikovo ore field***. There are also some occurrences of ilmenite-chlorite schists in this region.

Intracontinental rifting of subequatorial direction took place in the Eastern Balkan. This process is demonstrated by the formation of a flysch trough. Numerous faults of the same direction and local basalt eruptions developed in the West Balkan at the same time. Most likely, the initial iron mineralization in the ***Kremikovtsi ore field*** (north of Sofia) was deposited during the hydrothermal-sedimentary processes as a result of a high temperture anomaly related to these events.

The strata-bound copper-uranium deposits in Permian (Smolyanovtsi in Bulgaria) and Triassic (Doykintsi in Serbia) sandstones in the West-Balkan region are possibly related to this setting.

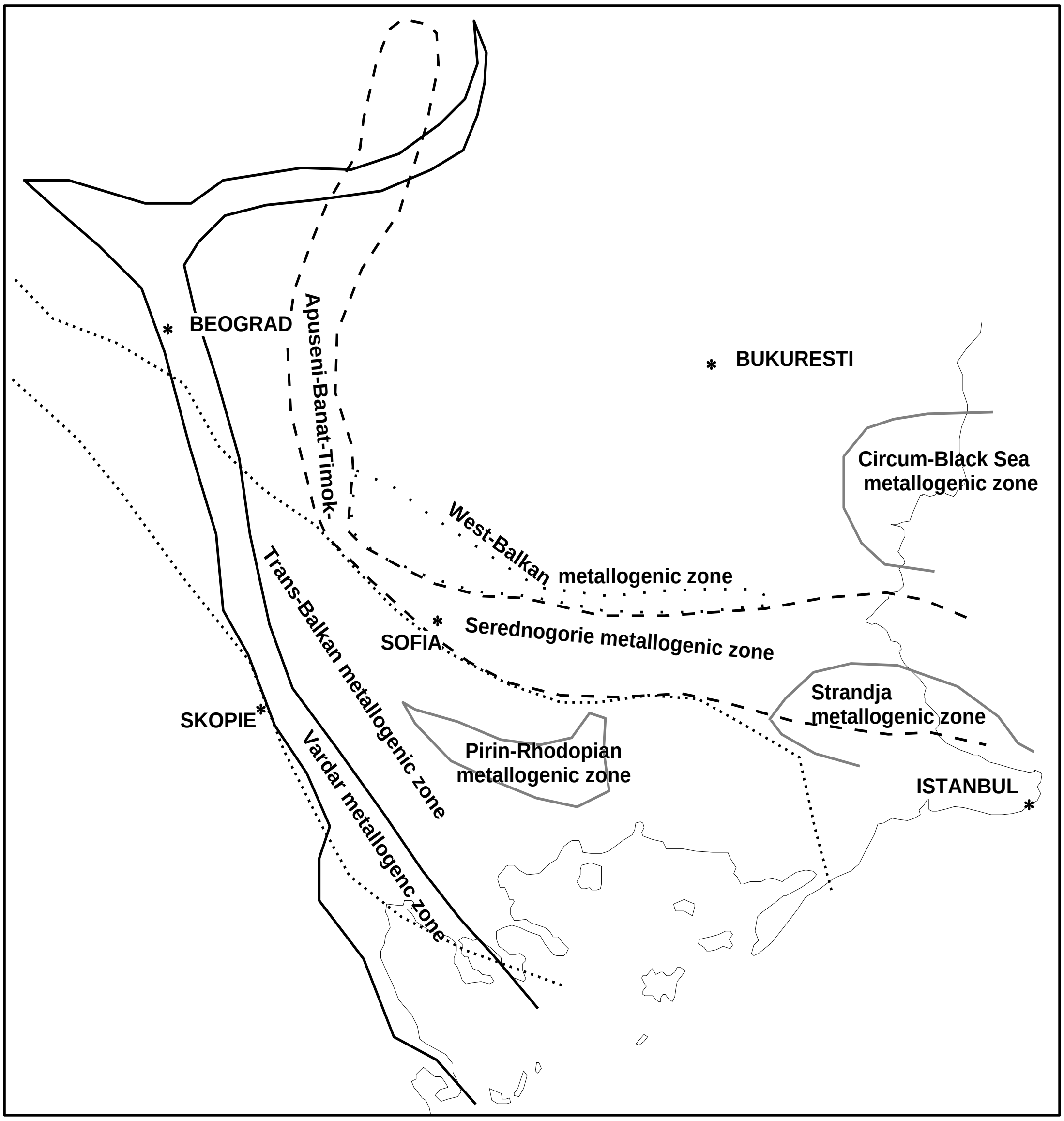

Figure 1. Main alpinian metallogenic units in the Eastern part of the Balkan Peninsula

OCEAN SPREADING SETTING AND RELATED MINERAL DEPOSITS

Ocean spreading is the second stage of the Alpine evolution. The spreading lead to a complete break up of the continental crust and initiation of the Mesozoic Tethys during the Jurassic. These events took place in the zone of Vardar River and propagated to the north along the line Kraguevats-Belgrade. As a result the Vardar ocean opened. A magmatic association of ophiolite type was generated [Karamata 1975]. Three major units of this Vardar ophiolite complex are well exposed: 1 – peridotite suite (with small dunite and lherzolite bodies) at the base; 2 – differentiated magmatic cummulates; 3 – Diabase-Chert Formation and associated terrigenous sedimentary rocks, gabbro and rare diorite to granodiorite intrusives. At the same time the territory to the northeast developed as a continental shelf.

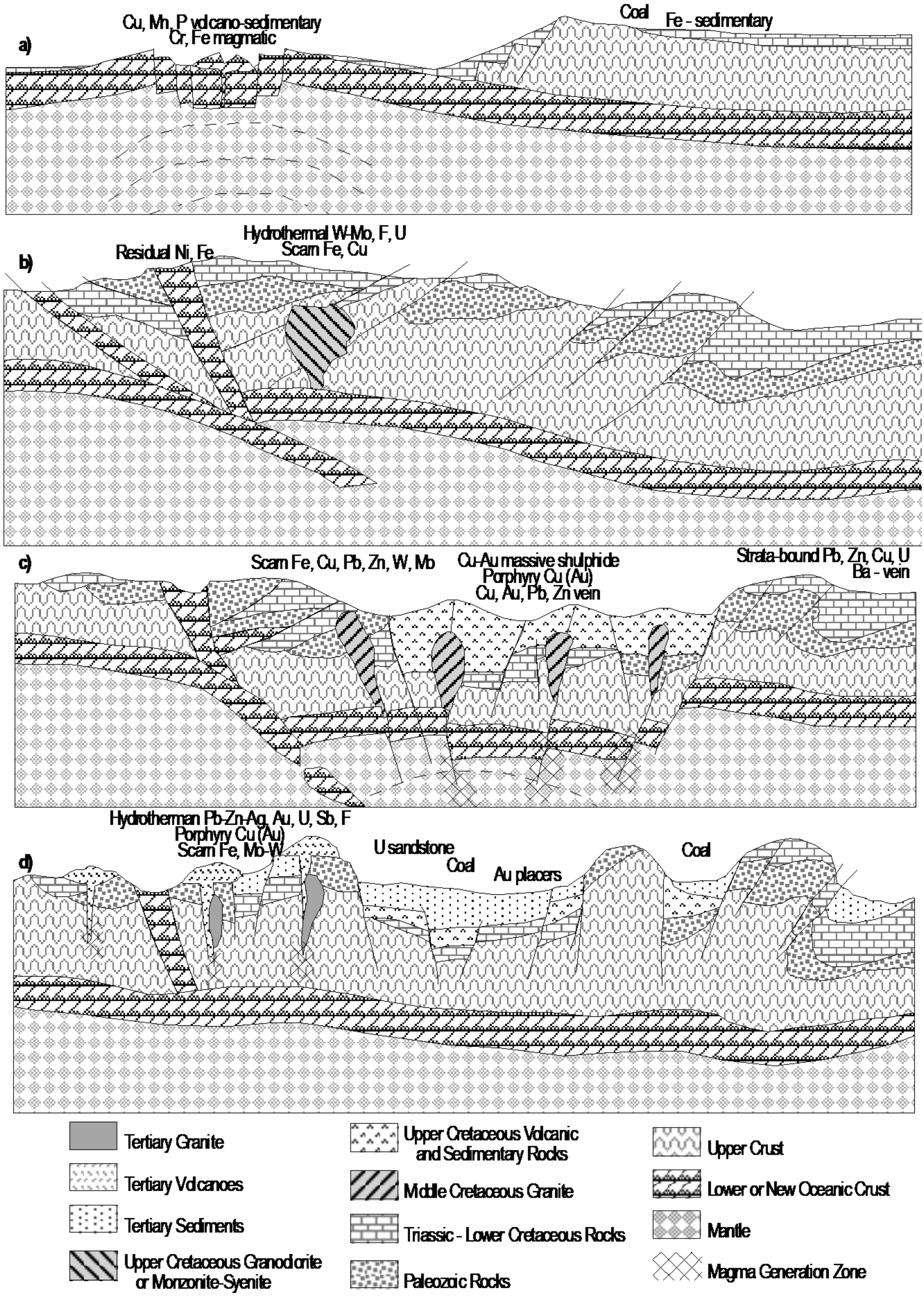

Figure 2. Models of the different tectonic settings and position of mineral deposits: a) spreading; b) early collision; c) intracollisional rifting; d) post-collisional orogen.

The development of the Vardar Ophiolite Complex and the related typical ore deposits defines the **Vardar Metallogenic Zone**. Podiform chromite deposits are most important. They are related to the Jurassic ultramafic complexes. The chromite deposits are related to dunite intrusions. Sheet-like, lense, nest, rarely pipe and schlieren type ore bodies are typical. The main ore deposits are located in Luboten (Raschka) region, near Skopje (Nada, Orashe, Kafe-Odzhak, Stankovats, etc.). The ore deposits in the Kopaonik Mauntain are located in the Yelitsa (Rudna Kosa, Peret), Turnava (Velika Chukara, Goluitsa), Troglav (Malinyak, Vidakov Prevoy) and Velouche regions. The main ore deposits in the Loyane-Preshevo region are Ostrovitsa, Furli Kamen, Fiorina, and Loki Kech. There are several ore occurrences in the Chalkidiki region, too.

Magmatic magnetite deposits are rare. They are represented by the Lipovats ore deposit (SE of Aranjelovats). It is related to the Shumadiya harzburgite.

Forsterite deposits occur in the Kopaonik (Polyane – NW of Rashka) and Golesh (Medvedtse – SW of Prishtina) ultramafic massifs.

Volcano-sedimentary copper, manganese and phosphorite deposits are related to the Diabase-Chert Formation. The copper massive sulphide deposits of Cyprus type are wide-spread to the North and South of the town of Chachak (Serbia).Typical representatives of this type are massive sulphide or disseminated ore mineralization in the Topolishnitsa, Stancha, Shevoulya, Laykovicha, Rechitsa, Novakovicha and Rebel deposits. Strata-bound manganese deposits (Drache – West of Kraguyevats) are rare. Several concretion-type phosphorite ore occurrences occur between Kraguyevats and Topola towns (Shoumadiya region).

During the ocean spreading stage, numerous sedimentary iron deposits were formed in different areas of the continental shelf. They are hosted in Lower-Middle Jurassic carbonate-terrigenous sediments in the ***Troyan ore region*** in the Central Balkan, as well as in the West Balkan, Strandja and Kraishte regions.

SUBDUCTION SETTING AND RELATED MINERAL DEPOSITS

The closure of the Vardar paleoocean towards the end of the Jurassic and the beginning of the Cretaceous marks the third stage of the Alpine evolution. The oceanic type crust subducted to the northeast under the European active margin and initiated a new magmatic front. A number of granitoid bodies were intruded along the line Chalkidiki-Shtip. At the same time a flysch-type back-arc basin developed in the Balkanides (Nish-Troyan trough after Nachev and Yanev [1980]).

Ore deposits, related to the subduction-type granitic intrusions along the eastern border of the Vardar Ocean, are not known. By Skenderov et al., [1986], the absolute age data suggest that the lead-zinc, barite and uranium ore deposits in the Ustrem region (SE Bulgaria) may be formed during that stage.

EARLY COLLISIONAL SETTING AND RELATED ORE DEPOSITS

The early collisional setting developed during the Early Cretaceous and marks the fourth stage of the Alpine evolution. Intensive folding and thrusting processes were concentrated mainly in two zones. The first one is marked by the thrust structures in the Serbo-Macedonian zone, Kraishte region, Southeastern Rhodope and Strandja Mountain. Some of these allochtons include obducted ophiolite sheets. The second zone extends around the Moesian platforme in the Fore-Balkan and Stara Planina Mountain. A typical hinterland fold and thrust belt was formed as a result. Most likely, the described as Late Cretaceous granite plutons in the area of the Rhodopes, Pirin and Rila Mountains are related to these collisional processes [Popov et al., 1996].

The **Pirin-Rhodopian metallogenic zone** is marked by the development of syncollisional granite plutons. Several small vein type tungsten-molybdenum deposits (Gruncharitsa) as well as metasomatic fluorite deposits (Mihalkovo area) have been explored. There are also numerous skarn or hydrothermal molybdenum, iron, copper, lead-zinc, antimonium, gold and uranium ore occurrences.

Numerous ore deposits are related to the weathering of ultramafic rocks. They were formed in uplifted area of the Vardar suture. A series of residual nickel and iron deposits originated as a result of lateritisation processes. Nickel-silicate deposits (Fe, Ni, Co, Cr) are wide-spread in Northern Greece (Edessa, Sfikia), Kopaonik (Rudjintsi, Velouche), Shumadiya (Ba) and Froushka Gora regions. Residual iron deposits, as for instance Mokra Gora in the Zlatibor region, are not very important. The magnesite deposits are of essential economic significance. They are represented by veinlet type deposits in the weathering crust, as well as by vein type deposits. The Brezak, Rajana, Tsvetni Vruh, Liska, Troglavchich, and Magura deposits are more important.

Several oolitic type sedimentary Fe ore deposits are located in the Shoumadiya region, between Beograd and the town of Kraguyevats. They are hosted mainly in Aptian and Albian sedimentary rocks. The origin of these deposits is related to the weathering of ultramafic rocks from the Vardar suture and migration of the Fe-bearing solution to the neighbouring basin.

INTRA-COLLISIONAL RIFT SETTING AND RELATED ORE DEPOSITS

The intra-collisional rifting during the Late Cretaceous marks the fifth stage of the Alpine evolution. It took place after the Early-Middle Cretaceous collisional deformations and before the Paleogene collisional processes. The Apuseni-Banat-Timok-Serednogorie rift-like tectonic and metallogenic zone was formed along the active continental margin, probably as a result of postcoliisional collapse and conjugated astenospheric diapirism [Popov, 1996; Popov et al. 2002]. A 2000-7000 m thick volcano-sedimentary complex and associated intrusions were formed. The magmatic rocks belong to 4 series: tholeiitic, Ca-alkaline, subalkaline and K-alkaline. This zone marks a new tectonic plan in the investigated territory. This is a transit-type structure, because it penetrated deeply into the

Carpathian tectonic system. The high temperature and intensive faulting controlled the metallogenic activation along the northern margin of the rift and the formation of the West-Balkan metallogenic zone.

During this stage, another flysch-type trough was formed upon parts of the Vardar suture, the Serbo-Macedonian and Pelagonian massifs

The Apuseni-Banat-Timok-Serednogorie metallogenic zone (ABTS zone) is unconformably superimposed upon older structures, including Early Cretaceous ones. Numerous ore deposits of about 14 different types associate with the volcanic and plutonic complexes. Porphyry copper (±Au, Mo) and massive sulphide (Cu, ±Au) deposits are most important. They are represented by the porphyry copper deposits Assarel, Medet, Elatsite (Panagyurishte region), Majdanpek, Veliki Krivel (Timok region), Moldova Noua (Banat region) and Prohorovo (Strandja region), as well as the massive sulphide deposits Bor (Timok region), Chelopech, Radka, Elshitsa, Krasen (Panagyurishte region).

A great diversity of skarn type ore deposits is widespread. The iron deposits Ocna de Fier (Banat region) and Krumovo (Strandja region), the copper deposits Malko Turnovo (Strandja region), Moldova Noua (Banat region), the lead-zinc deposit Dognecea (Banat region) as well as the tungsten-molybdenum deposit Baita Bihorului (Apuseni region) are the most representative ones.

Vein-type copper, gold-copper and gold-lead-zinc hydrothermal deposits are very typical of Bourgas region in the Eastern Srednogorie. There are also numerous small hydrothermal gold, silver-gold, gold-copper-lead-zinc, barite and uranium deposits.

Volcano-sedimentary manganese (Pozharevo – W Srednogorie) and iron deposits are also related to this stage.

The West-Balkan metallogenic zone is situated along a segment of the northern boundary of the ABTS zone. It comprises part of the hinterland miogeoclinal fold-and-thrust belt which was formed during the Early Cretaceos collision, and uplifted during the rifting. The Late Cretaceous metallogenic processes were controlled by the high-temperature front, related to the magmatic activity in the ABTS zone. Numerous strata-bound type hydrothermal lead-zinc-silver (Sedmochislenitsi, Izdremets), copper (Plakalnitsa, Venetsa) and uranium (Sliven) deposits were formed. They are hosted mainly in carbonate rocks. Shear-zone, vein or metasomatic stock type ore bodies are very rare. There are also numerous barite veins (Zverino).

LATE COLLISIONAL SETTING

The late collisional setting marks the sixth stage of the Alpine evolution. The collision processes continued after the Late Cretaceous. The intensive Laramide and Pyrenean tectonic deformations affected mainly the territory of the Srednogorie, Stara Planina and Fore-Balkan zones. Magmatic and metallogenic activity is not known during this stage. The final deformations occurred towards the end of the Oligocene, in the framework of the post-collisional stage.

POST-COLLISIONAL SETTING AND RELATED ORE DEPOSITS

The post-collisional setting marks the final stage of the Alpine evolution. The extensional regime commenced during the Priabonian and continued almost without breaks during the Oligocene and Neogene. The postcollisional orogenic belt was formed as a result of a general uplift. Intensive faulting, vertical block displacement and molasse type sedimentation in depressions are typical. The Trans-Balkan volcanic belt was formed as a result of the magmatic activity along the orogen axis. It is superimposed unconformably upon the collisional Alpine structures and intersects the Vardaride and Dinaride sutures. Most of the Tertiary magmatic rocks belong to the calk-alkaline, rarely – to the subalkaline series. Most likely, the magma-generation processes started during the final acts of the collision. At the same time, Early Paleogene-Miocene carbonate-terrigenous sequences of Crimea-Caucasian type were deposited in Dobrudja (NE Bulgaria). The Trans-Balkan and Circum-Black-Sea metallogenic zones were formed as a result.

The Trans-Balkan metallogenic zone is characterized by ore deposits that are developed predominantly in association with the Tertiary magmatic and depositional processes. Vein-type, rarely metasomatic lead-zinc (+Ag) ore deposits are wide spread. They are the most important and characteristic types for that metallogenic zone. Such are the ore deposits of Madan, Luki, Madzharovo, Davidkovo, Osogovo, Blagodat, Kratovo-Zletovo, Trepcha, Chalkidiki, Alexandroupoli etc. regions. Several gold deposits of vein (Chala, Madjarovo) or metasomatic type (Adatepe, Sedefche, Rozino) have been explored in the last years in the Eastern Rhodopean region, as well as in Northern Greece. Porphyry copper (Au-bearing) deposits occur in some places (Bouchim, Skouries). The porphyry-type molybdenum deposits (Machcatitsa, Axioupolix, Kimeria-Sterna) are not very significant. There is also a series of hydrothermal uranium (Smolyan), antimonic (±Au) (Alshar, Ribnovo) and fluorite (Slavyanka) deposits. Several skarn type iron (Damyan), copper (Pirinia) and lead-zinc (Osogovo region) deposits occur, too.

Several asbestos and rarely magnesite deposits were formed as a result of the Tertiary magmatic activity. The asbestos deposits are related to the area of intersection between the Tertiary Trans-Balkan Zone and the Vardar Suture. These mineral deposits were formed as a result of hydrothermal activity related to the Tertiary subvolcanic-hypabissal intrusions. They occur predominantly in the Kopaonik (Korlache, Bzenitsa, Shtava), Preshevo (Livi Do), Kozarevo (Ruyishte) and Shoumadiya regions.

Infiltration-type uranium deposits are related to the Tertiary molasse deposits in Upper Thrace (Momino, Orlov dol), Mesta (Eleshnitsa) and Struma grabens (Simitli, Melnik), as well as in Leskovac and Byasna Kobila areas. Shear-zone type infiltration uranium deposits occur in the areas of old granitic rocks.

The Circum-Black Sea metallogenic zone is located in NE Bulgaria and extends to Sauth Ukraine, South Russia and Georgia. Several sedimentary manganese deposits in the Oligocene deposits occur along the Bulgarian continental shelf (Shabla, Ignatievo) and in other parts of the zone (Nikopol, Chiaturi, etc.).

REFERENCES

Boccaletti, M., Manetti, P., Peccerillo, A. 1974. The Balcanids as an instance of back-arc thrust belt: possible relation with the Hellenids. Geol. Soc. Am. Bull., **85**, 1077-1084

Bogdanov, B., Dachev, H., Vulchanov, A. 1977. Metallogeny of Bulgaria in the context of plate tectonics. *In: Problems of ore deposits, 4th JAGOD Symp., Varna, 1974,* ***2***, 435-443

Boyanov, I., Dabovski, C., Gocev, P., Harkovska, A., Kostadinov, V., Tzankov, Tz., Zagorcev, I. 1989. A new view of the Alpine Tectonic Evolution of Bulgaria. *In: Geologica Rhodopica, I, Kl. Ohridski Univ. Press*, 107-121.

Dabovski, C. 1991. Modern concepts on the evolution of the Alpine orogen in the Eastern Mediterranean and the Carpathian-Balkan area. A review and some problems of Bulgarian geotectonics (in bulg.). Geotect., Tectonophys. And Geodynam., **22**, 45-79.

Dabovski, C., Harkovska, A., Kamenov, B., Mavrudchiev, B., Vasileva, G., Yanev, J. 1991. A geodynamic model of the Alpine magmatism in Bulgaria. Geol. Balc., **21** (4), 3-15

Dewey, J., Pitman, W., Ryan, W., Bonnin, J. 1973. Plate tectonics and the evolution of the Alpine system. Geol Soc Am Bull **84**, 3137-3180

Haydoutov, I. 1991. Origin and Evolution of the Precambrian Balkan-Carpathian Ophiolite Segment (on bulg. with engl. summ.). Ed Bulg Ac Sci: 179 p.

Gochev, P. 1991. The Alpine orogen in the Balkans – a polyphase collisional structure (in bulg.). Geotect., Tectonophys. And Geodynam., **22**, 3-44.

Grubic, A. 1974. Eastern Serbia in the light of the new global tectonics: Consequences of this model for the interpretation of the tectonics of the Northern Branch of the Alpides. *In: Metallogeny and Concepts of the Geotectonic Development of Yugoslavia (S. Karamata, ed.),* 179-212.

Grubic, A. 1980. An outline of geology of Yugoslavia. *26thInt Geol Congr Paris, Pint Depart Beograd,* 5-49

Hsu, K. J., Nachev, I. K., Vuchev, V. T. 1977. Geologic evolution of Bulgaria in light of plate tectonics. Tectonophysics, **40**, 245-256

Karamata, S. 1975. The geological evolution of the area of Yugoslavia: the nature and movements of plates and the importance of these properties and processes for metallogeny. *In: Metallogeny and concepts of the geotectonic development of Yugoslavia (S. Jankovic ed.), Fac. Min. and geol., Belgrade,* 109-118.

Nachev, I., Yanev, S. 1980. Sedimentary Geocomplexes in Bulgaria (on bulg.). Ed "Nauka i Izkoustvo": 203 p

Popov, P. 1981. On the tectono-metallogenic evolution of the Alpides in Balkan peninsula and situation of the Balkanides in them (in bulg.). Ann. HIMG, Sofia, **27**, 2, 27-35.

Popov, P. 1996. On the Tectono-Metallogenic Evolution of the Balkan Peninsula Alpides. *In Plate Tectonic Aspects of the Alpine Metallogeny in the Carpatho-Balcan Region IGSP Project No 356 Annual Meet., Sofia, (P. Popov, ed.)* ***1***, 5-17

Popov, P., Dumurdjanov, N., Jelev, V., Petrov, G. 1996. On Some Problems of the Alpine Evolution of the Bulgarian-Macedonian Part of Balkan Peninsula. *In: Terranes of Serbia (Knezevic V, Krstic B. ed.),* 97-102

Popov, P., Berza, T., Grubic, A., Ioane, D. 2002. Late Cretaceous Apuseni-Banat-Timok-Srednogorie (ABTS) magmatic and metallogenic belt in the Carpatian-Balkan orogen (in print).

Robertson, A. H. F., Dixon, J. E. 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. *In: The geological evolution of the Eastern Mediterranean. Geol. Soc. Blackwell Sc.. Publ., Oxford etc.*, 1-74.

Skenderov, G., Zhelyaskova, U., Arakelyants, A., Kotov, E., Palshin, I., Lilov, P. 1986. The biotite veins in Ustrem-Lesovo ore field and their significance as a geochronological marker (on bulg). Rev. Bulg. geol. soc., **47**, 3, 84-89.

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