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The Lece-Chalkidiki metallogenic zone: geotectonic setting and metallogenic features

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Abstract

Several characteristics define the contours of this significant metallogenic zone developed owing to post collision tectonomagmatic processes along the contact between the Vardar zone and Serbo-Macedonian massif (SMM): regional and local fracture structures, surface manifestations of the Tertiary volcanogene-intrusive magmatism and polymetallic mineralization styles (Pb-Zn, Cu, Au, Sb, As). The most striking are the fractures of NNW - SSE strikes as well as ring-radial ones typical of the volcanic structures (Lece, Zletovo, Pontokerasia). The absolute age of the calc-alkaline volcanic complexes ranges from 37 to 16 m.y. The strontium ratios for these magmatic rocks indicate a contamination of magma by material from the continental crust ($^{87}Sr/^{86}Sr$ 0.706318 - 0.706928). Ore deposits are grouped into several metallogenic districts and ore fields each characterized by specific styles of mineralization and a mineral/elemental association.

Kratka vsebina

Lece-Chalkidiki metalogeno cono, ki je nastala kot posledica post kolizijskih tektonomagmatskih procesov na stiku med Vardarsko cono in Srbsko-makedonskim masivom določajo regionalni in lokalni prelomi, vulkanogeno-intruzivne strukture in polimetalno orudenje s Pb in Zn, Cu, Au, Sb ter As. Najbolj značilni so v smeri NNW - SSE potekajoči prelomi in obročaste vulkanske strukture Leca, Zletova in Pontokerassia. Absolutna starost kalcijsko-alkalnega magmatizma, s katerim so v zvezi omenjene vulkanske strukture, je od 16 do 37 milijonov let. Izotopska sestava stroncija - razmerje $^{87}Sr/^{86}Sr$, ki je v območju od 0.706318 do 0.706928, kaže na kontaminacijo magme z materijalom iz kontinentalne skorje. Rudna ležišča so vezana za različne metalogene province ter rudonosna območja s specifično mineralizacijo in mineralno ter elementno asociacijo.

Introduction

The Lece-Chalkidiki metallogenic zone is situated in the marginal parts between the Vardar zone in the west and the Serbo-Macedonian massif (SMM) in the east. It represents an elongated metallogenetic unit starting with the Lece ore district in the N-NW, extending through the Kratovo-Zletovo, Buchim and Kilkis to the Eastern Chalkidiki ore districts in the S-SE. After this ore district, the zone under consideration, along with the Vardar zone, buries into the Aegean Sea and bends to Izmir in the east. It can be traced for over 700 km along strike with average width of 30 km (Fig. 1).

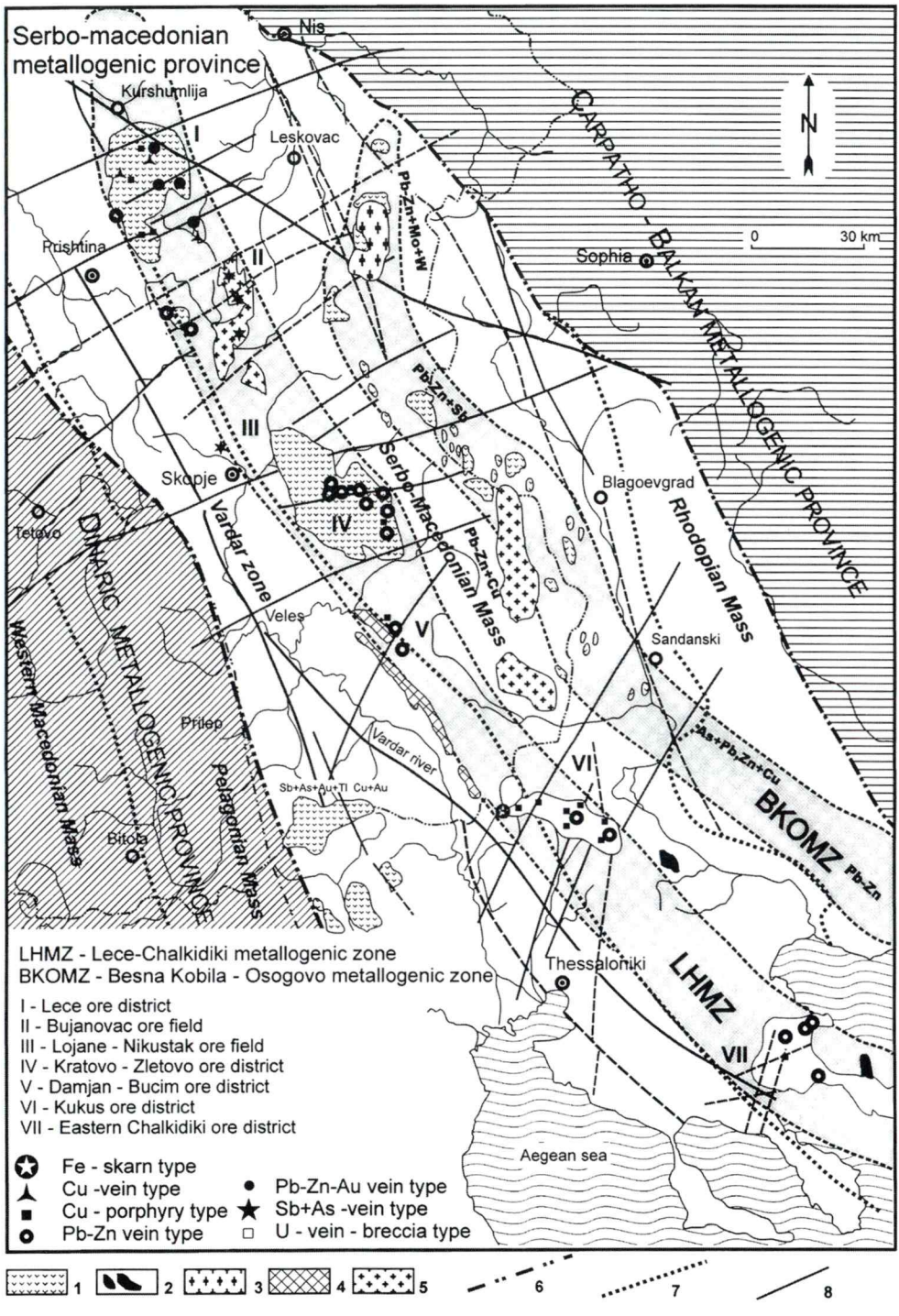

Fig. 1. Geotectonic and matallogenic position of the Lece-Chalkidiki zone

1. Neogene volcanics; 2. Tertiary intrusives; 3. Neogene granitoids; 4. Jurassic grano-diorites; 5. Hercynian granites; 6. Boundary of metallogenic provinces; 7. Boundary of metallogenic zones; 8. Lineaments

Lead and zinc are the dominant metals, followed by copper, gold, silver, antimony, arsenic and locally molybdenum. Uranium, PGE, bismuth and mercury also occur locally, but are less abundant.

Hydrothermal volcanogenic type of mineralization is most widespread - veins, stockwork-disseminated, and metasomatic (carbonate-hosted) deposits. Porphyry copper mineralization is related with subvolcanic and/or minor hypabyssal intrusions. Skarn type mineralization (mainly with magnetite and sulphides) occurs sporadically. Data about latest structural, magmatic, lithostratigraphic and metallogenetic characteristics which spatially belong to the Lece-Chalkidiki metallogenetic zone can be found in the papers of several authors. Among the first, mention should be made of those of Papadakis & Michalidis (1976), Arsovski & Ivanov (1977), Jankovic et al. (1980). However, detailed data, in terms of the metallogeny of the unit, are given by Serafimovski (1993).

Geotectonic setting

The Lece-Chalkidiki metallogenic zone developed along two regional tectonic units, the Vardar zone and the SSM.

The Vardar zone is a suture zone that developed following the closure of a branch of Tethyan ocean by Late Jurassic-Early Cretaceous times.

The SMM is a rigid tectonic block situated west of the Carpatho-Balkanides. The SMM may have been prior to the Cretaceous period an island arc, then welded with the Carpatho-Balkanides. It consists of Precambrian schists developed in two units-the Lower and Upper Complex. Such a tectonic environment was cut, during the Tertiary period, by several deep-fractured zones, striking mainly NNW-SSE. Calc-alkaline magmas penetrated along these regional dislocations at intervals, locally forming large volcano-plutonc complexes. The Lece-Chalkidiki metallogenic zone is associated with such structural-magmatic environment.

Regional dislocation controlled the position of the metallogenic zone and the volcano-plutonic complexes. The distribution of ore fields and individual deposits are mainly controlled by volcanic centers and local dislocations.

The parent magma was derived from the lowest level of continental crust, above the upper mantle. The collision between the African and the Eurasian plates resulting in thickening of the continental crust and its partial melting within the post-colision zone yielded calc-alkaline magmas. The strontium ratios indicate a contamination of magma by material from the continental crust (Table 1).

Table 1. The strontium ratio in the volcanics from Lece-Chalkidiki zone.

Locality	$^{87}Sr/^{86}Sr$ (%)	$^{87}Rb/^{86}Sr$ (%)
Zletovo	0.706318	0.4087
Borov Dol	0.706897	0.1246
Bucim	0.706928	0.2908
Damjan	0.706633	0.1459

The REE data may indicate similarities of igneous rocks in the Lece-Chalkidiki zone with those related with active continental margin (Serafimovski, 1993).The absolute age of this magmatism is in the range between 37.5 my and 16 my (Tables 2, 3).

Metallogenic features

The Lece-Chalkidiki zone is part of the Serbo-Macedonian metallogenic province as a larger metallogenic unit (Fig. 1). Polymetallic deposits are the basic metallogenic feature of the zone. Examinations performed defined various morphogenetic types among which hydrothermal lead-zinc and porphyry copper deposits are dominant (Table 1 and 2). Antimony vein and metasomatic lead and zinc (Olympias type) deposits are also dominant. In order to get a more complete view of the metallogentic features of individual deposits in the Lece-Chalkidiki zone the paper will give a detailed account of individual features of lead-zinc and porphyry copper deposits.

Lead and zinc are two prevailing ore metals in the zone under consideration discovered in many deposits and occurrences having various specific characteristics. In the Table 2 is given summary of the most signi-

Table 2. Metallogenic characteristics of the Pb-Zn deposits in the Lece-Chalkidiki zone

Deposit	Kiseljak	Buchim	Borov Dol	Vathi	Pontokerasia	Skouries
Host rock	Andesite	Gneiss/ Andesite	Andesite	Brecciated rhyodacite	Rhyodacite/ Granosyenite	Granodiorite Porphyry
Parent igneous rock	Subvolcanic stock/andesite	Subvolcanic stock/andesite	Subvolcanic stock/andesite	Rhyodacite dyke/Subvolcanic	Subvolcanic stock/dyke.	Stock; Granod
Absolute age, my	12-23	25-28	24-28	30	32	29.6
Horizontal projection	0.24 km^2	0.25 km^2	0.15 km^2	150x700 m	300x400 m 200x400 m	100x200 m
Vertical extent	300-500 m	250 m	300 m	500 m		700 m
Hydrothermal alteration	Biot,Ser,Sil,Pyr, Arg,Ch,Ty,Di,Cd Cr	Pot,Biot,Ser,Sil, Ch	Pot,Biot,Ser,Sil, Arg,Ch,Ep,Ca	Pot,Biot,Ser,Sil	Ser,Sil,Ch,Ar,Pyr	Pot,Ser,Arg,Ch
Association of minerals	Cy,Py,Mgt,Mo, Au,T,Ga,Sp,E,Bi	Cy,Py,Mgt,Au, He,B,Bi,E,Ga, Sp,Te,Ag,Pd	Cy,Py,Mgt,He, Mo,Au,B,Sp	Cy,Py,B,E,Ga,Sp, Mgt,He	Cy,Py:Stockwork diss,Ga,Sp,Veins	Cy,Py,B,Au,Mgt Sp,Ga,T
Main Constituents of ore	0.3 % Cu 0.3 ppm Au 1.0 ppm Ag 23 ppm Mo 4-10 % pyrite	0.3 % Cu 0.6 ppm Au 1.1 ppm Ag 13 ppm Mo 1-4 % pyrite Traces:Pd,Se,Te	0.3 % Cu 0.25 ppm Au 150 ppm Ag 24 ppm Mo 2 % pyrite	0.3 % Cu 0.15 ppm Au 0.35 ppm Ag 20 ppm Mo	0.3 % Cu 0.3 ppm Au 0.35 ppm Ag 20 ppm Mo	0.5 % Cu 0.7 ppm Au 2.5ppm Ag Traces: Pd,Te,Pt

Cy-chalcopyrite; Py-pyrite,B-bornite
Ga-galena; Sp-sphalerite; Mgt-magnetite
He-hematite; T-tetrahedrite; E-enargite
Bi-bismuthine; Au-native gold; Ag-silver min.

Pot-potassium; Biot-biotitization; Ser-sericitization; Sil-silification;
Agr-argilization; Ch-chloritization (proipilitic); Gr-greizenization;
(topaz,cassiterite, wolframite); Ep-epidotization; Ca-carbonatization
Pyr-pyritization; Ty-turmalinization; Di-diaspor; Cd-corundum

Table 3. General features of the porphyry copper deposits in the Lece-Chalkidiki zone

Deposit	Lece	Novo Brdo	Farbani Potok	Zletovo	Blizanci	Olympias
Host rock	Andesite, Breccias	Dacite, Andesite	Andesite,	Dacite, Andesite, Ignimbrite	Ignimbrite Quartzlatite	Granodiorite
Parent igneous rock	Subvolcanic intrusion/andesite	Subvolcanic intrusion/dacite, andesite	Subvolcanic dyke/andesite	Subvolcanic dyke/dacite, andesite	Subvolcanic dyke/quatzlatite	Subv.intrus /granodiorite
Absolute age, my	29.2	27.5	25.5	26.5	27	29.6
Horizontal projection	5.2 km^2	5 km^2	2 km^2	6 km^2	2.5 km^2	4.2 km^2
Vertical extent	800 m	300 m	800 m	1000 m	350 m	800 m
Hydrothermal alteration	Sil,Pyr,Kaol, Lim	Biot,Ser,Sil, Ch	Biot,Ser,Sil, Arg,Ch,Ep,Ca	Sil,Kaol,Ser,	Sil,Kaol,Ser,	Sk,Ep,Ser, Sil,Ca
Association of minerals	Ga,Sp,Py,Cy, T, Au,	Ga,Sp,Py,Pi, Cy, T	Ga,Sp,Py,Cy, Pi,T	Ga,Sp,Py,Cy, T,E,Mgt,He	Ga,Sp,Py,Cy,T	Ga, Sp, Py, Apy, Cy,T,E
Main Constituents of ore	1.5-2.5% Pb 3-5% Zn 4-7 g/t Au 15-30 g/t Ag	1-5 % Pb, 1-8 % Zn, 18 % Mn 3-4 g/t Au 100 g/t Ag	4 -12 % Pb 2-30 % Zn 150 g/t Ag	5.90 % Pb 2.07 % Zn 0.01 % Cd 44 g/t Ag	5.5 % Pb 2.61 % Zn 40 g/t Ag	3.5 % Pb 4.5 5 Zn 2.48 % As 6-7 g/t Au 130 g/t Ag
Mineral potential	800 000 t Pb+Zn 30 t Au 200 t Ag	500 000 t Pb+Zn 400 000 t Mn 15 t Au 450 t Ag	500 000 t Pb+Zn 750 t Ag	2.500000 t Pb+Zn 1300 t Ag	150 000 t Pb+Zn 70 t Ag	1.500000t Pb+Zn 400 000 t As 90 t Au 2 000 t Ag

Cy-chalcopyrite; Py-pyrite,Apy-arsenopyrite
Ga-galena; Sp-sphalerite; Mgt-magnetite
He-hematite; T-tetrahedrite; E-enargite
Au-native gold; Ag-silver min, Pi-pyrrhotite

Biot-biotitization; Ser-sericitization; Sil-silification; Kaol-kaolinization;
Pyr-pyritization; Lim-limonitization; Sk-skarnization; Ep-epidotization;
Ca-carbonatization; Ch-chloritization.

ficant metallogenetic features of the largest lead-zinc deposits in the zone. The table indicates that almost all deposits are associated with volcano-intrusive facies of Tertiary volcanism. Most of them have large horizontal strike in the mineralized area, the vertical range of mineralization exceeding 1000 m. All ore deposits possess complex mineral associations with galena and sphalerite as dominant minerals. Minerals contents are of interest in some deposits such as the gold contents in the Lece and Olympias deposits. The Zletovo is a typical vein type deposit, whereas Olympias is of hydrothermal metasomatic type. The ore mineralization in the Lece deposit is located within the silicified fracture zones. In addition to hydrothermal lead-zinc deposits, porphyry copper deposits discovered are also of interest. The basic metallogenetic features of this type of deposits, similarly to those already described, are shown in Table 3. The Table shows that they are low grade porphyry deposits of small horizontal and vertical range. Almost all porphyry deposits mentioned are in direct connection with subvolcanic dykes and stocks of the Tertiary igneous rocks. On average the copper content amounts to 0.3% except for the Skouries deposit. Gold content is also low except for the Buchim and Skouries deposits. A common feature of all deposits is the presence of various kinds of hydrothermal alterations which is a specific feature of porphyry copper deposits. It should also be mentioned that these deposits represent a specific group of porphyry deposits mainly connected with small subvolcanic intrusions. Besides the lead-zinc and copper deposits mentioned, skarn iron, epithermal arsenic and antimony, hydrothermal uranium etc. deposits are also determined in the zone. Compared with those described earlier, however, their significance, in terms of the metallogeny and economic interest, is much lower.

Conclusion

The Lece-Chalkidiki metallogentic zone under consideration represents a very important metallegentic segment in the geological composition in the south parts of the Balkan peninsula. It is essentally characterized by lineament structures, Neogene volcano-intrusive magmatism and polymetallic mineralization. Lead, zinc and copper followed by gold, antimony and arsenic are the dominant ore metals in the whole zone. The most significant mineral deposits are lead-zinc veins and metasomatic types as well as porphyry copper deposits.

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