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GEOLOGY OF ALSHAR POLYMETALLIC DEPOSIT, MACEDONIA

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Abstract: This work deals with the geological features of the Alshar deposit, the petrological characteristics of the volcanic rocks and with some moments related to the genesis of this low temperature hydrothermal deposit. together with the data about the age of the ore mineralization.

Key words: geology, Alshar

INTRODUCTION

The polymetallic ore deposit of Alshar is situated near Majdan village close to the Macedonian - Greek border in the south-western part of the Republic of Macedonia about 40 km south of the town of Kavadarci.

GEOLOGICAL AND STRUCTURAL FEATURES OF ALSHAR DEPOSIT

Alshar is a polymetallic sulphide deposit of antimony, arsenic, thallium, gold and silver. It was formed during the Neogene and is paragenetically related to the Kožuf tertiary magmatism. The ore deposit is located on one of the main tectonic ruptures which separates two large geotectonic units: The Vardar zone and the Pelagonian block "Elen Shupe" which belong to the border part of the Vardar zone. "Elen Shupe" is an elongated block with a NW-SE strike. It was built up of metamorphic rocks and granodiorites, as was the Pelagonian massif. The Alshar block tectonically overlies the eastern limb of "Elen Shupe".

According to its composition and geological features (lithological, stratigraphic and tectonic) the Alshar block belongs to the larger Vardar geotectonic zone. It was mainly built up of triassic marbled limestones and other metasedimentary rocks, schists and low degree metamorphic metasandstones as well as upper cretaceous sediments: conglomerates, sandstones, limestones etc.

A thin ophiolitic zone of northwestern extension with a series of serpentinized ophiolites, harzburgites and dunites, at some places intruded by diabases, is located between the two blocks, "Elen Shupe" in the southwest and Alshar in the northeast. The ophiolitic zone is in tectonic relation to both blocks. Further, two blocks have been cut by a transversal tectonic rupture with NE-SW extension which subsides towards the northwest. In the Neogene volcanic rocks were formed along this transversal line, on Mounts Kozuf and Kozjak, followed by strong extrusions of volcanic lavas and large masses of pyroclasts. Alshar polymetallic ore mineralization was formed at the crosscut of the main rupture near Majden village, with a NW-SE strike, and the transversal rupture with a NE-SW strike, as a result of the intrusion of the volcanic rocks with delenitic-latitic composition. This took place during a long period of time that started 5 million years ago. This conclusion has been drawn on the basis of numerous isotopic examinations of volcanic rocks taken from the vicinity of the deposit (Boev, 1988).

The ore deposit is located on the above-mentioned tectonic junction. The subvolcanic dike (delenito-latitic) was altered. The ore mineralization is in the dolomitized marbles in the contact parts and tectonic joints with a NE-SW and E-W strike. The ore solutions have mainly been deposited in dolomitized and silified marbles near the volcanic rock crosscuts. Mainly antimony-realgar mineralization with marcasite and gold in silified parts can be seen in the southern parts of the deposit, while realgar-auripigmentum mineralization with large contents of thallium minerals prevail in its northern part.

According to T. Ivanov (1964), the silified dolomites in the southern part of the deposit can be followed eastwards and transversally with a NW-fall, cca 250 m. Most of the deposit has been covered by upper pleistocene and quaternary sedimentary rocks and glacial occurrences.

A fluvioglacial detritus of pieces and blocks with different lithological composition is located in the most southwestern parts of the deposit. Borehole measurements have determined that the thickness of the detritus is about 30 m. Upper plioceneic and quaternary sediments which overlie the ore deposit consist of sandstones, clays, marls, gravel and tuffs. According to the determined fauna these sediments are considered to be Levantian rocks.

Many authors have studied the age of the volcanic tuffs and pyroclasts overlying upper pleistocene sediments in the Greek territory. J. Mercier and S. Sauvage (1965) determined the upper pleistocenic age on the basis of spores in the pyroclasts on Mount Voros (Kozuf). Nevertheless, we may come to the conclusion that the last volcanic stage on Mounts Kozuf and Kozjak took place during Upper Pliocene-Pleistocene. This has been proved by the age of the latitic lavas on the Greek side (between 1.9 and 1.8 m.y) (Kolios et al., 1980). The youngest trachytic and trachyrhyolitic rocks on our side can be found southwest of the Alshar deposit and Mount Kozjak in the vicinity of Sokol on the Macedonian-Greek border.

According to our knowledge the last volcanic stage on Mount Kozjak in relation to Alshar polymetallic ore deposit is post-ore formation. It produced large quantities of volcanic tuffs and pyroclasts in the northern parts of Mount Kozjak which overlie the upper pliocenic sediments and are of pleistocenic - quaternary age (Stafilov, Boev, et al., 1991).

VOLCANIC ROCKS IN ALSHAR DEPOSIT

The volcanic rocks in the deposit have been given by latitic-delenitic crosscuts. The examinations done so far by Boev (1988) gave the following chemical data for the 4 samples (the contents are given in %):

	1	2	3	4
SiO_2	56.70	60.12	61.77	59.80
TiO_2	0.78	0.70	0.60	0.70
Al_2O_3	18.15	17.75	17.72	17.95
Fe_2O_3	5.82	5.19	4.57	5.26
MnO	0.07	0.10	0.09	0.10
MgO	1.75	1.56	1.12	1.53
CaO	4.78	5.04	4.61	4.95
Na_2O	4.14	3.75	4.02	3.81
K_2O	5.58	3.80	4.28	3.80
P_2O_5	0.54	0.62	0.52	0.57
H_2O	1.35	1.36	0.69	1.53

Contents of the volcanic rocks: plagioclase, sanidine, biotite, amphibole, pyroxene.

Phenocrysts of fresh sanidine can be seen in strongly hydro- thermally altered volcanic rock in the crosscut near Majden village in the Alshar dyke. An isotopic analysis made by the K/Ar method in IGEM, Moscow showed that the consolidation of these volcanic rocks occurred 5.5 million years ago. We can also say that these subvolcanic rocks which underwent intensive hydrothermal alteration by the ore solutions had formed prior to the Alshar ore mineralization. The age of the tuffs is about 4.7 to 5.1 m.y. (Boev, 1990b). The age of the auripigment was determined as 5 m.y. by the "fission track" method (Jakupi et al., 19).

We can come to the conclusion that the Alshar deposit was formed over a long period of time - in the Pliocene, after the consolidation of the volcanic rocks. The data obtained by the determination of the rare Earths and the scattered elements shows that these rocks are rich in LIL elements, beryllium, stroncium and rare Earth elements: selenium, lanthanide elements and niobium as well as elements like nickel, chromium, copper, manganese etc.

HYDROTHERMAL ALTERATIONS IN THE ALSHAR DEPOSIT

The latite-delenitic dyke in the Alshar was hydrothermally altered. It cuts across the triassic sedimentary host rocks. The hydrothermal alterations are intensive in the host parties of the ore mineralization. They are represented by carbonate rocks and metasedimentary triassic rocks. A porphyrytic texture with fresh phenocrysts of sanidine and biotite can be seen through a microscope. The ground-mass is small grain with numerous alotriomorphic pyrite crystals.

Quartz is very common in the hydrothermally altered rocks, as a secondary mineral. The examinations of the hydrothermal alterations made so far determined the following changes: dolomitization of carbonate rocks, which can be found all over the mine, is most intensive. It has also been determined at a depth of more than 200 m. in the southern part of the deposit. The magnesium oxide contents in the dolomitic marbles ranges up to 22%. Argillitization can mainly be found in the volcanic rocks and is generally represented by kaolinization, the appearance of halloysite, sericitization and rarely vein carbonization.

Pyrophyllitization and chloritization are of small intensity (Boev et al., 1990). The dolomitic marbles have been intensively silified in the contact parts and the volcanic crosscuts in the southern part of the deposit. The silification is represented by small grained quartz. It is believed that the silification is closely related to the antimony ore mineralization and gold mineralization. Silified dolomites have not been determined at greater depths. The silification in the northern part resulted in the occurrence of chalcedony, while that in the marginal parts of the hydrothermal alterations resulted in opalitization.

Structural and Genetic Features of the Alshar Deposit. The Alshar deposit is located in the western margin of the Vardar zone. The tectonic margin was intensively fractured and mylonitized which resulted in its complex tectonic ore mineralization. The numerous small faults and fractures in the block have served for the penetration of subvolcanic rocks, as well as for the circulation of the hydrothermal ore solutions and for the deposition of the antimony-arsenic and thallium ore-mineralization (Ivanov, 1965).

The deposit was built up of metamorphic schists, triassic carbonate rocks and metasediments. It was formed in dolomitized carbonatic rocks and schists. It is important to point out that the deposit is divided into the northern and southern part. There are larger amounts of antimony than arsenic minerals in the southern part, while arsenic minerals prevail in the northern part. Thallium minerals are also present. They can be found in the lithological area of the whole ore deposit, but mostly in the northern part. Accumulation of marcasite ore bodies can also be found.

MINERAL PARAGENESIS, KINDS OF MINERALIZATIONS AND ORE BODIES

Because of its variety and rich mineralization Alshar is a unique ore deposit in the world. On the basis of the discovered ore mineral paragenesis it has been defined as antimony-arsenic--thallium-gold-silver bearing-barium deposit. This abundance of elements has mede possible the discovery of a large number of ore minerals formed by ascedent solutions of hypogenic and hypergenic origin (Ivanov, 1964).

The rich mineral paragenesis successively starts with high temperature associations of: magnetite, hematite, pyrite, arsenopyrite, bravoit, maucherite, marcasite, melnikovite, falkmannite, andorite, ramdorite, fizelite, bulangerite, polyvazite, native gold, moving to low temperature ore products like antimonite, bertierite, realgar, auripigmentum, lorandite, vrbaite, regenite, picopolite, clinopicopyrrhotite, parapyrrhotite, rebulite, simonite, bernardite, alsharite, native sulphur, baryte, and ends up in an association of secondary minerals: jarosite, senarmontite, valentinite, kermezite, servantite, stibiconite, scorodite, arsenolite, gypsum, azurite, malachite, epsomite, melanterite, lepidocrocite, galthite and limonite. Waste minerals are dolomite, quartz, chalcedony, calcite, opal etc.

A large number of thallium minerals are present in the mineral association. In terms of its amounts of thallium Alshar is the richest deposit in the world (Ivanov, 1965).

Several types of ore mineralization can be found:

- mineralization related to silifications (antimony, gold)
- mineralization related to silified tuffs and sedimentary rocks (antimony, arsenic, thallium)
- mineralization related to zones with explicit argillitization (thallium)
- mineralization related to fault and tectonic contact zones (arsenic, thallium)

The ore bodies posses different features as a result of the type of mineralization. The antimony mineralization in the southern parts is columnar shape with east-west elongation. It has been determined in horizons 852, 839 and 800 m.

Antimony and arsenic can be seen as disseminations, irregular forms and stringers. The variation coefficient for antimony and arsenic is 50.

The antimony-arsenic mineralization forms veins and depositions of small dimension and irregular forms in the altered dolomites.

The dissemination type of ore mineralization for the variation coefficient for antimony and arsenic is 100.

Specific crystalline antimonite drusies are distinguished in the vugs and caverns. Realgar can be found as thallium mineral (irregular or stringer occurrences) in the northern part of the deposit. The fractured arsenic-thallium ore bodies are found as silified dolomites and rarely in hydrothermally altered rocks with significant thallium mineral concentrations. This type of mineralization possesses large crystalline drusies of large auripigmentum crystals.

Marcasite ore bodies of massive sulphides with 90% marcasite are located in the central and marginal zones.

According to the latest calculation of the ore reserves in the Alshar deposit made by parallel cross sections we estimate 119 284 tons of ore of B + C category with 1.92% antimony and 0.69% arsenic (Stojanov, 1972). Calculations of thallium reserves have not been made. The thallium contents vary between 0.1 and 0.3% (Stafilov, Boev et al., 1991).

GENETIC AND METALLOGENETIC FEATURES OF THE DEPOSIT

The Alshar deposit was formed in favourable lithological, structural and tectonomagmatic conditions. According to our knowledge about the origin of the ore metals, the hydrothermal fluids, the conditions for the transportation of ore solutions from their source to the place of deposition as well as the mineral paragenesis, the succession of occurrences and the mineral relationships, we may say that the ore mineralization took place during a polyphase, long-term and complex genetic process. The ore mineralization is in close temporal, genetic-paragenetic and spatial relationship to the pliocene subvolcanic calc-alkaline magmatism (Stafilov, Boev et al., 1991).

The structural-tectonic predisposition had an impact on the intrusion of the volcanic and subvolcanic rocks and later on the hydrothermal solutions and fluids. This means that the ore mineralization occurred during the hydrothermal stage at different temperatures so that rich antimony-arsenic-thallium mineralizations occurred in the low heat epithermal phase at a temperature of 130 to 200 ^{0}C (Beran et al., 1990).

The hydrothermal phase started with such alterations as dolomitization, silification, sericitization, kaolinization, neobitization, chloritization etc. The ore mineralization started with the occurrence of the high temperature sulphide mineral paragenesis of arsenopyrite, pyrite, mancherite, marcasite etc.

The second hydrothermal phase took place as the result of a decrease in both temperature and pressure, which resulted in the occurrence of numerous mineral paragenesis of gold, silver, lead, and, partially, antimony. The third phase consisted of rich ore mineralizations like antimony, arsenic and thallium minerals. Finally, the hydrothermal process ended in the low temperature mineral products of barite, native sulphur, calcite, chalcedony, opal etc. The conditions for hypergenesis in the tectonized and surface parts are fairly favourable which resulted in the occurrence of a large number of secondary mineral products.

CONCLUSION

Alshar deposit is part of the Alshar ore district which belongs to the Kozuf metallogenic province (Janković, 1979). The metallogenic province lies normally to the main tectonic units: the Pelagonian massif, the Vardar zone, and the Serbo-Macedonian massif. The northern border lies in the territory of the Republic of Macedonia. Its southern border is in the territory of neighbouring Greece.

Beside Alshar and Dudica the ore mineralized points known so far are Smrdliva Voda, Dojran, Gradesnica, Susica, Ilovica, Stuka etc. This province contains homogeneous petrographic and magmatic composition such as the tertiary subvolcanic magmatism and ypunger volcanism.

The Kozuf metallogenic province contains copper-polimetallic mineralizations in the central zone (Dudica), lead-zinc and gold-silver in the middle and ore mineralizations of antimony and arsenic (Alshar, Konjsko, Susica, Gradesnica), thallium (Alshar), mercury (Konjsko, Dojran).

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