

AURIFEROUS MINERALIZATIONS IN THE MURGUL - ARTVİN - MARADIT AREA (NORTHEASTERN TURKEY)

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ABSTRACT.- The auriferous mineralizations, as the subject of this paper, are placed in the Murgul, Artvin and Maradit surroundings, in the extreme northeastern part of the Turkey. The area is between Black Sea coast to the northwest and Çoruh river to the east, northerly bordered by the Georgian - Turkish border and by the Artvin - Findıklı line to the south, including spring of the Murguldere. The field is made up of volcanic, volcanic-sedimentary, sedimentary and granitoid formations, from Jurassic to Quaternary time. In that period numerous composite petrogenetic complexes had been formed. The oldest is volcanic and volcanic-sedimentary complex including volcanic rocks of andesitic or intermediate-acidic character, Jurassic in age. They are accompanied by the Iskalka köprüsü and Budiyet köprüsü copper mineralizations. Gold in this complex has not been studied yet. This rock assemblage is overlain by the acidic rhyolitic and rhyodacitic volcanic and volcanic-sedimentary complex, associated with large copper deposits and a large number of still not explored or partly investigated copper occurrences, formed during the Upper Jurassic - Lower Cretaceous. The gold-bearing, related to this complex, is not distinctly developed. According to the present knowledge, precious metals as trace elements are registered in copper deposits in the Murgul surroundings (Anayatak, Çakmakkaya, Aduca dere, Kilise tepe etc), then in the Artvin vicinity (Kuarshan, Irsa Maden, Sinkot, Seyitler and Umasen). The similar gold and silver appearances are to be expected in the other copper mineralizations, particularly in the Hopa circles (Peronot, Sivrikaya, Kutunit and others). These copper occurrences and deposits are characterized by relatively low gold grades (mostly less than 0.5 ppm) and variable silver contents, with locally high grades (from traces to 180 ppm). However, if large copper reserves are taken into consideration, amounting more than 100 million tons, low grades became significant; at least 50 tons of gold and several hundred tons of silver is expected to be found. The next petrogenic complex was formed during the Upper Cretaceous - Paleogene time. This is a composite petrogenic unit, enclosing volcanic, volcanic-sedimentary and sedimentary formations. They represent a complete development, beginning from basalts and spilites, throughout andesites, to dacites and rhyolites. The most important rocks in this complex, bearing precious metals, associated with copper, zinc and lead mineralizations, are andesites, partly sediments, composed of re-deposited products of andesitic volcanism. In this petrogenic rock assemblage in the related metallogenic stage, two types of gold-bearing mineralizations are distinguished. These are the Akarşen, Hohur sırtı and Madenköy base metal deposit near Çayeli, with gold grading up to 11,43 ppm (in Madenköy) and silver contents ranging from several tens grams per ton of ore up to 241 ppm, including even 350 ppm in Akarşen galena. In the same complex, including the potentially ore-bearing sediments, such as tuffaceous sandstones, contents of 0,11 ppm gold and 2,25 ppm silver have been found. To the next precious metals type belong mineralizations nearby Pehlivan köy near Maradit. They occur in the highly hydrothermally altered andesites, with pyrite and copper minerals. As a special alteration type, adularization is remarkable, indicating the epithermal copper origin and accompanying the gold mineralizations. In only one sample 0,72 ppm gold and 50 ppm silver were detected. These features indicate it as a special mineralization type. The third of auriferous mineralizations is found in the Melo dere ravine (Gorge) near Artvin. This is the quartzdiorite, Eocene in age, locally bearing high chalcopyrite concentrations, with low gold grades (up to 0,03 ppm), but with higher silver (7,2 ppm). As it is visible from the presented facts, the Murgul - Artvin - Maradit area is considered as very interesting for the gold-bearing copper, zinc and lead mineralizations.

Key words: Gold, silver, volcanism, Murgul, Kuarshan, Artvin, Maradit, Turkey

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INTRODUCTION

The terrain with auriferous mineralizations that is the subject of this paper encompasses the metallogenic region between Hopa, Murgul, Artvin and Maradit (Artvin region, Fig. 1). Regardless of the fact that this region has been the object of interest and previous exploration, in the last 100 years or more, very little attention was given to gold and silver. However, during exploration for copper sulphides, zinc, lead and iron the gold content was occasionally determined. But, except data published by Kraeff (1963) on the gold and silver content in the polymetallic deposit Akarşen; data in the MTA inventory from 1966 for the deposit Kuvarshan, data on the gold content in Sinkot near Artvin (Kovenko, in Novović, 1979); Erseçen (1989) and Özgür (1992) for the deposits Anayatak and Çakmak-kaya, there were no serious attempts to investigate the concentrations, distribution and other characteristics of the noble metals in the mentioned region.

During exploration in the region of Murgul-Artvin-Maradit a large number of samples from numerous Cu, Zn and Pb mineralizations were collected from this region as well as samples from the sulphide deposit Madenköy near Çayeli. At the same time samples from the flotation concentrate were also taken. The collected material was analyzed and interesting results were obtained that served as a basis for this paper. Besides this, on the basis of field notes and limited literature data, knowledge was gained concerning the potential of some auriferous copper occurrences. Based on all the available data it was considered that it would be very useful to publish this data especially because, besides the published data by Özgür (1992) and sporadic information on the content of gold in some ore deposits, no published data exists.

BASIC GEOLOGICAL CHARACTERISTICS OF THE AURIFEROUS REGION MURGUL - ARTVİN - MARADİT

The most important geological characteristic of this region is volcanism. It represents those

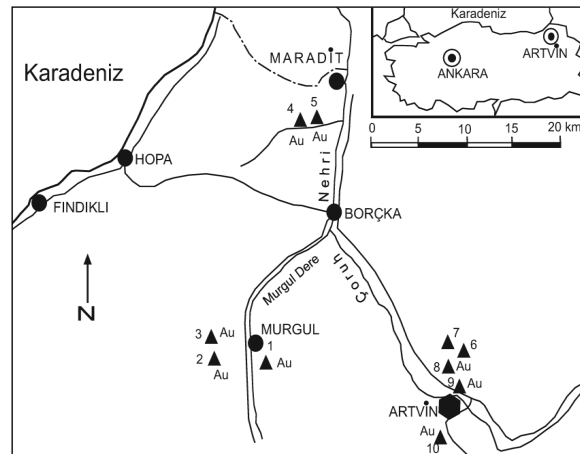


Fig. 1- Location map of gold- and silver-bearing sulphide occurrences in NE Turkey. 1. Anayatak and Çakmak-kaya, 2. Akarşen, 3. Hohur sırtı, 4. Pehlivan köy, 5. Çavuşlu, 6. Kuvarshan, 7. Irsa Maden, 8. Sinkot, 9. Seyitler and Umasen mahallesi, 10. Melo

activities which in a volcanogenic and volcanogenic-sedimentary environment played a leading role in the formation of sulphide deposits, mainly copper, followed by zinc, lead and molybdenum and with them associations of gold and silver.

Basically, in this region several periods of volcanic activity can be distinguished. The first occurred during Jurassic time, but it still is not more precisely defined.

In this period intermediate acid volcanogenic and volcanogenic-sedimentary formations were formed mainly composed of andesite volcanic rocks.

This is followed by Upper Jurassic - Lower Cretaceous volcanism that gave volcanogenic and volcanogenic-sedimentary formations mainly of rhyolite composition with which the largest copper deposits in this region are associated. After this period there is a break in volcanic activity, which is reactivated in Upper Cretaceous resulting in the creation of volcanogenic and volcanogenic-sedimentary formations. This volca-

nism is characterized with complete development, starting with basic rocks followed by intermediately acid to acid rocks. According to data of Pejatović (1979) it is mainly of tholeiitic composition. The intermediately acid part of this volcanism is characterized by the presence of copper, zinc and lead deposits with elevated contents of gold. However, they are of smaller economic interest than the deposits associated with the Upper Jurassic - Lower Cretaceous acid volcanism.

SIGNIFICANT METALLOGENIC CHARACTERISTICS OF VOLCANOGENIC ACTIVITIES WITH SPECIAL EMPHASIS ON NOBLE METALS (GOLD AND SILVER)

As already mentioned, the most significant characteristics of the Murgul region are large copper deposits of Upper Jurassic - Lower Cretaceous age with ore reserves totalling to over 100 million tons and a copper content of approximately 1%, and Upper Cretaceous - Eocene deposits (generally polymetallic) of copper, zinc and lead. Exploration of these deposits are not concluded and according to the existing knowledge the estimated ore reserves are below 5 million tons, but potentially much larger and with contents of copper, zinc and lead over 3%. In both cases these are mainly volcanogenic and volcanogenic-sedimentary deposits, of different mode of occurrence, starting with massive via stockwork-impregnation up to vein types and insignificant skarn mineralizations.

On the basis of existing data the most significant occurrences of gold and silver are in the deposits Anayatak, Çakmakkaya, Aduca dere, Hohur sırtı and Akarşen (in the vicinity of Murgul); Kuvarshan, Sinkot, Irsa Maden and others (vicinity of Artvin); and in the vicinity of Maradit (Güresen dere valley). All these localities are known as copper bearing where zinc is the most important accompanying metal and partially lead. However, gold and silver are also associated with these metals. Auriferous occurrences can be classified on the basis of the type of deposit and period of volcanic activity.

The oldest, auriferous mineralizations are associated with copper deposits formed during the activity of acid volcanism of rhyolite and rhyodacite composition during Upper Jurassic - Lower Cretaceous. This is the period when large copper deposits were formed. However, regardless of the fact that tennantite (silver bearing tetrahedrite) is often present in the paragenesis, in this period gold was not deposited in significant quantities, contrary to silver which often shows high concentrations.

After the Upper Jurassic - Lower Cretaceous metallogenic period a new Upper Cretaceous - Tertiary magmatism of tholeiitic composition followed. This volcanic activity is characterized by the presence of polymetallic deposits (copper, zinc and lead) and significant quantities of gold of which the most significant ones are Hohur sırtı and Akarşen (near Murgul), Pehlivan köy and Çavuşlu (near Maradit) and Madenköy (near Çayeli).

As an especially interesting copper occurrence, which has not yet been more precisely classified (it is believed that it is of Tertiary age) is represented with mineralized andesite volcanic rocks in the vicinity of Pehlivan Köy. Besides a high content of copper this occurrence also has elevated concentrations of gold. However, its significance is based on a very characteristic type of alteration that determines it as an epithermal type of deposit. The type of alteration in question is adularization, which was precisely determined. This is an important fact why this type of deposit is separated as a specific type of deposit and thus shall be presented as such.

AURIFEROUS MINERALIZATIONS IN THE VICINITY OF MURGUL

All auriferous mineralizations, in the vicinity of Murgul are grouped into two time periods. The first group is Upper Jurassic - Lower Cretaceous age when large copper deposits were formed. The second group is Upper Cretaceous - Tertiary (Palaeogene) in age when polymetallic deposit with significant concentrations of gold and silver

were formed. In general these deposits are of smaller economic interest than the first.

Upper Jurassic - Lower Cretaceous auriferous occurrences

As already mentioned, in this period large masses of rhyolitic volcanic rocks were formed in sub-volcanic and volcanic (mainly submarine) regions. At the same time, in association with these volcanic rocks large copper deposits were formed in the eastern Pontides. In the vicinity of Murgul a large number of copper deposits and occurrences with noble metals (Au and Ag) were formed. However a low content of gold is characteristic for these deposits. At the same time the content of silver varies with occasional high concentrations. Among these deposits the biggest and most important are Anayatak and Çakmakkaya followed by Aduca dere, Kilise tepe, etc.

Anayatak and Çakmakkaya.- Concerning the gold content for these two deposits very heterogeneous data exists. Pejatović (1979) quotes a report prepared by Daniels Griffith's Co - London from 1966 according to which 100 kg of flotation concentrate from Anayatak contains 1.2 g of gold (12 g/t) and 78.5 g (785 g/t) of silver. Subsequently in a joint paper (Engin, 1986) experts from M T A - Ankara quote the existence of gold occurrences in the vicinity of Artvin and Murgul. However, more detailed data and the gold contents are not cited. Furthermore, Özgür (1992) quotes that the average content of gold is 0.2 g/t and 25 g/t of silver.

Investigations carried out by the author of this paper were more detailed. Samples from Anayatak were analyzed and the obtained results are very interesting. Not taking into consideration the mineral composition and contents of the main elements (Cu, Zn, Pb, Fe, etc.) samples of different types of material were used: chalcopryrite with minor amounts of pyrite (or in other words rich chalcopryrite ore), amethyst, crystalline pyrite (pentagonal dodecahedron and octahedron) rhyolite tuff (hanging wall of the ore)

mineralized rhyolite tuffaceous breccia, mineralized rhyolite tuff, flotation concentrate of pyrite and chalcopryrite - pyrite (the last two were sampled 6.10.1970) from the Murgul flotation plant. The results of analyses of these samples are presented in table 1.

Data from table 1 clearly indicates that the gold contents are low and that the situation with silver is somewhat more favorable. In this sense the results of our investigations differ from the data quoted by Daniels Griffith's Co - London (1966, in Pejatović, 1979). In comparison to our results, significant differences are evident, which are difficult to explain. One of the possible explanations is that the flotation technology in 1970 was already out of date and that in the last years of the flotation plant in Murgul the percentage of recovery was considerably lower than in the beginning, not only for gold and silver but also for copper. However, it is a fact that the content of gold in the ore, which is mainly represented with chalcopryrite, and which can be almost set equal to the flotation concentrates low contents (table 1) of gold.

Table 1- Contents of microelements in ore and flotation concentrates from the Anayatak Deposit (ppm)

	Au	Ag	As	Bi	Mo
Chalcopryrite with minor quantities of pyrite	0.45	76-180	340	70	500
Crystalline pyrite	0.03	2	170	-	-
Amethyst mineralized with pyrite and chalcopryrite	0.05	1	250	-	5
Chalcopryrite-pyrite flotation concentrate	0.98	63	1740	320	60
Pyrite flotation concentrate	0.53	61	1140	-	-

According to this data it can be concluded that the copper deposit Anayatak basically has a low content of gold while the situation with silver is much more favorable. In the remaining samples the gold content are not of specific interest.

Kilise tepe.- Kilise tepe is located in the same zone as Anayatak and Çakmakkaya. All three

belong to the same volcanogenic phase of formation; they have the same mineral composition and occur in the same lithologic environment. However, investigations of noble metals, with the exemption of two samples, were not carried out. One sample represented pyrite-chalcopyrite impregnations in rhyolite tuffs. The gold content was 0.1 g/t and silver 7 g/t. The second sample represented mineralized quartz diorite (with 506 g/t of lead, copper 810 g/t and zinc 1.27%) where only 0.02 g/t of gold and 3 g/t of silver were found. For the other deposits, that are synchronous with Anayatak and Çakmakkaya, no data for the content of noble metals is available.

Regardless of the fact that no systematic investigations were carried out this situation leads to the conclusion that Jurassic - Neocomian metallogeny of copper is not characterized with elevated contents of gold. As a whole it can be concluded that the gold content in these copper deposits is generally low. Silver is of interest only locally when it is associated with chalcopyrite.

In the case of pyrite, which is illustrated by the crystalline pyrite sample, it is evident that gold is not associated with this mineral. The situation with silver is very similar. It is interesting to mention that higher concentrations of zinc are associated with elevated concentrations of noble metals. However, this correlation is not completely proven.

Considering the minerals that are carriers of gold and silver it can be assumed that chalcopyrite, arsenopyrite, probably sphalerite, and certainly tennantite are the main carriers of noble metals.

Upper Cretaceous - Tertiary (Palaeogene) auriferous sulphide mineralizations

Auriferous mineralizations, associated with this geological time period, located in the northeast part of Turkey cover a large area. In the northeast - southwest direction it spreads for approximately 150 km, in the northwest - southeast some 40 km. In the northeast this zone

begins at Maradit and in the southwest ends at Çamur yayla. However, this is not its end towards the southwest; many authors consider that it continues towards Madenköy at Çayeli. All auriferous mineralizations were formed in this time period and are associated with volcanogenic and volcanogenic-sedimentary formations with which polymetallic occurrences and ore deposits are also associated. In relation to the Upper Jurassic - Lower Cretaceous volcanogenic and volcanogenic-sedimentary complexes, sulphide deposits in this Upper Cretaceous - Tertiary complex are characterized with considerably higher concentrations of gold.

Auriferous occurrences in this period are localized in a region that is bordered with the international border of Turkey with Georgia, river Çoruh, Balıklı yayla and Çamur yayla. These are occurrences near Maradit (Çavuşlu and Pehlivan köy), near Murgul (Hohur sırtı and Akarşen) near Artvin (Melo dere Gorge). The polymetallic deposit Madenköy near Çayeli should be included in this group.

Hohur sırtı.- Occurrences of auriferous sulphide mineralizations at Hohur sırtı are located on a ridge that connects Hohur and Akarşen. This occurrence is located some 2.5 km west of the small town Murgul. The auriferous sulphide mineralization is located on the northwest slopes of Hohur sırtı with the highest point of 1075 m.

The geology is represented with marl, marly limestones, basalts, spilites, andesites, partially dacites and dacite-andesite pyroclastic rocks (tuffs, agglomerates, breccias, and tuffaceous sandstones), sandstones and limestones.

The auriferous mineralizations are associated with sulphides of copper, zinc and lead.

Due to the thick overburden of diluvium sediments and presence of active landslides, only one occurrence can be characterized as an "in situ" outcrop. However, the mechanical aureole of dispersion allows the assumption that there are several outcrops on this terrain. On the loca-

tion of one outcrop an old shaft and slag dump exist. Unfortunately it was not possible to determine by whom and when mining was carried out. It can be assumed that copper was mined. This ore occurrence was opened with extensive trenching with a team of geologists where the author of this paper was a member. Trenching showed that it belongs to an ore zone that could be followed for approximately 200 m and with an approximately north - south strike (Popović, 2002). This zone is intensely hydrothermally altered where kaolinization, silicification, pyritization and carbonization are the most dominant alterations. In the paragenesis the main ore minerals are: pyrite, chalcopyrite, sphalerite and occasionally galenite and tetrahedrite. The last mineral occurs as inclusions in chalcopyrite and sphalerite. Besides this traces amounts of marcasite, bismuth sulfosalts and secondary minerals of copper were determined.

Systematic sampling of the trench showed that the gold content varies from 0.5 to over 5 g/t and silver from 16 to 182 g/t (Table 2; Popović, 2002). Based on the mode of occurrence in the outcrop it can be concluded that this mineralization is of the stockwork-impregnation type with significant concentrations of gold and silver. Outside the mentioned outcrop only partial exploration was carried out rocks from the mechanical dispersion halo. Similar or identical results, concerning the contents of noble and base metals, were obtained. Other exploration works were not carried out.

Besides this occurrence, on the ridge between Hohur and Akarşen, in the horizon with tuffaceous sandstones, sulphide mineralization occurrences with elevated contents of gold and silver were also discovered (Table 3).

Due to the fact that this is a sedimentary rock it is certain that this mineralization (in spite of the low contents of gold) was formed by volcanogenic-sedimentary processes. The content of lead and zinc are higher than those of copper. However, this does not change anything. On the contrary, the contents of noble and base metals clearly indicate that this environment represents

a significant setting for the discovery of new deposits in the Murgul metallogenic region.

Akarşen. - Akarşen mountain with its 1769.8 m peak is located some 4 km southwest of the Hohur sirtı. A polymetallic deposit of copper, lead, zinc and noble metals is located in the vicinity of this peak. This deposit is known for over 100 years and it was mined in one period.

The geological formations in this region and in the vicinity of the deposit are almost the same as those at Hohur sirtı. The difference is that at Akarşen several smaller masses of quartz diorite occur that are accompanied by contact-metamorphic alterations.

The ore deposit Akarşen is composed of numerous ore bodies, of which some are associated with volcanic rocks. Their mode of occurrence is in the form of veins or impregnations. It is assumed that they are of volcanogenic origin but some of the ore bodies are of volcano-sedimentary origin. This is evident from the oval ore structures (Vujanović, 1976; Popović and Vakanjac, 2002) and sediment rocks with sulphide mineralization (this was described with the auriferous occurrences at Hohur sirtı).

In the ore paragenesis of this deposit the following minerals were identified: pyrite, chalcopyrite, sphalerite, galenite, tetrahedrite and argentite. It seems that tennantite is the main tetrahedrite mineral and is thus, together with argentite, the main carrier of noble metals.

According to the data of Kraeff (1963) the content of gold in the ore varies from 0.25 g/t to 7.2 g/t (the highest content of gold in the region of Murgul), according to the same author the content of silver is 338 g/t. With our investigations the following results were obtained (Table 4).

On the basis of all available data for this deposit, ore reserves of over 1 million tons should be expected, with a high content of copper, zinc, gold, silver and bismuth. At the same time it is estimated that 2 to 3 tons of gold and over 50 tons of silver can be expected. These

Table 2- Chemical composition of auriferous sulfide mineralizations at the Hohur sirtı (Popović, 2002).

contents ppm			contents %				
Au	Ag	Cd	Cu	Zn	Pb	As	Bi
5.32	84	-	4.84	7.75	0.10	0.10	0.022
0.44	20	42	2.72	13.50	0.02	0.04	-
0.85	22	-	1.26	0.60	0.26	0.13	-
0.48	16	-	2.11	0.41	1.03	0.03	-
x	182	1280	1.00	1.50	0.26	-	-

x- not analyzed

Table 3- Contents of some metals in tuffaceous sandstone.

contents in ppm					
Au	Ag	Pb	Zn	Cu	As
0.11	2.25	2200	2950	556	217

Table 4- Contents of noble metals and some microelements

contents in ppm				
Au	Ag	As	Bi	Cd
1.9	53	590	1700	40
3.84	75	x	x	x

x- not analyzed

estimates are a great challenge and encouragement not only for geologists but also for investors.

In the scope of this it should be mentioned that in the river Murgani Hevi, that drains the tributaries from Akarşen, a fragment of galenite was found where 0.03 g/t of gold and 350 g/t of silver were registered. This also has to be taken into account when evaluating the significance of Akarşen for noble metals.

OCCURRENCES OF NOBLE METALS IN THE VICINITY OF ARTVİN

Occurrences of noble metals in the vicinity of Artvin are mainly connected with sulphide mine-

ralizations of copper. These are: Kuarshan, Irsa Maden, Sinkot, Seyitler, Umasen and the Melo dere Gorge. Similar to the vicinity of Murgul the auriferous mineralizations can be classified according to the petrogenetic environment in which they occur. On the basis of this the following type of occurrences can be distinguished: associated with rhyo-dacite volcanogenic and volcanogenic-sedimentary complex (Jurassic - Neocomian) and occurrences associated with rock of Palaeogene age. Sulphide occurrences and deposit of copper, a lesser amount of zinc and lead are located on the right bank of the river Çoruh. The others are associated with granitoid rocks in the Gorge Melo dere.

Upper Jurassic - Lower Cretaceous auriferous occurrences

The auriferous sulphide occurrences, on the right bank of the river Çoruh, are associated with the rhyo-dacite volcanogenic and volcanogenic-sedimentary complex, regardless of the fact that numerous authors disagree about their age of formation. But due to similarities with the same types of formations in the vicinity of Murgul it is considered that these occurrences, considering the time of formation, should be treated the same way.

The region of Kuarshan.- encompasses several occurrences and deposits of which only the locality Kuarshan on the right bank of the river Çoruh is wellknown. According to this it is logical that this zone, some 10 km long, is named after this deposit and therefore the ore zone

Kuvarshan includes deposits and occurrences Kuvarshan, Irsa Maden, Sinkot, Seyitler and Umasen. All of these deposits and occurrences are located in the same petrogenetic environment (rhyo-dacites) and are characterized with intense hydrothermal alterations, especially pyritization, kaolinization, bleaching and silicification (Fig. 2).

The copper bearing ore deposit Kuvarshan is located some 4 km east of Çoruh. It is characterized with several ore bodies in the form of veins of lenses. According to data of previous authors (especially Kovenko, 1942; Kraeff, 1963; Novović, 1979; Simonović, 1972) copper ore in this deposit is associated with a tectonic (fault) zone and rhyo-dacite as the host rock. The ore, besides copper minerals such as chalcopyrite, bornite, chalcocite, contains pyrite as the most abundant mineral and this is why this copper deposit is defined as a pyrite type. Besides, the quoted minerals the ore also contains sphalerite that is relatively abundant and galenite and tetrahedrite that are present in minor quantities. A very important characteristic, for this paper, represents tetrahedrite, more precisely tennantite, which strongly indicates that in this deposit, elevated contents of, primarily, silver and lower contents of gold can be expected. It should be pointed out that no systematic investigations for gold and silver were carried out. In some documents (Engin 1986) it is quoted that gold deposits exist in the vicinity of Artvin, but without precise data on the locations. However, in another MTA inventory (MTA, 1996) a sample that contains 1 g/t of gold and 25-30 g/t of silver is mentioned. On the basis of this fact as well as information for other copper deposits of the mineral, stratigraphic and genetic characteristics it is possible to expect elevated concentrations of these two noble metals. As a confirmation of this opinion one more relevant fact are the determined elevated contents of gold at the Sinkot occurrence. Unfortunately, sampling that was carried out by Simonović (1972) and where the determined copper content varied from 0.06% and 6.01%, zinc from 0.31% up to 0.74%, the contents of gold and silver were not analyzed.

Irsa Maden.- is located 3 km north of Kuvarshan. As in the previous case this deposit was explored several times during the 20th century. Based on the data of Simonović (1972) this is the richest deposit in the vicinity of Kuvarshan. The content of copper is in the range of 0.01% - 7.33% and zinc from 0.32% up to 34.69%. Lead is partially absent, but in the rare galenite accumulations the lead content varies from traces to 24.82%. The mineral composition is represented with: pyrite, as the most abundant, followed by sphalerite, chalcopyrite, enargite, and rare tennantite. The most abundant secondary copper minerals are bornite, chalcocite and covellite. Galenite is present in significant quantities only sporadically.

Similar to Kuvarshan, in the deposit Irsa Maden tennantite was also determined in quantities that could be defined as insignificant. On the basis of this it can be assumed that, primarily, relatively significant quantities of silver can be expected. However, gold should not be excluded. The presence of tennantite in almost all deposits of north-east Turkey, in the forms of exsolutions in chalcopyrite indicates that it is possible to expect significant concentrations of silver in these deposits.

Sinkot.- is the next locality in this ore zone. The occurrence is located some 2.5 km southwest of Kuvarshan. It is characterized with intense hydrothermal alterations and very often a developed iron hat (gossan) above parts of the deposit with high concentrations of pyrite. As in the case of the two previously described deposits this deposit was the object exploration on several occasions; it was concluded that pyrite, as the most abundant mineral and source of the gossan material, and chalcopyrite are the main constituents of the ore paragenesis. This is a typical pyrite copper deposit where the contents vary from 100 g/t up to 7.64% of copper. The content of zinc varies from 0.28% to 2.26%; the content of lead only sporadically reaches 0.25%. However, what is significant and indicates a certain potentiality for noble metals, not only at this locality, but also for the whole ore zone Kuvarshan, are the contents of Au and Ag. Accor-

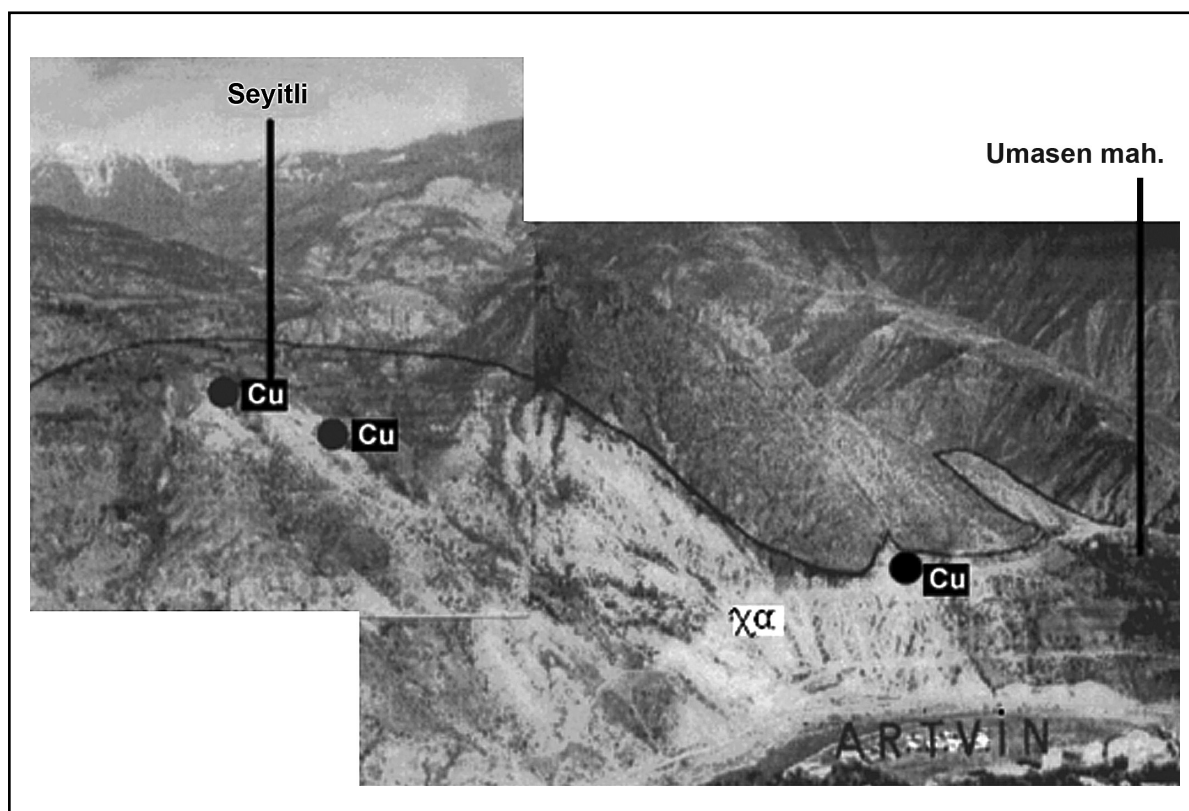


Fig. 2- View of the Seyitler and Umasen area with Cu, less Zn and rare Pb mineralizations in rhyolite volcanites (X^{α}) intensely hydrothermally altered.

ding to Novović (1979) who quotes Kovenkov's data, the content of gold varies from 0.25 g/t up to 0.5 g/t. This is obvious proof that possibilities of discovering higher concentrations of gold and silver exist (Table 5). Previously, insufficient attention was given to these possibilities.

They are located in the most southern part of the ore zone in the immediate vicinity of the Çoruh river (Fig. 2). Here, at a distance of 1 to 2 km several copper mineralization outcrops occur. The occurrences were also investigated in the past on several occasions. As in the previous occurrences, pyrite, chalcopyrite, sphalerite, rare galenite, tennantite were determined in the primary paragenesis. Chalcocite, covellite, malachite and limonite were identified among the sec-

ondary minerals. As shown it is obvious that tennantite is always present and taking into consideration that elevated contents of gold and silver were determined in them then it is logical to predict that the whole zone, starting from Kuarshan, via Irsa Maden and Sinkota all the way to Seyitler and Umasen mahallesi is gold and silver bearing.

Upper Cretaceous-Tertiary (Palaeogene) auriferous mineralizations

Occurrences registered west of Maradit occur exclusively in Senonian - Palaeogene volcanic rocks. In this region numerous sulphide mineralizations of copper, zinc and lead were discovered. Noble metals that are associated with

Table 5- Contents of gold and copper in Sinkota (Novović, 1979).

Au ppm	0.50	0.25	0.28
Cu %	0.80	0.07	0.24

the base metals were only partially investigated on samples from outcrops that were discovered in the valley of Güresen dere. One outcrop is located near the village Çavuşlu and named after this village. The second is located in intensely altered andesite volcanic rocks and named as the Pehlivan köy occurrence (Fig. 1). They are located approximately 1 km from each other. The occurrence Çavuşlu is located 1 km from the confluence of Güresen dere into the Çoruh river.

Some of these occurrences were known earlier. It is not clear for which occurrence is the data quoted in MTA (1966). Metal contents for this imprecisely located occurrence are as follows: Copper up to 9.23%, lead 5.86% and zinc 0.81%. The content of gold varies from trace amounts up to 3.5 g/t and silver 41 g/t. On the basis of the zinc and lead content it can be assumed that this is the vein occurrence Çavuşlu.

Sulphide occurrence Çavuşlu.- Concerning this occurrence it should be mentioned that this is an outcrop of a galenite-sphalerite vein that was investigated in the first half of the 20th century. This is confirmed by the existence of an old adit that was used to explore the approximately 1 m thick vein. The strike of this vein is NE - SW with a 500 dip towards southeast. The paragenesis is represented with: galenite, sphalerite, pyrite, chalcopyrite, arsenopyrite, pyrrhotite, tetrahedrite (probably tennantite). Two 1 m samples were taken (Popović, 2002) and the following contents on table 6 were obtained. According to the element contents it is obvious that zinc is the leading component in this occurrence, but the contents of lead and copper are also significant.

Table 6- Chemical composition of the ore vein Çavuşlu

Sample No.	%				ppm	
	Zn	Pb	Cu	As	Au	Ag
Sample 1	10.00	1.50	0.60	0.10	0.04	47
Sample 2	9.50	1.90	3.50	0.15	0.07	65

Of the noble metals, because of its contents, silver is of prime importance. It is assumed that silver is associated with tennantite. The content of gold is low and is therefore of lesser importance.

Pehlivan köy.- It is located 1 km west of the occurrence Çavuşlu towards Pehlivan köy an intensely hydrothermally altered andesite rock impregnated with pyrite and chalcopyrite. Besides, alterations, this andesite has a high content of malachite regardless of the fact that it has a low content of chalcopyrite, and this is the source of the high copper content. This occurrence differs from the previous in many ways. The previously described occurrence is a sphalerite-galenite vein. This occurrence is exclusively characterized by a copper mineralization. Its mode of occurrence is of the impregnation or stockwork - impregnation type. The previous one is associated with a fault and this one is a mineralized andesite. And finally, a special characteristic is the occurrence of adularization, which is characteristic for epithermal alterations. On the basis of this it is considered that this is a typical epithermal mineralization.

Regardless of the fact that no systematic sampling was carried out, the results show that the contents of zinc and lead are very low (maximum 900 g/t of Pb). However the content of copper varies up to 11.35% (it should be noted that this concentration was obtained from samples that were taken from the surface of the outcrop where supergene enrichment occurred). It is not possible to bring precise conclusions about the content of noble metals because only one sample was analyzed. This sample gave 0.72 g/t of gold, silver varied from 14 to 50 g/t (Popović, 2002).

Taking into account the proven adularization allows an optimistic prognosis that this occurrence deserves much more attention, not only as an occurrence of copper but also for noble metals.

Having in mind the fact that this occurrence belongs to the Upper Cretaceous - Tertiary volcanogenic and volcanogenic-sedimentary complex which were synchronous with this complex, it can be concluded that all occurrences in the region Murgul - Artvin - Maradit are epithermal types. With this the total potentiality of the sulphide mineralizations with which noble metals are associated considerably increases.

MADENKÖY

During our investigations we also visited the large polymetallic deposit Madenköy near Çayeli. On this occasion several samples were taken which were analyzed for noble and base metals. Because, this deposit is located in the same tectonic and metallogenic zone as Hohur sırtı and Akarşen we consider that it is interesting to quote the contents of metals that were obtained in the taken samples. Connecting this into a unique Upper Cretaceous - Tertiary zone, it can be considered that the region between Akarşen and Madenköy has a significant auriferous potential. This is also the opinion of other authors (Pejatović, 1973/1979). Therefore we considered that it is necessary to present our informative data here. This is important because of the high concentrations of gold and silver in Madenköy. The gold content is up to 11.43 g/t and silver up to 241 ppm.

CONCLUSION

Starting with the presented data it is obvious that the north-east part of Turkey, i.e. the region of Murgul - Artvin - Maradit, has a very significant ore potential. Primarily this is valid for copper as the leading metal. This is supported by the fact that the estimated ore reserves (including the already mined) are over 100 million tons with an average content of 1% Cu. Zinc follows copper but with smaller potential, and it is associated

with copper or polymetallic deposit where it is associated with Pb and Cu.

All the deposits and ore occurrences to a smaller or larger degree contain gold and silver. However, it should be pointed out that these sulphide deposits can be classified into two major groups. They are defined by their time of formation, association of metals, petrogenetic environment in which they occur, dimension of the deposits, content of metals and degree of gold and silver contents. On the basis of noble metals the deposits and ore occurrences can be classified associated with Upper Jurassic - Lower Cretaceous volcanogenic and volcanogenic - sedimentary complex of rhyolite and rhyo-dacite composition. The second group is represented with deposits and ore occurrences that are genetically associated with volcanogenic, volcanogenic - sedimentary and partially to sedimentary complex that was formed during Upper Cretaceous and Tertiary (Palaeogene) times.

The most dominant in the first group are deposits of copper that is followed by zinc and minor quantities of other metals (Pb, Mo). Usually, these are large deposits with ore reserves (individually) of over 10 million tons and content of copper around or over 1%. The second group is represented with polymetallic deposits with Pb, Zn and Cu as the leading metals. In general, these are small deposits and in the studied region the reserves of these deposits (individually) are less than 10 million tons with an average content of Pb + Zn + Cu over 5%. The polymetallic deposit Madenköy is an exemption because a part of the ore bodies contain over 1% of copper and ore reserves over 10 million tons. In the second group of ore bodies Pb - Zn are dominant with ore reserves of over 20 million tons and an average content of over 10% for the two metals.

Considering noble metals an important characteristic is the presence of tennantite in all deposits in the Murgul - Artvin - Maradit region. Besides, these argentite was registered in the polymetallic deposits which is a convincing fact concerning serious concentration of silver in both

type of deposits. However, for the older Jurassic - Neocomian deposits the gold contents are generally low (below 0.5 g/t). In the second case, the content of gold and silver in the polymetallic deposits are considerably higher (up to 11.43 g/t of gold and almost 400 g/t of silver).

On the basis of the existing knowledge the average gold content in Anayatak is 0.24 g/t; silver varies from 20 g/t up to 180 g/t but with an average of 25 g/t. Similar or even lower contents of gold and silver were registered in the vicinity of Artvin.

On the other hand in the polymetallic deposits at Murgul (Hohur Sırtı and Akarşen) the gold content varies from 0.44 g/t up to 8 g/t and silver from 22 g/t up to 180 g/t. In one sample of galenite, from the vicinity of Akarşen, 350 g/t of silver were found.

For the vicinity of Artvin there is little data for the content of noble metals in the Upper Cretaceous - Palaeogene formations. In the case of Maradit the gold content in the polymetallic vein occurrence Çavuşlu varies from 0.04 g/t up to 0.07 g/t, silver is from 47 g/t up to 65 g/t. In the second occurrence in this region, at Pehlivan köy, the content of gold is 0.72 g/t and silver up to 50 g/t. However, what is more important is the adularia type of hydrothermal alteration, which indicates epithermal mineralization. This opens numerous possibilities for the discovery of copper and gold deposits of epithermal type.

Finally in this paper Madenköy near Çayeli is included where 11.43 g/t of gold and 241 g/t of silver were determined.

As it can be seen the region of Murgul - Artvin -Maradit has exceptionally large potential not only for copper, zinc and lead but also for noble metals, in this case gold and silver.

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