COPPER-LEAD-ZINC METALLOGENIC PROVINCE IN PONTIDES, NORTHERN ANATOLIA

Y. BURKUT*
F. SUNER*

Introduction

The northern Anatolian metallogenic province has located geographically within the Black Sea Region and it has yielded parallel the sea in an area of about 150-300 km. This metallogenic belt is called as the Pontides and it is limited by the Black Sea from the North; by Northern Anatolian Fault from the south. The Eastern point of the belt includes Kafkas Mountains; the Aegean Sea is the western limit of the belt. (Figure 1). The Northern Aegean Part is also included into in this belt. Although this part contains some different geological sequences; it also canies some similar geological, tectonic and metallogenic properties; therefore we have taken into account this region into the Pontides as the other authors have accepted.

On the other band, in this study, we have summarised simply the complex stratigraphic tectonic and petrologic structures. We have not studied in detail the chrome bearing ultrabasic rocks and other magmatic and sedimentary ore occurrences obsei-ved in the Pontides.

General Geologic Properties of the Region

The Pontides can be subdivided into three parts as Western, Central and Eastern Chains. In these areas, there are three main groups of rocks; basement rocks consisting mostly of metamorphics, sedimentary - cover rocks and magmatic rocks. In the assemblage, several tectonic phases have been developed from Caledonian to Helvetic stage after which it was not observed considerable movements. During these tectonic regimes, continuous magmatic activities have been manifested in the area depending on

"Y. BURKUT <F.
F. SUNER
Department of Ore Deposits - Geochemistry, Istanbul Technical University, Istanbul, 80670, Turkey
Figure 1. General geologic and tectonic units of Pontides
orogenic periods. Around Kocaeli Peninsula and Marmara Sea, granitoides originated from Hersinian Phase; around Kiire (Kastamonu), Kimmerian gabbros-diabases-dolerites; in Giiratt§hane, Liassic granites and Tertiary granodioritic massives in Eastern Pontides together submarine volcanic activity during Cretace - Eocene periods have been observed (Figure 1).

The oldest formation in the area is arkosic serie that contains no fossils. In the serie, that is mostly outcropped around istanbul (Kocaeli peninsula), pelitic sandstones, arkosic conglomerates and arkoses are the main units most of which are probably Cambrian age. This sequence is overlain by Ordovician graptolite bearing shale unit that is overlain by Silurian greywake series that include quartzite veins. The top of these unites have covered by Halicitas bearing massif limestones. The other observed units were Pleuradictium - Trilobites bearing Devonian slates, clayey schists and Carboniferous hard coal seams and levels. They are observed in Zonguldak region, and deposited over Danintian limestones interbedding with Namurtian and Westfalian Sandstones and slates. In the region, Permian is represented as Fusulinas bearing limestones especially in Inegol (Bursa) district, the bottom of which was effected by metamorphism.

The Mesozoic has been determined with Triassic basement conglomerates making angular disconformity with Palaeozoic formation especially around Gebze (Kocaeli). Jurassic and Cretaceous formations were distinquised in two groups: as flysh and limestone sequences, containing Ammonites and Belemnites showing the properties of marine facies. Volcanism and plutonism, which were active in these epochs throughout Pontides, were resulted in ore formations and depositions in the area and this period has also related to the paroxysm phase of Alpine tectonism.

In the investigated area many sedimentary units ranging in age from Antecambrien, Cambrian to Paleozoic were generally subjected to regional metamorphism. They have been transformed to gneiss, micaschists and phyllites. Most of these rocks have been intruded by many granitoids that were originated by subduction or obduction related magmatic activities. As a result of this cutting process, contact metamorphism has been worked together with ore formations at the fractures and failed zones. Especially at the contacts of limestones - marbles with granodioritic granitoids, it was determined the contact deposit as pyrometasomatic skarn zones that were largely observed in Pontides (BiirkUt, 1966), (K6priiba§y, 1993 and Gedikofllu, 1982). The alterated plutonic rocks were very near to these zones and schelits are the main ore-minerals observed in these kinds of mineralizations. Various sulphur minerals, such as molybdenite, chalcopyrite, pyrite, and oxide minerals, such as hematite, magnetite, were the other and frequently observed principal occurrences.

The most typical example of these mineralizations, which were generally formed from I - type, sometimes hybrid, intrusions, was discovered in Bursa, Uludag Tungsten deposits. The mineralization has settled down at the contacts of Palezoic marbles and muscovite - biotite bearing granodiorite, the minimum age of which was determined as 24 million years using K/Ar method by Biirkut (1966). This process has also resulted in molybdenite formation in Gelemic, the province of Bursa. The mentioned metamorpliic series have observed very largely in the studied area forming the basement of younger sedimentary series.

Radiolarite bearing Cretaceous flysh series were interbedded with pillow lavas were originated from sea-floor volcanism and they were composed of basic-ultrabasic
series belonging to oceanic crust. This volcanism was active in a period of 80-120 million years just before granodioritic plutonism has intruded (Burkut, 1966) and therefore the products of the volcanism have been altered and serpentinitized. These units were observed very commonly and largely over sedimentary formation (Orhaneli-Bursa).

These oceanic crustal materials that were basically peridotitic in composition, were observed very largely on the surface and they were intruded by hypabissal rocks such as diabases, diorite-porphyry in various shapes. Because of these activities in the studied area many tectonic structures were determined. As a result of the effect of tectonics settings and elements mentioned above some early formed stratiform chromite deposits, that were hosted within dunites and harzburgites, have been crushed and disseminated in serpentinites that were formed during the same period. As a result of these processes, podiform chromite accumulations were formed in Kutahya and Eskisehir districts together with secondary magnesite deposits.

During Jurassic and Cretaceous periods, marine facies were dominant in the studied area. Although in the Pontides, Oligocene and Eocene were represented as nummulites bearing limestones facies; in Thrace, lacustrine and mostly laguner facies were observed. However, the main lacustrine units have been formed in Neogene age. In this period, continental volcanisms were commonly active. Among these deposits, many volcano-sedimentary deposits were precipitated with clayey-marls series. The significant examples are boron occurrences such as tliinalconite, ulexite, colemanite and soda (Trona) and exhalative iron (Hematite-limonite) accumulations. In this period, volcanic activity was resulted in a series of sedimentary sequences, in which some volcanic minerals, for example orpiment and realgar, were identified. Boron occurrences and limonite-hematite deposits were located in the western part of Pontide metallogenic province (Kirka, Kestelek and Sigadi$ Boron occurrences; Eymir Limonite-Hematite deposits). On the other hand, soda deposits have been found out in Beypazan, in Central Pontides.

In addition to the mentioned Neogene deposits, many lignitic coal deposits, which were very important energy resources for Turkey, were formed resulting in 20 billion metric tons of estimated reserves in Tertiary epoch. These deposits were determined together with lacustrine limestones during Miocene and Pliocene. All Tertiary units have been interbedded laterally sedimentary formations. In the Province, the top units were Plio-Quaternary series that were largely consisted of conglomerate, sandy and clayey formations, containing gypsum seams in some districts.

Copper-Lead-Zinc Deposits and the Related Series

These deposits have classified in two main groups in the point of view of genesis.

1. **Basic Rocks Hosted Massif Sulphide Deposits**

These kinds of deposits, that are accepted as the principal Pontide ore-formations of Cretaceous date are mostly copper occurrences and they are hosted in the rocks ranging in composition from diabase, dolerites microgabbros, spilitic pillow lavas.
Figure 2. General formation mechanism of massive sulfide deposits (Schematic)
together with dacitic dykes and other known rocks of submarine volcanism (Figure 2) to their metamorphic equivalents. This volcanism is also the main reason of well developed alteration zoning which is characterized mainly by albitization, chloritisation, silicification and other alteration products that are observed commonly in the area. These kinds of dykes and intrusions have also caused local skam type and vein type mineralisations. All rocks mentioned here were the parts of oceanic crusts and they are rich of tectonic settings and schistic characters formed as a result of the conditions of deposition environments (Birkiit, Suner, Kinkoflu, 1993).

In these environments, submarine volcanic exhalations have resulted in ore formations by means of diffusion processes of the fluids that were effective in the ore deposition area, within sedimentary sequences composed mostly of fyişh and clayey materials, because of diffusion processes of the fluids that were effective in the ore deposition area. An example of this kind of procedure has been manifested in the area between Kiire and Taşkoprii districts, within the Central Pontides, the northern part of Kastamonu city, in the form of many copper bearing disseminated pyritic occurrences of small reserves. The copper grade of these ores was about 1%, generally are between 0.5 and 2%, and their each reserves were not large. The other known massive sulfide deposits have been discovered in Murgul (the province of Artvin), Madenkoy (the province of Rize), Kopriibasi, Lahanos (the provinces of Giresun).

The Kître has a reserve of about a few million tons and it has been exploited. In this deposit the main ore mineral is chalcopyrite; pyrite is also commonly observed. The observed gang minerals are calcite, quartz, chlorite; in the alteration zones; montmorillonite, sericite and jasper. The significant property of the ore bearing formations is the presence of Cobalt the calculated content of that is between 0.005 - 0.5%. This element had been upgrated in tailings that is remnant bulks of mine workings, as a result of refinery procedures. In this region a lot of the bulks were observed, pointing out the presence of many mining activities during the history of region. Therefore the exploitation of Co from these tailings may be economic.

Otherwise, massive ores are not rich in nickel and vanadium. Using the microprobe and SEM microscopic data the mineralogical feature of these bulks was studied and their pangenesis has been determined as Co - Pentlandite - Smaltine and Cobaltine. In some cases, especially if the dimensions of minerals were very small, the determinations of the mentioned cobalt minerals were very difficult. In these cases, it was assumed that Co element must has been replaced in the lattice of pyrite instead of Fe. This is a kind of substitution of Co and Fe in the minimi.

Gold was the other determined trace element in all ore occurrences observed in the area, as a result of a substitution in the lattice. The calculated average Au content is about 1 ppm, in other words between 0.5 and 1.5 gram per ton. Additionally, malachite and azurite were determined as secondary copper minerals in oxidation zones of the deposits; chalcocite, covellite and bomite in sementation zones.

These deposits were very similar to the Cyprus - type deposits in the point of view of mentioned petrographic and petrologic properties. In these deposits, it has been also determined the minerals that have formed under high temperature conditions, in a range of 250-350° C, such as Valeriite and Cubanite, indicating the reactions between the solutions and submarine volcanic products. Furthermore, small reserves of Mn occurrences were observed in the provinces, possibly as a result of exhalative-sedimentary processes.
These deposits were formed in relation to the volcanism that were the result of island arc magmatism (Figure 3). Ore bearing magmatic rocks, that were of Tertiary date, were dacite, andesite, rhyolite or porphyry granodiorites and quartz-diorites (Ayan and Dora, 1993), (Gedik and others, 1997), (Gedikoglu, 1973) originated by subvolcanic activities. These rocks were exhibited commonly the typical alteration processes in the form of propilitisation, especially in the potassic and algalitic zone (Ozgenf, 1993). The rocks were very crushed and generally millonitisated in the ore formation areas; cracks and fractures were filled up by secondary quartz formations.

These kinds of ore depostions that were represented by the presence of quartzitisation were very common in the area and they were mostly observed in the apical zones of plutons. This type of ore formation was called as ore - breaching procedure. In these occurrences, the main ore mineral was calcopryrite and in some locations, multicolored mineralisations (Irrisation) were very common because of oxidation. Therefore, the mineral was termed as irrisated chalcopyrite and it was observed together with mostly pyrite and partly sphalerite, bornite, galenite (Biirkii, 1966), (Gokfe and others, 1993).

In Pontides, the most typical examples of these ore formations were discovered in Artvin-Balcih, (Yavuz and Biirkii, 1993a), Trabzon-Giizelyayla (Yavuz and Biirkii 1993b) and Kuvarschan districts. In some places where ore mineralisation were very complex, tetraedrite was the principal mineral as we have discovered in Bulancak ore.

In the area, as we have also stated in the first group of deposits, malachite, azurite and cuprite in the oxidation zone; bornite, covellite and chalcocite in sementation zone were determined in small quantities. The other remarkable examples of these kinds of occurrences were observed in Fayeli and more than four hundred locations, most of which were non-economic. The determined Cu grade are between 1 and 1.5 % in these deposits and in all porphryic formations Mo was the determined trace element the grade of that was about 0.15 % in ore-mineral. Furthermore, Au was also found out in the range from 1 to 3 ppm in some ores. Particularly, in the studies of complex and tetraedrite bearing ores Au grade was measured up to 10 gram ppm. Otherwise, in some ores, Ag contents were also very high, in the range of 0 - 100 ppm and the content was up to 300 ppm together with high Pb content in some samples.

The other observed property in the deposits was that Chalcopyrite contents have decreased relatively in the contrary of galenite and sphalerite toward to the bottom of the deposits. Therefore, depending on the structure of the ore zone, a Zn - Pb transition part was determined in porphyry formations. In these kinds of deposits, where fine-grained galenites were dominant, Ag contents were very high, up to 300 - 500 ppm, as nugget Ag and Argentite (in Gumil§hane district). Jamestonite and Bumotite were other observed sulphur minerals (in Balya district).

These deposits were very common throughout the Pontide Province. In the last formation periods of the deposits, known as telethermal activities, gold occurrences were also determined. The grades was up to 20 ppm, and toward to the bottom of the deposits a transition zone of gold - quartz originated volcanogenetically were also observed (in Mastra district).
Figure 3. General Geologic Framework of Porphyry Type Deposits
CONCLUSIONS

1. The Pontide Metallogenic Province, that can be subdivided into three main parts as Western, Central and Eastern Pontides, has covered a large number of ore deposits and mineralisations, particularly in Eastern unit.

2. The host rocks of the Pb-Zn-Cu deposits can be classified in two groups as Basic Series and Acidic-intermediary Series.

3. Basic Series contain Massive Sulfide Pb - Zn - Cu Deposits as the principal ore mineralisations. In the series, vein type occurrences and Mn accumulations have been also observed.


5. Some trace element contents of the rocks observed in the area, such as Co and Au, are high. Therefore, the exploitation of the mentioned elements might be economic.

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