ABSTRACT

A metallogenic map at the 1/500 000 scale have been prepared of the area to the east of Trabzon, Northeastern Black Sea region, Turkey and Southwestern Georgia. 229 mineral deposits and mineralizations have been plotted on to the map. Taking the kind, genesis of the deposits and the geology into account 6 metallogenic provinces covering large areas have been designated and their descriptions have been given.

These provinces are porphyry copper-molybdenum, skarn iron, vein sulphides, volcano sedimentary(Kuroko) sulphides, volcano sedimentary manganese deposits and mineralizations. They represent the mineralizations basically from the same igneous source. In the deeper levels acidic intrusives causing porphyry and vein type mineralizations, in the upper levels intermediate-acidic volcanics causing volcano sedimentary mineralizations.

In the area porphyry copper-molybdenum deposits and mineralizations zone represent deeper levels of erosion of the mineralizing sequence. Then the succession follows upwards as vein, volcano sedimentary sulphides and volcano sedimentary manganese deposits and mineralizations. In other words volcano sedimentary manganese mineralizations represent uneroded or less eroded mineralization sequences.

The area is promising from the mineral deposits potential point of view. Mountainous terrain, poor access, long rainy seasons, heavy vegetation cover make geological studies and exploration work rather difficult. New ideas supported with new technologies would likely to lead to the discovery of new deposits. In that respect combined airborne geophysics surveys using helicopters would help detecting some unknown mineralizations in the area. On the other hand paleovolcanology-paleomorphology studies in selected areas such as Murgul, Kutlular etc. would help localizing concealed deposits.
INTRODUCTION

A joint study on the metallogeny of the area covering to the east of Trabzon (Northeastern Black Sea region) Turkey and Southwestern Georgia was initiated within the framework of the already ongoing joint project between the Mineral Research and Exploration General Directorate (M.T.A. Ankara) of Turkey and the Geological Institute of Georgia on the study of the geology along the border zone of the two countries.

The metallogeny study group consisting Dr. Tandoğan Engin, Murat Er, Necmi Yüce of M.T.A. Turkey and Dr. Vaja Buadze, Yuri Bakhadze of State Department of Geology (S.D.G.), Georgia had a field meeting in September-October 1995. The group first met in Trabzon on the 15th September 1995 and visited Güzelyayla (Maçka) porphyry copper-molybdenum; Mastra (Gümüşhane) gold; Kutlular (Sürmene) copper; Madenköy (Çayeli) copper-zinc; Anayatak; Çakmakkaya; Akarşen; Çarkbaşı; Kızılkaya (Murgul) copper deposits and mineralizations.

Following the visits in Turkey the group went to Tblisi, Georgia on the 30th September 1997 and visited Madneuli copper-zinc-lead-gold deposit; Tsitelisopeli; Sakdrisi gold; Domanisi copper-gold mineralizations in the Bolnisi area; Chiatura manganese deposit; Merisi (Adjara) copper-molybdenum mineralization; Gudna (Tsablana) alteration zone.

During the field meetings the groups exchanged information and had valuable discussions on the deposits and the mineralizations visited. Dr. Buadze had S isotope studies done and some chemical analyses made at the S.D.G. laboratories on the samples collected during the field visits in Turkey.

The groups agreed to prepare a metallogenic map of the area covering east of Trabzon (Northeastern Black Sea region, Turkey) and Southwestern Georgia at the 1/500000 scale (Appendix, 3).
GEOLOGY AND METALLOGENY
General Tectonic Setting

In a general way Turkey is divided into 4 main tectonic zones. From north to south they are Pontides, Anatolids, Taurids and Border folds (Ketin 1966).

The Pontides comprise three major tectonic units juxtaposed in Late Mesozoic. The Istranca massif in the Northeastern Turkey in the Thrace, The İstanbul and the Sakarya zones in the west and the Eastern Pontides in the Northeastern Turkey. The Eastern Black Sea region is in the eastern section of the Pontide zone. This belt extends for about 500 km. from Kızılırmak river near Samsun Northern Turkey to the Lesser Caucasus in Georgia in the east.

The northern part of the zone is dominated by volcanic and volcanoclastic sequences. The south is marked by older sediments, metamorphics and granites.

Pontides are regarded to have developed and remained as a continental crust until Jurassic when the north Anatolian oceanic crust started subducting northwards below the Pontides thereby initiating an island arc environment where a zone close to the Black Sea shore line acted as hosts to numerous strato-volcanoes and their products with the associated massive sulphide mineralizations. Resulting Cretaceous volcanics and volcanoclastics cover extensive areas (Pejatovic, 1979; Aslantar et al., 1995; Tokel, 1995).

The magmatic activity was also powerful through Eocene when reversal magmatic front had taken place during which andesitic volcanics and plutonic rocks had invaded the then inactive trench in the south and the remains of the Anatolian plate. This provided a further opportunity for mineralization.

Post Eocene uplift, tilting towards north and erosion have enabled the roots of the old strato-volcanoes to be exposed. As a result it appears that the deeper level mineralization as portrayed by the porphyry copper-molybdenum type is exposed in the southern part of the Pontides, while most of the volcano-sedimentary massive sulphide deposits and mineralizations are restricted to the northern coastal zone.

Geology and Mineralizations

The Eastern Pontides volcanic province is located along the Alpine metallogenic belt and has dimensions of 500 km. By 110 km. Along E-W and N-S direction respectively. The volcanics in the area are the product of major orogenic activities which took place during Lias, Upper Cretaceous and Eocene. On the base of field work and geochemical data 4 volcanic cycles such as; Jurassic, Upper Cretaceous lower, Upper Cretaceous upper, Tertiary cycles have been determined (Çamur et al., 1995).

The age of acidic intrusives present in the region are Paleozoic, Upper Jurassic-Upper Cretaceous, Eocene.
The Eastern Black Sea region is stratigraphically divided into two zones, such as southern and northern zones. A line drawn along the southern boundaries of the acidic intrusives along E-W direction defines the boundary between the two.

The region includes Pre-Mesozoic metamorphic basement and overlying lithostratigraphic units of Jurassic to Recent. In general the southern zone is dominated by the Pre-Mesozoic metamorphic basement and the sedimentary rocks whereas volcanics and volcano sedimentary rocks dominate the northern zone.

The oldest rocks exposed in the southern zone are the metamorphics and Lower Devonian Gümüşhane granite (Yılmaz, 1974).

Lias in the Eastern Pontides is represented by basic volcanics, coarse clastics and carbonates to the top. Lias volcanics extending E-W direction are widespread in the southern zone and have limited extensions in the north. They are conformably overlain by carbonates of Upper Jurassic to Lower Cretaceous.

Upper Cretaceous volcanics are widespread and they were developed in 4 major stages. The initial stage includes basic lavas and their pyroclastics which are overlain by dacitic and rhyolitic rocks of the second stage. The third stage volcanics are basaltic and andesitic lavas and pyroclastics which are intercalated with the sedimentary rocks which are overlain by acidic volcanics (rhyodacites, rhyolites) of the fourth stage.

Alternations of sandstones, shales and marls of Paleocene to Lower Eocene conformably rest on the volcano sedimentary sequences of Upper Cretaceous and Unconformably overlain by the Eocene volcanics in the both zones.

The youngest volcanics of the Eastern Pontides are those of Plio-Quaternary. In addition to the Cretaceous and Tertiary volcanics, acidic intrusives cover large areas. They vary from Permien to Eocene. The most extensively exposed Kaçkar granitoid batholith, south of Rize was emplaced during Lower Cretaceous-Upper Eocene. Generalized columnar section of the Eastern Black Sea region is given in Fig., 1 (Er, 1989; Güven, 1993; Aslaner et al., 1995).

The Eastern Black Sea region is an important area from the mineralizations point of view, particularly for the massive sulphide; copper-lead-zinc mineralizations. The history of mining in the region goes back to 500 B.C.

Main mineralizations present in the region are copper-lead-zinc; manganese; copper-molybdenum; gold; Iron. Some clay; kaolinite; bentonite deposits are also present in the area.
Fig. 1. Generalized columnar section of the Eastern Black Sea Region (after Güven, 1993).
METALLOGENIC MAP AND METALLOGENY

Metallogenic Map

On the Turkish side 1/250 000 scale geological map compiled by Güven (1993) and 1/500 000 scale geological map compiled by Akdeniz (1995) have been used to prepare the geological base for the metallogenic map. V. Buadze provided the geological map and the data on the mineralizations in the Georgian side. Summarized data on the 215 deposits and mineralizations in the Turkish side and 14 the Georgian side are given in the Appendix, only in the report.

The legend for the 1/2 500 000 scale metallogenic map of Europe (Carte metallogénique d l'Europe 1968-1970) which was prepared by a working group under the auspices of Unesco have been adapted for the map.

Using the existing geological maps, communicating with the relevant geologists the geology of the study area was generalized, reframed to fit the legend adapted. While doing this certain difficulties particularly on the generalization of the lithologies were inevitable. These difficulties were overcome by communicating with the geologists who actually worked in that particular area.

Practically whole of Turkey have been subjected to Alpine orogeny (Ketin, 1966, Tengün 1995). While marking the units effected by Alpine orogeny, it was difficult to differentiate which units were effected by Early Alpine (A1), Middle Alpine (A2) or Late Alpine (A3). Because of this on the map (Appendix, 3) Alpine orogeny is shown in a general way such as Alpine orogeny undifferentiated (A). In the project area 215 deposits and mineralizations in Turkish side and 14 in the Georgian side have been plotted on the map and consecutive numberings have been used. Size of the deposits have been marked as 0; 1; 2 based on their metal contents. Past productions(if any) and remaining reserves have been taken into account. The relationship between the size and the metal contents of the deposits are given in Table, 1.

| Table, 1. Tonnage in metal or mineral content(figures in metric tonnes) constituting the dividing line between the size of the deposits(Laffitte, 1984). |
|-----------------------------------------------|---------------------|--------------------|---------------------|---------------------|---------------------|---------------------|
| Aluminium                                    | 2000000             | Iron               | 50000000           | Pyrite              | 1000000             |
| Antimony                                     | 20000               | Kaolin-clay        | 2000000            | Silver              | 500                 |
| Barite                                       | 1000000             | Lead-zinc          | 2000000            | Sodium(chloride)    | 10000000            |
| Beryllium                                    | 1000                | Lithium            | 10000              | Sulphur             | 1000000             |
| Borates                                      | 5000000             | Magnesite          | 2000000            | Talc                | 500000              |
| Chromite                                     | 1000000             | Manganese          | 1000000            | Tin                 | 20000               |
| Cobalt                                       | 1000000             | Mercury            | 30000              | Titanium            | 5000000             |
| Columbotantalite                             | 20000               | Molybdenum         | 50000              | Tripoli             | 500000              |
| Copper                                       | 1000000             | Nickel             | 2000000            | Uranium             | 10000               |
| Diamond                                      | 1000000*            | Phosphates         | 10000000           | Vanadium            | 50000               |
| Fluorite                                     | 5000000             | Platinum           | 10                 | Wolfram             | 100000              |
| Gold                                         | 50                  | Potash             | 50000000           | Zircon              | 100000              |

*Carats

On the metallogenic map (Appendix, 3) the type, the shape, the size and the genesis of the deposits have been marked with colours and combinations of figures.
**Metallogeny**

From the summary data given in the Appendix,10 the deposits and the mineralizations can be grouped as volcano-sedimentary manganese deposits and mineralizations; volcanogenic massive sulphide deposits and mineralizations (Kuroko type); Skarn (contact metasomatic) iron mineralizations; vein type copper-lead-zinc deposits and mineralizations; porphyry copper-molybdenum mineralizations; volcanogenic copper mineralization in the ophiolite.

**Manganese Mineralizations,**

Manganese mineralizations around Trabzon form the upper most part of the mineralized volcanic sequence. They are located in the Mesozoic-Lower Tertiary (Upper Cretaceous-Paleocene) calc-alkaline volcanics-volcanoclastics (andesite, dacite, rhyodacite, rhyolite). Near Trabzon, mineralizations are stratigraphically below the Lower Tertiary calc-alkaline volcanics-volcanoclastics. To the east around Rize and eastwards they appear to be in the Mesozoic-Lower tertiary dacitic and Lower Tertiary andesitic rocks.

With some interruptions manganese mineralizations form a belt extending northeast-southwest direction parallel to the coast line as well as to the general trend of the geology. In the east near Hopa the zone takes a southeasterly turn. Apart from this main zone, some isolated manganese mineralization areas forming the upper part of the volcanogenic mineralization are also present.

Mineralizations are mainly in the Upper Cretaceous dacitic tuffs and red limestones. They form veins, bands and lens shape bodies. Psilomelane is the dominant manganese mineral. Pyrolusite, braunite and manganite are the other minerals present. The grade varies from 10-51% Mn. In places silicification accompany the mineralizations.

According to their metal contents size wise all of the manganese mineralizations have been grouped as 0 and they are genetically classified as volcano-sedimentary.

In the past many of these manganese occurrences were subjected to small scale mining, but at present no manganese mining is being carried out in the area.

**Volcanogenic Massive Sulphide Deposits and Mineralizations,**

Volcanogenic massive sulphide (copper-lead-zinc) deposits and mineralizations are the most characteristic and economically important in the study area. The mineralizations are disseminated, veins, veinlets and some massive forms. Pyrite, chalcopyrite are the main minerals. In some deposits sphalerite, galena are also present in substantial amount. Silicification and argillization generally accompany the mineralizations.

They are closely related to the Mesozoic-Lower Tertiary calc-alkaline volcanics and pyroclastics (dacitic-rhyodacitic, rhyolitic rocks), particularly to the Upper Cretaceous
pyroclastics. Footwalls are characterized by dacitic, rhyodacitic, rhyolitic lavas, tuffs and breccias. Pumice tuffs, mudstones, clays, marls to a lesser extent basalts and in places purple coloured dacitic, andesitic tuffs-lavas form the hanging wall.

Massive sulphide mineralizations and the related volcanics extend northeast-southwest direction parallel to the manganese mineralization zone, but stratigraphically below it. Ore formations are mainly related to the paleomorphological highs (anticlines?, domes?) and lows. Caldera related structures are also favourable locations for the mineralizations.

According to their metal contents 0; 1; 2 size deposits and mineralizations are present in the area. Anayatak (55*), Çakmakkaya (56)(Murgul); Cerattepe (84) (Artvin); Madenköy (116) (Rize) deposits are the size 2 deposits. In general they are classified as volcano-sedimentary (Kuroko) type.

Massive sulphide deposits generally display zonal arrangements. Sphalerite and galena at the outer margin and the upper part of the ore body, passing downwards into chalcopyrite and then into pyrite rich part at the lower parts. Barite usually overlies the sphalerite rich top part of the ore body. Ore bodies have massive, stockwork-disseminated, brecciated types. It is not always possible to see all these types in every deposit.

Both footwall and hanging wall rocks were subjected to hydrothermal alterations. Silicification, sericitization, chloritization form zonal alteration on the footwall side of the ore bodies. Alteration on the hanging wall side is relatively weaker. Hematitization is the dominant alteration on this side.

In the west near Trabzon Manganese mineralizations appear to be the upper most level of the mineralizations. But in the east, northeast of Artvin near to the Georgian border there appear volcanogenic massive sulphide mineralizations in the Eocene andesitic volcanics. Stratigraphically above the volcano-sedimentary manganese mineralizations. This may be another volcanogenic massive sulphide mineralization zone, stratigraphically above the other one. The known mineralizations in this zone are all in the 0 group.

Volcanogenic massive sulphide zone can not be followed into Georgia.

Porphyry Copper-Molybdenum Mineralizations,

Porphyry copper-molybdenum mineralizations in the area are associated with the Alpine granitoids (Jurassic-Upper Cretaceous; Middle Eocene). They have a northeast-southwest general trend. Some intrusives with limited outcrops have been mapped as quartz porphyries.

Mineralizations are mainly located along the southern part of the granitic intrusives. There are also some isolated mineralizations in the northern part. Main minerals present are pyrite. Chalcopyrite and molybdenite. They form veins, stockworks and disseminations. The mineralization is related to the intruding granites, quartz monzonites, quartz porphyries and intruded metasediments, volcanics(andesites, basalt lavas, pyroclastics). Phyllic and
propylilitic alterations are noticable. Potassic alterations are marked by the presence of biotite. The zones are obscured and have limited extensions.

According to their metal contents all of the mineralizations except the two (Ulutaş; Güzelyayla) have been grouped as 0. Ulutaş (202) (İspir) and Güzelyayla (169) (Maçka) have been grouped as 1 and 2 respectively. Although metal contents put Ulutaş and Güzelyayla mineralizations into group 1 and 2 but as the average grade is 0.3 and 0.4% Cu equivalent respectively, they have been considered low grade for exploitation (Er et al., 1995).

The samples collected from the Güzelyayla mineralization during the field excursion of the group were subjected to the fluid inclusion and sulphur isotope studies by Buadze in the SDG laboratories. According to the findings Güzelyayla is in the "economic deposit of porphyry copper class", lower levels of the

*Figures after the name of a deposit or a mineralization indicate deposit no in the Appendix, 10 and on the map (Appendix, 3). Mineralizations should be economically rewarding (Buadze et al., 1996).

**Skarn (Contact Metassomatic) Iron Mineralizations,**

Skarn iron mineralizations are mainly in the central part of the area along the contact between granitic intrusives and the clayey limestone levels which are interbedded in the andesite-basalt lavas and the pyroclastics of Jurassic-Cretaceous. Isolated intrusive outcrops also have contact metasomatic iron mineralizations.

Main minerals are magnetite and specularite. Some sulphide minerals usually accompany the iron minerals. Epidotization, chloritization and in places silicification accompany the mineralizations.

According to their metal contents all of the iron mineralizations have been grouped as 0. Because of their small reserves and presence of sulphide minerals, none of them have been found to be exploitable.

**Vein Type Copper-Lead-Zinc Mineralizations,**

Vein type copper-lead-zinc mineralizations are mainly located to the south, within and around the granitic intrusives. The zone can be extended northeastwards into Georgia. Mineralizations developed in the form of hydrothermal veins in the limestones which are interbedded with dacite, andesite-basalt lavas and pyroclastics of Jurassic-Cretaceous.

The minerals present are sphalerite, galena, pyrite, chalcopyrite. Argillization, limonitization, Silicification generally accompany the mineralization.

According to their metal contents all of the vein type copper-lead-zinc mineralizations in the Turkish side are in 0 group. Some small scale mining operations are present in the region, Gümişkıhanları (162) is the only one in the study area.
A vein type copper-lead-zinc mineralization zone is present in the Bolnisi area to the east in Georgia. Mineralizations are related to the andesitic, rhyodacitic volcanics of Mesozoic (Upper Cretaceous). Madneuli (13) one of the largest in Georgia is here in this zone. Size wise the deposits are mostly in group 2.

Madneuli copper-zinc-lead deposit was first mined for barite which formed the upper part in the past. Now the deposit is being mined for copper and the work is in progress to exploit the gold rich silicified upper part which had been removed and stocked near by to mine barite and massive sulphides underneath.

The mineralization is in the ignimbrites, tuffs and tuffits. The minerals are pyrite, galena, sphalerite, chalcopyrite. They are in the form of stockworks. Silicification, sericitization are the alterations accompany the mineralization.

The zone here has east-west orientation. Because of the nonorogenic Quaternary basalt cover the zone can not be correlated with the one in Turkey.

There is not any operating gold mine in the study area, for that matter nor in Turkey and in Georgia. In recent years with the increases of gold prices in the world market and the developments in the beneficication technologies there has been gold exploration in Turkey in general as well as in the study area. As a result, at present Cerattepe(184)(Artvin) and Mastra (Gümüşhane) just off the study area economically minable gold-silver deposits have been discovered. Because of the environmental concerns mining permissions have not been granted yet.

In the study area in Turkey, Olucak (227) and Kaletaţ (229) (Gümüşhane) are the gold mineralizations along with sulphides. They are in the form of veins and veinlets and lens shape bodies in the silicified parts of dacitic tuffs (Jurassic), Lower Cretaceous limestones, Eocene felsic tuffs. The minerals are pyrite, chalcopyrite, sphalerite, galena, faehlerz, electrum, realgar, orpiment. At their present state, size wise they are in 0 group (Appendix, 3,10)

In Georgia in the Bolnisi area apart from the Madneuli deposit(13), others like, Kvemo-Bolnisi (8), Tsiteli-Sopeli (9), David-Garaji (10), Sakdrisi(11), Dambludi(14) mineralizations; in the Adjara region Vaio (3), Namonastrevi (4), Tsablana (5) and Merisi (6) mineralizations are being explored for gold. Gold mineralizations in the Adjara region is mainly associated with the Eocene pyroclastics. On the other hand in the Bolnisi area with the Upper Cretaceous volcanics. Pyrite, galena, sphalerite, chalcopyrite, barite, gold, silver are the minerals encountered. Silicification, sericitization are the common alterations accompanying the mineralizations (Appendix, 3,10).

**Volcanogenic Massive Sulphide Mineralization In ophiolite,**

In the south to the south of Bayburt and to the south of porphyry copper-molybdenum mineralization zone, there is a copper mineralization in the basic volcanics of the ophiolite. The ophiolite (Appendix, 3,10) has about 50 km. Long extension along northeast-southwest
direction, and is obducted on to the Mesozoic limestones. The age ascribed to the ophiolite is Upper Cretaceous. Helva maden (125) is the only known mineralization in this setting in the study area.

The mineralization has a lens shape and has a volcano-sedimentary origin (Cyprus type). The minerals are pyrite, chalcomnite, malachite, azurite, subordinate chalcocytite. Size wise it is in the 0 group (Appendix, 3,10). In the past the Helva maden was exploited in a small scale by solution mining.
The Eastern Black Sea region has an extensive cover of arc volcanics and acidic (granitoid) intrusives. The volcanics are basalts, andesites, dacites, rhyodacites, rhyolites and pyroclastics. The age of the volcanics range from Jurassic to Eocene. Upper Cretaceous calc-alkaline volcanics are more widespread. The age of the acidic intrusives varies from Paleozoic, Upper Jurassic-Upper Cretaceous, Eocene.

The area is important for mineral deposits and mineralizations. 229 mineral deposits and mineralizations (215 in Turkey, 14 in Georgia, Appendix, 3, 10) have been plotted on the metallogenic map (Appendix, 3). From south to north, mineralizations and mineral deposits can be grouped into certain zones, such as:

- Volcanogenic massive sulphide mineralization in the ophiolite
- Vein type copper-lead-zinc deposits and mineralizations
- Porphyry copper-molybdenum mineralizations
- Skarn (contact-metasomatic) iron mineralizations
- Volcanogenic (Kuroko type) massive sulphide deposits and mineralizations
- Volcano-sedimentary manganese mineralizations

They represent the mineralizations basically from the same igneous source. In the deeper levels acidic intrusives causing porphyry and vein type mineralizations, in the upper levels intermediate-acidic volcanics causing volcano sedimentary mineralizations. In the area porphyry copper-molybdenum deposits and mineralizations zones represent deeper levels of erosion of the mineralizing sequence. Then the succession follows upwards as vein, volcano sedimentary sulphides and volcano sedimentary manganese deposits and mineralizations. In other words volcano-sedimentary manganese mineralizations represent uneroded or less eroded mineralization sequences (Fig., 2).

Vein type copper-lead-zinc mineralizations and to a certain extent porphyry copper-molybdenum mineralization zone can be followed from Turkish side northeastwards into Georgia. The vein type copper-lead-zinc mineralization zone which has east-west orientation in the Bolnisi area in Georgia can not be correlated with the zone in Turkey.

Metallogenic provinces cover large areas. The region has been subjected to detailed geological studies and mineral exploration. Certain degrees of success have been achieved so far in discovering mineral deposits. With the geology of the region in one hand and with the metallogenic considerations on the other, one can assume that more deposits are likely yet to be discovered.

The region is mountainous, heavy rainfall throughout the year, covered with thick vegetation and access is poor in the field. Those make geology and mineral exploration difficult. New ideas, supported with new technologies would lead to the discovery of new
deposits. In that respect one would think combined airborne geophysics surveys using helicopters would be beneficial. On the other hand paleovolcanology-paleomorphology studies in selected areas would help localizing concealed deposits.

Figure, 2, Magmatic succesions and related mineralizations.
REFERENCES


Laffitte, P. 1984, Explanatory memoir of the metalogenic map of Europe and neighbouring countries. Earth sciences, 17, Unesco.


