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MINERALOGY AND GEOCHEMISTRY OF THE KOCADAL (TORUL, GÜMÜŞHANE, EASTERN BLACK SEA REGION, TURKEY) Zn-Pb-Ag, Au and Cu MINERALIZATIONS

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Research Article

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ABSTRACT

The Kocadal base and precious metal mineralizations are located in the southwest of Gümüşhane province of the eastern Pontide orogenic belt. In the vicinity of the Kocadal mineralization, Gümüşhane granite, lithologies of the Hamurkesen, Berdiga, and Mescitli formations, dacite porphyry and andesite porphyry are present with abundant alluvium. Based on geological, mineralogical, and geochemical features, three mineralization styles have been recognized at the Kocadal area: (i) Mineralizations around Batarya tepe include (ia) Zn mineralization within the conglomerates and sandstones of the Hamurkesen formation and (ib) Zn-Pb-Ag-(Au) mineralization associated with dacite prophyry, (ii) Au mineralization, which occurs to the southwestern of Batarya tepe, and (iii) Cu mineralizations related to quartz veins and veinlets at Gözelerin Dere. Mineralized gravels within the conglomerates contains mainly sphalerite and pyrite, whereas hydrothermal mineralizations associated with porphyritic dacite comprise pyrite and sphalerite, with minor galena, chalcopyrite, pyrrhotite, arsenopyrite, marcasite, fahlerz, pyrargyrite, and proustite. Alteration patterns of hydrothermal mineralization in the field, from older to younger, are classified as: (i) tremolite-actinolite±garnet, (ii) quartz-sericite-chlorite, and (iii) carbonate-quartz. Mineralized gravels within the conglomerates contains mainly sphalerite and pyrite, whereas pyrite, chalcopyrite, and galena are common in quartz veins at Gözelerin Dere. Geostatistical studies based on the results of geochemical analysis of core samples reveal the presence of the distinct element associations for the different styles of mineralizations.

1. Introduction

Mineral deposits and mineral occurrences associated with the magmatic rocks in the southern part of the Eastern Black Sea Region form an E-W extending zone. This zone includes porphyry Cu-Mo, epithermal Au-Ag and vein type base metal and precious metal mineralizations (Figure 1). Kocadal base and precious metal mineralizations are located in the central part of this zone and are in the 24 km to the Southwest of Gümüşhane, in the 1/25000 scale map sheets H42-a2, a3, b1 and b4. Some of the mines operational in the region are Mastra Au, Midi (Zn-Pb-Cu-Au-Ag) and Hazine Mağara (Pb-Zn-Au-Ag). Apart from these, there are also numerous mineralization occurrences in the region.

There have been numerous studies concerning basic geology and mineralizations in and near Gümüşhane region. First studies on the mineralizations in the study area were carried out by Baytekin and Uslu (1974). Later on Çınar et al. (1983) and Türk (MTA)-Japan Joint Project (1985) (Türk (MTA)-Japon Ortak Projesi, 1985) carried out geological studies in the study area. All these studies were in the frame work of regional prospection and mineralizations in the Kocadal area were considered to be hydrothermal mineralizations developed along the fracture systems. In 2009-2014 Demir Export Inc carried out detailed geological mappings and surface geochemical studies to delineate mineralization areas and conducted core drillings to test dip down extensions of the mineralization. In this work some of Demir Export's data have been used to explain and discuss geological, mineralogical and geochemical characters of the Kocadal base metal and precious metal mineralizations and different types of mineralizations have been identified and described. By doing this it was meant to provide some information to help future mineral exploration activities in the region.

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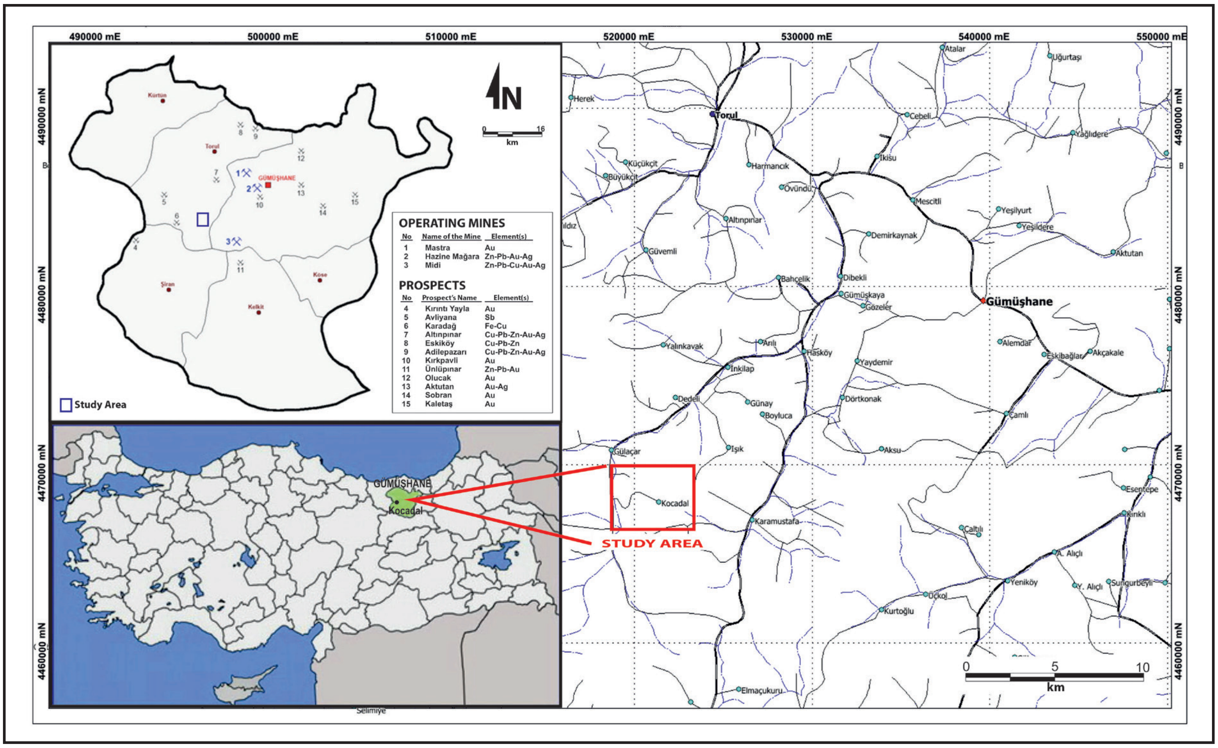


Figure 1- Location map of the study area.

2. Regional Geology

Study area is located in the Southern part of the Eastern Pontides (Hamilton, 1942; Ketin 1966; Ketin and Canıtez, 1972; Özsayar et al., 1981; Bektaş et al., 1984). The basal rock units present in the area are Paleozoic Kurtoğlu metamorphics (Yılmaz, 1972). These rock units were intruded by Permo-Carboniferous granitic intrusives (Çoğulu, 1970; Yılmaz, 1972), developed from the southern plunge of northern branch of Paleo Tethys (Dewey et al., 1973; Şengör and Yılmaz, 1981; Bektaş et al., 1999; Eyüboğlu, 2010; Eyüboğlu et al., 2012). These units were discordantly overlain by volcano-sedimentary Hamurkesen formation of Lower-Middle Jurassic, characterizing rifting in marine environment related to the extensional tectonics (Eyüboğlu et al., 2010, 2014). This succession at the next stage of rifting was concordantly overlain by Upper Jurassic-Lower Cretaceous Berdiga formation consisting platform limestones, characterizing shallow marine environment (Eyüboğlu et al., 2010, 2014). Berdiga formation is concordantly overlain by flysch like (Güven, 1993) Turonian-Paleocene, Mescitli formation (Pelin, 1977). All units in the area have been cut by Eocene dacite porphyries related to volcanic arch (Eyüboğlu et al., 2011). Dacite porphyries have intrusive relationships with the Hamurkesen formation and the Gümüşhane granite. Because of these relationships, dacite porphyries can be correlated with the Lower Eocene Zigane granitoid (Ketin 1966; Bektaş et al., 1995; Karslı, 1996) present in the area, related to the magmatic arch which was active during Late Cretaceous-Early Eocene (Şengör and Yılmaz 1981; Okay and Şahintürk 1997; Yılmaz and Karslı 1997; Yılmaz et al., 1997; Bektaş et al., 1999; Şengör et al., 2003), (Figure 2).

3. Local Geology

In the study area and in the surrounding areas various kinds of lithologies at various ages are present. From oldest to youngest they are; Gümüşhane granite, Hamurkesen (Zimoköy) formation, Berdiga formation, Mescitli formation, dykes and alluviums (Figure 3).

3.1. Gümüşhane Granite

In the study area Gümüşhane granite is the oldest unit. It was named as Gümüşhane pluton by Çoğulu (1970) and Yılmaz (1972). Lermi (2003) described Gümüşhane granite and said that it has granite, granodiorite, tonalite, quartz monzodiorite, quartz diorite and diorite mineralogy.

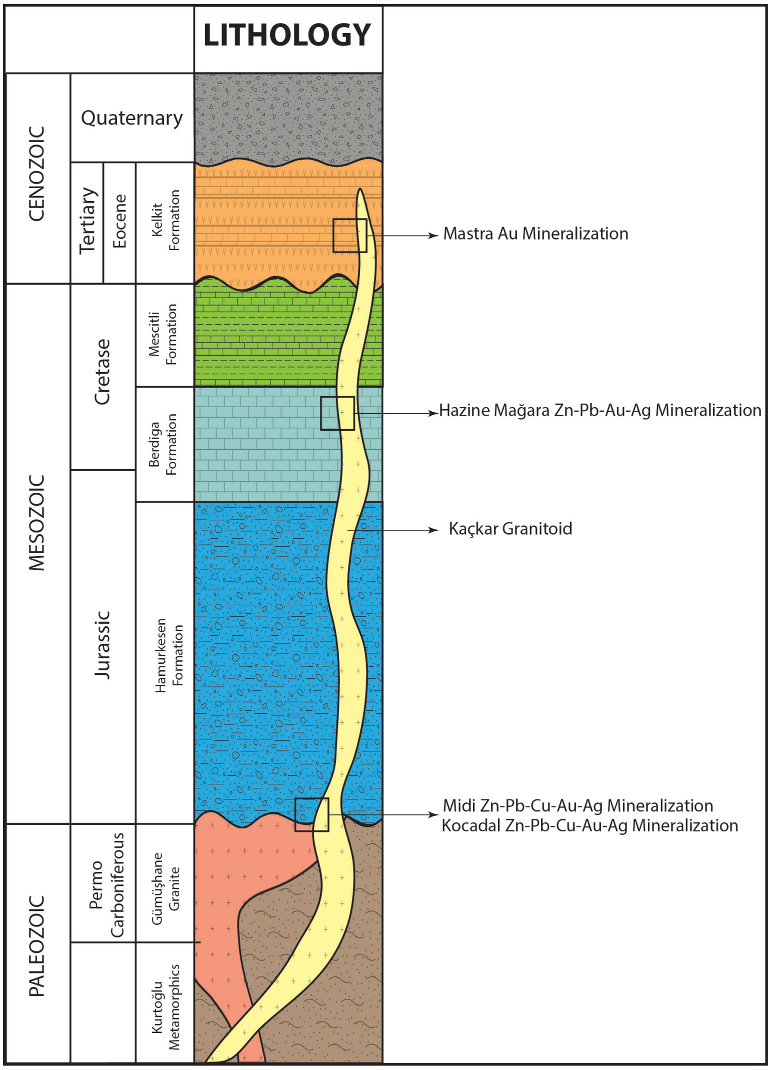


Figure 2- Generalized column section of the study area (modified after Lermi 2003).

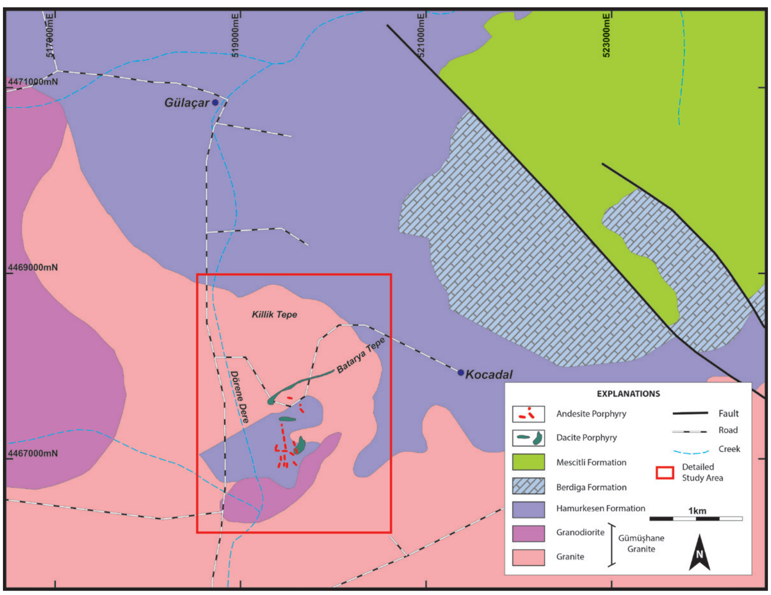


Figure 3- 1/500.000 scale geological map of the study area (modified after Şenel, 2002).

Rock units outcropping in the western and northern part of the study area are granite, granodiorite and quartz diorite. Gray-beige coloured granites and quartz diorites crop out around Killik Tepe (Killik Hill). These two rock units have intricate relationships and have various amounts of plagioclase, orthoclase and amphibole minerals, biotite, chlorite and small amount of pyroxenes. Size of minerals is up to 0.5 cm Diorites and quartz diorites considered to be last phase crop out around Batarya Tepe and have darker colours and smaller size minerals than granodioritic rocks. They are consist of 50% plagioclases and have alkali feldspars, quartz, amphibole, pyroxene minerals, epidote and chlorite (Lermi, 2003).

3.2. Hamurkesen Formation

Lower-Middle Jurassic volcano-sedimentary succession named as Hamurkesen formation by Ağar (1977) or Zimonköy formation as named by Eren (1983) overlays Gümüşhane granite with an unconformity. Based on the colour and lithological difference the Hamurkesen formation has been divided into two different members. The formation at the base starts with basalts, spilitic basalts, pyroclastics, dolerites of the İkisu member, concordantly overlain by andesites and pyroclastics with clayey limestone and sandstone lenses of the Karaca volcano-sedimentary member (Eyüboğlu et al., 2006).

The units cropping out around Batarya Tepe and in the southern part are conglomerates-sandstones with gray-black coloured sand to block size fragments (Figure 4A) and in places in limited narrow patches with volcanic interlayers (Figure 4B-4C). Bedding is not observed at the lower parts but in the upper parts as the grain sizes become smaller medium beddings become noticeable. The unit consists of magmatic rock fragments, quartz grains an lesser amounts of metamorphic rock fragments, the matrix is made of clay and sand size of similar materials. The unit also has magmatic rock pebbles with disseminated and massive ore mineralizations. In general in the unit semi rounded fragments with corners are dominant (Figure 4 D).

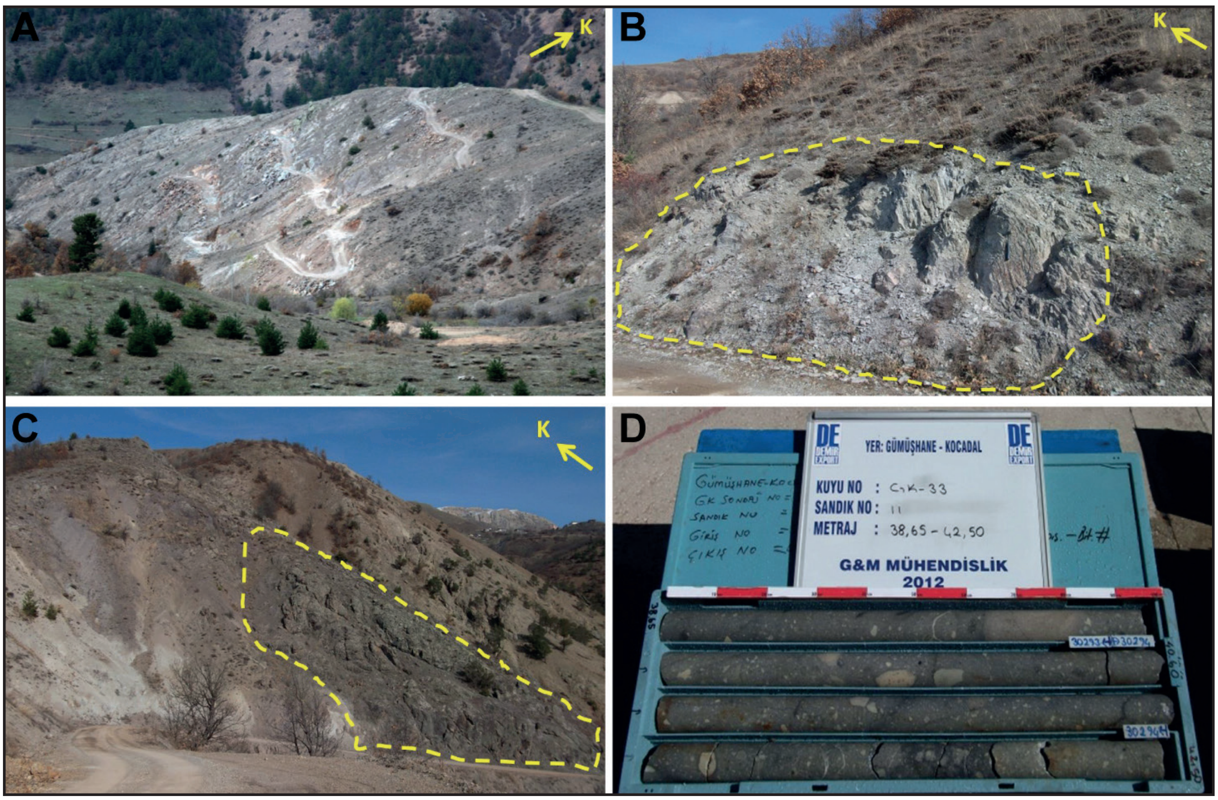


Figure 4- A) General field view of the conglomerates-sandstones of the Hamurkesen formation B) Volcanic (rhyolite) parts in the Hamurkesen formation C) Pyroclastic (agglomerate) parts in the Hamurkesen formation D) General view of the conglomerates-sandstones in the drill cores.

3.3. Berdiga Formation

Berdiga formation named by Pelin (1977) at the base starts with yellow coloured sandy limestones upward goes to red coloured limestones then to sandstone-siltstone-claystone-marl and limestone interbeds and also tuff intercalations concordantly overlies the Hamurkesen formation. The Berdiga formation is Upper Jurassic- Lower Cretaceous age (Taslı, 1984).

The unit is represented by gray-white coloured limestones, outcrops in the northern part of the study area at the high altitudes. The limestones display medium thick beddings and have extensive karsts structures.

3.4. Mescitli Formation

The unit was first named as Kermutdere formation by Tokel (1977). It is mainly made of flysch facieses sediments outcropping along the Southern Pontide zone. The unit later on was named as Mescitli formation by Güven (1993). The unit concordantly overlies the Berdiga formation. It starts with red-Bordeaux coloured clayey limestones and is a thick succession made of alternations of gray coloured marl-shale-clayey limestone with sandstones intercalations. In some locations tuff intercalations are also present. In Eastern Pontides All along Late Cretaceous, along with the products of developing active volcanisms Mescitli formation developed in deep marine environment. It is a thick succession at Turonian-Paleocene age (Güven, 1993).

The unit outcrops in the north-eastern part of the study area, is represented by red-bordeaux coloured clayey limestones with thin and thick beddings

3.5. Dikes

In the Eastern Pontides three different ages of magmatic activities are under considerations (Okay and Şahintürk, 1977); (I) First period is Early Jurassic-Middle Jurassic tholetiic rocks, related to extensional regime (Peccerillo and Taylor, 1975; Gedikoğlu, 1978; Akın, 1979; Eğin et al., 1979; Akıncı, 1984, Gedik et al., 1996). (II) In the region second period developed as a result of Turronian-Maestrichtien age subduction, generally sub alkaline related to oceanic island arc magmatisms (Adamia et al., 1977; Eğin et al., 1979; Kazmin et al., 1986; Çamur et al., 1996). Same magmatism has been claimed to be related to Late Cretaceous-Early Eocene magmatic arc (Şengör et al., 2003). It is quite possible that dikes present in the study area are related to the third of these activities.

In the study area there are dike systems with different phase and different chemical compositions cutting one another.

Dacite porphyries outcropping in the Batarya Tepe area located in the fracture systems varying between N60ºE and E-W strikes (Figure 5 A). Dacite porphyries in the field have white and beige colour, they have extensive quartz phenocryst in clayey matrix. Dacite porphyries have intrusive relations with the Hamurkesen formation and Gümüşhane granites and display 1-5 m thick topographic eaves in the field. As a result of alteration original texture and mineralogy of the rocks have been totally destroyed, but still signs of porphyritic texture are still identifiable. Mineralogical studies showed that apart from quartz all other minerals have been altered. In the specimens quartz, sericite, plagioclases (subjected to carbonate and clay alterations) and eroded quartz are present. Matrix materials are clay, carbonate sericite and quartz (Figure 5 B-C).

In the study area relatively younger dykes with andesitic (?) composition have N-S and E-W extensions (Figure 6 A) cut Hamurkesen formation and dacite porphyries in the south-western part of the Batarya Tepe. These dykes are maximum 4 m thick and are followed about 60 m along their strike directions. Andesitic dikes form relatively smoother features on the topography than porphyries. In the outcrops they are dark gray, mineralogical studies show that they porphyritic texture and include some phenocryst of plagioclases, mafic minerals and few quartz. Apart from quartz all other minerals have been fully altered. Plagioclases have been sericitized and carbonation. Mafic minerals (hornblende) have been altered to chlorite and carbonate and are seen as pseudomorphs. Matrix materials have also been altered and include plagioclase microlites, quartz, chlorite and a few opaque minerals (Figure 6 B-C).

As andesitic dikes (?) cut older porphyries and they have also been cut, so it is considered that andesitic dikes represent a later stage of magmatic activities.

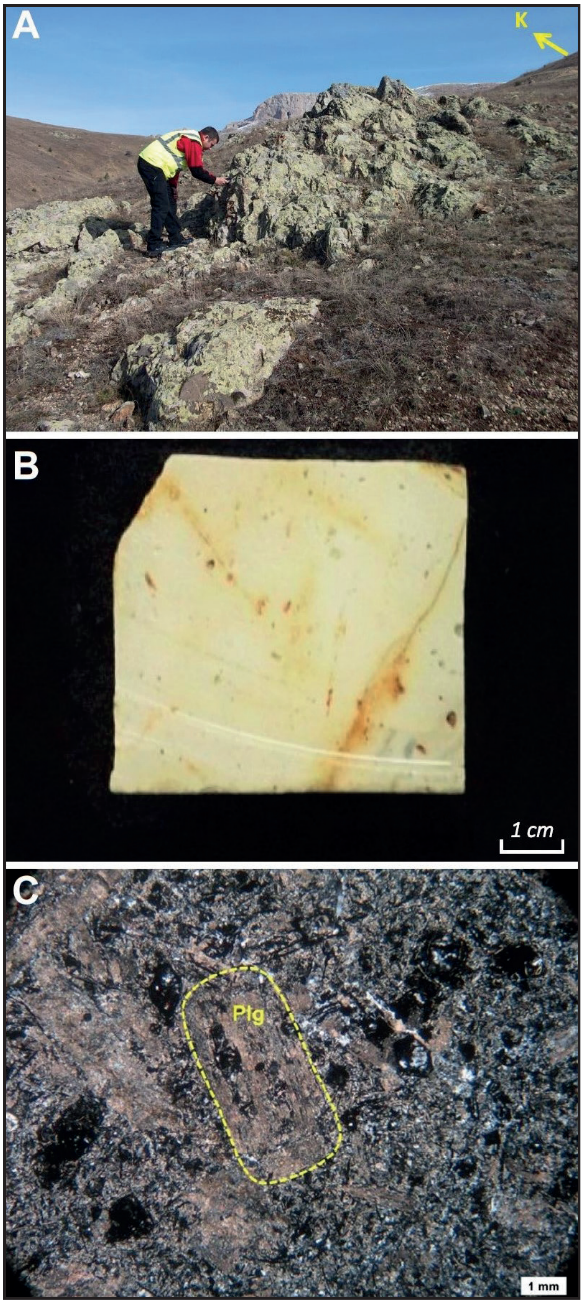


Figure 5- A) General field views of dacite porphyries, B) Hand specimen, C) Thin section view.

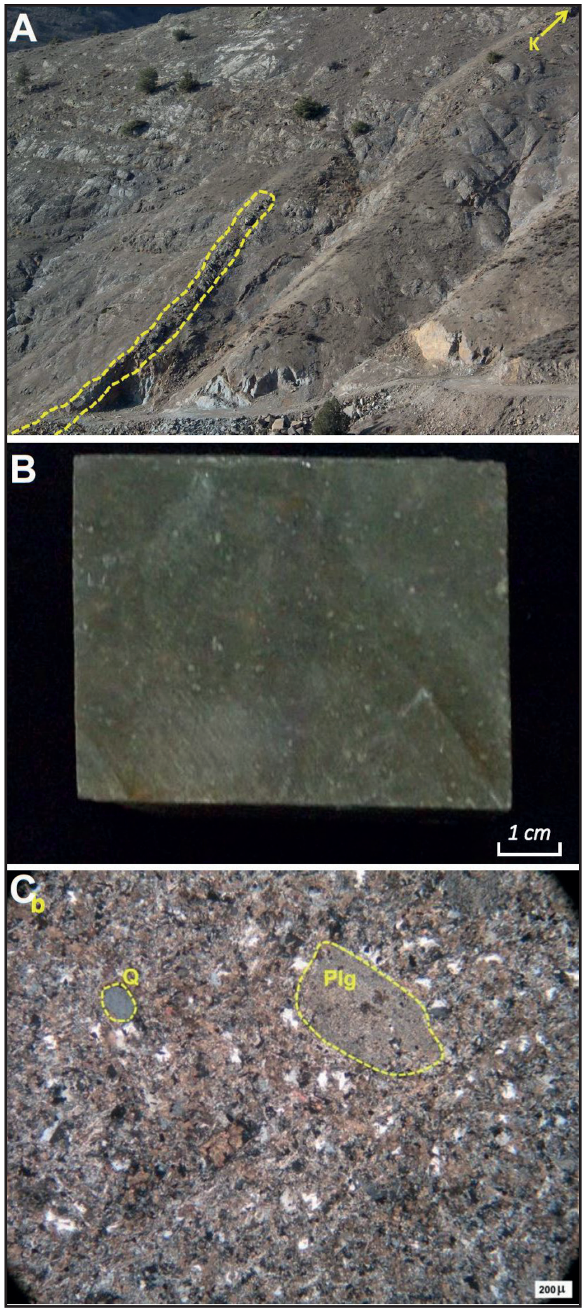


Figure 6- Andesitic dikes A) Field view, B) Hand specimen view, C) Thin section view.

These dykes in the study area have intercepting relations with older units, so they are considered to be Eocene age.

3.6. Alluvium

Stream sediments in the study area are present around Kara Dere. In the field in and around Kara Dere alluviums cover a 300 m long and 100 m wide area. Elements of the alluvium are rounded and are loosely cemented.

4. Structural Geology

In the study area as Lower-Middle Jurassic Hamurkesen formation overlies basement Permo-Carboniferous Gümüşhane granitoid with basal conglomerates indicating unconformity showing that geological time gaps and long period of erosion during this time gap. Units of the Berdiga and Mescitli formations in the study area have concordant relationships indicating that in the area tectonically they had a quite sedimentation process.

In the study area 3 different fracture systems are present. They have NE-SW and NW-SE strike directions. Fracture system with NE-SW system has N60ºE and E-W strikes, dacite porphyries have developed in these fractures. N-S fracture system is closely associated with the andesitic dike systems, intercepting all older units in the study area NW-SE fractures area the youngest and intercept all other structure systems.

5. Mineralizations

In the study area mineralizations are present in three different locations. They are (ia) pebbles with sphalerites derived from the Gümüşhane granite (?), transported (magmatic) type mineralizations (ib) in the western slopes of Batarya Tepe Zn-Pb-Ag (Au) mineralizations in the N70ºE, E-W extending dacite porphyries in the conglomerates-sandstones of the Hamurkese formation, (ii) In the south-western part of the Batarya Tepe Au mineralizations in the dacite porphyries in the sandstones and (iii) around Gözelerin Dere Cu mineralizations in the N-S extending quartz veins and veinlets in the Gümüşhane granite (Figure 7) .

5.1. Batarya Tepe Zn-Pb-Ag-(Au) Mineralizations

Two different types and at two different ages mineralizations can be considered in the Batarya Tepe, they are (ia) transported type (magmatic origin) mineralizations, possibly associated with the Gümüşhane granite (Figure 8) and (ib) hydrothermal type mineralizations possibly related to the dacite porphyries intercepting granites and sandstones.

Presence of disseminated sphalerite bearing pebbles in the conglomerates-sandstones at the base of the Hamurkesen formation represent transported type (magmatic) mineralizations. The pebbles thought to have driven from the Gümüşhane granite is considered to be the right way to assume magmatic origin. Silicificiations argilizations and sericitization are extensive in these magmatic pebbles

Batarya Tepe Zn-Pb-Ag-(Au) mineralizations are associated with N60ºE, E-W striking and 60º-85º South

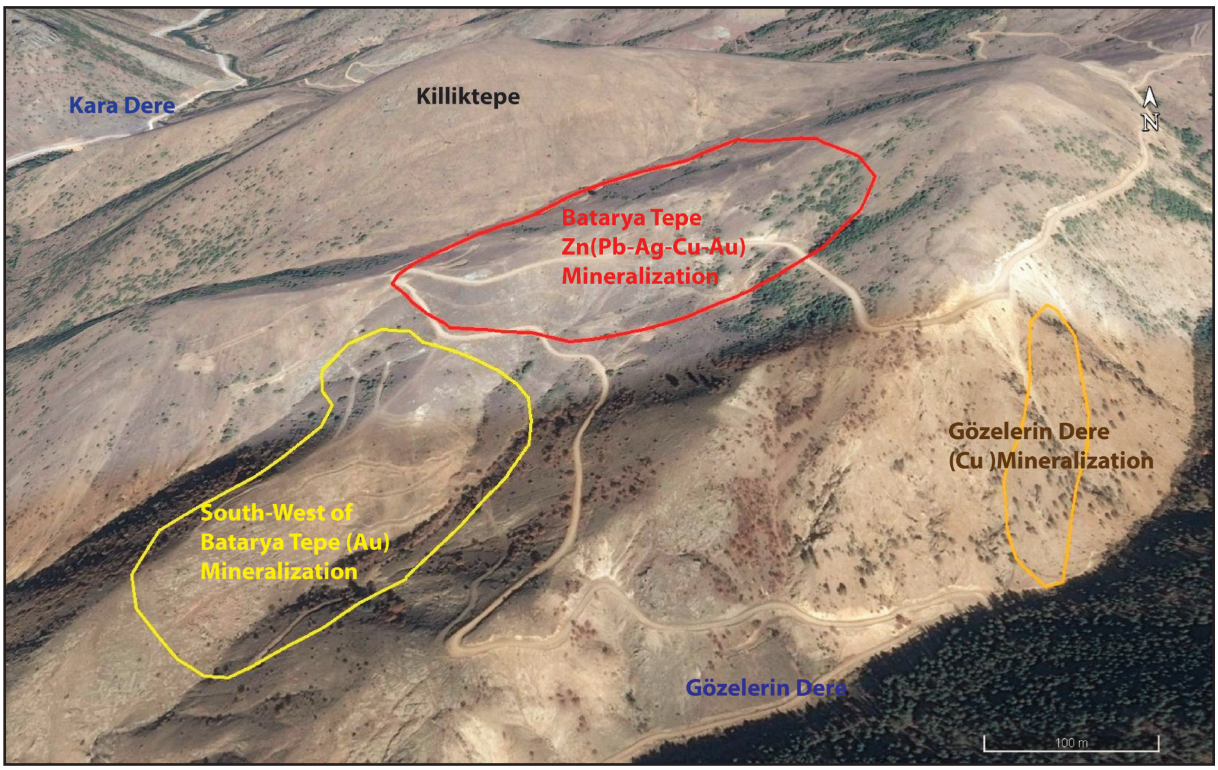


Figure 7- Google earth view of the mineralization areas.

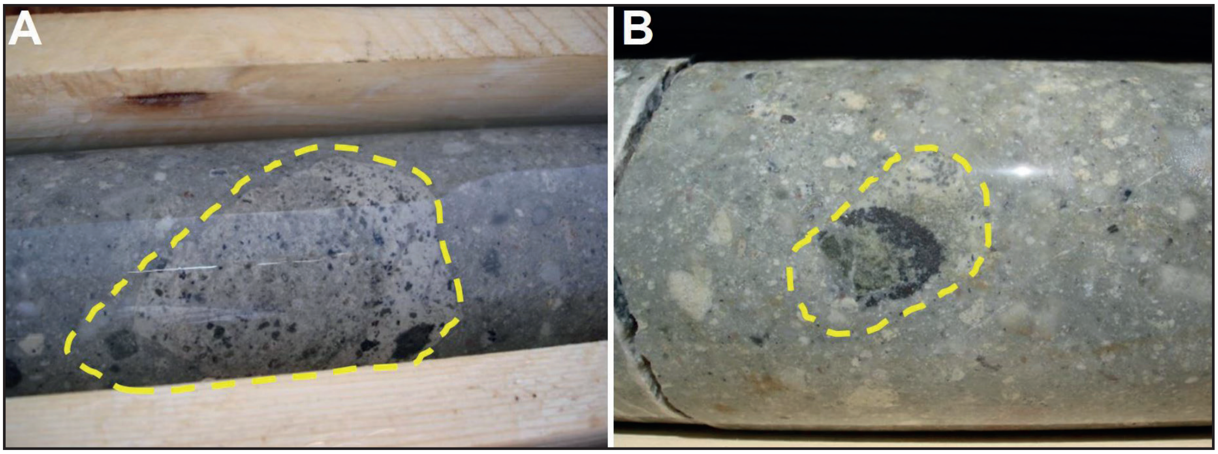


Figure 8- Mineralized pebbles in the conglomerates-sandstones of the Hamurkesen Formation A) Disseminated mineralizations in the pebbles, B) Massive mineralization in the pebbles.

dipping or vertical dacite porphyries. Conglomerates-sandstones of the Hamurkesen formation have been intercepted by dacite porphyries. Mineralizations and alterations have developed in dacite porphyries and in the rocks in contact with. Thickness, extension along the strike-dip directions of the mineralizations are connected and varied with thickness of the dacite porphyries, permeability, porosity, degree of fracturings of the host rock. On the surface alterations of silicificiation, argilization and limonitization and in places brecciations accompany mineralizations. In the Batarya Tepe these mineralized zones cover 150 x 400 m^2 area. With the surface and drill data it is concluded that these zones have 10-50 m continuation along the strike directions and are 1-5 m thick.

5.2. South-West of Batarya Tepe Au Mineralizations

Gold mineralizations in the south-western part of Batarya Tepe is associated with the conglomerates-sandstones of the Hamurkesen formation and with the N-S extending dacite porphyry dikes intercepting these units. In this part in the conglomerates-sandstones there are quartz, sphalerite and galenite bearing veinlets with limited extensions. On the surface carbonate-silica-chlorite-sericite alterations are observed in the dacite porphyries and in the conglomerates and in the sandstones. In this part sandstones-conglomerates and dacite porphyries have been cut by andesitic dikes. Taken surface and underground data together, it has been concluded that the mineralized zone is about 800 m long and up to 400 m wide.

5.3. Gözelerin Dere Cu Mineralizations

Gözelerin Dere Cu mineralizations are located in the ridge between Batarya Tepe and Gözelerin Dere. Within the zone milky quartz veins in varying thickness, varying degrees of silicificiations and argilizations are observed. Milky quartz veins may be up to 30 cm thick. Disseminated pyrite, very few chalcopyrite, galenite and in places malachite, azurite and limonite are present in the milky quartz veins and veinlets. Mineralizations are in the vertical tectonic lines with N10ºW and N-S strikes in the granodiorites of the Gümüşhane granite. They are up the 5 m thick and can be followed about 300 m along their strike directions

6. Mineralization Types

6.1. Transported (Magmatic) Type Mineralizations

In the Hamurkesen formation two different types mineralized rock fragments are present. Size of the mineralized rock fragments vary 1-5 cm. One type is granitic rock pieces (pebbles) with disseminated mineralizations (Rock pieces from the Gümüşhane granite) (Figure 8 A). Second type is massive ore pebbles (Figure 8 B).

6.2. Hydrothermal Type Mineralizations

In the study area hydrothermal mineralizations are observed in the granites, conglomerates-sandstones and dacite porphyries in the form of veins, veinlets, network, disseminations and smears.

6.2.1. Mineralizations in the Quartz Bearing Carbonate Veins-Veinlets

Sphalerite, galenite, pyrite and in places chalcopyrite minerals are present in the 0.5 cm – 1 m thick quartz-carbonate vein-veinlets (Figure 9 A). In places veins have been brecciated (Figure 9 B).

6.2.2. Network Type Mineralizations in Fractures and Cracks

Network type mineralizations are observed along the fractures and cracks in the rocks developed in various directions (Figure 9 C, D). These structures are filled with sulphide minerals and on the surface they are oxidized and have blackish-red coloured appearance.

6.2.3. Disseminated Type Mineralizations

Disseminated types of all kinds of ore minerals present in the region are encountered in the Batarya Tepe in the dacite porphyries and in their host rocks there. In the Gözelerin Dere copper mineralizations chalcopyrite, pyrite and galenite are also disseminated type (Figure 9 E).

6.2.4. Smear Type Mineralizations

Limonite smears are present in the cracks and fractures of all kinds of rock types present in the study area (Figure 9 F).

7. Alteration

By using drill cores alterations have been studied in detail and alteration patterns from old towards young have been grouped as (I) tremolite-actinolite ± garnet, (II) Quartz-sericite-chlorite and (III) Carbonate-silica alterations. During the processes of mapping because of surface effects and alterations masking one another alterations of silicification, argillization and quartz-sericite-chlorite-clay-carbonate minerals, have been marked with the dominant minerals present (Figure 10).

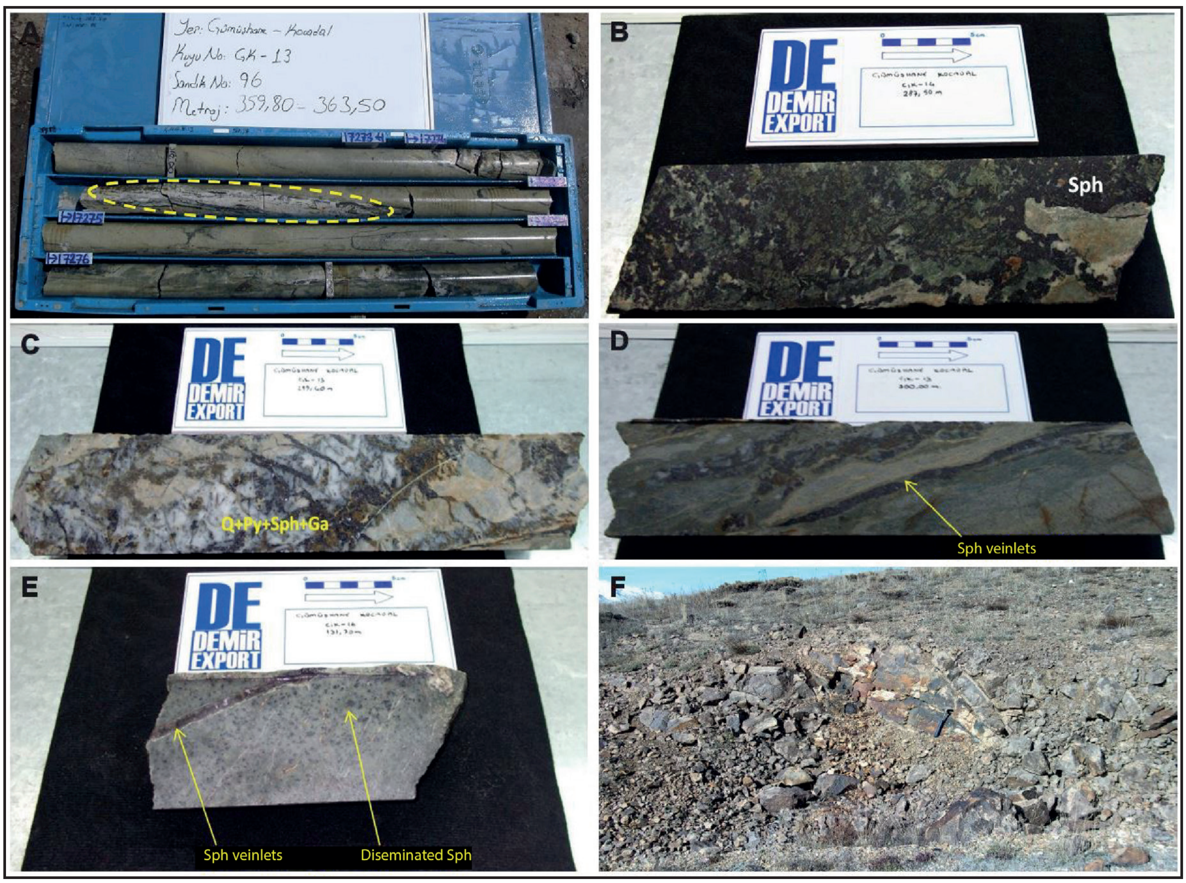


Figure 9- A) Quartz-carbonate vein with sphalerite, B) Mineralized (phalerite) brecciated zone, C) Network type mineralizations in cracks and fractures (Q: Quartz, Py: Pyrite, Sph: Sphalerite, Ga: Galenite), D) sphalerite vein along fractures and cracks, E) Disseminated type mineralization (Sphalerite), F) Smear type mineralization (limonite).

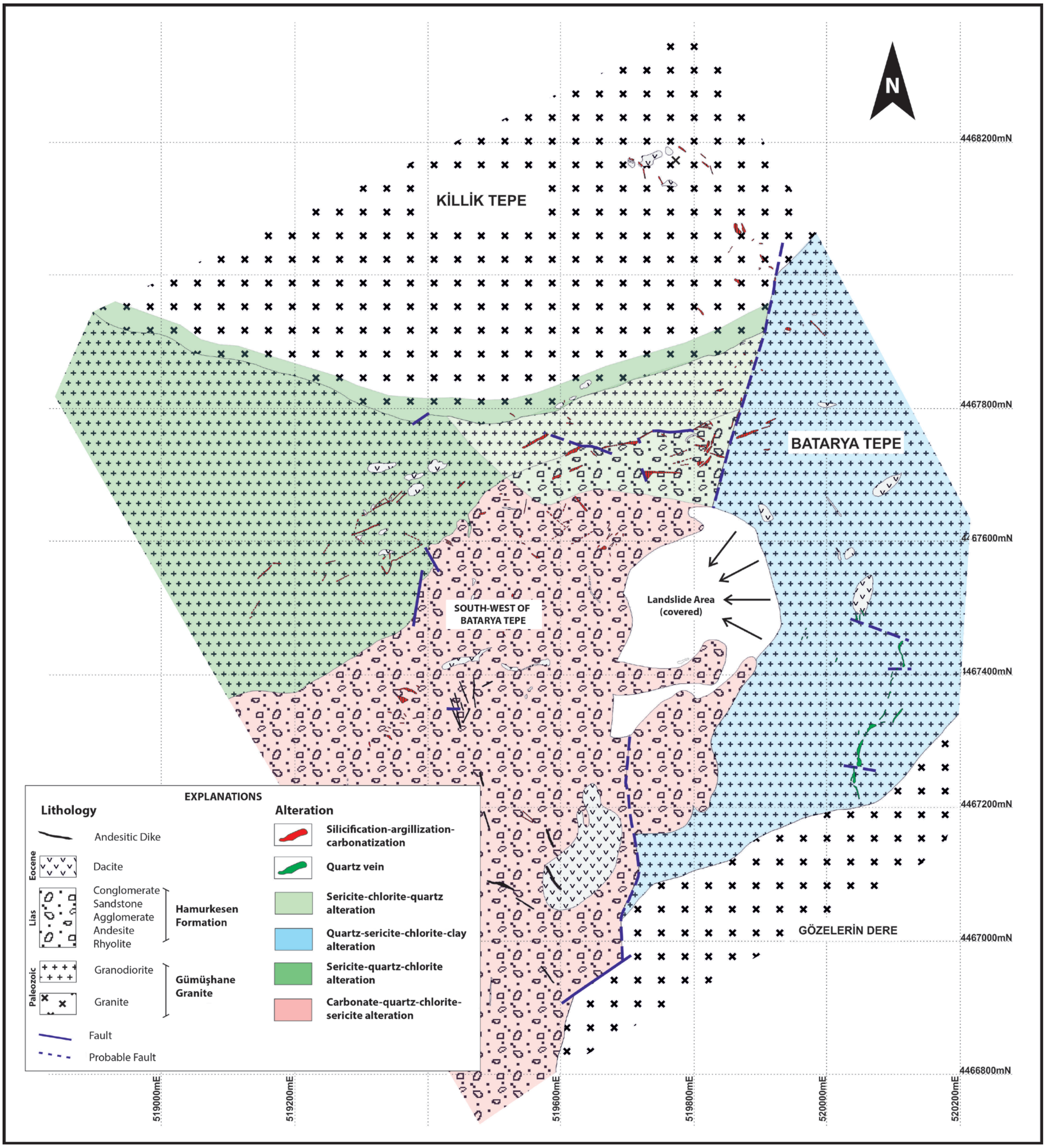


Figure 10- Geology of the Batarya Tepe Mineralizations and alterations map.

In Batarya tepe Tremolite-actinolite ±garnet alteration in general is observed as metasomatisms of veinlets of plagioclases and/or mafic minerals in dacite porphyries, conglomerates-sandstones and granites. Pyrrhotite, pyrite and sphalerite are the ore minerals in this alteration paragenesis.

In Batarya Tepe and south-west of Batarya Tepe, quartz-sericite-chlorite assemblage have developed from the changeover of feldspaths and mafic minerals or in the form of veinlets in the Conglomerates-sandstones and dacite porphyries present. Pyrite and sphalerite are the ore minerals present in this alteration paragenesis.

Last alteration period; carbonate (calcite-dolomite)-silica alteration is observed in Batarya Tepe and in the south of Batarya Tepe. While this alteration in Batarya Tepe is seen to have developed from the mafic minerals in the granites and dacite porphyries or from the changeover of previously developed alteration minerals or have developed as veins intercepting the whole system, on the other hand they developed in the conglomerates-sandstones in association with the veins and veinlets. In the south-west of Batarya Tepe carbonate-silica alterations are seen as veins and veinlets. In the south-west of Batarya Tepe where carbonate-silica alterations are present as veins and veinlets, here sphalerite, galenite, fahlerz, arsenopyrite, pyrargyrite, proustite, chalcopyrite, bournonite and pyrrohotite minerals are present.

8. Mineralogy of the Ore Mineralizations

Ore microscopy studies carried out on the samples from transported (magmatic) and hydrothermal mineralizations in the study area showed that main minerals are pyrite and sphalerite. Along with these main minerals chalcopyrite, galenite, pyrrhotite, arseopyrite, marcasite, fahlerz, bournonite, pyrargyrite and proustite are also present. Secondary ore minerals; digenite, smithsonite, and limonite accompany to the paragenesis.

In Batarya Tepe mineralized pebbles in the conglomerates-sandstones of the Hamurkesen formation have sphalerite, pyrite. Sphalerites are xenomorph and have up to 3-4 mm varying grain size, rarely include pyrrohotite and chalcopyrite inclusions and exholitions. Pyrites are hypidiomorph and have up to 5 mm grain size.

Detailed informations on the minerals of hydrothermal mineralizations, which is present in three different locations in the area, are given below.

8.1. Pyrite

Two generations of pyrites are present. First generation of pyrites are hypidiomorphic (Figure 11 A, B), partly, among themselves forming interlocked crystal groups. They are about 0.5 mm size. First generation of pyrites are the oldest mineral of the paragenesis have cataclastic and mesh texture. They have been metasomatized by other minerals. They are interlocked with sphalerites. Second generations of pyrites are not too many and are the products, transformed from pyrrohotites (Figure 11 A, B). These types of pyrites in general are seen as skeletons interlocked with marcasites.

8.2. Sphalerite

Sphalerite minerals in general are xenomorph grains and have pyrite, pyrrohotite, inclusions and chalcopyrite and pyrrohotite exsolution lamellae. These features indicate that sphalerites started developing from hot hydrothermal solutions. Sphalerites have been cut by silver minerals (pyrargerite and proustite) and fahlerz (Figure 11 C) and galenite. Sphalerites have internal glare, indicating that they have excessive Fes in their crystal structure.

8.3. Chalcopyrite

Chalcopyrites are mostly large xenomorph grains and in general interlocked with sphalerites or intercepting them. They also are as exsolution lamellae and as inclusions in sphalerites

8.4. Galenite

Galenites are mostly observed in the quartz-carbonate veins and are the youngest mineral in this paragenesis. Grain sizes reach up to 1.1.5 mm. In galenites there are tiny pyrargerite and prusite grains.

8.5. Pyrrohotite

Pyrorrhotite is found in small amount, is present as exsolutions and inclusions in sphalerites and as inclusions in pyrites and arsenopyrites. In tremolite-actinolite±garnet veins and in places where quartz-sericite alterations are effective major part of the disseminated type pyrrohotites have been changed into marcasite or pyrite. Pyrrohotite lamellae changed into pyrite and marcasite have been filled with sphalerite and galenite (Figure 11 D).

8.6. Arsenopyrite

Arsenopyrites are commonly found in in quartz-carbonate veins. Idiomorph and hypidiomorph arsenopyrite crystals are found as rhombic and needle like. Size of arsenopyrite crystals may reach up to 1 mm. Galenite, tiny pyrrohotite, fahlerz and sphalerite grains are observed in marcasites. Arsenopyrites in parts are interlocked with each other and in parts, have cataclastic textures, in places encircle pyrites and replace it by metasomatism.

8.7. Marcasite

Mascasite is found as alteration products of pyrites and hexagonal pyrrohotites. Marcasites changed from pyrrohotites are as lamellae. Marcasites resulted from the hydrothermal alteration of hexagonal pyrrohotites and pyrites have banded structure. With the development of sericite-clay-carbonate alteration pyrohotites and first stage pyrites have changed into marcasite. Marcasites are noticeable with high reflectivity, light yellow colour, reflection pleochroism and anisotropy.

8.8. Fahlerz (Tetrhedrite-Tennantite)

Fahlerz is commonly found in the quartz-carbonate veins, mostly xenomorphic fine grains with about 10-15 microns size. Fine grains of galenite, bournonite, pyrargyrite and proustite grains are found in fahlerz.

8.9. Pyrargyrite/Proustite

Pyrargyrite/Proustite is found small amount in quartz-carbonate veins. They encircle fahlerz grains and replaces them (Figure 11.E). Size of the largest interlocked pyrargyrite/proustite group is about 0.1-0.15 mm. They are also present as thin veinlets cutting sphalerites and as small grains in the galenites (Figure 11.F).

8.10. Bournonite

Bournonite grains are not very common in quartz-carbonate veins, they are found in fahlerz with galenite grains. Grain size is about 10-15 microns. Bournonites are found in chalcopyrites and in places in the cracks and partly display parallel twining.

8.11. Digenite

Digenites as secondary minerals are present small amount and generally found surrounding sphalerites and chalcopyrites as thin zone. They are also found filling the cracks of these minerals.

8.12. Smithsonite

Smithsonite is found as very fine grains in the cracks and fractures.

8.13. Limonite

Limonite is the alteration mineral of the sulphides found on the surface along the cracks and fractures.

By looking at the above given features and their mineralogical relations with each others of the minerals present, paragenesis of the hydrothermal minerals from old to young are; pyrrohotite, pyrite (I), sphalerite, chalcopyrite, galenite, bournonite, fahlerz, arsenopyrite, pyrite (II), pyrargyrite/proustite, digenite, smithsonite and limonite (Figure 12).

9. Geochemical Studies

In the study area to establish the dimensions, origin and economical potential of the mineralizations, geochemical studies carried out on the samples collected. In this connection first soil samples were collected then drill cores.

9.1. Soil Geochemistry

Soil geochemical studies have been carried out to establish surface extension of the mineralizations in and around Batarya Tepe. 12 sample lines along N-S direction with 100 m in between have been established. Length of the lines varied between 250 m to 850 m. Soil samples were collected along those established lines with 50 m intervals.

Collected samples without being subjected to any treatment like sieving etc. were sent to the ALS Chemex Laboratories for chemical analyses. In the laboratory the samples were dried, sieved through 50 mesh sieve and have been analysed 50 elements by ICP MS method.

Analyses of Au, Ag, Pb, Zn and Cu have been statistically studied. On average, standard deviations higher than +1 (+1 σ) have been considered weak anomaly and on average standard deviations higher than +2 (+2 σ) have been considered strong anomaly. In the study area, in three different parts contour maps have been prepared for Au, Ag, Pb, Zn and Cu for average+1 and +2 standard deviations. Certain anomaly groups have been established in three areas. They are; (I) Zn-Ag-(Au, Cu, Pb) anomaly district around Batarya Tepe, (II) Au anomaly district south-west of Batarya Tepe and (III) Cu anomaly around Gözelerim Dere district. When Strong Zn anomaly

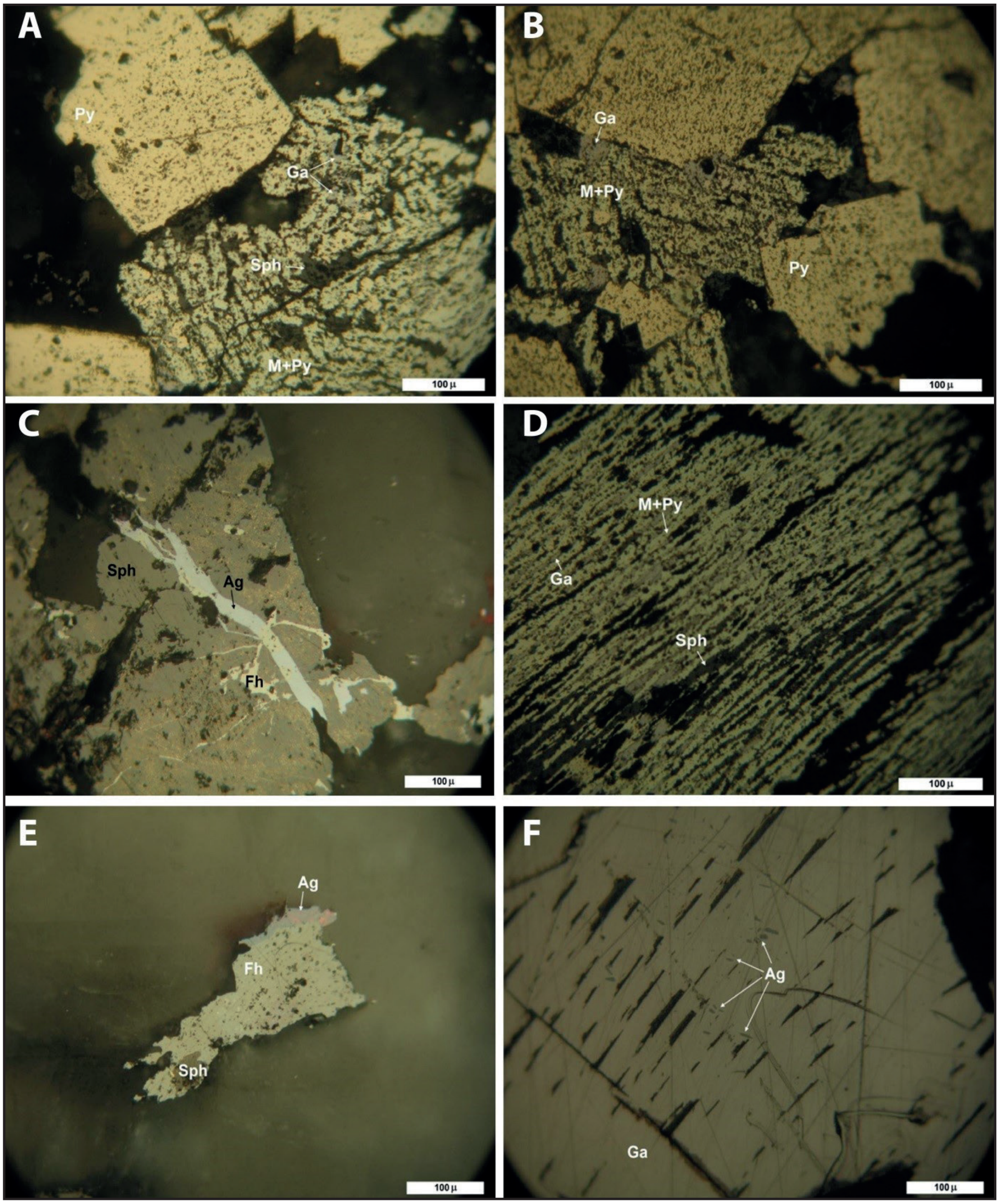


Figure 11- Hydrothermal mineralizations in the Batarya Tepe A,B) Change of first generation pyrite and arsenopyrite into marcasite and pyrite. Filling of pyrrohotite lamellae by sphalerite and galenite, C) Fahlerz and silver (pyrargyrite/proustite) cutting sphalerite, D) Change of pyrrohotite into pyrite and marcasite, filling of pyrrohotite lamellae by galenite and sphalerite, E) Silver mineral encircling fahlerz, and silver minerals in fahlerz, F) Silver minerals inclusions in galenite (Ag: Silver, Fh: Fahlerz, Ga: Galenite, M: Marcasite, Py: Pyrite, Sph: Sphalerite) .

around Batarya Tepe is considered together with the weak anomaly it is noticed that it is extending E-W direction. In the strong Zn anomaly area in Batarya Tepe there are also strong Ag, Au, Cu and Pb anomalies. In the south-west side of Batarya Tepe strong Au anomaly, accompanied by strong Pb anomalies has N-S extension. On the other hand in the northern part of the Gözelerin Dere there is a N-S extending Cu anomaly (Figure 13).

9.2. Core Samples Geochemistry

To be able to study the deep down distribution pattern of the soil geochemical analyses findings,

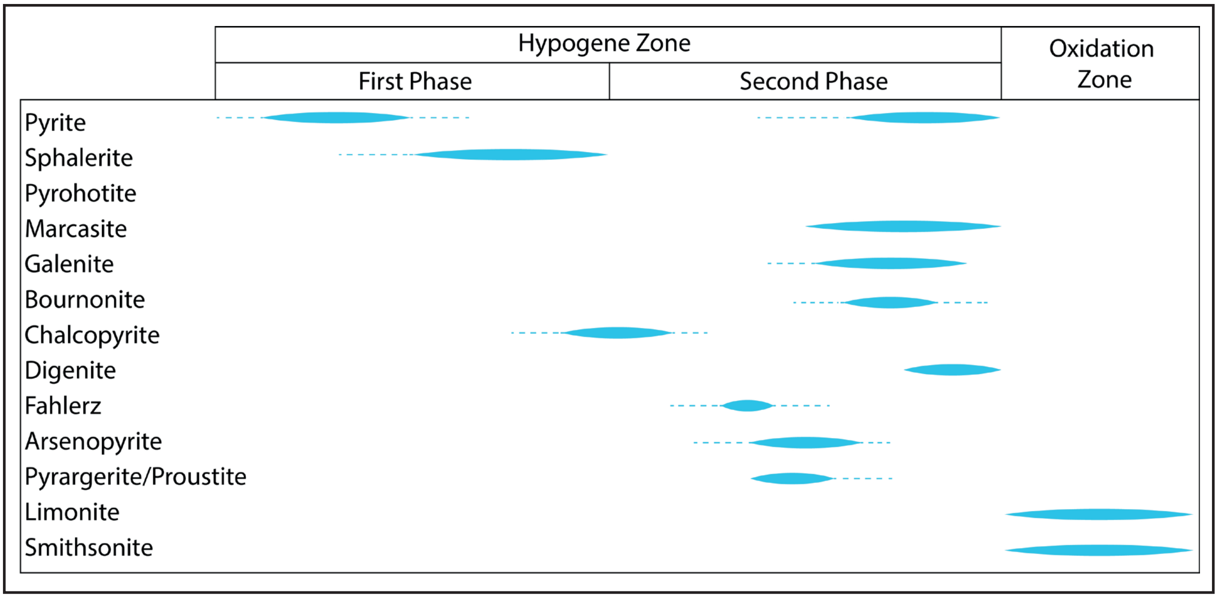
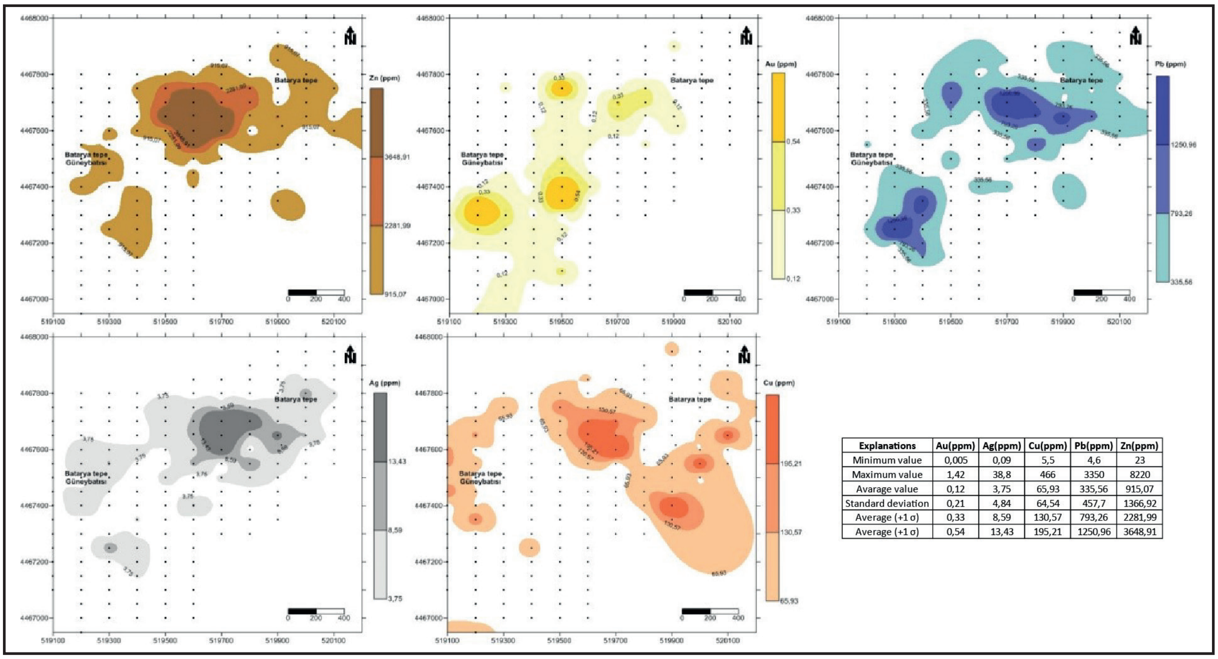


Figure 12- Paragenesis of the hydrothermal mineralizations.



Explanations	Au(ppm)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)
Minimum value	0,005	0,09	5,5	4,6	23
Maximum value	1,42	38,8	466	3350	8220
Avarage value	0,12	3,75	65,93	335,56	915,07
Standard deviation	0,21	4,84	64,54	457,7	1366,92
Average (+1 σ)	0,33	8,59	130,57	793,26	2281,99
Average (+1 σ)	0,54	13,43	195,21	1250,96	3648,91

Figure 13- Zn, Au, Pb, Ag and Cu anomaly areas worked out from the soil geochemistry.

core samples of the mineralized zones of the drillings conducted on the Batarya Tepe and on the south-west of Batarya Tepe have been analysed and statistical data of the analyses of all elements are given in table 1.

In Batarya Tepe and in south-west part of it, to be able to understand elements togetherness of the analyses in different lithologies, correlation coefficients of 50 elements data set have been calculated. While evaluating correlation coefficients of the analyses, for Batarya Tepe mineralizations, over 5000 ppm values for Zn and over 0.1 ppm values for Au for the south-west part of Batarya Tepe have been selected. From the cumulative distributions of the coefficients, for positive correlations; coefficients 0.5 and over, for negative correlations; coefficients -0.5 and under have been accepted to be presenting meaningful correlation couples. Elements present in the mineralizations in different lithologies considered

Table 1- Statistical data on the analyses of the mineralized zones of the core samples.

Sector	Lithology	Statistics	Au_ppm	Ag_ppm	Al_pct	As_ppm	Ba_ppm	Be_ppm	Bi_ppm	Ca_pct	Cd_ppm	Ce_ppm
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralizaitons	Conglomerate-Sandstone (N=349)	Max	5.61	149.00	9.51	6490.00	1380.00	3.37	293.00	4.96	346.00	195.00
		Min	0.0025	0.62	0.28	7.30	10.00	0.25	1.02	0.15	14.45	19.00
		Average	0.08	9.33	6.64	270.76	285.30	1.60	16.70	1.03	42.93	57.07
	Dacite Porphyry (N=184)	Max	5.17	906.00	8.99	10000.00	7830.00	2.95	227.00	8.13	521.00	131.50
		Min	0.00	1.14	0.22	8.20	10.00	0.25	0.03	0.06	10.40	13.10
		Average	0.17	19.06	5.99	769.51	274.08	1.84	14.24	0.89	53.44	41.54
	Granite (N=545)	Max	4.14	110.00	9.88	10000.00	6060.00	3.14	422.00	9.20	347.00	215.00
		Min	0.00	0.30	0.29	1.00	20.00	0.25	0.14	0.07	16.10	14.00
		Average	0.08	7.74	6.78	421.05	273.52	1.79	14.78	1.55	51.34	49.34
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-Sandstone (N=149)	Max	6.26	98.50	7.91	5080.00	1320.00	2.65	17.90	5.17	48.00	62.90
		Min	0.10	0.20	0.28	6.60	10.00	0.50	0.05	0.57	0.01	35.70
		Average	0.52	4.30	4.70	662.40	233.56	1.50	1.43	2.33	4.00	52.69
	Dacite Porphyry (N=80)	Max	14.80	454.00	8.43	5430.00	790.00	2.49	5.00	5.78	33.10	64.60
		Min	0.11	0.50	0.28	13.00	10.00	0.25	0.02	0.20	0.51	24.20
		Average	0.84	15.34	4.27	1068.98	216.75	1.41	0.85	1.08	7.98	36.58

Sector	Lithology	Statistics	Co_ppm	Cr_ppm	Cs_ppm	Cu_ppm	Fe_pct	Ga_ppm	Ge_ppm	Hf_ppm	In_ppm	K_pct
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralizaitons	Conglomerate-Sandstone (N=349)	Max	43.70	265.00	3.96	4870.00	14.25	23.10	0.41	6.40	37.30	4.77
		Main	2.80	2.00	0.95	12.20	2.04	5.00	0.05	0.50	0.07	0.22
		Average	11.00	24.61	1.86	246.65	5.38	17.02	0.18	2.18	4.95	3.21
	Dacite Porphyry (N=184)	Max	279.00	319.00	5.19	10150.00	14.35	23.30	0.34	5.10	24.10	4.03
		Min	0.60	0.50	0.65	27.90	1.12	5.00	0.05	0.50	0.02	0.19
		Average	10.10	21.85	2.03	309.77	4.24	15.60	0.14	2.06	4.52	2.79
	Granite (N=545)	Max	428.00	289.00	8.97	42170.00	14.40	27.00	0.40	4.20	72.10	4.69
		Min	1.80	0.50	0.92	8.50	1.15	5.00	0.05	0.50	0.07	0.19
		Average	13.91	21.24	3.33	275.72	6.03	17.11	0.17	1.65	5.42	2.74
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-Sandstone (N=149)	Max	19.20	32.00	4.62	384.00	7.74	20.00	0.25	3.40	3.85	4.73
		Min	3.20	2.00	1.19	8.20	1.65	5.00	0.11	2.20	0.04	0.23
		Average	8.84	12.65	2.51	44.43	2.93	12.69	0.17	2.82	0.28	2.30
	Dacite Porphyry (N=80)	Max	20.00	103.00	4.93	220.00	4.65	17.85	0.19	2.70	1.17	4.05
		Min	0.50	0.50	0.97	4.00	0.55	5.00	0.03	1.30	0.04	0.27
		Average	2.31	5.58	1.71	52.46	1.65	10.93	0.12	1.99	0.33	2.06

Sector	Lithology	Statistics	La_ppm	Li_ppm	Mg_pct	Mn_ppm	Mo_ppm	Na_pct	Nb_ppm	Ni_ppm	P_ppm	Pb_ppm
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralizaitons	Conglomerate-Sandstone (N=349)	Max	92.80	36.20	2.52	14350.00	16.60	1.21	43.90	105.00	1680.00	14250.00
		Min	5.00	2.30	0.21	1000.00	0.31	0.01	6.30	1.60	240.00	12.70
		Average	26.34	5.99	0.98	5192.35	2.01	0.04	11.70	16.21	647.91	394.43
	Dacite Porphyry (N=184)	Max	82.30	37.20	4.35	47200.00	76.90	0.73	33.80	137.00	1460.00	24500.00
		Min	5.00	2.00	0.05	216.00	0.20	0.01	2.70	0.20	10.00	20.20
		Average	19.17	7.15	0.78	2924.57	1.95	0.05	9.10	6.51	347.50	917.06
	Granite (N=545)	Max	129.50	52.10	4.08	9210.00	14.60	2.28	18.20	121.50	1860.00	17050.00
		Min	5.00	1.90	0.22	402.00	0.16	0.01	2.00	0.20	10.00	12.80
		Average	22.08	11.47	1.46	3965.24	1.57	0.25	8.07	4.80	552.39	532.50
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-Sandstone (N=149)	Max	32.30	16.40	2.39	11100.00	8.71	1.62	12.40	28.40	630.00	4460.00
		Min	5.00	2.30	0.46	752.00	0.50	0.01	8.50	5.10	380.00	3.00
		Average	19.84	5.78	1.10	3391.24	1.76	0.10	10.73	12.02	506.98	415.14
	Dacite Porphyry (N=80)	Max	26.40	25.50	2.78	8420.00	10.95	0.85	10.20	62.10	1530.00	8910.00
		Min	5.00	4.00	0.14	373.00	0.50	0.01	6.40	0.30	180.00	25.90
		Average	15.19	6.91	0.51	1676.66	1.58	0.04	8.61	4.25	288.63	869.78

Sector	Lithology	Statistics	Rb_ppm	Re_ppm	S_pct	Sb_ppm	Sc_ppm	Se_ppm	Sn_ppm	Sr_ppm	Ta_ppm	Te_ppm
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralizaitons	Conglomerate-Sandstone (N=349)	Max	197.00	0.004	9.34	169.50	29.00	7.00	17.80	132.00	2.81	1.07
		Min	63.10	0.001	0.07	0.87	2.00	0.50	1.10	2.00	0.35	0.03
		Average	128.50	0.001	2.17	7.57	10.71	2.00	7.28	26.65	0.88	0.18
	Dacite Porphyry (N=184)	Max	177.50	0.007	10.00	505.00	33.40	11.00	16.20	359.00	2.47	2.17
		Min	49.70	0.001	0.50	1.00	0.50	0.50	1.20	2.00	0.15	0.03
		Average	118.52	0.002	2.20	20.92	8.61	2.04	4.98	25.01	0.71	0.12
	Granite (N=545)	Max	288.00	0.010	10.00	184.50	32.90	10.00	16.20	510.00	3.12	1.40
		Min	37.40	0.001	0.01	0.74	1.60	0.50	1.10	3.70	0.13	0.03
		Average	132.20	0.001	2.16	9.97	16.57	1.85	5.36	43.12	0.69	0.12
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-Sandstone (N=149)	Max	184.00	0.004	7.47	51.10	12.40	3.00	10.40	93.30	0.94	0.42
		Min	74.90	0.001	0.27	0.66	2.00	0.50	1.80	3.00	0.65	0.03
		Average	145.38	0.001	1.38	7.34	7.43	1.36	3.55	19.58	0.80	0.08
	Dacite Porphyry (N=80)	Max	153.00	0.007	3.12	214.00	16.80	2.00	4.20	203.00	0.82	0.29
		Min	64.30	0.001	0.06	1.00	0.50	0.50	0.70	3.00	0.35	0.03
		Average	120.67	0.001	0.81	15.16	2.34	0.98	1.44	18.06	0.70	0.05

Sector	Lithology	Statistics	Th_ppm	Ti_pct	Tl_ppm	U_ppm	V_ppm	W_ppm	Y_ppm	Zn_ppm	Zr_ppm	Hg_ppm
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralizaitons	Conglomerate-Sandstone (N=349)	Max	38.40	0.80	10.00	14.80	161.00	45.70	27.00	91200.00	500.00	1.00
		Min	1.50	0.01	0.40	0.30	3.00	2.80	6.40	5030.00	19.40	0.01
		Average	10.00	0.29	1.35	2.73	66.20	9.40	12.19	11660.20	76.42	0.13
	Dacite Porphyry (N=184)	Max	26.80	0.56	5.00	12.40	217.00	26.00	26.10	98200.00	183.50	6.20
		Min	0.90	0.01	0.32	0.50	0.50	1.10	4.20	5040.00	15.00	0.01
		Average	7.81	0.15	1.10	2.48	37.17	6.79	11.13	13058.86	57.17	0.24
	Granite (N=545)	Max	38.00	0.70	10.00	19.30	261.00	21.70	26.70	95800.00	99.40	3.04
		Min	1.20	0.01	0.36	0.50	1.00	1.10	4.30	5010.00	10.90	0.01
		Average	10.36	0.29	1.40	3.17	97.68	8.37	12.78	12267.08	41.36	0.22
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-Sandstone (N=149)	Max	10.80	0.30	5.00	5.00	71.00	12.80	20.20	10600.00	109.50	1.00
		Min	6.20	0.01	0.60	1.40	2.00	1.40	10.10	12.00	70.80	0.01
		Average	9.29	0.16	2.44	3.18	38.70	5.07	13.86	1125.23	88.12	0.28
	Dacite Porphyry (N=80)	Max	10.00	0.43	5.00	5.00	122.00	8.20	13.90	9160.00	99.00	1.00
		Min	1.20	0.01	0.58	0.40	0.50	1.00	8.20	144.00	35.30	0.01
		Average	7.15	0.05	2.26	2.93	6.54	3.13	10.01	2105.83	53.58	0.36

to have different origin so those elements showing meaningful correlations with each other are given in table 2.

Elements togetherness have been worked out from the correlation coefficient studies for the Zn-Pb-Ag-(Au) mineralization of the samples collected from the conglomerates-sandstones in Batarya Tepe, is given in table 3. First group of togetherness is represented with Zn-Ag-Cd-S, Second group with Se-Cd and third group with Cd-Zn-In-Se. In the same district correlation coefficients of the mineralized zones in the dacite porphyries have also been studied and two elements togetherness have been worked out; first group is; Zn-Ag-Cd-Mo-Sb-Se-Sr and the second group is; Zn-In-S togetherness. Correlation coefficients of the analyses of the samples from the granites indicated Au-As-Sb, Zn-In-S and Zn-Cd-S togetherness's.

In Batarya Tepe south-west Au mineralizations, correlation coefficients of the analyses of samples collected from the conglomerates-sandstones showed 3 elements togetherness (Table 4). They are Zn-In-Cu; Zn-Pb-Cd and Zn-Te-Cu-In-Cd-Hg togetherness's. In the same area correlation coefficients of the samples from dacite porphyries also indicated 3 different elements togetherness, they are Au-As; Zn-Cd-Pb-In-S-Te and Ag-In-Sb. togetherness's.

In and south-west Batarya Tepe dacite porphyries are considered to be the source of hydrothermal solutions causing mineralizations. Mineralizations here present different elements combinations. These differences are also noticeable in the conglomerate-sandstone samples from these two areas and also in the granitic rock samples only from Batarya Tepe. Partial resemblances of the correlation coefficient groups of the analyses of the conglomerate-sandstone and granitic rock samples indicate that magmatic type (transported) mineralized pebbles derived from the Gümüşhane granites have been incorporated in the conglomerates-sandstones.

In two areas, elements combinations of the mineralizations, particularly observed in the dacitic rocks show noticeable variations. In the south-west of Batarya Tepe, it is noticeable that within the elements groups Au, Pb, As and Te are incorporated into the groups. This may mark zonings in the mineralizations and may also show different phases of dacite porphyry intrusions.

In the Gözelerin Dere analyses of the 5 samples collected from the Cu mineralizations in the quartz veins show following variations Cu: 97.2-160 ppm, Au: 0.005-0.111 ppm, Ag: 0.07-5.91 ppm and Pb: 16.8-1.160 ppm.

According to Stanton (1972) sulphides with magmatic origin mostly have smaller than 20.000 S/Se ratios. An S/Se ratio of the samples collected from the conglomerates-sandstones in Batarya Tepe is 10.85 and in the south-west Batarya Tepe is 10.146. These ratios indicate that hydrothermal solutions have magmatic origin (Table 5).

10. Conclusions

In the study area in Kocadal (Torul, Gümüşhane) mineralizations have been identified in three different areas. They are (I) Batarya Tepe Zn-Pb-Ag-(Au) mineralizations, (II) South-West Batarya Tepe Au mineralizations and (III) Gözelerin Dere Cu mineralizations.

Batarya Tepe Zn-Pb-Ag-(Au) mineralizations have two different origins; pebbles with sphalerite derived from Gümüşhane granite in the conglomerates-sandstones of the Hamurkesen formation, Zn-Ag-(Au) mineralizations associated with dacite porphyries which have intrusive relations with the conglomerates-sandstones of the Hamurkesen formation and with the Gümüşhane granite (Figure 14). In the South-west of Batarya Tepe Hydrothermal Au mineralizations have been identified in the dacite porphyries which has intrusive relations with the conglomerates-sandstones. Around Gözelerin Dere Cu mineralizations are present in the quartz veins and veinlets in the Gümüşhane granite. Kocadal Batarya Tepe and South-West Batarya Tepe mineralizations are genetically associated with Eocene dacite porphyries. Mineralizations display alterations in wide areas and include disseminated, veinlets/veins and stockwork type mineralizations.

Porphyry type Lengshuıkeng Pb-Zn ore deposit has developed in association with granite porphyries which has intrusive relation with Upper Jurassic volcanic rocks. Yijue (1985) studied this deposit and showed that alteration pattern from granite porphyry

Table 2- In whole of the drill core samples, elements showing meaningful correlations with each other.

	Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralization		South-West of Batarya Hill (Au) Mineralizaiton		
	Conglomerate-Sandstone	Dacite Porphyry	Granite	Conglomerate-Sandstone	Dacite Porphyry
Au	–	As, Sb, Pb	As, Sb	–	As
Ag	Bi, Cd, Cu, Pb, S, Sb, Te, Zn	Ba, Cd, Mo, Sb, Se, Sr, Zn, Hg	Bi, Pb, Sb, Te	Fe, S, Sb	In, Sb
Zn	Ag, Cd, In, S, Se	Ag, Cd, In, Mo, S, Sb, Se, Sr Hg	Cd, In, S	Cd, Cu, In, Pb, S, Te, Hg	Cd, Cu, In, Pb, S, Te, Hg
Se	Zn, Hg, Cd, In	Ag, Cd, S, Sb, Sr, Zn, g, Mo	–	–	–
Pb	Ag, Zr	Sb	Ag, Cd	Zn, Cd	Cd, In, S, Sn, Te, Zn
Te	Ag, Bi	Bi	Ag, Bi, Cu	Zn, S, Cu, Co	Bi, Cd, Pb, S, Sn, Zn, In
In	Cd, S, Zn, Se	S, Zn, Bi	Zn	Cd, Cu, Zn, Hg	Ag, Bi, Cd, Cu, Pb, Zn, Hg
Bi	Ag, Te	In, Te	Ag, Te	Te	In, Te
Cd	In, S, Se, Zn, Ag, Cu	Mo, S, Sb, Se, Sr, Zn, Zr, Ag, Ba, Hg	Pb, S, Zn	In, Pb, Zn	In, Pb, Sn, Te, Zn, Hg, S
S	Ag, W, Zn, Cd, Co, Fe	Cd, In, Fe, Sb, Se, Zn	Cd, Zn	Ag, Co, Fe, Sb, Te	Cd, Fe, Pb, Sn, Te, Zn, In
Sb	Ag, As	Au, Ag, As, Mo, Pb, S, Zn, Hg	Au, Ag, As	Ag, Fe, S	Ag
Fe	Co, Mn, Ni, P, S, Se, Ti, V, W	Ge, Mg, Mn, P, S, Sc, Ti, V, W	Li, Mg, Mn, Sc, V / (Hf, La, Nb, Ta, Th, Zr)*	Ag, Co, S, Sb	Ca, Co, Cr, Cs, Li, Mn, Mg, Na, Ni, P, S, Sc, Sr / (Ta, Nb)*
Mo	–	Ag, Ba, Cd, Sb, Se, Sr, Zn, Hg	–	–	–

()* decribes meaningful negative correlation

Table 3- Zn-Pb-Ag-(Au) elements togetherness's in the Batarya Tepe mineralizations.

			Elements groups showing pozitive correlation (for r>0.5)
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralization	Conglomerate-Sandstone	1st group	Zn, Ag, Cd, S
		2nd group	Se, Cd, In
		3th group	Cd, Zn, In, Se
	Dacite Porphyry	1st group	Zn, Ag, Cd, Mo, Sb, Se, Sr
		2nd group	In, Zn, S
	Granite	1st group	Au, As, Sb
		2nd group	Zn, In, S
		3th group	Zn, Cd, S

Table 4- In Batarya Tepe South-West, elements togetherness in Au mineralizations.

			Elements groups showing pozitive correlation (for r>0.5)
South-West of Batarya Hill (Au) Mineralizaiton	Conglomerate-sandstone	1st group	Zn, In, Cu
		2nd group	Zn, Cd, Pb
		3th group	Zn, Te, Cu, In, Cd, Zn, Hg
	Dacite Porphyry	1st group	Au, As
		2nd group	Zn, Cd, Pb, In, S, Te
		3th group	Ag, In, Sb

Table 5- S/Se ratios of the mineralizations from different lithologies.

		S_pct	Se_pct	S/Se
Batarya Hill Zn(Pb,Ag,Au,Cu) Mineralization	Conglomerate-Sandstone	2,17	0,00020	10852,67
	Dacite Porphyry	2,20	0,00020	10791,36
	Granite	2,16	0,00018	11704,3
South-West of Batarya Hill (Au) Mineralization	Conglomerate-Sandstone	1,38	0,00014	10146,69
	Dacite Porphyry	0,81	0,00010	8249,902

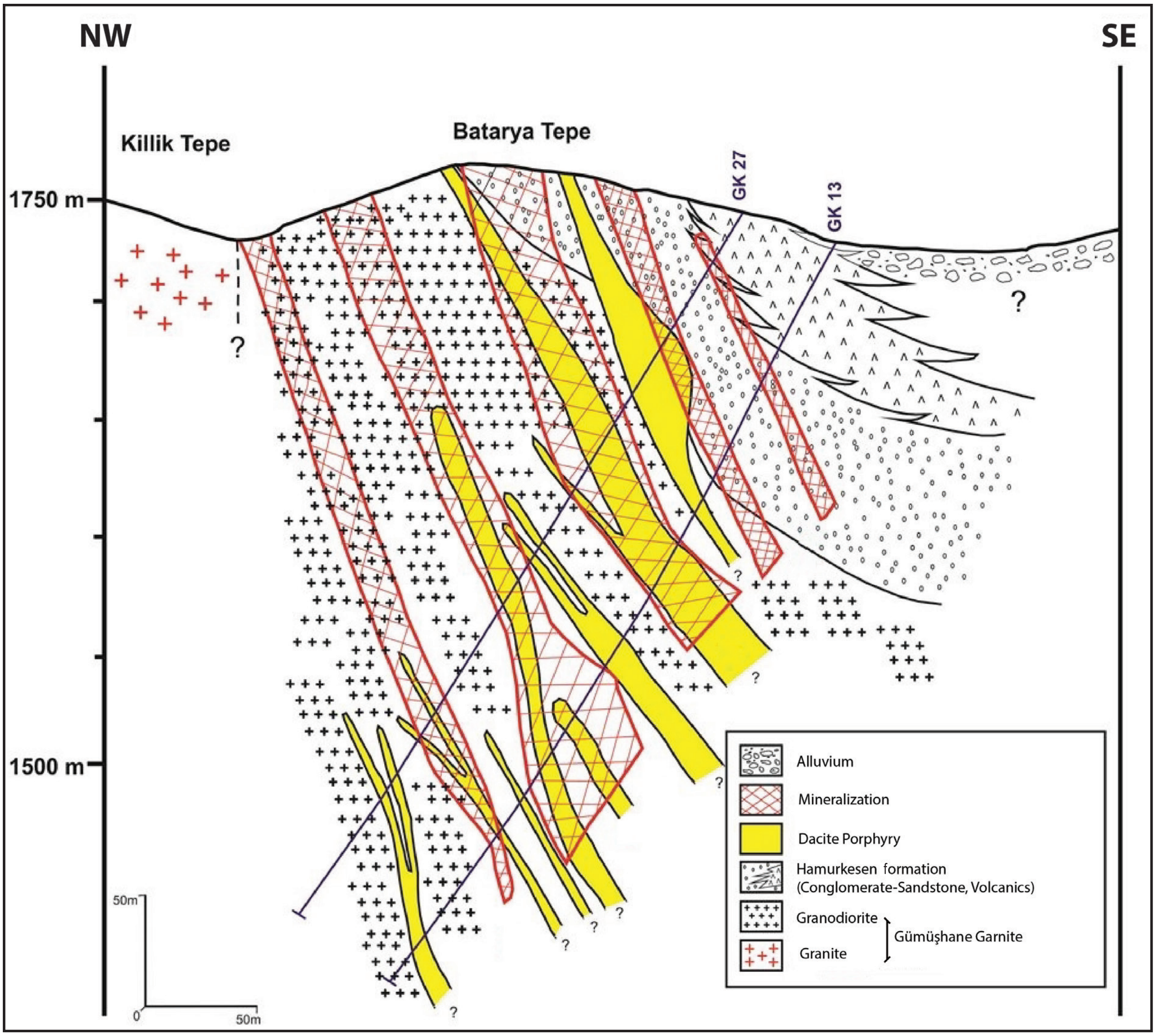


Figure 14- Geological cross section showing dacite porphyries and host rock-mineralization relations.

center towards the host rock have chlorite sericite and carbonate combinations. Lengshuıkeng is defined as low grade porphyry Zn-Pb deposit. As Batarya Tepe Zn (±Pb, Ag, Au, Cu) mineralizations has similar features, so it may also be considered to be a porphyry type mineralization.

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