SUBDUCTION RELATED
ORE DEPOSITS

INTERNATIONAL WORKSHOP

SUBDUCTION RELATED ORE DEPOSITS

23-26
SEPTEMBER
2017

KARADENİZ
TECHNICAL
UNIVERSITY
OSMAN TURAN
CONVENTION CENTER
TRABZON, TURKEY

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ABSTRACT BOOK

TMMOB JEOLOJİ MÜHENDİSLERİ ODASI

SOCIETY for GEOLOGY APPLIED to MINERAL DEPOSITS

International

Workshop

Subduction Related Ore Deposits

Abstract Book

23-26 September 2017
Karadeniz Technical University, Osman Turan Convention and Congress Center

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International Workshop on Subduction Related Ore Deposits

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23.09.2017 (Technical Session-1)		
09.00-09.30	Registration	
09.30-10.30	Opening ceremony	
10.30-10.45	Break	
10.45-12.00	**Dr. Aral Okay**	**Subduction, magmatism and metamorphism - case studies from Anatolia**
12.00-13.15	Lunch	
13.30-14.30	**Dr. İlkay Kuşcu**	**Magmatic Hydrothermal Systems: Porphyry and Skarn Deposits of Turkey**
14.30-15.00	**İsmail Cihan**	**Ulutaş (Erzurum-Turkey) Cu-Mo Deposit**
15.00-15.15	Break	
15.15-16.15	**Dr. Fernando Gervilla**	**Podiform chromitites: how do they form and evolve in suprasubduction mantle?**
16.15-16.45	**Erkan Bayraktar**	**Espiye Kuroko type VMS and Lahanos Cu-Zn deposits from Giresun, Turkey**
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14.00-14.30	**Ercan Karakullukçu**	**Murgul (Artvin, Turkey) VMS Cu deposits**
14.30-15.00	**Dr. Necati Tüysüz**	**Gold in the Pontide magmatic arc**
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SUBDUCTION, MAGMATISM AND METAMORPHISM - CASE STUDIES FROM ANATOLIA

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Abstract

During the Late Paleozoic and Mesozoic the Pontides in northern Turkey generally formed part of the active margin of Laurasia with the Tethyan oceans subducting north under the Pontides. The Pontides had a long history of subduction-accretion, with a documented subduction history extending from Carboniferous to the Late Cretaceous, when the Pontides were separated from the mainland Laurasia with the opening of the Black Sea as a back-arc basin. The subduction was finally terminated in the early Tertiary when the Pontides collided with the Anatolide-Tauride Block. The northward subduction under the Pontides seems to have been semi-continuous with only a lull in the latest Jurassic to earliest Cretaceous (Tithonian – Berriasian).

The main lines of evidence for subduction are magmatic arcs, subduction-accretion complexes and high pressure – low temperature metamorphic rocks. Magmatic arcs of Carboniferous, Jurassic and Late Cretaceous ages are recognized in the Pontides and a major Triassic magmatic arc is most probably present north of the Black Sea under the Tertiary cover of the Scythian Platform.

Upper Triassic subduction-accretion complexes, generally called as the Karakaya complex, are widespread in the Pontides; they are made up of thick sequences of Permo-Triassic metabasites of oceanic island or oceanic plateau origin and strongly deformed Triassic greywackes with exotic blocks of Permian and Carboniferous limestone. The metabasites of the Karakaya Complex includes tectonic slices of eclogite and blueschist dated to the latest Triassic. Jurassic subduction-accretion complexes are increasingly being recognized along the southern margin of the Pontides. They consist mainly of metabasite, phyllite and recrystallized carbonates. Lower Cretaceous (Albian) accretionary complexes, including eclogites and blueschists, crop out widely in the southern parts of the Central Pontides. Upper Cretaceous subduction-accretion complexes consist mainly of oceanic crustal rocks and are commonly termed as the ophiolitic mélange.

MURGUL ORE DEPOSITS AND GEOLOGY

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Abstract

Murgul region basic rocks composed of exposed Paleozoic aged metamorphic rocks along the Artvin-Choruh valley, affected by Alpine orogenesis located in north east of the eastern pontide tectonic belt, are represented by volcanic rocks indicating the island arc formed during the period from Liassic to Pliocene. Upper Cretaceous is the most intense period of this volcanism, especially in this period it has developed as submarine volcanism. Sedimentation took place during the volcanic breaks and volcanic rocks were also accompanied by sedimentary rocks.

Mineralization is being observed along the boundary of the upper level of old dacitic tuff with the age of upper Cretaceous with cover rocks in massive type, and network and scattered type in the dacitic tuffs. Akarsen mattress from Murgul mine beds is massive type, Damar-Bognari, Cakmakkaya, Carkbaşı, Kizilkaya and Isirliktepe are network and scattered types. Structurally, the mineralization is controlled by dom-anticline, synclinal-bowl structures. Mineralization develops as network and scattered in dom-anticline, and in the syncline-cups it develops as massive type.

Ore minerals are mainly pyrite and chalcopyrite, and lesser values of Brittite, marcasite, idait, prostit, pearseit, neodijenite, hematite, wurtzite, simitsonite, calcite, chalcopyrite, Pyrarjirit, aeikinite, tetradimide, klaustalite, tellurobismuthine, hessite, vittisenite. Gangue minerals are mainly quartz, siderite-ankerite calcite, chlorite, barite and gypsum.

KUROKO TYPE VMS BEDS AROUND ESPIYE AND LAHANOS Cu-Zn BED

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Abstract

Study area located in the middle of the eastern Pontide structure association has been formed as a result of severe volcanic activity in Upper Cretaceous - Eocene time interval. As a result of this volcanic activity, a thick volcano-sedimentary sequence has occurred. This sequence composed of their lava and pyroclasts with change from basalt to dacite. Sometimes these are accompanied by sedimentary units such as limestone, mudstone, sandstone and marl.

In very old times in the region there were many massive operated-consumed, partially produced, continuing production and exploration activities sulphide beds. The most important ones from north to south are Agalik, Karaerik, Karilar, Lahanos, Killik, Kizilkaya and Karakishla. These beds are similar to each other in terms of host rock alterations, shape and mineral paragenesis and mineral relationship. The best representation of Kuroko type VMS beds in the region, continuing production and exploration activities of Lahanos Cu-Zn bed as in the past located within the borders of Şahinyuva village, about 25 km away from Espiye.

In the study area upper Cretaceous volcano-sedimentary rocks are observed. These volcanic arc products rocks have composed of dacite and their pyroclasts. Units from bottom to the top are sorted as Dacitic tuff, purple tuff - mudstone, dacite, dacitic tuff-breccia- purple tuff-breccia-purple tuff. Biotitic dacite intrusion is being monitored in the northwestern part of the area. In this bed, Network-spun ore under the massive ore body didn't develop well. Macroscopically, massive ore contains pyrite, chalcopyrite, sphalerite, galena, calcite and bornite. As a result of detailed mineralogical studies of the bed, the main ore minerals are pyrite, chalcopyrite, sphalerite, tennantite, tetrahedrite, bornite. A lesser value of marcasites, galenite, energite, luzunite, idait, chalcone are accompanied by these minerals. Additionally, trace elements such as covelline, grinocite, geocronite, emplectite, vittichenite, tetradimite / tellurobismuthine, bismuthine, hecite, altaite, mavsonite, native-gold-electrum are also observed. Gangue minerals are barite, quartz and clay minerals and less value of carbonates.

PODIFORM CHROMITITES: HOW DO THEY FORM AND EVOLVE IN SUPRASUBDUCTION MANTLE?

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Abstract

Podiform chromitites constitute major resources of chromium on Earth and the only source of refractory-type chromite ores (min. 25 wt% Al_2O_3; min.60 wt% Cr_2O_3 +Al_2O_3; max. 15 wt% FeO). They are usually hosted within intensely tectonitized peridotite forming the mantle section of several ophiolite complexes but mainly in those composed of strongly depleted harzburgite and replacive dunite. Some key features of "ophiolitic chromitites" include: 1) variable ore tonnage (from <10,000t up to 300Mt); 2) irregular ore bodies with pod-like morphology, surrounded by variably thick dunite envelopes and arranged discordant, subconcordant or concordant with respect to the foliation of host peridotites; 3) variable chromite texture (massive, disseminated, nodular, antinodular, orbicular...); 4) rather constant chemical composition within single ore bodies but highly variable at the scale a given ophiolite massif or complex; 5) variable platinum-group element (PGE) contents (usually between 30 and 2,000ppb ΣPGE) having platinum-group mineral (PGM) assemblages largely dominated by Os, Ir and Ru minerals (mainly members of the laurite-erlichmanite solid solution series (RuS_2-OsS_2) and Os-Ir alloys).

Podiform chromite ores are almost exclusively found in the subarc mantle of intraoceanic island arcs, including those beneath fore-arc, intra-arc and back-arc positions. This has led to many authors to interpret the genesis of the podiform chromitites as related with arc-type melts generated in the suprasubduction zone. The models proposed for the genesis of almost monomineralic chromitite bodies are varied, including (1) cotectic crystallization of chromite+olivine followed by mechanical separation of chromite (Lago et al., 1982), (2) changes in fO_2 (Hill and Roeder, 1974; Melcher et al., 1997), (3) assimilation of mafic rocks (Bédar and Hébert, 1998) and (4) mixing of primitive, olivine-saturated basalts with more fractionated melts (Arai and Yurimoto, 1994; Arai and Abe, 1995). The latter mechanism has been recently adapted to a new scenario where partial melts migrate along an interconnected network of dunitic channels and mix at the intersection of channels (González-Jiménez et al., 2014). Such a network of channels provides an ideal framework capable to sustain a continuous supply of melts with a variegated provenance and/or SiO_2, which once mingled at the intersection of channels may evolve to hybrid-mix melts able to crystallize only monomineralic chromite. In this model, the size of the chromitite bodies and texture that may form is a direct function on melt/rock ratios and on the existence of a hot source that supplies melts to the system.

Recently, some researchers have identified the presence of a new suite of inclusions in the chromitite, which includes minerals typical of high-pressure such as diamonds, coesite and stishovite as well as other that only form in highly reduced environments like moissanite, FeSi alloy, native Cr, native Al, native Fe… (Yang et al., 2014; McGowan et al., 2015). The identification of this strange suite of mineral has opened new avenues of research and interpretations, leading to believe that some podiform chromitites might record different stages of a complex evolutionary story. This would start by their crystallization at low pressure conditions followed by subduction down to the transition zone and late upwelling/exhumation to shallow mantle domains again. Additionally, Re-Os model ages

calculated from Re-Os isotopic data by in situ LA-MC-ICPMS on individual PGM inclusions within chomite and U-Pb ages of zircons recovered from chromitites frequently provide a rather widespread age spectra, providing further support to such evolutionary story of chromitites in time and space (e.g. McGowan et al., 2015). Additional evidences for a different type of subduction-upwelling evolution of podiform chromitites in suprasubduction zone environments could come from some metamorphic features. The presence of vermicular intergrowths of Al-rich and Fe^{3+}-rich chromian spinels formed by break down of high temperature (and probably high pressure) chromite unusually rich in Fe_2O_3 and other trace elements in chromitites from Sierras Pampeanas, Argentina (Colas et al., 2016), provide evidences of complex prograde-retrograde metamorphic paths.

References:

Arai, S.and Abe, N. (1995). Reaction of orthopyroxene in peridotite xenoliths with alkali basalt melt and its implications for genesis of alpine-type chromitite.*American Mineralogist* 80, 1041–1047.

Arai, S. and Yurimoto, H. (1994). Podiform chromitites of the Tari-Misaka ultramafic complex, Southwest Japan, as mantle–melt interaction products. *Economic Geology* 89, 1279–1288.

Bédard, J.H. and Hébert, R. (1998). Formation of chromitites by assimilation of crustal pyroxenites and gabbros into peridotitic intrusions: North Arm Mountain massif, Bay of Islands ophiolite, Newfoundland, Canada. *Journal of Geophysical Research* 103, 5165–5184.

Colás, V., Padrón-Navarta, J.A., González-Jiménez, J.M., Griffin, W.L., Fanlo, I., O'Reilly, S.Y., Gervilla, F., Proenza, J.A., Pearson, N.J. and Escayola, M. (2016). Compositional effects on the solubility of minor and trace elements in oxide spinel minerals: insights from crystal-crystal partition coefficients in chromite exsolution. *American Mineralogist* 101, 1360-1372.

González-Jiménez, J.M., Griffin, W.L., Proenza, J.A., Gervilla, F., O'Reilly, S.Y., Akbulut, M., Pearson, N.J.and Arai, S. (2014). Chromitites in ophiolites: how, where, when, why?, Part II. The crystallization of chromitites. *Lithos* 189, 140–158.

Hill, R. and Roeder, P. (1974). The crystallization of spinel from basaltic liquid as a function of oxygen fugacity: *Journal of Geology* 82, 709-729.

Lago, B., Rabinowicz,M. and Nicolas, A. (1982). Podiform chromite ore bodies: a genetic model. *Journal of Petrology* 23, 103–125.

Melcher, F., Grum, W., Simon, G., Thalhammer, T.V.and Stumpfl, E.F. (1997). Petrogenesis of the ophiolitic giant chromite deposits of Kempirsai, Kazakhstan: a study of solid and fluid inclusions in chromite. *Journal of Petrology* 38, 1419–1458.

McGowan, N.M., Griffin, W.L., González-Jiménez, J.M., Belousova, E., Alfonso, J.C., Shi, R., McCammon, C.A., Pearson, N.J. and O'Reilly, Y.O. (2015) Tibetian chromitites: excavating the slab graveyard. *Geology* 43, 179-182.

Yang, J.S., Robinson, P.T. and Dilek, Y. (2014) Diamonds in ophiolites. *Elements* 10, 127-130.

NON-METALLIC AND SEDIMENTARY MINERAL DEPOSITS ASSOCIATED WITH ACTIVE CONTINENTAL MARGINS

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Abstract

Active continental margins which are marked by subduction zones and can be mapped in modern fold belts around the Pacific Ocean and from the Pyrenees through to the SE Asian mountain ridges are favorable geodynamic settings for non-metallic and sedimentary mineral deposits. Sedimentary deposits in and at the edge of modern fold have been derived from the erosion of the rising mountain chains and from sedimentary processes, also known as chemical weathering which led to the supergene alteration of hypogene metal deposits whose origin and present position is accounted for by subduction. There is a gradual change from hypogene metallic deposits, mainly Cu and Au into hypogene non-metallic deposits enriched in phyllosilicates. To shed some light on these "mineral catenas" research into mineralogy, geochemistry, geology, geophysics, sedimentology and geography is mandatory. Which non-metallic commodities or industrials are mainly exploited along active continental margins? There are two different kinds of zonation at active continental margins, one oriented horizontally is related to the geodynamic setting and extends perpendicular to the active margin and a vertical one reflecting the morpho-climatic dynamic in this peculiar crustal section from the foothills to the top of the mountain.

Near the trench and most distal relative to the high-altitude mountain range, beach placers evolved taking up the clastic residue left over as obducted ophiolitic rocks undergo weathering and erosion (chromite, olivine, magnetite, PGM, Au). Being subjected to subaerial and submarine weathering and hypogene alteration, these basic and ultrabasic rocks get coated with ochre and umber deposits as well as penetrated by veinlets of magnesite and zeolite, which on one hand may be of economic grade and attractive to mining engineers but on the other hand could be detrimental to the construction raw materials so that it loses its rock strength. The construction raw material unaffected by such deleterious alteration is won in the upper basic volcanic and plutonic units of these ophiolitic series and prevalently quarried for aggregates and dimension stones.

Heading towards the continent, the magmatic suite sees the ultrabasic and basic magmatic rocks to turn into a series of intermediate and felsic magmatic rocks which are associated with a characteristic assemblage of deposits enriched in industrial minerals. Apart from sulfur produced by fumaroles, there is a wide range of phyllosilicates concentrated to economic grade in what is called the argillic alteration. Kaolinite, dickite, nacrite, halloysite, smectite, illite and pyrophyllite attain ore grade. Those minerals are often associated in caldera and maar lakes with diatomite, zeolites and different modifications of silica used, in places, as precious stones of jeweler´s quality.

Alunite-group minerals found in this environment deserve particular attention for their role these sulfate-phosphate minerals play as marker minerals and as industrial mineral forming deposits of their own. There are gradual transitions from high-sulfidation-type gold deposits to epithermal alunite-deposits barren in precious metals.

The felsic to intermediate volcanic, subvolcanic and pyroclastic rocks cater for a much wider spectrum of final use than their basic and ultrabasic counterparts on the seaward side of the catena. It is the group of the so-called "3-P deposits", harnessing the pumice, puzzolana and perlite deposits which are accumulated as air fall tuffs and ash flows forming a

pyroclastic apron around the volcanic domes and subvolcanic necks. The various types of 3-P deposits and most pyroclastic rocks came into being either by the interaction of the hot felsic magma with cold ground water at shallow depth on the ascent or as the avalanches of lava and ash flows ran into a lacustrine environment. Phreatomagmatic eruptions and steam-heated epithermal deposition are only two different sides of the same coin.

The uplifted mountain ranges expose a morpho-climatic zonation that is in vertical equivalent to what is known from the equator through the polar region in horizontal. The chemical weathering operative along this horizontal transect from the lower to the higher latitude is also reflected in the vertical built-up of gossans of hypogene ore deposits from the lowland through the unvegetated mountain ridges above the tree-line.

As a consequence of strong uplift and erosion, placer deposits and red-bed deposits, mainly enriched in Au and Cu, come into existence at a distal position relative to the mountainous areas. If chemical weathering keeps pace with uplift and erosion, gossans and metalliferous duricrusts ("orecretes") will develop proximal to the mountain range and/or within the deposits, proper. This tremendous variation in the ratio erosion/ weathering has on one side positive effects on the supergene alteration of ore deposits in that gossans of different generation were telescoped into each other and by doing so upgrade the metal content and on the other hand may have negative effects on the non-metallic deposit mainly sand because of the limited time and transport distance given the debris to result in a quartzose sand qualifying as a good construction raw material depleted in labile constituents such as feldspar and lithoclasts.

MAGMATIC HYDROTHERMAL SYSTEMS: PORPHYRY AND SKARN DEPOSITS OF TURKEY

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Abstract

The geological endowment of Turkey has largely been gained by interplay between the NeoTethys ocean and Afro-Arabian passive margin and Eurasian active margin since the Permian. Starting from Early Cretaceous, the opening, final closure, and terminal suturing of the Tethys oceanic realms, resulted in subductional and postcollisional events, collision of continental fragments and voluminuous magmatism. These events generated voluminous calc-alkaline and alkaline magmatism, which reflects a transition from arc to postcollisional settings and the effects of collision and onset of crustal thickening and subsequent extension between ca. 110 and 9 Ma. Collectively, the magmatism created a fertile metallogenic environment with abundant porphyry Cu, orthomagmatic, volcanogenic massive sulfide, skarn, epithermal, and iron oxide Cu-Au deposits, clustering in narrow arc segments, and post- to late-orogenic transtensional and transpressional settings. Both alkalic and calc-alkalic porphyries are present. The alkalic porphyry deposits (Kisladag and AS) are more like Au to some extent Au-Cu type, and refer to the youngest phase of the mineralization and economically more significant compared to calc-alkalic counterparts. In many deposits, copper is associated with gold, including those at the southeastern Anatolian orogenic belt (SEAOB). The Cu-only or Au-only deposits/prospects are numerous in the western Anatolian province (WAP) while Mo-only and Mo-Cu prospects are widespread in the Pontides and central Anatolian crystalline complex (CACC). Of these, Cu and Au are being mined in WAP and SEAOB. Subvolcanic environments with preserved extrusive rocks are the preferred setting for porphyry Cu-Au and Au systems in the WAEP while plutonic and volcano-plutonic environments are more common in Pontides and CACC. The porphyry systems are clustered mainly along arc-parallel faults, crustal-scale transverse faults, and normal and detachment faults. Based on geologic, geochemical, and ^{40}Ar/^{39}Ar geochronological data, four metallogenic episodes have been identified within these continental fragments. The magmatic rocks hosting these systems are characterized by a gradual increase in La/Yb ratios, and southward shifts of the magmatic locus with time, particularly in western Anatolia. The skarns and skarn deposits, an important class of mineral deposits in Turkey, were formed between Late Cretaceous and Oligo-Miocene period. These deposits are the prime sources of iron, tungsten, lead and zinc commodities of Turkey. The skarns in Turkey are generally classified as calcic exoskarns and occasionally as magnesian exoskarns. The economic mineralization are largely confined to calcic exoskarns with exception of some Fe-skarns hosted by endoskarns. The vast majority of Fe-, and Fe-W skarns are associated with endoskarn assemblages whereas some Fe-, and Pb-Zn-skarns are associated both with calcic and magnesian exoskarns. The skarns that coexist as proximal calc-silicate assemlages within major high-level porphyry Cu systems are largely controlled by regional, large-scale structures such as strike-slip faults or core-complex systems.

ULUTAŞ (ERZURUM-TURKEY) Cu-Mo DEPOSIT

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Abstract

The Ulutaş Cu–Mo prospect lies within the Ispir batholith Based on drill-hole data, the total reserves were estimated at 73.6 Mt at a grade of 0.31% Cu and 0.022% Mo (Giles, 1973; Soylu, 1999; Yiğit, 2009).Porphyry type Cu–Mo mineralization at the Ulutaş prospect is hosted by granite porphyry and quartz porphyry of the Ispir batholith, which is a calc-alkaline multi-phase plutonic complex varying from granite through quartz diorite to syeno-diorite. The oldest units exposed in the northwestern part of the Ulutaş area are Paleozoic–Lower Mesozoic metamorphic rocks. The metamorphic basement is covered by strongly folded, weakly metamorphosed Cretaceous lava flows of dacitic to rhyolitic composition and pyroclastic rocks with intercalations of laminated mudstone, and shale (Giles, 1973; Taylor and Fryer, 1980). The basement units and volcano-sedimentary sequence are intruded by Ulutaş intrusions that form an erosion window in the Eocene units, comprising andesitic to basaltic lava, tuff and agglomerate with marl, conglomerate, sandstone and limestone intercalations (Giles, 1973; Taylor and Fryer, 1980). A granite porphyry hosting Cu–Mo mineralization exposed in the northern part of the area represents the largest intrusive unit in the region. It is characterized by a pronounced porphyritic texture at the outcrop scale. Central parts of the granite porphyry are characterized by intrusions of NE-trending, steeply dipping quartz porphyry dykes or stocks, with a porphyritic texture with phenocrysts of embayed quartz and a fine-grained groundmass of quartz and highly sericitized plagioclase. Both granite porphyry and quartz porphyry are crosscut by dioritic, andesitic dykes hosting pyrite–chalcopyrite veinlets (1 to2 mm), The granite porphyry contains micro-granular, roughly oval medium to dark gray dioritic enclaves, which have sharp contacts with their host. All units are overlain by Pleistocene to recent glacial debris and alluvial sediments (Giles, 1973).Porphyry-type mineralization in the Ulutaş area consists of stock work veins and NW-striking quartz veins, with disseminated chalcopyrite along the vein systems, and molybdenite within the 1–2 cm thick quartz veins (Soylu, 1999).

MODERN AND ANCIENT VMS MAGMATIC-HYDROTHERMAL SYSTEMS

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Abstract

There is overwhelming evidence in typical VMS systems that evolved seawater was the main ore fluid component and that ore metals and sulphur were leached from their footwall sequence. These processes account for quartz–chlorite–sericite–pyrite alteration assemblages that formed from low- to moderate-salinity fluids with $\delta^{18}O < 5‰$. The few deposits that are most likely to have a significant magmatic–hydrothermal component are those that deviate significantly from this norm. Studies of well-established magmatic–hydrothermal deposits such as porphyry Cu, high-sulphidation epithermal and skarn/carbonate replacement Sn deposits indicate that these deposits formed from volatile-rich magma bodies, in quite variable geotectonic settings. Over the last decades, tectonic and chemical controls on magmatic–hydrothermal ore systems have been increasingly recognised. However, criteria used either to indicate, or to exclude a magmatic–hydrothermal component in VMS systems are generally equivocal. An assessment of existing evidence suggests that a minority of VMS deposits have significant magmatic–hydrothermal contributions. These can be split into two groups: (1) Cu-Au-rich deposits characterised by advanced argillic alteration assemblages and sulphur isotope evidence of disproportionation of magmatic SO_2, and (2) Sn-rich deposits in which the Sn is associated with high-temperature assemblages, cassiterite has magmatic-like trace element signatures and the Sn-bearing ore fluids were ^{18}O-enriched. Of these, the first group is reasonably known, whereas only one example of the second group – the Neves Corvo deposit – is documented yet.

METALLOGENESIS AT THE NEVES CORVO DEPOSIT, IBERIAN PYRITE BELT

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Abstract

The Iberian Pyrite Belt (IBP) stands out amongst volcanic-hosted massive sulfide provinces as truly giant, perhaps unique in its overall content of zinc and copper, high density and huge size of its deposits (> 85 deposits; total tonnage > 1,700 Mt; 7 giant deposits > 100 Mt). Massive sulfide deposition occurred during the waning stages of felsic volcanism within a thin volcanic-sedimentary complex during Upper Devonian times. The IPB metallogenesis combine many distinctive characteristics of VMS deposits worldwide with some features akin to SEDEX deposits. Crustal thinning and magma underplating provided long-lasting high heat flow and high regional geothermal gradients, which promoted leaching reactions and, hence, the generation of metal-rich solutions in deep-seated hydrothermal aquifers. A major component of metals directly supplied by magmatic sources seems unlikely for the generality of the deposits, given the similar and regionally homogeneous radiogenic isotopic signatures and metal ratios showed by the ores and their footwall successions, combined with the shallow emplacement and dry nature of the felsic magmatism.

Neves Corvo is the richest and one of the largest deposits known to date in the IPB. The geochemistry of the Neves Corvo ores contrasts with that of typical IPB deposits. The primary copper grades and the copper ratio significantly deviate from the IPB standards. In addition, the total tin metal content (in excess of 0,3 Mt), the tin grades attained by the stringer and massive cassiterite ores (up to 60 % SnO_2), and the copper-tin metal association in the massive sulphide ores are truly unique features among the IPB deposits known. A magmatic-hydrothernal model is proposed for the genesis of this particular deposit. Pb, Os and Nd isotopic signatures preserved in the stringer and massive cassiterite ores, imply external sources, which compare to those of granite-affiliated cassiterite. Alteration mineralogy and geochemistry, coupled with oxygen and hydrogen isotopes indicate that the Neves Corvo ore fluids were hotter and more acidic than typical IPB ore-forming fluids, but the overall low-sulfidation characteristics of the deposit are beyond debate. Nevertheless, unlike in typical porphyry-copper and epithermal systems, magmatic fluids associated to tin-rich granitic plutons are reduced and contain H_2S as the dominant vapor species. These circumstances imply that any magmatic fluid contribution to the Neves Corvo ore-forming system is not expected to require assignment of its mineralogical record to predominant high-sulfidation characteristics.

GOLD IN THE PONTIDE MAGMATIC ARC

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Abstract

Eastern Black Sea region known as the Pontide magmatic arc embraces favorable properties such as intensive and widespread magmatic activities and fracture systems developed due to north-south compression of the Pontides since Late Mesozoic and therefore host several well-known massive sulfide and epithermal gold deposits, yet some still to be discovered. The gold occurrences are mainly associated with NE-SW and NW-SE trending fracture and fault zones which served as channelways for hydrothermal solutions to circulate and hence loci for gold deposition.

Gold deposition in these occurrences is mainly caused by boiling and mixing processes. Hydrothermal waters enriched in gold- bearing complexes are mainly derived from granitic intrusions emplaced between 47-42 million years. However, Incursion of a considerable amount of meteoric waters into magmatic waters played an important role in destabilization of gold complexes. Depositional temperatures of gold indicate mainly epithermal and less mesothermal conditions for mineralizations.

The mineral chemistry, nature of fluid inclusions together with isotopic data and alteration products suggest intermediate to low-sulfidation epithermal types of gold deposition in the region. Exception might be the Kaletaş gold occurence which is hosted by limestone enriched with organic material. Hence, it might be classified as one of the Carline types.

ALTERATION EFFECTS ON PODIFORM CHROMITITES IN KIZILDAĞ OPHIOLITE (S-TURKEY): IMPLICATIONS FOR METAMORPHISM PROCESSES

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Abstract

Chromitites, associated with upper mantle depleted peridotites in Kızıldağ Ophiolite (KO), are represented by mostly massive and disseminated texture. Banded and nodular chromitites were also rarely observed. Although the chromitites consist of fresh chromite grains in general, altered grains of ferrian chromite (up to 200 micrometer length) were identified in some high–Al and intermediate chromitite samples. Ferrian chromite grains show a wide range of Cr_2O_3 (47.81–62.98 wt.%) and Al_2O_3 (2.91–11.23 wt.%) contents, and calculated values of Cr# [Cr/(Cr+Al) atomic ratio] and Mg# [$Mg/(Mg+Fe^{2+})$ atomic ratio] are 0.74–0.93 and 0.35–0.56, respectively. Moreover, FeO and Fe_2O_3 concentrations in ferrian chromites are 18.89 (average wt.%) and 6.91 (average wt.%), respectively.

Minor and trace element (Ni, Mn, Ti, V, Zn, Co, Ga, Sc) concentrations in ferrian chromite grains from KO chromitites were obtained by LA–ICP–MS. Altered grains in high–Al chromitite samples are mostly more enriched in terms of these elements than intermediate ones. The average concentrations of Mn, Ti, V, Zn and Co in ferrian chromites of high–Al chromitites are 1637, 465, 592, 1005 and 199 ppm, respectively, whereas these values are 712, 358, 498, 943 and 157 ppm, respectively in intermediate ones. Nevertheless, Ni, Ga and Sc values (average 1256, 35 and 1.33 ppm, respectively) of altered grains in intermediate chromitite samples are more enriched than high–Al chromitites. Sc contents in ferrrian chromites from both type of chromitite samples show strong negative anomalies relative to MORB values; however, some altered grains from the high–Al chromitites represent M–shaped Zn–Co–Mn positive anomaly. The Al, Fe^{+3} and Cr cation values of ferrian chromite grains indicate that KO chromitites were mostly affected by green schist facies metamorphism process; however some samples exhibit a lower amphibolite facies condition. The major oxide and trace element composition and morphological properties of ferrian chromite grains suggest that the KO chromitites were modified by metamorphism processes from lower amphibolite to green schist facies at lower than 550 ^{o}C.

PRELIMINARY INVESTIGATION OF THE SOURCE OF PLACER GOLD AT SARDIS, NE TURKEY

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Abstract

The placer gold deposit at Sardis (Pomza Export Mining Company) is öne of the most important placer gold deposits currently operating in Turkey. However, mining at Sardis, dates to ~700 BC when gold was extracted from the Pactolus river accounting for the wealth and influence of the Lydian's and King Creosus. The gold is found only in the oldest Neogene alluvial fan conglomerates, which in historical times were cut by the Pactolus river. The original source of the gold has not been definitively found but is believed to have come from metamorphic units in the Menderes Massif above the placer deposit.

Quartz veins, located above the mine area, show at least two distinct hydrothermal events that cut the metamorphic fabric. Initially there was deposition of calcite in the vein that has been replaced by the growth of euhedral quartz. Opaque minerals are largely absent in the veins but euhedral arsenopyrite was developed in the metamorphic wall rocks adjacent to the vein becoming less abundant away from the contact. The arsenopyrites have subsequently been altered and are now largely crystals of iron oxide containing remnants of the original arsenopyrite. There are also numerous inclusions of light rare earth element (La, Ce, Pr, Nd, Sm) phosphates in the metamorphic rock, but it is not clear, at this time, if these are related to the fluids that produced either the original or replacement vein minerals. SEM-element mapping indicates that the arsenopyrites originally contained gold as there are some small micron sized particles remaining and there may also have been a more homogeneous gold distribution within this mineral. Conversion to iron oxides has mobilised the gold and none is present, above the detection limit of the technique, in iron oxides. Oxidation of the arsenopyrite created a series of fracture networks and this is typical of Orogenic gold deposits in the Yukon and elsewhere, where late fluids convert early sulphides to oxides and the space created is then the host for gold precipitation. Further studies will examine the importance of this for gold deposition at Sardis.

OPHIOLITIC CHROMITITES FROM THE KIZILYÜKSEK AREA OF THE POZANTI-KARSANTI OPHIOLITE (ADANA, SOUTHERN TURKEY): IMPLICATION FOR CRYSTALLIZATION FROM A FRACTIONATED BONINITIC MELT

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Abstract

Ophiolitic rocks are widely distributed in Turkey. One type, the Pozantı-Karsantı ophiolite from southern Turkey, contains a large number of chromitite deposits located mostly in the mantle peridotites and close to the Moho transition zone dunite and cumulate dunites. Cr-spinel grains from the chromitites are represented by high Cr# [100 × Cr / (Cr + Al) = 68–81], and their Mg# [100 × Mg / (Mg + Fe^{2+})] range from 54 to 71. Gallium and Co contents vary between 18 and 32 ppm and 185–266 ppm, respectively, and they show negative correlation with Cr#. A detailed optical investigation reveals that the Cr-spinel grains contain silicate, platinum-group mineral (PGM) and base metal sulfide (BMS) inclusions. Single phase inclusions of amphibole are the only hydrous silicate phases in the investigated chromitites, and they contain low TiO_2 (< 0.43 wt.%). Olivine, with high Fo (~ 96) and NiO contents (0.48–0.68 wt.%), and clinopyroxene, with low TiO_2 (< 0.1 wt.%), Al_2O_3 (< 2.84 wt.%) and Na_2O contents (< 0.4 wt.%) were also observed as primary silicate inclusions. Chromitites contain low concentrations of total platinum-group elements (PGE) ranging between 32 and 162 ppb, with an average value of 93 ppb. Primitive mantle-normalized PGE diagrams show almost flat to positive slopes from Os to Rh (Rh_N/Os_N = 0.99 to 8.5) and negative slope from Rh to Pt and Pd. All samples show marked positive Ru anomalies. Consistent with the geochemical data, Ru, Os, and Ir bearing PGE sulfide (laurite-erlichmanite solid solution series [(Ru, Os)S2–(Os, Ru)S_2] phases) are the most common PGM detected in the investigated chromitite samples. They show a narrow range of Os-Ru substitution [Ru#; Ru/(Ru + Os) = 0.72–0.97], indicating no erlichmanite in the PGM paragenesis. In addition to the most common PGM laurite, several osmium (Os, Ir), iridium (Ir, Os), irarsite, and one single grain of speryllite ($PtAs_2$) were detected as magmatic inclusions in Cr-spinel. Three unknown PGE/PGE–BME (base metal element) phases were also detected in Cr-spinel grains with compositions that correspond to the chemical formulas of $(Os, Ru, Ir, Rh, Fe, Pd)_2S_5$, $Ir(Rh,Pt,Ni,Cu)S_3$, and $(Ir, Rh, Ru)_2(Ni, Cu)S_3$, respectively. The high Cr# and low Ti content of Cr-spinel grains and amphibole inclusions with low Ti content as hydrous phases in Cr-spinel grains require a hydrous melt depleted in incompatible trace elements for the formation of investigated chromitites; therefore, we suggest a fore arc tectonic environment for the generation of Kızılyüksek chromitites. The presence of Os-Ir alloys and Ru-rich laurites implies that Cr-spinel crystallization took place at relatively high temperature (1100–1300 °C) and low $f(S_2)$ (between − 1 and − 3) conditions. Major and trace element compositional variations of Cr-spinel, wide variation of Rh_N/Os_N ratios of the chromitites and depletion of Os in the chromitites compared to Ir and Ru may imply that Kızılyüksek chromitites crystallized from a variously fractionated boninitic melt.

FLUID INCLUSION STUDY OF THE BIZMIŞEN SKARN DEPOSIT RELATED TO EOCENE INTRUSIVE ROCKS, EAST-CENTRAL ANATOLIA, TURKEY

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Abstract

The Bizmişen (Erzincan) skarn deposit is located in the east of the Central Anatolian Crystalline Complex consisting of metamorphic rocks, ophiolites and magmatic intrusions. The region hosts various styles of mineralization, such as Pb-Zn-skarns, Fe-Cu skarns, Fe-fluorite mineralization, Au-Cu, Mo-Cu and Au deposits related to the Late Cretaceous to Eocene Central Anatolian granitoids. The Bizmişen skarn deposit is the one of the most important operating mines, with a total reserve of 23.8 Mt of magnetite ore at 53% Fe. Skarn zones occur at the contacts of Eocene aged post collisional calc-alkaline intrusive rocks (diorite, quartz diorite) with the Upper Triassic-Upper Cretaceous Munzur Limestones, the tectonically imbricated Upper Cretaceous ophiolites and the Campanian-Maastrictian volcano-sedimentary suite. Plutonic rocks were intruded into limestones and ophiolites producing iron mineralization (skarn, vein/lens, replacement and placer types), clay alteration zones (argillic alteration) and occurrences of skarn minerals (garnet, diopside, epidote, scapolite, tremolite, chlorite) within the plutonic body. Ore minerals are magnetite, hematite with subordinate pyrite, chalcopyrite, covelline, chalcosite, goethite and limonite, gangue minerals are calcite, quartz and barite. The skarn related mineralizations is found in different geological settings: (1) Endo-skarn lenses within granites rocks, (2) Ore bodies at the contact between granites and Upper Jurassic-Lower Cretaceous recrystallized limestone (3) Lenticular veins at the contact between Jurassic-Lower Cretaceous ophiolites, ophiolitic mélanges and granites, (4) Stratiform ore bodies extending from the granite contacts through the Campanian-Maastrichtian(?) volcano-sedimentary suite beneath the ophiolitic nappes and Neogene cover.

Fluid inclusion studies, conducted on calcite, quartz, barite, epidote and garnet indicate the formation of these intrusion-related minerals was between 200-300°C from the fluids with low to moderate salinities. The iron ore minerals, represented by secondary inclusions, formed at 350-400°C from the fluids with moderate to high salinities. LA-ICP-MS analyses of fluid inclusions in calcite, quartz, barite and epidote minerals (especially wide range of K/Na values, K/Na - Ba/Na and Zn/Na - Pb/Na distributions) indicate that there was a long period of hydrothermal activity and mixing of different fluids with a decrease in temperature. There was a degree of equilibration of a high temperature fluid (most probably the mineralizing fluid) with feldspars at temperatures consistent with those measured by microthermometry. The highest K/Na ratios are indicative of extensive breakdown of feldspars by acid-sulphate alteration. The trace elements are consistent with moderately oxidising fluids and fluid mixing, although as trace metal contents are temperature sensitive a decrease in concentration could be the result of decreasing fluid temperatures.

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MAGMATIC SHIFT FROM Si-POOR TOWARD Si-RICH LEUCITE-BEARING REE-ENRICHED POTASSIC LAVAS VIA INCREASING DEGREE OF PARTIAL MELTING FROM A CARBONATED MANTLE METASOME: AN EVIDENCE FROM KAYIKÖY LAVAS, ISPARTA, SW ANATOLIA, TURKEY

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Abstract

Two leucite bearing potassic lavas almost consecutively (K-Ar age of 3.2-3.5 Ma) emplaced, with a close tectonic position, in the Kayıköy Pliocene graben basin of Isparta region. Feldspar-free and feldspar-bearing leucitic lavas mineralogically composed of diopside, barian phlogopite, +plagioclase, leucite, olivine with rare Cr-spinel, nepheline, hauyne, +calcite and magnetite. The feldspar-free leucitic lavas are significantly richer in CaO (13.50-14.40 wt%), K_2O (4.00-4.42 wt%), MgO (8.52-9.36 wt%), and poorer in SiO_2 (44.00-46.04 wt%), Al_2O_3 (12.10-12.64 wt%), and Na_2O (2.34-2.74 wt%), in contrast to the plagioclase bearing leucitic lavas, which are poorer, respectively, in CaO (10.80-1.20 wt%), K_2O (3.25-3.81 wt%), MgO (5.85-6.24 wt%), and richer in SiO_2 (48.69-49.22 wt%), Al_2O_3 (15.88-16.28 wt%), and Na_2O (3.19-3.49 wt%). The feldspar-free lavas with high K_2O/Na_2O ratios ~1.5 are more potassic rocks than the plagioclase bearing lavas with low K_2O/Na_2O ratios ~1. Similarly, silica-poor feldspar-free lavas show higher enrichments in most of the incompatible elements (e.g., Ba, 2700-10000 ppm; Sr, 3700-4100 ppm; Th, 34-37 ppm; Zr, 270-320 ppm) with high ΣREE (710-810 ppm) and elevated LREEs/HREEs ratios [(La/Yb)N, 73-80], than those of silica-rich plagioclase bearing lavas (Ba, 2300-2500 ppm; Sr, 2800-3000 ppm; Th, 30-32 ppm; ΣREE, 520-560 ppm, [(La/Yb)N, 45-47]. The chondrite normalized REE-patterns of the Kayıköy mafic volcanics are similar to those of ocean island basalt (OIB) but the LREEs are strongly enriched relative to average OIB. The extremely high concentrations of LREE may suggest that the mantle source was modified by LREE-enriched carbonatite metasomatism. Trace element patterns of the Kayıköy lavas have also good correlation with those of carbonatites. Olivine - Cr-spinel pairs with high Fo (0.90) and Cr# (0.74) and high incompatible and LREE contents in Kayıköy mafic volcanics are consistent with near primary magmas equilibrated with enriched and heterogeneous (peridotitic/pyroxenitic) mantle sources. Their mantle-like Sr^{87}/Sr^{86}-Nd^{143}/Nd^{144} isotopic compositions also coincide with carbonatites. Additionally, groundmass calcites in feldsparbearing lavas include remarkable contents of SrO, (up to 0.13 wt%) and BaO, (up to 0.18 wt%). The petrological features confirm the notion that the mantle sources of Kayıköy mafic leucite lavas was enriched with subordinate amounts of carbonatite metasomatism. It is proposed that partial melting of such newly generated metasomes in the subcontinental lithospheric mantle resulted in the parental melts of carbonate-bearing the Kayıköy mafic volcanics. The carbonated mantle source produced silica-poor, feldspar-free leucitic magmas at the onset of partial melting, and these magmas shifted toward silica-rich, leucite and plagioclase-bearing magmas as the degree of melting increases. The high REE enrichments in the potassic lavas from the Isparta region may be indicative for carbonatite deposits.

MINERALOGY AND MINERAL CHEMISTRY OF THE ARAPUÇANDERE PB-ZN-CU (AG-AU) MINERALIZATION IN THE NORTHEAST OF YENICE (ÇANAKKALE), BIGA PENINSULA, NW TURKEY

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Abstract

The Tethyan Belt is marked by a major porphyry-related mineralized zone that extends across central and southeast Europe, Turkey, and Iran through the Himalayan region to Papua New Guinea, and is one of the world's largest metallogenic belts. The Arapuçandere Pb-Zn-Cu (Ag-Au) mineralization in the northeast of Yenice (Çanakkale) is an economically important deposit with two main mineralized veins called vein IV and vein V in the Biga Peninsula. This study focuses on the relationship between mineralogical distribution and chemical composition based on samples that were collected vertically and horizontally from the five different mining levels of the deposit at elevations of 308 m, 275 m, 240 m, 200 and 160 m asl. Major ore paragenesis within the veins displays a similar assemblage, consisting of galena, sphalerite, chalcopyrite, pyrite, magnetite, Ag-sulfosalts and Ag-rich fahlores and minor amounts of Fe- and Co-rich sulfarsenides, and gold in order of abundance. Hematite, goethite and chalcocite-covellite are secondary phases resulting from supergene alteration. Major gangue minerals in both veins exhibit a zonation pattern represented by decrease in quartz and increase in calcite with locally minor barite towards deeper levels of the deposit.

Two types of pyrite have been observed as early and late stage mineralization phases. The early pyrite rarely exhibits complex rhythmic intergrown with Co-rich bands as a cobaltoan pyrite that contains significant amounts of Co (up to 6.6 wt. %). The second type is characterized by subhedral to anhedral crystals that are disseminated along veins and veinlets of early stage mineralization. Argentite, acanthite, jalpaite, polybasite-pearcite, freibergite and Ag-rich tetrahedrite-tennantite are the most widespread Ag-bearing sulphosalt minerals in the overall vein zone. They are associated with late stage mineralization, and mainly occur either as fracture-fillings, or as haloes surrounding the early sulfides. Gold occurs as rounded-shaped inclusions within chalcopyrite and galena, and present variable Au and Ag contents. Electron microprobe measurements also have shown that most gold grains are compositionally zoned. Gold grains present a marked variation in their contents in Cu, Fe and S, as a function of their host sulfide and sulphosalt phases. The ore assemblages and moderate iron content of up to 11 mole percent of FeS in sphalerite typically refer to the properties of base metal-rich Ag±Au intermediate sulfidation epithermal deposits.

GEOCHEMISTRY, FLUID INCLUSION AND STABLE ISOTOPE CONSTRAINTS (C AND O) OF THE SİVRİKAYA FeSKARN MINERALIZATION (RİZE, NE-TURKEY)

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Abstract

The Sivrikaya Fe-skarn mineralization is hosted by dolomitic limestone layers of Lower Cretaceous volcano-sedimentary unit. Intrusion of the Upper Cretaceous İkizdere Granitoide, in the volcano sedimentary unit resulted skarn mineralization along the granitoide-dolomitic limestone contact and nearby. The ore is associated with exoskarns, which characterised by prograde garnet, pyroxene and retrograde epidote, tremolite, actinolite, quartz, calcite and chlorite. The primary ore minerals are composed of mainly magnetite and specularitic hematite with minor amount of pyrite and chalcopyrite inclusions. Skarn minerals of garnet and pyroxene are calcic with a composition of $Ad_{79,45-99,03}Gr_{0-17,9}Spr+Alm_{0,97-2,65}$ and $Di_{69,1-77,1}Hd_{22,2-29,8}Jo_{0,6-1,4}$ respectively. Both andradite rich garnet compositions and, diopside rich clinopyroxenes from Sivrikaya deposit are compatible with oxidized type skarn deposits. In addition to retrograde brecciation of garnet and magnetite, breccia filling type epidote and quartz precipitation in volcanic host rocks are characteristically identified in the field.

Homogenization temperatures (Th) of the fluid inclusions are in the range of 166 - 462 °C. Calculated salinity content, in all fluid inclusions are in the range of 0,35 – 14.3wt% NaCl equ. Well defined positive correlation between Th and salinity data indicate that meteoric water were involved in the hydrothermal solution. Eutectic temperatures between -49.8 to -55 °C correspond to the presence of $CaCl_2$ in the early stage fluid inclusions. On the other hand eutectic temperature of later stage fluid inclusions are correspond the presence of $MgCl_2$, $FeCl_2$ and NaCl with a temperature range of -38 °C and -21.2 °C.

None of the fluid inclusions were found to be containing separated carbonic phases at room temperature. But limited amount of CH_4 were identified in the inclusions by Raman spectroscopic studies. Oxygen isotope ratios both in dolomitic limestone and skarn calcite were highly depleted comparing to the typical δ18O values of marine limestones. This is indication of dilution of meteoric water in the system. But highly depleted C isotope ratios of dolomitic limestone, comparing to the skarn calcite, and decarbonatization trend of organic matter in the skarn carbonates indicate that organic matter in the carbonates were effective on the decreasing isotopic ratios. Limited amount of CH_4 in the fluid inclusions were also quite possible by thermal degragation of these organic materials.

EXPLORATION OF NEW CHROMITE DEPOSITS WITH SUPRA-SUBDUCTION ZONE SIGNATURE IN THE KHOY OPHIOLITE, NORTHWESTERN IRAN, NEAR IRAN-TURKEY BORDER

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Abstract

Exploration of podiform chromite deposits has been a challenge because of their unpredictable occurrence, the small size of most orebodies and the presence of intensive tectonic dislocations. Most orebodies are irregularly dispersed and relatively small (between 0.0004 and 1 Mt, averaging 0.011 Mt.; USGS, 2012). The Khoy ophiolite is one of the largest Iranian ophiolite complexes and coverd a widespread area in northwest Iran along the Iran-Turkey border. This ophiolite is one of the most promising area for prospecting chromite deposits because of extensive outcrops of ultramafic rocks. Some geological and geochemical prospections were carried out for recognition of chromite deposits over an area of about 500 km^2 (at the 1:20000 scale) by the authors during the last 15 years. Lithogeochemical investigation and testing of bedrock mineralisation were performed relatively straightforward by the sampling of outcrops in areas where chromite orebodies cropped out or soil cover was thin,. In contrast, lithogeochemical sampling and testing of chromite mineralization in locations with thick cover were carried out by pitting and trenching. These investigations led to the exploration of a chromite ore field with a remarkable potential since more than 20 chromite orebodies were recognized. Few of the recognized chromite orebodies were economically evaluated and are currently in exploitation. They approximately content 220000 tones proven and 750000 tones probable reserves based. Composition of chromite is rich in chromium. Geochemical data indicate that these chromite deposits formed in a supra-subduction zone (SSZ).

- The most important geological criteria for prospecting chromite deposits in the Khoy ophiolite are:
- Chromite bodies are surrounded by dunitic envelopes with variable thickness, especially around those of banded structure.
- Recognized chromite-rich zones are mainly located near gabbro and microgabbro stocks.
- Most chromite lenses are oriented along an east – west trend, although few of them occur outside such trend.
- Existence of chromite fragments on stream beds can be considered a good guide to define the entry of these anomalous rocks to the stream sediment. Similarly, heavy mineral sampling in stream sediments is useful for detection of chromite-bearing zones.
- Morphologically, chromite outcrops often occur protruding from host rock because of their higher resistance to erosion.
- Chromite-bearing zones usually do not have or exhibit thin vegetable cover despite the high rate of annual rainfall.

DETECTION OF CHROMITE-BEARING MINERALIZED ZONES USING ASTER DATA IN THE KHOY OPHIOLITE COMPLEX, NORTHWESTERN IRAN: EXPLORATION STRATEGY

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Abstract

The present research study evaluates the discrimination of chromite bearing mineralized zones within the Khoy ophiolie complex in northwest Iran by analyzing the capabilities of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite data. Spectral transformation methods such as optimum index factor (OIF), band ratio (BR), spectral angle mapper and principal component analysis (PCA) were applied to ASTER and bands for lithological mappings. Some chromite ore bodies were recognized but only few of them were explored. The chromite deposits have lenticular, tabular and irregular vein shapes and emplaced in depleted mantle hurzburgite. Occurrences include both Cr-rich and Al-rich varieties. This area has mountainous feature and extremely rugged topography with difficult access, so prospecting for chromite deposits is challenging by geological mapping. Therefore the use of remote sensing techniques is very useful and effective to determine the chromite-bearing zones in terms of saving cost and time. ASTER bands contain improved spectral characteristics and higher spatial resolution to provide more detailed mapping of the areas of chromite mineralized zones in the ultramafic section of the Khoy ophiolite. A specialized optimum index factor RGB (8, 6, 3) was developed using ASTER bands to differentiate lithological units. Colour composite of band ratios such as RGB ((4+2)/3, (7+5)/6, (9+7)/8) and (4/1, 4/7, 4/5) and (4/3*2/3, 3/4, 4/7) provide best results in separating lithologies in the Khoy ophiolite. Principal component analysis with color composite such as RGB (pc1, pc2, pc3) and RGB (pc7, pc5, pc4) were used for lithology mapping. Spectral angle mapper classification method was applied to the VNIR+SWIR 9-band stack. In this method the spectral of chromite ground points were used. Finally, delineation of the area of chromite mineralized zones were performed by integration of obtained data such as fault maps, discriminated lithology, chromite outcrops and SAM maps in GIS system and this zones were offered for detailed exploration of new chromite deposits.

PETROGENESIS AND FLUID INCLUSIONS OF THE KOUH-E LATIF SKARN IRON ORE DEPOSITS, CENTRAL IRAN

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Abstract

The Kouh-e Latif iron deposit is located approximately 205km NE of Isfhan and is a small area in the NE of Urumieh– Dokhtar Magmatic Arc, Iran. The skarn hosted in a Cretaceous limestone, intruded by granite and granodiorite. The calcic skarn has experienced two stages of metamorphism: 1) prograde stage, which include endoskarn and exoskarn facies with clinopyroxene, garnet, scapolite and albite mineralization, and 2) retrograde stage which produced actinolite, epidote, chlorite and apatite assemblage through retrograde alteration. The ore minerals in Band-e Nargesskarn are magnetite, with minor chalcopyrite, pyrrhotite and pyrite. Gange minerals are predominantly diopside, andradite, epidote, chlorite, quartz and calcite. Micro-thermometric measurements yield a homogenization temperature range for skarn alteration between 414 and 448ºC, with a salinity of 11 to 13.186 wt.%NaCl equivalent. Fluid inclusions in calcite associated with mineralization generally consist of a vapor bubble and a liquid phase with a rare occurrence of three-phase inclusions. Homogenization temperatures for two phase inclusions vary from 168 ºC to 203 ºC with a salinity of 0.5 to 2 wt% NaCl equivalent. Homogenization of three phase inclusions was observed between 162 ºC to 278 ºC with salinity of 4 to 23 wt.%NaCl equivalent. The high-temperature and highsalinity of fluids indicate magmatic nature of the trapped fluids within progradeskarn mineral assemblages in contrast the fluids with lower temprature and lower salinity displaying a possible meteoric source within the retrograde skarn assemblages. Therefore moderate temperature and high-salinity fluids could infer to possible isothermal mixing between the fluids.

A REVIEW OF ORIGINS AND OCCURRENCES OF NIOBIUM-TANTALUM, TIN AND TUNGSTEN MINERALIZATION IN RWANDA

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Abstract

Given that Mesoproterozoic Kibaran belt in Central Africa has recently subdivided into the Karagwe Ankole belt (KAB) and Kibara belt (KIB) separated by Rusizian terrane. KAB, spanning Rwanda, Burundi, SW Uganda and NW Tanzania, and KIB together host a large metallogenic province that contains numerous rare -metal ore deposits mineralized in Tantalum-Niobium, Tin and Tungsten. The part of Rwanda that comprises Karagwe -Ankole Belt contains the bulk of Cassiterite, columbite-tantalite, wolframite, and occur in Nb-Ta-Sn pegmatite, Sn greisen and W-Sn hydrothermal quartz vein deposits which are component of one composite metallogenic system related to the granite generation (G4-granite or Tin granite) that operated at 986±10Ma. Hydrothermal Fluid indicated H_2O–CO_2–CH_4–N_2–NaCl composition, a moderate salinity (7.44-9.9 eq. wt.% NaCl) , high pressure ~100MPa and ~ 300°C. The isotopic composition of the fluids indicates that the mineralised quartz veins most likely formed from a fluid largely influenced by metamorphic processes. This paper represents a review of existing works on 3Ts mineralization and occurrences in Rwanda, current states of knowledge are also presented.

STABLE ISOTOPE STUDIES (Δ^{18}O AND Δ^{13}C) ON FE-SKARN MINERALIZATION ASSOCIATED WITH ÇELEBI GRANITOID (KIRŞEHIR, CENTRAL ANATOLIA, TURKEY)

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Abstract

In Central Anatolia, following the closure of the northern branch of the Neo-Tethys ocean, wide range of intrusive rocks were emplaced such as S-, I- and A-type plutonic rocks. Metallogenic investigations show that various type ore deposits were formed in relation to I- and A-type plutonic rocks. Among them, Bugüz and Kargınyenice iron deposits are located about 20 km west of Kaman (Kırşehir). These deposits occur in a skarn zone at the contact between the Upper Cretaceous Çelebi Granitoid and calcic Paleozoic Bolçadağ Marble. Both endo- and exo-skarn zones are recognized along the skarn belt. Endoskarn zone is exposed in the Bugüz and Kargınyenice villages whilst exoskarn zone is commonly observed in Kargınyenice. Endo- and exoskarn zones are represented by pyroxene-plagioclase and pyroxene, pyroxene-garnet and epidote-actinolite mineral facies, respectively. Iron mineralization is formed as veins-lenses and disseminated in all the mineral facies. In prograde stage, magnetite mineralization occurs in coexistence with pyroxene, garnet and plagioclase. In retrograde stage, magnetite, hematite and trace pyrite are formed together with actinolite, epidote, chlorite, calcite, quartz and zeolite alterations. The last stage is represented by post skarn, magnetite and/or hematite mineralization and is cut by barren quartz, calcite or gypsum veins and limonite.

According stable isotope compositions, δ^{18}O (22.58 to 25.72‰ $_{(VSMOW)}$) and δ^{13}C (3.44 to 3.94‰ $_{(VPDB)}$) values for the Bolçadağ Marble indicate a marine origin. The carbon and oxygen isotope values of skarn calcites are δ^{18}O: 4.34 to 15.86‰ and δ^{13}C: 0.23 to -3.57‰ for the Kargınyenice and δ^{18}O: 16.74 to 23.50‰ and δ^{13}C: -3.50 to -5.31‰ for the Bugüz. Depletion in δ^{18}O and/or δ^{13}C is attributed to magmatic and meteoric fluid infiltration in the Kargınyenice deposit and indicate an open system volatilization process in the Bugüz ore deposit.

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REE GEOCHEMISTRY, MINERALOGY AND ORIGIN OF MANGANESE MINERALIZATIONS IN YOZGAT (TURKEY)

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Abstract

The study area is located in the northern part of the Central Anatolian Crystalline Complex (CACC) at the border of İzmir-Ankara-Erzincan Suture Zone. Studied mineralizations occurred within Artova Ophiolite Complex (AOC). Manganese mineralizations that occur within radiolarites are banded, laminated and lenticular and are intensely fractured and folded. Manganese mineralizations are distributed over six different regions, namely Derbent, Baltasarilar, Cihanpasa (northwest of Yozgat), Buyukmahal (northeast of Yozgat), Eymir (Sorgun-Yozgat) and Tarhana (Kadisehri-Yozgat) where pyrolusite, psilomelane, manganite and braunite comprise the main paragenesis and jacobsite, magnetite and goethite are the minor phases.

Except for some of the Derbent samples, the other samples in the area show negative Eu anomaly. These values are indicative of insufficient interaction with volcanic rocks (basalt, diabase) during the mineralization while the negative and positive Eu anomalies recorded in the Derbent region would show contribution by hot hydrothermal fluids which increased the temperature. The negative Eu anomaly may also imply that hydrothermal source was distant from the mineralization or it may be highly mixed with seawater. Total 25 samples collected from Cihanpasa and Buyukmahal areas are represented by negative Ce anomaly and have resemblance to low-temperature hydrothermal deposits. Samples from the other deposits display both negative and positive Ce anomalies. Based on this both hydrothermal and hydrogenetic processes were effective in the formation of the mineralizations.

High Ba content and decreasing pattern from LREE to HREE together with negative Ce anomalies and trace element distributions indicate that mineralization in the area was derived from a primary hydrothermal source. In addition, diagenetic and epigenetic processes may also play an important role in the manganese deposition.

PASSIVE MARGIN ECONOMIC MINERAL DEPOSITS OF SOUTHEASTERN ANATOLIA, TURKEY: DEPOSIT TYPES AND TRACE ELEMENT CONSTRAINTS

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Abstract

The passive margin sedimentary sequence of the Hakkari region, southeastern Anatolia, Turkey consists of Ordovician to Tertiary quartzite, sandstone, shale, limestone, and marl and also reveals a diversity of economic mineral deposits. World class zinc - lead, barite, asphaltite, and phosphorite deposits are also found in the region.

A unique fracture filling, chalcopyrite-quartz mineralization occurs in the Ordovician quartzites. Sedex-type Zn-Pb sulphide deposits and their oxidation products of Zn-Pb carbonate-oxide ore occur in the Triassic units as ore bed alternations and also feeder veins. Bedded and vein-type barite deposits occur in the Jurassic carbonates. Phosphorite deposits (Ca phosphates) occur in the late Cretaceous sequence. Asphaltite is seen as E-W striking veins that cut the Cretaceous, Paleocene and Eocene formations and represent oil injections along the thrust fault zones that formed at the end of the Eocene. Despite the occurrence of asphaltite and lead-zinc ore veins in the same geological setting, a possible genetic link between these deposits in terms of sulphate reducing agent has not been determined.

In the zinc-lead ores, the trace element geochemistry is characterized by significant amounts of Tl [301 ppm] , As [3938 ppm], Hg [15 ppm],Sb [114ppm].Se [3 ppm], Mo [90 ppm],Mn [5629 ppm], and Ba [1189 ppm]. Ba enrichment is typical throughout the stratigraphic section as both monomineralic ore beds and also as gangue minerals in the zinc lead ores. These trace element enrichment in the ore indicates that the source of the metals possibly was an aluminosilicatic rocks and/or a contienetal crust.

THE ORE STRUCTURES AND TYPES OF THE KIZILCAÖREN REES-F-BA-TH DEPOSIT: IMPLICATIONS FOR CARBONATITE ORE INJECTIONS

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Abstract

The Kızılcaören carbonatite-hosted REE-F-Ba-Th deposit in westernTurkey is a world class REE deposit (Kaplan 1977a, Kaplan 1977b, Stumpel and Kırıkoğlu, 1985) and occurs in Permotriassic metasedimentary units consisting of shale, sandstone, and conglomerate. Silicification and brown iron oxides are the most distinctive host rock alterations close to the ore zone; however, the ore does not show such alteration. The late Oligocene (24 Ma, K/ Ar method, Nikiforov et al. 2014) ore bodies are elliptical and display two types of ore: 1) a very well-layered soft ore and, 2) a massive and relatively hard ore. The layered ore is the main ore type throughout the deposit, and locally, several mineral phase are dominant. These include barite, manganese oxide, fluorite, and bastnasite. The layered ores are relatively soft with gently dip, however, in contrast, the massive ore bodies are steeply dipping close to vertical dip. The ore minerals of the massive ore are fine-grained, relatively hard and homogeneous. A weak fluid-flow-related mineral orientation is also found in the massive ore. According to these features, the massive ore has been interpreted as feeder veins of the layered ores. Crosscutting relationships between the feeder veins and layered ore indicate polyphased mineralization which was dominated by successive Ba, Si, Mn, F, REEs pulses. Field evidence indicates that a gas rich carbonatitic ore fluid was injected along the fault zones during the latest Oligocene during extensional tectonism (Seyitoğlu and Işık 2015) and related phonolite-thracite intrusion. Successive ore deposition was formed by gas-triggered, open-space creation, and a magmatic dyke and sill emplacement like episodes with carbonantite fluid infilling processes. As a whole, the umbrella- or mushroom-like geometry of the ore body indicates an upward pushing of the fractionated carbonatite melts during ore deposition by a magmatic body which underlies beneath the deposit.

GEOCHEMISTRY OF RARE EARTH ELEMENT SOURCE ROCKS IN TURKEY

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Abstract

Very recently, much more study have been focused on the REE enrichments in different geological setting because of their economic and strategic importance. The REE mineralizations of Turkey are associated with both magmatic hydrothermal system and also related to the surficial supergene processes. Carbonatite - hosted hydrothermal mineralizations were formed deep to shallow seated hydrothermal processes with relatively high temperature and pressure conditions, whereas the surficial REE enrichments are related to the weathering of argillic rocks and their subsequent transportation and accumulation into the small depressions. The aim of the study is to provide an overview of the nature of the rare earth elements that occur in different rock units in Turkey. During this project the geological and geochemical nature of the REEs – bearing rocks such as carbonatite, alkali intrusive related flourite - REEs ores, bauxites, phosphorites and low grade metamorphosed argillic rocks were studied.

The possible rare earth element source rocks – materials in Turkey can be divided into the five types according to their rock associations and the processes of formation. The first is carbonatite- hosted hydrothermal type that includes the highest TREEs (Total Rare Earth Elements) between 29 982 ppm and 7 255 ppm. The second is alkaline intrusive- hosted -type that includes 1363 ppm to 540 ppm TREEs. The third is the placer - hosted –type formations that includes average 717 ppm TREEs. The fourth is associated with bauxites range between 2930 ppm to 1693 ppm. REEs contents of the slate of the some bauxite protolith shows very high TREEs (1548ppm) which is characterized by a relative heavy REE enrichments. The fifth potential source for REEs is phosphorite deposit which includes very low content of TREEs compared to those of the well-known world examples. While the former four types of resources occur on the Anatolide- Tauride tectonic unit, the fifth type syn-sedimentary phosphorite formation occurs on the Arabian continent.

MINERALOGY AND GEOCHEMISTRY OF METALLIFEROUS CHEMICAL SEDIMENTARY ROCKS FROM UPPER-CRETACEOUS VMS DEPOSITS OF THE EASTERN PONTIDE (NE TURKEY)

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Abstract

Chemical sedimentary rocks are a common, although minor, component of the Upper Cretaceous volcanic belt in the Eastern Pontide which hosts volcanogenic massive sulfide (VMS) deposits. These metalliferous sediments have been recognized in Lahanos, Çayeli, Kanköy, and Kutlular massive sulfide deposits. They are important stratigraphic marker horizons in the Eastern Pontide VMS deposits and readily distinguished by their red color imparted by abundant iron oxides. Chemical sedimentary rocks are commonly located at the top contact of the footwall lithologies or within the lower part of the overlying hanging-wall sequence. Chemical sediments directly overlie the massive stratiform ore and vary in thickness from a few millimeters to ~2 meters. At Lahanos, this layer extends continuously across the entire massive orebody, whereas, in Çayeli and Kutlular mines, it can be traced only discontinuously above the orebody. Ore-bearing chemical rocks contain numerous crosscutting veinlets dominated by quartz, with subordinate barite veining. Wavy structures, soft sediment deformation, and slump/collapse structures are common.

The chemical sediments are composed of kaolinite, siderite, barite, quartz, hematite, and amorphous materials. They also contain variable amounts of chalcopyrite, pyrite, fahlores, galena, rutile, and limonite. Chemical sedimentary rocks from the Pontide VMS deposits do not show significant geochemical variability within individual deposits, whereas geochemical variability within different deposits is more obvious. Silica, Fe, Mn, Ca elements reflect the main mineral constituents of the chemical sedimentary beds. Silica occurs as quartz and kaolinite. Calcium is enclosed in calcite. Minerals of Fe are predominantly hematite, with lesser amount chlorite and siderite. With a few exception, chemical sediments have very high contents of SiO_2 (15 - 84 wt %). They display variable contents of CaO (0.04 - 40.66 wt %) and MgO (0.04 - 9.63 wt %). Al_2O_3 contents (0.3 - 20.8 wt %) are similar within individual deposits, but are variable within different deposits. MgO content ranges from 0.04 to 9.63 wt %. MnO, Na_2O, K_2O, P_2O_5, and TiO_2 concentrations are low in most samples and do not display a substantial variation. Significantly high Sr content (358-458 ppm) is expected given the high CaO concentrations, as Sr commonly substitutes for Ca in carbonates. High CaO and Loss on ignition (LOI) are indicative of the presence of significant carbonate. The chemical sediments are characterized by high metal contents. They contain elevated levels of Cu, Zn, Pb, Au, Sb, and Ba. High values of Au (avg 1.1 ppm) have been detected in some samples and particularly in Kutlular samples (up to 10 ppm). Chemical sedimentary rocks are commonly replaced by sulfide minerals (mainly pyrite and chalcopyrite) suggesting that sulfide precipitation has continued after deposition of these unique rocks.

The most comprehensive study to date on these unusual rocks has been done in the southern Urals. Ferruginous and manganiferous rocks related to VMS deposits of the Urals are subdivided into jasperites, gossanites, and umbers. The characteristics of chemical sediments in the Eastern Pontides are comparable to those defined in the southern Urals.

GEOLOGY, U-PB GEOCHRONOLOGY, AND STABLE ISOTOPE GEOCHEMISTRY OF THE TUNCA SEMI-MASSIVE SULFIDE MINERALIZATION, BLACK SEA REGION, NE TURKEY: IMPLICATIONS FOR ORE GENESIS

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Abstract

Upper Cretaceous volcano-sedimentary sequences of the Eastern Pontide orogenic belt, NE Turkey, host significant VMS mineralization, including near Tunca. The initial stages of felsic volcanism within the mineralized area are marked by the eruption of dacitic lavas and breccias of the Kızılkaya Formation. This was accompanied by the emplacement of dome-like hematitic dacites. Autobrecciated and volcaniclastic rocks, both in situ and resedimented, were likely generated from extrusive portions of these dacite bodies. Basaltic volcanism is marked by the eruption of the lava flows and pillow lavas of the Çağlayan Formation. Hiatuses in basaltic activity are marked by thin horizons of volcaniclastics and mudstones. The uppermost felsic volcanic units are accompanied by resedimentation of autoclastic facies from previous volcanism and represent the latest phase of Upper Cretaceous volcanism in the area. The semi-massive sulfide mineralization is associated with a late stage of the initial felsic volcanism. U-Pb LA-ICP-MS zircon dating of a dacitic tuff breccia yielded an age of 88.1 ± 1.2 Ma (Coniacian-Upper Cretaceous), which is interpreted to be the timing of the sulfide occurrences.

A concentric zonal alteration pattern is observed in the field. The hydrothermally altered host rocks consist mainly of the following assemblages: (1) an inner zone of quartz-pyrite-sericite-chlorite±mixed layer sericite/smectite; (2) a quartz-pyrite-mixed layer sericite/smectite±chlorite±smectite zone surrounding the inner zone; and (3) quartz-pyrite-laumontite±sericite±chlorite assemblages that are locally concentrated along the outer zones of the field. The footwall alteration zone has a large lateral and vertical extent. Hanging-wall alteration is of very low intensity compared to the footwall alteration, typical of most VMS systems worldwide. Zonal alteration around the Tunca mineralization is considered to be a product of contemporaneous processes that occurred during the lateral migration of fluids outward from the center of the discharge, or interactions during single or several cycles of hydrothermal activity. A weak hanging-wall alteration is considered to represent on-going hydrothermal activity after deposition of hanging-wall lithologies. Fluid inclusion data indicate precipitation or mobilization processes within a relatively narrow temperature range of 152° to 255°C (avg. 200°C). The low-salinity fluids in the inclusions, less than 5.9 wt % NaCl equivalent, are consistent with typical modified seawater-dominant hydrothermal vent fluids. Sulfur isotope analysis of the Tunca sulfides yields a narrow range of 1.5 to 4.1 per mil. These δ^{34}S values are typical of many VMS deposits. Most of the recorded δ^{18}O values (+7.1 to +14.0 per mil) are greater than 9 per mil. The most intensely hydrothermally altered rocks tend to have lower δ^{18}O values relative to the less altered rocks. The most geologically

reasonable interpretation of the genesis of the Tunca mineralization is the continuous interaction between the host rocks and seawater-derived fluids, without significant involvement of a magmatic fluid. In the discrimination diagrams the geochemical data of the host rocks clearly plot in the volcanic arc field. The trace element geochemical signatures of the host rocks indicate that the Tunca field likely formed in an extensional tectonic regime during subduction.

Sulfide mineralization at Tunca has long been targeted by mineral prospectors due to the presence of mineralized boulders in stream beds. These sulfide ore boulders have previously been referred to as seafloor accumulation. However, detailed examination of these sulfide blocks has shown that they are characterized by a semi-massive texture, resulting from the stringer sulfide veins that represent the channelways for the upwelling hydrothermal solutions. The Late Cretaceous Tunca mineralization represents volcanogenic semi-massive sulfide deposition that formed largely in the subsurface with no known seafloor expression of mineralization on the seafloor. The Tunca mineralization may share many similarities with the conventional VMS deposits but likely formed in a relatively shallow-water environment.

SULFUR, CARBON AND OXYGEN ISOTOPES IN FE MINERALIZATION SYSTEMS AT TOROUD MAGMATIC ARC, NORTH EAST OF IRAN

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Abstract

Toroud magmatic arc is part of Alborz magmatic belt that is situated in the Semnan province, North East of Iran. Based on mineralization, iron deposits in Toroud magmatic arc classified into magnetite and hematite type. Nukeh, Panjkoh and Lajaneh deposits are magnetite type and Hamyard and Chaloo deposits are hematite types. Iron deposits in this area have different country rocks of mineralization. Country rocks in Nukeh, Hamyard and Panjkoh deposits are tuff and volcanic rocks. But limestone is the main country rocks of mineralization in Lajaneh and Chaloo deposits. All of iron deposits in Toroud magmatic arc associated with diorite and monzonite intrusions of Eocene age.

The sulfur isotope values ($\delta^{34}S$) of pyrite vary from -1.5 to +6.7(‰, CDT) in different iron deposits. Calcite occurs as a paragenetic mineral with magnetite and hematite in these iron deposits. $\delta^{18}O$ and $\delta^{13}C$ values of calcite are within the range of -5.2 to -1.5 ‰ (VPDB) and 9.98 to 19.16‰ (SMOW), respectively. The $\delta^{34}S$, $\delta^{18}O$ and $\delta^{13}C$ of iron deposits in Toroud magmatic arc demonstrate that these deposits formed by mixing of magmatic and meteoric waters.

PRELIMINARY FLUID INCLUSION STUDIES OF CU-MO BEARING QUARTZ-SULPHIDE VEINS IN THE TEPEOBA DEPOSIT, EYBEK GRANODIORITE (NW TURKEY)

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Abstract

The Biga Peninsula, is a part of the Tethyan Metallogenic Belt, in northwest Turkey which contains a wide variety of different types of mineralization such as Au-Ag, porphyry Au-Cu-Mo, Fe-skarn and epithermal Pb-Zn-Cu-Au deposits. The Tepeoba Cu-Mo deposit is hosted by Permo-Triassic metamorphic/sedimentary rocks and Oligocene-Early Miocene granitoids. The mineralization is primarily hosted in a series of brecciated veins and stockworks within the host rocks. The primary minerals consist of chalcopyrite, pyrite, molybdenite, sphalerite and pyrrhotite, with secondary supergene limonite, malachite and azurite. The deposit has a total reserve of 26 million tons at average grades of 0.33% Cu and 0.041% Mo. The style and mineralization in the Tepeoba deposit is similar to other previously studied porphyry systems in this part of Turkey.

A preliminary microthermometric study of fluid inclusion assemblages (FIAs) in quartz was undertaken to determine the P-T-x conditions during different stages of mineralization. Petrographic observations show there to be V-rich, L-V and L-V-halite inclusions present in the veins. Homogenization temperatures of L+V aqueous inclusions average 350 ºC with average salinities of c. 9 wt.% NaCl equiv. Halite-bearing L-V inclusions have homogenization temperatures of the vapour to liquid at temperatures as high as 490 ºC and dissolution of halite up to 300 ºC equating to salinities of c. 35 wt.% NaCl equiv. V-rich inclusions tend to be smaller at around 10-15µm and are almost completely filled by vapour making a determination of the vapour homogenization difficult. The association of V-rich and L-V-Halite inclusions and the recorded temperatures and salinities are consistent with porphyry style mineralization. However, the lower homogenization temperatures of L-V inclusions and their lower salinities would also be consistent with epithermal style mineralization. Further studies will elucidate the relation and temporal links between the higher and lower temperature fluids and link this to specific mineral deposition stages. The data are consistent measurements of fluid inclusions of other porphyry copper deposit and prospect in the western Turkey.

ÖKSÜT (DEVELİ, KAYSERİ, TURKEY) HIGH SULFIDATION EPITHERMAL GOLD DEPOSIT: GENETIC INVESTIGATION

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Abstract

Öksüt (Kayseri) high sulfidation epithermal gold mineralization is located in Central Anatolian Volcanic Province (CAVP) a part of Central Anatolian Crystalline Complex (CACC). According to petrographic and geochemical studies, the host rock of the mineralization is hornblende-rich basaltic andesite and covered by pyroxene-rich basaltic andesite of Develidağ Volcanic Complex. Zircon U-Pb geochronological analysis reveal that the age of post-mineral basaltic andesite (cover rock) is determined as 5.674±0.068 to 5.700±0.019 Ma and host rock age is pending. NW – SE trending fault system is the main structural controls of alteration and gold mineralization, but younger NE – SW – trending faults overprint and offset the deposits.

Öksüt epithermal deposit consists of seven potential mineralized zones and the most promising ones is Keltepe (1 million Oz / 22.8 million tonnes with 1.4 gr/t Au average), Güneytepe (125.000 Oz / 3.3 million tonnes with 1.2 gr/t Au average). Different types of breccias, defined in the hornblend-rich basaltic andesite, host the gold mineralization in Öksüt deposit. Five different breccia types were identified and their spatial-temporal association with the mineralization were recognized. Two different mineralization have been recognized in study area; oxidation-related gold mineralization and sulphide mineralization (mainly copper sulphide-rich). Gold was not detected by the petrographic works due to its under microscopic size, however, significant amount of copper-bearing minerals (mainly enargite, chalcocite, covellite, chalcopyrite and malachite) were identified in samples taken from the base of oxidation-related gold mineralization (sulphide-rich and/or moderately oxidized). Two main alteration zones were identified: (1) Silicification and (2) quartz ± alunite alteration, and the mineralization is enveloped by extensive zones of advanced argillic alterations characterized by quartz, kaolinite, pyrophillite ± illite. $\delta18O_{Fluid}$ and δD_{Fluid} compositions were calculated by alunite-water and quartz-water fractionation equations with estimated temperature of 250°C are -88,84 to -88,34 per mil ($\delta D_{alunite\text{-}fluid}$), and -5,41 to -1,31 per mil ($\delta^{18}O_{quartz\text{-}fluid}$), respectively. These values are attributed to a mixing process between magmatic water and meteoric water. Fluid inclusion assessments were failed because silicification formed mainly cryptocrystalline quartz minerals, too small for fluid inclusion analysis.

ALTERATION ZONES, GEOCHEMISTRY OF HOST MAGMATIC ROCKS AND GEOCHRONOLOGY OF THE AFYON – SANDIKLI (AS) ALKALINE PORPHYRY Cu-Au DEPOSIT

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Abstract

The AS (Afyon-Sandıklı) porphyry Cu-Au deposits is one of the alkalic porphyry systems formed by Late Miocene magmatism in Western Anatolia. The deposits are co-genetic to nine magmatic rocks including feldspar porphyry monzonite, feldspar porphyry latite, Kfeldspar syenite, latite porphyry, trachyte, trachytic dyke, micromonzonite porphyry dike, pyroclastic rocks and lava flows, and hydrothermal breccia.

The alteration mapping has been achieved by analyses of 299 rock samples collected from the surface exposures for terraspec analyses. The potassic alteration consists primarily of hydrothermal biotite. During thin-section identification no hydrothermal K-feldspar was detected in this alteration. The potassic alteration was partly overprinted by sericitic alteration. Phyllic alteration is mainly represented by sericite accompanied by quartz and pyrite. The dominant micas are fine crystalline muscovite and illitic muscovite. Besides, the terraspec analyses also resulted in identification of paragonite and phengite in the phyllic alteration zone. Terraspec analyses enabled the identification of advanced argillic alteration, and showed that the predominant mineral assemblages are alunite, kaolinite and dickite. Besides, pyrophyllite has also been defined at the shallow levels above the potassic alteration that also host the main mineralization. Additionally, tourmaline that forms discrete fine grained crystals, veins, and as breccia cement was identified at western part of the ore body. Chlorite and epidote was identified by petrographical analyses, and this forms the dominant alteration mapped at the northern and southern part of the deposit.

Geochemical results from the magmatic rocks are alkaline in nature and show shoshonite to ultra potassic affinity. They are enriched in large ion lithophile elements, and are depleted in high field strength elements with respect to primitive mantle. The light rare earth elements (LREE) are relatively enriched compared to heavy rare earth elements (HREE). These features suggest a metasomatized mantle source with residual garnet and lower hydrous phase for the source of magma.

The timing of magmatism and alteration has been obtained by U-Pb SHRIMP and Ar-Ar analyses of zircons and alunite minerals separates from fresh and altered rocks, respectively. The U-Pb SHRIMP analyses showed that the post-mineral intrusive phase has an age of 10.9±0.089 Ma, whereas the host monzonitic rocks yielded an age range between 10.5-12.5 Ma. The Ar-Ar geochronological measurements indicate that hydrothermal event age is 11.2 ± 0.5 Ma.

Keywords: porphyry copper, hydrothermal alteration, terraspec, geochronology, Sandıklı, Afyon, Turkey

FIELD TRIPS

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ÇAYELİ VOLCANOGENIC MASSIVE SULPHIDE DEPOSIT

Location and site installations

The Çayeli (Madenköy) massive sulfide deposit is located about 6 km south of the coastal town of Çayeli (Rize) in NE Turkey. The deposit crops out at an elevation of 165 m. The Çayeli Cu-Zn massive sulfide deposit is located at 41°01′ N latitude and 40°45′ W longitude in the rugged terrain of the Black Sea region. The mine is situated on the left bank of the Buyukdere river in a heavily populated rural area where the main crop is tea. The Mine area is covered by thick vegetation. Site installations are built on the river's flood plain and include a covered stockpile area, warehouse, maintenance building, mill, shaft, and various offices and service buildings.

Exploration history

Mining activities along the Black Sea coast and Çayeli date back to Phoenician times. At the beginning of this century minor exploration by the Russians was reported and, between 1930 and 1955, various shafts and adits were driven and some minor production took place. The work that led to the present mine was started in 1967 by the Turkish Government Agency "General Directorate of Mineral Research and Exploration" (Turkish acronym: MTA), which carried out a geophysical survey and drilling programme and drove an adit into the massive sulfide ore. In the 1970s, Etibank (now Eti Maden A.Ş.) acquired the mineral rights to the property. In 1981, ÇBI (Çayeli Bakır İşletmeleri) was formed as a joint venture between Etibank, Phelps Dodge, and Gama to develop the orebody. Phelps Dodge sold its share to Metall Mining (INMET) in 1988. Further underground work and metallurgical testing was carried out from 1988 to 1991. After positive results, a production decision was made and in August 1994, the first concentrate was produced. The Çayeli area has been explored intermittently since the 1930s. In 2013, First Quantum Minerals (FQML) acquired Inmet Mining Corporation (INMET). Recently, the deposit has been mined by First Quantum Minerals Ltd. Mine is expected to operate until at least 2019.

Geologic description

Based on major changes in volcanic style, the stratigraphic sequence has commonly been divided into dacitic/rhyolitic series (footwall lithologies), basic and volcano-sedimentary series (hanging-wall lithologies), and mafic-felsic sills and intrusives (e.g., Altun, 1977; Çağatay and Boyle, 1980; Pearson, 1997) (Fig. 1).

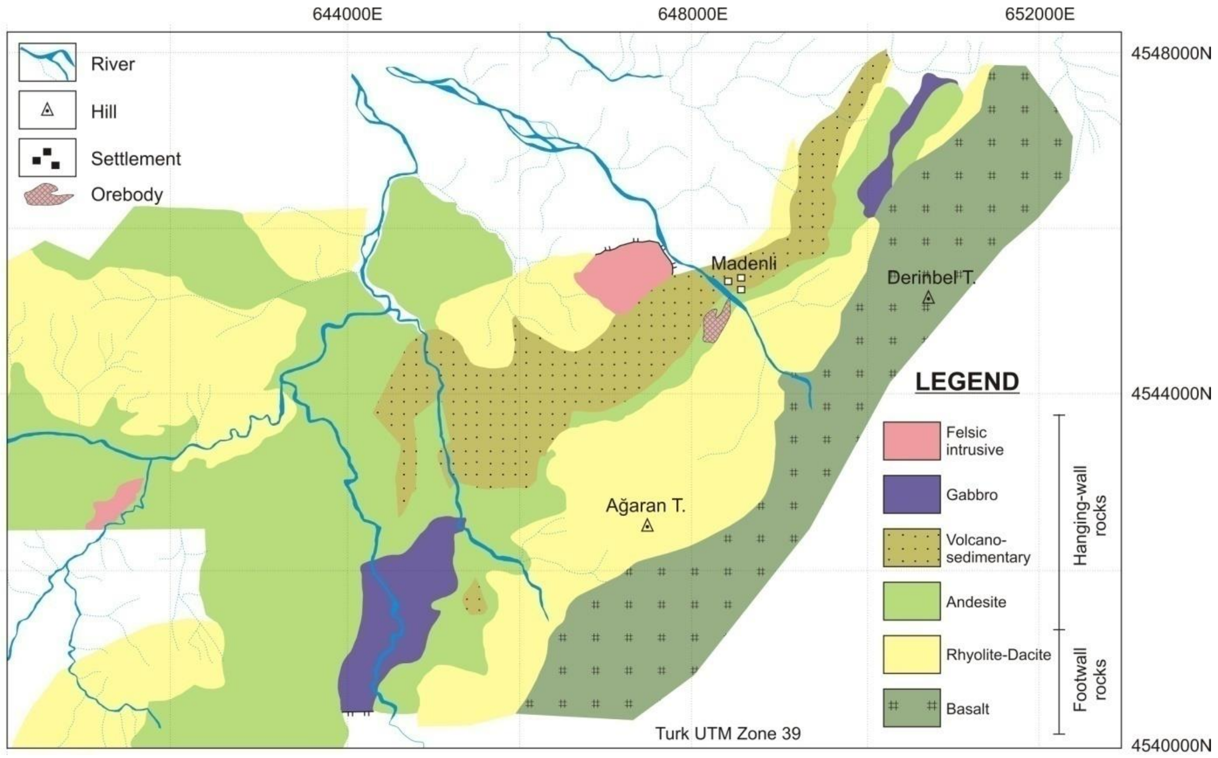

Figure 1. Geology of the Çayeli area showing location of the orebody (from source modelling studies of Çayeli Bakır İşletmeleri-2010).

The dacitic/rhyolitic series is characterized by the predominance of flows and domes featuring massive, lobates, pillowed, and brecciated lithofacies. This series is mainly composed of aphyric dacite, quartz and feldspar dacitic/rhyolitic breccia, and phyric felsic dykes and flows. The most characteristic feature of the dacitic/rhyolitic host rocks is the ubiquitous presence of flow lamination. These rocks present textures of flows and domes, passing from massive to lobate and brecciated lithofacies. The dacite/rhyolite is generally whitish but in places shows all the color variations from red (hematization), green (chloritization), creamy-beige (ankeritization), chalky-white (clay-alteration), and yellow to rusty (jarosite-pyrite). It represents the only unit in the area affected by penetrative and strong alteration. The highest thickness of the dacite/rhyolite dome is around 700 m, centered on the VMS area and gradually pinches out to a mere 50 m on its NE and SW extension (Pearson, 1997). This sequence is refered to in the literature as the Kızılkaya formation.

The basic and volcano-sedimentary series represents the hanging-wall of the Çayeli deposit. Its division from the underlying footwall lithologies is caused by a recurrence of mafic volcanism. This series is a volcano-sedimentary sequence of intercalated pillowed basalts, volcaniclastic rocks, and calcareous mudstones. These rocks are accompanied by mafic sills and felsic-mafic tuffs. The immediate hanging-wall of footwall dacite/rhyolite is characterized by the abundance of mafic sills. Two horizons of pillowed basalt occur in the hanging-wall lithologies. Basalt is green, slightly amygdular, and the interpillow hyaloclastic material is highly chloritized. It shows peperitic texture where the muddy limestone is mixed between the pillows. The volcano-sedimentary sequence represents a particular sediment package containing variable amounts of volcaniclastic material (felsic and mafic) and mudstone. The volcaniclastic unit represented by bedded and graded greywacke and mudstone is severely affected by brittle deformation. The gabroic sills are characterized by their strong magnetism, massive texture, and the occurrence of columnar joints. Frequently, a multi-chilled margin can be observed within a single sill and textural variations from fine grained to amygdular, becoming progressively coarser grained with the occurrence of feldspar, clinopyroxene, and olivine phenocrysts. Their geometry show irregular tabular bodies and pods suggesting sill emplacement in the unlithified units. Felsic intrusive rocks crosscut all rock types (Revan and Göç, 2016).

Structure

The Çayeli area, as part of the eastern Black Sea region, is characterized by horst and graben tectonic style. Faults trending NE and NW occur in the area. These are steeply dipping and usually reverse faults. Tectonic lines appear to have had a controlling effect on volcanism in the belt. Subsequent block faulting related to tectonic uplift resulted in the exposure of dacitic windows within later volcano-sedimentary cover, exemplified by that of the Çayeli area (Çağatay and Boyle, 1980). The most striking structural element is the Buyuk stream that divides the area into NE and SW blocks. The river represent a strong arcuated lineament, and the possible structural limit of a major caldera has been documented in terms of lithologic discontinuity (Pearson, 1997). The VMS deposit is located around a circular structure (possible a caldera), ~20 km in diameter.

Mineralization

The deposit is at the contact between the altered footwall felsic volcanic rocks and hanging-wall mafic volcanic rocks (Figs. 2, 3). The footwall rocks (approximately 700 m thick) consist of felsic and basic lavas and related autoclastic facies. The hanging-wall stratigraphy consists dominantly of andesite-basalt lavas and related fragmental rocks. Mineralization consists of sea-floor massive and subsea-floor stockwork sulfides. The orebody has a known strike length of more than 650 m, extends to a depth of at least 560 m, and varies in thickness from a few meters to 80 m (with an average of ~20 m). Average dip is ~60° to the NNW. Development of this mine began in early 1990 and a total of 15 Mt were produced by the end of 2012, at an average grade of 4.03% Cu and 6% Zn. Average Au is 1.2 gr/t and Ag values reach up to 150 gr/t, plus a lesser amount of lower grade stockwork sulfides (Table 1). There are four types of ores in the Çayeli mine; (1) yellow, (2) black, (3) clastic, and (4) stockwork ore. Clastic ore consists of pyrite, chalcopyrite, and sphalerite clasts, from 2mm to more than 20 cm in diameter in a sulfide matrix. The black ore consists of pyrite and chalcopyrite clasts from 2mm to >20cm in diameter in a fine-grained matrix of pyrite and sphalerite containing more than 10% sphalerite. Yellow ore consists of pyrite and chalcopyrite clasts, up to 20 cm in size, in a sulfide matrix containing less than 10% sphalerite. Table 2 shows the median metal grades of the different ore types. Copper values are highest for the yellow ore, which has a median copper grade of 5.13% Cu, and zinc values are highest in the black and clastic ores with median grades of 11.55% and 13.6% respectively. Ag and Au values are highest in the clastic ore. On a forward-going basis some 35% of Çayeli reserves are clastic, 65% yellow stockwork and black (IGCP-502 Field trip, 2004; Revan and Göç, 2016). Main ore minerals are pyrite, chalcopyrite, and sphalerite, with lesser amounts of galena, bornite, tennantite, marcasite, covellite, chalcocite, and various sulfosalts (e.g., Altun, 1977; Çağatay and Boyle, 1980; Revan et al., 2014).

Figure 2. View to the Çayeli Cu-Zn deposit, facing W-SW. Massive ore is located between hanging-wall and footwall lithologies, but an exact location is unavailable. The footwall lithologies consist of felsic and mafic rocks. Hanging-wall lithologies mainly consist of basalt/andesite and related fragmental rocks.

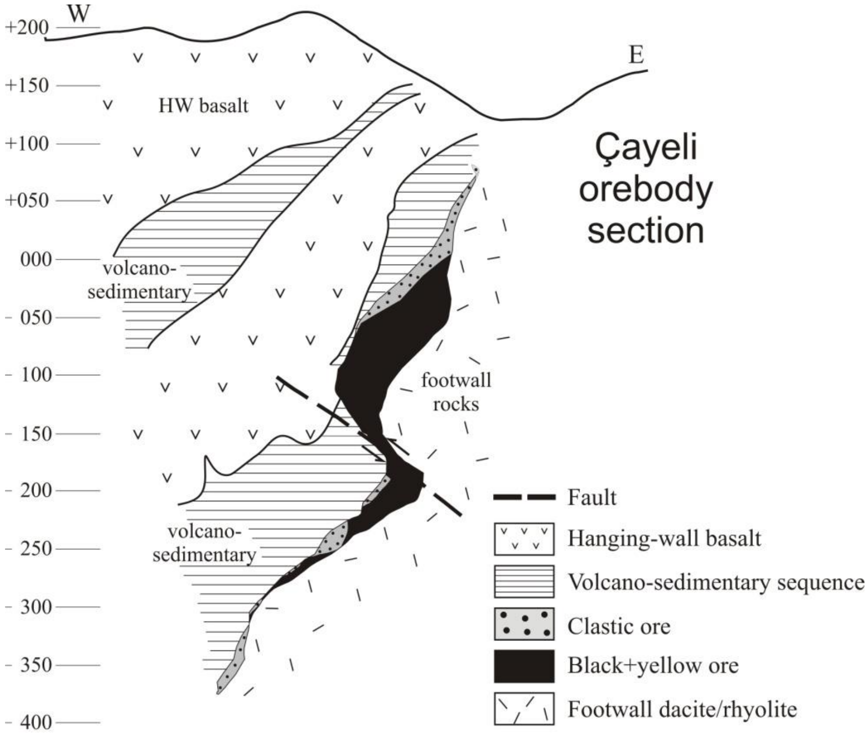

Figure 3. Simplified cross section through the Çayeli deposit showing the distribution of stratigraphic units relative to the mineralization (from Revan and Göç, 2016).

Table 1. Çayeli Reserves

		Tonnes (millions)	Cu (%)	Zn (%)	Au (g/t)	Ag (g/t)
Reserves	Proven	7.4	4.0	5.8	0.6	44
	Probable	8.6	3.2	5.5	0.5	49
Reserve Total		16.0	3.6	5.7	0.5	47
Resource Inferred		3.3	5.8	8.7		
Reserves and Resources		18.3	4.0	6.0		
Total		24.5	4.1	6.0		

Source: Çayeli Mineral Inventory (2003)

Table 1. Çayeli Ore Types

	Average Metal Grades				
Ore Type	Cu (%)	Zn (%)	Pb (%)	Ag (gr/t)	Au (gr/t)
Yellow	5.1	1.7	0.0	18	0.6
Black	2.8	11.6	0.3	50	1.2
Clastic	4.4	13.6	0.7	139	1.9
Stockwork	2.1	0.1	0.0	2	0.1

Source: Çayeli Mineral Inventory (2003)

Ore facies and mineralization styles are given in Figure 4. Mineralization consist of sea-floor massive and subsea-floor stockwork sulfides. In the Çayeli mine, ore-bearing sedimentary facies has the distinctive red colour (Fig. 4a) and can be traced discontinuously for approximately 550 m atop the massive ore body. The thickness of this layer ranges from a few centimeters to ~2 meters (Revan et al., 2013). Sulfide ores from the Çayeli VMS deposit exhibit clastic textures and are heterogeneous (Fig. 4b). The chimney fragments and, to a lesser extent, fossil fauna fragments form the major constituents of clastic sulfide ores (Figs. 4c, d). The size of individual sulfide minerals varies from mm to cm scale. Sulfide fragments are generally composed of pyrite, chalcopyrite, sphalerite, bornite, and galena. Rarely, relics of the host facies (volcanic and sedimentary rock fragments) occur within the massive orebody and may also contribute to the constituents of clastic sulfide ores. Large and small fragments are found together.

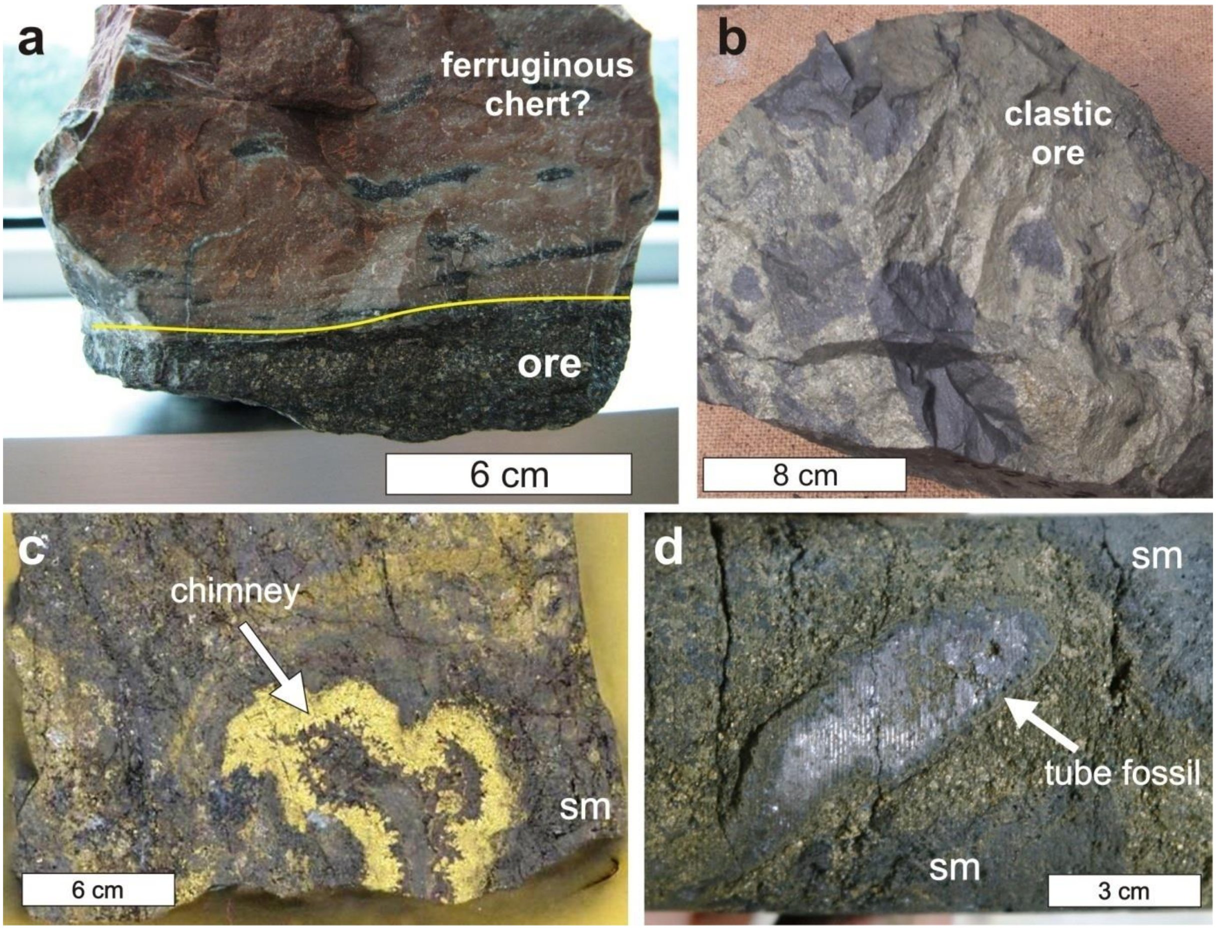

Figure 4. Photographs of selected ore facies. (a) massive ore directly overlain by siliceous chemical sediment. (b) Sulfide fragments in clastic ore consist mostly of pyrite, chalcopyrite, and sphalerite. (c) The chimney fragment, reaching up to 8 cm, is in a clastic sulfide matrix. (B) Sulfide fragments consisting mostly of sphalerite and pyrite are accompanied by tube worm (?) traces. Abbreviations: sm-sulfide matrix.

Age

The extention of mineralization into directly overlying sequences in which a variety of foraminifera (*Marginotruncana coronata* BOLLİ, *Marginotruncana pseudolimeiana* PESSAGNO, *Dicarinella* sp., *Dicarinella* cf. *asymetrica* (SİGAL), *Heterohelix* sp., *Marginotruncana* sp., *Globigermelbides* sp., Radiolaria) appears indicates Turonian to Santonian as an upper limit for sulfide accumulation (Revan, 2010). Senonian fossils (Globotruncana calcarata Cushman, Gl. cf. fornicata Plummer, Gl. cf. Hnneiana (Dlore), Gl. cf. concavata (Brotzen), Gumbelina sp., Gl. cf. area Cushman) were also identified by Altun (1977).

GÜZELYAYLA PORPHYRY Cu-Mo DEPOSIT

Location

The Güzelyayla porphyry Cu-Mo mineralization is located about 4 km south of the town of Maçka (Trabzon) in NE Turkey. Maçka is connected to Trabzon by a paved road and it takes 40 minutes to travel from Trabzon to Maçka by car. It takes about 15 minutes to travel to the deposit from Maçka. The Güzelyayla porphyry Cu-Mo deposit is located in the rugged terrain of the Black Sea Region. The deposit crops out at an elevation of 1750 m.

Exploration history

The Güzelyayla porphyry Cu-Mo deposit represents the first porphyry-style discovery in the district. Between 1970-1974, a regional geochemical exploration program was conducted by MTA. Copper and molybdenum anomalous zones were detected during the reconnaissance programme. Between 1985 - 1987, JICA (Japan International Cooperation Agency) and MTA (General Directorate of Mineral Research and Exploration) conducted a geophysical survey (IP and SIP), mapping, geochemistry (stream sediment, rock chip samples), and drilling (17 drill holes, amounting to 4969 m). Sporadic exploration activity from the early 1970s to the present has led to the conclusion that the mine is too remote to be economic.

Geologic description

The known stratigraphy in the Güzelyayla prospect is entirely composed of Upper Cretaceous volcanic rocks with intercalations of siltstone-mudstone and limestone, and all volcanic-and volcano-sedimentary units are crosscut by a porphyritic granite, a dacite porphyry, and quartz porphyry dykes (Çınar and Yazıcı, 1985; Nebioğlu, 1983).

A porphyritic granite is the largest intrusive body in the mapped area of the Güzelyayla prospect (Fig. 5). It is pinkish to gray in color and has a dominantly porphyritic texture. Plagioclase and quartz are the common phenocrysts within the medium-grained and epi-granular groundmass. The porphyritic granite is crosscut by the dacite porphyry, which host the Cu-Mo mineralization. The dacite porphyry is mainly composed of quartz, plagioclase, K-feldspar, biotite, and minor amphibole. Magnetite, hematite, and rutile are present in nearly every sample. Apatite and zircon are common accessory minerals of the dacite porphyry (Delibaş et al., 2015). Quartz porphyry crops out around the Küçüksivri Mountain and at the Maden Creek. It has intruded into andesite lava and partly into the altered porphyritic granite. It is inferred that intrusion of quartz porphyry is later than the intrusion of dacite porphry.

Andesite dyke is massive and has a porphyritic texture. It is also referred to as quartz-bearing andesite. Small basalt dykes (a few meters in thickness) are distributed in various parts of the area.

Limestone is grayish white and has a massive structure with no bedding. At Kirazdere, limestone has been altered to crystalized limestone due to thermal effect by intrusion of porphyritic granite.

Siltstone-sandstone horizons are interbedded with andesitic lava and can be traced discontinuously. These horizons are thick and indistinctly to well-laminated. They are distributed at the Kirazbaşı Mountain in the eastern part of the field.

Basalt/andesite lava is a pale green to dark green massive or hyaloclastic basaltic andesite. Basaltic andesite lava consists of breccia and matrix of same material including subangular pebbles of limestone and siltstone. The rock has undergone strong alteration and has developed many cracks and fissures caused by intrusion. Well-layered andesitic tuff is partly intercalated with andesitic lava (JICA, 1986).

Basalt lava is distributed around the northwestern part of the mineralized field. It consists of basaltic lava and pyroclastic rock. This rock is a dark green to reddish brown in color. It has undergone alteration to chloritization and epidotization. Basalt lavas are fine-grained and are commonly vesicular to amygdaloidal, with amygdules composed of chlorite (JICA, 1986).

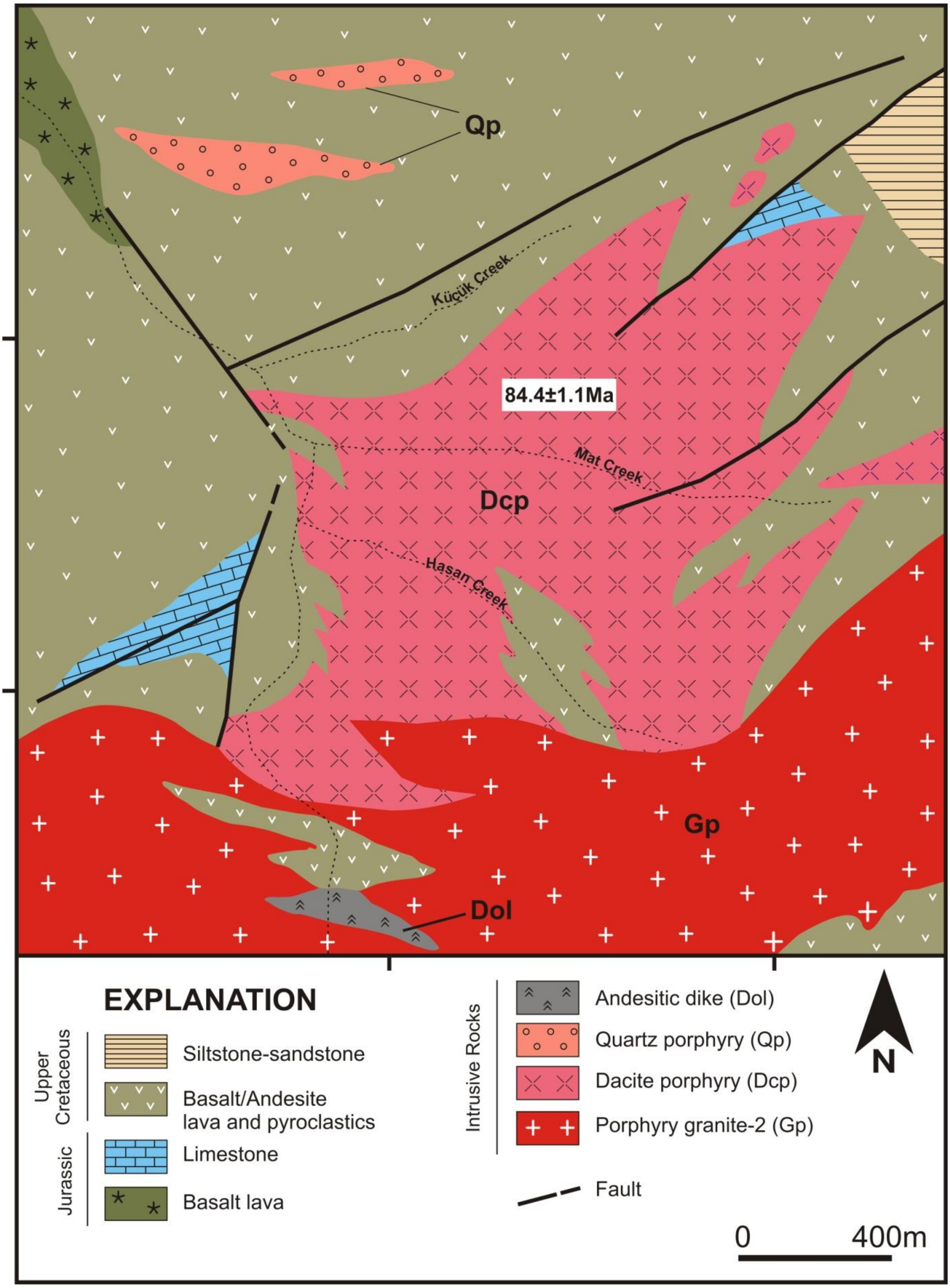

Figure 5. Geological map of the Güzelyayla Cu-Mo prospect showing the distribution of the major volcanic and volcano-sedimentary units (modified from Japan International Cooperation Agency-JICA, 1986; Çınar and Yazıcı, 1985).

Structure

Mineralized field is situated on the edge of an anticlinal strructure extending N-S to NE-SW from Hamsiköy to Dikkaya. Geological structure is mainly controlled by this anticlinal structure. Some structural disturbances occurred due to effects of the porphyritic granite intrusion and subsequent fault activity. The fault, considered to passing through east side of the Maden Creek in a N-S directional system, extends northward out of the surveyed area, while it diminishes at the southern extention as it is cut off by the intrusion of the unaltered porphyritic granite. Displacement by the fault has raised the western side, judging from the distribution of the Berdiga Limestone. In the Güzelyayla mineralized field, the faults are generally oriented in NE to SE directions, reflecting the geological structure of this area. The Küçükdere, Dikkaya, Matdere, and Kirazdere faults were delineated based on drilling survey. Results of the geophysical survey revealed that there is strong mineralization accompanied by pyrite in the periphery of the altered porphyritic granite, and also that the mineralized and unmineralized field are divided by a fault (JICA, 1986).

Mineralization

Mineralization is associated with andesitic-dacitic volcanic rocks and porphyry granitic intrusion that intersect these volcanic rocks. The Güzelyayla porphyry Cu-Mo prospect consists of a stockwork-type Cu-Mo mineralization crosscutting a calc-alkaline 81.4±1.1 Ma-old dacite porphyry and Late Cretaceous calc-alkaline andesite (Delibaş et al., 2015). Prospect consists of two types of mineralization known as stockwork-type and dissemination (Fig. 6). Stockwork-type quartz veins crosscutting the dacite porphyry and Cretaceous volcanic rocks are typically rich in chalcopyrite, pyrite, pyrrhotite, rutile, and minor molybdenite, whereas disseminated mineralization in dacite porphyry is characterized by chalcopyrite, magnetite, and pyrite (Fig. 7). The main ore minerals are pyrite, chalcopyrite, rutile, and pyrrhotite, along with minor molybdenite, sphalerite, magnetite, and galena. Some late-stage quartz veins (0.1 to 4 cm thick) are highly rich in molybdenite. Supergene sulfides including chalcocite, covellite, and digenite are commonly present. Pyrite is embedded as disseminations, networks, and veins and associated with other sulfide ores.

The alteration zone has a large lateral and vertical extent (1.8 x 1.8 km). There are three principal types of alteration: potassic, sericitic, and pyropylitic alteration (Fig. 8). Chalcopyrite, pyrite, pyrrhotite, covellite, and chalcocite are typically enriched in stockwork-type quartz veins within a potassic alteration zone, whereas molybdenite enrichment is related to late-stage quartz veins within a sericitic alteration zone. Altered clay minerals detected through X-ray diffraction analysis are mostly sericite and chlorite, along with minor kaolinite, pyrophylite, montmorillonite, and mixed-layer mineral. The zoned alteration pattern at Güzelyayla is similar in character to the alteration surrounding the typical porphyry deposits.

Exporation companies allowed to define 186.2 Mt at 0.3% Cu equivalent and 0.002 – 0.021% Mo of total proven and probable reserves according to Er et al. (1992) and Güner and Güç (1990).

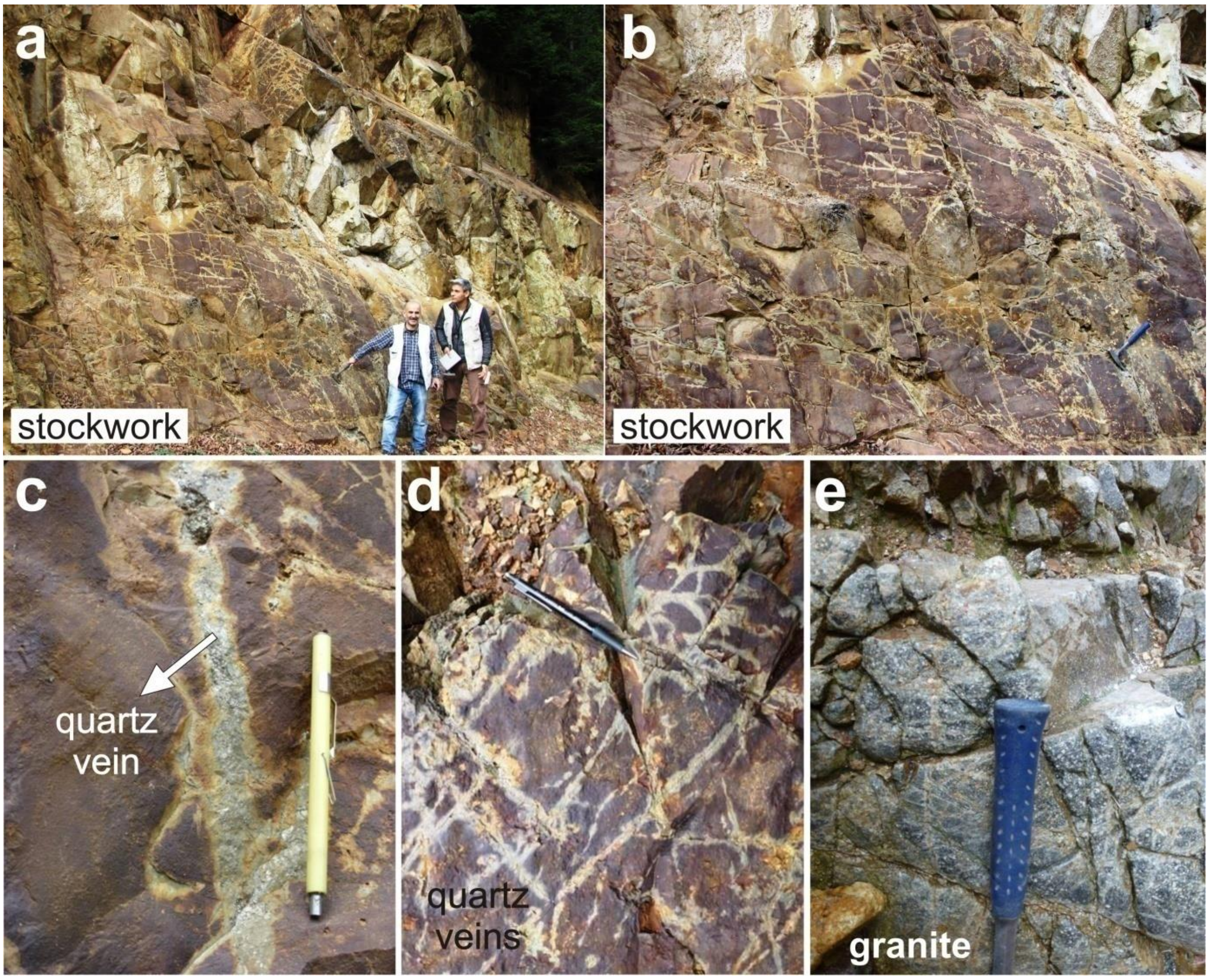

Figure 6. Examples of different mineralization styles associated with the Güzelyayla Cu-Mo prospect and host rock lithologies (a - b) Stockwork mineralization in dacite porphyry. (c - d) Quartz-sulfide veins in altered porphyry. (e) Close-up view of the less altered porphyritic granite in the field.

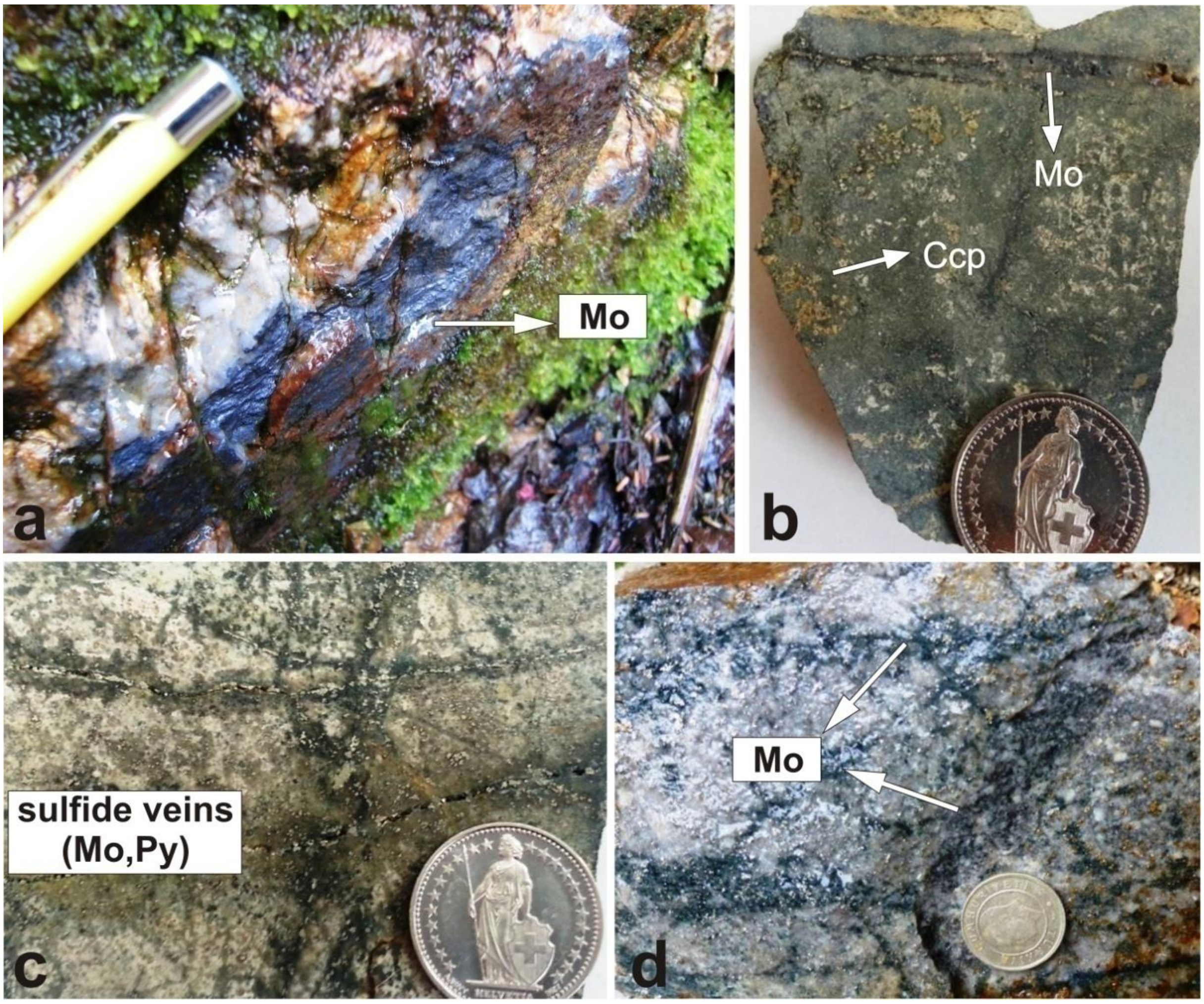

Figure 7. Examples of different mineralization styles associated with the Güzelyayla Cu-Mo prospect. (a) Molybdenite veins in dacite porphyry. (b) Molybdenite vein and chalcopyrite dissemination. (c) Quartz-molybdenite veins in altered porphyry. (d) Molybdenite veins in altered porphyry (Abbreviations: Py- pyrite, Mo – molybdenite, Ccp – chalcopyrite).

Fluid inclusion studies were conducted on quartz to determine the formation temperature of the Güzelyayla mineralization (JICA, 1986). 2719 fluid inclusions were measured from 150 samples. The mean value of homogenization temperature is 350° in quartz veins of dacite porphyry, 388° in the quartz veins in basaltic andesite. Although the total range of values are between 250° and 660°C, most inclusions in the quartz homogenized between 350° and 450°C. The salinities of fluid inclusions in quartz crystals were between 4.8 and 20.6 wt. % NaCl equivalent. The fluid inclusion temperature and salinity values obtained for Güzelyayla are highly consistent with values for most of the known porphyry deposits.

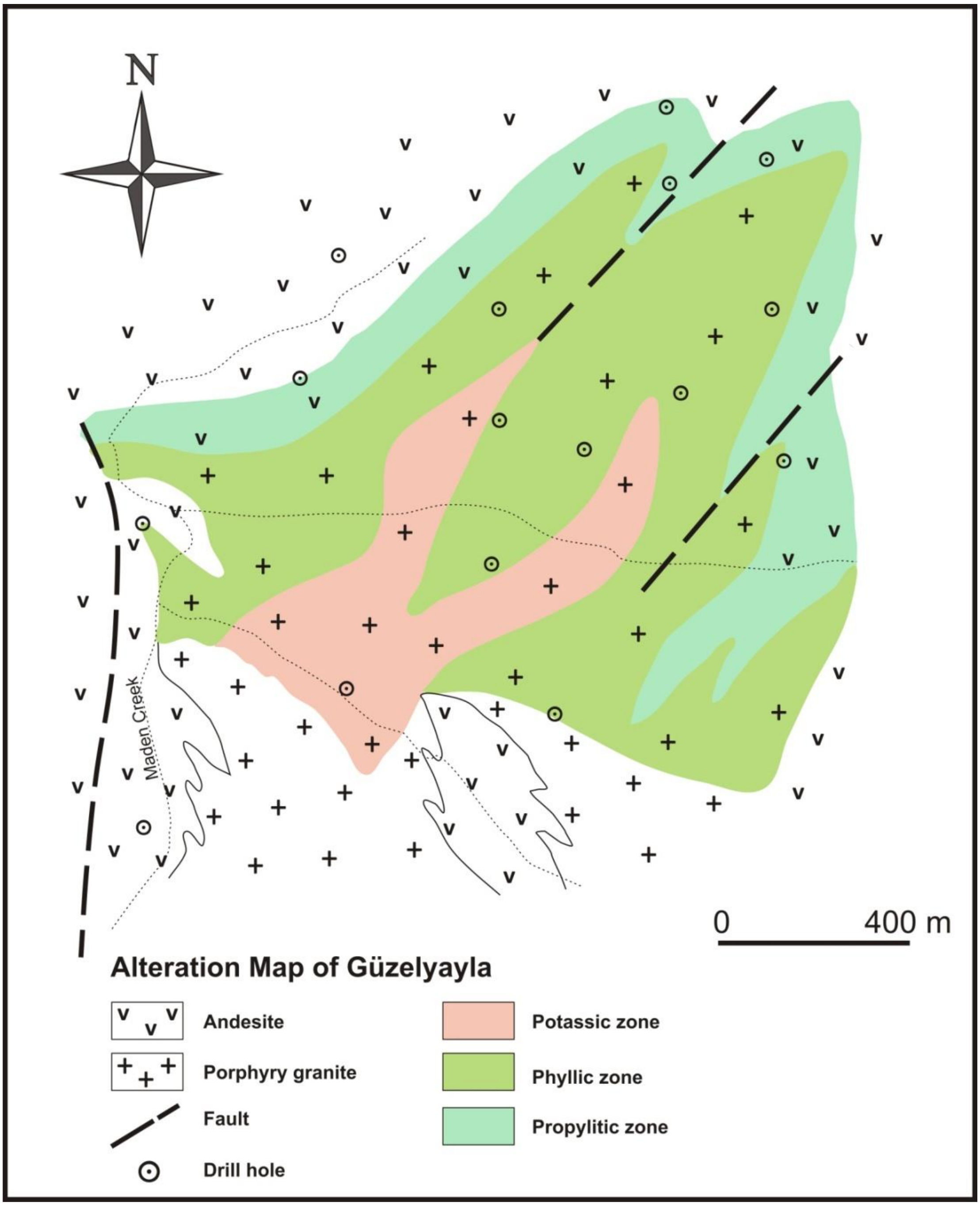

Figure 8. Zoning of alteration minerals in the host rocks around the Güzelyayla prospect (modifed from JICA, 1986).

Age

Fossils identified in the limestones of volcanic sequence (*Neotrocholina* sp., *Anomalinidae*, Lageniidae, Rudistiidae, Bryozoa, Textularia sp.) span the Jurassic to Upper Cretaceous. LA-ICP-MS U-Pb zircon age date reveal that Güzelyayla Cu-Mo mineralization is hosted by a 81.4±1.1 Ma-old dacite porphyry.

MASTRA (GÜMÜŞHANE) Au-Ag DEPOSIT

Location and site installation

The Mastra Au-Ag deposit is located about 15 km northwest of the city center of Gümüşhane. The Mastra deposit is located in the rugged terrain of the Black Sea region. The deposit, lying near the crest of the mountain, crops out at an elevation of ~1350 m. The mine is situated in a sparsely populated area and accessed by a combination of highway and paved roads. Site installations are built at the edge of the mountain and include a covered stockpile area, warehouse, maintenance building, mill, shaft, and various offices and service buildings (Fig. 9a).

Exploration history

The Mastra Au deposit was first discovered by MTA geologists during the visual prospecting in 1991. The work that led to the present mine was started in the early 1990s by the Turkish Government Agency “General Directorate of Mineral Research and Exploration” (Turkish acronym: MTA), who carried out the drilling program (10 locations). In 1994, Eurogold Mining Company acquired the mineral rights to the property. Further work was done by “Eurogold Mining Company” and drilled 79 holes (amounting to 12,024 m) in the field. In 2005, Koza Gold Mining Company acquired gold mine from Eurogold Company. Further underground and surface work (in addition to drilling program, various shafts and adits were driven) was carried out from 2005 to 2006. In 2009, Koza Mining started gold production in Mastra. Recently, the deposit has been mined by Koza Gold Mining Company.

Geologic description

The Mastra gold deposit is located at the southern zone of the Eastern Pontide orogenic belt. In the region, surrounding rock units, from the base upward, are composed of the Lias volcaniclastics, Lower Cretaceous limestones, Upper Cretaceous flysch, and Eocene volcano-sedimentary rocks. The host rock are andesitic lava and pyroclastics of the Kabaköy formation which are overlain by siltstone, sandstone, and tuffaceous units of Kelkit formation. Mineralization occurs within the NW-SE striking, steeply northeast dipping shear zones, resulting from granitic intrusions.

Mineralization

The Mastra Au-Ag (plus base metal) deposit is hosted by porphyry andesite lava and associated brecciated rocks in the Eocene volcanic rocks. Gold-bearing quartz vein zone is within a fault zone striking N50-70W and dipping 65-80NE. Quartz vein zone has a strike length of 2.5 km and a width of a few centimeters to 5 meters (Figs. 9, 10). Hydrothermal alteration around mineralized quartz veins is represented by chloritization, silicification, sericitization, carbonatisation, epidotisation, and clay alteration. A zonal alteration pattern is observed around the mineralized zone (Fig. 11). Three principal types of alteration, from the outer to inner, have been identified: (1) propylitic, (2) argillic-sericitic, and (3) silicification.

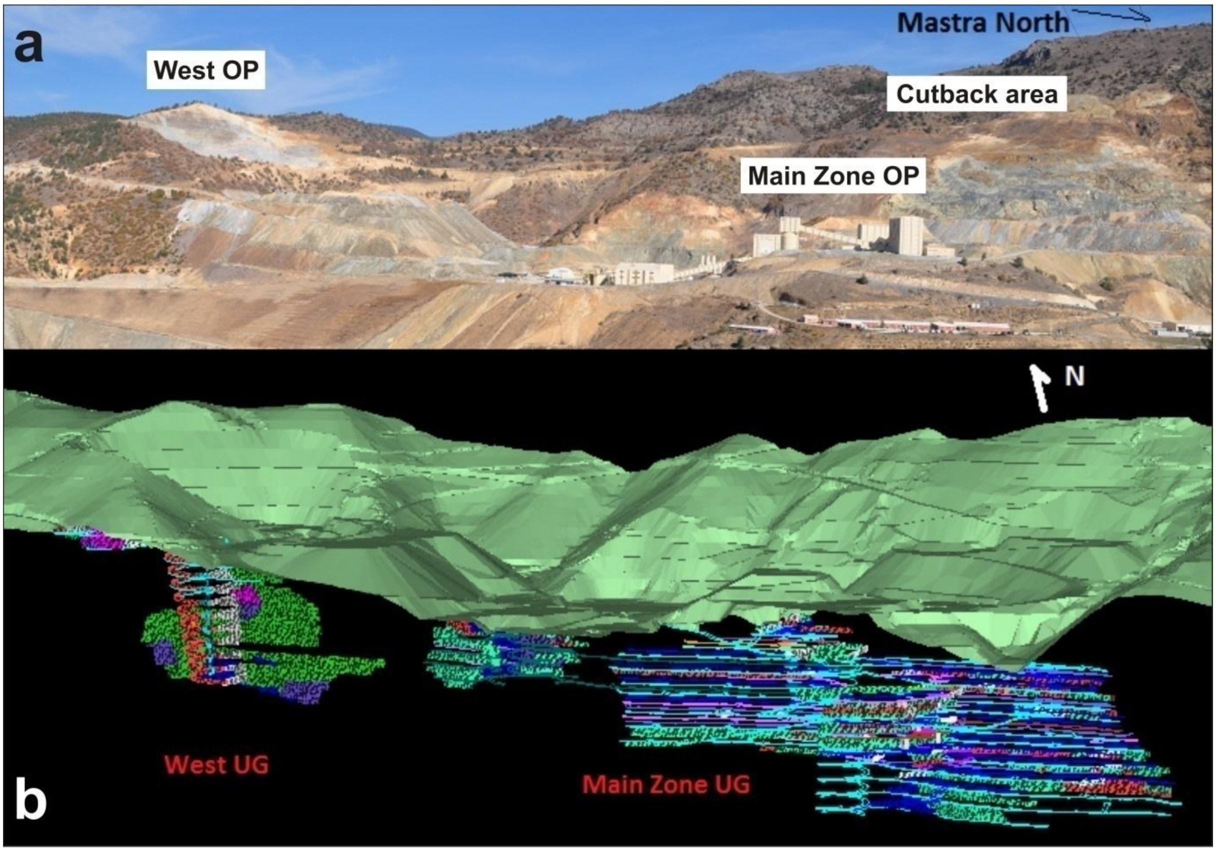

Figure 9. View to the Mastra Au-Ag deposit.

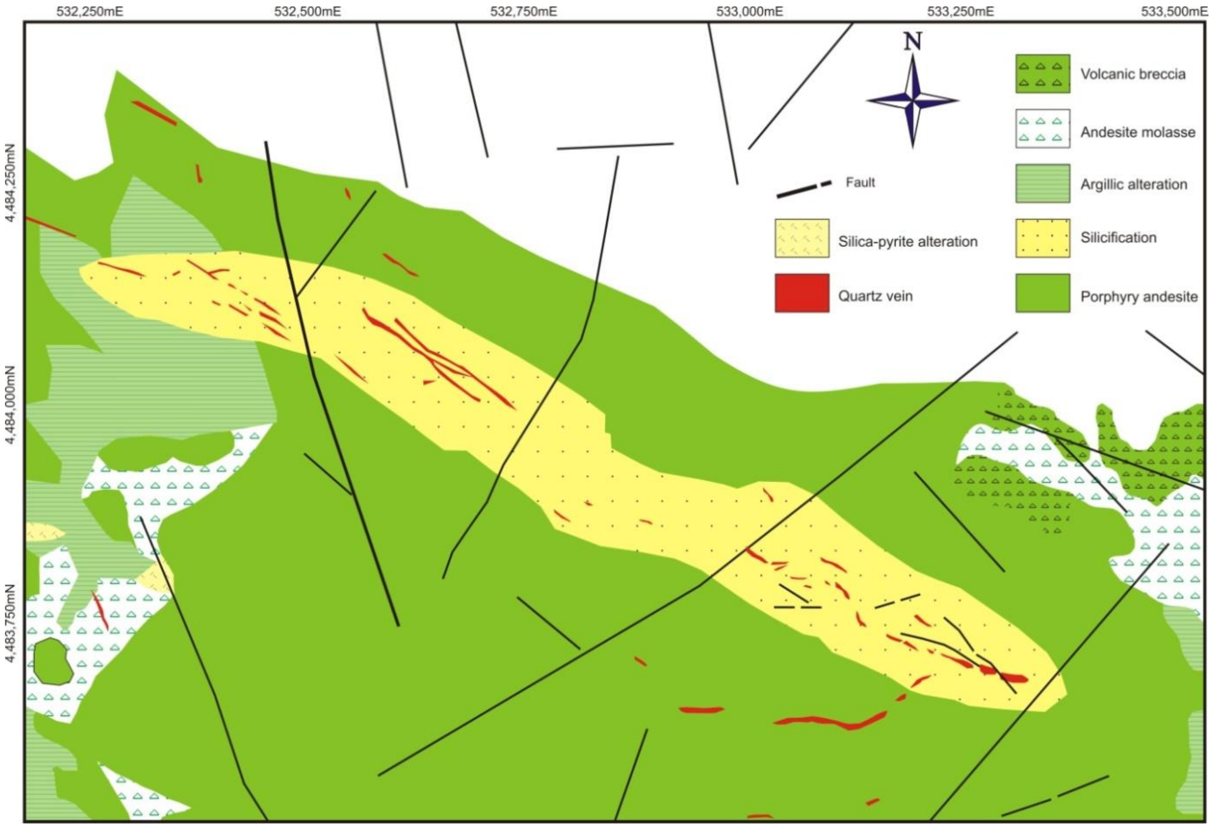

Figure 10. Geology of the Mastra deposit showing location of the mineralized zone and zonal alteration pattern (from Koza Gold Mining Company).

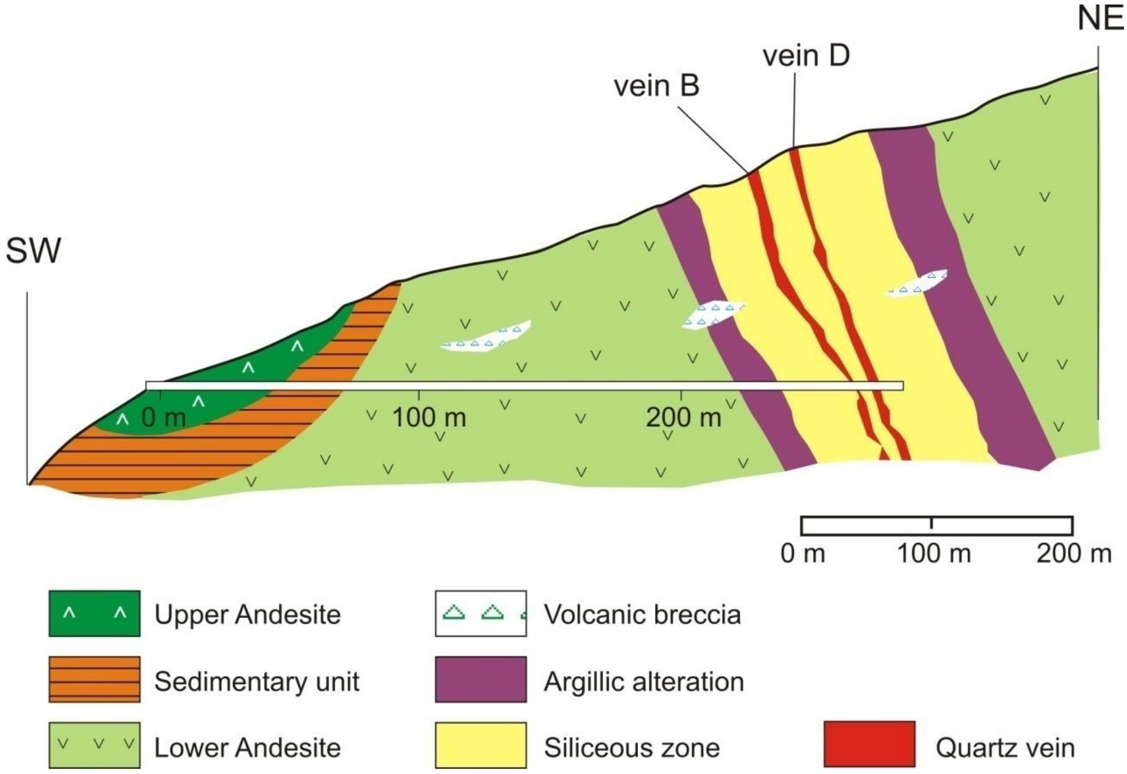

Figure 11. Geological cross-section through an orebody at the Mastra Au deposit (Modified after Eurogold Mining, 1998).

The main ore minerals are gold, silver, pyrite, chalcopyrite, sphalerite, sulphosalts, galena, tetrahedrite, tennantite, digenite, and covellite/chalcosite. Quartz, barite, adularia, calcite, serusite, gypsum, hematite, limonite, sericite, and clay minerals are the gangue minerals. Quartz veins exhibit various type of ore textures, including void-filling, brecciated, cockade, crustiform, colloform, comb, and lattice textures (Fig. 12). Brecciated, cockade, comb, and void-filling textures reflect epithermal conditions. Chalcedonic quartz veins are commonly seen in the eastern part of the Mastra mineralized field in which pyropylitic alteration is intense. Chalcedonic quartz veins contain higher grade Ag and lower grade Au. Many of these features conform to the adularia-sericite epithermal gold-silver deposits described in the geological literature.

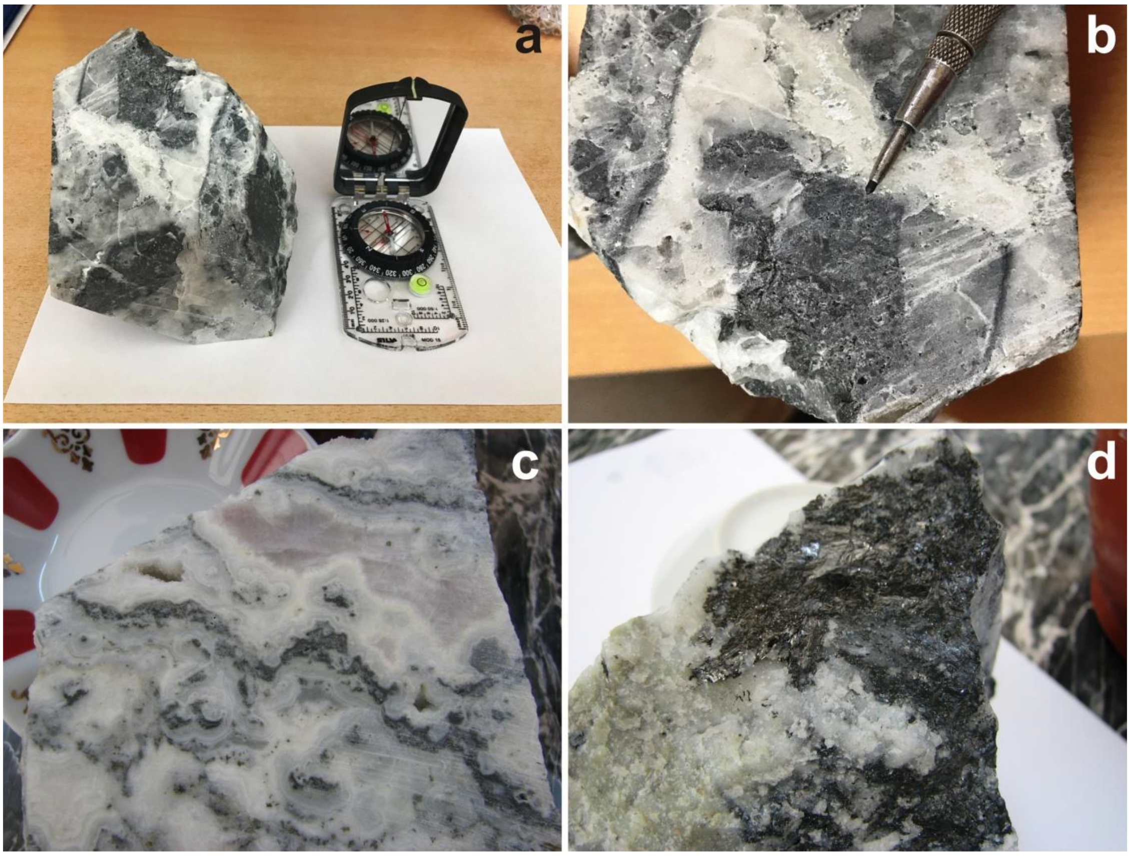

Figure 12. Photographs of selected ore textures from the mineralized zones. (a-b) Sulfide mineralization at Mastra comprising chalcedonic and vuggy quartz. (c) High grade (>25 g/t Au) crustiform and colloform banded quartz. (d) Massive quartz containing sulfide minerals (mainly pyrite, galena, and sphalerite).

The gold occurs free within quartz and size range for gold grains is 10 – 200 µm. Deposit locally contain high-grade gold ore (up to 1250 g/t Au). In total, a proven and probable reserve of about 1,466,000 Mt of ore has been estimated at Mastra, with an average grade of 6.61 g/t Ag and 5.81% Au (cut-off grade = 2.56 g/t). Between 2009 and 2015, 18.47 t Au and 5.53 t Ag have been produced.

ULUTAŞ (İSPİR-ERZURUM) Cu-Mo DEPOSIT

Location and site installation

The Ulutaş-İspir Cu-Mo deposit is located about 6 km northeast of the town of İspir in the city of Erzurum. It is located at 40°33′ N latitude and 40°52′ E longitude in the rugged terrain of the Black Sea Region. The elevation ranges from 2000 to about 2800 m. Several drill roads provide access to the target area (Fig. 13).

Exploration history

The Ulutaş deposit was discovered by the UN (United Nations) and MTA (General Directorate of Mineral Research and Exploration) mineral exploration team in late 1971 during the reconnaissance geochemical programme. Preliminary field evidence at that time indicated a widespread but erratic sulfide system exposed at the surface, consisting predominantly of pyrite, with minor chalcopyrite and molybdenite. In 1972, United Nations and MTA conducted geophysical (IP) survey and drilling in the mineralized field. The work that led to the present mine was started in 2012 by the Demir Export A.Ş., which carried out the drilling program. After positive results, a production decision was made. Demir Export Company is preparing to commence production at the Ulutaş deposit.

Geologic description

Geology of the Ulutaş area can be divided into three areas; quartz monzonite porphyry in the north and central areas, Eocence volcanic rocks to the east, and glacial or superficial deposits to the southwest (Fig. 14). An outcrop of skarn has been identified within the quartz monzonite porphyry approximately 700 m west-northwest of Ulutaş village, referred to as "Skarn-II". Metasediments are exposed to the south of Skarn-II. Southern portion of the map area is largely covered by landslide, alluvium, and slope debris. The principal area of current interest is located in the southwest of the license area and is covered by glacial moraine masking a skarn deposit, referred to as "Skarn-I". The steep downhill slope to the northeast of Skarn-I has limited outcrops of quartz porphyry, metasediments, epidote skarn, hematite skarn, quartz monzonite, and mafic dykes. Skarn-I hosts copper-zinc-silver mineralization of potential economic interest. The Ulutaş area is also of long-term interest targeting the copper-molybdenum porphyry deposit.

Palaeozoic or Lower Mesozoic (Pre-Jurassic) Metasediments: The oldest rocks in the Ulutaş area is a sequence of metasedimentary mica schists, gneissic schists and augenschists intercalated with amphibolite and marble lenses of the albite-epidote-amphibolite facies. Lineation of the foliation planes plunges shallowly to the west. Lensoid to irregularly shaped, coarsely crystalline marble bodies occur within schist units. Marble can be exposed for as much as 300 m along strike and varies in thickness from 1 to 60 m. Where the marble is close to, or cut by, a later igneous dyke and/or fracture zone, it has been erratically metamorphosed to a predominately anhydrous tactite assemblage. Amphibolite layers are generally thin located between the gneiss and schist sequences, parallel to the foliation.

Figure 13. Soutwest-facing view of Ulutaş-Ispir mineralized field.

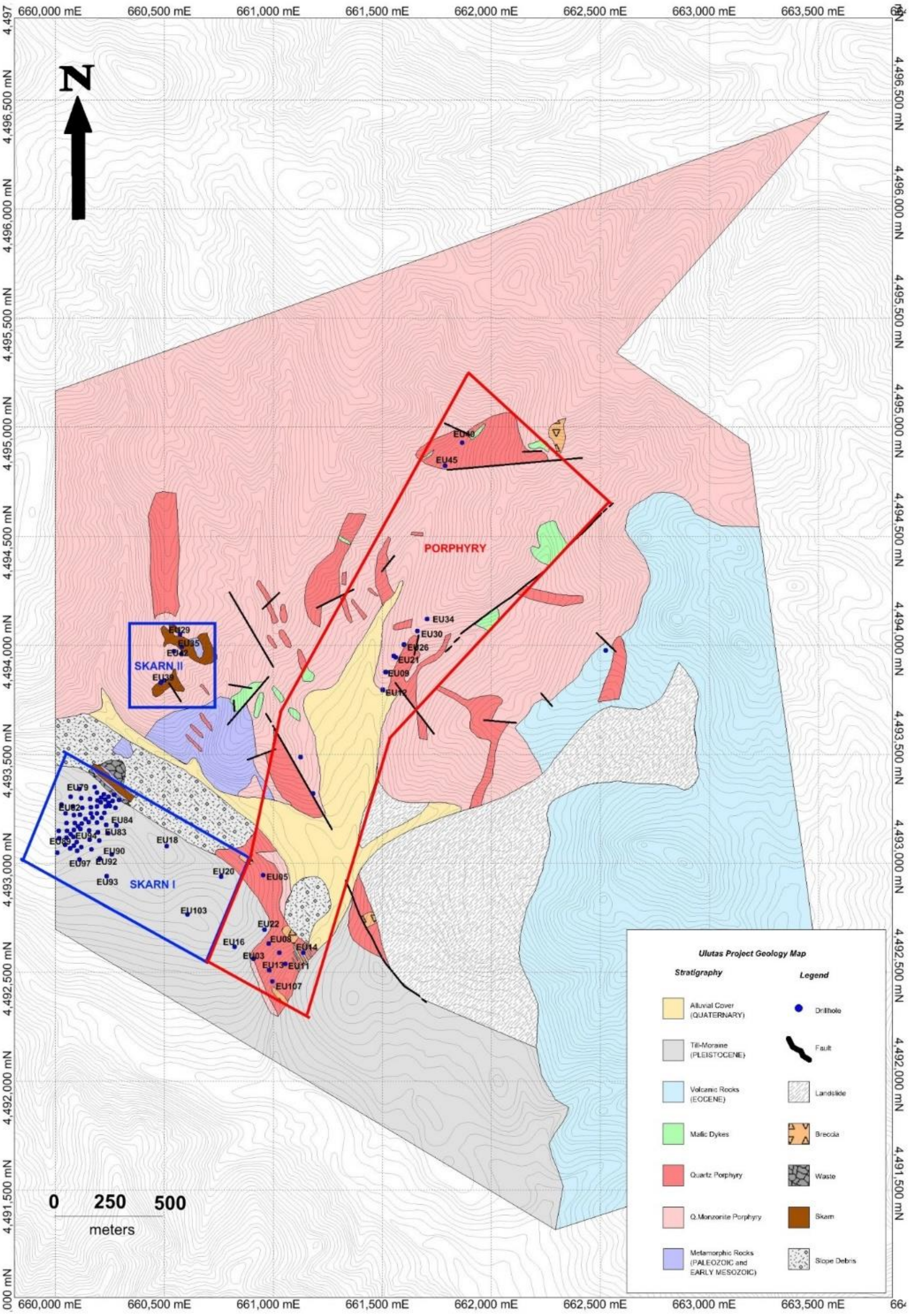

Figure 14. Ulutaş exploration targets and Demir Export drilling locations (from Demir Export A.Ş).

Quartz Monzonite Porphyry (Ulutaş stock): The Ulutaş stock composed of quartz monzonite porphyry is orientated N-NE (approximately two kilometres by five kilometres) (Fig. 15). To the northeast of the licence area, near the village of Moryayla, the stock is faulted up against post-intrusive Eocene volcanics. The stock dips under the Eocene volcanics, glacial debris and alluvium to the east and south within the licence area. Due to the intense alteration, the original monzonitic texture has been destroyed. The stock consists predominantly of medium- to fine-grained quartz-monzonite porphyry with local chemical and textural transitions to granodiorite and porphyritic quartz monzonite. Gradational and sharp contacts between the phases are noted in the field and it would appear that the stock, at its present level of erosion, is a heterogeneous mixture representing a multiple-intrusive body (at least two phases have been recognised). Sericitic (quartz-sericite), propylitic, intermediate argillic, potassium silicate, and carbonate alteration zones have been recognized at Ulutaş.

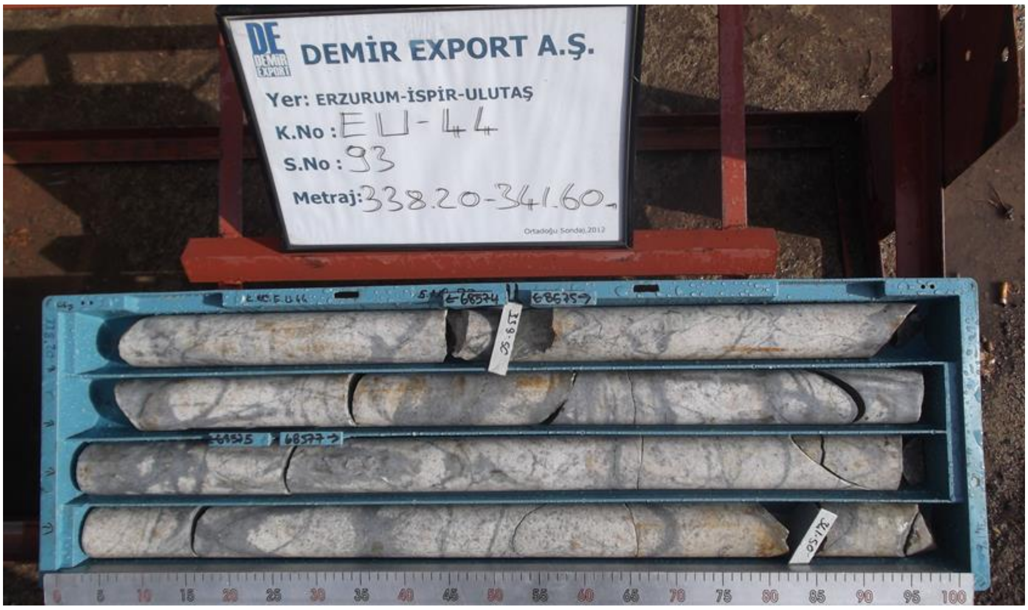

Figure 15. Core samples of quartz-monzonite porphyry.

Quartz Porphyry: The Ulutaş stock (quartz monzonite porphyry) has been extensively intruded within the license area by multiple-phase and co-magmatic rocks of latitic to rhyolitic composition (Fig. 16). “Quartz porphyry” is used collectively to include a wide range of felsites and felsite porphyries. Intrusive rocks are associated with hydrothermal intrusion-breccia bodies, healed shatter zones, and pebble dykes. Gradation appears to exist between silicified breccia bodies, in-situ shattered rock and unbroken dykes or plugs of quartz porphyry. Quartz porphyries occur as steeply dipping plugs, dykes (some of them radial), irregular shaped bodies within the quartz monzonite or as small exposures projecting through the post-intrusive cover. The multiple-phase quartz porphyry is related to several individual centers of multiple intrusive activity. The centers are closely related in time and space and are co-genetic. Each center was the focus for a wide-range of igneous and breccia activity, and took place at slightly differing structural levels within the quartz-monzonite host. Drilling works indicate that the quartz porphyry bodies do not enlarge with depth, but probably pinch to deeper channels. The quartz porphyries were probably intruded into the upper zone of the Ulutaş stock.

The intrusive breccia bodies and shatter zones appear to be contemporaneous with the injection of the various types of quartz porphyry. They have generally been healed by a later quartz porphyry phase or silica. Hydrothermal pebble-breccia and dykes appear to be late in the igneous hydrothermal sequence and are noticeably localized along internal quartz porphyry contacts and fracture zones or near the contacts of quartz porphyry bodies with the host rock.

Extensive hydrothermal alteration of the quartz porphyry intrusive/breccia complex makes recognition of the original rocks difficult. Three principal rock types have been identified: quartz latite porphyry, porphyritic latite, and porphyritic rhyolite. They are characterized by fine-grained to aphanitic groundmass and the presence of rounded and embedded quartz phenocrysts in varying proportions.

Figure 16. Core samples of quartz porphyry.

Mafic Dykes and Sills: Rocks of intermediate to basic composition are relatively widespread and occur as erratic but intersected large zones in the drill holes (Fig. 17). They occur typically as highly fragmented, altered xenolithic blocks or intrusions, and as dykes and sills within the pre-Jurassic metamorphic sequence. Three episodes of mafic dyke and sill intrusion have been identified. Volumetrically, the most important episode appears to be the oldest intrusion, post-dating the Ispir batholith and pre-dating the Ulutaş stock. The youngest episode appears to be contemporaneous with the Eocene volcanic rocks.

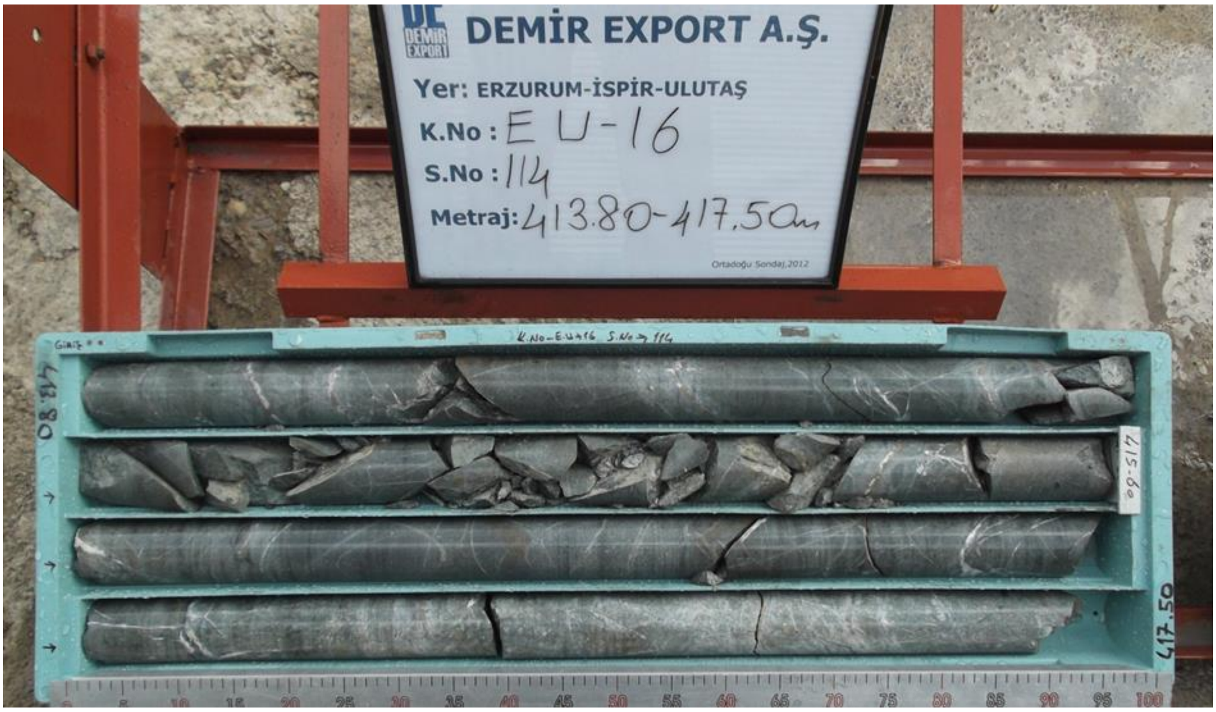

Figure 17. Core samples of mafic dykes and sills.

Eocene volcanic rocks: The Eocene volcanic sequence is a thick sequence of layered andesite to basaltic flows, tuffs and agglomerates deposited on a post-quartz porphyry erosion surface. The base of the sequence is composed of pyroclastic rocks with interbedded lenses of locally nummulite-containing (fossils) marl, conglomerate, sandstone, and limestone. The Eocene volcanic rocks dip gently to the southeast and are up to 250 m thick.

Pleistocene to Quaternary deposits: Pleistocene glacial deposits cover the bedrock in the project area but have been eroded to expose bedrock in places (Fig. 18). The glacial material (“till”) may be either a terminal or lateral moraine stemming from the glaciated Capans Valley. A large landslide covers bedrock in the central part of the license area. It likely originated from the Eocene volcanic rocks. The surrounding slopes are covered by a soil (or talus) of variable thickness. A few small terrace gravels are found in the alluvium.

Figure 18. Core samples of Pleistocene glacial deposits.

Mineralization

The Ulutaş copper-molybdenum porphyry and copper-zinc skarn deposits are situated in the southern zone of the Eastern Pontides orogenic belt.

The Ulutaş Cu–Mo deposit lies within the Ispir batholith based on drill-hole data, the total reserves were estimated at 73.6 Mt at a grade of 0.31% Cu and 0.022% Mo (Giles, 1973; Soylu, 1999). Porphyry type Cu–Mo mineralization is hosted by quartz monzonite porphyry and quartz porphyry of the Ispir batholith, which is a calc-alkaline multi-phase plutonic complex varying from granite through quartz diorite to syeno-diorite. A granite porphyry hosting Cu–Mo mineralization exposed in the northern part of the area represents the largest intrusive unit in the region. It is characterized by a pronounced porphyritic texture at the outcrop scale. Central parts of the granite porphyry are characterized by intrusions of NE-trending, steeply dipping quartz porphyry dykes or stocks, with a porphyritic texture with phenocrysts of embayed quartz and a fine-grained groundmass of quartz and highly sericitized plagioclase. Both granite porphyry and quartz porphyry are crosscut by dioritic, andesitic dykes hosting pyrite–chalcopyrite veinlets (1 to 2 mm). The granite porphyry contains micro-granular, roughly oval medium to dark gray dioritic enclaves, which have sharp contacts with their host (Delibas et al., 2015). Porphyry-type mineralization consists of stockwork veins and NW-striking quartz veins, with disseminated chalcopyrite along the vein systems, and molybdenite within the 1–2 cm thick quartz veins (Soylu, 1999).

The new U-Pb age zircon ages, lithogeochemical and radiogenic isotopic data of granitic rocks associated with the Ulutaş mineralization suggest that it formed in arc-related environment during subduction of the Neo-Tethyan ocean during the Cretaceous (Delibas et al., 2014).

Porphyry type Cu-Mo mineralization

The Ulutaş porphyry hosts a low-grade copper-molybdenum (Cu-Mo) sulfide system related to the quartz porphyry intrusive/breccia system, co-incident with the major zone of hydrothermal alteration. Hypogene sulfides consist of pyrite with chalcopyrite and molybdenite, with traces of galena and sphalerite. Mineralisation occurs as sporadic disseminations, fissure filling and in stockwork veining within the main copper-molybdenite-pyrite zone, and as weak lead-zinc-pyrite fissure filling on the outer fringes (Fig. 19). Copper occurs as disseminated grains of chalcopyrite along quartz veins and as secondary copper mineral such as malachite-chrysocolla along fracture surfaces. The overall pyrite-chalcopyrite ratio is 12:1 (Giles,1973). Molybdenite which is the main ore mineral of molybdenum is associated with 1-2 cm thick quartz veins in the potassic zone (Fig. 20) (Soylu, 1999).

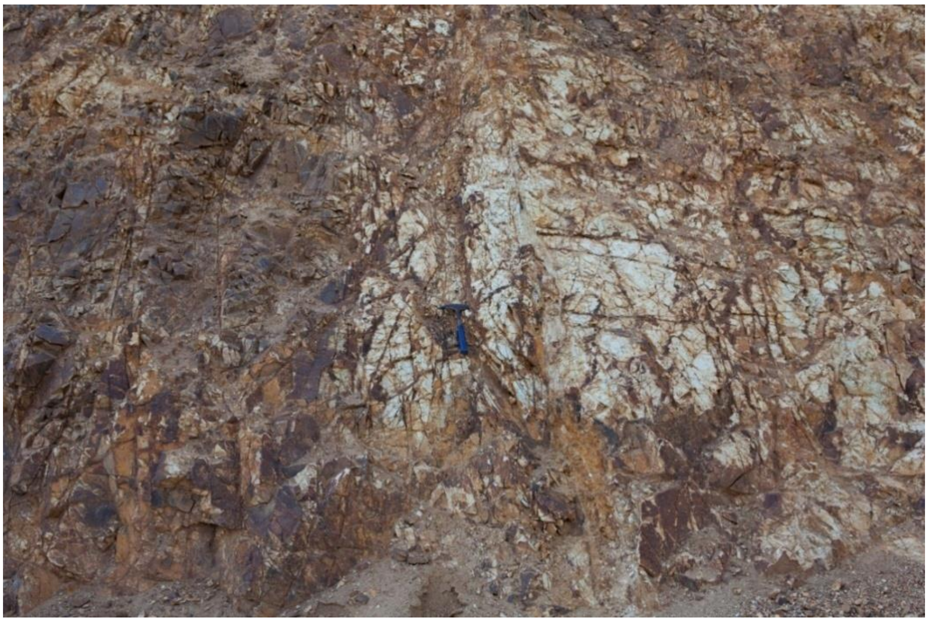

Figure 19. The stockwork veins exposed by road cut.

Figure 20. Molybdenite within the quartz-sulfide vein.

Skarn type Cu-Zn mineralization

The Ulutaş Skarn-I mineralization is divided into an upper and lower portions. The upper skarn is typically dark brown and 15 to 20 m thick. Disseminated- and veinlet-hosted hematite and magnetite is observed; whereas pyrite is associated with quartz and carbonate minerals (Fig. 21).

Figure 21. Hematite ± Garnet ± Magnetite (Upper Skarn).

The upper and lower skarns are separated by the granite; however, a transition from the upper to lower skarn is observed as a reduction of hematite and an increase of epidote.

The lower skarn is a dark brown to grey and 10 to 40 m thick (Fig. 22). In the deeper parts of the lower skarn, distinct zonation of epidote + chlorite ± garnet is observed.

The lower epidote + chlorite ± garnet skarn hosts a considerable amount of disseminated and veinlet sulfide mineralization. The paragenesis of the sulfide mineralisation has been determined as: (1) chalcopyrite + pyrite ± sphalerite; (2) sphalerite + pyrite ± chalcopyrite; and (3) sphalerite + chalcopyrite + pyrite.

Chalcopyrite and sphalerite are occur as disseminated mineralization within the host rock, in fractures (as sulfide veinlets) and in quartz/carbonate veinlets.

Figure 22. Epidote + Chlorite ± Garnet (Lower) Skarn.

The chalcopyrite within the chalcopyrite + pyrite ± sphalerite assemblage is seen as large subhedral crystals (mm in size), clamped together with pyrite. A lesser amount of sphalerite includes sub-microscopic chalcopyrite inclusions. A small amount of hematite in the chalcopyrite + pyrite ± sphalerite assemblage has been reduced to magnetite (observed on the periphery of pyrite and chalcopyrite crystals). In the sphalerite-dominated paragenesis, chalcopyrite is generally seen as medium to large euhedral or subhedral crystals that include sphalerite inclusions. In addition, the chalcopyrite and tennantite cuts the sphalerite and/or fills sphalerite fractures.

The sphalerite within the sphalerite + pyrite ± chalcopyrite and sphalerite + chalcopyrite + pyrite associations are seen as large subhedral crystals (mm in size) and as inclusions within medium to large crystals of pyrite and chalcopyrite. Pyrite, pyrhotite, and chalcopyrite are observed as inclusions and fracture infills within sphalerite. Garnet crystals are seen as gangue minerals within the sphalerite paragenetic associations.

The host lithologies in the Ulutaş deposit have been subjected to a pervasive hydrothermal alteration. Potassic, sericitic (phyllic alteration), silicification, and argillic alteration occur in intrusive igneous rocks. Propylitic and skarn alteration occur in metamorphic rocks. Potassic, propylitic and argillic alteration were mapped in the minerlized area by using Terraspec Halo spectrometer (Fig. 23).

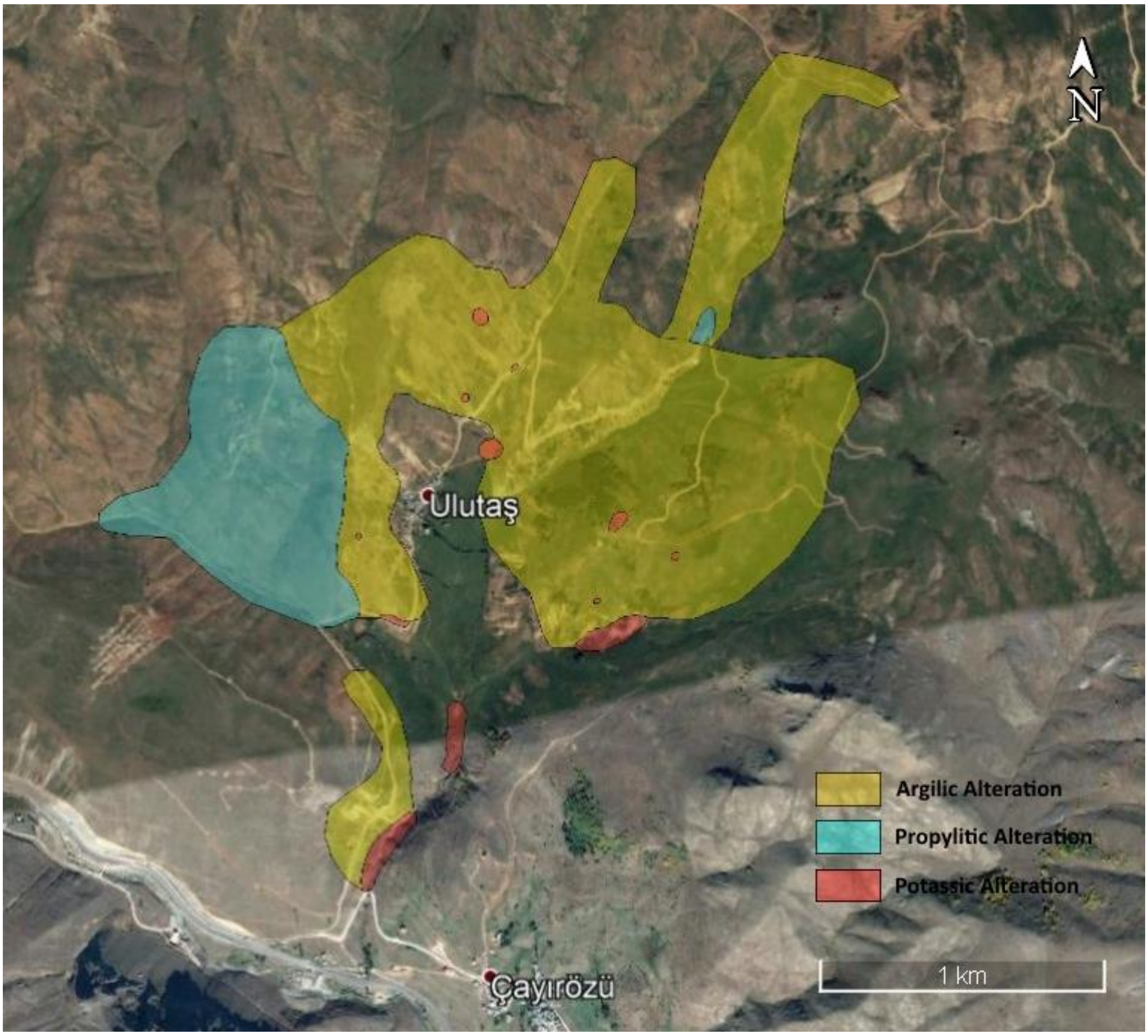

Figure 23. Alteration map of the Ulutaş mineralized field (from Demir Export A.Ş).

Potassic alteration in the Ulutaş deposit occurs in the quartz monzonite and is characterized by the development of secondary biotite, K-feldspar, granular and vein quartz, with minor sericite and magnetite. *Phyllic alteration* occurs in the quartz monzonite and quartz porphyry intrusive breccia complex unit. The mineralogy and texture of the protoliths have been completely destroyed by the development of sericite, quartz and pyrite. It occurs in intrusive igneous rocks and metamorphic rocks. It is characterized by quartz vein and veinlets. *Argillic alteration* is characterized by partial to complete replacement of plagioclase grains by kaolinite and/or montmorillonite with lesser sericite and traces of chlorite, and by retention of the magmatic textures of the Ulutas stock. *Propylitic alteration* occurs at the contacts of the quartz monzonite with lower volcanic sequence and pre-Jurassic metamorphic rocks. It is characterized by the development of chlorite, epidote, calcite, and quartz. The propylitic alteration at the contact with metamorphic sequence is mostly dominated by chlorite, epidote, and calcite, whereas the alteration assemblage in the contact zones around volcanic rocks is chlorite, calcite, and quartz (Soylu, 1999).

There is skarn-mineral assemblage that consists of garnet, epidote, and pyroxene at contacts of quartz monzonite with marble lenses in metamorphic sequence.

The Ulutaş Cu–Mo prospect lies within the Ispir batholith based on drill-hole data, the total reserves were estimated at 73.6 Mt with a grade of 0.31% Cu and 0.022% Mo (Giles, 1973; Soylu, 1999).

Resource Statement of the Porphyry Cu-Mo Deposit

(According to MTA and UN, 1974)

Total Resource (Tonnage)	Cu (%)	Mo (%)
142.848.00	0,26	0,018

Also in the same report, high grade ore also recognized (1974):

Total Resource (Tonnage)	Cu (%)
13.000.000	0,4
7.270.000	0,54

According to MTA Underground Resource Inventory of the Turkey;

Total Resource (Tonnage)	Cu (%)	Mo (%)
73.600.00	0,31	0,022

Resource Statement of the Skarn-I Cu-Zn Deposit

All of these data obtained from the Erzurum-Ispir Skarn-I Cu-Zn Project Report (2015).

Ulutaş Skarn-1 Mineral Resource Estimate (**Copper Zone**) – 27th November 2015

Class	Cut-off Zn (%)	Tonnage (Mt)	Copper		Zinc		Silver	
			Grade (%)	Total metal (t)	Grade (%)	Total metal (t)	Grade (g/t)	Total metal (Moz)
Indicated	0,42	1,58	2,07	32.800	0,310	4.900	45,56	2,32
Inferred	0,42	0,9	1,39	12.500	0,48	4.300	33,44	0,96

Ulutaş Skarn-1 Mineral Resource Estimate (**Zinc Zone**) – 27th November 2015

Class	Cut-off Zn (%)	Tonnage (Mt)	Copper		Zinc		Silver	
			Grade (%)	Total metal (t)	Grade (%)	Total metal (t)	Grade (g/t)	Total metal (Moz)
Indicated	1,17	1,27	0,27	3.500	6,83	86.900	12,13	0,50
Inferred	1,17	1,75	0,23	4.000	5,75	100.400	11,43	0,64

Age

The Ulutaş mineralization is hosted within a highly sericitized quartz-porphyry that intruded into a 132 ± 0.60 Ma calc-alkaline porphyritic quartz monzonite.

REFERENCES

Altun, Y., 1977, Çayeli-Madenköy bakır-çinko (Cu-Zn) yatağının jeolojisi ve cevherleşmeye ilişkin sorunlar. M.T.A. Dergisi, 20, 31-46.

Çağatay, M.N., Boyle, D.R., 1980. Geology, geochemistry and hydrothermal alteration of the Madenköy massive sulphide deposit. Eastern Black Sea Region, Turkey. Proceedings of fifth IAGOD Symposium. Stuttgart, Germany 1, 653-677.

Çınar, S., Yazıcı, E.N., 1985. Trabzon-Maçka-Güzelyayla köyü bakır-molibden zuhuru ve civarına ait rapor. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 8025 (in Turkish, unpublished).

Delibaş, O., Moritz, R., Ulianov, A., Chiaradia, M., Göç, D., Revan, M.K., 2014. Timing and geochemical characteristics of magmatism associated with Porphyry-type mineralization in the eastern Pondites, Turkey: Implications for ore-formation within the Pontide paleo-magmatic arc. Bull. Shk. Gjeol. 1/2014, Spec. Issue. Proceedings of XX Congress of the CBGA, Tirana, Albania, 24-26 September, p.151-152.

Delibaş, O., Moritz, R., Ulianov, A., Chiaradia, M., Saraç, C., Revan, M.K., Göç, D., 2015. Cretaceous subduction-related magmatism and associated porphyry-type Cu-Mo prospects in the Eastern Pontides, Turkey: New constraints from geochronology and geochemistry. Lithos, 248-251, 119-137.

Er, M., Özdoğan, K., Tüysüz, N., 1992. Geology and Mineralization of Güzelyayla porphyry Cu-Mo occurrence, Trabzon, NE Turkey. Pre. International Symposium on the Geology of the Black Sea region, pp. 226-231.

Giles, D.L., 1973. Geology and mineralization of the Ulutaş copper-molybdenum deposits, eastern Anatolia, Turkey. United Nations Development Programme, Technical Report 6, 110p. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 5237 (unpublished).

Güner, S., Güç, A.R., 1990. Trabzon-Maçka-Güzelyayla yöresindeki porfiri tip Cu-Mo maden jeolojisi raporu. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 41770 (in Turkish, unpublished).

JICA, 1986. The Republic of Turkey Report on the cooperative mineral exploration of Gümüşhane Area, Phase III. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 8298 (in Turkish, unpublished).

MTA and UN, 1974. Ulutaş Bakır-Molibden sahasının jeolojisi ve cevherleşmesi. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 5309 (in Turkish, unpublished).

Nebioğlu, T.Y., 1983. Trabzon-Maçka-Güzelyayla köyü civarındaki porfiri tip Cu-Mo zuhurlarına ait ön rapor. General Directorate of Mineral Research and Exploration Report (MTA), Report No: 7817 (in Turkish, unpublished).

Pearson, V., 1997. The progress report on the geology of Çayeli Bakır Isletmeleri. Unpublished report to ÇBI. 20 p.

Revan, M.K., 2010. Determination of the typical properties of volcanogenic massive sulfide deposits in the eastern black sea region. Unpub. Ph.D. thesis, Hacettepe Univ., Ankara, 320 p. (in Turkish).

Revan, M.K., Göç D., 2016. The Upper Cretaceous volcanogenic massive sulfide (VMS) deposits of the Eastern Pontide orogenic belt (NE Turkey). Tethyan tectonics and metallogeny, SEG Post-GSA Conference Field Trip Guide Book, Sept. 29-Oct. 2, 2016.

Revan, M.K., Genç, Y., Maslennikov, V.V., Maslennikova, S.P., Large, R.R., Danyushevsky, L.V., 2014. Mineralogy and trace-element geochemistry of sulfide minerals in hydrothermal chimneys from the Upper-Cretaceous VMS deposits of the Eastern Pontide orogenic belt (NE Turkey). Ore Geol Reviews 63, 129-149.

Revan, M.K., Genç, Y., Maslennikov, V.V., Ünlü, T., Delibaş, O., Hamzaçebi, S., 2013. Original findings on the ore-bearing facies of volcanogenic massive sulphide deposits in the eastern Black Sea region (NE Turkey). Bull Miner Resour Expl Turkey147, 73-89.

Soylu, M., 1999. Modeling of Porphyry Copper Mineralization of the Eastern Pontides. Ph.D. thesis Middle East Technicl University (127 pp.).

Road Log to the Çayeli Mine

Departing from Trabzon, Eastern Black Sea Region

Distance (km)	
0	Road log begins at the city center hotel in Trabzon (see Fig. 24).
90	Road east to the coastal town of Çayeli. Upper Cretaceous and Eocene volcanic rocks (mainly andesites and basalts) are exposed along the coastline (elevation of 3 m).
96	Turn south at the town of Çayeli. Drive along the Büyükdere river to the village of Madenli. Along the road Eocene volcanic rocks and alluvial sediments are mainly exposed. Cross the river by a first bridge before you get to the village of Madenli. Drive along the bridge to the first stop location (elevation of 165 m).
102	Return to the town of Çayeli. Turn to the west at the Çayeli.
172	Drive along the coastline to the city of Trabzon.

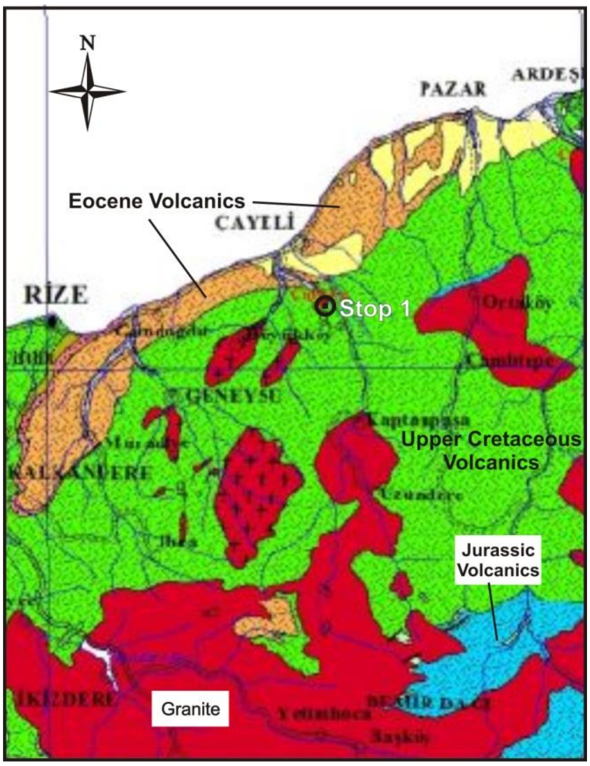

Figure 24. Geologic map of Rize region. See stop 1 on the map for the Çayeli mine.

Road Log to the Güzelyayla Porphyry Cu-Mo mineralization and Mastra Au-Ag Mine Departing from Trabzon, Eastern Black Sea Region

Distance (km)	
0	Road log begins at the city center hotel in Trabzon (see Fig. 25).
50	Road south to the mountainous town of Maçka. Upper Cretaceous and Eocene volcanic rocks (mainly andesites and basalts) are exposed along the roadside. Turn to the east at the town of Maçka.
55	Drive along the road about 5 km to the Güzelyayla prospect located near the small village of Güzelyayla (elevation of 1750 m).
60	Return to the town of Maçka. Turn to the south at the town of Maçka
113	Drive along the road to the İkisi county, Gümüşhane.
118	Drive along the road about 5 km to the Mastra mine located near the small town of Mastra.
231	Return to the city of Trabzon.

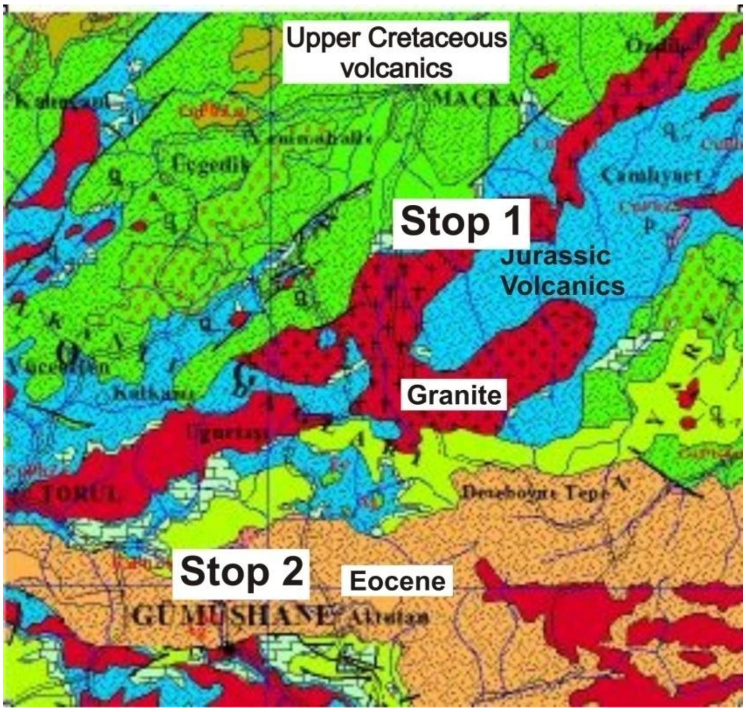

Figure 25. Geologic map of Trabzon and Gümüşhane region. See stops 1 and 2 on the map for Güzelyayla and Mastra, respectively.

Road Log to the Ulutaş (İspir-Erzurum) Mine

Departing from Trabzon, Eastern Black Sea Region

Distance (km)	
0	Road log begins at the city center hotel in Trabzon (see Fig. 26).
65	Road east to the coastal town of İyidere, Rize. Upper Cretaceous and Eocene volcanic rocks (mainly andesites and basalts) are exposed along the coastline (elevation of 3 m).
102	Turn south at the town of İyidere county. Drive along the paved road to the İkizdere County, Rize. Upper Cretaceous and granitic rocks are mainly exposed along the roadside.
154	Drive to the small village of Ulutaş village in İspir County. Along the road, Upper Cretaceous-Eocene volcanic and granitic rocks are mainly exposed.
308	Return to the city of Trabzon.

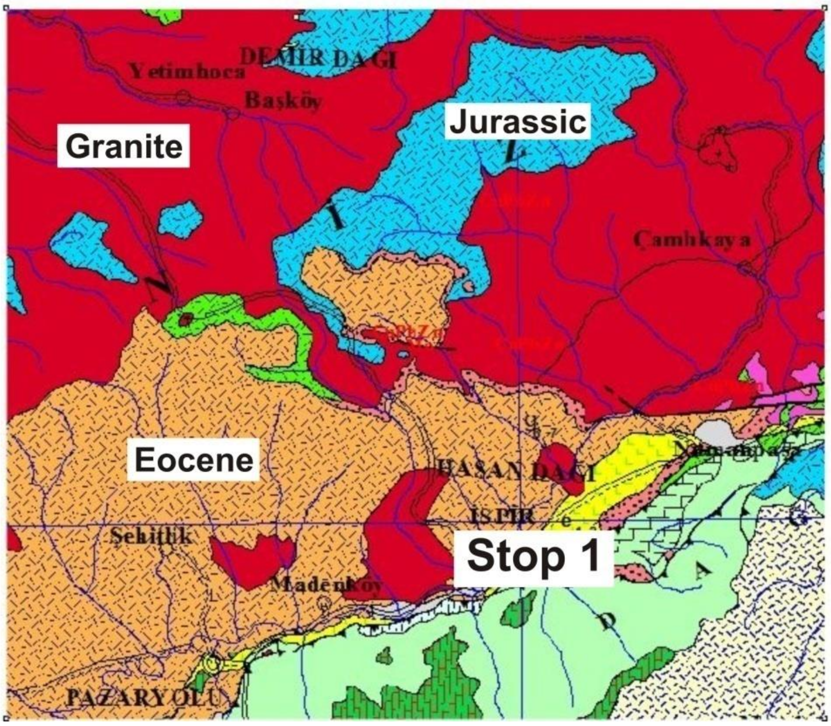

Figure 26. Geologic map of Ispir region. See stop 1 on the map for the Ulutaş deposit.

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MADENCİLİK VE TİCARET A.Ş.

TRABZON TİCARET VE SANAYİ ODASI
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