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Geophysical Surveyof Copper Mineralization In Central Pontides, Turkey

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ABSTRACT: *This study includes geophysical survey performed on the field and at office for copper mineralizationon study area within borders of Hanönü (Kastamonu) and Boyabat (Sinop) provinces.Geological units of the area are considered to evaluate VES measurements, and geoelectric structure is correlated with these units. In this way, geological structure is attempted to indirectly identify. Not always geological structure is literally compatible with geoelectric structure. Data from performed studies does not directly express mineralization. However, this method is based on correlation of high resistive and low resistive media with geological structure to identify mineralization. With curves from VES measurements performed on study area and evaluation results, 17 profiles compatible with tectonic orientation and structures were prepared by RockWorks program to better interpret geoelectric structure. In addition, resistivity level maps were prepared to see horizontal and vertical changes in resistivity values of layer. Geophysical measurements of 6 profiles were performed using geoelectric tomography device to determine continuity of gossans in lateral and vertical orientations on study area.Based on geophysical measurements performed, mineralization appears to be present in shallow levels to the south of study area and in deeper levels to the north. Geophysical measurements and interpretation are consistent with geological data of the site. As a result of geological and geophysical surveys, it is considered appropriate to perform core drilling on relevant study area in accordance with exploration priority order. The study area are divided into 6 zones on this zone map. It is proposed to start drilling from Zone 1 to Zone 6.*

KEYWORDS : *Hanönü-Boyabat mine sites, Central Pontides, Copper mineralization, Vertical electrical sounding, Resistivity imaging, Gravity, Aeromagnetic*

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I. INTRODUCTION

The study area are located within Kastamonu and Sinop in the Central Black Sea region and Sinop sheet Nos.E33-d1, E33-d4, E33-d3 and F33-a2 and map scale of 1/25 000 (Fig. 1). A large number of rural settlements exist in the study area. The site includes rough terrains and forestlands.

The area is located in the northeast to Ilgaz Mountains. The major elevation of the area is Elekdağ. The study area are contained in the Central Black Sea region and substantially represent geographical, climatic and demographical characteristics of the area. Topographically, the area appears highly rough, therefore settlements are scattered across the area.To describe the morphotectonic structure of study area, morphological, relief and three-dimensional geomorphological maps of 1/25.000 scale were prepared for a wide area between Taşköprü-Hanönü-Gökçeağaçsakız-Koçak-İmamlı-Akyürük-Kurusaray.

Gökırmak runs forming a wide convex arch to the north of study area. A large part of study area are located within a rough terrain to the south of Gökırmak, and a small part of them is located to the north of Gökırmak. In general, there are crest extending NE-SW and deep valleys in N-S direction in the study area. In addition, there are streams in the NE-SW direction.

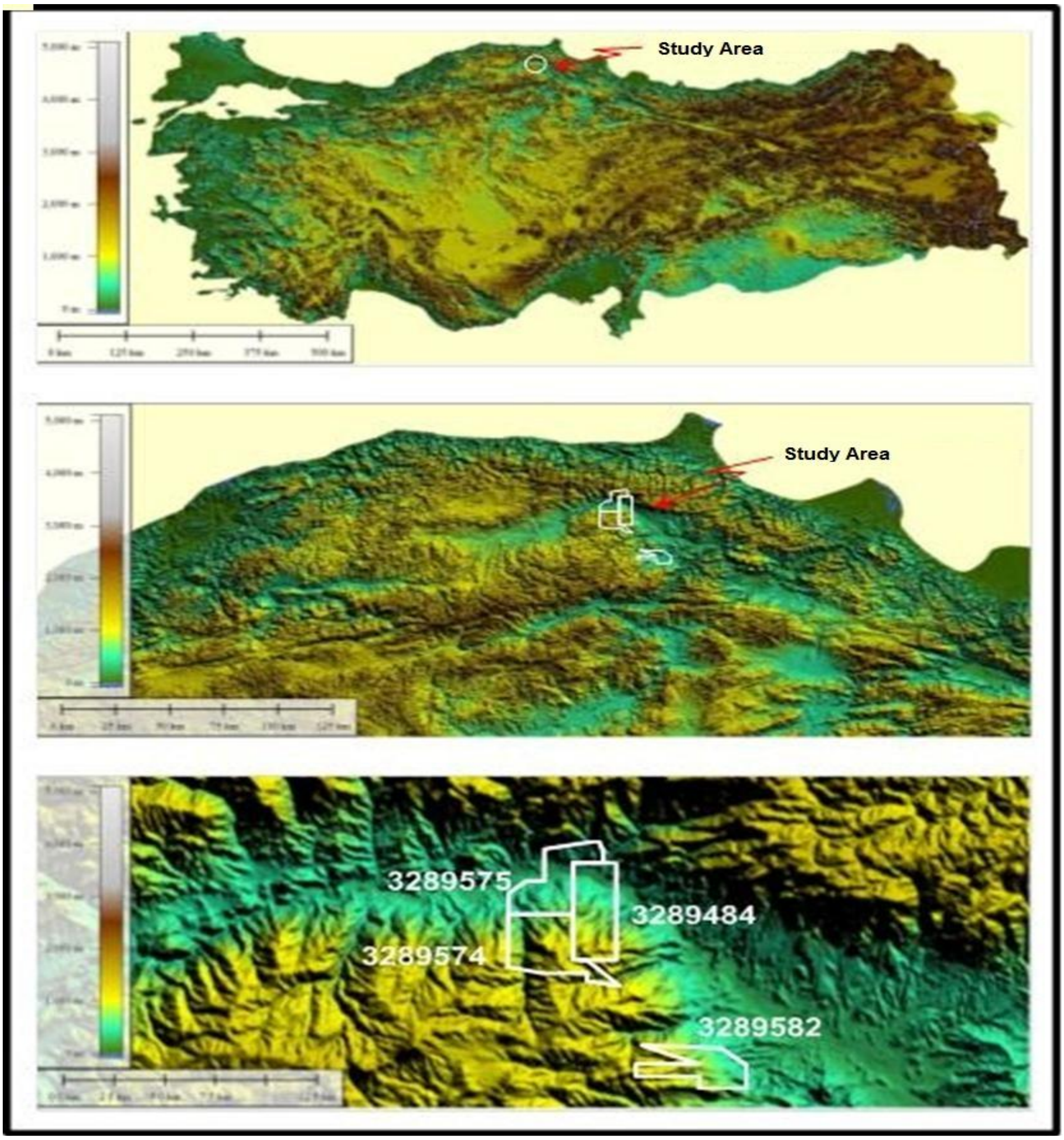


Fig. 1. Site location map of the area involving study area

II. GEOLOGY OF STUDY AREA

Rocks within the study area are divided into three groups (bottom-to-top): Mafic and Ultramafic Rocks Pre-Liassic period (Elekdağ Meta-ophiolite) and Domuzdağ Metamorphic complex, Liassic Akgöl formation and sediment units after Liassic period. Furthermore, there are volcanic rocks such as gabbro and diorite dykes intruded into some of these rocks.To the south of study area, Elekdağ Meta-ophiolite and Domuzdağ complex Pre-Liassic aged and volcanic-subvolcanic units referred to as Akgöl formation and metamorphosed in green schist fasies, and to the south sediment units after Liassic age are surfaced (Figs. 2 and 5; Özdemir, 2015).

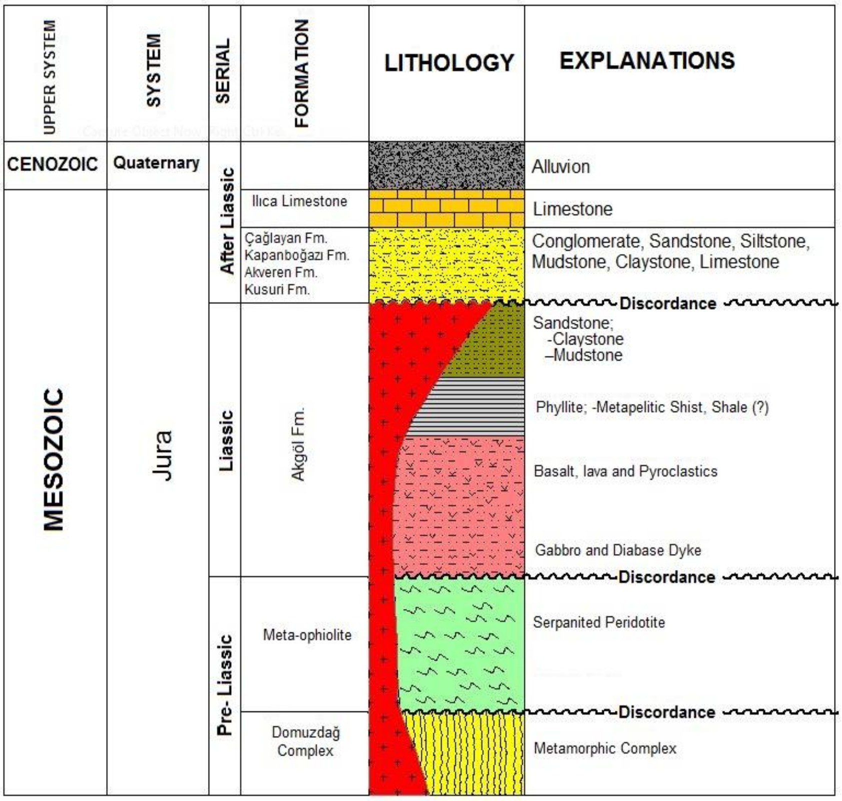


Fig. 2. Stratigraphic vertical section of study area (No scale) (Özdemir, 2015)

Pre-Liassic Units;

To the south of study area, Elekdağ Meta-ophiolite of 35 km in length and 3-4 km in width is located in SW-NE orientationwith no uniform stratigraphic position, tectonic contact with each other, mafic in lenses and intermittent slices (massive metagabbro,layered gabbro lenses, and isolated diabase-microgabbro-pegmatiticgabbro dykes cutting the entire sequence) and ultramafic (serpentinite, serpentinitized belt peridotite, serpentinitized massive peridotites). Upper section ofElekdağMeta-ophiolite (plate dykes, mafic lavas, and pelagic sediment) is not preserved. The lower contact of Elekdağ Meta-ophiolite has blue schist of Domuzdağı Metamorphic complex associated with tectonic (Özdemir, 2015).

Units of Liassic Age (Akgöl Formation);

Akgöl Formation, first defined by Yılmaz and Tüysüz (1984), is composed of sediment-based phyllite, schist and metadiabase primarily associated with them and subsequently defined by Sütçü et al., 1994) as a formation that mostly has alkaline metalava and metatuff, and less schist and phyllite in parts. The unit is composed of metalava with abundant garnets and glaucophane, metapelitic sediment and metadetritic sediment. Akgöl Formation, located in the area between Çangaldağ and Elekdağ and defined by Ustaömer and Robertson (1999) as Bayam melange, was referred to as Gökbelen Formation by Eren (1979).

Akgöl Formation tectonically obducts Elekdağ Meta-ophiolite and is inharmoniously obducted by the Upper Cretaceous Çağlayan Formation. The sequence is primarily made of alkaline metalava and metatufss at the bottom and schist and phyllite at the upper parts. Phyllites among metamorphics where the effect of foliation and folding can be seen are greenish, grey, blackish, fine grained soft-crumbly crops in the topography. Foliation is well established and nacreous due to mica minerals. The schist is yellow, grey and blackish and very well foliated (Özdemir, 2015).

The schist seen at the lower of phyllite indicates the increased severity of metamorphism. The schist is firmer and relatively coarse grained. The main components of schist are quartz and mica, and garnets and glaucophane minerals are visible. Petrographically, lithology of chlorite-epidote schist, chloric-mica schist quartz mica-schist is identified (Erol, 2007).

Metabasites is a type of rocks that contain dark color minerals such as chlorite, epidote and amphibole as a main mineral in its green tons. In addition to schist texture partly folded, there are sections where no foliation exists. Another characteristic ofAkgöl formation is that the upper parts of the sequence has marble lenses. Marble lenses are white-grey in color. The unit was defined by Sütçü et al (1994) as the member of

Demircimüezzin marble in 30-40m thick, and correlated by Yılmaz and Tüysüz (1984) as a section of Akgöl Formation. The marble is hard and very faulted and the bedding is not established.

There is no evidence to date Akgöl Formation, however the age of the formation is considered Triassic-Liassic because it is cut by Dogger granites, stated to be 170 million years old, transitional with Permian Elekdağ Meta-ophiolite at the bottom, and because it is inharmoniously covered by Malm-Lower Cretaceous İnaltı and Çağlayan formations (Sütçü et al., 1994). In the study by Yılmaz and Tüysüz (1988), it was considered Pre-Liassicperiod. Ustaömer and Robertson (1999) suggest that this formation is not well established. They consider the unit to belong to Paleo-Tethys and provide and age Pre-Jura.

Akgöl Formation has a reverse fault over mafic and ultramafic rocks (Elekdağ Meta-ophiolite). At lower levels, basaltic volcanic rocks are massive and pillow lava upward and turns into breccia character at upper levels. To the south of study area, there are peristerite phyllite-schist with the low effect of metamorphism, to the north of study areathere are black shale (claystone), siltstone, sandstone, and rarely limestone and dolomitic limestone at upper sections. The lower section of this sequence is made of very fine grained black shale and upper section is primarily made of sandstone, considered to be regressive because the grains become larger to the upper section.Basaltic volcanic rocks are particular important as they contain ore deposits, and display massive character at lower levels and pillow lava character to upper levels, the top level has a breccia character. It is partly cut by dykes. Breccia basalts have argely undergone hydrothermal alteration. Massive basalts are green, blackish green, very fine grained and has a subophitic texture. The prevailing mineral is plagioclase and between plagioclase is clinopyroxene. There are secondary quartz formations along the fractures in addition to quartz mineral. Plagioclase has albitization, sericitization and little argillisation. In addition, rock is commonly split and has little amount of epidote, prehnite and opaque minerals. Pillow lavas, indicative of undersea eruption, are greenish gray, greenish black in color. Their long axis ranges from 3-5 cm 2-3 m. The longer axis of pillows can be several fold of shorter axis in length. Pillow lavas are mainly composed of plagioclase (Labrador) and clinopyroxene. Plagioclases are very fine grained, prismatic, and partly have lathes and micro-phenocrystal, and plagioclase microlites have albitization and sericitization. Partial sericitization and chloritization are also observed. Chlorite and carbonate are filled between plagioclases. The rock contains leucoxene. The top levels have breccia basalts. Pillow lavas are transitioned laterally and vertically. The greenish grey breccia structure includes fractures, calcite, chlorite, albite, chert, gypsum, iron oxide and pyrite filled(Özdemir, 2015).

Units after Liassic Age;

In the study area, units after Liassicperiod consist of Çağlayan Formation made of sedimentary units such as limestone, conglomerate, sandstone, siltstone, claystone, and mud stone; Kapanboğazı Formation; Akveren Formation; Kusuri Formation; Ilıca limestone, and alluvial deposits(Özdemir, 2015).

III. GEOPHYSICAL DATA, MEASUREMENTS AND INTERPRETATION

Physical properties of geological units in mine sites differ by their where they are located. Using this fact, data supporting information on the depth, size and shape of mines can be obtained by geophysical methods. From the perspective of exploration effectiveness, geophysics is obviously important in exploration activities. The primary condition to define any mine is to conduct a geological survey on the site. Surface geological surveys cannot fully define a mineralization. Therefore, it is necessary to explore the mine site using geophysical methods in line with initial geological studies.

A geophysical survey is to examine invisible and unknown units of the earth using physical principles of the nature in order to fully define it based on physical properties. In this sense, it is necessary to examine the mine site, which is a stationary environment, using differences in its physical properties. So, a mine site, which has been explored by means of geophysical measurements, can be examined based on various physical parameters and a model can be created in accord with the environment. Currently, rapid development of technologies, particularly advancements in computer technologies, ensure to have more realistic and visual results from such studies. Despite this, the most important fact is still engineering interpretation.

Evaluation of geophysical data with geological data is absolutely necessary for selecting a drilling location in light of geophysical measurements as well as for drilling to achieve favorable results for the mine. The electrical conductivity of metallic mines is generally higher than that of rocks in the mine location. In addition, specific gravity or magnetization sensitivity coefficient of certain minerals is sometimes low and sometimes high depending on the rock that contains such mineral. Thus, to interpret the local gravity of examination site, aerial magnetic maps and results of resistivity measurements, they were correlated with geological data.

3.1. Aerial magnetic and regional gravity data

In general, dark colors on the regional gravity color contour map represent the youngest and low-density rocks, and light colors represent high-density old rocks. Methods used to interpret aerial magnetic data and to model geological structure causing this anomaly include reducing magnetic data to pole level, identifying approximate borders of geological structure causing anomaly, and 2B geological modelling of aerial magnetic data.Aerial magnetic color contour maps clearly differentiate basic, ultrabasic,ophiolitic and volcanic rocks from other rocks.Fig. 3 presents the residual gravity map for study area. Low-density (areas giving low gravity value) rocks (Pre-Liassic units) are represented by dark blue, light blue and green color tones, and high-density rocks (basalts of Akgöl Formation, Elekdağ Meta-ophiolites, Domuzdağ complex) are represented by yellow and red color tones. Almost half of the study area are located where low-density rocks exist.

Fig. 4 shows the aerial magnetic map for study area. On this map, locations of rocks with no magnetism (fully sedimentary rocks) and rocks with low magnetism are represented by dark blue, light blue and green color tones. Other areas represent rocks containing minerals with magnetism such as magnetite, ilmenite, pyrrhotine, etc. (especially basalts, etc.). Such rocks are represented by yellow, red and white color tones.

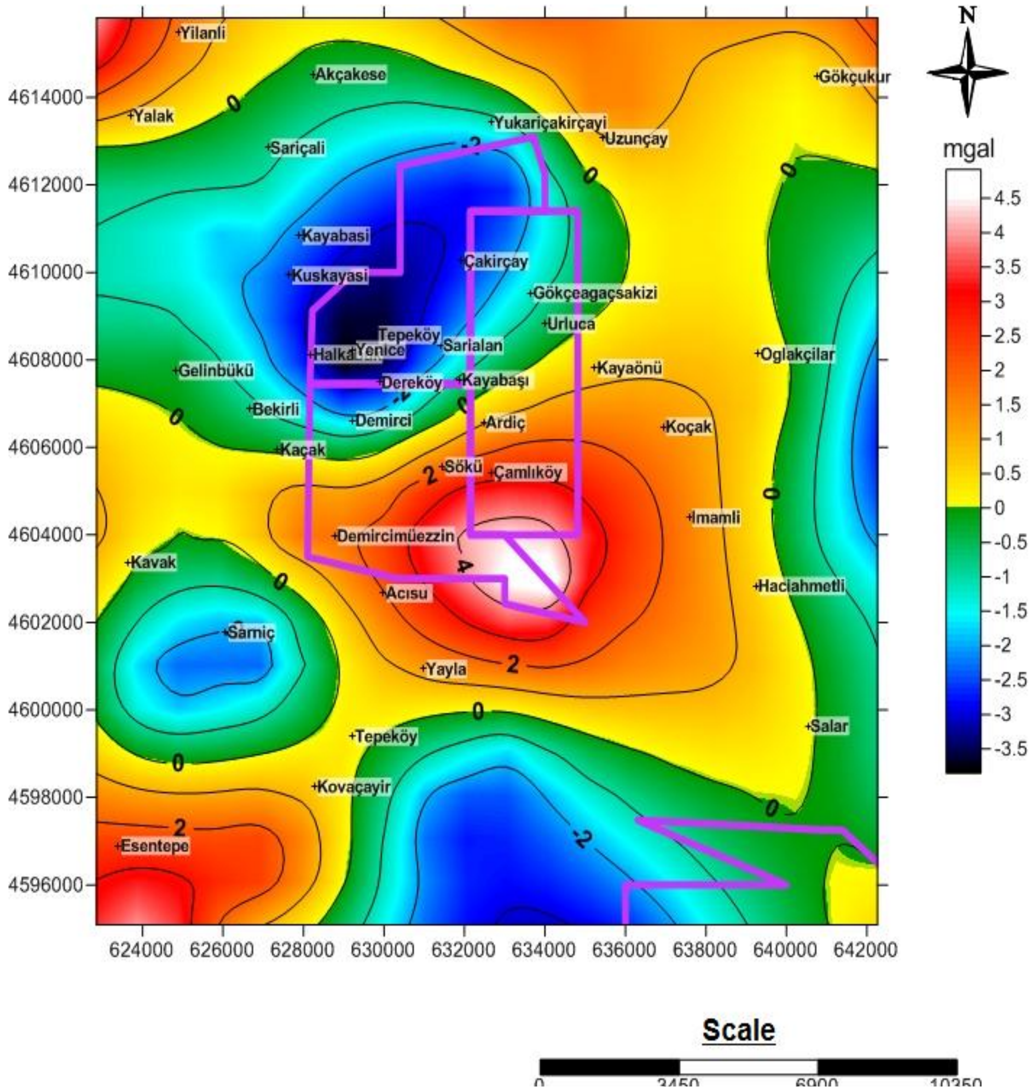


Fig. 3. Color contour map for residual gravity anomalies of study area and surrounding

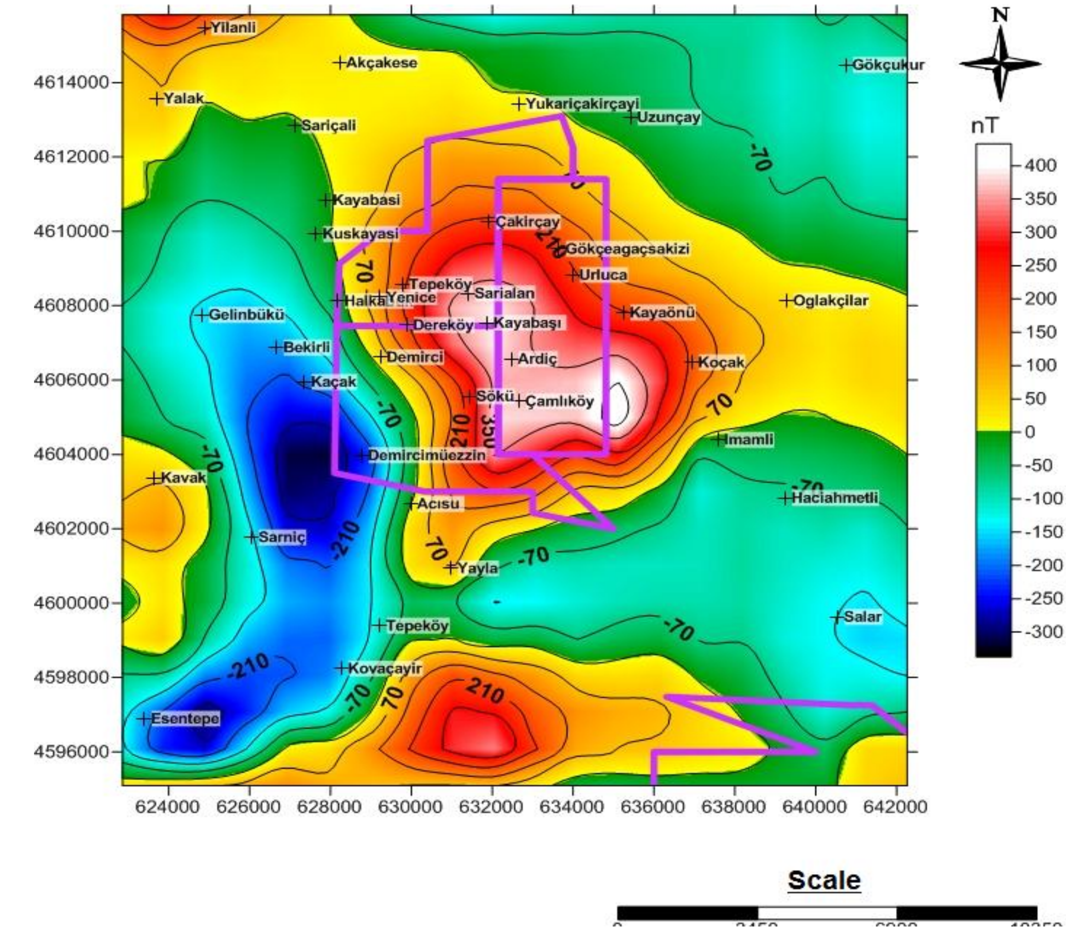


Fig. 4. Color contour map for residual aerial magnetic anomalies of study area and surrounding

3.2. Vertical electrical sounding (VES)measurements and interpretation

The resistivity method is based on using differences in resistance of the environment. Method is based on measuring potential field differences created on the ground by electric current delivered to the earth at any two points, and examining according to Ohm law. The resistivity method can be performed using Schlumberger or Wenner electrode array to determine the dimensions of mineralization and associate them with geological structures. Two dimensional electric structure sections are 3D assessed on the basis of the site and all measurements are individually evaluated in order to interpret accurate resistivity of the site.

As is known, physical properties of rocks forming the earth’s crust vary by their location and geological formation. Electrical resistivity characteristics of rocks also vary in a wide range. Definition of a rock based on resistivity value differs for each mine site. It is necessary to interpret resistivity curve patterns considering this basic criterion. Resistivity values and curve patterns derived from these values are not only affected by physical properties of the rock in a mine site. General tectonic structure of the site influences resistivity values with respect to expansion orientation. In general, the rugged structure of mine sites prevents to take measurements in the desired expansion orientation. In this case, it should be known well how to make evaluations and how to use resistivity methods.

Some part of study area do not have an appropriate topography for geophysical applications. Some sections of areas where geophysical measurements were performed are highly steep and rugged. It was not possible to take VES measurements in the required depth on steep areas. However, pushing the limits 116 VES measurements were performed on areas suitable for deep investigation and a geological structure of maximum 412 m in deep was studied. Fig. 5 showposition of the VES measureson the study area and geological map.

Geoelectrical measurements were performed using a resistivity device and equipment of 3 amp. The power supply was a gasoline generator generating an alternating current of 220 Volt and 5.5 Kwa. The sensitivity of receiver was 0.01 mV/scale.In the system, the alternating current (AC) from power supply of generator group is first adjusted by variac then transported on a rectifier to convert into direct current (DC). This direct current (DC) is delivered to subsurface. DC output voltage is max. 1000 volt and the current delivered to subsurface is max. 2 amp.The current electrodes (C1, C2) are long bars made of stainless steel. Potential electrodes (P1, P2) non-polarized copper sulfate electrodes. Cables are fully copper and well insulated. Because the objective if geoelectrical survey of study area was to examine variance of geological units into deep, Schlumberger electrode array was used for VES measurements.

Geological units of the area are considered to evaluate VES measurements, and geoelectric structure is correlated with these units. In this way, geological structure is attempted to indirectly identify. Not always geological structure is literally compatible with geoelectric structure. Data from performed studies does not directly express mineralization. However, this method is based on correlation of high resistive and low resistive media with geological structure to identify mineralization.

With curves from VES measurements performed on study area and evaluation results, 17 profiles compatible with tectonic orientation and structures were prepared by RockWorks program to better interpret geoelectric structure. In addition, resistivity level maps were prepared to see horizontal and vertical changes in resistivity values of layer.

Akgöl Formation where mineralization is expected in study area is overthrusted on mafic and ultramafic rocks (Elekdağ meta-ophiolite) by a reverse fault. In lower levels, massive basaltic rocks are characterized by upward pillow lava and breccia at top levels. To the south of license area is pelitic phyllite-schist with effect of low metamorphism, and to the north of license area is black shale (claystone), siltstone, sandstone, and rarely limestone and dolomitic limestone at upper levels. Lower level of this sequence has very fine grain black shale and upper level mainly has sandstone, and as grains become larger to the upper level, it appears to have regressive character.

Basaltic volcanic rocks, particularly important for containing ore deposit, are massive at lower levels, pillow lava to upper level, and brecciated at the top. It is partly cut by dykes. Brecciated basalts are largely altered hydrothermally. In particular, sedimentary cap rocks and hydrothermally altered brecciated rocks located at the top of basaltic series should give low resistivity values. Resistivity values will be much lower if these levels contain an ore. Therefore, the maximum resistivity value is 110 ohm.m on geophysical cross-sections and level maps in order to identify these much lower resistivity levels on study area.

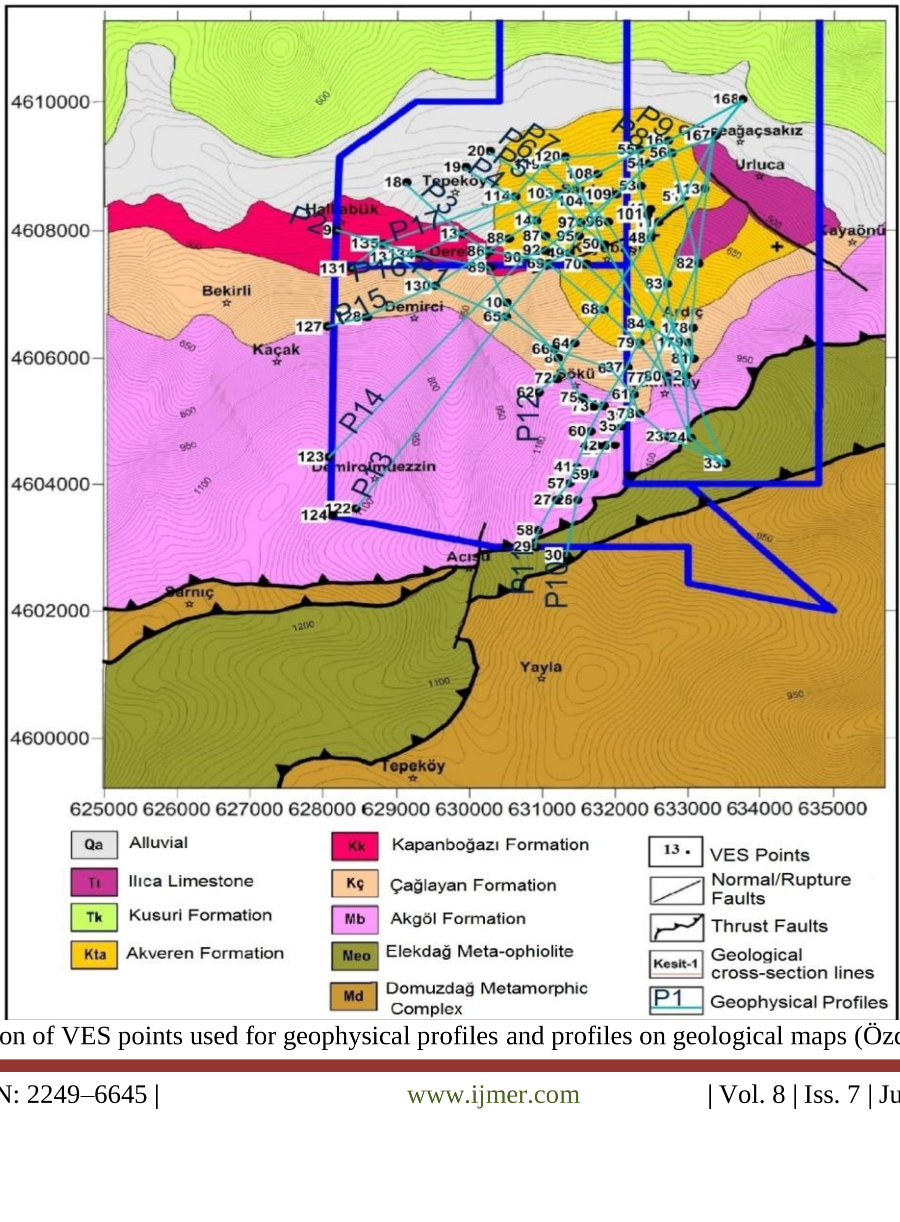


Fig. 5. Position of VES points used for geophysical profiles and profiles on geological maps (Özdemir, 2015)

Level maps are particularly important to present association of ore spread with the depth for exploration activities. Harmonization of level maps means that errors are minimized in identifying location of drilling. Decrease in resistivity within the same unit is due to mineralization. Resistivity distribution maps of 18 levels were prepared for the license area because resistivity distribution varies by depth. Resistivity level maps represent distribution of resistivity values of geoelectric layers, which are obtained by evaluation of VES measurements in depths of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 275, 300 m. Distribution and number of measurement points is inadequate to determine in detail the resistivity structure of all study area. However, measurements were performed in orientation and locations that could define general structure of relevant area and study area are defined by correlation of these measurements.

Metallic minerals has a character to reduce resistivity of their own location due to its mineral nature. Decrease in resistivity on level maps is interpreted as reflection of influence of faulting and possible levels with ore on resistivity values. Spread of these levels in depths of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 275 and 300 m on resistivity level maps was observed to monitor possible mineralization in lateral and vertical orientations on study area.Therefore, the maximum resistivity value is 110 ohm.m on geophysical cross-sections and level maps in order to identify these much lower resistivity levels on study area.

It is now possible to transfer raw resistivity values measured on the relevant field to electronic media and make a 3D model. In this procedure, raw resistivity values and coordinates measured on the field are inserted in the programs as data so that a three dimensional model of data is achieved as a solid model using "Grid Model" and geostatistical methods. Fig. 6 shows 3D resistivity model for study area and Fig. 7 shows fence diagrams. To interpret possible mineralization in study area, 3D resistivity and stratigraphy models (solid model and fence diagram) are consistent with tectonic orientation.

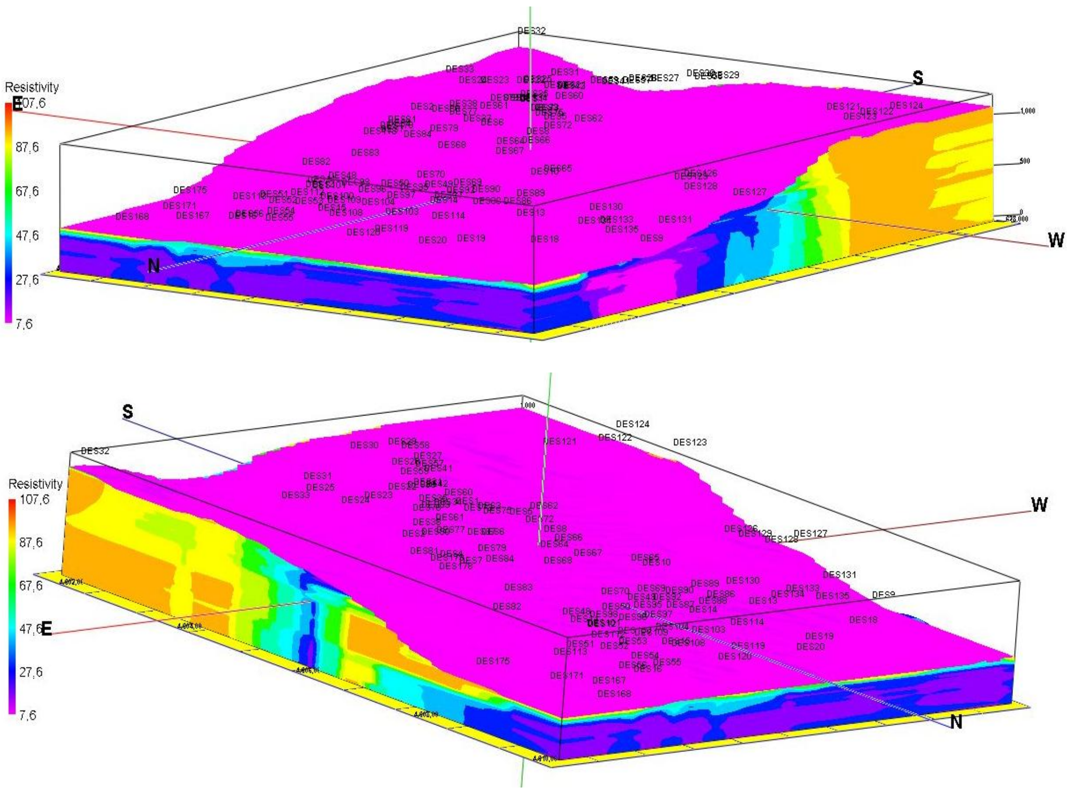


Fig. 6. 3D model of resistivity measurements on study area

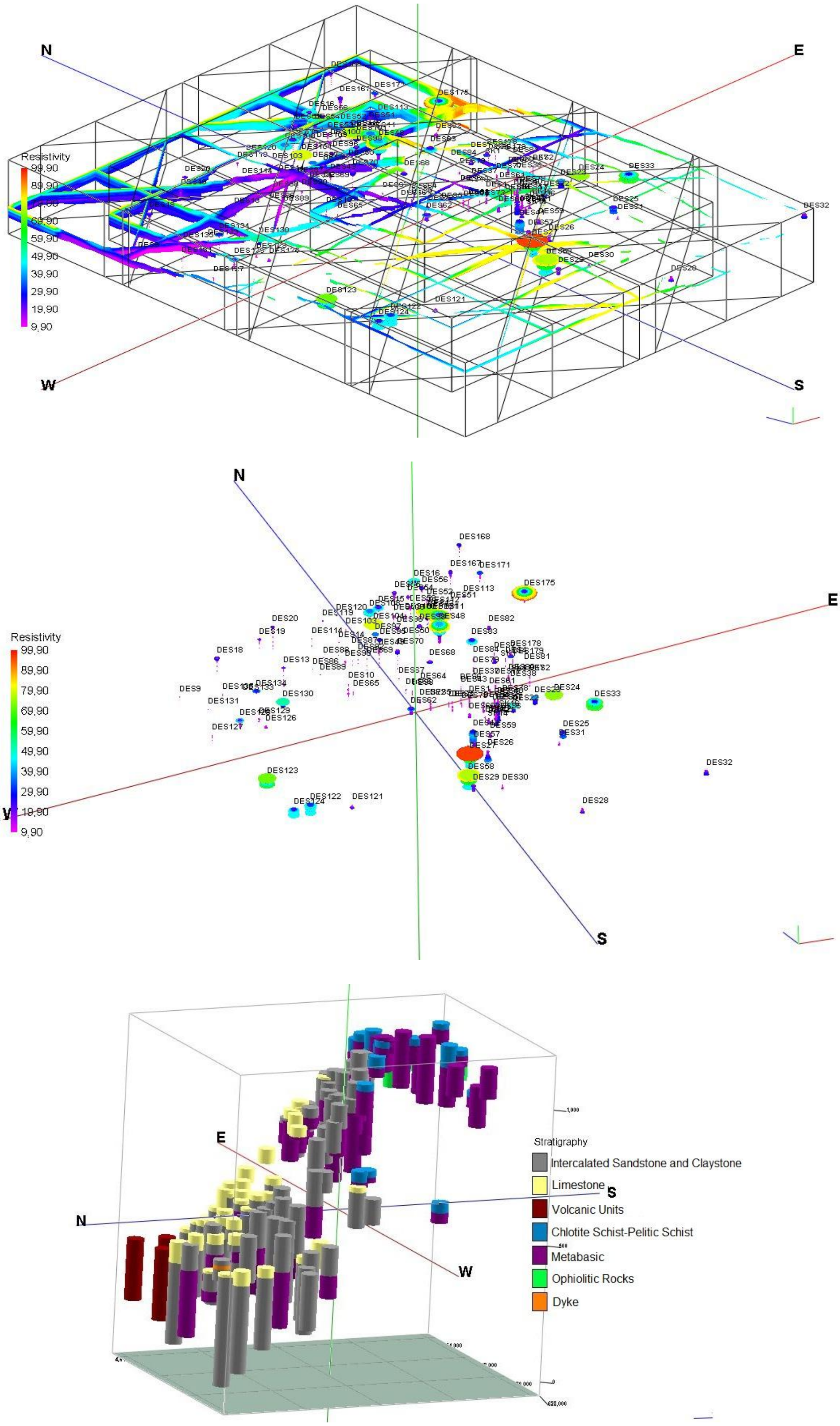


Fig. 7. Fence diagrams of resistivity measurements on study area

3.3. Geoelectric tomographymeasurements and interpretation

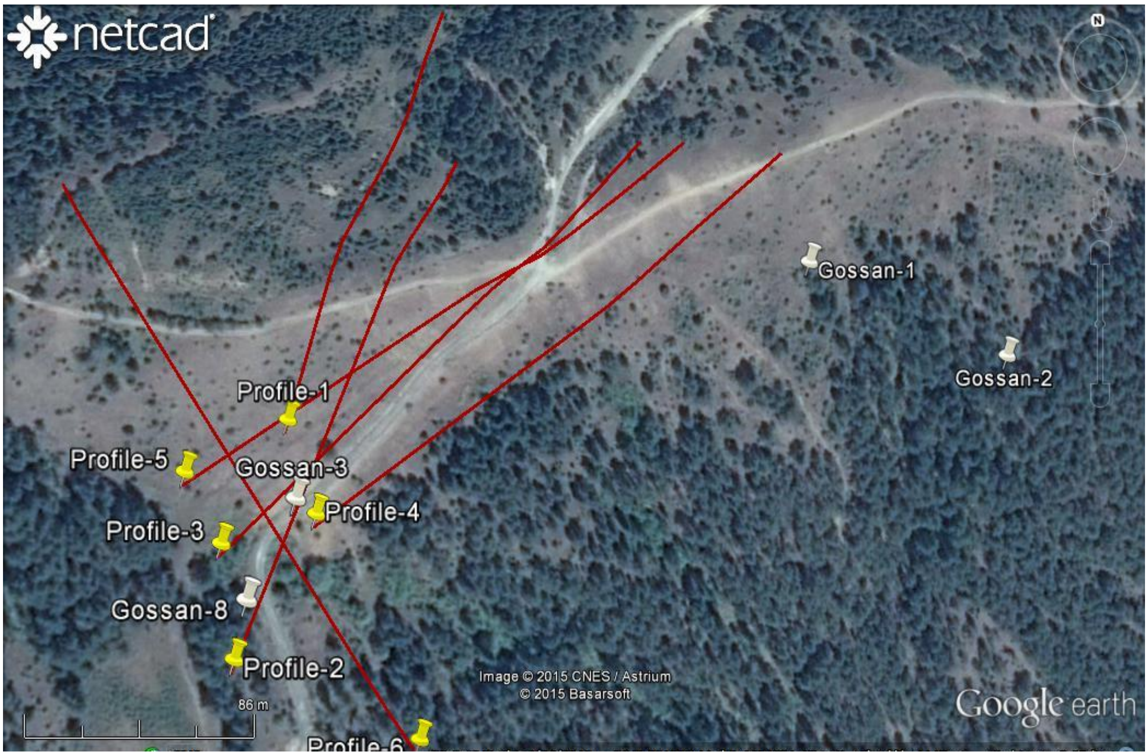
Recent evolution of electronic and computer components has allowed to develop multi-electrode resistivity method (also referred to as electric resistivity imaging) that can be automatically changed and allow taking profile measurements along orientation. Such measured apparent resistivity pseudo-section data is interpreted a reverse analysis algorithm to achieve resistivity-depth sections that indicate possible indication locations along the profile.

The first study on multi-electrode resistivity measurement method was performed in 1988. This method has been comprehensively debated and used over the last 4-5 years. Implementation of this method appears to become common in Turkey as well.The two dimensional electrical resistivity method is aimed at achieving real model parameters of subsurface using apparent resistivity values measured on the land. The technique was first referred to as “Resistivity Imaging” in 1987, which was used to create a two dimensional resistivity section of work area surrounded by a certain number of electrodes. Use of this term was well established by obtaining results having similar resolution to X-ray imaging through resistivity method, and it was noticed that achieved resolution gave better and more useful results compared to traditional resistivity method, therefore this method is preferred to other geophysical methods in an increasing trend. Subsequently, resistivity method has been widely used to resolve many geological problems as it can provide two or three dimensional resistivity distribution of subsurface almost as real using advanced data collection and evaluation stages.

Recently, 2D resistivity imaging methods are used to map areas with complex subsurface geology where traditional resistivity drilling or profile investigations are inadequate. Multi-electrode resistivity method involves electrodes penetrated with equal intervals (e.g., 5 m) along a line as well as multiple cables (containing multiple wires) that connect these electrodes. The number of electrodes can vary by purpose and scope of the study. In general, systems with 28, 56, 84 and 112 electrodes or 20, 30, 50, 60 electrodes are manufactured. The most expensive material of the system is cables. Electrodes are stainless steel electrodes used for previous systems. Resistivity measuring devices includes a changing and storing memory according to predefined measurement sequence of these electrodes (a file where current and voltage electrodes are numbered in a defined system). With various combinations of current (A,B) andvoltage (M,N) electrodes, a complex profile section is achieved through the greatest exploration depth subject to total length of the cable. Various electrode arrays (Wenner-Schlumberger, Dipole-Dipole etc.) are available.

Measuring device is computer controlled in multi-electrode method. All electrodes are connected to measuring device by one cable and a sequential measurement is performed for required electrode array. In the end, measurement and direct profile measure are obtained at certain stations (points) for certain AB/2 values. Today, measurement is quick and easy through multi-electrode measuring devices. Therefore, profile measurement has become a common technique. Data derived from this method can provide information on subsurface resistivity structure both in vertical and horizontal orientation. This method involves advantages of profile measurement methods. Data derived from profile measuring technique provide information on 2D resistivity structure of subsurface both in lateral and vertical orientation. A pseudo-section can be drawn by apparent resistivity values measured with this method. A qualitative interpretation is possible using drawn data. For quantitative interpretation, it is necessary to perform 2D reverse analyses of pseudo-section.

Geophysical measurements of 6 profiles were performed using multi-electrode (60-electrode) Turkuaz-60 resistivity imaging device to determine continuity of gossans in lateral and vertical orientations on study area.The objective was to determine continuity of gossans in lateral and vertical orientations on study area but not to investigate general geological structures on the area. Fig. 8 shows position and coordinates of geoelectric tomography measurements performed on work areas on study area. After evaluating measurements, geoelectrical cross-sections of measurement profiles provided in Figs,9 to 14were prepared using EartImager2D software.Therefore, the maximum resistivity value is 3000 ohm.m on geoelectrical cross-sections in order to identify these much lower resistivity levels on study area.



Profile No	Coordinate	Start	End	Coordinate	Start	End
Profile-1	Y	631862	631797	Profile-4	Y	632046
	X	4604756	4604496		X	4604633
Profile-2	Y	631872	631778	Profle-5	Y	631997
	X	4604649	4604396		X	4604648
Profile-3	Y	631974	631771	Profile-6	Y	631696
	X	4604652	4604443		X	4604608

Fig. 8. Google Earth image and corrdinates of geoelectric tomography profiles

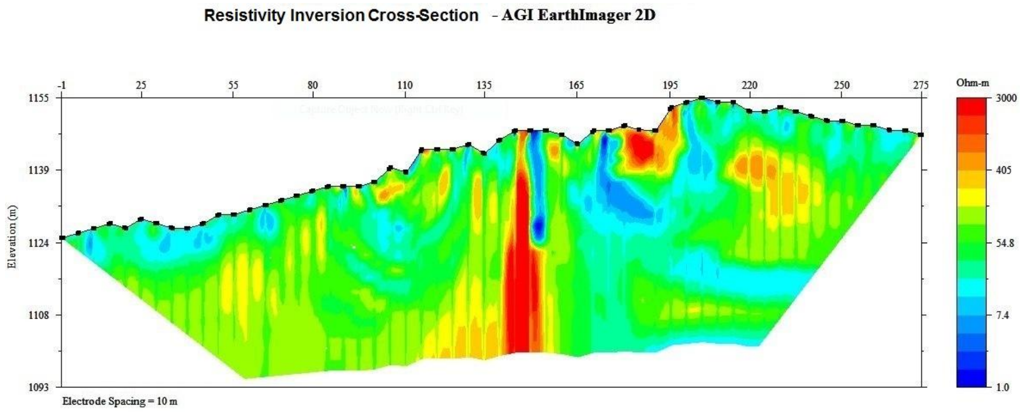


Fig. 9. Geoelectric cross-section from Profile-1 measurement

Profile-1 measurement is in SW-NE orientation. In geoelectric cross-section from Profile-1 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50ohm.m. In addition, angle of geological units appear around 90^0. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

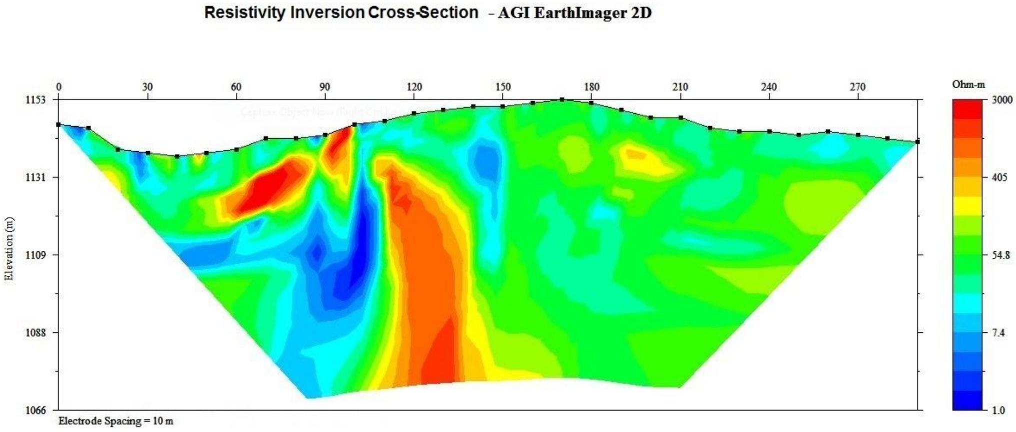


Fig. 10. Geoelectric cross-section from Profile-2 measurement

Profile-2 measurement is in SW-NE orientation. In geoelectric cross-section from Profile-2 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50 ohm.m. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

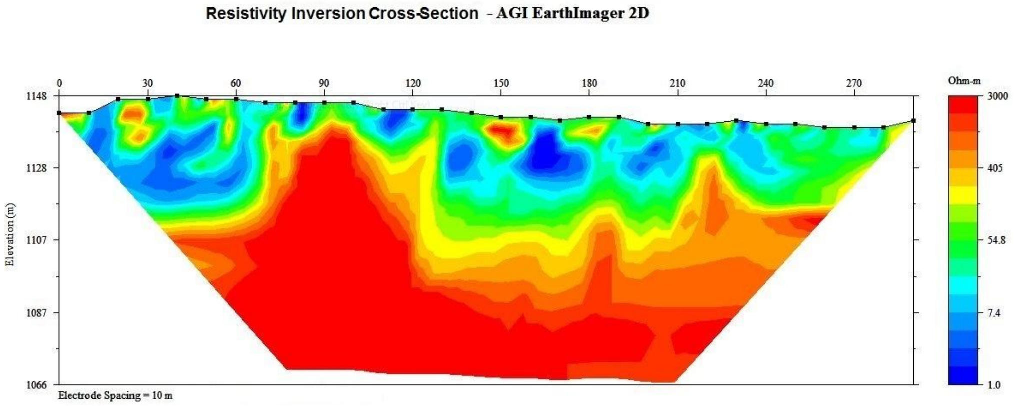


Fig. 11. Geoelectric cross-section from Profile-3 measurement

Profile-3 measurement is approximately in W-E orientation. In geoelectric cross-section from Profile-3 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50 ohm.m. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

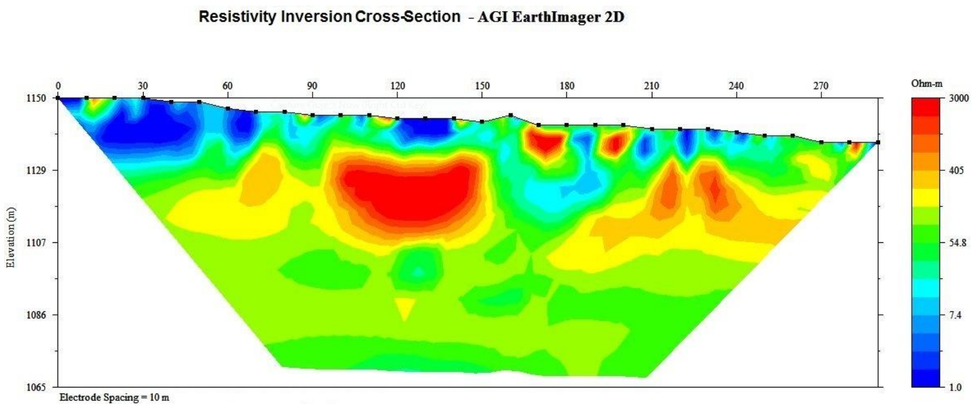


Fig. 12. Geoelectric cross-section from Profile-4 measurement

Profile-4 measurement is approximately in W-E orientation. In geoelectric cross-section from Profile-4 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50 ohm.m. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

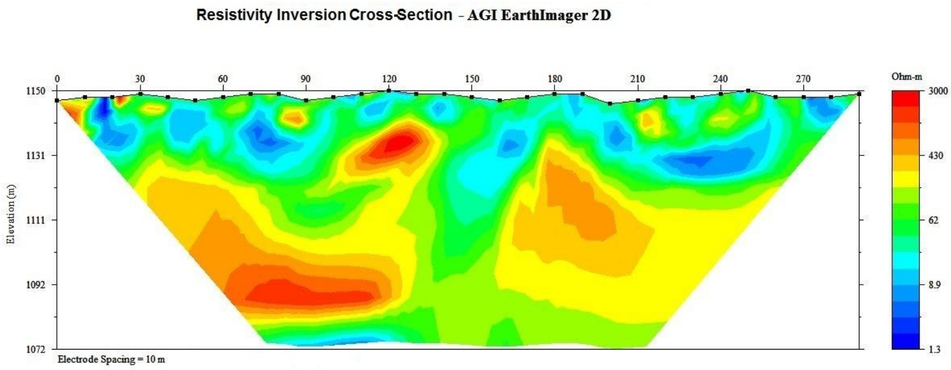


Fig. 13. Geoelectric cross-section from Profile-5 measurement

Profile-5 measurement is approximately in W-E orientation. In geoelectric cross-section from Profile-5 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50 ohm.m. There is fracturing due to local tectonic activity in a level of 130-150 m of geoelectric cross-section. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

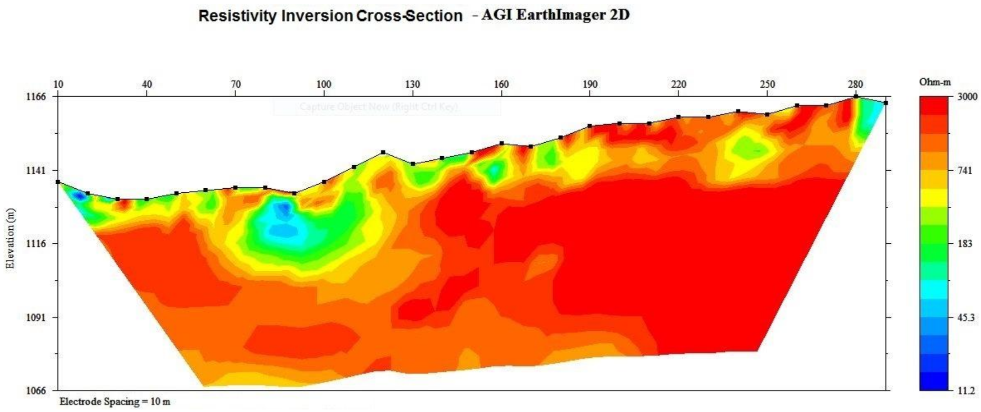


Fig. 14. Geoelectric cross-section from Profile-6 measurement

Profile-6 measurement is approximately in S-N orientation. In geoelectric cross-section from Profile-6 measurement: gossans, pelitic schist, calcschist and chloride-schist give a conductivity lower than 50 ohm.m on metabasics with conductivity higher than 50 ohm.m. There is a pocket with possible ore in a level of 70-120 m of geoelectric cross-section. Since copper ore has a good electrical conductivity, zones with very low resistivity are targeted ore levels in geoelectric cross-section.

Akgöl Formation where mineralization is expected in study area is overthrusted on mafic and ultramafic rocks (Elekdağ meta-ophiolite) by a reverse fault. In lower levels, massive basaltic rocks are characterized by upward pillow lava and breccia at top levels. To the south of license area is peliticphyllite-schist with effect of low metamorphism, and to the north of license area is black shale (claystone), siltstone, sandstone, and rarely limestone and dolomitic limestone at upper levels. Lower level of this sequence has very fine grain black shale and upper level mainly has sandstone, and as grains become larger to the upper level, it appears to have regressive character.Basaltic volcanic rocks, particularly important for containing ore deposit, are massive at lower levels, pillow lava to upper level, and brecciated at the top. It is partly cut by dykes. Brecciated basalts are largely altered hydrothermally. In particular, sedimentary cap rocks and hydrothermally altered brecciated rocks located at the top of basaltic series should give low resistivity values. Resistivity values will be much lower if these levels contain an ore. Therefore, the maximum resistivity value is 110 ohm.m on geophysical cross-sections and level maps in order to identify these much lower resistivity levels on study area.

Possible mineralization areas are identified by geophysical resistivity measurements performed for determining expected mineralization at crosscut of faults in different orientations located rather middle and southern margins of study area. Geological units of study area consist of Liassic sedimentary cover deposits.

Based on interpretation of geophysical measurements and cross-sections, various Liassic schists, metabasics with surface spread as well as gabbro and diabase dykes cutting them to the south of study area constitute the basis of working area. These rocks located in basement of study area have substantially undergone alterations with effects of heavy tectonism on study area as well as faulted, fractured and mineralization effects. It is considered that study area are likely to have a significant mineralization because these basement rocks in particular have low resistivity and display a wide spread on resistivity level maps.

Based on geophysical measurements performed, mineralization appears to be present in shallow levels to the south of study area and in deeper levels to the north. Geophysical measurements and interpretation are consistent with geological data of the site. As a result of geological and geophysical surveys, it is considered appropriate to perform core drilling on relevant study area in accordance with exploration priority order given in Fig. 15. The study area are divided into 6 zones on this zone map. It is proposed to start drilling from Zone 1 to Zone 6.

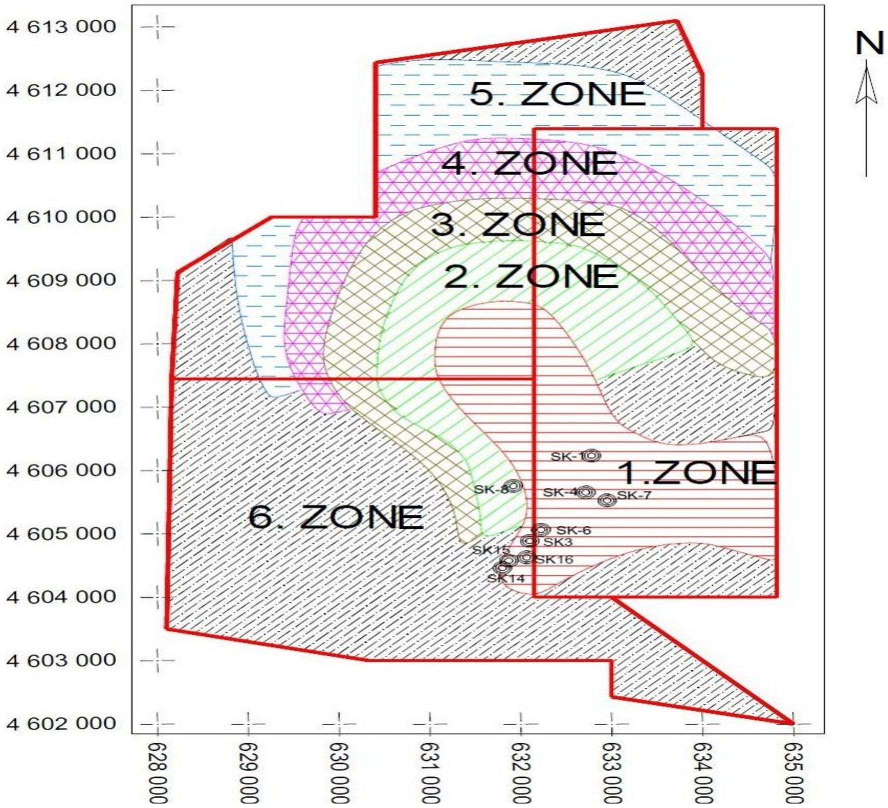


Fig. 15. Exploration priority order map (zone map). SK : recommended drilling locations

IV. Conclusions

Geological units of the area are considered to evaluate VES measurements, and geoelectric structure is correlated with these units. Data from performed studies does not directly express mineralization. In addition, resistivity level maps were prepared to see horizontal and vertical changes in resistivity values of layer. Geophysical measurements of 6 profiles were performed to determine continuity of gossans in lateral and vertical orientations on study area. Based on geophysical measurements performed, mineralization appears to be present in shallow levels to the south of study area and in deeper levels to the north. Geophysical measurements and interpretation are consistent with geological data of the site. As a result of geological and geophysical surveys, it is considered appropriate to perform core drilling on relevant study area in accordance with exploration priority order. The study area are divided into 6 zones on this zone map. It is proposed to start drilling from Zone 1 to Zone 6.

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