

Geological Setting and Ore Perspective of the New Discovered Gadir Low Sulfidation Epithermal Deposit, Gedabek NW Flank, Lesser Caucasus, Azerbaijan

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Abstract Gadir deposit is located in the East of Yogundag, near Gedabek deposit, also, Shamkir uplift of the Lok-Karabakh structural-formation zone in the Lesser Caucasus Mega-anticlinorium of Azerbaijan. The deposit has complicated geological structure, and consists of different age and different composite intrusive bulks and fracture structure consisted of complicated with Middle and Upper Jurassic sediments. A structural position of Yogundag area (also, Gadir) predetermined a set of magmatic complexes and a character of magmatism occurrence for Gedabek-Bittibulag deeper fault direction as a whole including the investigated area where are widely developed a set of volcano-pluton formations and volcanism of central character. Gadir was first suggested as a low sulfidation epithermal deposit type by Gedabek Exploration Geologists (2014) following field work and geological interpretation. The Gadir deposit is belong to Pb-Zn-Cu-Ag-Au vein deposit which is characteristic to Low Sulfidation epithermal deposit. The main ore minerals are sulfides. Sulfides consist of pyrite, sphalerite, galena, and trace amounts of chalcopyrite.

Keywords Epithermal Deposit, Low Sulfidation, Gadir, Gedabek, Azerbaijan

1. Introduction

The Lesser Caucasus is part of the Tethys metallogenic belt, which is one of the world's major metal producing belts. The Lesser Caucasus is located in a continental collision zone between the Eurasian and the Africa-Arabian plates (Figure 1) [25]. The formation of various types of ore deposit in the Lesser Caucasus is related to three major tectonic settings associated with the closure of the Tethys Ocean: (1) the subduction of the Tethys during the middle-Jurassic-early Cretaceous; (2) the

collision stage associated with the closure of the Tethys during the upper-Cretaceous, and (3) different post-collisional processes occurring during the Cenozoic. Although, ore deposits located in the Lesser Caucasus are poorly reported in the occidental literature [1, 17].

This study provides a preliminary description of the subduction related Gedabek ore district, located in the Jurassic-Cretaceous Lok-Karabakh volcanic arc, and considered as the biggest porphyry-epithermal ore field of Azerbaijan. A more detailed study of the Gedabek deposit is also proposed here to better characterize the formation processes of this controversial epithermal deposit, still preserved despite its Mesozoic setting.

Gedabek-Bittibulag ore knot is located along Gedabek-Bittibulag deeper fault, from the Yogundag Mountain area to Bittibulag copper-arsenic deposit. This area it with respect to tectonics and metallogenic is confined to volcano-plutonic structure of Shamkir uplift of Lok-Karabakh structure-formation, Lesser Caucasus metallogenic zone (Figure 2). The ore perspective areas (porphyry, high and low sulfidation epithermal deposit types) are embedded in cone-shaped Mountain Yogundag at elevation 2085m and Gyzyldjadag at altitude 2250.6m [2].

The ore knot in southern of Gedabek ore district has been explored for porphyry-epithermal ore perspective areas due to its favorable geological setting for Gedabek and Gadir type of deposit. In the result of exploration activities there were discovered several new local epithermal mineralization areas, one of which has underground mining, named Gadir deposit (low sulfidation type) and named Ugur exploration area - Reza gold deposit. Other ore perspective areas are in advanced stages of exploration, such as Umid, Zefer and Bittibulag [5].

Identification of exploration targets by mineral prospecting often includes reviews of available information, interpretation of remote sensing data, geological mapping and soil geochemical surveys.

TETHYS METALLOGENIC BELT

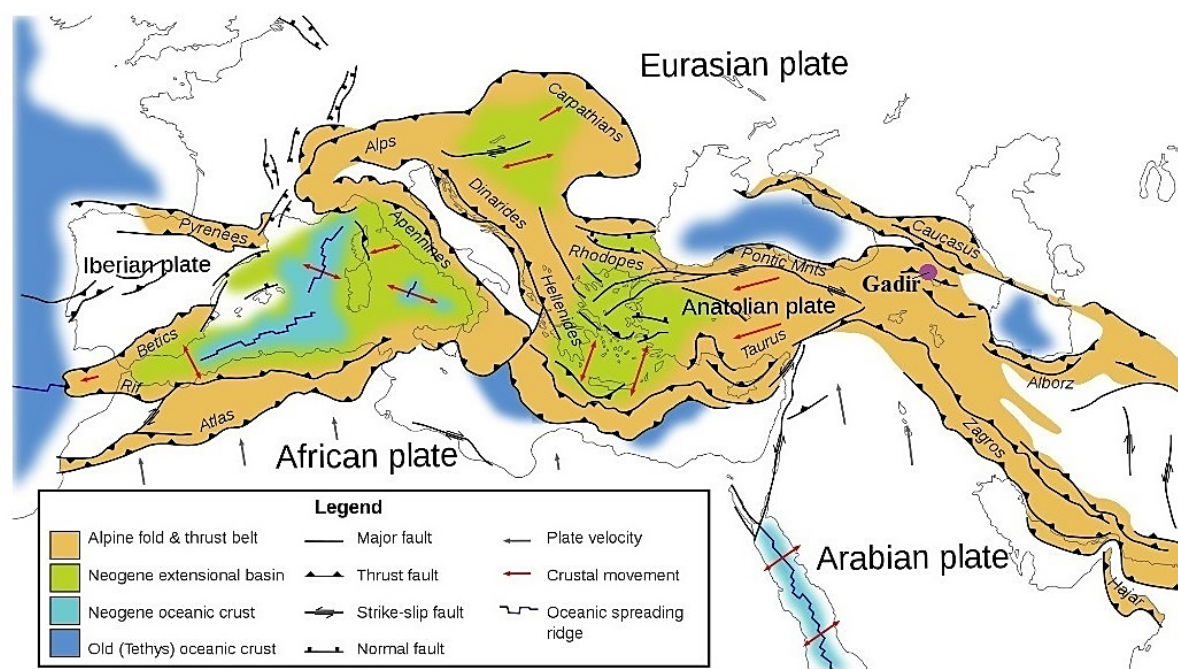


Figure 1. Location of Gadir low sulfidation epithermal deposit; in Lesser Caucasus Mega-anticlinorium of Tethys metallogenic belt [25]

Underground mining activity at Gadir started about 4 years ago, and is more recently exploited for copper, silver and gold. The deposit was described as low sulfidation epithermal deposit [16]. The ore mineralization is hosted by a large body showing an upper flat-lying contact with Bajocian-Bathonian andesitic tuff and located above a Kimmeridgian diorite intrusion. The ore body has a porphyritic texture formed by quartz eyes in a microcrystalline matrix. This study questions the primary magmatic nature of the ore body and proposes a formation by a hydrothermal quartz \pm adularia \pm pyrite alteration.

Geochemistry of magmatic rocks, sampled within the Gedabek ore district, indicates a calc-alkaline magmatism related to a subduction setting, with basaltic to andesitic compositions. Geochemistry of the ore body at Gadir is based on immobile elements, and indicates an andesitic composition of the initial rock overprinted by the quartz \pm adularia \pm pyrite alteration [17].

The field study in the underground reveals a pervasive propylitic alteration of the andesitic tuff and a pervasive quartz \pm adularia \pm pyrite alteration which forms the ore body. Field observations also reveal a strong lithological control of the propylitic and the quartz \pm adularia \pm pyrite alterations, within sub-horizontally bedded volcanoclastic rocks. The central part of the open pit is characterized by the intersection of two main fault structures spatially associated with a late argillic alteration extending vertically, and small semi-massive sulfide mineralization [17].

The combination of data provided by the company exploiting the Gadir deposit, field observations, geochemistry, metal content analyses, a detailed petrography, microprobe analyses, X-ray diffraction analyses, sulfur and oxygen isotope analyses allows us to propose an evolution in time and space from an early and large low-intermediate-sulfidation hydrothermal system toward a later and more focused intermediate-high-sulfidation system at Gedabek [17].

The superposition of these two distinct groups of epithermal systems are possibly formed by unrelated hydrothermal events. However, a model of formation by a single continuous hydrothermal system cannot be discounted and is also discussed.

The main aim of this article is to describe the characteristics of the Gadir deposit, including a model for the geology, mineralogy and petrographic features. The article will be as the first discovering report about Gadir Low-Sulfidation Epithermal Gold Deposit. It will be helpful on understanding the mineralization and hydrothermal alteration processes at the deep zones.

The information from core logging from underground drilling can indicate the nature of this epithermal deposit and can identify the main directories in discovering the porphyry deposit. This information is parallel providing with thin section and mineralogical investigations.

Also the underground mapping is the best way to modeling of ore controlling faults and dyke into depth and to predict the continuation of the ore.

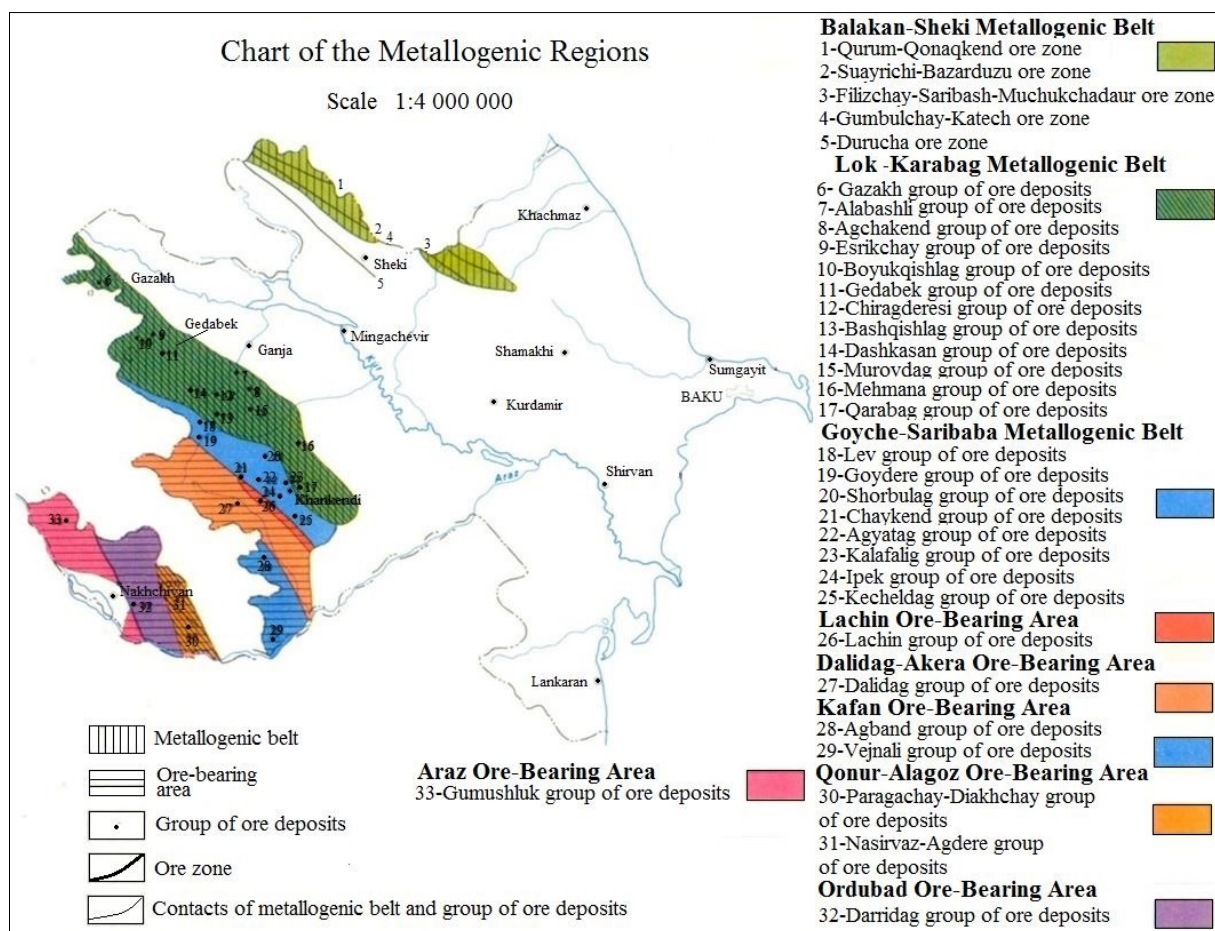


Figure 2. Location map of the Gedabek ore district in Chart of the Metallogenic Regions, Azerbaijan Republic

2. Gadir Low Sulfidation Epithermal Deposit

The NW Flank of Gedabek Mine is located in the Yogundag Mountain area. Yogundag it with respect to tectonics and metallogenic is confined to Gedabek volcano-plutonic structure of Shamkir uplift of Lok-Karabakh structure-formation, Lesser Caucasus metallogenic zone. The ore perspective areas, also Gadir low sulfidation epithermal deposit (Gadir lsd) is embedded in cone-shaped Mountain Yogundag at elevation 2085m [9,16].

2.1. Location and History

Gadir deposit is located in the East of Yogundag, near Gedabek deposit, also, Shamkir uplift of the Lok-Karabakh structural-formation zone in the Lesser Caucasus Mega-anticlinorium of Tethys belt. The Gadir underground mine area is licensed as a 20.8 ha open-field site near the North-West flank Gedabek Mine, located approximately 400 m from mine, in a mountainous area known as Yogundag.

While carrying out geological exploration works in the

NorthWest flank of Gedabek Mine, Gedabek Exploration Group (GEG) and geological consultant Allahverdi Agakishiyev discovered the Gadir low sulfidation deposit in 2012. Here are the probably outcrop of quartz porphyry subvolcanic formation was considered as the main factor, also observed intensive silicification alteration on surface. In the aim of discovering the ore formation in contact part of this rhyolite-dacite subvolcanic body was drilled AIMCDD86 drill hole in 2012. During geological-structural mapping, it has been defined Gadir Horst structure [9, 16].

2.2. Regional Geological Setting

The Gadir Area has a complex geological structure, and it has become complex with the intrusive masses and breaking structures of different ages and different composition. Lower Bajocian is essentially composed of an uneven succession of diabase and andesite covers, agglomerate tuffs, tuff-gravelites and siltstones. Tuffs of the Lower Bajocian were exposed to strongly metamorphism (hornfelsed) as a result of the impact of Upper Bajocian volcanism and intrusives of Upper Jurassic age. Rocks related to the Bathonian stage have developed

mainly in the top of Yogundag.

Gedabek ore district and Shamkir uplift in general is complex in terms of its tectonic structure and its magmatism is complex too. Magmatic processes in this region have occurred intensely. There are 3 phases of magmatism in the ore area: Bajocian, Bathonian and Upper Jurassic phases (Figure 3). The Bajocian phase is divided into two sub-stages: Lower Bajocian age rocks – intermediate and basic composition pyroclastic volcanic and volcanic disturbed rocks – occupy the central portion of Shamkir uplift, and have become complex with intrusive and subvolcanic complexes and breaking structures of different ages, morphology [19].

Acid composition products of the Upper Bajocian magmatism are represented very broad by all facies within Gedabek ore district. It can be considered that the magmatic center of the Upper Bajocian period is located in the Shamkir uplift. Andesite, partially andesite-basalt composition products of the Bathonian phase of magmatism, as well as various composition pyroclastic materials and lava flows Upper Jurassic phase are spread mainly in the sidelines of Shamkir uplift. Along the breakings structures and in the areas between them, rocks along micro cracks have become strongly quartzitized, kaolinized, sericitized and in most cases changed to secondary quartzite.

Breaking structures have not caused Lower Bajocian rocks to become too complex. The main complexity were generated by subvolcanic masses of rhyolite, rhyodacite and quartz-porphyry composition of Upper Bajocian age which occurred along the Gedabek-Bittibulag depth fault and which began to cool down in the area close to the surface. These magmatic masses were deprived of high

pressures but were in contact with the magmatic source which had not yet cooled down. High temperature hydrothermal solutions that were separated from the magmatic source moved along the subvolcanic mass cracks and contacts and created hydrothermal metasomatic alterations of various types within them and in the surrounding rocks [19].

Rhyolites and rhyodacites changed to various types of secondary quartzite, and the surrounding rocks changed into secondary quartzite, skarn rocks and hornstones depending upon petrographic, mineralogical and lithological compositions. However the processes mentioned above did not occur all through the subvolcanic masses and contact rocks. These processes occurred in such areas where there was a constant contact (open channel or open contact zone) between the subvolcanic and magmatic source. One of such areas was the Misdag area in which Gedabek mineral deposit (mine) is located. When subvolcanic masses began to cool down dynamic forces constantly influenced some of its regions, in particular the regions that were in active contact with the subvolcanic source, and dense crack points and damage regions started to emerge here. Such regions were very favourable for the movement of hydrothermal solutions that were rich in chemical elements.

In subsequent stages, hydrothermal solutions which were separated from the magmatic centre and moved along the subvolcanic cracks and contact areas led to the creation of golden copper-pyrite stocks of different sizes emerging along the upper contact of the subvolcano. There are created inside the secondary quartzite in the areas with few cracks and no upper closed screens tiny chords around these stocks.

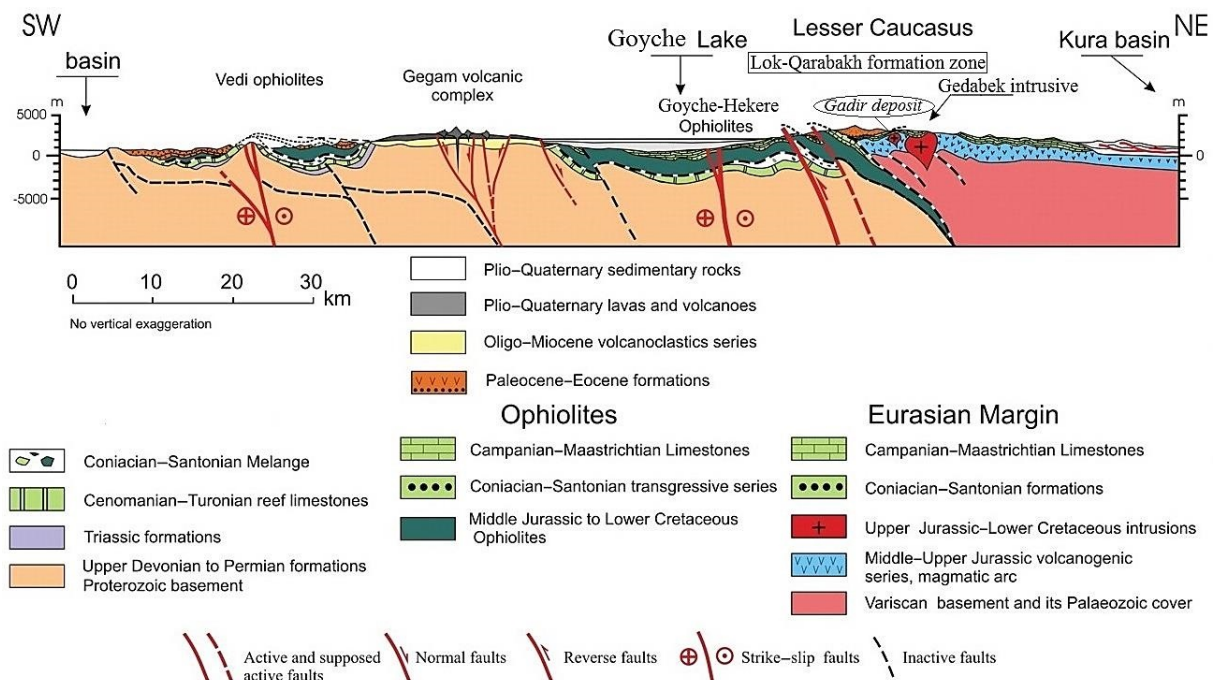


Figure 3. Location of Gadir low sulfidation epithermal deposit: Lithological-structural cross-section from Vedi ophiolites to Kura basin [19]

The following folded structures were described by numerous researchers within the bounds of NW Flank of the Gedabek Mine: Arykhdam-Shekarbek anticline and Godekere-Yenikend syncline.

Arykhdam-Shekarbek anticline fold axis is observed from a confluence of rivers Gedabekchay and Shamkhirchay, passes across village Arykhdam and stretches in a northwest direction to village Shekarbek. In a structure core are cropped out effusive and effusive-pyroclastic sediments of Lower Bajocian substage being overlapped by vulcanites of Upper Bajocian Substage on extrusive. In the southeast of a central part of fold was interrupted Gedabek granitoid massif. In its northwest plunge among Lower and Upper Bajocian vulcanites are observed numerous subvolcanic bodies morphologically represented by compound stock-like and dyke forms [2].

Godekere-Yenikend syncline is traced from northwest of village Godekere across villages Gozgaraly, Saryhesenli to an east edge of village Yenikend. At the NW Flank of the Gedabek Mine, along on Yogundag Mountain it is shaded by a like volcanic structure. The syncline is composed of volcanogenic, volcanogenic-sedimentary of Bathonian Stage. The fold structure is gentle-symmetric with a rock dip on limbs at an angle 10-15°.

There are 3 groups of fault zones on the basis of strike direction and morphological characteristics: 1) faults-dislocations in north-west direction (Gedabek-Bittibulag deeper fault, Misdag ore-controlling fault); 2) faults in north-east, submeridional direction and reverse faults (Gedabek-Ertepe, Gerger-Arykhdam, Gadir ore-controlling faults); 3) transverse faults (local fault).

Gedabek-Bittibulag deep fault has a thickness approximately 2 km for Yogundag Area. This deeper fault is divided in two parallel parts: 1. Gedabek-Bittibulag East fault (old data) and 2. Gedabek-Bittibulag West fault.

Gedabek-Bittibulag East fault has dips to the northeast at an angle 70-85°.

Along a fault zone on its east side Upper Jurassic volcanogenic-sedimentary formations are substantially schistose and intrusion rocks are turned into genesis formations. Along a zone of gneiss and schistosity the mineral neo-formations are elongated along a zone and have a concordant dip. During an injection of granitoid intrusion along a zone of enhanced fissuring were occurred a penetration of numerous various-forming dike-like intrusive rocks into enclosing rocks with a formation of typical injected-magmatic migmatites of quartz-diorites in andesites and their tuffs. The rocks of the northeast side for Gedabek-Bittibulag fault are down faulted. The displacement amplitude is up to 450-500 m.

It testifies to Gedabek-Bittibulag fault is one of ancient and macrobian structures within the bounds of the investigated region. It bounds Gedabek deposit from the east.

Gedabek-Bittibulag West fault system defined by GEG

in 2014 year. This fault is traced on top of the Yogundag Mountain. The West deeper fault has dips to the southwest at an angle 70-85°. Along a fault zone on its east and west side are Bathonian volcanogenic.

Gerger-Arykhdam fault, bonded the Gadir Area from the north, it is intercepted by Gedabek-Shekarbek fault and dips to the southwest at an angle 80-85°. The thickness changed from 5-10 m up to 20-30 m. The rocks in a fault zone are strongly crushed, grinded, limonitized and silicified. Volcanogenic and volcanogenic-sedimentary rocks of Bathonian Stage on a northwest side of fault are down-faulted at 150-200m and set in a tectonic contact with Lower Bajocian volcanic-sediments. Andesite mantles, alternate with fine- and medium-fragmental, agglomerated tuffs of Bathonian aged andesites, are propylitized near the fault.

The later concerning the described systems of the faults within the deposit bounds are the sub-latitudinal faults having a northwest strike (270-310°) and a steep dip to the north (80-85°). The thickness of these faults doesn't exceed 50m. The rocks along these faults are brecciated, slightly schistose and kaolinized.

Gedabek-Ertepe fault is traced with interruptions starting from southwest of proper Gedabek deposit and divided to Garadag and Boyuk Galacha Mountains in the northeast direction and then it obviously fades out; slightly expressed in separate areas. The fault becomes more intense in a region of Mountain Maskhit where it intersects Ertepe-Kharkhar fault.

A thickness of crushing zone does not exceed 70-80 m; it comes to 5-10 m in places and dips to the southeast at angle 75-80° and greater.

In a region of Mountain Boyuk Galacha (on the east side) along the described discontinuity there are noted old adits where on a surface it is widespread copper mineralization (malachite, azurite). Here it is intersected by small faults of northwest strike. Upper Bajocian rhyolites, rhyolite-dacites and their tuffs are enclosing rocks therein. Then it is overlapped by a thick mantle of Holocene sediments.

Gedabek ore-boundary fault starts from East of Gedabek high sulfidation epithermal deposit and continue through the North parts of Gadir, Umid, Mubariz and Zefer areas. Also this fault is separated in several blocks by ore controlling faults in each area. Deep angle of this fault is approximately 70-75° to the South and South-West.

2.3. Local Geological Setting

Gadir low sulfidation epithermal deposit is located in the area East side of Yogundag Area. Gadir deposit has complicated geological structure, and consists of different old and different composite intrusive bulks and fracture structure consisted of complicated with Middle and Upper Jurassic sediments (Figure 6 & Figure 7).

Geological structure and ore presence of the NW Flank of Gedabek Mine were elucidated by numerous researchers

as Akir Isazadeh, Hesên Chelebi, Guillermo Turner-Saad (2011-2013), Robin Tolbert (2014), Sean Muller (2014), Gedabek Exploration Geologists and others [16].

Geological structure and conditions of the NW Flank of Gedabek Mine formation are briefly given below (Figure 6 & Figure 7). The NW Flank of Gedabek Mine is composed of:

Volcanogenic rocks of Lower Bajocian. On the studied mapping area Lower Bajocian volcanogenic rocks (or sediments) are widely developed and stretch from South-East of Yogundag area (Gedabek deposit) to the center and North-East directions to Zefer area.

The lower horizons of the sediments for this substage aren't outcropped on the investigated area. The sediments of Lower Bajocian Substage in Gedabek deposit and NW Flank are represented (from bottom to top) by:

1. Andesite-basalts and andesite porphyrites with low-thick interlayers of thin fragmental crystalline-lithoclastic tuffs of andesites. The exposure thickness is 119m. Mantle alternation of andesites, andesite and andesite-basalt porphyrites with packets of medium- and thick-layered fine- and medium-fragmental tuffs with diabase mantle in a basis.
2. Mantles of diabases and diabase porphyrites. The thickness is 8.0m. The total thickness of Lower Bajocian formations is more than 147m.

Andesites are macroscopically represented by taupe (dark grey), greenish-grey thick rocks. They under a microscope have a porphyritic structure. Porphyry exhalations are represented by plagioclase. Plagioclase is also observed in a main bulk as fine, medium and coarse grains. In a main bulk are quite often observed chlorite, epidote and sometimes zeolite.

Andesite-basalts are represented by taupe, almost black, massive rock of porphyry structure. Under a microscope a porphyry structure is observed in the rock. Porphyry exhalations are represented by quite large, tabular individuals which are substantially pelletized and sericitized. The main bulk has a microlitic structure and extensively chloritized and sericitized.

Upper Bajocian volcanogenic rocks. These rocks represented by rhyolite-dacite lava facie and rhyolite subvolcanic rocks. The rocks of this substage on an investigated area are widely developed and traced from the southeast (Gadir Gallery area) to the centre (east contact of Gedabek Hydrothermal Eruption Breccia Pipe) and northeast directions to Mubariz Area. In the northwest of Mubariz area observed outcrop of AC rhyolite-dacite subvolcanic facie.

In tectonic condition they are confined to a block of Arykhdam anticline bounded from northeast and southwest by Gedabek-Bittibulag and Gedabek-Shekarbek faults respectively that are composed of magma-incurrent and ore-incurrent canals of Upper Bajocian volcanism.

The rocks of the effusive facies are represented by various fragmental tuffs (from ash to agglomerate) and mantles of rhyolite and rhyolite-dacite porphyrites. They have light-grey with pinkish, sometimes yellowish grey color.

The rocks under a microscope have felsite structure and contain fragmental individuals of quartz and plagioclase. In rare cases there is observed mica.

Cement is represented by an argillaceous-siliceous bulk coating the fragments. The rocks of the effusive facies of Upper Bajocian Substage aren't out cropped within the bounds of the deposit. There is observed funnel facies of their subvolcanoes being of great importance to a location of the Yogundag epithermal system.

Bathonian volcanogenic rocks. Renewal of volcanic activity was started in Bathonian Stage however there occurred some displacement of their composition to basicity side and spatial location of their flow centers. Volcanic formations of Bathonian Age within the bounds of the mapping area are observed to the upper layer of Eastern sector and all area of Western sector of the Yogundag Mountain.

On sediments of Upper Bajocian Substage are transgressively occurred formations of Bathonian stage represented by an alternation of fine- and thin-layered, ashy and agglomerated tuffs with rare interlayers of andesitic-porphyrific breccia and andesitic-dacitic lavas.

Their thickness is various and by the data of the GEG comes to 160-180 m within the bounds of the prospecting area.

Volcanogenic sedimentary rocks consist from volcanic and sedimentary materials, which can be solid and detrital or chemical. Detrital or pyroclastic material lays down friable accumulations of clumps, lapilli, volcanic sand, and volcanic ash. When it is cemented into the place where it fell or is re-deposited, generally pure, most often homogeneous, volcanogenic sedimentary rock (tuff), containing only a small admixture of sedimentary material, is formed. This volcanogenic rock has mainly seen the top of the Yogundag Mountain (thickness approximately 3-15 m).

Metamorphic rocks. Within the bounds of the prospecting area are widely developed different facies of contact-metamorphic and hydrothermal-metasomatic rocks. Contact-metamorphic rocks are represented by hornfels and silicified andesite rocks.

Hornfels have been formed due to enclosing intrusions of medium and medium-basal rocks in a zone of contact aureole and they are represented by the following types of facies: albite-epidote-hornblende, hornblende-hornfels and pyroxene-hornfels.

Rocks of high-thermal facies (pyroxene-hornfels) occur in an internal zone of contact aureoles and medium and lower-thermal facies comprise middle and external zones. In the external zone is also observed slightly metamorphosed (corneous) rocks.

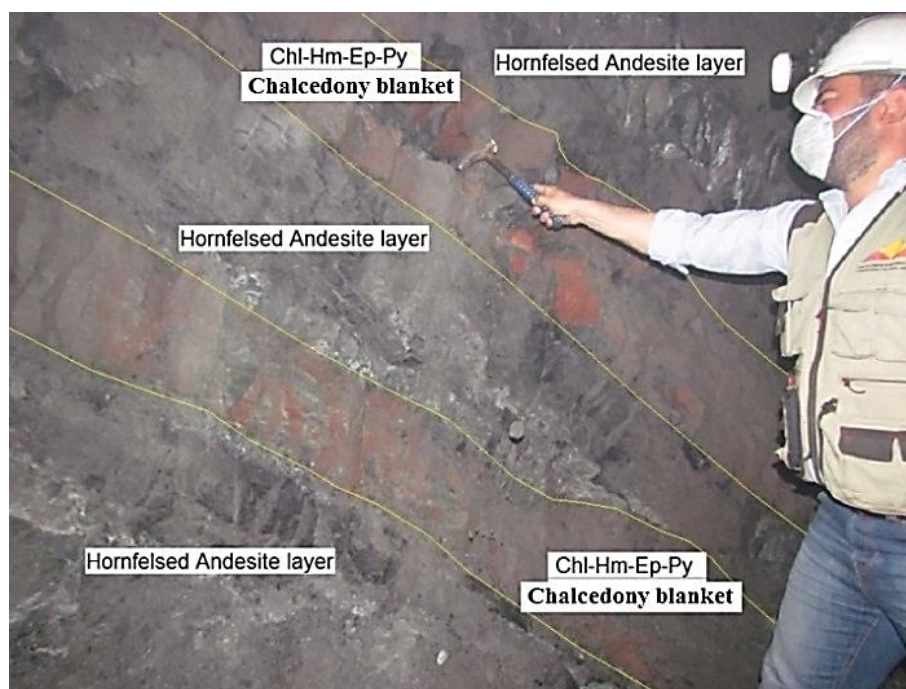


Figure 4. Contact zone: Altered Moderate Hornfelsed Andesite layers with Chalcedony blanket (abbreviation: Chl-Hm-Ep-Py = Chloritic-Hematitized-Epidote-Pyrite), Gadir Gallery [16]

Hornfels and corneous rocks are macroscopically represented by dark, almost black thick fine-grained rocks with typical shelly fracture.

The rock by mineralogy generally consists of chalcedony blanket, plagioclase, pyroxene, biotite, epidote and magnetite. There are less common amphibole, chlorite, pyrite and etc. (Figure 4). The rock is characterized by an outline crenulation of separate crystalline grains and quite often manual location of different minerals that is biotite in most cases.

Silicified andesite rocks are developed in an exocontact band of rhyolite subvolcanic facie.

Diorite and Andesitic Porphyritic dyke: Out of magmatic formations in an ore field are also observed the rocks of Gedabek intrusion which described in chapter “Geological structure of region”. The deposit is genetically connected with Gedabek intrusion (its quartz-diorite phase).

Dyke formations within the ore perspective areas bounds are widely developed and represented by early quartz-diorite, microdiorite and late diabase formations. Diabase dykes are mainly developed and generally confined to latitudinal discontinuities. Andesite and microdiorite dykes are less developed and confined to discontinuities of various directions from the North to the North-West.

Quaternary sediments in the prospecting work area are widely spread and represented by Quaternary and Holocene. Quaternary formations are developed outside the prospecting area along the valley beds Umid, Gadir,

Mubariz, Gatyrbulagy and etc. where they form series of river terraces. Their thickness comes to 5-25 m. Holocene elluvial-delluvial sediments are developed on the divided parts: the mountain slopes and the river valleys.

They are represented by fine and large acute-angled, sometimes poorly rounded fragments of different rocks, loams and sandy loams that are in most cases overlapped by soil layer. Along the riverbeds and the dry ravines are developed alluvial formations represented by rock debris, fine-fragmental gravel, sandy loam and sand rarely. Their thickness oscillates from 0.5 up to 10m.

The Gedabek hydrothermal eruption breccia pipe (GHEB pipe) is located in the central-eastern part of the Yogundag Mountain around the Gadir low sulfidation deposit (Figure 5 & Figure 6). The present shape of the pipe with about 50m diameter resulted from both volcanic and erosional processes. Erosion has reached the deep levels of the pre-pipe stratovolcano at the bottom of the depression and the hills forming the margins of the pipe. Breccia pipe are mostly consist of after Bathonian andesitic lava and tuffaceous sedimentary rocks. A rhyodacite dome is well preserved in the center of the volcanic structure [16].

The total thickness of the volcanic pipe is not known exactly. The lower part of the Pipe is drilled and South part of the pipe consists of submarine dacitic and andesitic lava and tuff of after Bathonian age.

The few meter thick hydrothermal products cover an approximately 1000 m² area and bed on andesite lava flow. This hydrothermal environment can be divided into several

zones: a white (strong silicified andesitic porphyritic rocks), poorly-sorted and clast-supported breccia occurs in the center. The white color fragments are well rounded and primary hematite (specular and bladed texture, characteristic to GHEB pipe) is located in cement material. The outermost layered siliceous deposit contains 10-20 m thick uneven beds on the surface toward the South-East part of the volcanic structure. The mixed tuff that surrounds the zone of breccia and siliceous layers contains pumice, quartz, glass and andesite fragments and is characterized by argillic alteration, weak silicification (opal) and subordinate presence of alunite. The surrounding and underlying pyroxene andesite is partly altered to smectite (after plagioclase) and hematite-limonite (after mafic minerals). In the western part of the hydrothermal center the zonation cannot be observed due to the recent cover and erosion. The textural, mineralogical and geochemical characteristics suggest that this outcrop represents a paleosurface of a hot spring center in which eruptions occurred during hydrothermal activity. The accumulated breccia was cemented by the precipitations from the outflowing fluids and the layered zones towards the margins represent a transitional zone to a Gedabek Silica Sinter apron (Figure 5 & Figure 6).

Argillic (alunite-kaolinite) alteration occurs in the central and Southern part of the Gedabek hydrothermal eruption breccia. The host tuff beds are intensely silicified with microcrystalline quartz and opal. Alunite occurs as fine crystals in the matrix of the tuff and coarse-grained, comb-textured aggregates in the fractures of the silicified rock.

The adularia-sericite alteration in the subvolcanic facies of the lower andesite represents the deepest level of hydrothermal effects in the Gadir and Umid area. This type of alteration follows N-S and NE-SW directions and envelops quartz veins that are 3-10 cm wide and can be followed up to 1 km length. These subvertical-vertical veins are banded and locally brecciated. Distal alteration zones comprise quartz, chlorite, epidote and pyrite. The veins and their stockwork zones contain minor disseminated pyrite, malachite, hematite, magnetite and secondary Mn-oxy-hydroxides.

Gedabek Silica Sinter. Silica sinter observed around GHEB pipes in the central part of Yogundag Mountain.

Gadir Silica Sinter forms from discharging alkali chloride hot springs and provide evidence at the surface of a deeper geothermal reservoir. Long after hot spring discharge ceases, sinter textures are preserved and an exploitable geothermal system may remain at depth. Therefore, sinters may be the only evidence at the surface of a hidden geothermal resource. The recognition and mapping of preserved environmentally-significant textures in ancient sinters reveals hot spring paleo-flow conditions and temperature gradient profiles from high temperature vents to low-temperature distal-apron slopes. Sinter dating reveals the timing of discharging hot springs enables the tracking of discharging fluids on a regional scale and identifies sinters that are most likely to be related to a blind geothermal resource. Sinter textural mapping combined with sinter dating, provides a simple tool that assists existing exploration techniques used in the search for hidden geothermal resources [11, 16].

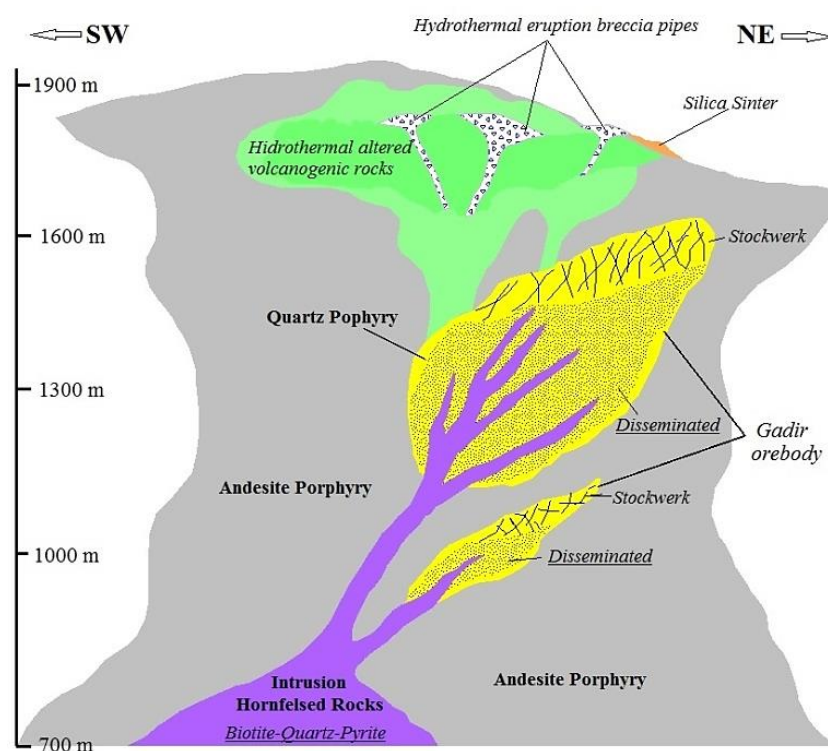


Figure 5. Gadir low sulfidation epithermal 2D model SW-NE direction (by GEG, 2014)

Gadir quartz veins where the ore is settled are general in the most of the epithermal mineralizations. The kind of the hydrothermal activity is easily decided by studying the textures observed within a quartz vein met in the NW Flank. Therefore, the place of this quartz vein in the epithermal system on the paleo-topography can be estimated. It is decided whether the precious metals zone of the vein was cut by the erosion or an ore existence can be expected at depth while there is not any evidence on the surface. As a consequence, the textures of the quartz veins are used as guide in the exploration.

Two major textural groups are recognized on the hand specimens collecting during the field studies in the Yogundag epithermal system: 1) Primary growth textures representing the open-space fillings; 2) Superimposed.

Primary quartz vein textures are classified as buck, comb and banded textures. Superimposed textures are replacement and breccia textures. Quartz textures can be seen in all epithermal settings. These textures can be formed by different quartz species such as quartz, chalcedony, opaline and amethystine. Banded textures of microcrystalline quartz are more dominant at the boiling level or just above. Massive or slightly banded chalcedony exists in the shallow depth. Sinter consisting of amorphous chalcedony is seen at the surface.

In general, the richer part of the epithermal vein in precious metals exists at the banded textures, whereas, the base metal content has located in the below part. In the deeper parts of the vein is representing by the comb texture.

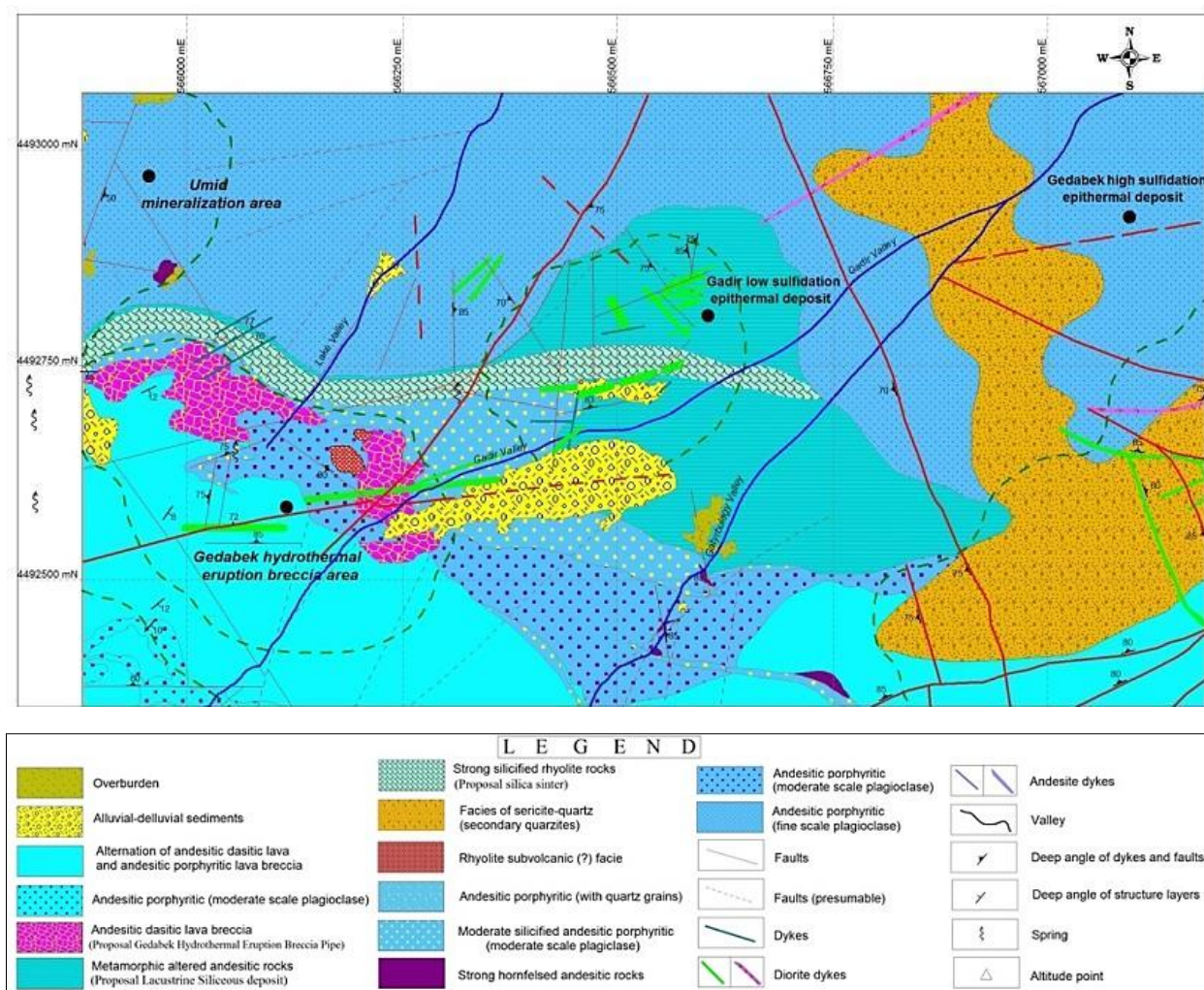


Figure 6. Lithological-structural map of the Gadir low sulfidation epithermal deposit

Gadir lacustrine siliceous deposit. The sedimentary sequences of the lacustrine basin are in East of Gadir outcrop over an approximately 85000 m² area. The original size of the basin is not known because it is bordered by normal faults to the west and south. The basin history was reconstructed by GEG (2015) from observations of more than 12 drill holes. The limnic sequence of the basin is cover by andesite flow related to the intermediate volcanic activity between the fourth and fifth rhyolite tuff unit of the area. The upper parts of the lava beds show shallow subaqueous accumulation with breccia [16].

In the lacustrine sequence, three major consolidated siliceous layers occur. However, there are unconsolidated beds which are composed of uncemented quartz plates 5-20 m size and very little argillic material. The siliceous layers show bedding in which the individual layers have very variable thickness from a few centimeters up to 1-2 meters. The thick siliceous layers also contain interbedded rhyolitic tuff without silicification. This field evidence suggests that the silica was precipitated as very fine mud from the hydrothermal solutions. The color of individual beds varies from white to grey, white, brown and black. The variation of the color from layer to layer is related to the presence of minor mineral particles. Red and brown layers contain fine Fe-oxides, while black layers contain framboids of pyrite and marcasite. These sulfides occasionally correlate with the distribution of organic material. The siliceous beds are generally characterized by high concentrations of Sb, and lesser As and Hg, as well as some Ag (based on assay results of drill holes).

Close to the centers, the thickness of siliceous deposits is up to 10-12 meters, while on the margins they totally pinch out. In feeder zones within the basin, also outlined subaerial hydrothermal centers around the depression. These centers now form small hills with strongly silicified and brecciated rocks.

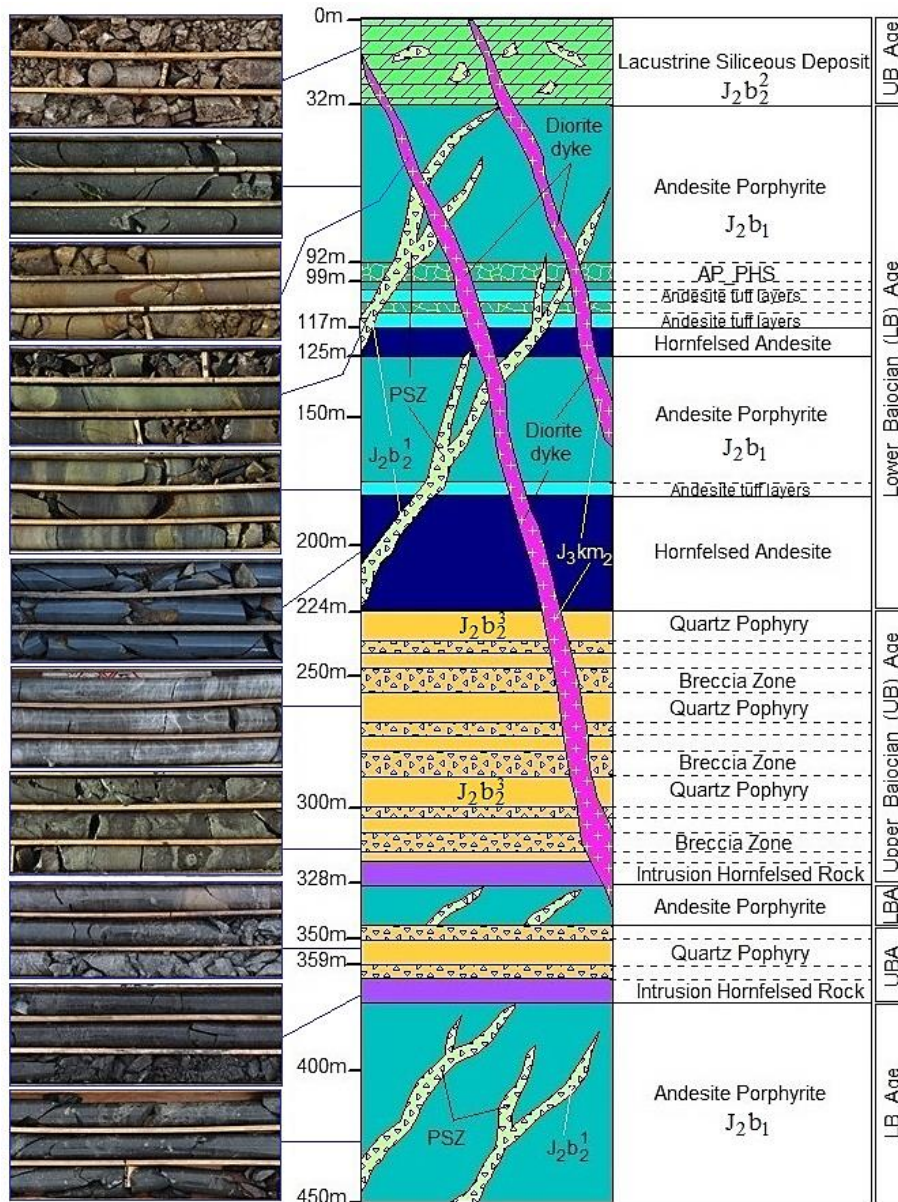


Figure 7. Stratigraphic column and typical core has shown multiple hosts for NW Flank of the Gedabek Mine (also, Gadir LSED (by GEG, 2015)). Abbreviations: PSZ-Propylitic Silicification Zone; LB-Lower Bajocian; UB-Upper Bajocian [16]

Local structure: In the Gadir LSED area is main three faults types:

1. Gadir pre-mineralization faults;
2. Gadir mineralization bearing faults;
3. Gadir post-mineralization faults.

Gadir Mineralization Bearing Faults

Gadir deeper (ore-controlling) bearing fault the later concerning the described systems of the faults within the deposit bounds are the sub-latitudinal faults having a northwest strike ($270-310^\circ$) and a steep dip to the south ($80-85^\circ$). The thickness of these faults doesn't exceed 50 m. The rocks along these faults are brecciated, slightly schistose and kaolinized.

Gadir parallel bearing fault system passes through north of the previous fault along a north flank of Gadir mineralization area. On a map both faults change a strike from the west (270°) to the northwest (310°), are turned by a concave side to the north towards a subvolcanic body of rhyolite-dacites and have a semi-annular character. Along these fault is observed a vertical displacement of rocks. The north blocks are down about 60-75 m concerning the south

blocks. All described systems of the faults are pre-mining and divide the deposit into the separate blocks dislocated along a vertical line at different levels concerning one another and formed a small dome-like elevation. Also several parallel faults (Gatyrbulagy, Umid, Mubariz and Zefer) of NW Flank have the same situation (strike, deep angle) with Gadir parallel fault.

2.3.1. Gadir Anomaly

The soil geochemical anomaly of complex elements such as Au-Ag-Pb-Sn-Sb is located to the West from discovered ore body in Gadir area (Figure 8). This may refer to andesitic composition tuffs having structure elements deeping to South and South-West. Each element such as Zn-Mo-Te-As-Ba-Te-Hg-and Cs individually form anomaly around Gadir area. It may be connected with the element migration through intensive cracks and faults. The drilled drill holes in Gadir area were not completely bordered the ore and availability of element anomalies may indicate to other hidden ore bodies at the deep. There is planning to continue exploration works by gallery drifting and drilling drill holes in Gadir area [7].

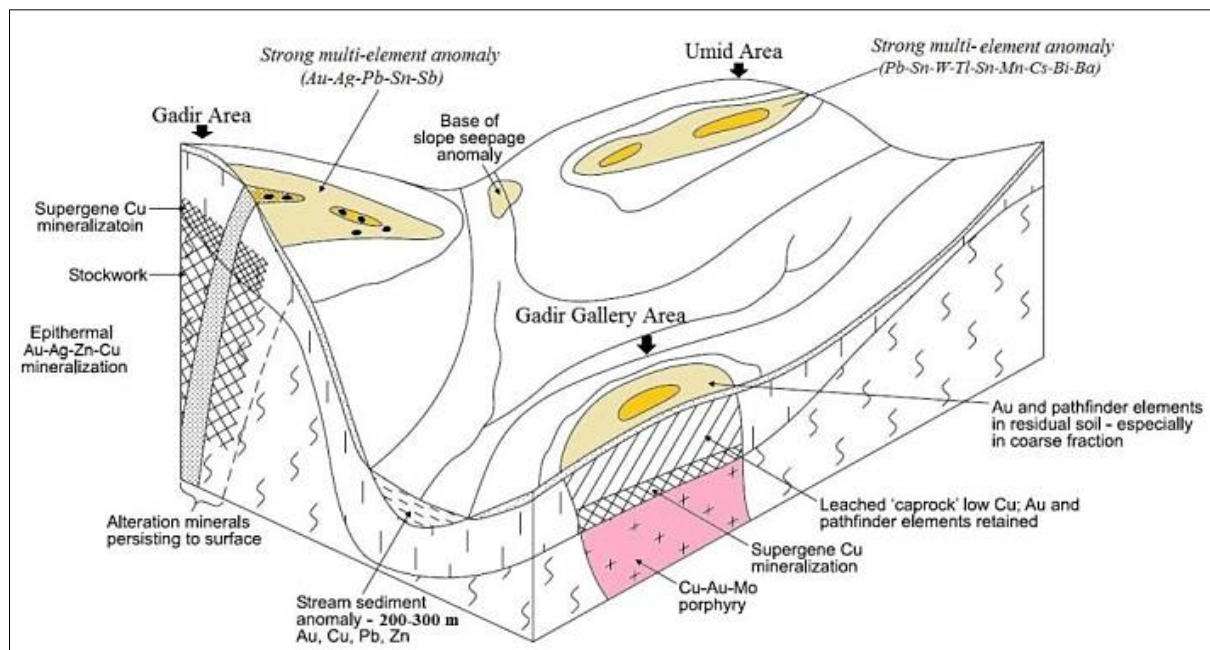


Figure 8. Dispersion model for Gadir Gallery, Gadir and Umid Area

2.4. Hydrothermal Alteration

As above mentioned Gadir deposit confined to the low sulfidation epithermal system, as well as this system characterized by a range of hydrothermal alterations. During the field alteration mapping the following hydrothermal alteration was obtained in Gadir horst (Figure 10).

Propylitic alteration: The moderate propylitic alteration mostly developed in North and North-West part of Gadir horst area and is observed in the andesitic tuff formation, in the external part of the deposit. This alteration is mainly controlled by the permeability of tuff layers. The most common minerals of this alteration are chlorite and epidote.

Despite the alteration, the primary texture of the tuff is still observable. In thin section most of the chlorite replaces clasts, epidote is rather disseminated in the matrix together with chlorite (Figure 9 (right)). However, some tuff layers show a preferential replacement by epidote. Microscopic observations also indicate local replacement of the matrix by magnetite.

Silicification alteration: During field mapping provided by GEG in 2015 silica sinter layer was obtained above Gadir uplift. The thickness of silica sinter varies from 5m to 10m, in average 6-7m (Figure 9 (left)). This was one of the primary criteria indicated that Gadir horst belong to low sulfidation epithermal deposit. The dip angle of layer is approximately 25-30° and strike to South and South-West. Silica sinter may consist mainly of opal, but could as well be made mainly of very fine-grained quartz similar in structure to jasper. In small parts may assume an agate-like structure, but in most cases the banding is different from that in an agate.

Another type of silica alteration on Gadir horst is **lacustrine siliceous deposit (LCD)**. Sedimentary sequences of the LCD basin are in East part of Gadir outcrop (Figure 9 (right)). The original size of the

alteration is not known because it is bordered by normal faults to the west and south. The alteration history was reconstructed by GEG (2015) from field mapping. LCD mainly consists of alternation of silica sinter layer with hornfelsed andesitic tuff sedimentary layers. This field evidence suggests that the silica was precipitated as very fine mud from the hydrothermal solutions. The color of individual beds varies from white to grey, white, brown and black. The variation of the color from layer to layer is related to the presence of minor mineral particles. Red and brown layers contain fine Fe-oxides, while black layers contain framboidal pyrite and marcasite. These sulfides occasionally correlate with the distribution of organic material. The siliceous beds are generally characterized by high concentrations of Sb, and lesser As and Hg, as well as some Ag (based on assay results of drill holes).

Phyllic Alteration: This alteration is a hydrothermal alteration zone in a permeable rock that has been affected by circulation of hydrothermal fluids. Phyllic alteration is characterized by the assemblage of quartz-adularia-pyrite, and occurs at high temperatures and moderately acidic (low pH) conditions.

In Gadir horst phyllic (quartz-adularia-pyrite) alteration mainly and mostly related with Quartz Porphyry Body (QPB) where ore is localized. According to epithermal alteration model the AIMCDD115, AIMCDD116, AIMCDD117A drill holes intercepted the phyllic alteration around of massive sulfide stock, which is intercepted by AIMCDD106 and AIMCDD107 drill holes. Quartz-adularia veins mostly developed in silicified hydrothermal breccias and stuff in QPB. The thickness of these veins is approximately 1mm. Also they could be like sheeted and truncated veinlets.

Tourmaline may appear as radiating aggregate or prismatic crystals between the quartz-adularia assemblages.

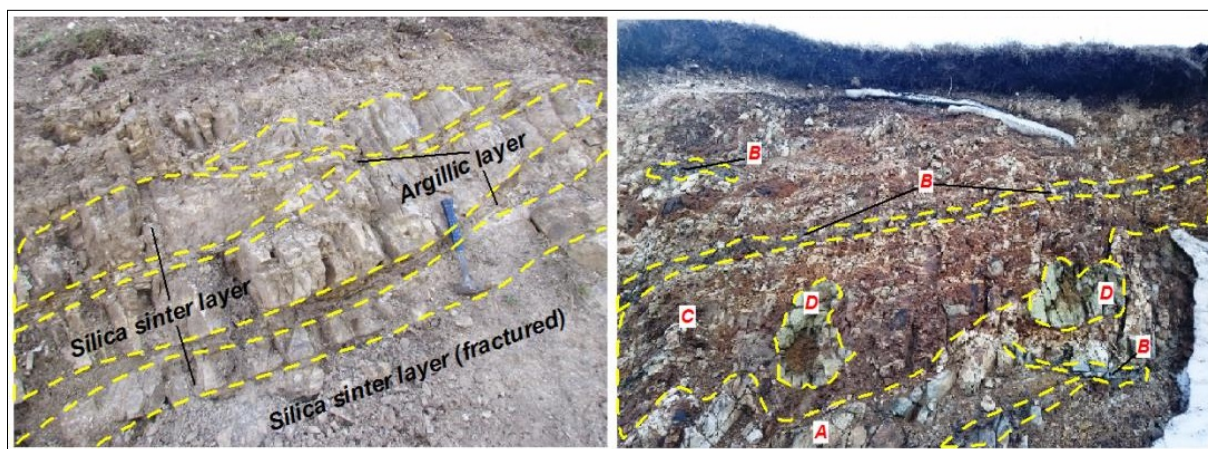


Figure 9. Silica sinter layer (left) and lacustrine siliceous deposit with fragments of eruption breccia (right): A-silica sinter layer, B-hornfelsed andesitic tuff sedimentary layer, C-silica sinter layer filled by Fe oxide minerals, D-prophylic altered breccia

Argillic alteration: This alteration is hydrothermal alteration of wall rock which introduces clay minerals including kaolinite, smectite and illite. The process generally occurs at low temperatures and may occur in atmospheric conditions. Argillic alteration is representative of supergene environments where low temperature groundwater becomes acidic. Argillic assemblages include kaolinite replacing plagioclase and montmorillonite replacing amphibole and plagioclase. Orthoclase is generally stable and unaffected. Argillic grades into phyllic alteration at higher temperatures in an ore deposit hydrothermal system.

Potassium metasomatism alteration: Potassium metasomatism of diverse origins has affected volcanic and sedimentary rocks. The volcanic rocks that range in composition from basalt to rhyolite may have low Na_2O and anomalously high K_2O content which is indicative of metasomatism. Based on their anomalously high K_2O content in deep zones of Gadir deposit referred to as high-potassium alteration.

In Gadir deposit under quartz porphyry this alteration has deep features. The characteristic minerals of the potassic alteration are K-feldspar, biotite and sericite (Figure 10). This mineralogical assemblage develops with a pervasive character in the central part of the porphyry quartz-microdiorite stock. The potassic alteration with

adularia is specific for the epithermal system associated with volcanic rocks. This alteration, characterized by the replacement of the primary minerals with secondary biotite, K-feldspar, sericite is associated with sulfides (pyrite, chalcopyrite), magnetite and pyrrhotite. This mineral assemblage suggests the presence of a “porphyry copper” system [18,20].

As we see in this section the sample of hornfelsed rock consists in 35% of quartz-adularia, 35% of biotite (mica), 29% of pyrite and 1% of accessory minerals (apatite, sphen and etc.). The relatively high concentration of quartz-adularia in percent became due contact metasomatism between hornfelses with quartz-porphyry. The higher concentration of biotite mineral in percent mean the transformation of primary minerals (pyroxen+magnetite+quartz) under the high temperature and pressure.

In addition low sulfidation (LS) epithermal gold deposits of the alkalic and subalkalic subtypes share a number of characteristics and are described together. Differing characteristics of the less common alkalic LS deposits are highlighted where appropriate. Most LS gold deposits are found in intra-arc or back-arc rifts within continental or island arcs with bimodal volcanism. Rifts may form during or after subduction or in post collisional settings.

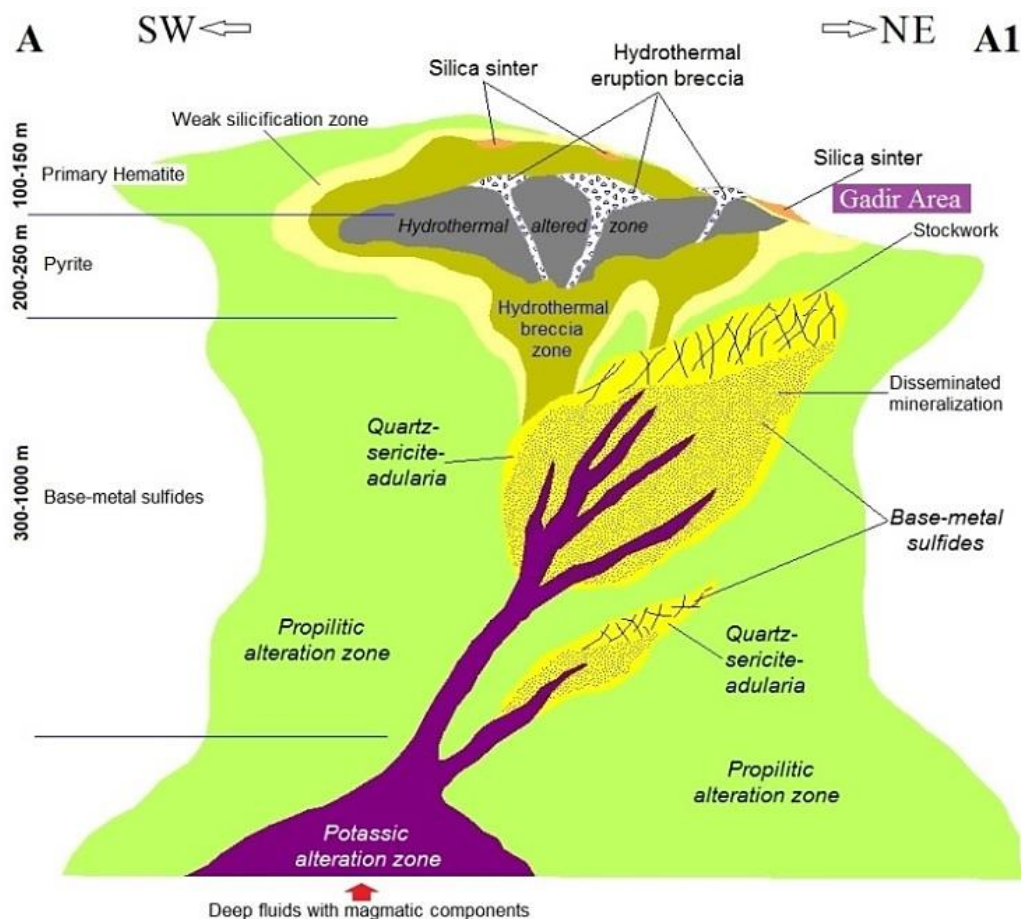


Figure 10. Hydrothermal alteration cross section SW-NE direction for Gadir LSED (by GEG, 2015) [16]

Additionally, some LS deposits are found in andesite-dacite-rhyolite volcanic arcs, but only in clearly extensional settings [21]. Deposits of the alkalic subset of low sulfidation epithermal deposits are specifically associated with alkaline magmatic belts but share an extensional setting with their calc-alkaline counterparts. At the deposit scale, LS gold deposits are typically hosted in volcanic units, but can also be hosted by their basement.

Alteration mineralogy in LS systems shows lateral zoning from proximal quartz-chalcedony-adularia in mineralized veins, which commonly display crustiform-colloform banding and platy, lattice-textured quartz indicative of boiling; through illite-pyrite to distal propylitic alteration assemblages (Figure 10). Vertical zoning in clay minerals from shallow, low temperature kaolinite-smectite assemblages to deeper, higher temperature illite have also been described [22]. As with HS and IS systems, host rock composition can also cause variations in the alteration mineral zoning pattern in LS systems. Alteration assemblages in alkalic LS deposits commonly contain roscoelite, a V-rich white mica, and abundant carbonate minerals [8].

2.5. Mineralization

The Gadir deposit is belong to Pb-Zn-Cu-Ag-Au vein deposit which is characteristic to Low-Sulfidation epithermal deposit. The main ore minerals are sulfides.

Sulfides consist of pyrite, sphalerite, galena, and trace amounts of chalcocopyrite [16].

Silver content of the deposit is highly variable. The higher grade silver zones tend to be peripheral to the high grade gold zones. The majority of the gold mineralization is very fine-grained (0.5 to 30 microns) occurring as free grains in quartz gangue, and locked grains in pyrite, chalcocopyrite and sphalerite. Gold is also, to a lesser extent, present in galena. Higher gold grades, however, are not directly related to sulfide percentages.

There also occur secondary sulfides. Quartz and clay grades (kaolinite, chlorite, hydromicas saturated by iron oxides) are basic gangue minerals.

The main ore bearing mineral associations are described below:

Quartz-chalcocopyrite-galenite-pyrite-barite± magnetite association mainly obtained in upper levels of Gadir mine. Chalcocopyrite, sphalerite, galenite, pyrite are in disseminated shape. Barite and magnetite occur in veinlets (Figure 12).

Quartz-chalcocopyrite-pyrite-sphalerite association occurs parallel with above mentioned association minerals mainly has fine disseminated structure like stock (Figure 11).

These two associations are main ore-rich bearing. The highest grade of gold is located in upper levels in Gadir mine.

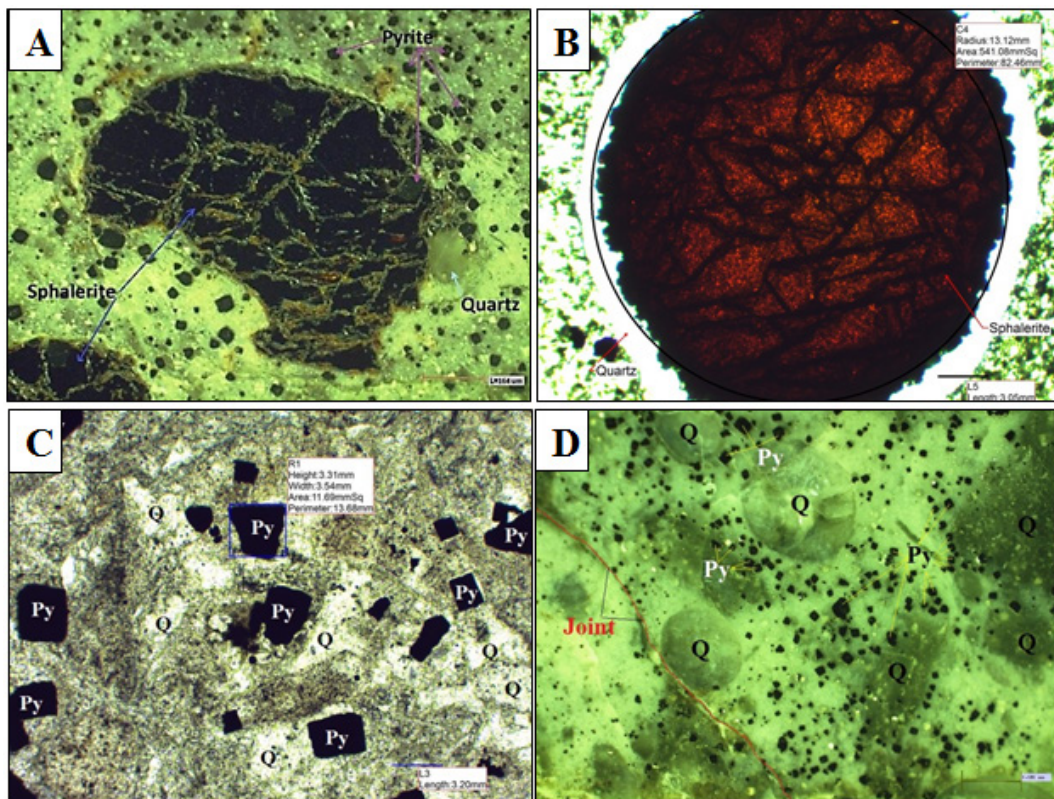


Figure 11. Photomicrographs (reflected light) and SEM imagery (back-scattered) of mineralizations from the Gadir deposit: A) Quartz-pyrite-sphalerite association; B) Sphalerite grain in quartz; C) Cubic pyrite crystal; D) Quartz-pyrite association Abbreviations: Q = quartz; Py = pyrite

Quartz-tourmaline-pyrite association is located in marginal parts of the ore-rich zone. Radial tourmaline surrounded by chlorite-epidote.

Quartz-pyrite±barite association occurs like massive pyrite stocks. Pyrite has coarse grain size minerals. Intensive developed the crystalline pyrite in intergrown with disseminated forms.

Quartz-chalcopryite±pyrite association developed in uppers and intermediate levels. Chalcopryite is disseminated and contain high grade of ore. Pyrite has less quantity and very grain size, located in relicts of contact rock (Figure 12).

Quartz-sphalerite±barite association like previous occurs in upper levels. Massive sphalerite ore-stock intercepted by barite veinlet.

Quartz-amethyst-pyrite association occurs in marginal part of quartz-tourmaline-pyrite mineral association, in edge part of Gadir deposit. Amethyst may occur in strong silicified stuff (or breccia) in quartz porphyry or in volcanic rocks near to contact of andesite with quartz porphyry.

Quartz-biotite-pyrite association occurs in deepest zone, below quartz porphyry body. This association related with potassic metasomatism alteration. The biotite, as lamellar or as grain crystals substitutes the plagioclase phenocrysts and the mafic minerals. Together with the sericite, apatite and quartz they also form grain aggregate in groundmass.

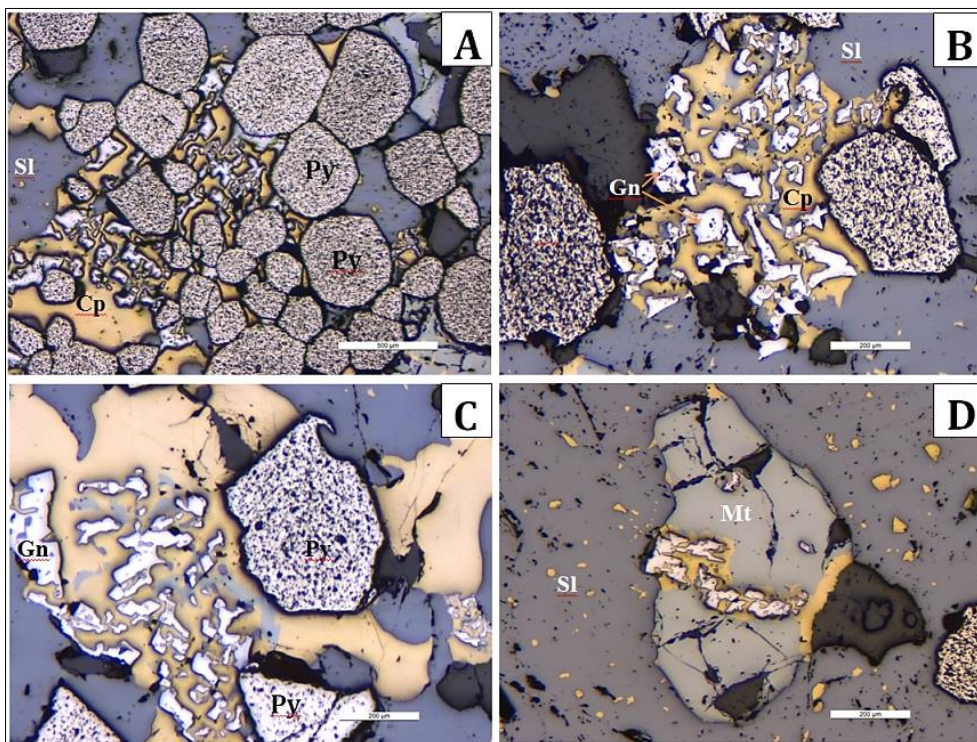
Pyrite in it turn has intermediate distribution. Association is manly located in hornfels intrusion which is closely related ore mineralization.

Quartz-carbonate±pyrite±chalcopryite association occurs as the late stage mineralization. It developed mostly in phyllic altered zone – quartz porphyry, less in propylitic altered zone – andesitic volcanic tuff.

All these mineral associations are intercepted by carbonate veinlets which more occur in fault and fractures zones.

Veins show banding, indicative of deposition in open spaces, whereas in other areas they show brecciation or narrow veins in stock-work fashion that indicate that the structure was closed or partially closed to fluid passage. Typically the ore zones of the veins form undulatory bands with vertical. At depth the veins commonly contain coarse massive veins of sulfides, whereas the upper portions generally show barren or low grade coarsely banded veins of quartz and calcite.

The sulfides in these veins can be coarse-grained and massive (massive veins of sulfides), can form bands alternating with quartz, chalcedony and calcite, or can occur as fine disseminations in quartz and calcite. Sulfides are generally fine to medium grained when they form bands. The sulfide minerals present in these veins include pyrite, sphalerite, galena, arsenian-pyrite-arsenopyrite, marcasite chalcopryite and pyrrhotite.



Abbreviations: cp = chalcopryite; gn = galena; mt = magnetite; py = pyrite; sl = sphalerite

Figure 12. Photomicrographs (reflected light) and SEM imagery (back-scattered) of mineralizations from the Gadir deposit: A) Cubic pyrite crystals showing granular textures. B) and C) Galena as inclusions of bright white fractured crystals, only found with on the chalcopryite. D) Magnetite-replacing chalcopryite. Within the chalcopryite are fractured, disseminated inclusions of galena. Sphalerite shows exsolution texture with chalcopryite, forming chalcopryite disease in sphalerite.

3. Methodology

Exploration Activities

The first step is to conduct a review of historical and existing data. Especially from closed down mines and terminated exploration, there often exist core samples and other relevant information which can be accessed. This can be result in great savings of time and money required for new activities. One of the cheapest phases of property exploration is preparation of a comprehensive, detailed and accurate geological map which often starts with basic instruments such as tape and compass. The accuracy can be enhanced by using air photos to help locate outcrops, major fault zones and basic topographic control. Each step adds some more costs, but it also improves the accuracy and detail of the resulting map.

Exploration is a term embracing geophysics, geochemistry, and finally the more costly activities drilling into the ground for obtaining samples from any depth. Efficient mineral exploration depends on increasingly sophisticated map production for planning purpose and access routes, for geological, geophysical, geochemical and structural mapping [14].

The collection of assay data is crucial to the development and exploration potential of Gadir, it shows in what direction the ore body and zones of highest grade mineralization are moving.

Soil Geochemical Surveying

Geochemical surveying is another exploration technology featuring several specialties, the main one being to detect the presence of metals in the topsoil. By taking a large number of samples over an extended area and analyzing the contents of each metal, regions of interest are identified. The area is then selected for more detailed studies. The geochemist will take stream samples on a regional basis covering many square kilometers of the supposed favorable terrain. That survey will be followed by more detailed sampling of variations in chemical composition of drainages and by soil sample grids in anomalous areas [12].

Gadir exploration works commonly includes programs of soil sampling. This entails digging holes at certain intervals to collect soil samples from identified horizons. The samples are placed in bags, dried, screened to collect the finer material and analyzed for "pathfinder" elements. A soil sampling survey might result in thousands of samples which need computer programs for efficient data handling.

During May and August 2014 year, 1359 soil samples were took on the Yogundag Mountain (NW Flank of Gedabek Mine) at 50m x 50m grid line. The purpose of the survey was to take soil geochemical samples on the identified five new potentially perspective areas. The soil samples were taken at depths of between 10-130cm with their respective coordinates taken and recorded. Other parameters which were recorded during sampling were the

landscape, regolith and vegetation [7].

The advancement and understanding of element mobility in soil profiles now sees near surface sampling playing a greater role around known mineralization (brownfields surveys) by providing vectors towards deeply buried targets. Planning an effective sampling program requires consideration of many variables, from site selection and spacing, soil horizon and fraction to be sampled, method of sampling and finally sample preparation and analysis at the laboratory.

Sample preparation at the laboratory should minimize any possible sources of contamination, so sieving is a recommended technique. Preparation should be conducted in a dedicated area, away from routine, higher grade samples. A wide range of analytical methods is available, from partial extractions such as Ionic Leach, to near total digestion, such as ME-MS41L, offering multi-elements to ppb levels of detection. These methods use the highly sensitive ICP Mass Spectrometer, thus providing a high degree of confidence in targeting early stage drilling.

The soil geochemical samples were taken from horizon "B". Traditionally 'B Horizon' soils have represented visual positions where elements have concentrated as minerals such as silicates, iron oxy hydroxides and carbonate crusts to name a few. This 'pre-concentration' can represent an ideal sample material for collection given the analytical methods now available.

Many soil samples programs have taken at the depth 10-130cm. During sampling the horizon "B" was the dominant. But in case when the bedrocks was on the surface and there was impossible to take samples form horizon "B" samples were took from soil in contact with rocks.

As with most sampling methods, it is important to be as consistent as possible in terms of type of material collected (but not necessarily the depth of sampling).

For most soil sampling surveys, 300-500 gr samples are sufficient although larger samples (2-3 kg) may be collected for duplicate and other purposes. Collected samples are generally placed in chemical-free paper (geochemical) bags suitable for air drying or drying in an oven. Sampling and field sieving was conducted in areas free from wind-blown contaminants, away from roads, fences, buildings, dams, and away from active mine sites.

Sampling method and approach: The MMI sampling and assays were done consistently for each survey and all assays at the same laboratory. Samples were collected 30cm below the true soil interface. Attention was done not to vary depth beneath true soil interface. Attention was done to collect sample in a consistent manner. For this sampling we took samples (called T-samples) from the same points where we took our previous samples for horizon "B".

Petrographic Microscope Data

In order to understand the ore geology, and the host rock geology of the deposit, sampling was carried out. This

entailed taking samples from the underground exploration galleries, and taking them to the surface. The samples that showed the most interesting geology, mineral assemblage or relevance to the project was chosen to be polish sectioned and polish block back at Baku State University and Cardiff University.

SEM or Scanning Electron Microscope is a machine that allows the user to look at a sample in extremely high magnification and resolution. In the interest of the development and exploration potential of Gadir, SEM was used to find native visible Au grains as well as paragenetic sequences with other sulfides. The sample was initially placed in a vacuum chamber, containing two graphite rods whilst the sample was pressurised at 10^{-4} kbars. These rods had a high current passed through them, causing the graphite to sublime and produce carbon 'dust'. The carbon dust settles on the sample at a thickness of 19-20 nm. The carbon coating allows the electrons emitted from the SEM to settle over the surface of the sample, rather than reflected as and so the resolution is improved.

A piece of copper tape is applied to attract any excess electrons, which could interfere with the SEM picture. The electron gun produces the electron beam controlled by an anode and a cathode. The sample is placed in the SEM chamber, which is also pressurised to 10^{-4} kbar. For the purpose of this study a 50-micron aperture was used.

As the electron beam hits an atom, contained within a mineral, the atom emits an electron from its outer shell, which is taken up by a positively charged detector. The electromagnetic energy given out by the electron is specific for each element, allowing a chemical signature to be produced. The SEM sends the information to a computer with the software INCA, which analyses the information and displays it. The data is then ready for analysis and to be exported in form of a picture of the mineral and a graph of the elemental peaks, allowing the user to quickly analyse the chemical composition of the mineral being investigated.

LA-ICP-MS (Laser Ablation) Data

To support the SEM and petrographic microscope studies performed on polish thin sections from Gadir, a LA-ICP-MS study was carried out on a polished block, consisting of sphalerite, galena, chalcopyrite and pyrite. The LA-ICP-MS or Laser Ablation Inductively Coupled Plasma Mass Spectrometry is an analytical tool used to discover the presence of elements dissolved inside the lattice of other minerals. This analytical method is used to find dissolved gold in crystal lattices of sulfides. LA-ICP-MS uses a high intensity laser beam that focuses on a particular section on the sample, creating a linear path across the centre of the sample. This high intensity laser beam causes the minerals at the surface to sublime; this process is known as ablation. After producing the vapor, the particles are transferred to a secondary excitation source, where they are digested and ionized. The ionized particles produced from the laser ablation are then

channeled into a mass spectrometer.

The mass spectrometer is highly sensitive and able to pick up small elemental peaks and percentages. For the purpose of this study and in the interest of the development potential of Gadir, the focus for the LA-ICP-MS was to detect Au and Ag peaks in different elemental phases. As well as Au, the LA-ICP-MS can detect elements, which could be classified as pathway elements for Au such as Sb and As. The data for LA-ICP-MS is displayed in the form of a graph, with counts per second displayed on the y-axis on a logarithmic scale and time displayed on the x. With this data and the knowledge of when the Laser Ablation enters a different mineralogical phase, it is possible to formulate an idea of what mineral lattices are hosting the Au and Ag and what 'pathfinder' elements the Au and Ag follows. After the counts per second for Au are recorded the scale is then converted to parts per million (ppm) using a technique described by a lecturer at Baku State University and Cardiff University.

4. Results

At Gadir area, on the basis of field observations, geochemistry based on immobile elements and oxygen isotope data of the "quartz-porphyry" ore body, this study excludes its primary magmatic nature and proposes it to be the result of a quartz \pm adularia \pm pyrite alteration overprinting the andesitic tuff along a more permeable horizon.

Field observations combined with metal content analyses reveal an extensive low grade ore body associated with the quartz \pm adularia \pm pyrite alteration, and high grades semi-massive sulfide lenses spatially associated with fault structures in the central part of the deposit. Sulfur isotope data obtained for sulfide and sulfate mineralizations indicate an igneous source of sulfur, precipitated in a reduced environment. Furthermore, the general enrichment in volatile elements (Te, Se, Hg, Sb, As) is typical of an epithermal environment [6,16].

Based on a detailed petrographic study of the different mineralization types, this study defines a new paragenetic sequence subdivided in four stages. The first stage is represented by the quartz-adularia-pyrite assemblage observed as a pervasive hydrothermal alteration and as small semi-massive lenses localized in the central part of the deposit. The quartz-adularia-pyrite assemblage was formed in a reduced and neutral environment typical of low-intermediate sulfidation systems. The second stage consists of a chalcopyrite-sphalerite dominated mineralization with a general intermediate-sulfidation state, and shows an evolution from the low-intermediate toward the intermediate-high boundaries of the sulfidation state. The third event is the late copper enrichment of high sulfidation state, represented by the replacement of the second stage chalcopyrite and sphalerite by chalcocite, covellite, and enargite mineralization. The fourth stage is

dominated by galena and tennantite mineralization, interpreted to be associated with an intermediate-high sulfidation state, but its timing in the paragenetic sequence remains ambiguous.

The mineral paragenesis of the mineralization can be divided into five stages in Gadir deposit (Figure 13).

Main sulfide stage is characterized by deposition of medium and coarse-grained quartz, initially euhedral galena, pyrite II, chalcopyrite and tetrahedrite. The alteration assemblage accompanying main sulfide stage is muscovite illite and montmorillonite whereas ankerite-dickite-kaolinite may have formed in the later part of main sulfide stage and/or during the supergene stage. Moderately deformed arrays of triangular cleavage pits are commonly present within galena, suggesting that galena has undergone some deformation without complete recrystallization during later tectonic events.

Stage 1: This stage is characterized by deposition of coarse-grained galena and sphalerite with fine grained silver sulfosalts and minor chalcopyrite. Sphalerite in this stage is commonly zoned showing the dark brown to black color, with yellow-orange rims low in iron. Inclusions of chalcopyrite and pyrrhotite are common in sphalerite. Chlorite also occurs associated with this massive vein but it

seems to be late with respect to sulfides.

Stage 2: This stage is characterized by deposition of medium- to fine-grained quartz and calcite veinlets cross cutting the coarse-grained sulfides in Stage 1 and the host rock. This quartz and calcite typically show abundant disseminated sulfides and it is possible that at least some of them are reworked grains formed during Stage 1.

Stage 3: This stage is characterized by deposition of alternating bands, rarely symmetrical crustiform-banding, of quartz, calcite and sulfides (sphalerite, galena, pyrite and arsenopyrite). Minor constituents forming thin bands or included in quartz and calcite bands are epidote, hematite and clay minerals. Pyrargyrite and the other silver sulfosalts occur disseminated in quartz and calcite or associated with sphalerite and galena in the bands of sulfides.

Stage 4: This stage consists of calcite, dolomite – ankerite and quartz veins or stringers with pyrargyrite that cross cut stages 1, 2 and 3.

Stage 5: This stage is barren and consists of milky and amethyst quartz and calcite with minor disseminated pyrite and marcasite and sometimes fluorite. Fluorite appears to be the last mineral to have been deposited.

MINERAL ZONATION OF GADIR DEPOSIT

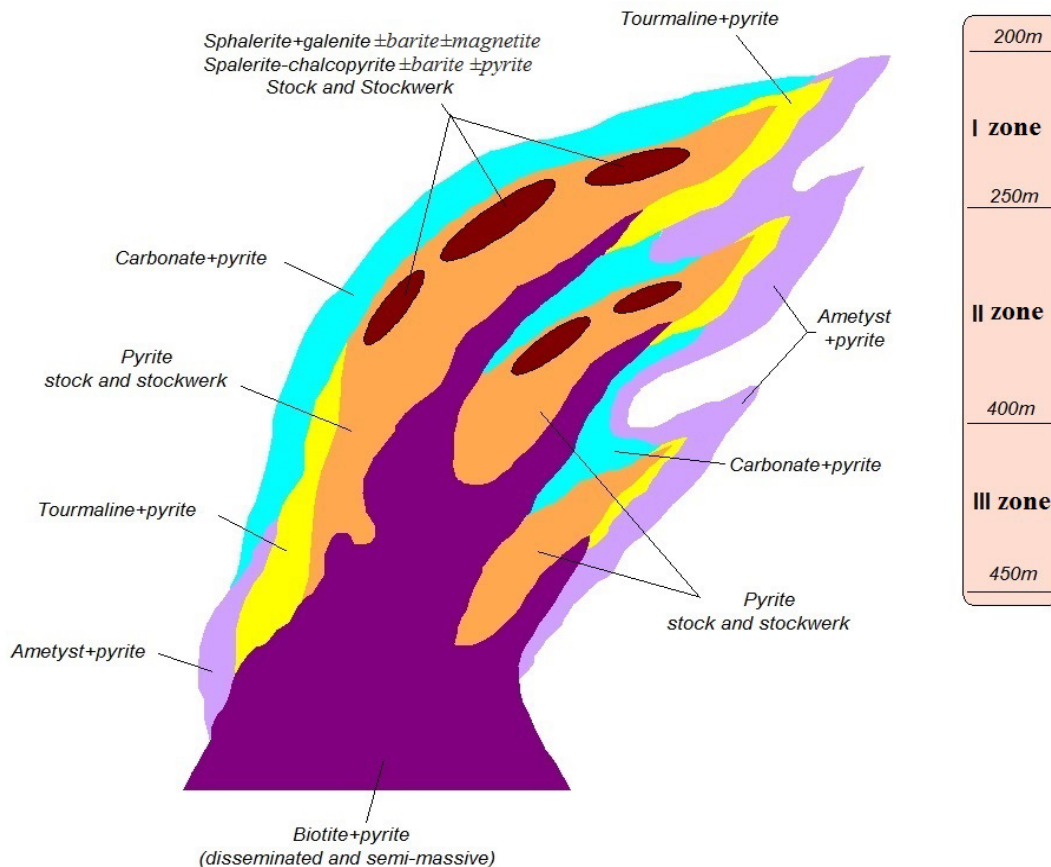


Figure 13. 2D Model of mineral zonation of Gadir deposit

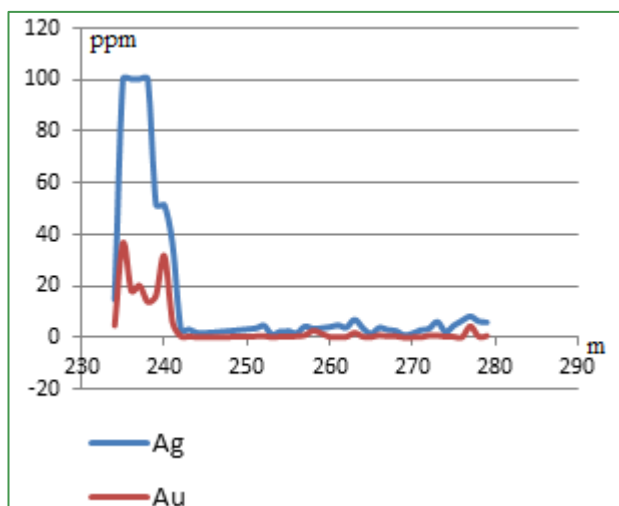


Figure 14. Ag and Au correlation of the different mineral associations

Metal Contents

The Ag/Au ratio (base drill hole assay results) varies between 0.01 to 47 (maximum 79), average about 10. As seen from diagram this ratio is not constant into depth which is characteristic for low sulfidation epithermal deposit (Figure 14). Ag is especially enriched in the hydrothermal breccia bodies, as well as in association with the polymetallic ores where the observed concentration is up to 50 ppm [24].

Despite of this Ag and Au has good correlation between each other (coefficient is 0.867). The different mineral associations have different ranges of Au, Ag and Cu grade. The monomineral analyzes mentioned above is one of the providers of this [23].

In below images are shown the Ag, Au and Cu grades of different mineral associations and rock type. All Ag, Au and Cu grades data are summarized in the table. It is clear that quartz-pyrite-chalcopyrite-sphalerite association and andesite-quartz porphyry (contact rock) rock type are the main rich metal containing (Table 1) [24].

Table 1. Metal content of mineral associations and rock types

Mineral associations and rock types	Metal content		
	Ag ppm	Au ppm	Cu %
Quartz-sphalerite-pyrite stock	136.3	1.56	0.44
Andesite (contact with quartz porphyry)	5.19	0.46	0.01
Quartz-sphalerite-chalcopyrite-pyrite-barite	136.2	1.56	0.44
Andesite-quartz porphyry (contact rock) with kaolin lenses	25.93	6.81	0.21
Quartz-pyrite-chalcopyrite	5.02	0.24	0.08
Quartz-pyrite veinlet ± illite	12.37	1.15	0.06
Andesite (contact rock) with quartz porphyry + biotite	1.52	0.1	0.02
Andesite with magnetite vein and weak silica solution	0.375	0.025	0.01
Quartz porphyry with strong silicified solution and breccia, sphalerite and pyrite in nest	10.86	0.23	0.01
Quartz porphyry with pyrite-tourmaline mineralization and phyllic-potassic alteration	4.37	0.13	0.01

The other ore polymetallic elements such as Cu, Pb and Zn have a good correlation between each other. The coefficients of correlation between these elements and gold are shown in Tables 2 & 3 [23].

Table 2. Correlation coefficients between Cu, Pb and Zn.

Ore type	Quantity of samples	Elements			
			Cu	Pb	Zn
Massive	20	Cu	1,00		
		Pb	0,50	1,00	
		Zn	0,58	0,91	1,00
Vein-disseminated	26	Cu	1,00		
		Pb	0,81	1,00	
		Zn	0,86	0,84	1,00

Table 3. Correlation coefficients of Au between Cu, Pb and Zn in vein-disseminated ore type

Quantity of samples	Elements		
	Cu	Pb	Zn
20	0,69	0,80	0,93

The correlation diagrams between Cu, Pb and Zn into depth are shown in Figure 15 [23].

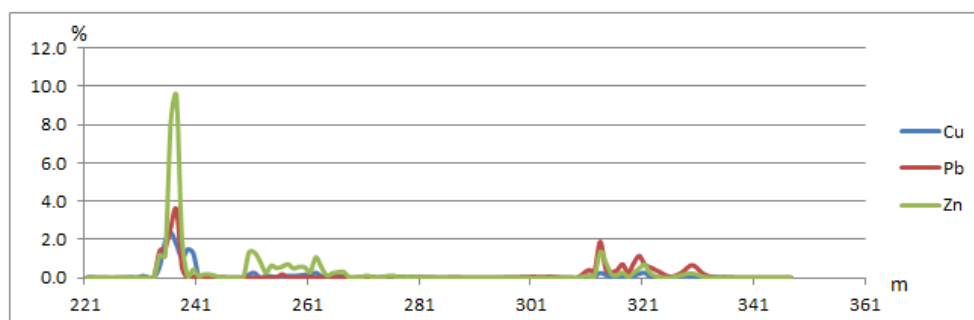


Figure 15. The correlation diagrams between Cu, Pb and Zn

It is apparent from the present study that the hydrothermal system was predominantly formed in an early low-intermediate-sulfidation environment, locally overprinted by a high-sulfidation system. Fluids forming the low-intermediate-sulfidation system were neutralised and reduced by wall rock interaction, either during their ascent from a deep seated magmatic intrusion, or during convection within a hydrothermal reservoir. The opposite is required for the formation of the high-sulfidation hydrothermal system, which was formed by oxidised and acidic fluids generally exsolved from a shallow magmatic intrusion and enhanced by mixing with meteoric water.

Future work should include a better mapping of the different alterations and mineralization types. A fluid inclusion study of the mineralization appeared to be difficult at Gedabek, but would be crucial to constrain the depth and temperature of formation of the hydrothermal system. Additional dating of the mineralization would be key data to exclude or support the hypothetical role of the Gedabek intrusion as the mineralizing intrusive event. Furthermore, a more detailed study of the high-sulfidation mineralization is necessary to better constrain its time and spatial relationship with the low-intermediate sulfidation state system [3,4].

Any comments and suggestions are welcomed so that we can constantly improve this template to satisfy all authors' research needs. In recent years geological exploration and scientific investigations in the Gedabek deposit are clarified that deposit is a part of the epithermal system which belong to high sulfidation type with Cu-Au-Ag ore mineralization. Discovering of Gadir low sulfidation deposit with Au-Ag-Zn-Pb ore mineralization gives background to think about the existence of porphyry system (Cu-(Au, Mo)) near Gedabek deposit.

5. Discussion

Ore District Formation

Observations made in the Gedabek ore district are in agreement with the description as a porphyry-epithermal district. The alteration model, proposed by Gedabek Exploration Geologist (2015), suggests that the Gedabek, Gadir, Umid, Zefer and Ugur ore perspective areas represent the upper part of the epithermal system. This is more or less consistent with the Gedabek-Bittibulag ore belt estimated at ~10 km by GEG. However, no explanation was proposed to explain the preservation of the Bittibulag high-sulfidation epithermal deposit [10].

Volcanoclastic rocks, dated from Bajocian to Bathonian are intruded by two main intrusive events. The comparison of different ages of these intrusions and dating of the Kharkhar mineralization (Re-Os, Moritz, 2012, pers. comm.) are represented [17]. Every intrusion spatially

associated with ore deposits (Gedabek, Dashkasan, Djaygir, Ertepe) indicate similar ages belonging to the second intrusive event. This is consistent with the Kimmeridgian mineralising event observed in the Lok-Karabakh volcanic arc [10,19].

Despite the general alteration in the area, geochemical data from the Gedabek ore district are consistent with a subduction related magmatism, generally with a basaltic to andesitic composition.

Formation of the Gadir Deposit

GEG reported that the Gadir deposit was formed by two events. The first event is the formation of the "pyrite stock" (here interpreted as a quartz-adularia- pyrite alteration) related to small Later Bajocian sub-volcanic rhyolite-dacite bodies. The second event is described as "copper-pyrite" and "copper-zinc" mineralization (here, named chalcopyrite-sphalerite-dominated mineralization) and is reported to be formed by the post-magmatic activity of the Gedabek intrusive.

Low-intermediate- and intermediate-high-sulfidation epithermal deposits are commonly described to both develop in converging plate tectonic settings. However, distinct processes of formation are characteristic for these two different types of epithermal deposits [20,22]. Therefore, the occurrence of a typical low sulfidation mineralization at Gadir would rather be the result of the superposition of two distinct events, with a close spatial but no genetic association.

The low sulfidation system at Gadir (quartz \pm adularia \pm pyrite alteration and chalcopyrite-sphalerite-dominated mineralization) could have been formed by a deep seated intrusion. The oxidised and acidic magmatic fluids released by the intrusion would be neutralised and reduced by wall-rock interaction along their ascent and form a low sulfidation deposit at the epithermal level.

However, this study also proposes an alternative model to explain the formation of the Gadir deposit with a continuous evolution from a low-intermediate- toward an intermediate-high-sulfidation system.

Favored Model for the Formation of the Gadir Deposit: Analogy with the Tokaj Mountains Deposits, Hungary

The favoured model for the formation of the Gadir deposit is based on the model by Ferenc Molnár and etc. (2003) for the Tokaj Mountains deposits [13]. This model provides a possible explanation for the formation of the alteration and mineralization sequences, observed at Gadir, within a continuous evolution of the system in space and time.

Applicability to the Gadir deposit:

Both the propylitic and quartz \pm adularia \pm pyrite alterations show a strong lithological control, with the

alteration of some preferential tuff layers. No lower permeability horizon is described at Gadir; however it is obvious that the pathway followed by fluids is mainly controlled by tuff permeability. Furthermore the assumption of a less permeable horizon is consistent with the flat-lying contact reported between the quartz \pm adularia \pm pyrite alteration and the subhorizontal andesitic tuff.

The model proposed by Sander and Einaudi (1990) does not discuss the origin of the fluids at Round Mountain [17]. One possibility at Gadir would be the exsolution of fluids from the cupola of the diorite. However, there is no evidence about the source and the nature of the magmatic-hydrothermal ore forming fluids at Gedabek.

Mineralization observed in the QPB indicates redox and pH conditions favorable for the solubility of gold. No evidence of minor superficial discharge or mixing with meteoric water above the system is reported at Gedabek, but such evidence may have been eroded. However, if there was large local surficial discharge, then the gold content may have been transferred to a shallower geothermal system, and would not have been preserved at Gedabek.

General Remarks:

This model of formation is not commonly described in the literature and involves processes unlikely to happen in many systems. Therefore, further work is necessary to confirm the applicability of the Gadir model on the Yogundag epithermal system. However, every observation done in this study is consistent with such a model and allows us to explain the formation of the pervasive quartz \pm adularia \pm pyrite alteration and the different features observed in the South-East part of the Yogundag epithermal system: (1) the high grade semi-massive sulfide lenses; (2) the fluid evolution from low-intermediate- to high-sulfidation state; (3) the transition toward sericitic and argillic alterations; (4) the occurrence of vuggy-silica and (5) silica sinter and lacustrine siliceous deposit reported by GEG (2015).

This study is mostly focused on the “central part” of the deposit. However, if this model is confirmed for the formation of the Gadir deposit, other parts of the deposit with similar features can be expected. Therefore, fault structures and associated silicification alteration would be good indicators to explore for other high grade lenses at Gadir.

Gold Precipitation Mechanisms:

The Gadir deposit is mainly represented by the pervasive quartz \pm adularia \pm pyrite alteration, and the local pyrite-chalcopyrite-sphalerite-dominated mineralization. Other mineralization types are minor in volume, and only associated with the central part of the deposit.

Therefore, the environment of the hydrothermal system at Gadir can be considered to be globally neutral (adularia) and reduced (pyrrhotite inclusions, sulfur isotopes). It can

be noticed that in general the environment at Gedabek is favorable for the gold to stay in solution as Au(HS)-complex.

Unfortunately, this study does not provide any data to constrain the pressure and temperature during mineralization at Gedabek. However, Simmons et al. (2005) proposed a general range of temperature comprised between 300 and 150°C for low-intermediate-sulfidation deposits. Therefore, it represents the gold solubility for the highest temperature expected in low-intermediate-sulfidation epithermal systems (300°C).

Because of the lack of evidences, this study does not allow us to establish any preferential mechanism for gold precipitation at Gadir. However, two main processes for gold precipitation are described at other deposits, and are based on a complementary fluid inclusion study. GEG (2015) propose two main processes for gold deposition at Gadir: (1) slow cooling of the bulk hydrothermal reservoir leading to a low grade and large tonnage gold deposition together with quartz and adularia; and (2) local mixing with meteoric water leading to high gold deposition. These two mechanisms are discussed here in the aim to test if they are applicable to gold deposition at Gadir.

Classification of the Gadir Deposit:

Based on commonly used classifications for epithermal deposits, Gadir is predominantly characteristic of a low sulfidation deposit or of “quartz \pm calcite \pm adularia \pm illite” assemblage. However, minor mineralization typical of the “low sulfidation type”, or typically associated with “quartz + amethyst \pm tourmaline \pm dickite \pm smectite” assemblages, is also observed around Gadir orebody [15,16].

Therefore, these classification are not the most appropriate ones for the description of the Gadir deposit. The Gadir deposit is better described following the systematic of classification proposed by GEG (2015). These studies therefore allow us to classify the Gedabek deposit as a “quartz \pm adularia \pm pyrite altered Au-Cu-Ag epithermal deposit”.

6. Conclusions

This study provides new data on the geological of the NW Flank of Gedabek porphyry-epithermal deposit, and a new insight into the lithological-structural, hydrothermal alteration and mainly mineralogical formation of the Gadir low sulfidation epithermal deposit. Geochemistry carried out on various magmatic rocks from the Gedabek ore district indicate a calc-alkaline composition for the magmatism related to the subduction setting of the Lok-Karabakh volcanic arc, with basaltic to andesitic compositions [10].

The Yogundag epithermal system was introduced by GEG with more lithological factors such as silica sinter, lacustrine siliceous deposit, eruption breccia pipe. The

latest international geological models show that the potential ore located around of eruption breccia. These factors is helpful in understanding the model of ore forming in epithermal processes and will be guideline for future exploration drilling on silica sinter and around of eruption breccia pipe zones. During the detailed geological mapping was corrected the contact zones between the rock which composed the volcanic of Bajocian and Bathonian ages. Also was corrected the texture of rock consisting the sediment of above mentioned ages.

The Yogundag epithermal system is located on Gedabek-Bittibulag deep fault which is has ore potential. All soil geochemical data, lithological and structural factors show that, the horst zones are potential for ore. The Gadir area is located in geomorphological visible horst. The identified horsts also will be guideline for setting the new drill holes locations.

The zoning alteration in Gadir area is determined by: the variation of the composition in the magmatic intrusions, the variation of the physicochemical conditions in the mineralization periods specific to the two magmatic chambers (East and depth). In the East part of the area alteration is associated with the porphyry quartz-dioritic stock. The surface and subsurface alterations are associated with eruption breccia pipes in NW Flank.

In the central part of the stock the potassic alteration (K-feldspar+biotite) associated with disseminated pyrite and chalcopyrite, also is emphasized for epithermal porphyry-copper system. The phyllic alteration is disposed in the exterior part of the potassic zone. It is associated with base-metal veins and partially with the copper veins situated in the nearest parts of the quartz-dioritic stock. In the outward parts of the quartz-dioritic stock there are disposed argillic alteration, silicification and potassic alterations. These are associated with gold and with the upper part of the base-metal veins and lenses.

The zoning of the alteration associated with the porphyry quartz-diorite dykes from the NW part of the Gadir area is typically near vertical. In the deepest parts of the intrusions the propylitic alteration is predominant and it is associated with the copper mineralization. The phyllic alteration is present with an extensive development in the quartz-diorite body and especially in the lava flows of the andesites, associated with the Pb-Zn mineralization. The upper parts of the volcanic structure are dominated by the

argillic alteration together with the silicification specific to the complex mineralization (Pb-Zn-Cu-Au-Ag). The overlapping is specific for the alteration types in the Gadir ore deposit.

For better understanding the hydrothermal alteration processes look at the international geological model which is applied for Yogundag epithermal system (Figure 16).

The soil geochemical works of the NW Flank of Gedabek Mine area confirmed presence of ore perspective areas for gold, silver, zinc and copper. Au-Sb-Bi-Th-Ce-Zr anomalies mark the paths of all major structure zones in the Gadir and area with general direction of NE-SW, which coincide to a proven control of mineralizing fluids along those fault zones. These anomalies confirm paths of already proven ore bodies in the Gadir low sulfidation deposit.

Results of soil geochemical data have shown that there is a relationship between K, Mg, Al, Cu, Mo, Au and Ti values in the rock units and different alteration zones in the NW Flank. Moreover, statistical parameters and interpretation of these elemental values have shown that there are also high amounts of Ti, Al, K and Mg values. K values are high in the silicification alteration zone, especially in the Gadir.

Epithermal gold deposits occur largely in volcano-plutonic arcs (island arcs as well as continental arcs), with ages similar to those volcanism. Gedabek and Gadir deposits are located on the arc which possible to see by geomorphological situation. The deposits form at shallow depth, around 1.5km, and are hosted mainly by volcanic rocks. The two deposit styles form by fluids of distinctly different chemical composition in contrasting volcanic environment.

The results of exploration in Gadir area show that the most of alterations which related with ore mineralization are located along the Gedabek-Bittibulag deep fault.

The mineral assemblages (pyrite, chalcopyrite, sphalerite, pyrrhotite and magnetite) and types of hydrothermal alterations (propylitic, oxidation, argillic, silicification and carbonatization) factors give us reason to say that Gadir area is belong to low sulfidation epithermal system.

All above described and mentioned give us assurance that there must be porphyry body discovering of which requires more advanced field exploration (mapping and sampling) and deeper drill wells.

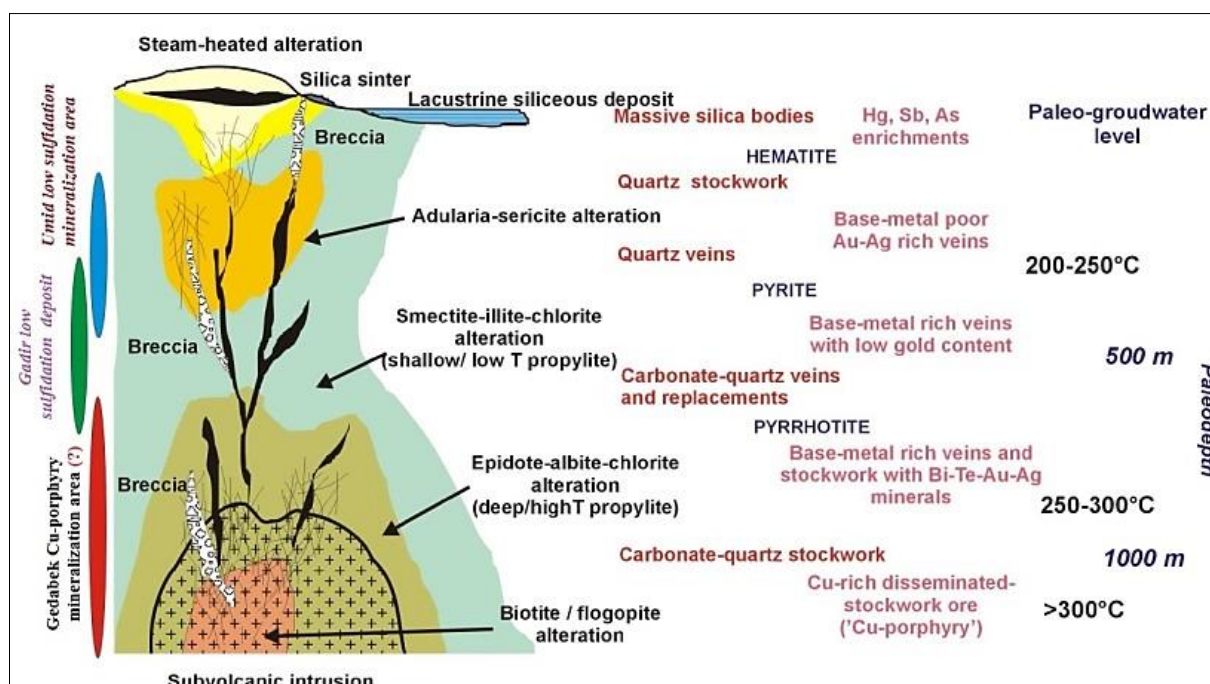


Figure 16. Epithermal model for Gadir low sulfidation deposit (on example of Tokaj Mountains epithermal system data, Hungary) [13]

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