Revista Geoaraguaia
ISSN:2236-9716
Barra do Garças – MT
v.11, n.2, p.49-74. Dez-2021

STUDY OF PETROGENESIS, MODELING AND INVOLVED FLUIDS IN IGNEOUS ROCKS IN THE AREA OF TANURJEH DEPOSIT

ESTUDO DA PETROGÊNESE, MODELAGEM E FLUÍDOS ENVOLVIDOS EM ROCHAS ÍGNEAS NA ÁREA DO DEPÓSITO DE TANURJEH

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ABSTRACT

Tanurjeh porphyry copper-gold deposit is located in Khorasan Razavi province, south of Neishabour and 5 km south of Tanurjeh village. The types of rocks in the study area include andesite, porphyry diorite, quartz porphyry diorite, porphyry granodiorite, rhyolite, rhyodacite and tuff, and metal minerals include magnetite, chalcopyrite, pyrite, iron oxides and hydroxides, covellite, malachite, galena, sphalerite, malachite, rutile and gold particles. To accurately detect copper and gold anomalies from the field, the fractal geometry-number method was used. A combination of exploratory layers was performed to identify suitable areas for exploratory drilling. To determine the temperature of the deposit formation and its chemical properties, salinity of the trapped fluids was taken. Evaluation of the involved fluids indicates that the primary fluids have high salinity and the secondary fluids have medium salinity and primary fluids homogenize at 319 to 514 ° C and secondary fluids at 138 to 345 ° C. These results show the mineralization of copper and gold in terms of porphyry system type and mineralization can continue to depths of more than 350 meters. However, the absence of stock quartz veins, the presence of a large siliceous zone and the lack of mineralization of copper are some of the things that make a difference compared to porphyry copper systems. As a result, this area can be considered as a porphyry copper-gold mineralization area in which mineralization has been done in depth and in the vicinity of the intrusion mass and in some places points are seen as streaks on the surface.

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Keywords: Petrogenesis; Involved Fluids; Igneous Rocks; Tanurjeh Deposit.

RESUMO
O depósito de cobre e ouro de pórfiro de Tanurjeh está localizado na província de Khorasan Razavi, ao sul de Neishabour e 5 km ao sul da vila de Tanurjeh. Os tipos de rochas na área de estudo incluem andesito, pórfiro diorito, quartzo pórfiro diorito, pórfiro granodiorito, riolito, riodacito e tufo, e minerais metálicos incluem magnetita, calcopirita, pirita, óxidos e hidróxidos de ferro, covelita, malaquita, galena, esfalerita, partículas de malaquita, rutilo e ouro. Para detectar com precisão anomalias de cobre e ouro do campo, o método do número da geometria fractal foi usado. Uma combinação de camadas exploratórias foi realizada para identificar áreas adequadas para a perfuração exploratória. Para determinar a temperatura de formação do depósito e suas propriedades químicas, a salinidade dos fluidos aprisionados foi medida. A avaliação dos fluidos envolvidos indica que os fluidos primários têm salinidade elevada e os fluidos secundários têm salinidade média e os fluidos primários homogeneizam a 319 a 514 ° C e os fluidos secundários a 138 a 345 ° C. Estes resultados mostram a mineralização de cobre e ouro em termos de tipo de sistema de pórfiro e mineralização podem continuar a profundidades de mais de 350 metros. No entanto, a ausência de veios de quartzo de reserva, a presença de uma grande zona siliciosa e a falta de mineralização do cobre são algumas das coisas que fazem a diferença em comparação com os sistemas de cobre pórfiro. Como resultado, esta área pode ser considerada como uma área de mineralização de cobre-ouro pórfiro em que a mineralização foi feita em profundidade e nas proximidades da massa de intrusão e em alguns pontos são vistos como listras na superfície.

Palavras-chave: Petrogênese; Fluidos envolvidos; Rochas ígneas; Depósito Tanurjeh.

INTRODUCTION

The chemical composition of igneous rocks indicates the closest magmatic composition from which the rock crystallizes. During the process of cooling and crystallization of magma, many factors have affected it, which cannot be understood only by relying on rock petrography. The chemical composition of igneous rocks actually reflects the source and nature of magma, the process of separation, pollution and some other phenomena. In this section, according to the nature of the rocks in the study area, the geochemistry of intrusive and outbound igneous rocks will be discussed separately. The study area with an approximate area of four square kilometers in Khorasan Razavi province is located approximately 220 km southwest of Mashhad and 55 km northeast of Kashmar city and is accessible from Torbat-e Heydariyeh- Kashmar road. This region is located in the geological sheets of 1: 250,000 Torbat-e Heydariyeh and 1: 100000 of Faizabad. This deposit is part of the Khaf-Kashmar-Bardeskan volcanic-plutonic belt. This belt with Khavari- Bakhtari process is located in the east of Darouneh fault and continues in Afghanistan (Karimpour et al. 2002) (figure 1).

This belt is mainly composed of acidic to intermediate and sometimes mafic volcanic rocks with Tertiary age. These rocks include dacite, rhyodacite, andesite, pyroxene, andesite-basalt, latite, trachyandesite, tuff, lapillar tuff and agglomerate. Granitoid massifs with a combination of granite, granodiorite, diorite and alkaline feldspar granite have penetrated volcanic rocks (Karimpour, 2002; Yazdi et al. 2017; Baratian et al. 2018). The diversity and tectonic position of Cenozoic magmatism has led to form mineral reserves such as gold and copper in the form of porphyry such as Tanurjeh, Iron skarn (Sangan), golden iron oxides (Zar mountain in Torbat-e Heydariyeh) in the north of Tanurjeh village (Karimpour, 1955). The oldest rock units in the area are related to the Paleogene and the newest rock units are related to the Quaternary.

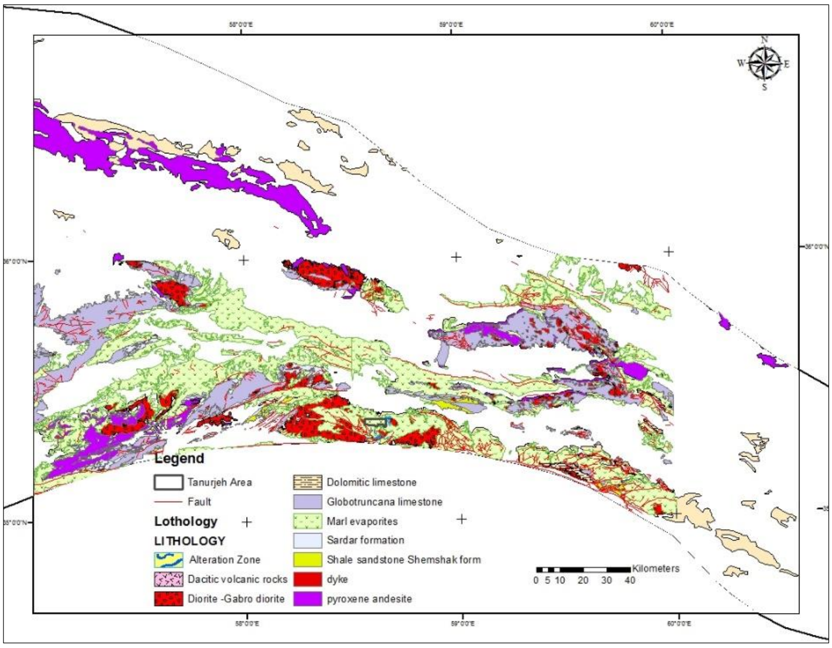

Figure 1. Position of Tanurjeh Deposit on Khaf-Darouneh Belt.
Source: Authors (2020).

BACKGROUND OF STUDIES

The Geological Survey of Iran has conducted studies on phosphate in the area in 1983 within the framework of the Phosphate Exploration Project (Geological Survey 1983; Jafari, Yazdi 2014; Yazdi et al. 2016, Bazoobandi et al. 2016; Jehangir Khan et al. 2021). In 1987, Behroozi surveyed this area in terms of general geology and published the result in the form of a geological map of Faizabad at a scale of 1: 100000 (Iranian Geological Survey and Mineral Exploration Organization). In this study, he has referred to volcanic activities with Tertiary age, including tuff, ignimbrite and andesitic to dacitic lavas. In 1988, Karimpour, in an article entitled "How to form and select suitable environments for exploring epitermal gold reserves", examined the potential of gold in the Neishabour-Kashmar section. The Geological Survey and Mineral Exploration Organization of the country has studied the mineralization of antimony and arsenic in the Kashmir region during 1986 and 1988. In 1996, the organization collected samples of river sediments on the Semnan-Kashmar axis in the framework of a regional exploration project, with the help of Chinese experts. The resulting geochemical maps also cover the study area.

In 1994, Abbasian studied the volcanic rocks of the Tanurjeh region from a petrological point of view. In 1998, Mostaghel studied and evaluated the magnetic mass in the north of Tanurjeh in the form of a master's thesis on the technical-economical evaluation.

Ferdos Sarandibi, has studied the Sarsefidal area near the Tanurjeh area in 2004 in his dissertation. In 2007, Kimia Ajaebi studied the geochemistry, petrogenesis and origin of hydrothermal fluids in the Tanurjeh mineralization area in the north of Kashmar.

METHODS AND MATERIALS

To study the chemical composition of intrusive and outbound igneous rock assemblages in Tanurjeh area, 150 rock samples were collected from different sections. According to the laboratory facilities, study objectives, diversity of composition and extent of the studied area, 19 samples were selected and chemically analyzed by XRF and ICP methods.

THREE-DIMENSIONAL MODELING PROCESS IN TANURJEH AREA

The first step is exploratory drilling and then the collection, preparation and classification of information. Exploratory drilling steps including geometric characteristics of drilling boreholes, drilling network, access road construction and preparation of drilling site, drilling boreholes, equipping the workshop and setting up the machine, monitoring the drilling site, drilling management and project control, extraction and logging of cores, cutting of cores, sampling and analysis of samples, drilling results, determination of storage and modeling of the deposit.

Required Data for modeling and storage evaluation include coordinates of points taken to draw a topographic map in the UTM coordinate system, geological data and geological profiles, Borehole coordinates of drilling boreholes, slope and azimuth of boreholes, lithological column of drilling boreholes, samples taken from wells and their analysis results, tectonic data and structural geology to especially faults, the specific gravity of the various sections of the deposit are the data on the samples taken from the deposit and the results of their chemical analysis. Three-dimensional modeling of Tanurjeh index is based on available data from 6 exploratory boreholes. The data collected from the exploratory boreholes were entered and categorized into Excel software. The structure of the database was adapted to the Rockworks modeling software and the existing information was entered into the software for processing, and in the next step, the dimensions of the project were determined.

INTRODUCTION OF PROJECT DIMENSIONS AND SPECIFICATIONS OF EXPLORATORY BOREHOLES

In order to model and evaluate the deposit, the dimensions of the exploration project and the dimensions of the micro-blocks in the block model of a deposit must be specified. These dimensions are in the X direction from 437700 to 437935, in the Y direction from 3792365 to 3792650 and in the altitude direction or Z from 1610 to 2030 meters. Based on surface geochemical evidence, investigation of potash, phyllic and argillic surface alterations and the stone units of the area were designed and drilled boreholes from the margin to the inside of the intrusion-porphyry system. All samples of drilling cores (approximately 336 samples - one meter per sample) were chemically analyzed in Zar Mehr laboratory by Fire assay method to analyze the main elements. Also, 20 samples were sent to the Alborz Research Center for analysis of ICP-MS and XRF. A view of drilling cores as well as calopyrite mineralization in a core can be seen in Figure 2.

Figure 2. A View of Drilling Cores As Well As Calopyrite Mineralization Can Be Seen in One Core. Source: Authors (2020).

The borehole cross-section model for the bedrock of lithological units is shown in figure 3.

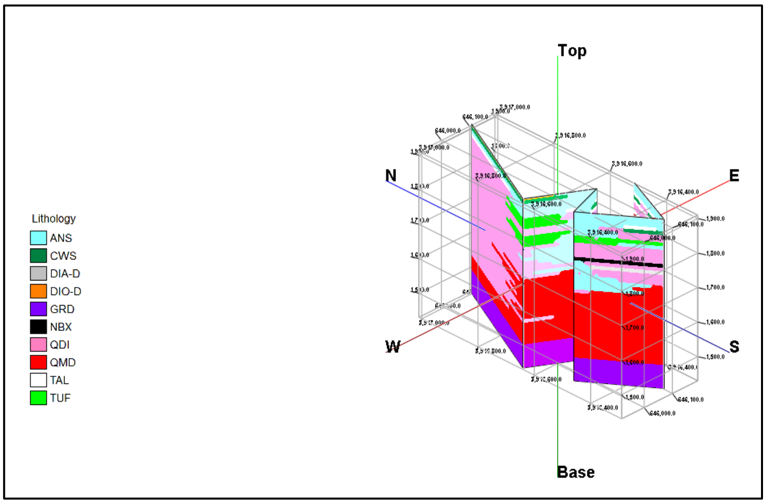

Figure 3. Borehole Cross-Sectional Model for Bedbug Units. Source: Authors (2020).

SAMPLING AND PREPARATION OF SAMPLES FOR THE GENESIS OF TANURJEH INDEX

From the five selected quartz specimens, only one specimen was involved in simultaneous mineralization with a fluid micro thermometer. However, because the fluids involved in the quartz of other sections were very small, it was not possible to detect phase changes under the micro thermometer. After selecting the samples, double polished sections were prepared according to the method, for microscopic and micro thermometric studies (Shepherd et al., 1985; Yazdi et al. 2015; Baratian et al. 2020; Yazdi, Sharifi Teshnizi 2021). Micro thermometric studies of the involved fluids, which include cooling and heating, have been investigated in the Economic Geology Laboratory of Payam-e Noor University of Tabriz. In this laboratory, temperature parameters were determined using the THMS600 stage heating and freezing model of Linkham, which was installed on an Olympus microscope. To calibrate the device, sodium nitrate standards with a melting point of C+910˚and carbon tetrachloride with a melting point of C 22.33 ̊C were used.

DISCUSSION

CLASSIFICATION OF IGNEOUS ROCKS BASED ON MIYASHIRO DIAGRAM (1974)

In Miashiro (1974) diagram, the two alkaline and sub-alkaline ranges are separated by the weight percentage of SiO2 versus the total FeOt / MgO. Based on this, the samples related to Tanurjeh deposit are in the range of calc-alkaline and tholeiitic (figure 4).

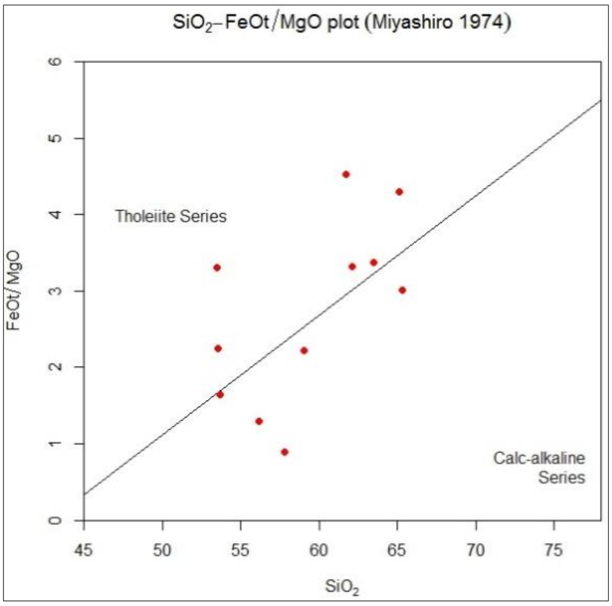

Figure 4. Diagram of Miyashiro (1974).
Source: Authors (2020).

AFM CHART BY IRWIN BARAGAR (1971)

In the diagram of Irwin and Baragar (1971) which is a combination of Kono (1968) and Irwin and Baragar (1971) diagrams and consists of three parameters F = FeO + Fe2O3, A = K2O + Na2O and M = MgO, the samples are in the range of calcoalkaline and tholeiite (figure 5).

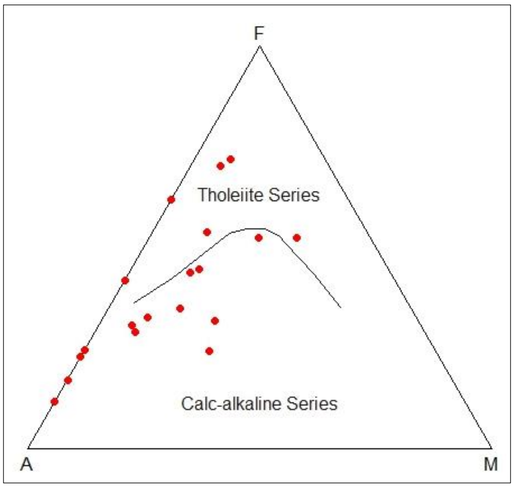

Figure 5. AFM Plot.
Source: Irwin and Baragar (1971).

NAMING OF INTERNAL IGNEOUS ROCKS

For this purpose, TAS charts related to Middlemost (1985 and 1994) have been used for variation in naming (figure 6). Based on this diagram, Tanurjeh deposit rocks are in the range of quartzmonzonite, diorite, monzonite, granodiorite, and granite.

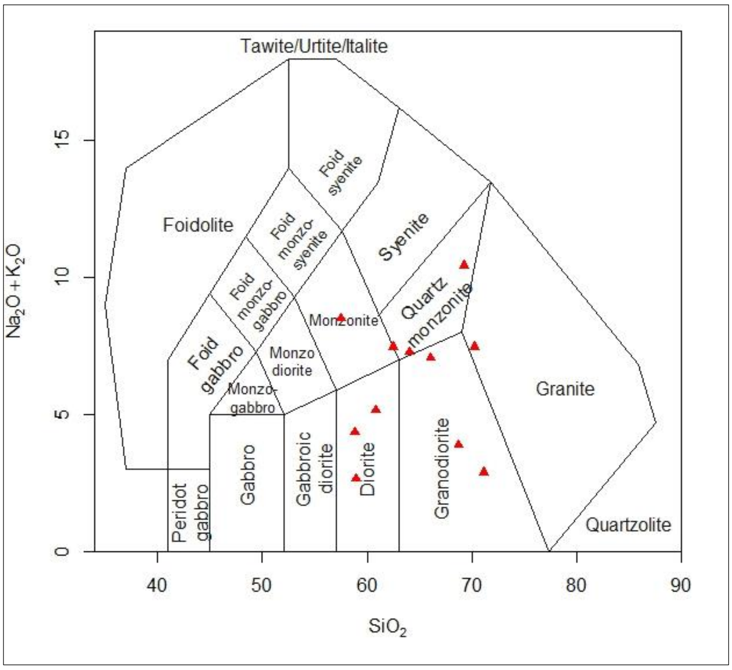

Figure 6. Naming of Internal Igneous Rocks of Tanurjeh Deposit Using Middlemost Diagram (1994). Source: Authors (2020)

NAMING THE OUTPUT IGNEOUS ROCKS

For this purpose, TAS diagrams of Cox et al. (1979) have been used (figure 7). Based on these diagrams, Tanurjeh deposit rocks are in the range of rhyolite, dacite, and basaltic andesite.

Revista Geoaraguaia
ISSN:2236-9716
Barra do Garças – MT
v.11, n.2, p.49-74. Dez-2021

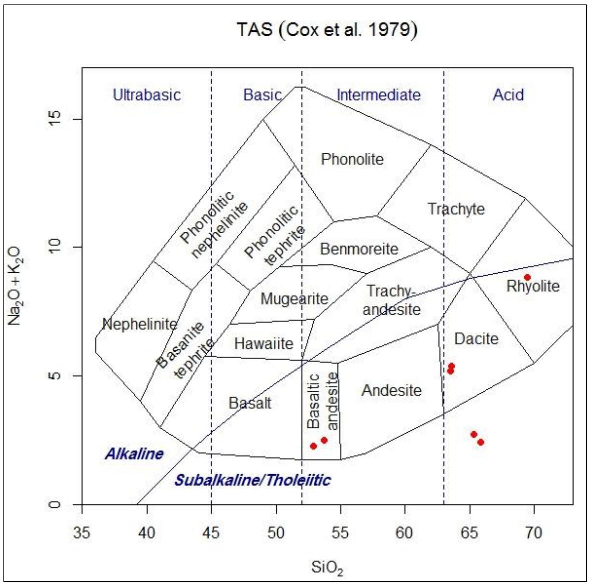

Figure 7. TAS Chart , Cox et al. (1979)

INVESTIGATION OF GEOCHEMICAL RELATIONSHIP OF INTERNAL ROCKS IN THE STUDIED AREA

Of course, the amount of the elements that enter the mineral structure at the beginning of crystallization, in the remaining liquid decreases and instead, elements that do not enter the crystal structure of unmineralized minerals increase in the melt. As shown in figure 8, with increasing SiO2, all minerals have a negative trend, which probably indicates a logical trend of subtraction. The negative trend of Na2O and the positive trend of K2O are probably due to alteration. In the case of trace elements, most elements are dispersed. Only Ba and Zr have a positive slope.

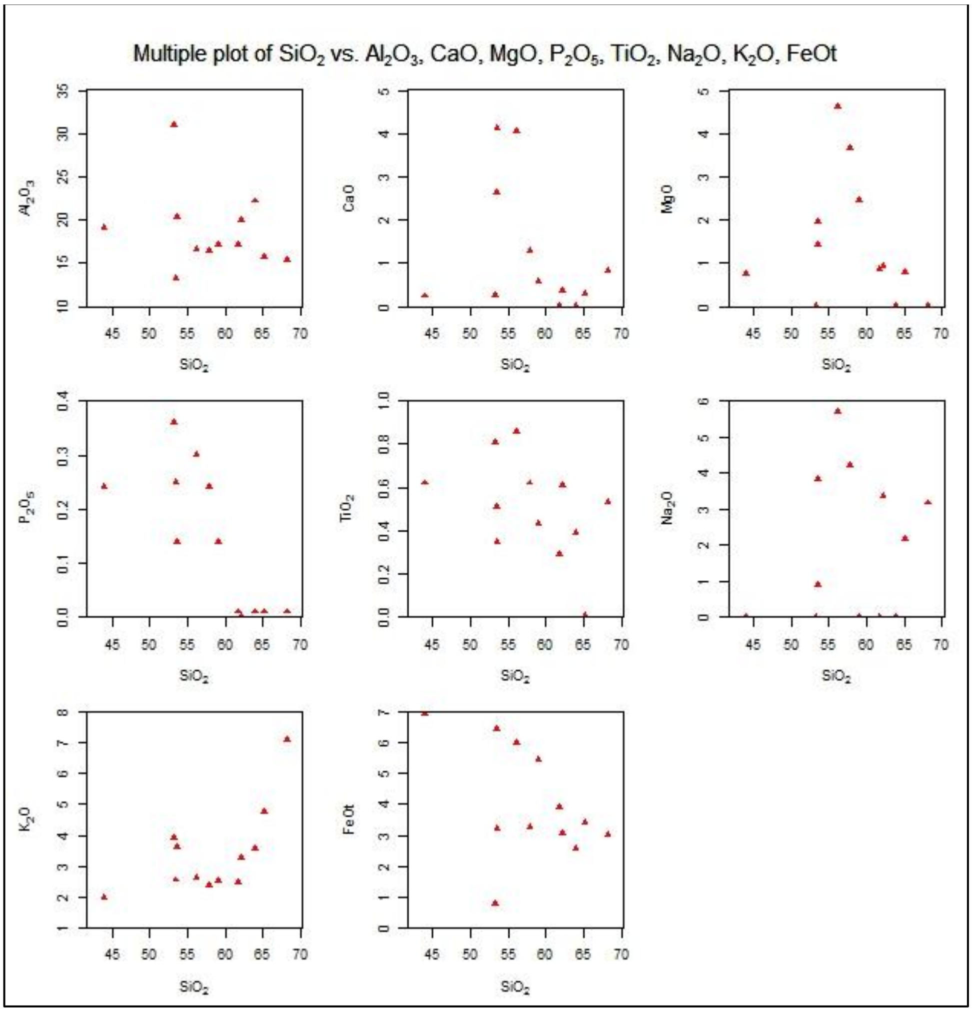

Figure 8. Investigation of Geochemical Relationship of Inner Rocks Based on the Main Elements Against Sio2.
Source: Authors (2021).

According to studies, the main elements such as Al2O3 and K2O versus MgO show a logical process of subtraction and other elements are dispersed. Among these, elements such as Zr, Ba and A / CNK ratio show a negative trend and elements Rb, Sr, Ba, and the sum of Y and #mg show a positive trend against MgO.

INVESTIGATION OF GEOCHEMICAL RELATIONSHIP OF OUTPUT ROCKS IN THE STUDIED AREA

In the rocks of the studied area, the elements MgO, TiO2, P2O5, FeO against SiO2 have a negative trend, which indicates a logical trend of subtraction. K2O has a positive slope.

The trace elements Ba, Zr and Cr are also positive for the slope. Also, the main and rare elements are opposite to MgO, the main element SiO2 has a negative slope and shows the subtraction process. The elements Al2O3, TiO2 and FeO have a positive trend. The trace elements Ni, La, Zr, Y and Ce have a positive trend and the elements Ba and Cr have a negative trend and #mg shows a positive trend against MgO.

GEOCHEMISTRY OF RARE EARTH ELEMENTS IN THE INNER ROCKS OF THE STUDIED AREA

The diagram of rare earth elements related to different rocks can be seen in figure 9. In general, these rocks are relatively rich in LREE elements compared to HREE elements and show the process of subtraction. Most specimens are deformed (negative anomaly), Eu, and this negative Eu anomaly can be related to the subtraction of plagioclase and their removal from the rock. On the other hand, the samples show negative anomalies of Er, Yb, Sm, Dy.

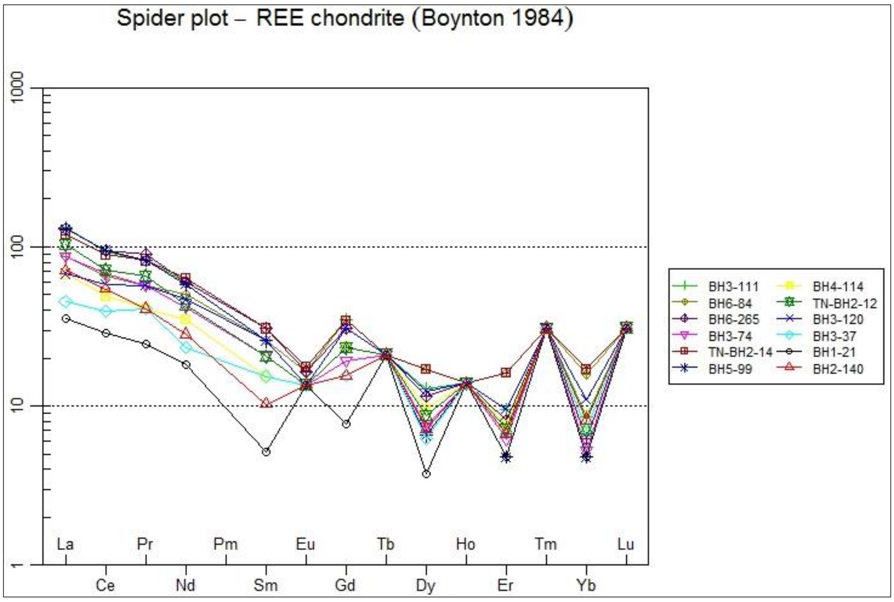

Figure 9. Diagram of Rare Earth Elements in the Inner Rocks of Tanurjeh Deposit.
Source: Boynton (1984).

GEOCHEMISTRY OF RARE EARTH ELEMENTS IN THE OUTCROP ROCKS OF THE STUDIED AREA

Revista Geoaraguaia
ISSN:2236-9716
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The diagram of rare earth elements related to different rocks can be seen in figure 10. In general, these rocks are relatively rich in LREE elements compared to HREE elements and show the process of subtraction. Most specimens have Eu depletion (negative anomaly), and this negative Eu anomaly can be related to the subtraction of plagioclase and their removal from the rock. On the other hand, the samples show a negative anomaly of Dy Er, Yb.

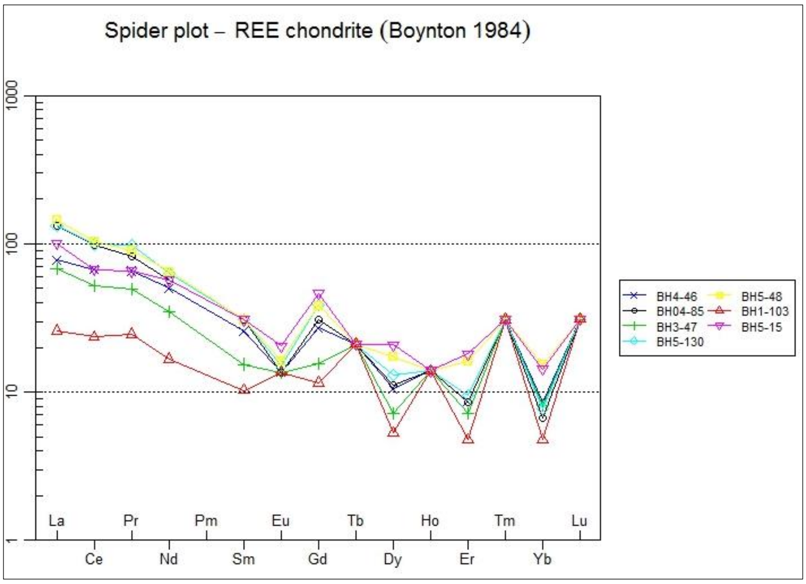

Figure 10. Diagram of Rare Earth Elements in the Outcrop Rocks.
Source: Boynton (1984).

<u>MAGMATIC ORIGIN AND TECTONIC POSITION</u>

Maniar and Piccoli (1989) internal diagrams indicate that the internal rocks of the studied area are related to orogenic and non-orogenic stages. Samples located in the areas of POG (post-orogenic granite), CAG (continental arc granite), CCG (continental collision granite), IAG (arched island granite) are among the orogenic granites and samples taken in the CEUG (non-orogenic continental granite) range, RRG (rift-related granite) are non-orogenic granites (figure 11).

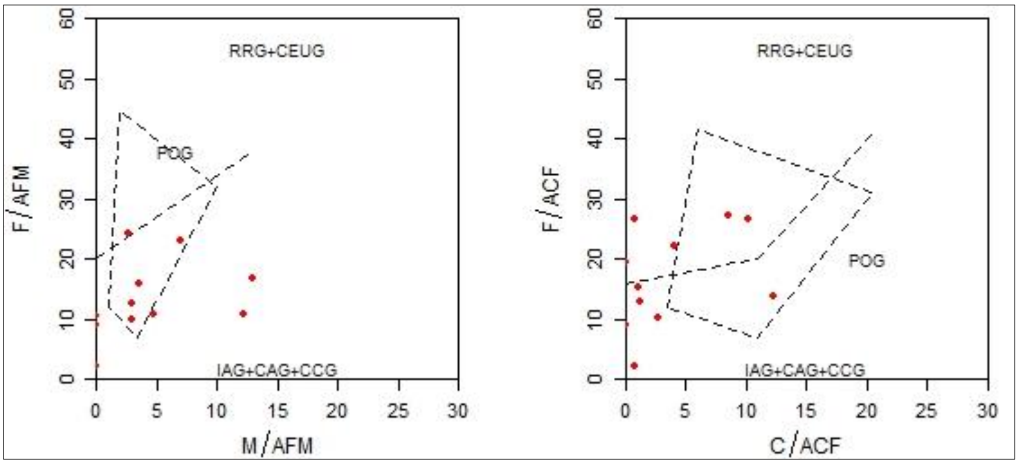

Figure 11. Diagram of the Magmatic Origin of the Inner Rocks of Tanurjeh Deposit. Maniar and Piccoli (1989)

FEO-MGO-AL2O3 OUTPUT DIAGRAM

According to this diagram, the outcrop rocks of Tanurjeh deposit are located in the area of arched islands and active continental margins and islands of the center of expansion (figure 12).

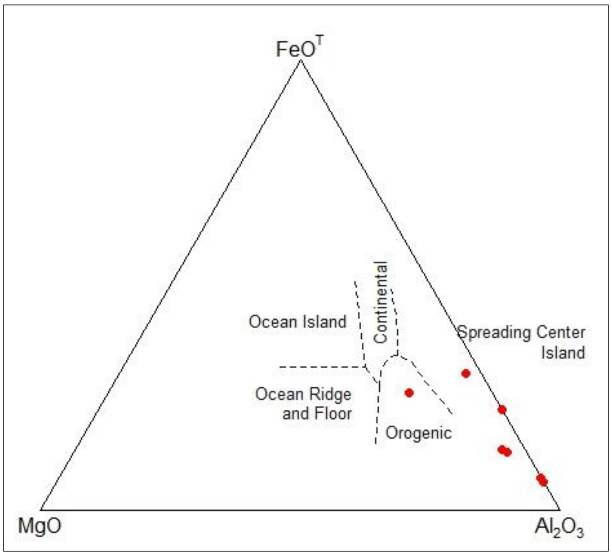

*Figure 12***.** Pearce Diagram (1977), the Magmatic Origin of the Output Rocks
Source: Pearce et al. (1977).

NORMALIZATION TO CHONDRITE FOR ROCKS IN THE STUDIED AREA

In the spider diagrams of Tanurjeh deposit normalized with chondrite (Thomson; 1982), a relative decrease in Nb compared to other highly incompatible elements is possible. The most prominent geochemical feature is magmas produced in subduction zones (active continental margin) (figure 13).

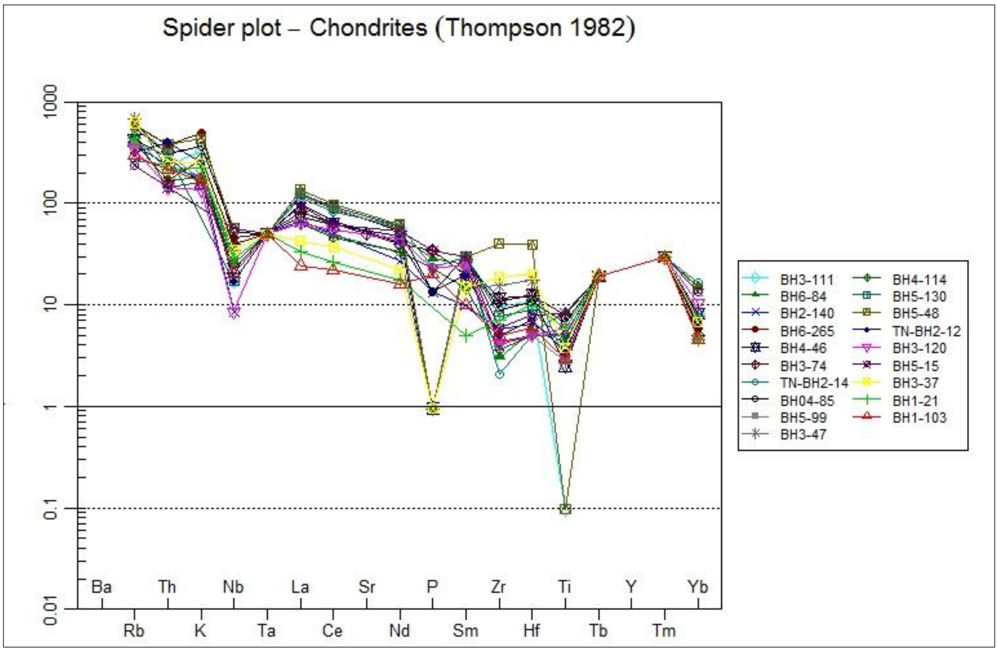

Figure 13. Spider Diagrams of Tanurjeh Deposit Normalized with Chondrite.
Source: Thomson (1982).

<u>NORMALIZATION OF MORB MID-OCEAN RIDGE BASALTS FOR TANURJEH DEPOSIT ROCKS</u>

In 1983, Pierce introduced the MORB normalization values, providing a suitable model for evolutionary basalts and mid-ocean basalts. In this model, the mobility of the elements decreases from left to right and the incompatibility of the elements increases from right to left. In the spider diagram, the intrusive rocks of the study area are normalized diagonally. There is a pattern of LILE elements in this family of enrichment relative to HFS. Increased concentrations and enrichment of LILE elements (especially K, Rb) and lithophilic elements (Th, Rb and to some extent Ba) can indicate contamination of the crust and other primary magma contamination processes. The elements Ba, Rb, Th and K are enriched more than ten times diagonally and show a decreasing trend diagram from moving elements to non-moving elements. The relative decrease in Nb is usually associated with the absence or melting of minerals carrying these elements or the crystallization of these minerals (Figure 14).

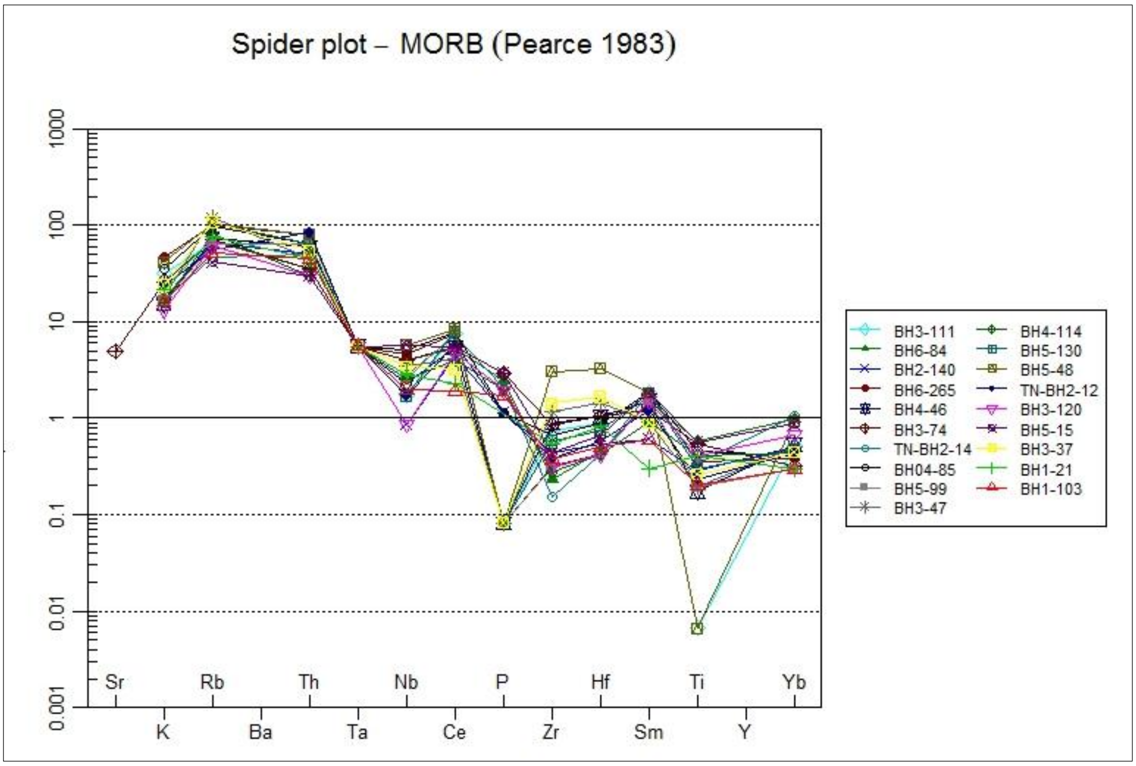

Figure 14. Spider Diagram of Intrusive Rocks of Tanurjeh Deposit Which Are Normalized with Oblique.
Source: Pearce (1983)

NORMALIZATION TO THE PRIMARY MANTLE FOR ROCKS IN THE STUDIED AREA

Wood et al. (1979) used the initial mantle composition before the formation of the continental crust to compare changes in the composition of basaltic lavas and their internal equivalents. In this model, the elements are arranged according to compatibility and in proportion to the small percentage of mantle melt. In this diagram, the enrichment of elements from left to right shows a trend with a relative decrease. One of the reasons for the very weak enrichment of Ba, Rb, Cs elements is the slight crustal contamination and very little differentiation in the intrusive rocks of the studied area (Figure 15). The decrease in Nb, which is an indicator of continental rocks, may be another confirmation of the participation of the crust in magmatic contamination processes. On the other hand, the supply and reduction of Nb-Ti can also indicate contamination with the lower crust and the index of abundance zones (active continental margin).

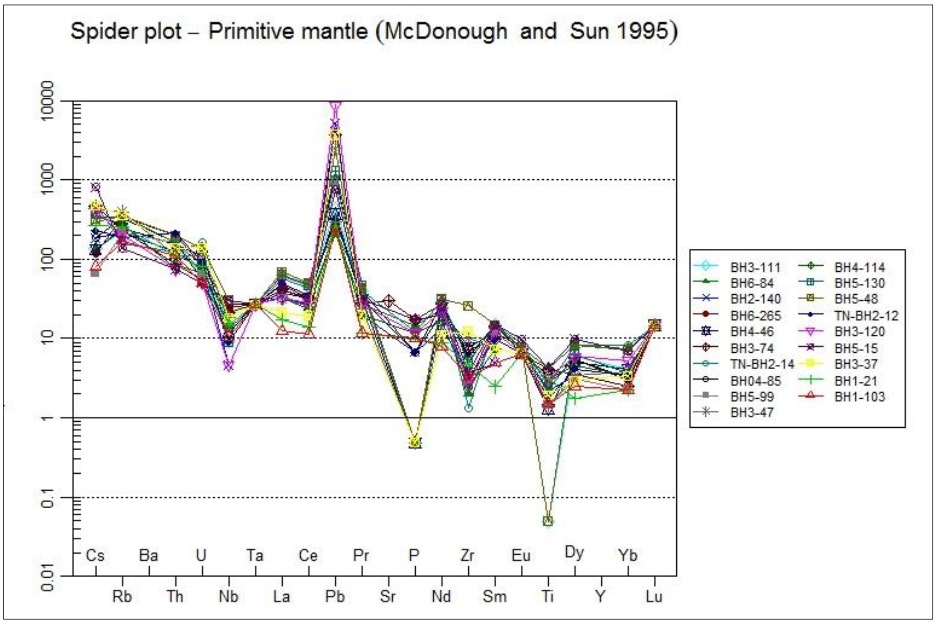

Figure 15. Normalization to the Primary Mantle for Tanurjeh Deposit Rocks.
Source: McDnough and Sun (1995).

GEOLOGICAL MODEL

Alterations in the Tanurjeh area include argillic, phyllic, potashic and propylitic with minerals from inside the epidote and chlorite and outside from zeolite, albite, montmorionite and calcite, argilic alteration with characterized by kaolinite, montmorionite, carbonate, cercite, pyrite and alunite minerals and phyllite alteration by cercite, quartz, pyrite, chlorite and kaolinite minerals. Propolitic and potash alterations are the dominant alterations in this range. Potash alteration surrounds a smaller volume (figure 16).

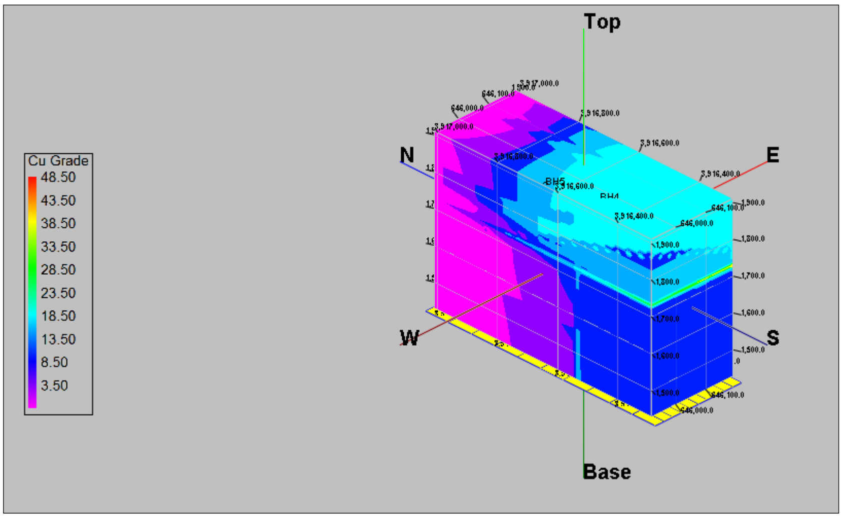

Figure 16. Potassium Alteration Surrounds a Smaller Volume.
Source: Authors (2021).

THREE-DIMENSIONAL MODEL OF ZONES

Three areas have been identified in deposit enrichment. The oxide zone includes iron oxides and hydroxides, copper oxides, malachite and azurite. The transition zone in this section is reduced by the amount of malachite and azurite minerals and to some extent has chalcocite, colitis, chalcopyrite and pyrite. Hypogene zone which in this section includes chalcopyrite and to some extent pyrite are the main minerals of this section (figure 17).

THREE-DIMENSIONAL MODEL OF COPPER AND GOLD

In this deposit, the largest volume of copper and gold is in the hypogene zone. According to the studies, the copper-gold porphyry index of Tanurjeh has oxide zones, transition from oxide to hypogene, and the highest concentration of copper and gold is related to the hypogenic part. Due to the specific topographic conditions of this area, it seems that the environment was not ready for the formation of the supergene zone. It is possible that only in small parts, the regeneration environment has the conditions for the formation of a supergene zone locally, which has caused the filling of parts of the transition zone.

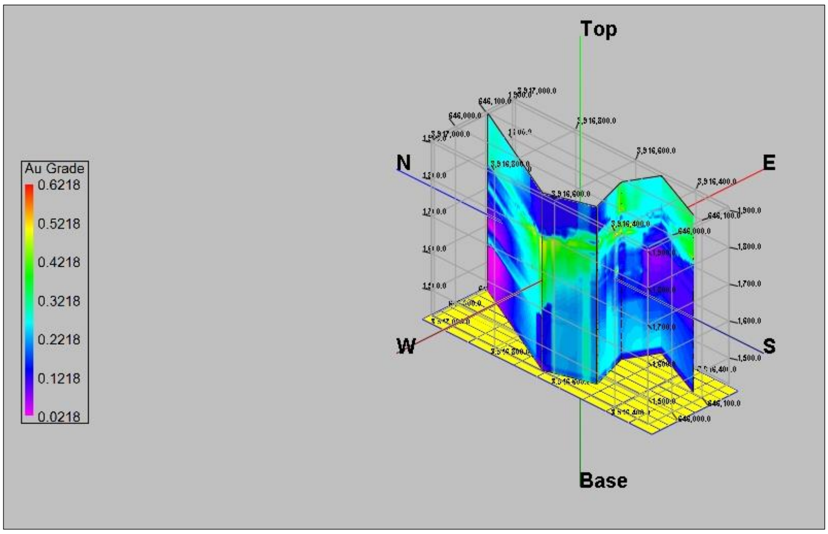

Figure 17. Hypogene Zone Which in This Section Includes Chalcopyrite and to Some Extent Pyrite Are the Main Minerals of This Section.
Source: Authors (2021).

GENESIS INDEX OF TANURJEH

The petrography of the fluids involved includes studying the fluids using a simple light microscope before performing the cooling and heating experiments. The first and most important part of the study of involved fluids, identifying petrographic relationships and identifying features such as shape, size, frequency of fluids involved, type of fluids involved (primary, secondary and pseudo-secondary), fuzzy ratios, determining the type of fluids and phenomena changing the involved fluids after being trapped is like necking and seepage. In the studied samples, primary involved fluids, secondary and pseudo-secondary fluids were identified. Primary involved fluids are larger in size than secondary involved fluids and pseudo-secondary fluids and have grown along crystalline surfaces. Due to the fact that fluids involved in secondary and pseudo-secondary, are of the least importance in micro thermometric studies, and the data about them are error-prone, they have been omitted, and only the initially involved fluids have been studied.

BOILING PHENOMENON

In fuzzy fluid sections with a degree of filling of 40-50%, next to which there is a gas-rich fluid and when we see these two fluids together, the phenomenon of boiling has occurred. The boiling phenomenon occurs when the hydrostatic pressure is higher than the lithostatic pressure, which is clearly seen in sections (figure 21).

Figure 21. Boiling Phenomenon in Two-Phase Liquids Rich in Liquid and Gas.
Source: Authors (2021).

MICRO THERMOMETRY OF INVOLVED FLUIDS

The calculated salinity for the involved garnet and pyroxene fluids belonging to the progressive metasomatism stage shows between 12.3 to 20% equivalent of NaCl. Also, the highest frequency is related to salinity between 16 to 18% of the equivalent of NaCl. The highest frequency of eutectic temperature is also seen in the data related to -52 to -54 degrees Celsius, which is equivalent to the composition of the fluid containing NaCl, CaCl2 and CO2 (Shepherd et al., 1985). The low temperature of the eutectic point indicates the presence of CaCl2 and possibly FeCl2 along with NaCl in the fluid (Kodera et al., 2004). Many deposits, especially those formed in epidermal or magmatic-hydrothermal environments, are slightly enriched in CO2 (typically less than 3 mole %) (Wilkinson, 2001). The presence of CO2 reduces the initial melting temperature of ice (TE) to less than -54 ° C (Shepherd et al., 1985; Wilkinson, 2001). The presence of CO2 reduces the initial melting temperature of ice (TE) to less than -54 ° C (Shepherd et al., 1985; Wilkinson, 2001). The calculated salinity for the quartz in the quartz-calcite lag vein shows values between 5.8 and 11.9. The eutectic temperature is between -13.7 and -18. Graphs of the salinity amplitude and eutectic temperature of quartz in the delayed quartz-calcite vein are plotted .

With increasing temperature (° C), the halite crystal first disappears at 257 ° C and the bubble gradually shrinks to disappear at a temperature of Th, which in the above example it is equal to 307.8 ° C.

1. 90.1 degrees;
2. 160.8 degrees;
3. 232.4 degrees;
4. 310.4 degrees;
5. 305.7 degrees;
6. 310.4 degrees.

CONCLUSION

Tanurjeh deposit is located in Feyzabad 1/100000 sheet on Khaf-Darouneh belt. Oligocene deposits cover the studied area and host volcanic and subvolcanic masses with intermediate to acidic composition. The total set of igneous rocks in the area includes andesite, porphyry diorite, quartz porphyry diorite, porphyry granodiorite and monzonite. The volcanics of the studied area mostly have an intermediate composition and therefore most of the volcanic rocks in the area are andesite, rhyolite and rhyodacite.

Potassium alteration in Tanurjeh deposit is characterized by the presence of secondary biotite, secondary potassium feldspar, quartz, chalcopyrite, pyrite and magnetite. The phyllic alteration zone is characterized by the presence of quartz, sericite and pyrite. Because this set of minerals also occur as sub-minerals with the potassium set. This alteration is sometimes accompanied by silicification alteration and in some cases argillicization. The argillic alteration zone in the Tanurjeh deposit is found locally within other alterations and adjacent to veins and joints in surface outcrops. The manifestation of this alteration is more or less characterized by the clay formation of the host rocks and the presence of jarosite. Propylitic alteration is observed as a green halo in the outermost part of the deposit and its mineral set includes chlorite, epidote and calcite. The study of exploratory boreholes in Tanurjeh deposit shows that out of 1300 meters of boreholes drilled in 6 boreholes (5 boreholes in Omidbakhsh area A and 1 borehole in Omid Bakhsh area C) in 1 borehole, good copper-gold mineralization has been observed. In-depth studies of rock type include andesite, diorite, quartz diorite and porphyry granodiorite. Therefore, superficial and deep lithology are also confirmatory. The zones and minerals detected in Tanurjeh deposit include hypogene zone according to drilling boreholes. Alterations of the porphyry system were detectable in the boreholes. In Tanurjeh mineral deposit, gold is found as free grains in sulfide phases such as chalcopyrite and also in the field of iron oxide (resulting from oxidation of sulfides). It can be stated that gold is transported along with mineralizing solutions by chloride (and possibly bisulfide) complexes and with changes in the physicochemical conditions of the environment and solution, reducing heat, pressure, boiling occurrence, reducing sulfur fugacity due to the deposition of sulfide minerals, gold-bearing complexes become unstable and as a result gold is released and enters sulfide minerals and precipitates with them. In fact, gold complexes become unstable when hydrothermal solutions become sulfur-depleted due to the deposition of sulfide minerals. This leads to the release of gold and as a result, gold enters sulfide minerals such as chalcopyrite and precipitates with them. Gold may also be separated from copper-iron-sulfur solids by low-temperature and delayed deposition solutions. This process can lead to the release of gold particles and grains and its spread throughout the deposit complex or even its concentration in epithermal and polymetallic veins outside the deposit zone. Therefore, this process can justify the presence of gold in the form of free particles inside the siliceous veins and even in the surrounding rock around the Tanurjeh deposit.

According to geological and geochemical studies, Tanurjeh deposit is a porphyry copper-gold mineralization system. Studies of trace elements, especially rare earth elements, show that the igneous rocks of the area have a geochemical nature of calcoalkaline. In terms of tectonomagma, active continental margins are formed in the subduction environment. Existence of intrusions with diorite to quartz diorite and monzonite composition, severe tectonics, thermal alterations of potasic, phyllic, propylitic, argillic and siliceous zones, abundant presence of quartz-magnetite veins and stockworks, the presence of iron oxides, the scattered observation of chalcopyrite mineral in drilling cores are among the reasons for this claim.

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