

Petrography, Geochemistry and Mineralography of Volcanic Rocks in Sistanak Area (South East Qaen)

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Abstract: *Sistanak copper deposit is located in the south-east of Qaen (South Khorasan), and in the east of Iran, geographically. Generally speaking, this area is located in the east of the central zone of Iran, one part of which is located in flysch zone and the other in the Lut block. Stratigraphically speaking, no stones older than the Jurassic Age were found in the area. Petrographically speaking, the volcanic stones of the area are divided into two groups of lava (andesitic and andesite-basalt) and pyroclastic (agglomerate and tuff). These stones fall in the class of calc-alkaline and high potassium calc-alkaline. Based on the chemical combination, these volcanic stones fall in the categories of andesitic and andesite-basalt. The main copper ores of andesitic lava contain native copper, chalcocite, malachite. Also, iron-oxide ores like hematite and goethite exist in the samples. Naturally, mineralography zone is located in the highest level of volcanic lava and the minerals exist in the outer layer. This indicates the epigenic quality of the resources. According to the geological and mineralizational characteristics, Sistanak copper deposit is probably a Michigan type deposit.*

Keywords: Andesite, Active Continental Margin, Calc-Alkaline, Native Copper, Sistanak Qaen

INTRODUCTION

The studied area is located in Khorasan Province, 44 km south-east of Qaenat, between 59°36'39.82" to 59°42'52.08"W and 33°37'6.70 to 33°34'37.95" N. Also it is located in the South-west of geological record of Abiz 1:100.000. Generally speaking, it is located in the east of the central zone of Iran, part of which is inside fleschy zone and the rest in the Lut block. The stones here are average to acidic. According to studies, rocks were mostly andesite, andesite-basalt and tuff pyroclastic and agglomerate. They are as old as Jurassic (Figure 22).

Methodology

In a field operation, 9 stone samples were collected with the least amount of weathering. Using these samples, 16 thin pieces were made in the National Geology Laboratory. They were studied at Shahid Beheshti mineralogy laboratory (For the names and properties of the samples, see Table 1). Also, 7 XRF samples were prepared to study the main elements of the stones. The samples were sent to the Iranian Mineral Processing Company whose analysis method was melting.

Lithology

1. Andesite

The oldest stone unit found in the Sistanak map (1:20000) is the Andesite unit that is as old as the Jurassic. This unit has developed greatly in the southern part of the map. Connection of the Andesite unit to its neighboring unit is a fault.

Table 1. The properties of the samples

Row	Section name	Sample size	Geographical Coordinates (UTM)
1	Sis T1	2	751108 3720269
2	Sis T4	2	751149 3720064
3	Sis T5	2	750764 3720525
4	Sis T8	2	750148 3722081
5	Sis AN1	1	747655 3721101
6	Sis AN2	2	747355 3722081
7	Sis AN3	2	748108 3722229
8	Sis AG1	2	750855 3720082
9	Sis AG2	1	747473 3722222

The weathered surfaces are black or dark grey in Sistanak area. But the fresh and just broken surfaces are grey to red. On the surface of the rock, transparent ores are visible, most of which are plagioclase and their size reaches two or three millimeters. Andesite in the Sistanak area are in form of current in the southeast-northwest direction; but in some cases this trend becomes an irregular porphyry (Figure 1).

Andesite tissue is usually a fine grained porphyry. Phenoceric porphyry andesitic syatites consist of plagioclase crystals (mostly with a regional pattern) and tufts of mafic ore. The background rock can be glassy or current-form. There are cavities and camouflage tissues andesite; and generally these cavities are filled with minerals such as quartz, chlorite and calcite. Pyroxene is the second phenocrysts in the sample. It is not great in amount. The pyroxenes are often shapeless to semi-shaped.



Figure 1. The stone unit of andesite in outcrop (A) and manual sample (B)

Pyroxins are trapped in the layers of plagioclase. The abundance of opaque minerals in this rock type is much higher than other stones in the area. Microlytes in the andesitic field of this sample show no sign of indication. In addition to micro-fibers, glass is also present. Coarse-grained texture occurs under saturated water and average-pressure drop rates conditions (Tsuchiyama, 1985). The presence of normal and sieve plagioclase texture cannot be solely because of the removal of the pressure. For this, mixing with a humid and hotter magma is essential for the formation of a sieve texture (Kuscu & Floyd, 2001). (Stewart & Pearce, 2001) argue that the instability of plagioclase crystals in the course of the fast upward moving of the magma leads to the emergence of sieve texture in plagioclase. Because some parts of the plagioclase melt. Products from the melting of plagioclase begin to crystallize within the plagioclase. Glomerulophorphic tissue is also seen in some samples. Glomerulophorphyrite tissue indicates an imbalance in the magma forming these rocks (Figures 2 and 3).

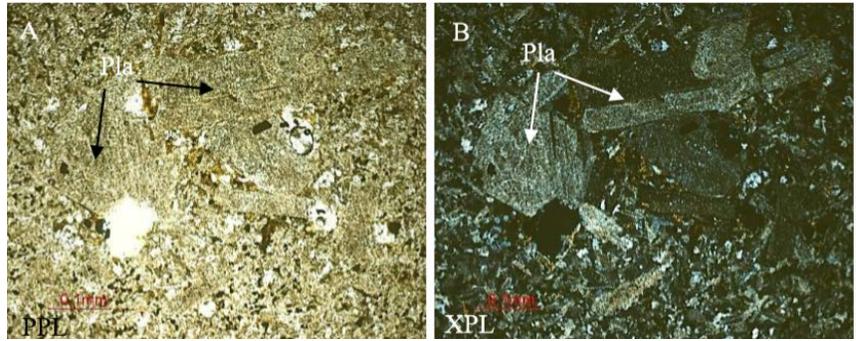


Figure 2. Ores and patterns in andesite sample (plagioclase)

2. Andesite- Basalt

The andesite-basalt unit has a trend similar to other volcanic regions that extend from the southeast to the northwest of Sistank. It is not big compared to other units, and it is scattered in the area. The unit is more focused on the eastern area.

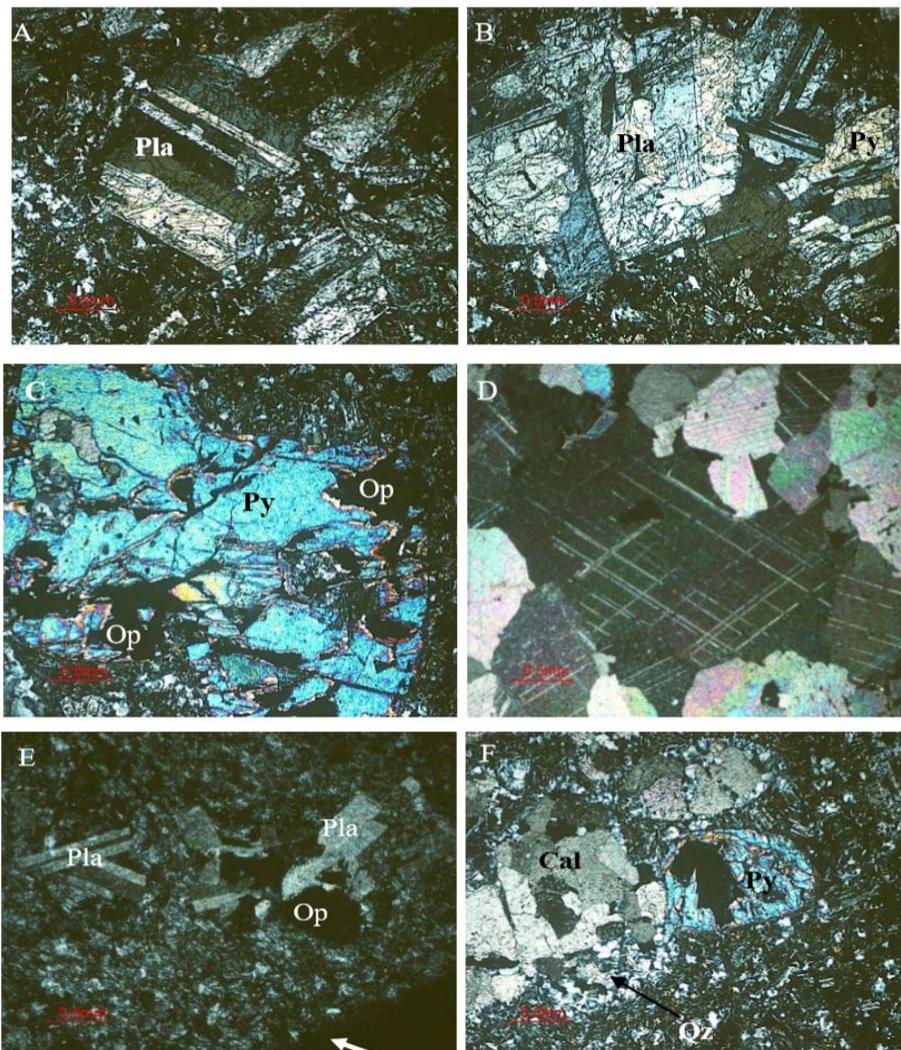


Figure 3: Plagioclase (pla) with mackle polysynthetic and sieve texture (A), zone and pyroxin plagioclase (py) (B), soarse crystal of pyroxin with opaque ore (Op)(C), cavity filling with calcite (Cal) (D), Glomerulophrophy texture and Phenocrysts of plagioclase (E), Amygdala tissue with cavities filled with calcite and quartz.

In the manual sample, there are cavities mostly filled with quartz. On the surface of the stone, there are ores that are transparent and blady. Petrography study indicates that they are plagioclase. Also, the ore of chlorite which is green also exists. The weathered surface is grey and the recently broken surface is black (Figure 4). The main texture in basalt- andesite unit is glassy. Of course, there are fines blades of plagioclase, called microlite. Pyroxene is usually coarse ore, and it is usually semi- to fully- shaped. Though plagioclases are coarse, but they are not abundant. In this stone type, plagioclase is the prevalent ore (Fig 5, 6).



Figure 4: Andesite-basalt unit in outcrop (A) and manual sample (B)

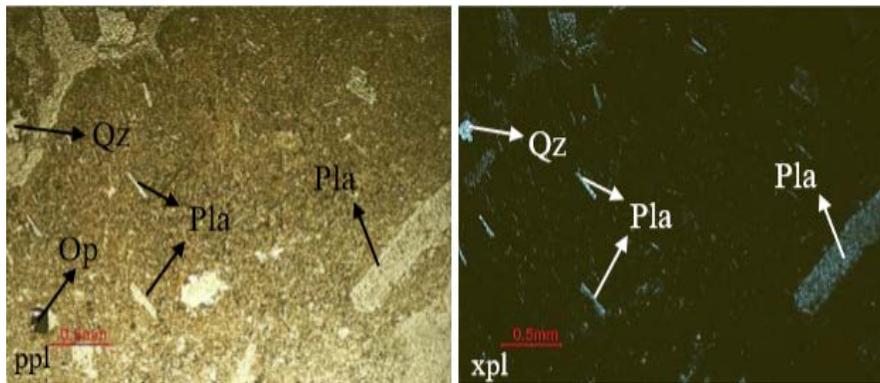
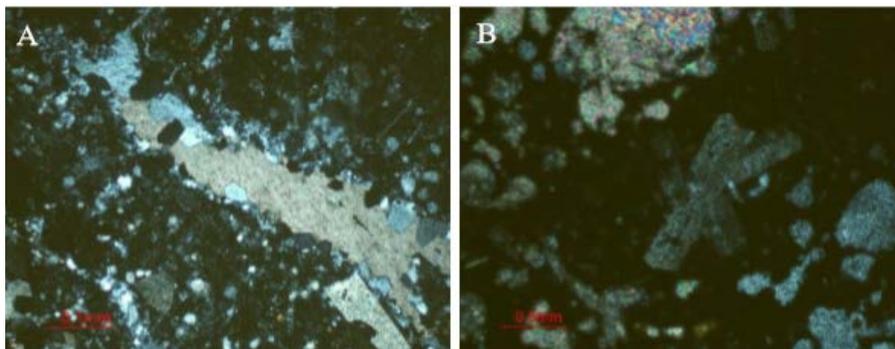


Figure 5: View of porphyry tissue with glassy background and plagioclase microlites in andesite-basalt



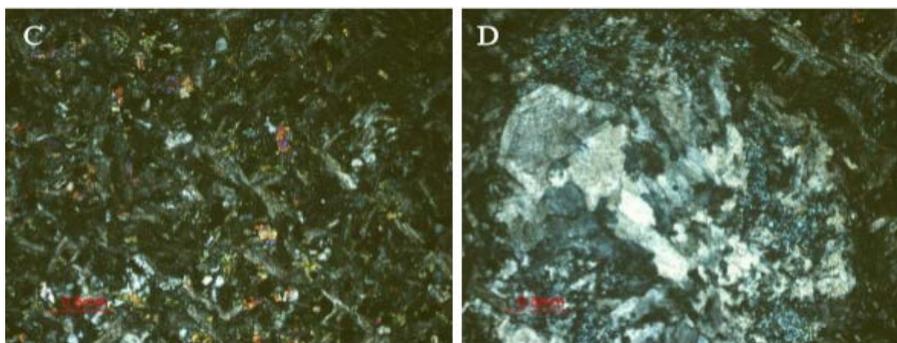


Figure 6: Filling of cavities with calcite and quartz in sample (A), Glomerulophorphytic tissue in the sample (B), Felt tissue (C) and Amigdala tissue filled with quartz and chlorite (D)

3. Agglomerate and Tuff

Agglomerate unit is younger than Andesite unit. The boundary of this unit with the previous unit is a fault. It has a normal boundary with the next. The expansion of the Agglomerate unit is in the southern part of the map. Agglomerate unit is the second dominant unit in the area. The effects of chlorite and iron oxide resulting from surface weathering are seen in these agglomerates. In the agglomeration unit, the tuff unit is exposed in a greenish layer. The tuff unit is not widely spread and it is distributed locally and scattered among the agglomerate unit. The layering of the tuffs indicates the involvement of sedimentary processes in the area. The central unit of Tuff is in the west of Sistanak. The manual sample has a greenish-gray color. The fine and white grains appear on the surface of the rock, most of which are plagioclase, and few are quartz (Fig 6, 7, 8).



Figure 7: Agglomerate with different grain sizes



Figure 8: Tuff layering (A) and a manual sample of Tuff (B)

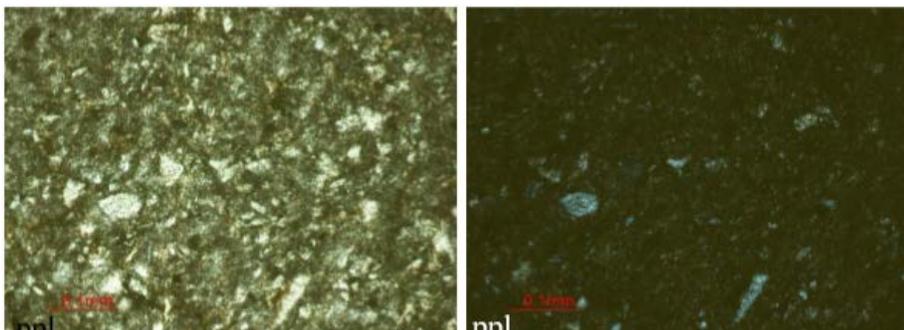


Figure 9: Tuff texture and phenocrysts

Geochemistry

Naming the studied stones

The percentage of SiO₂ in the stones of Sistanak is between 60.59 and 54.27. Based on the chemical combination, the volcanic stones are graphed in (Cox et al., 1979) diagram. This is based on the weight percentage of Alkaline (Na₂O+K₂O) and Sillies (SiO₂). They are placed in the andesite-basalt range. De la Roche et al. (1980) proposed a pattern for classification of igneous and intrusive rock based on their cation percentages (Fig 10).

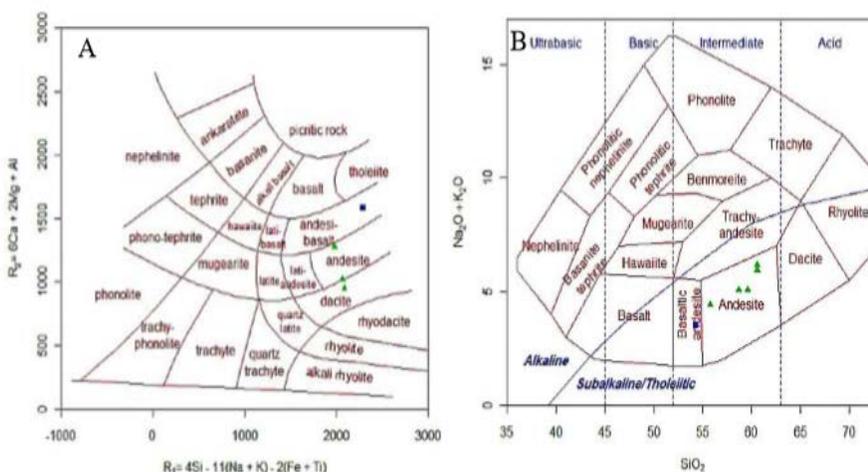


Figure 10: The situation of the samples on the weight percentage diagram versus the weight percentage of Sillis (Cox et al., 1979) (A), The situation of the studied samples on the diagram (De la Roche et al., 1980) (B), The triangles stand for andesite-basalt and the squares stand for basalt.

Magma series determination

According to petrography studies, the volcanic of the area, include andesite and andesite-basalt. These stones are classified as calc-alkaline and calc-alkaline potassium (K₂O versus SiO₂ diagrams; from (Peccerillo and Taylor, 1976)). The studied samples are close to alumna regarding saturation and according to A/CNK-A/NK graph are placed in meta-alumna area (figure 11). The igneous samples are placed in the calc-alkaline area in AFM diagram (Irvin and Baragar, 1971). Andesite-basalt sample is between the two areas (Figure 12).

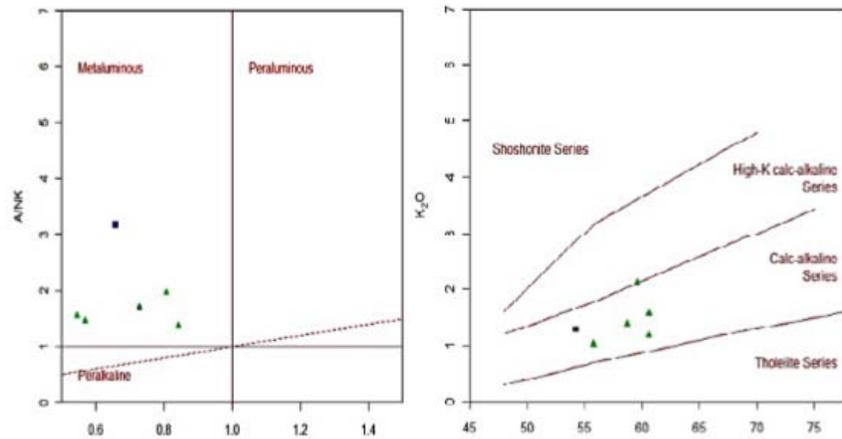


Figure 11. The right one is K₂O versus SiO₂ (Peccerillo and Taylor, 1976)

The left one is A/CNK-A/NK diagram from (Shand, 1943). Triangles stand for andesite-basalt and squares stand for basalt

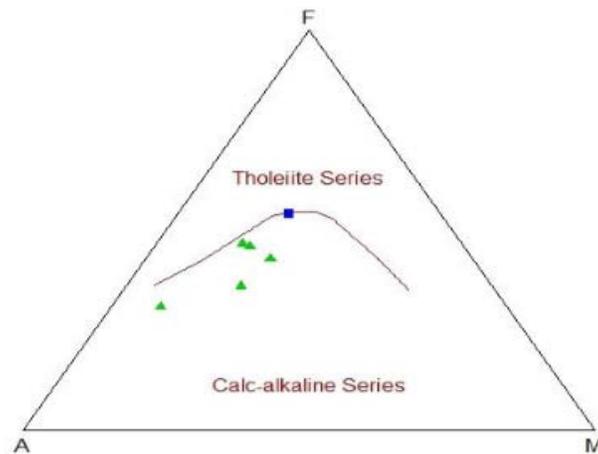


Figure 12. The location of the samples on AFM diagram (Irvin and Baraar, 1971)

Determination of tectonic situation

Two chemical specifications are apparent in these stones:

- Al₂O₃ is high and about 16 percent.
- The Mg# = (MgO / (MgO+FeO) number of these stones is low and about 0.4 percent.

The amount of Al₂O₃ in the above samples indicates the crystallization of mafic ores from the primary magma in relatively high pressures (Yoder and Tilley, 1962). This leads to the concentration of aluminum in the remaining magma; so, crystallization of plagioclase occurs in lower pressures. The amount of CaO reduces with the increase in SiO₂. This may be because of the change of calcite plagioclase to sedic while crystallization of the magma. The weak connection of CaO compared with SiO₂ might be because of albitization of plagioclase crystals (Morata and Aguirre, 2003). The magma that created the analyzed samples has an average Mg of 0.4 and Cr of 54.33 and Ni of 15.16; so, it is not in balance with the above mantles, or that it has gone through magma changes, or it is divided from magma. According to Zr and its amount, the studied stones stand in a great diversity (90- 186). In this sense they are similar to calc-alkaline. The volcanic rocks of the study area are placed in the magma arc region. Regarding geochemical properties and also

considering the spatial and temporal position of the Sistanak volcanic rocks, it seems that these rocks are associated with the magmatism caused by the subduction of the Afghan block below the block of Lut. They are created in the same magma environment (Muller and Groves, 1997).

In order to differentiate the magma arc of the active continental brink from the magma arc of the arc islands, according to Pearce and Norray (1983), it seems like the magma arc that creates the stones of the area is derived from an ocean crust eruption to a continental crust. The ratio of the Zr/Y elements can be used to determine the tectonic system (Pearce, 1979). If the ratio is $Zr/Y > 3$ then they belong to continental volcano arc and if $Zr/Y < 3$ then it belongs to the ocean volcano (Figures 13 and 14).

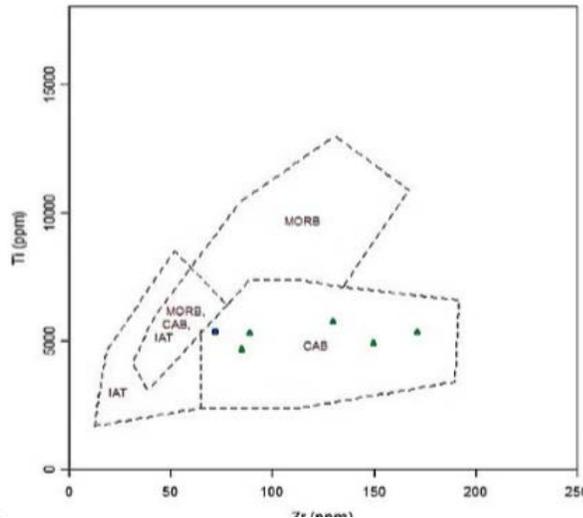


Figure 13. The location of volcanic stones of Sistanak on Pearce and Cann graph (1973)

Normalized spider diagrams of the rare earth elements compared with contridge and primary mantle indicates the enrichment of rare and incompatible earth elements. These features of the calc-alkaline volcanic arcs are active marginal subduction zones and the lithophoresis of Y, Ti and Nb elements, such as depletion of high-intensity elements on the continents. These properties can be a sign of the shell's affinity in the magmatic process, and Ba, Cs, and K are like large crustal ions (Harris, 1986). (The obvious features of continental rocks Nb and Sr are also negative anomalies (Figures 15 and 16).

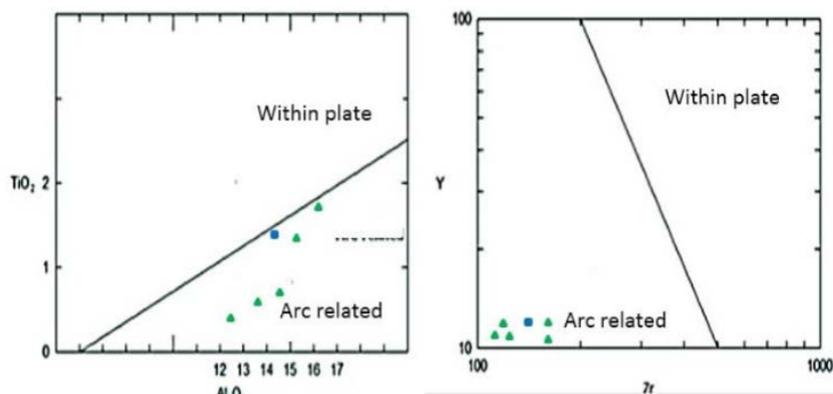


Figure 14. Determination of tectonic environment of the volcanic stones of Sistanak (Muller and Groves, 1997)

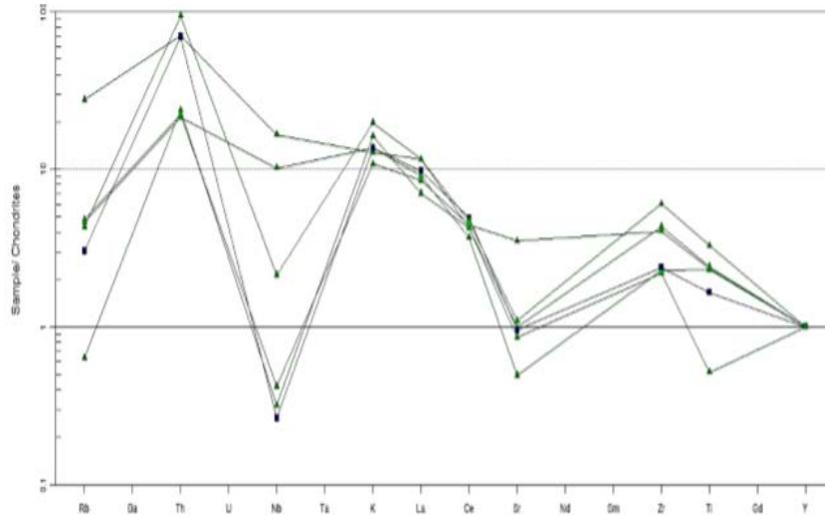


Figure 15. Normalized spider diagram based on chondrite

Description of copper mineralogy in the Sistanak area

The copper mineralogy in the Sistanak area is sparse and occurs in the form of a number of very thin lenses, as well as thin veins and branches that fill the empty space resulting from the presence of joints, gaps and cavities. From the mineralogy point of view, copper mineral consists of pure copper, copper, malachite and calcocyte forming the main mineral part.

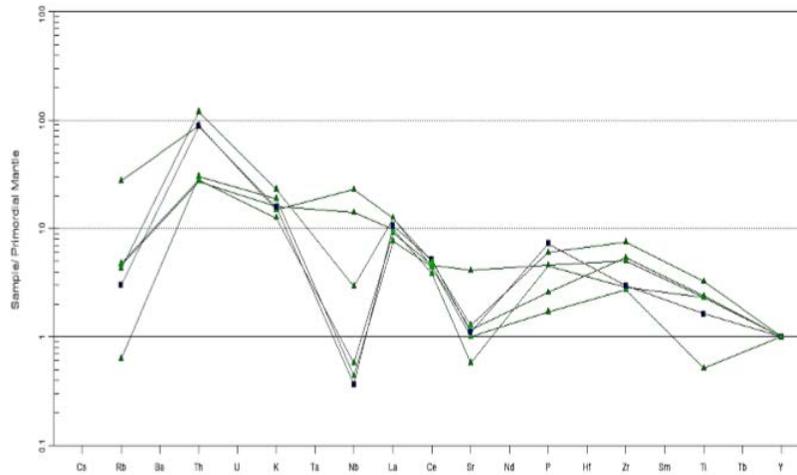


Figure 16. Normalized spider diagram based on the primary mantle

The mineralogy stone is the andesitic lava with amygdaloidal tissue. The mineralogy of copper in the area is basically confined to a three-dimensional andesitic unit of the volcanic sedimentary fringe horizon, and hence is confined to the cypresses of the cypridite type. The mineral horizon of the lane adheres to the volcanic stones. On the margin of pure copper mineral, which forms the cavities the same slope and along the host volcanic rocks, other minerals are green, dark-gray and red, microscopic studies have shown that minerals are malachite, copper and calcocyte.



Figure 17. Filling of andesite cavities with natural copper

In most cases, calcosite ore shows development in sulfide and oxide ores. Among those are degenerate, boronite, colitis and hematite. The utmost co-growth and compaction is about cacosite, hematite and gotite ores (Figure 18).

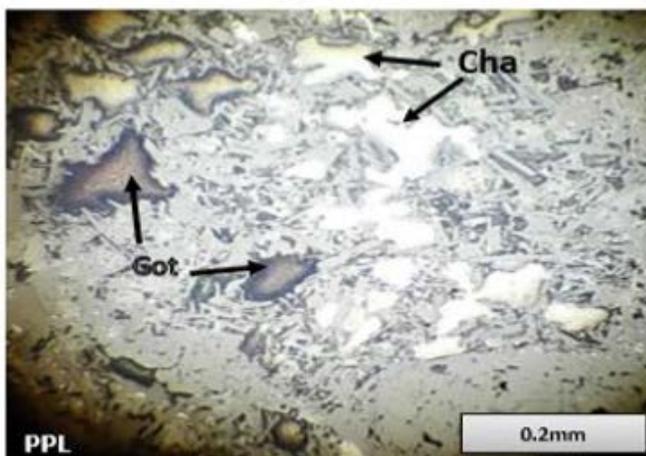


Figure 18. Chalcopyrite (Cha), Gotite (Got) and hematite blades

Chalcopyrite is healthy and non-altered in very rare and grainy sections. During the microscopic studies, we realized that the phosphate-like phases were high in the sections. These phases were copper oxide minerals known as copper, which in all parts, the particle of pure copper.

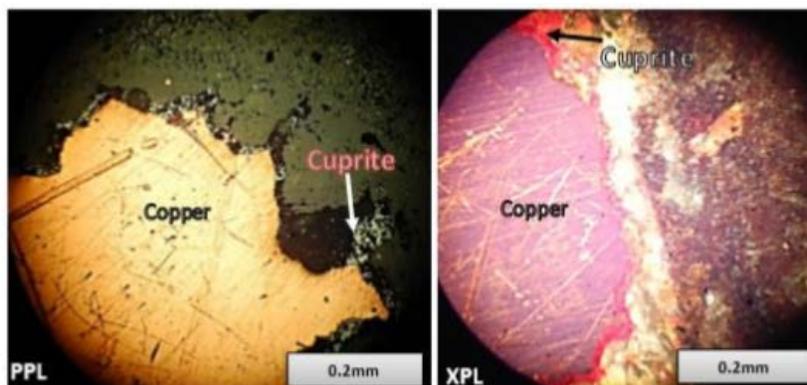


Figure 19: Natural copper close to cuprite

In most cases, the gaps and cavities are filled with hematite. Ores that grow in open spaces usually have good regional structure (figure 20). Gotites have pebble texture in some samples. Pebble texture is a subdivision of cloeid texture (Figure 21).

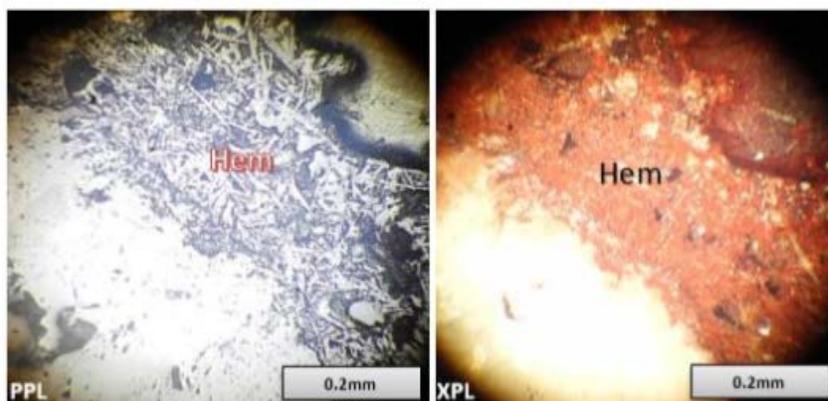


Figure 20: Filling of the cavities with hematite mineral

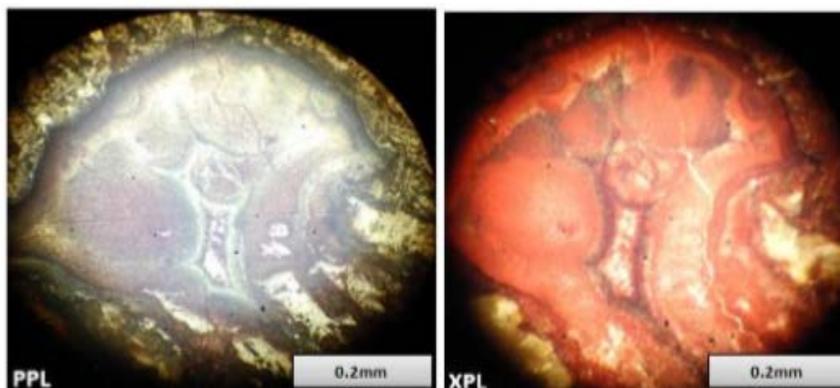


Figure 21. Pebble texture in goethite

Totally, the copper minerals studied in this paper include:

1. Calcocyste and a small amount of chalcocyste (a component of copper sulfide minerals)
2. Natural copper (a metal element)
3. Coprite (among copper oxide minerals)
4. Malachite (a copper carbonate mineral)

The sequence of the ores as deep-seated and at high temperatures is shown in Figure 2. The formation of minerals shows the surface-level minerals resulting from the alteration of primary minerals (Table 1).

Mineralography characteristics in the Sistanak area

The properties of copper mineralography in the Sistanak area is as follows:

1. Copper mineralography in the Sistanak occurred on the stones of the Andesite host city with amygdaloid tissue
2. The presence of natural copper mineralogy
3. Mineralography is limited to the specific horizons of the layers. So, this is a mineralography of the Streiband type.
4. The predominant mineralography tissue is a type of vacancy filler and also branches that is a specific tissue type of low pressure regions. (Shahabpoor, J. 2008)

5. The presence of paragenesis malachite, calcocyte and copper, all indicate the low temperatures of this deposit. (Temperature for coulite formation is 157 and for Calcocyte formation is 160 (Guilbert and Park, 1997).
6. The absence of alteration in a regionally, zoned, and separable manner.
7. The small amount of natural copper represents the presence of sulfur in the formation environment of the ore and is a PH close to the neutral environment.(Qorbani,2002)

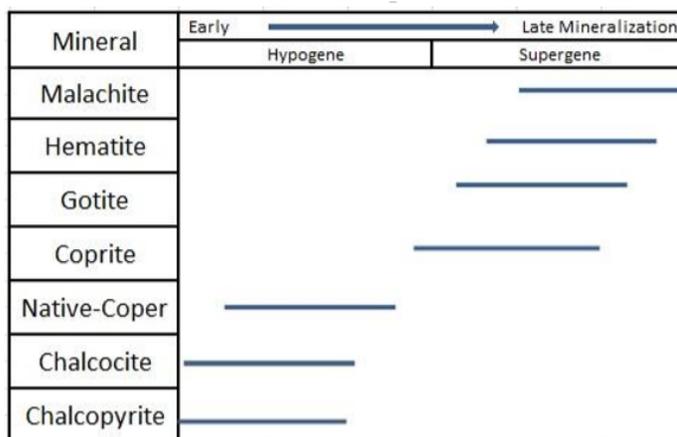
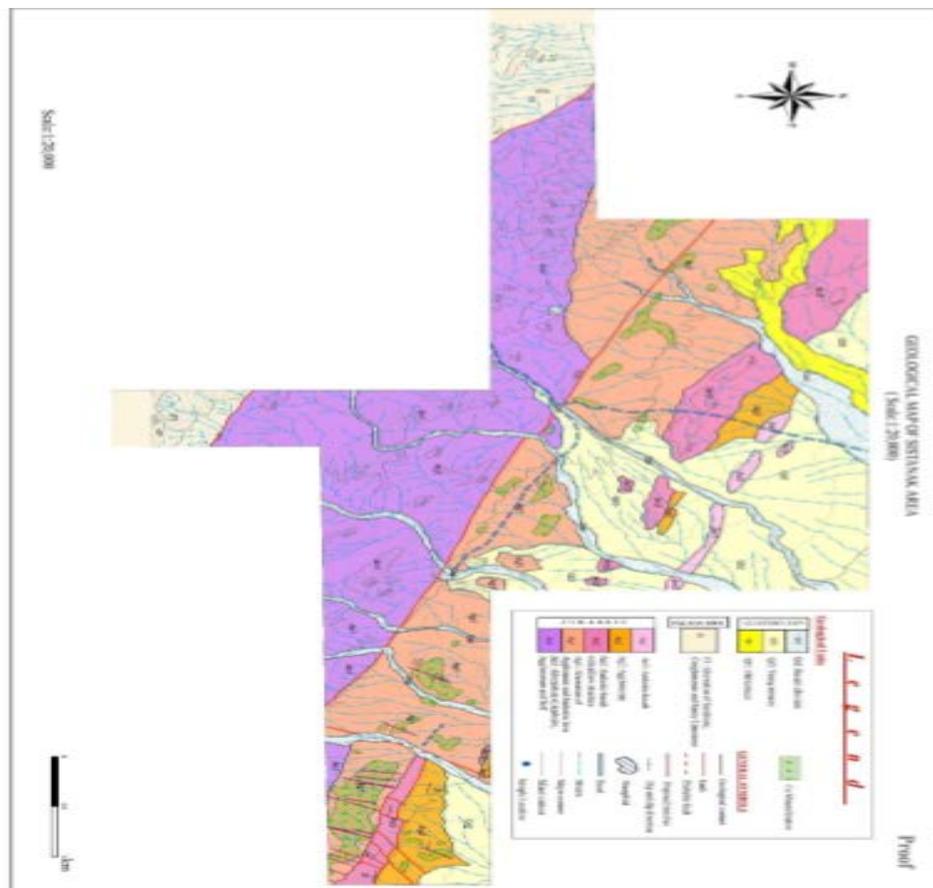


Figure 22. Paragenesis sequence of Siatanak copper deposit

Conclusion

Mineralogy, tissue and stone properties of Sistanak copper deposit, which was formed by volcanic rocks of andesite and andesite-basalt, and the geosynthetic characteristics, of high copper reminds us of the Michigan deposit in the US. In the Michigan Type deposit, natural copper is the main mineral. In this deposit, the size of amygdales and filled branches with natural copper reached up to 10 cm. In the Michigan type, natural copper is ranked first in deposit paragenesis. Other oxide minerals are coperite, tenorite, and chrysolate. In the Michigan type of copper mines, copper sulfide is not present. These two properties exist in the Sistanak copper deposit. Pure copper mineral in the Stainak is one of the main copper ores. The Michigan deposit has no alteration on the surface of the earth, which is also featured in the Sistanak area. The lack of sulfur in copper deposits is unusual. In the Michigan reserves types, due to lack of sulfur, copper enters the structure of oxide minerals. In Sistanak, too little sulfur can cause copper oxide ores. In the Sistanak area, the size of amygdala filled with copper is about two to three millimeters; in a way that in most cases, pure copper can be seen with the naked eye. This feature is also better seen in the Michigan deposit type. Regarding the mineral genes, it seems that the mineralography is a mosaic type constituent, namely, copper mineralization, sporadically dispersed, in form of branches in the host volcanic and pyroclastic stone.



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