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Petrography and geochemistry of metasomatic rocks in Se-Chahun mine, Bafgh, Central Iran

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Key words: Geochemistry, Metasomatism rocks, Petrography, Se-Chahun mine.

Abstract

Bafgh mineral region is part of the Central Iran micro continent. Host rocks of Se-Chahun mine are mostly under the effect of sodic, sodic-calcic, potassic and low-temperature alterations. Sodic-calcic alteration was wider than sodic and potassic alterations. Host rocks are classified to two grouped on the basis of structural changes: micro crystal metasomatits that mostly are seen with dark gray to green-gray color. Minerals set forming these rocks are similar to other metasomatits with macro crystal structure (actinolite, albite, epidote and magnetite). Main minerals forming macro crystals included actinolite, albite and magnetite; and by going near to mineralization place, magnetite mineral percentage increases. In altered rock of the mine AI and CCPI indexes were 79-20 and 90-19 orderly for low-altered and altered rocks and alteration strength increases from relatively healthy rhyolite rocks to other rocks. Existed amphibole mineral in altered rocks were classified in the range of calcite amphibole with the type of actinolite to ferroactinolite and plagioclases compounds varied from oligoclase to andesine. alkalin samples of feldspar located in the range of 70%-90% of orthoclase.

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Introduction

The study of cores and carried out observations in workbench of Se-Chahun mine and microscopic considerations show that Fe mineralized host rock, mostly is outer igneous (rhyolite) and sedimentary-volcanic belonging to Rizzo formation that are severely affected by metasomatism.

Host rocks of Se-Chahun mine are mostly under the effect of sodic, sodic-calcic, potassic and low-temperature alterations. Sodic-calcic alteration was wider than sodic and potassic alterations (particulary in mineralization regions). It should be mentioned that magnetite mineral in rocks belonging to soddic-calcic alteration is more frequent than sodic and potassic altered rocks; and the reason of it, is companionship of magnetite-apatite mineralization with sodic-calcic alteration. Sodic-calcic altered rocks mostly have mineral set of termolite-actinolite, albite, magnetite, epidote, calcite and low amount of rutile, chlorite and titanite. These rocks are classified in to two groups on the basis of structural changes:

Micro crystal structure

Micro crystal metasomarisms mostly have gray to gray-green color. Mineral sets forming these rocks include (actinolite, albite, epidot and magnetite) (Fig. 1).

Fig. 1. Host rock of micro crystal, penetration of fluids into previous micro crystal rock and formation of epidote setting (bright green) among rest segments of previous host rock.

The boundaries of these rocks with macro crystal metasomatims belongs to sodic- calcic alteration and is accidental. These rocks have accidental boundary with magnetite ore and don't have iron oxide halo. Regarding micro size of these rocks, it can be concluded that primary rocks are micro crystal and volcanic. In these rocks albite and actinolite veins are formed in later stages (Fig. 2).

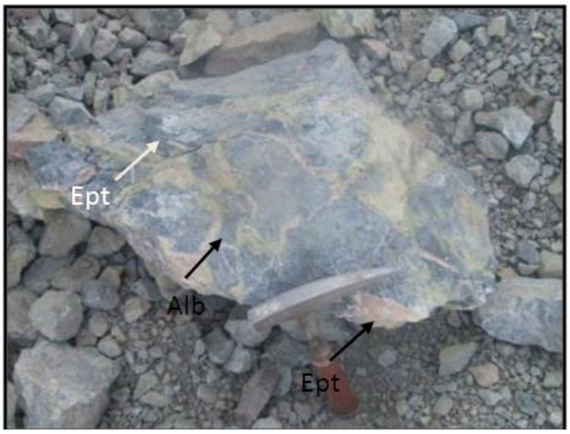


Fig. 2. Albite and epidot in metasomatism micro crystals in the region.

Macro crystal structure

The main minerals of this structure include actinolite, albite and magnetite, that the percentage of magnetite mineral increases by going near to mineralization location (Fig. 3). Magnetite mineral has triangular texture in these rocks which is the indicator of its late nature in comparison with other forming minerals (actinolite- albite) (Taylor, 1992). This texture is a kind of filling texture of empty spaces.

Fig. 3. Host rock of macro crystal, with relatively homogenous texture that locates actinolites besides magnetite.

Calcite veins that have been formed in the rocks are related to after mineralization stages. In some cases sulfide minerals specifically pyrite comes along with carbonate veins. It should be mentioned that pyrite is observable in rock setting of calcite or alone (Fig. 4,5). In far regions from mineralization rocks' textures are more homogenous and magnetite mineral is rarely observable.

The aim of this study is recognize metasomatism in host rocks of Se-Chahun mine and divided to sodic, sodic-calcic, potassic and low-temperature alterations.

Fig. 4. Entrance of calcic veins in metasomatism rocks far from mineralization place.

Fig. 5. A rock sample from far region of mineralization, magnetite signs are not observable in these rocks.

Material and methods

Sampling and analytical method

During the field observations, 150 rock samples were collected from the study area. After studying the manual sample, 125 thin sections preparation and was studied with polarizing microscope. 15 samples of metasomatic rocks were obtained by using the ICP-MS chemical analysis and were sent to AcmeLabs in Canada. Geochemical data was also analyzed by using Excel, GCDKit, Igpet, and Minpet programs.

Electron Microprobe Analysis

Feldspar, plagioclase and amphiboles analyses were obtained by wave length dispersive X-ray spectrometry on polished thin sections prepared from each rock sample described above for 12 elements using a Cameca SX-100 electron microprobe at the I.M.P.R.C. Typical beam operating conditions were 15 kV and probe current 11 nA. The result of analysis studied with Excel and GcdKit software.

Area under study

Bafgh mineral region is part of the Central Iran micro continent. Ancient magnet studies on rocks and iron deposits are related to Precambrian to lower Cambrian, and are the indicator the equivalence of regions' rocks with same age rocks in India and Pakistan; on this base, it is suppose that central Iran the same as India was part of the Gondwana (Bacher *et al.*, 1973). The region that is around Bafgh is considered as a part of Central Iran zone, and has conserved its characteristics as a platform till Triassic period, but it has been affected by folds and thrusts since Jurrasic.

Evolution of East micro continent and center of Iran is explainable by Pan orogenic-African in 600 years ago (Bacher *et al.*, 1973). The comparison between sedimentary basin, magmatic belt and existed faults in Saudi Arabia, East micro continent and center of Iran is not possible easily, because ths micro continent was located at the east part of Saudi Arabia 600 years ago, and has been rotated several times till separation from Gondwana (DarvishZadeh, 1992), for example, the extension of Bafgh-Saghand region was east-West in Cambrian period (Fig. 6).

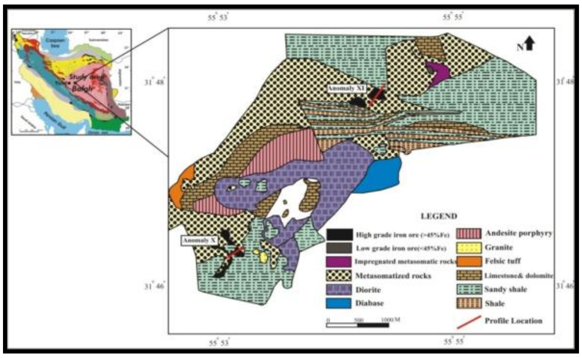


Fig. 6. Geological map of Se-Chahun's region (adopted form National Iranian Steel Company, 1975).

Results and discussions

Geochemistry of metasomatism rocks in Se-Chahun mine

Rare Earth elements (REE) has consistent ion 3^+ with similar size and same physicochemical characteristics. By enhancement of atomic number, these elements show a little different chemical behavior because of homogenous reduction of ion sizes. Such characteristics among rare Earth elements cause their separation as a result of some geological processes. This phenomenon is helpful in determination of rock set's genre and the nature of geological processes.

Previously it was believed that REE are inactive elements which alteration and washing processes is ineffective on them (Palacios *et al.*, 1986). But some other studies on REE in hydrothermal solvents (Michard and Alberdeh. 1986 and Luis *et al.*, 1997) and altered rocks in epithermal and porphyry copper areas (Alderton *et al.*, 1980, Tiller and Ferry, 1980, Hopef, 1993 and Aribas *et al.*, 1995) showed that these elements act as mobile elements in some conditions such as higher ratio of water in comparison with rock and frequency of ion complex of Cl^-, SO_4^{3-} , CO_3^{2-}, F^-.

Usually REEs form complex with SO_4^{3-} and Cl^- and become mobile under acidic conditions (Hess, 1995 and Wood, 1990). In the other hand these elements may be released from primary minerals in the condition of low PH, while in alkaline conditions they sediment as hydroxide, carbonate or adsorption of clay minerals. Separation and differentiation from HREE are controlled by mineralogy of primary unaltered rocks, carbonated fluids (Tors Alvardo *et al.*, 2007) and differences in cations' capacity of REEs (Parsapour *et al.*, 2009). Most of the REEs have $3^=$ capacity and their ion diameters decrease by enhancement of their atomic number, but Eu and Ce show different geochemical behavior, in a way that Eu has 2^+ capacity in revival conditions and Ce has 4^+ capacity under oxide conditions; in such situation ionic potential increases and as a result they have lower mobility. As outcropped rocks in workbench of Se-Chahun mine are altered and the nature of primary host rock is changed completely, it is necessary that geochemistry of these rocks be considered separately.

Host rock samples are classified in rhyolite and rhyodacite range on Dolarosh *et al.* (1980) classification graph. Hydrothermal alteration causes different changes in the amount of main and subsidiary elements of Se-Chahun host rocks.

The amount of SiO_2 in healthy and altered host rock is 55.37 and 72.9 orderly and total mean of alkaline elements (Na_2O+K_2O) is 5.04 and 6.54 orderly. The percentage of these elements is the indicator of the effect of alteration on these rocks. Therefore to name host rocks Winchester and Floid's (1977) graph was used (Fig. 7). In this graph, low mobile elements were used for naming and host rocks have classified in rhyolite and rhyodacite.

To calculate chemical changes of total rocks under the effect of alteration, (Chlorite-carbonate-pyrite index) was used for felsic volcanic rocks (Large *et al.*, 2001). In addition, for calculating chemical changes during alteration, alteration index was used (Eshikva *et al.*, 1976). This index is calculated regarding following formula:

$$AI = \frac{100(K2O + MgO)}{(K2O + MgO + Na2O + CaO)}$$

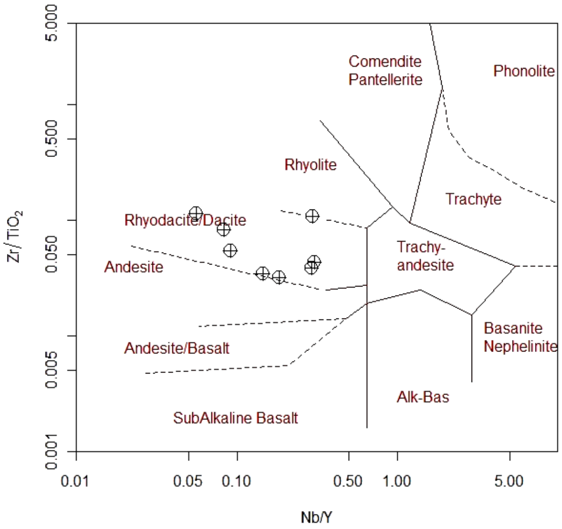


Fig. 7. Naming host rocks by Winchester and Floyd (1977).

This index was applied for the first time in 1976 by Eshikava *et al.* for quantifying chlorite and sericite alteration intensity. Key interactions that are calculated by this index include breakage of sudic plagioclase and volcanic glass and their substitution with sericite and chlorite. Descriptive reactions for this alteration are presented below:

1) $3NaAlSi_3O_8+K^++2H^+= +6SiO_2+3Na^+$ (1)

2)$KAl_3Si_3O_{10}(OH)_2+3H_4SiO_4+9Fe^{2+}+6Mg^{2+}=3Mg_2 Fe_3 Al_2Si_3O_{10}(OH)_8+2K^++28H$ (2)

The first reaction is indicator of sericite substitution with albite in volcanic rocks in upper parts of alteration system (Deet *et al.*, 1983 and Esto *et al.*, 1987). The second reaction is related to substitution of chlorite with sericite that is an important process in mineralization of Maceio sulfide (Songester, 1972, Large, 1992 and Sharto *et al.*, 2001).

It should be mentioned that AI index means the ratio between elements of a rock during chlorite and sericite alteration by missing elements. This index in healthy rocks varies between 20-60 and in altered rocks it varies between 50-100. The amount of AI=100 shows complete substitution of feldspar and volcanic glassy rocks by sericite or chlorite. As extraction of sodium is the indicator of sodic plagioclase breakage, there is a strong relation between AI and sodium depletion. In fact in most of the carried out studies for determine the intensity of alteration, sodium depletion was used instead of AI (Frenkline *et al.*, 1975 and Hashigucci *et al.*, 1983).

Using AI index has two limitations; first, carbonate alteration cannot be judged and second, the boundary between chlorite and sericite alteration cannot be possible. By innovation of Chlorite-carbonate-pyrite index (CCPI) these two problems eliminated relatively.

$$CCPI = \frac{100(MgO + FeO)}{(MgO + FeO + Na2O + K2O)}$$

In above formula, FeO is equivalent of sum of ($FeO+Fe_2O_3$). In fact this index is designed for measuring enhancement of MgO and FeO beside enhancement of Mg-Fe chlorites amounts that substitute with Albite and potassium feldspar or volcanic rocks sericite. This index has direct relationship with Mg-Fe carbonate alteration (such as dolomite, ancrite and sedirite) and is enriched with pyrite, magnetite or hematite. Regarding this index, those amounts that are more than 80 are indicators of relatively intensive to intensive alterations.

One of the most important limitations of CCPI is that it strongly affects by magmatic differentiation and fluctuation of volcanic rocks' primary compunds. Final members such as albite, potassium feldspar, sericite, chlorite, pyrite, dolomite, ancrite and epidote are located in the boundaries of this box. The corresponding points of each sample were located in alteration determination graph (Fig. 8). Regarding this fig., AI and CCPI for each of the relatively altered and altered rocks are 20-79 and 19-90% orderly and alteration strength increases from relatively healthy rhyolite rocks to altered rocks.

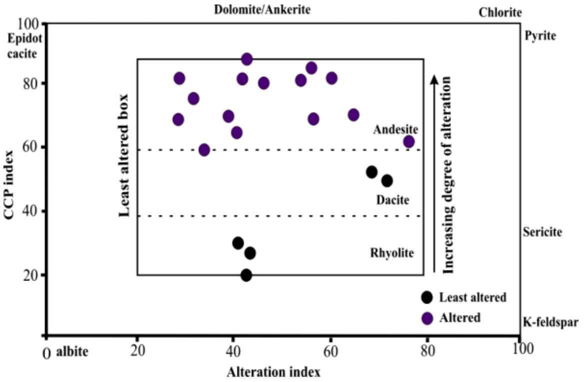


Fig. 8. The graph of CCPI by AI and location of relatively altered to altered samples of Se-Chahun region on it.

In Fig. 9, diagonal line connecting potassium bearing feldspar to epidote separates boundary of hydrothermal alteration phenomenon (in north east part of graph) and diagenetic phenamenons (in south west part of the graph). In addition, identified procedures by numbers on black arrows are presented as follow:

Procedure 1- Alteration of weak sericite in the edge of hydrothermal systems in felsic volcanic host rocks
Procedure 2- Alteration of Sericie- intensive chlorite± pyrite
Procedure 3- Alteration of chlorite ± sericite ± pyrite
Procedure 4- Alteration of chlorite – carbonate
Procedure 5- Alteration of Sericie – carbonate
Procedure 6- Anomalistic alteration of potassium bearing feldspar- sericite

According to above fig., mineral and chemical changes occurred in volcanic rocks of Se-Chahun mine are as a result of hydrothermal processes and are not related to digenetic events. In the other hand, no distribution of analysis results in alteration determination graphs show that all rocks are affected by the same solvent with not wide thermal range and mostly low to average range, because almost all of altered volcanic rocks are located around 5 and 4 procedures and despite of four distinct separation zones of sodic, sodic-calcite, pottasic and propylitic in lithology studies, the zone is under the effect of carbonate-sericite and chlorite-carbonate alteration from alteration phenomenon nature's point of view. Absence of samples near vertical side of determination graph means lack of sever alteration and not high temperature. It should be mentioned that the compound of percalcium in alteration hydrothermal solvent is the indicator of logical relation between these solvents and calc-alkaline magma that is of region's volcanic rock generator and it can be considered as an evidence for altered magmatic fluids' source (Fig. 9).

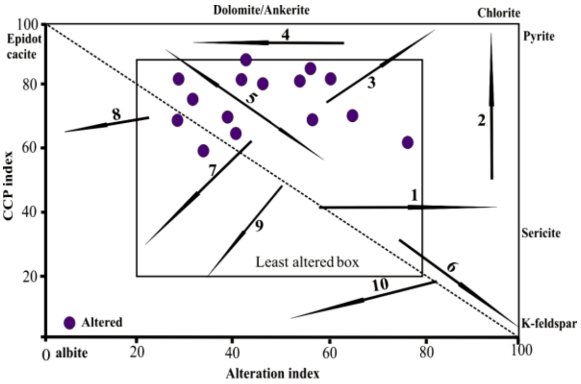
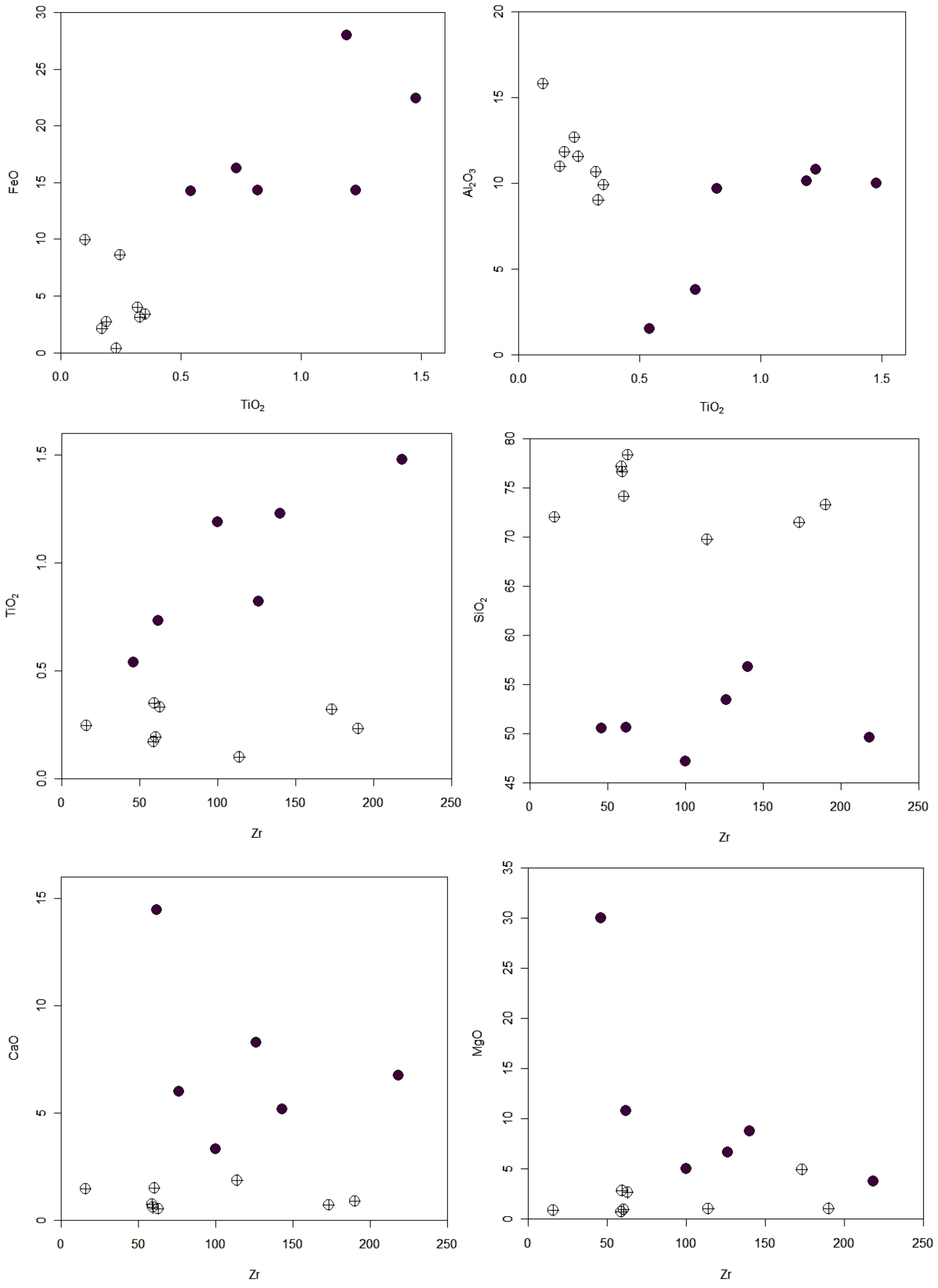


Fig. 9. Territory related to digenetic alteration (down, left side) and hydrothermal (up, right side) in alteration determination box. Arrows are indicators of general procedures for hydrothermal and digenetic alterations.

Because of alteration event in the region, beside mineralogical studies and determination of altered zones, these zones were studied from the aspect of changes and mobility of elements. Geochemical studies of total rock can be helful in understanding of primary rocks' changes during alteration and the effect of alteration process on REE and main elements' mobility. To do so, the processes of non-mobile elements' changes (Al, Ti, Nb, Y and Zr) against each other's and against other elements were used (Adof *et al.*, 2005). In the graphs of Fig. 10, main elements' oxides and Nb and Y by Zr have been drawn. On the basis of graphs by proceedings of alteration the percentage of elements of FeO, MgO, TiO_2 and CaO increased and oxide percentage of SiO_2 decreased. The percentage of Al_2O_3 did not change during alteration and this shows non formation of muscovite in altered rocks. In addition rare elements of Nb increased and Y decreased. REEs such as Y may be consistent during alteration; this can be as a result of various mechanisms, 1- conservation of primary minerals that are resistant against alteration, 2- stability of new-formed crystals, and 3- absorption by clay minerals.



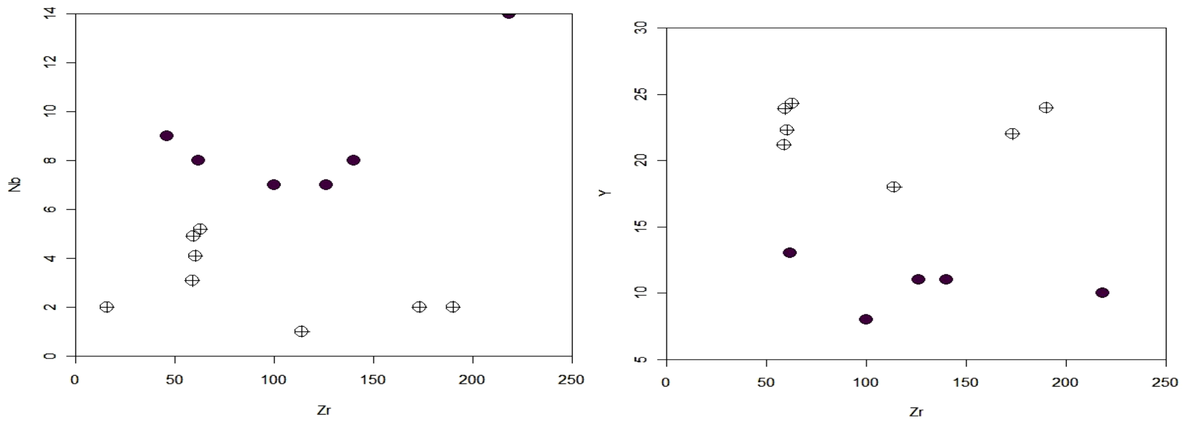


Fig. 10. The comparison between main and rare elements' oxides of altered and low altered rocks, the signs of altered and low altered rocks.

The chemistry of host rocks' mineral of Se-Chahun deposit

Amphibole

Amphibole is important silicate mineral in altered host rock of Se-Chahun mine. Amphiboles of these rocks were analyzed by electron microprop method. According to Leek *et al.*'s(1997) (Fig. 11) method for classification of amphiboles samples were grouped in the range of calcite amphibole in class of actinolite to ferroactinolite. Analysis of actonite crystals showed that marginal points if crystal had lower FeO and more MgO. This indicated the formation of ferroactonite edges.

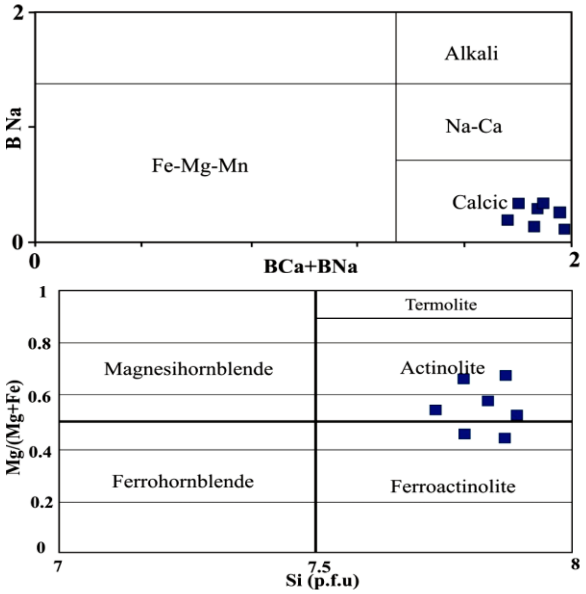


Fig. 11. Classification of host rocks' amphiboles of Se-Chahun mine according to Leek *et al* (1997).

Feldspars

Feldspars are alkaline alumina silicates and earthalkalines having K, Na, Ca, Sr and Br cations. Feldspars' common compounds can be shown by orthoclase-albite-anorite system. Members between albite and orthoclase are named alkaline feldspar, and members between albite and anorite are named plagioclase.Feldspars of Se-Chahun host rock were analyzed by micro prop electron method. Plagioclases compounds varied from oligoclase to andesine (Fig. 12).

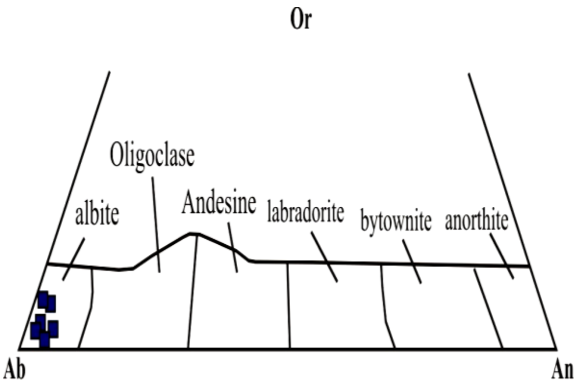


Fig. 12. Classification of plagioclases on the basis of chemical compounds (Dor *et al.*, 1992).

Alkalin samples of feldspar located in the range of 70%-90% (Fig. 13). The difference between samples' compound is because of presence of pertite texture that occurs as the both growth of sodic and potassic feldspar.

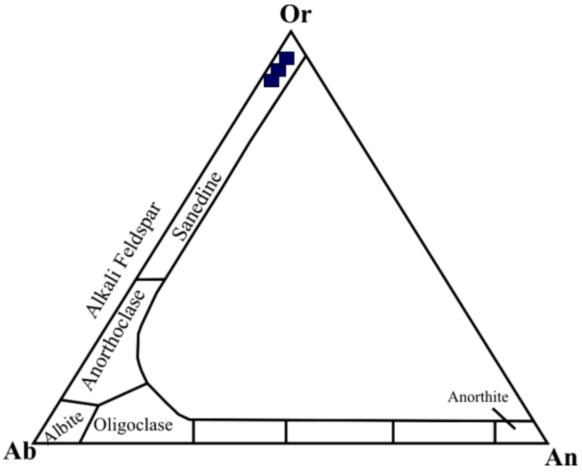


Fig. 13. Alkaline classification of feldspars of the region according to chemical compound (Dor *et al.*, 1992).

Conclusion

Host rocks are classified to two grouped on the basis of structural changes: micro crystal metasomatits that mostly are seen with dark gray to green-gray color. Minerals set forming these rocks are similar to other metasomatits with macro crystal structure (actinolite, albite, epidote and magnetit). Main minerals forming macro crystals included actinolite, albite and magnetite; and by going near to mineralization place, magnetite mineral percentage increases. In altered rock of the mine AI and CCPI indexes were 79-20 and 90-19 orderly for low-altered and altered rocks and alteration strength increases from relatively healthy rhyolite rocks to other rocks. Existed amphibole mineral in altered rocks were classified in the range of calcite amphibole with the type of actinolite to ferroactinolite and plagioclases compounds varied from oligoclase to andesine. Alkalin samples of feldspar located in the range of 70%-90% of orthoclase.

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