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Mineralogy and Geochemistry of Rhyolitic domes and Perlites in the Ghledokhtar, Northwest of Iran

Amin Allah Kamali*, Mohsen Moayyed, Amir Mohamedgol, Ali Asadi
Departmentof Geology, Faculty of Natural Sciences, University of Tabriz, Iran.
* Corresponding author; Email: aminkamali1984@gmail.com
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Abstract : Volcanic rocks of Ghledokhtar are located some 15 km southeast of Mianeh Township, East Azarbaijan province, northwestern Iran. Acidic rocks of the area include Oligocene rhyolite, rhyodacite, perlite and lava. Rhyolites and rhyodacites are exposed in the form of domes as well as lava flows. Perlites that occurs in the lower parts of the rhyolites and rhyodacite domes, was formed by the rapid cooling of acidic lavas and volcanic glasses such as obsidian, which later converted to Perlite in the presence of atmospheric and hydrothermal waters. Agate in Ghledokhtar area has occurs in voids inside the acidic volcanic units of Oligocene. Formation of silica in the host- and surrounding rocks including cavities may be attributed to hydrothermal gases in the region. Mineralogically the rhyolitic and rhyodacitic rocks include sanidine, quartz, plagioclase, hornblend, biotite and opaque minerals with microlithic porphyry texture. Geochemically, however, rhyolites indicate calc-alkaline nature belonging to I-rhyolites and magnetite series. The rhyolites of the area, in relation to (give details of abbreviation first) HREE in parenthesis and HFSE (same as above), are enriched in LILE (as above) and LREE (as above) but depleted in Ta and Nb as they are related to an arc system. The tectonic setting and origin show that they represent rocks that are associated with subduction and were contaminated by the upper crust. Besides, they show negative anomalies of Nb, Ta, P, Ti and Pb. Tectonic setting and discrimination diagrams point that the rocks were formed due to subduction of the neotethys beneath the central plate of Iran, in the central Iranian active continental margin.

Keywords: Ghledokhtar, rhyolites, subduction, perlite

1. Introduction

The studied area is located around 15 km southeast of Mianeh Township (Gledokhtar), in the East Azarbaijan province. The volcanic domes of the Ghledokhtar have penetrated into the Eocene volcanic rocks and the accompanying pyroclastic rocks. Studied volcanic rocks forms a part of an important tectono-magmatic unit, called as Central Iran Magmatic Complex. Alternatively, in the Tertiary-Miocene acidic volcanic rocks of Mianeh area, many reservoirs of perlite have been identified and some had been exploited. The lithological and geochemical characteristics of these deposits and their generation processes have not been examined so far. Considering chronological and geological similarities between the studied area and Aghkand and Soleymanbolaghi areas in the northern part of Zanjan, a comparison has been done between them. Generally, exposed acidic rocks of Aghkand and Soleymanbolaghi areas include rhyolite-hyodacite, perlite, pichestone and ignimbrite with the age of Oligocene. Dome-shaped and lava-flow outcrops of rhyolites and rhyodacites are observed. Perlites underlie rhyolite and rhyodacite domes (Ebrahimi *et al.*, 2016 and Sadri *et al.,* 2015). Previous studies in this area from different perspectives are by Kamali *et al.*(2010). In the present study, petrology, geochemistry, nature of magma, tectonic setting as well as the formation processes of perlites has been discussed.

2. Geological Background

Gaflankouh volcanic rocks are located in southeast of Mianeh (between 45 08' 11 and 48 10' 23 and latitudes of 39 22' 50 and 39 24' 20” (Fig.1.a, b and c). Pyroclastic rocks are one of the oldest rock units which extensively spread in the eastern, western and centeral parts of the studied area. Primary volcanic activity, with severe explosive nature, produced various pyroclastic sediments that were followed with lava flows. Submarine explosive eruptions resulted in to formation of tuff, agglomerate and breccia with ignimbrites in dry environments. The tuffs are mostly gray and the ignimbrites are observed coarse-shaped and brown with welded and flow structures. Basalts, andesites and trachyandesites are gray to dark gray and have phenocrysts of plagioclase. The pyroclastic rocks of the area are also cut by a series of feeding dikes which continue until the lower surface of basalt andesites.

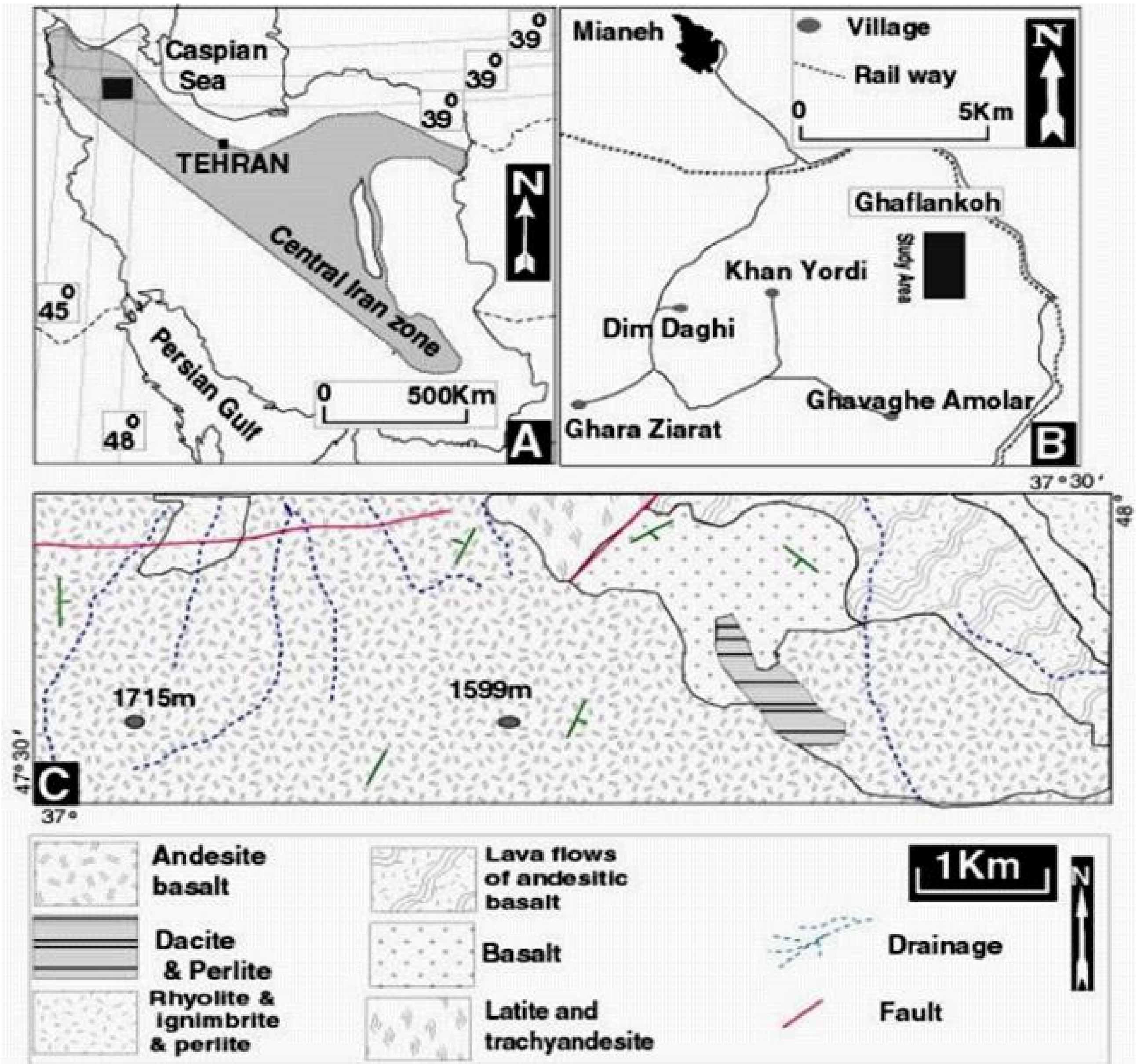

Fig. 1. Location of the studied area in northwestern Iran (a); Roads leading to Gaflankouh (b); Geology map of the region (c) (Adapted from geological map of Mianeh; 1; 100000).

All Eocene volcanic rocks on either sides of the Ghezelozan river and the northeast of area are covered by a series of eruptions of rhyolitic to dacitic in nature in the form of domes and slightly flows (Fig 2a). Perlite forms the lower part of the domes and the upper part is composed of laminated rocks (Fig 2 b). The acidic rocks of the area, show abundant erosion-cavities, which were later filled with silica (as agate and quartz) and calcite (Fig 2 a). Perlites, the dehydration products of glasses, such as obsidian, are observed mainly in the center part of the area and the lower parts of the rhyolitic domes. The existence of perlite in the lower part of the dome indicates that after eruption of lava as a silica dome, magmatic water was absorbed by the lower parts of the dome that resulted in the conversion of the glass to perlite due to effects of dehydration and exotic water. This perlite preserves its lava shape with apparent flow structure (Kamali *et al.*, 2010).

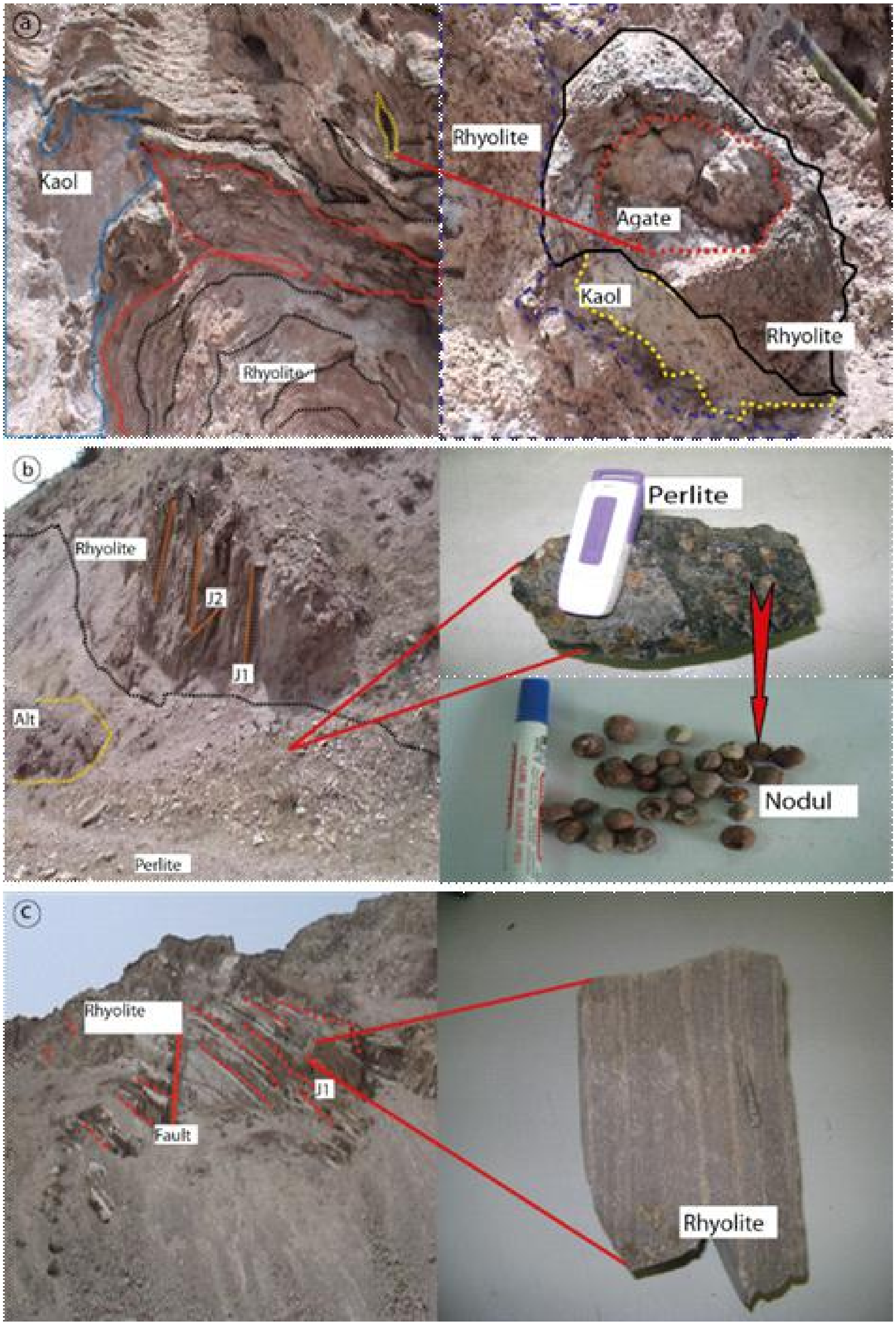

Fig. 2. Flow structures and weathering of rhyolites, kaolinitization and agate mineralization in the caverns of the rocks in the area (a); Two types of joints in rhyolites, perlite mineralization and siliceous nodules inside perlites (b); Corrosion faults and joints in rhyolites and flowe structure in hand specimens (c). ((Nodul) Nodul; (Alt) alteration; (T.st) tafoni structure; (J) Joint; (Kaol) Kaoline).

Ignimbrites often have flow origin and onion weathering texture (Fig 2, c). Light-colored appearance of perlites in field observations is actually the result of the clay minerals formed during weathering. In the hand specimens of perlites there are many nodules with radii of about 2 centimeters which have silica composition (Fig 2 b). The area is affected by numerous faults. Normal faults have north-south trend and eastward slopes. Whereas, reverse faults have northwest-southeast trends and northeast slopes. Normal faults have cut through basaltic andesites. Reverse faults, however, are seen in pyroclastic rocks. As the initial phase volcanic eruptions appeared as pyroclastic rocks and due to magma pressure the reverse faults cut off the pyroclastic rocks and finally magma was poured and basaltic andesite lavas were formed. Normal faults were formed due to the evacuation of the magma and collapse of the central volcanic area (Kamali *et al.,* 2011).

3. Research Methodology

This research includes field- and laboratory studies. Out of the forty rock samples were collected, 25 were studied petrographically, 9 samples were analyzed using ICP MS and 1 using XRD at Sahand Industrial University. Analyses of 6 (from Aghkand were used for comparison (Ebrahimi *et al.,* 2016) and Soleymanbolaghi (Sadri *et al.,* 2015), Zanjan. The major elements were analyzed using the ICP-ME 06 method and with an accuracy of 0.01weight percent and rare earth elements (REEs) were analyzed according to the ME-MS81 method with an accuracy of 0.01 ppm.

4. Petrography

Megascopically fresh samples of dacits and rhyolites look gray in colour. However, on weathering they look in colour varying from gray to pink. Pterographically the rocks show porphyritic texture with amphibole phenocrysts and cavities filled with silica and calcite. Minerals include sanidine, quartz, plagioclase, hornblend, biotite as well as opaque minerals. Sanidine occurs as in the form of euhedral to subhedral phenocrysts with microlihts that show carlsbad twinning (Fig 3a). Plagioclase shows zoned euhedral to subhedral phenocrysts (Fig 3b). Hornblende, mostly opacified show euhedral to subhedral forms (Fig 3a). This event, being indicative unstable conditions for hornblende minerals during magmatic crystallization, is a kind of mineral reaction in which the sides are molten. This melt was not in equilibrium with the mentioned mineral. Medium grained biotite occurs in euhedral to subhedral forms (Fig3, b) and in dark-brown color (oxy-biotite.

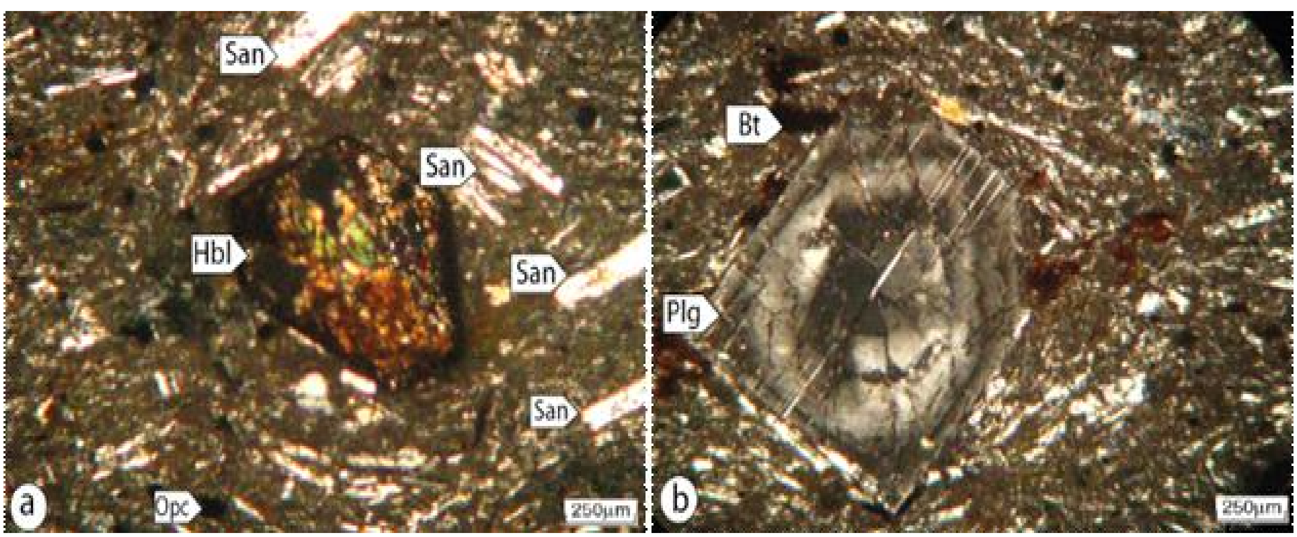

Fig. 3. a) Sanidine (San), opacified hornblende (Hbi); b) plagioclase zoning (Plg) and biotite with burnt margins (Bt).

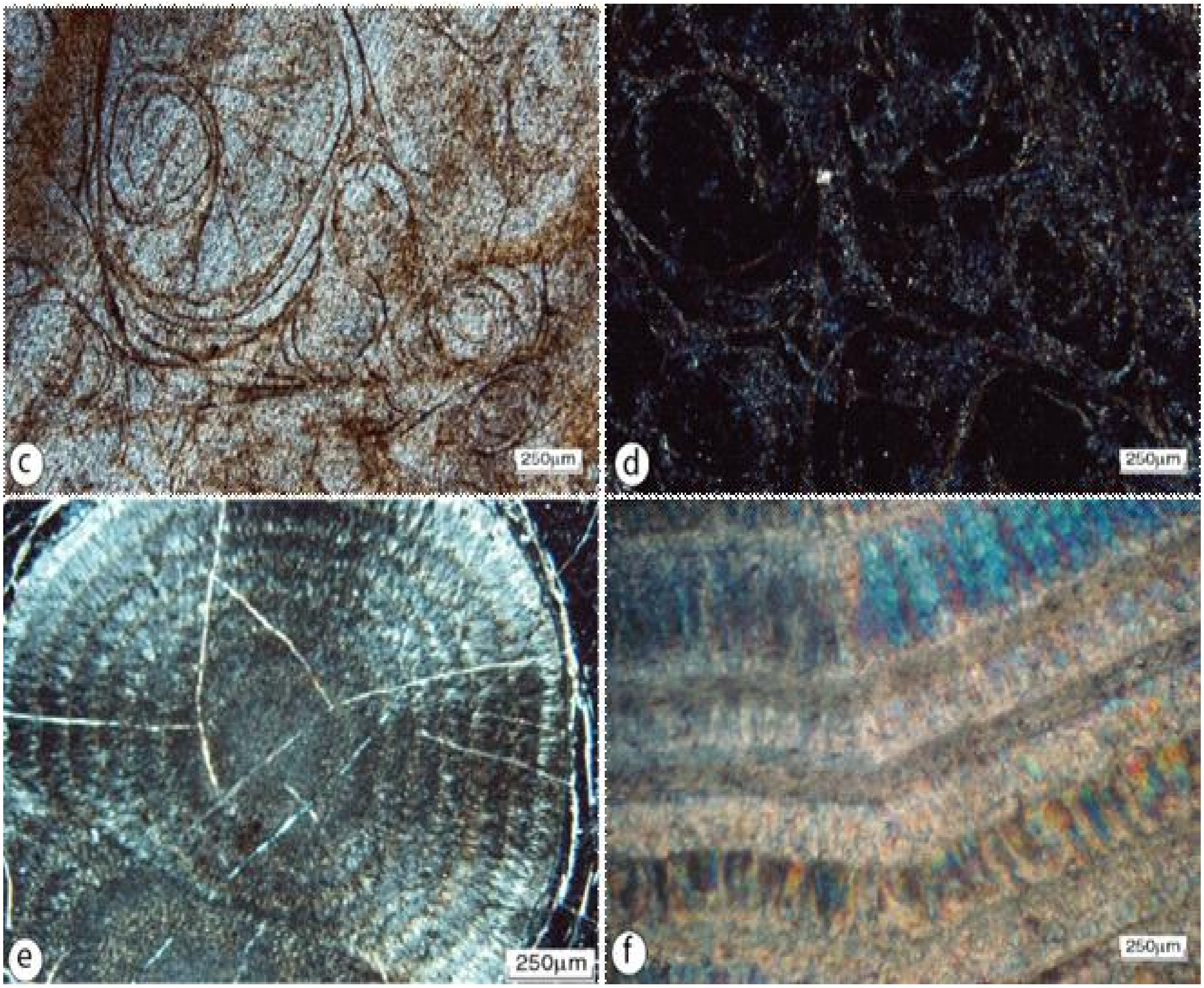

Fig. 3. c) Onion weathering structure of perlite (PPL); d) Onion weathering structure of perlite (XPL); e) Nodules inside perlite (XPL); f) band and fiber textures of Agates.

The opaque minerals occur, partially as secondary mineral in abundance. Porphyry microlitic is the main texture and trachytic is the minor texture. Perlites are usually brightly colored and glassy types are gray or dark green with conchoidal fracture and pearly luster and often have a glass matrix and the dominant texture is perlitic (Fig 3c). This texture is identified with circular lines and concentric circled or crescent shapes (Fig 3d). In fact these perlites are hydrated obsidians that appear in the form of concentric fractures (perlite fractures) and show onion skin weathering (Fig 3e). Around perlite fractures, devitrification state is observed and obsidian is often found indicating dehydration in rhyolitic glasses (obsidian) and its conversion into Perlite. Spherulite and ignimbrite textures are observed in rhyolites and ignimbrites. Agate occurs in banded forms (occasionally firbrous, Fig 3f) formed due to the coexistence of filamentous quartz and chalcedony layers because of the changes in the conditions affecting the rocks from outside and sedimentation of silica gels in these layers. Remnants of acid magmas in the region are the source of these silica gels. A silicate source is necessary for the formation of agates which could produce the necessary silica for the formation of agates as a result of volcanic wall-rock alteration by the hydrothermal processes (Götze *et al.,* 2001). Basically there are two possible hypothesis for agate formation: first is based on agates in the host rock or surrounding rocks formed by hydrothermal gases that fill the cavities while the second claims that agates are formed by the sedimentation of silica gels within the magma containing the trace elements and the water (Merino *et al.,* 1995). The presence of a marked flow structure in rhyolites and ignimbrites indicates their high viscosity (Fig 2c). Based on petrographic evidence, in acidic volcanic rocks in the studied area agates are formed as a result of the crystallization of silicate phases from acidic magmas while the liquid phase rich in silica or silica gel is left behind. In some agates, the crystallization of the non-silicate phase appears as calcite at the end of the crystallization process. Silica gel, which is in steam or liquid state, has entered the seams, gaps and cavities of acidic volcanic rocks such as rhyolites and ignimbrites and during gradual cooling has formed chalcedony in the rocks of the area. In different cavities silica gel crystallizes differently. If the amount of silica gel is sufficient (super saturation) in the cavities, the crystallization process quickly generates intermittent layers of chalcedony on the vein walls. If the silica gel volume is less than the volume of the cavity and also the silica gel is saturated in silica, the crystallization rate reduces and instead of chalcedony bands, quartz crystals, fine to coarse grained, form from the margin to the core of the cavity. The geod cavity formation is the result of the empty part in the core. Cavities in geodes are filled with outside materials such as calcite or manganese.

5. Perlitization

The occurrence of perlite in Iran is usually limited to rhyolitic-belts Tertiary to Quaternary). Perlites generally occurs in domes at a height of a few hundred meters. However, glass zones occurs in ignimbrite flows and other complexes adjacent to dikes and sills. According to some old theories, perlite was a primary source. Accordingly. the presence of 2 to 5 % of water in perlite is connected with the rapid cooling of acidic magma in a rich-water environment. Later, the theory of dehydration of volcanic glasses such as obsidian is known as an alternative process for perlite formation and is considered as a secondary source for perlite formation (Ross and Smith, 1995). Accordingly, perlite can be formed as a result of the subsequent dehydration of obsidian. The water in obsidian is derived from magma, whereas the water that exists in perlite is formed during dehydration following the crystallization of magma. Typically, after the rhyolitic lava leaves and cools rapidly, the water enters into the lower parts of the domes and makes it possible for the glass (obsidian) to convert to perlite through dehydration (Fridman *et al.,* 1966). The dehydration of a thin layer of primary obsidian causes the expansion of the rock. It results in the formation of cracks and their developments lead to perlite formation (Chesterman, 1954). It was concluded, from perlite studies in California, that perlite is composed of obsidian in the presence of water vapor pressure. The following steps for perlitization were proposed: a) obsidian emplacement in the shape of dome, dike and sill; b) Obsidian conversion to breccias after emplacement; c) Water vapor in proximity to obsidian and its conversion to perlite; d) and finally the alteration of perlite to clay minerals because of excessive dehydration and passage of time. Up 3% of water absorption by obsidian results in water saturation conditions. This water is located in the obsidian structure in the form of molecules (perlite). In addition to the effect of the water as melting aid, this water is the source of explosive force caused by evaporation during perlite expansion. The degree of obsidian dehydration is in direct relationship with dehydration time and environment temperature. The explosive eruption of rhyolite magma and its rapid cooling has formed rhyolitic volcanic glass. In the process of dehydration, volcanic glasses with rhyolite and dacitic composition can be altered to perlite which has many crossover and curved cracks that surround unaltered glass cores (Denton *et al.,* 2009). The perlitization process is a kind of low temperature alteration of glass (obsidian) (about 400 °C) via atmospheric waters (Emery, 2011). The atmospheric waters are expressed based on the total water content and the dehydration temperature as the molecular water or hydroxyl groups. The degree of glass dehydration depends on many factors such as PH, the presence of cations in water, humidity, the nature of glass, temperature and permeability (dependent on joints and faults) (Dickens, 2007). The study of perlite samples has shown that with the progression of the perlitization process, the content of total volatile materials increases. Hence, perlitization is confirmed to happen due to the introduction of exotic waters (Denton *et al.,* 2009). In the Ghledokhtar region of Mianeh there are rhyolitic domes in some of which, perlite deposites are formed in lenses and layers. The surface of perlite is white in color due to weathering effects and the formation of clay minerals. Field and petrography studies indicate the presence of light gray rhyolitic tuffs and lava in the area. In hand specimens of perlite in the studied area there are nodules of about 2 centimeters with a silica composition (Fig 3, f). Perlite production is the result of secondary dehydration along the joints, gaps and voids of volcanic glasses. The alteration of perlites and changes in mineral composition in the studied rocks are caused by dissolving and disposing of glass and the formation of cavities. Moreover, the formation of chalcedony and clay minerals has played a role. This theory is confirmed by the presence of clay and chalcedony minerals in the area. High levels of volatile content in acidic magmas cause tephra eruption. After tephra eruption that opens the outlet (vent), materials rich in volatiles move upward and reach the surface in the form of pumices with large cavities filled with gas. According to field evidence, the evaluation of perlite formation processes in the studied area is possible by the model of Flink (1983).

6. Geochemistry

The results of the chemical analyses of the samples of Ghledokhtar, Aghkand and Soleymanbolaghi areas are shown in Table 1. Volcanic samples are classified as rhyolite, dacite and basaltic andesite (Fig 4, a). The amount of SiO_2 varies between 62.2 and 77.4 and the amount of TiO_2 is between 0.35 and 0.69 that are common for rhyolites. High amounts of CaO (2.87) indicate the presence of carbonate in the cavities. The data show that the average amounts of TiO_2 and Fe_2O_3 in the rhyolites are in a range of 0.45 to 3.88. The amount of SiO_2 is high in these rhyolites (76.2% to 81.5%). The Fe_2O_3, CaO, MgO and Na_2O, however, are low. These rocks show calcalkaline nature (Fig 4, b). The abundances of rare earth elements of the study samples have been normalized to the primary mantle (Sun and Mcdonough, 1989) and chondrite (Boynton, 1984) (Fig5, a and b).These rocks are enriched in LREE and LILE ((La/Sm) N = 7.75) and are depleted in HREE ((Gd/Yb) N = 2.25). In this chart, P, Ti, Ta, Nb and Ba elements have negative anomalies whereas, Pb shows a positive anomaly. The depletion of Ti and the related elements such as Nb and Zr are characteristic of calc alkaline magmas associated with volcanic arcs in comparison with magmas in lithospheric plates. The fluids and melts derived from the oceanic crust with upper mantle wedge metasomatism result in negative Nb and Ta anomalies (Chappell, 1999). However, amounts of depletion are different in different rock groups in magmatic arcs.

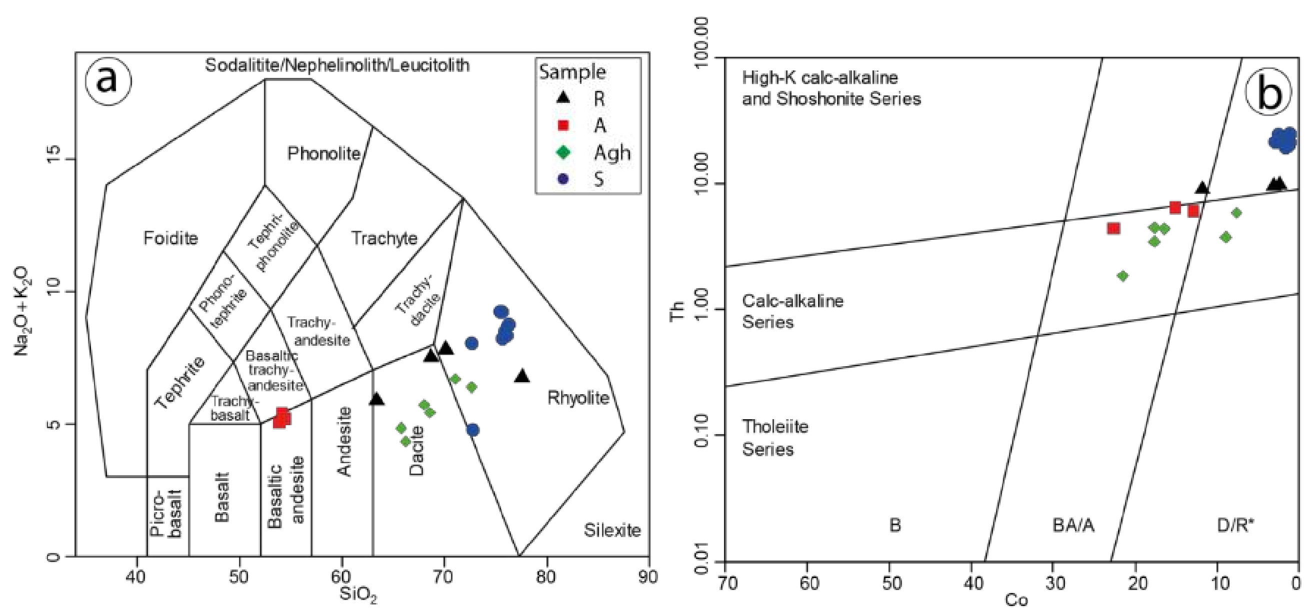

Fig. 4. a) Classification of volcanic rocks in the studied area and in Aghkand, Soleymanbolaghi, Zanjan areas for comparison according to the diagram of Middlemost (1994); b) Diagram of Th against Co (Hastie *et al.,* 2007) to determine the magmatic series of the studied rhyolitic domes (In all diagrams, the sign of Rh is used for acidic rocks, A is used for Basaltic Andesitic rocks, Aghused for Aghkand and S for Soleymanbolaghi).

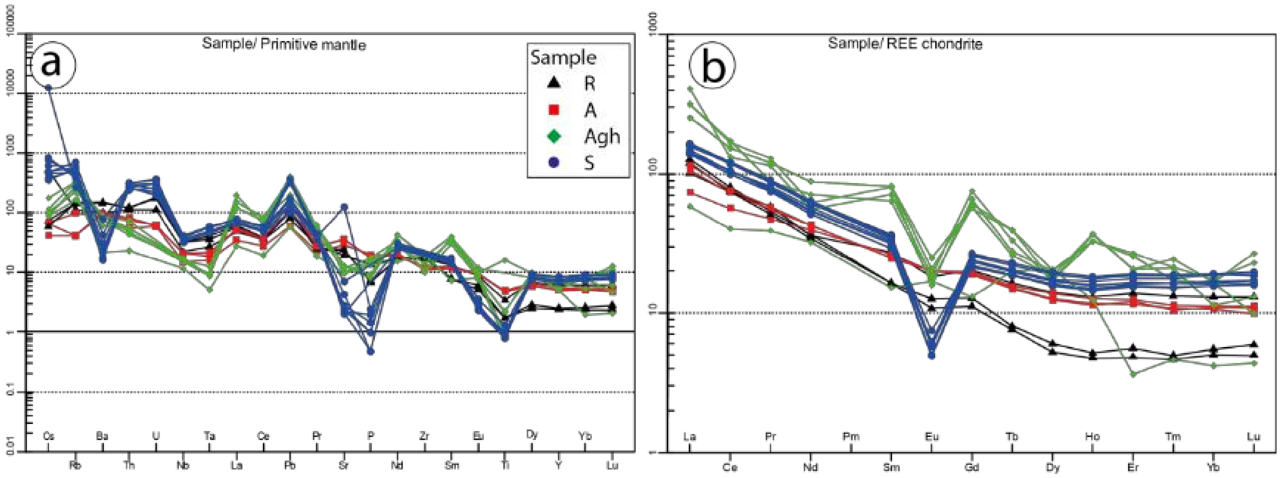

Fig. 5. a) Normalized spider diagrams of the rock in the studied area and Aghkand and Soleymanbolaghi and Zanjan for comparison with the primary mantle (Sun and McDoungh, 1989); b) Normalized spider diagrams for the studied rocks and Aghkand and Soleymanbolaghi, Zanjan for comparison with Chondrite (Boynton,1984).

Positive anomalies of Pb refer to the metasomatism of the mantle wedge by fluids originated from the oceanic crust or the contamination of magma with the continental crust (Kamber *et al.,* 2002). The anomaly of Eu was calculated by (Eu/Eu*=EuN/ (Sm) N*(Gd) N) method and it was smaller than 1 for the rocks of the studied area. Therefore, they have negative anomalies. Eu/Eu* ratio is between 0.755 and 0.935 that is the result of plagioclase removal from melt by fractional crystallization or a partial melting that is the result of negative Eu anomaly. Negative anomaly of Eu is indicative of plagioclase removal during the evolution of volcanic rocks. All Eu/Eu* ratios for the area's rocks and compared samples are smaller than 1, as shown in Fig1. Thus, they have negative anomaly. The negative anomaly for Eu is characteristic of calc-alkalin lavas (Martin, 1999).

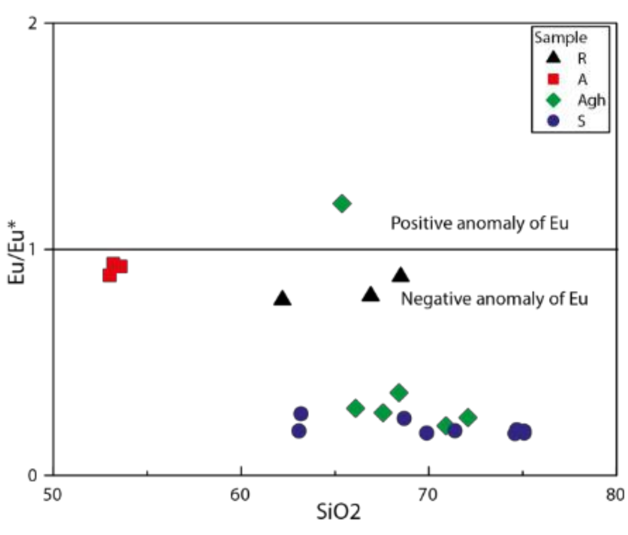

Fig. 6. diagram of SiO_2 against Eu / Eu * to determine positive and negative anomaly of Eu.

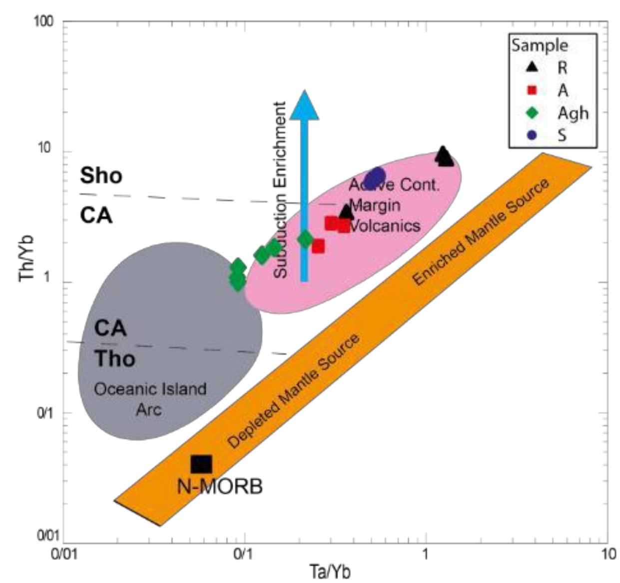

Fig.7. diagram of Ta/Yb against Th / Yb (Pearce, 1983) for the studied samples and and the regions of Aghkand and Soleymanbolaghi, Zanjan for comparison.

As it is clear in fig 6, the study samples are similar to the rocks of the Aghkand and Soleymanbolaghi areas in terms of the enrichment in LREE and LILE and the depletion in HREE and HFSE. The pattern of rare earth elements in the rhyolites is parallel to each other and indicates the enrichment of the LREE relative to HREE. The flatness of HREE shows the incompatibility pattern after crystallization (Singh *et al.,* 2006). The low concentration of HREE relative to LREE is due to the factors such as low melting point, the presence of garnet residues in the source rock and magma contamination. High concentration of LREE in acidic magmas can be representative of fluid phase accumulation in acidic magma during separation (Keppler, 1996 and Kogiso *et al.,* 1997). The relationships between the Eu, Ba and Sr anomalies in the analyzed rhyolites indicate that the negative Eu anomaly along with low concentration of Ba and Sr are determined through the maximum subtraction of K-feldspars (Eby, 1992 and Xu *et al.,* 2007). High LREE/HREE and LILE/HFSE ratios and negative TNT anomalies are characteristics of the studied rocks which can be attributed to the rocks that accompany volcanic arcs. In fact, these anomalies along with high proportions of LILE/HFSE in volcanic rocks in calc-alkaline arc settings are the result of the introduction of LILE components subducted plate into the wedge of the upper mantle (Mohamed *et al.,* 2000). Normally, the magmas in subduction zones are produced by the partial melting of the metasomatized mantle (Pearce and Peate, 1995). At the end of the magma production, in the subduction regions, the composition of the metasomatized mantle and the dynamics of the mantle control the production of magma (Stern, 2001). The subduction process plays an important role in increasing the LILE/HFSE and LREE/HREE ratios that are considered as subduction signatures. The enrichment in LILE such as K, Pb and Cs, the ratio of LREE/HREE and HFSE as well as the apparent negative anomalies of Nb and Ti could be explained. Negative anomalies of Ta, Nb and Ta are characteristic of magmatic arc rocks (Dostal *et al.,* 2001). In other words, the enrichment in LILE along with the depletion in Ti, Nb and Ti Ta can be the result of inhomogeneity of the lithospheric mantle enriched during subduction (Whalen *et al.,* 1987). The studied samples and the rocks of Aghkand and Soleymanbolaghi show dominantly the features of Arctic islands and active continental margins (ACM) (Fig 7). The Ta/Yb and Th/Yb ratios (Fig 7) also emphasize the subduction-related enrichment for the lavas. These rocks are fromed by partial melting in an enriched mantle. The Th/Yb ratio of rhyolites is higher than this ratio. This is attributed to the processes that depend on subduction. Arc magmas are mainly produces by partial melting in the mantle wedge due to the addition of metasomatic components released from the oceanic lithosphere. Metasomatic fluids may include hydrous fluids (supercritical) or the primary melts (derived from sediments or basaltic crust subducted into the mantle wedge) which lowers the solidus of mantle and results in magma generation. The diagrams of Gorton and Schandle (2002) have been used to determine the tectonic setting of the study samples. As a result, the studied rocks as well as the rocks of the aghkand and Soleymanbolaghi areas, with active continental margin (ACM) nature, have been produced by subduction (Fig 8). Samples are enriched in LILE and depleted in HFSE and have high ratios of K_2O/Rb and FeO/MgO that are 0.037 and 3.44 respectively. These results are indicative of an I-type and continental margin volcanic arcs. Moreover, negative Nb anomalies are characteristic of continental rocks. Therefore, the negative anomalies of the mantle magmas can be due to the contamination of these magmas by crustal materials during ascent and emplacement. Besides, during the subduction of an oceanic crust beneath a continental crust, minor phases such as ilmenite and rutile are stable in the subducted oceanic crust and preserve HFSE elements such as Nb and Ta and prevent their introduction into the magma and result in negative anomalies (Bogoch *et al.,* 2002). Generally, several evidence like 1) being located in an orogenic belt, accompanied with volcanic rocks like ignimbrite and andesitic tuff; 2) a diverse complex of lithological units; 3) The presence of hornblend and biotite and the lack of muscovite; 4) different chemical compositions of the samples in terms of the SiO_2 content (Chappell, 1999) and the negative correlation beyween P_2O_5 and SiO_2 (Chappell and White, 1992) are representative of I-type rhyolite in the studied area. Due to the high ratios of Nb/U (5.84-11.88) and Nb/Th (1.6-2.3) in the rocks of the region and the closeness of these proportions to the reported values of volcanic arcs (respectively 1.6-11 and 0.36-5.2), it can be expressed that the magma of these rocks is similar to the volcanic arc magmas. However, some major element concentrations, the enrichment in LILE and LREE in relation to HREE and HFSE along with the depletion in Ta and Nb are similar to the arc-related rocks (Stolz *et al.,* 1996). This model of element distribution is related to Dostal *et al.,* (2001) which is characteristic of the rocks in subduction zones or the rocks that have been erupted by the upper crust. Rhyolitic rocks are enriched in most of the incompatible rare elements that is a reflection of an enriched mantle source as well as crustal contamination.

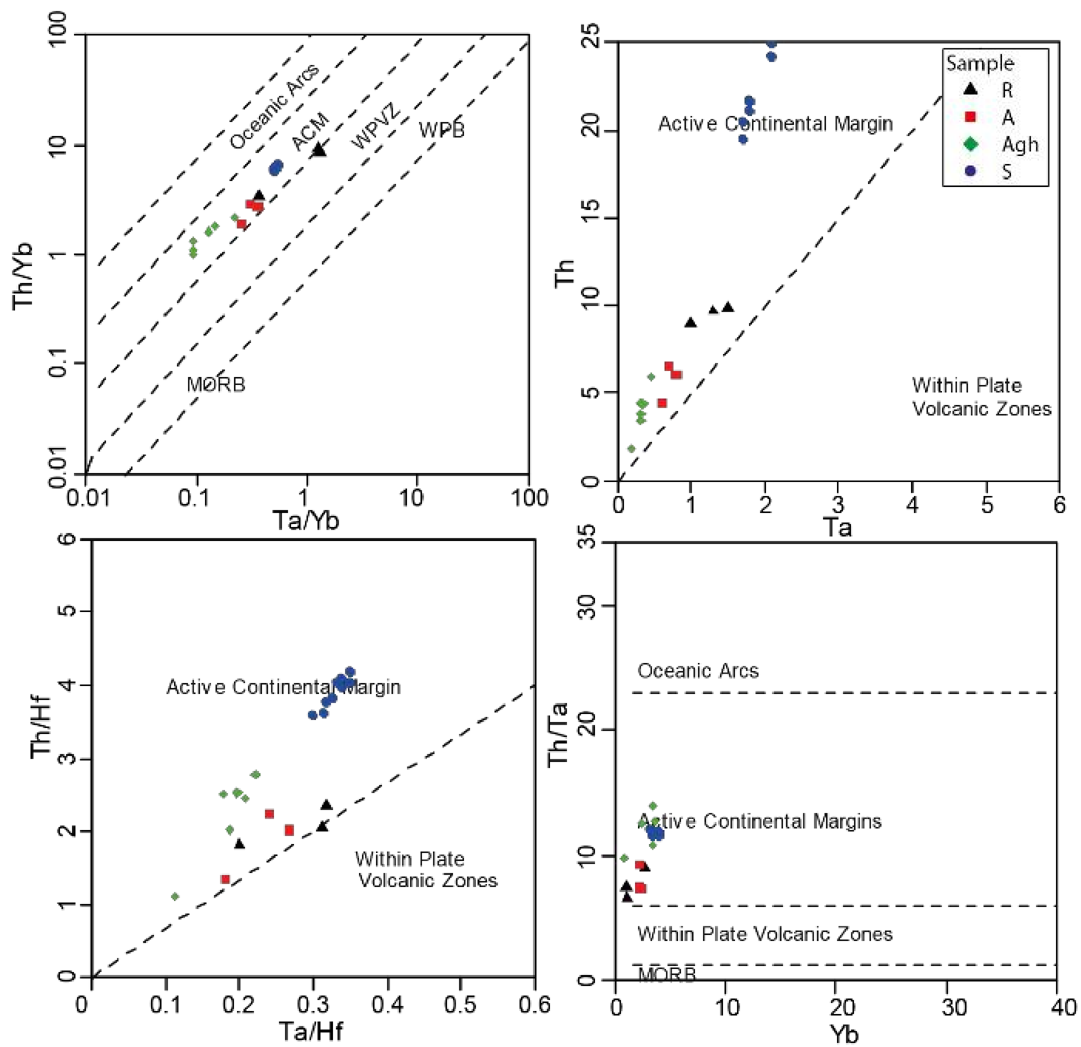

Fig. 8. Determination of the tectonic settings of the study region and the regions of Aghkand and Soleymanbolaghi, Zanjan for comparison in the arc related area.

Considering the low content of MgO in the rhyolitic rocks (lower than 0.55) the negative anomalies of Ti ($TiO2$ = 0.35-0.56), low P content and all the aforementioned features, it can be deduced that the acidic lava is probably derived from a basaltic lava. This idea is reinforced by the presence of underlying pyroclastic deposits (Ignimbrites and Tuffs). The hydrous and explosive nature of the volcano is supported through several pieces of evidence such as the presence of sedimentary deposits, coarse grained amphiboles in some lavas, hydrothermal fluids that have strongly affected the rocks of the area and low magnesium content in these rocks. Andesites and dacites are dominant in the majority of arcs and the continental margins. The existence of ignimbrite deposits with rhyolithic and rhyodacitic compositions in the area indicates a mature arc. According to Pichavant (1993), andesites are larger in arcs of the continental crust and rhyolitic ignimbrites are only seen in continental arcs and in some cases they can be generated by partial melting. According to the geochemical characteristics and considering the chronology and location of the Ghledokhtar's volcanic rocks they are possibly associated with the subduction of the neotethys oceanic crust beneath central Iran and related magmatism in an arc.

7. Conclusion

Geochemical study shows rhyolitic, dacitic and andesite basaltic composition of rocks. Mineralogically the rocks include sanidine, quartz, plagioclase, hornblend, biotite and minor minerals. The perlites of the area show concentricity of fractures that appear as onion weathering structures. In the acidic volcanoes, following the explosive eruptions that are the result of the viscosity and high volatile content of the magma, without volatiles, lavas are usually emplaced on the surface of the earth with no explosions and are associated with the formation of obsidian. The obsidian layers in the presence of water can be converted into perlite via ionic exchange. Several structures in the agates (asteroid, geodesy, radial, fibrous and cauliflower) are formed due to the sedimentation processes of rich

silica solutions in the gaps and cavities of the rocks. The banded or fibrous texture is formed by the coexistence of quartz and chalcedony layers. The reason for the presence of such layers is the changing environmental conditions of the sedimentation of silica gels. The source of these silica gels is the remnants of the acid magmas that have formed the rhyolitic and ignimbrite rocks of the area. Based on geochemical studies, silica domes are of I-type and calc alkaline nature. These rocks are enriched in LREE and LILE ((La/Sm) N = 7.75) and show depletions in HREE ((Gd/Yb) N = 2.25). P, Ti, Ta, Nb and Ba elements have negative anomalies whereas, Pb shows a positive anomaly. The depletion in Ti and related elements such as Nb and Zr are characteristic of calc-alkaline magmas associated with volcanic arcs in comparison with magmas related to lithospheric plates. The depletion in Ti and related elements such as Nb and Zr are characteristic of calc alkaline magmas associated with volcanic arcs in relation to magmas of lithospheric plates. Negative anomaly of Eu indicates plagioclase removal during the evolution of volcanic rocks in the area. The flatness of HREE patterns shows incompatibility of elements after fractional crystallization. Theses rocks show enrichment in LILE and depletion in HFSE. The K_2O/Rb and FeO/MgO ratios are 0.037 and 3.44, respectively. The samples of the volcanic arc in a continental margin is of I-type nature that is associated with subduction processes during which the Neotethys oceanic crust subducted central Iran and a magmatic arc was formed. All in all, the volcanic rocks of Aghkand and Soleymanbolaghi areas (Zanjan province) and the rhyolites of the studied area have similar chronological, tectonic setting and geochemical characteristics.

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