World Journal of Environmental Biosciences

Available Online at: **www.environmentaljournals.org**

Volume 6, Supplementary: 43-49

ISSN 2277- 8047

Petrology and Petrogenesis of Mianrahan Pillow Lavas, Northeast of Kermanshah, West of Iran

Hamideh Farahmand[1], Mohammad Ali Arian[2*]

[1]*PHD student, Department of Geology, Faculty of Science, North Tehran Branch, Islamic Azad University, Tehran, Iran*.
[2]*Supervisor, Department of Geology, Faculty of Science, North Tehran Branch, Islamic Azad University, Tehran, Iran*.

ABSTRACT

Mianrahanophiolitic complex is located in the west structural zone of Iran in the northwestern part of the Zagros zone and includes mantle sequence, gabbro, pillow lavas with pelagic limestone, radiolarian cherts and the Cretaceous radiolarites. Pillow lavas are one of the most important rock units of Mianrahan ophiolite. These lavas have basaltic andesite trachyte composition and somewhat andesite trachyte composition. The mineral component of pillow lavas of Mianrahan ophiolite are plagioclase, clinopyroxene (augite), magnetite, chlorite, epidote and calcite. The basalts are geochemically the alkaline series. Also, the data demonstrates that all the samples of light rare earth elements (LREE) enriched while the samples of light rare earth elements (LREE) show less enrichment. According to the diagnostic plots of tectonics locations, pillow lavas are located in the range of basalts associated with the arc and in the supra-subduction zone. Geochemical studies indicate that the basalts of spinel lherzolite mantle have originated at the depth of less than 60 km and melting rate of less than 15%.

Key words:*Mianrahan, Zagros, pillow lavas, calc alkaline, supra subduction.*

Corresponding author: Mohammad Ali Arian

INTRODUCTION

In general, the Mesozoic ophiolites in Iran have been considered as the remains of a large oceanic crust, such as Neo-Tethys basin (Ricou and et al, 1974) or as a narrow continental rift, such as the Red Sea (Sabzehei and etal, 1974). On the other hand, (Stocklin ,1977)ophiolitic belt has divided the Iran's cretaceous part into two sub belts:1- external sub belt (Tabriz-Kermanshah ophiolites) 2- internal sub belt (central iran's ophiolite-melange belt). Ophiolites of Zagros belt were divided into two ophiolite-radiolarite parts in Kermanshah (Golonka J) and Neyriz, Fars Province (Ricou ,1971). Kermanshah ophiolites is a complex of ophiolites in the west of Iran and follows Zagros orogenic system. This ophiolitic complex is locatednear the northwest end of the Zagros mountain range (Figure 1). Examining the mafic and ultramafic chain of Kermanshah ophiolitic complex showed thatLherzolite, harzburgite and gabbro of this ophiolitic complex has been formedin the Triassic - Cretaceous period in the Neo-Tethys Ocean expansion zone located between the Iranian Arabic plates.

Pillow lavas in ophiolites are signs of outflow of lava in an aqueous environment and provide valuable information about the origin of the raw lava, the percentage of fusion part, the tectonic environment and volcanic processes for geologists (Dilek Y and etal, 2003).Pillow lavas are part of formation and important componentin many ophiolitic complexes and occupy the certain horizon in the crustal remainder, directly beneath the sedimentary part and on the diabase dykes (Coleman,1977). Pillow lavas in ophiolitic complexes indicate their formation in the position and expansion origin of the sea bed. In the present study, pillow lavas of Mianrahanophiolitic complex have been studied based on field and geological investigations and geochemical data of the whole rock was used to name the original elements, multiple rare earth units of ophiolite and also to assess the genetic relationship between these rocks and to determine their tectonic setting.

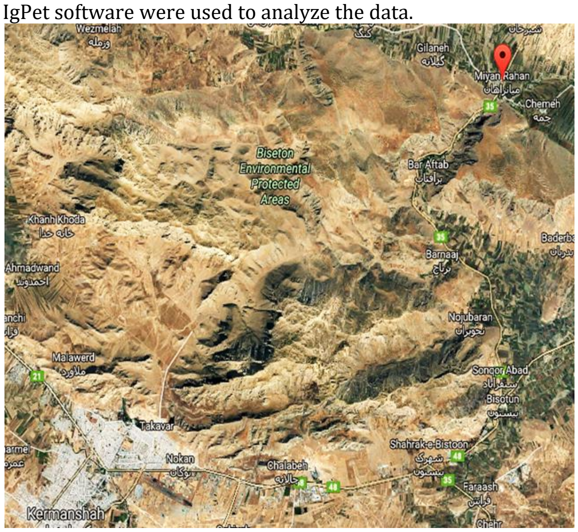
Geology

Ophiolites were not accidentally exposed on earth and their occurrence in specific age groups and different orogenic belts show the difference in the time of appearance and their replacement and they can record the evidence of important magmatic and tectonic processes such as Rift-Drift in itself. Investigating structural, lithological and geochemical evidences of rock units of ophiolites provides valuable information about the role of mantle bumps, spherical loose protrusions (asthenosphere) caused by the collision, crust growth through magmatism and tectonic accretion in subduction-accretion cycles and changes in the structure and composition of the mantle source (Dilek, & Robinson, 2003).

Mianrahanophiolitic complex is located at N 34º 30' to 35º and E 47º to 47º 30' (figure2) and in the Zagros zone and in particular in the border between Zagros belt and Sanandaj – Sirjan zone (Figure1). In the literature on this area, (Stocklin , 1977) believes that Kermanshah ophiolites was observed as an ophiolitic mélange and formed by separated outcrops of mantle peridotites, gabbro rocks, series of dykes and pillow lavas. Mianrahanophiolitic complex is composed of mantle and crustal components including peridotite, serpentinized peridotites, gabbro, dolerite dykes, pillow lavas, limestone and radiolarites.

Pillow lavas are one type of rocks frequently observed in Mianrahanophiolitic complex. Studied pillow lavas were examined in two separate areas: one part in the north of Khanghaholia village and another one in the north of AkbarAbad village. These pillow lavas are associated with the last result of magmatic activity on the oceanic crust. These rocks are covered by radiolarian cherts and upper Cretaceous limestone.

In order to examine the mafic stones in the Mianrahan area, pillow basalts were examined through field investigations and then the outcrops were sampled. After preparingthin sections and conducting petrographic studies, in order to determine geochemical characteristics and tectonomagmatic position, basalt samples were powered and the main elements were measured using alkaline fusion method and rare elements and REE were measured by ICP-MS method.GCDKit software and IgPet software were used to analyze the data.



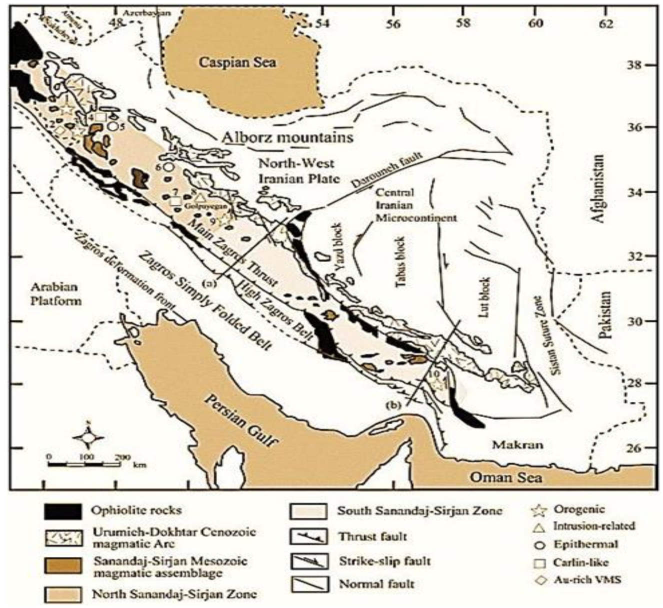


Figure 1: Main tectonic units of Iran showing the location and broad distribution of various types/styles of the major gold deposit/prospects in the northern and southern Sanandaj–Sirjan Zone, its Mesozoic magmatic assemblage related to Urumieh-Dokhtar magmatic belt, and the location of two cross-sections (a and b) on it (after from Alavi, 1994; Ghasemi and Talbot, 2006). 1- Kharapeh, 2- Barika, 3- Saqez-Sardasht orogenic gold zone (Qolqoleh, Kervian, Qabaqloujeh, HamzehQaranein, and Alut), 4- Aghdarreh-Zarshuran, 5- Tuzlar, 6. Sari Gunay, 7- Akhtarchi, 8- Astaneh-Sarband, 9- Muteh, 10- Zartorosht. Orogenic; intrusion-related; epithermal; Carlin and Carlin-like; and gold-rich VMS deposits/occurrences.

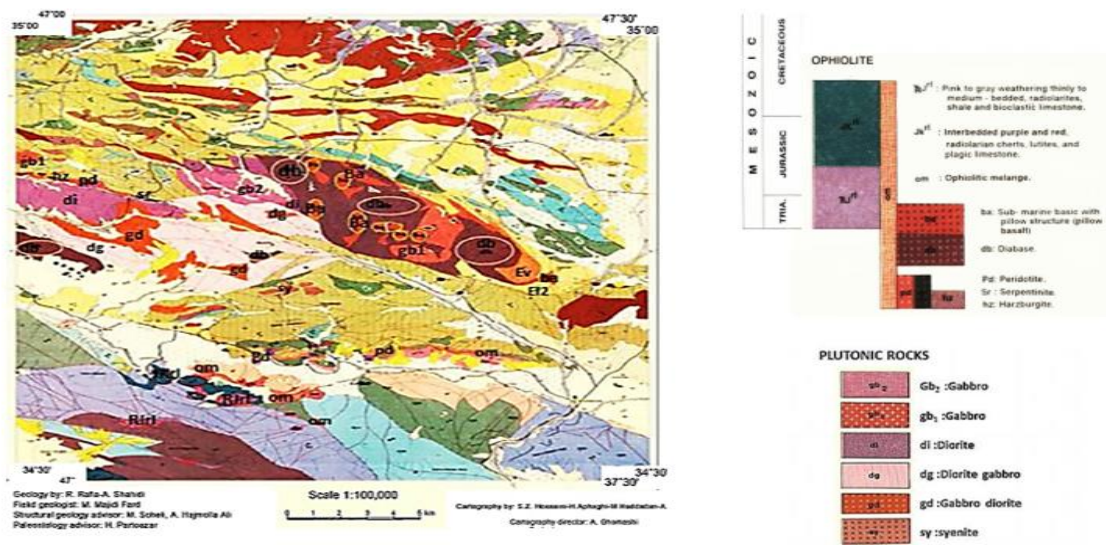


Figure 2: Geological map of the study area(Rafia&Shahidi, *1999*) ophiolitic out crops show with circles.

Lithology

Field observations of pillow lavas of Mianrahan area show that these rocks have pillow structure and are belonged to the output sequence of ophiolitic complex. Pillow lavas, in an ophiolitic sequence, form the highest igneous unit and composed ofmantle material and through liquid transfer to the ocean bed. Mafic stone form the most of ophiolitic part of the studied area. These rocks include pillow lavas which were exposed in the northern part of AkbarAbad village and around Khanghaholia village (figure3). Basaltic lavas usually form upper part of ophiolitic series. Submarine basaltic lavas are usually found in two forms in the area. Its pillow type is more than its non-pillow type.

Based on petrographic studies, in KhanghahOliah village, pillow lavas have basaltic andesite trachyte composition (basaltic latite) and in AkbarAbad village, they have somewhat andesite trachyte composition (figure 5). Pillow basalts in the area are observed in dark grey. Fine and needle plagioclase crystals can be observed in these rockswith the naked eye. These rocks predominantly have inter-granular to micro-litic texture. Microscopic vesicular and variolitic textures were identified as their textures. The majority of these basalts contains cavities filled by chlorite, calcite and sericite and in some others they have been filled by iron oxides. There are complete and skeletal Clinopyroxenes that indicate rapid crystallization. Additionally, pyroxene crystals has grown in a stretched form between plagioclase crystals. In addition to pyroxene, Titano-magnetites have grown among plagioclase crystals. There is sometimes glass among plagioclase crystals that has become chlorite. Inside the chlorite cavities (old empty cavities), epidote has grown. In the samples with inter-granular texture, the space between plagioclases has been filled by augite and opaque minerals (opaque) (Fig. 4-a). Plagioclase crystals are observed withclinopyroxene, hornblende and iron oxides (Fig. 4-g,h). Large crystals contain plagioclase and augite. In order to compare petrographic studies with the results of chemical analysis the plot presented in (LeBas and etal, 1986) was used that according to it the samples of KhanghahOlia village and Akbarabad village are located in the basaltic andesite trachyte realm and the andesite trachyte realm, respectively. These are consistent with the results of Petrographic studies (Figure 5).The main minerals forming the rock are:

Plagioclase: hypidiomorphic to self-organized plagioclase crystals are seen as phenocrysts, microphenocrysts and narrow and stretched needles in the rock bed.

Clinopyroxene: clinopyroxene crystals are also hypidiomorphic to amorphous and they are found more in the rock background.

Matrix: matrix consists of plagioclase, glass and opaque minerals in different proportions.Plagioclase and pyroxene are dispersedly found in a matrix.

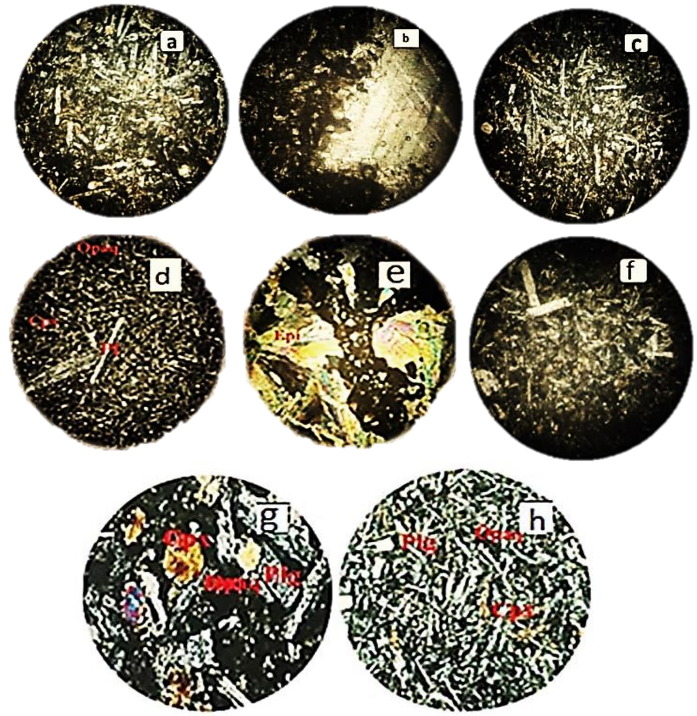


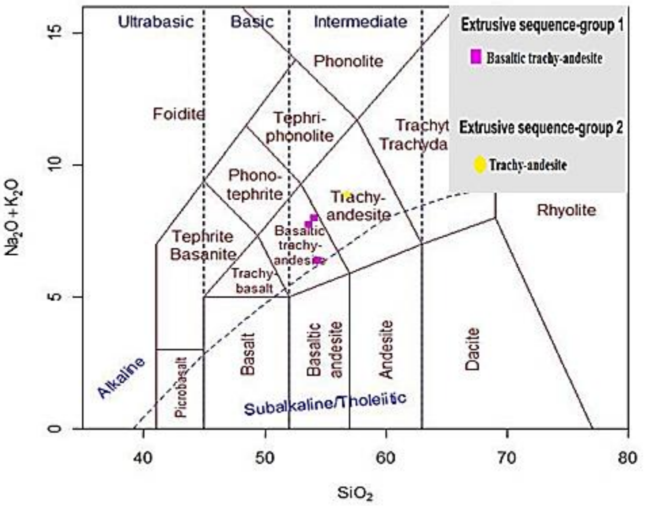
Figure3. View of pillow lavas outcrops in the north of Akbarabad village.

Figure 4: Microscopic images of pillow lavas in the studied area (in light 40X.P.L)

a. Intergranular texture with plagioclase and clinopyroxene blades.
b. Cavities filled by calcite in vesicular pillow lavas.
c. ClinopyroxeneSpherulite with plagioclase in the form of variolitic texture.
d. Cpx: Clinopyroxene - Opaq- Pl: plagioclases with variolitic texture.
e. Epi: microscopic images of epidote.
f. Porphyric-vitrophyric textures on the periphery of the pillow lava.
g. andh. Clinopyroxene crystals, Opaq and plagioclase with intergranular texture (in light X.P.L40).

Geochemistry

Studying pillow lavas in the plot provided in (LeBas and etal, 1956) shows that more samples were placed in the basaltic



andesite trachyte zone and one sample has been shifted to upper areas due tothe increase in the total alkali $Na_2O + K_2O$ caused by alteration and was placed in the andesite trachyte zone (figure5). Compared to plutonic rocks, the extrusive rock sequences cooled more quickly and so, magmatic subtraction process in these rocks was insignificant, their chemical composition, especially their chilled margin, largely represent the composition of parent magma forming Mianrahanophioliticcomplex.

Figure 5: Geochemical classification of extrusive rock sequence of Mianrahan ophiolite

in the plot proposed by LeBas et al. (1986).

In Th to Co plot [16], pillow lavas of Mianrahanophiolitic complex show the calc alkaline process (Fig.6).

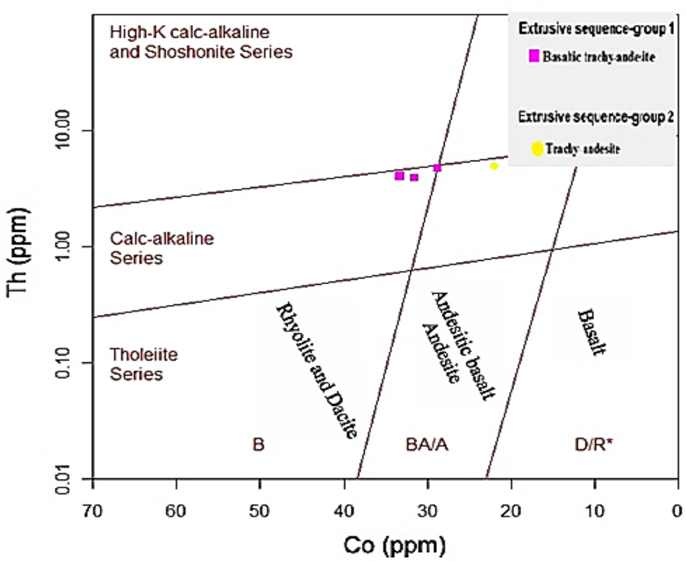


Figure6. Investigation of magmatic series of extrusive rock sequence ofMianrahanophiolitic

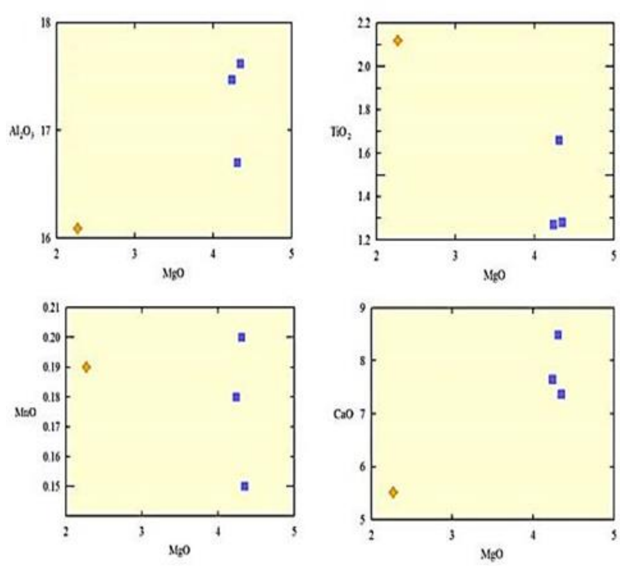
complex on the plot proposed by Hasti et al. (2007).

The studied samples relatively have high amount of TiO_2 and P_2O_5 and their values change in the range of 1.27-2.12 %Wt and 0.24-0.47 %Wt, respectively. The ratio of these two main oxides show stable process compared with MgO (Fig.7). The amount of

SiO_2 in the lavas changes in the range of from 54.99- 57.58 %Wt. The greatest amount of MgO is related to the samples from the area around the Akbarabad village (4.35%) while the least amount of MgO can be seen in the northern part of Khanghaoliavillage (2.27%). Additionally, these rockscontain significant amounts of Ta, Th, U and Hf which change in the ranges of (1.52- 1.09 ppm), (4.74- 3.94 ppm), (0.69- 0.45 ppm) and (5.3- 3.43 ppm) respectively (Table 1). The highesT rate of L.O.I is related to the samples from the area around the Akbarabad village (7.77) while the lowest rate of L.O.I can be seen in the northern part of Khanghaolia village (2.43). In figure (15-6), the frequency of major oxides of extrusive rock sequence of Miyanrahanophiolitic complex is plotted to MgO. In the plot representing the changes of TiO_2 to MgO (Figure7), the percentage of TiO_2 in the exclusive rock sequence has increased with the increase in subtraction and reduction in MgO. According to figure (15-6), the changes in Al_2O_3 to MgO show linear trend with negative slope. The studied samples show linear trend in the amount of Cao as the results of changes in MgO. The changes in MnO as the result of changes in MgO are shown in figure7.

The samples show positive trends like the trend related to TiO_2. In the exclusive sequence lavas, Na_2O values changes in the range of 5-7%Wt. These rocks show positive trend on the Na_2O-MgO plot. In the case of sodium and calcium oxides, due to alteration caused by seawater, scattering of points can be seen in the plots.This change comes more from hydrothermal processes (Thompson, 1983).

Compared to other oxides, changes in K_2O show larger scattering. This is likely due to alteration and removal of potassium of them. The changes of P_2O_5 to MgO is shown in figure 15-. P_2O_5 is a compound that its value increases with the progress of subtraction in magma and its value in the intermediate and acidic lavas is greater compared to basic lavas. In this lavas, apatite is crystalized as mineral. In the Fe_2O_3-MgO changes plot, with the increase in subtraction, the samples become rich in iron.



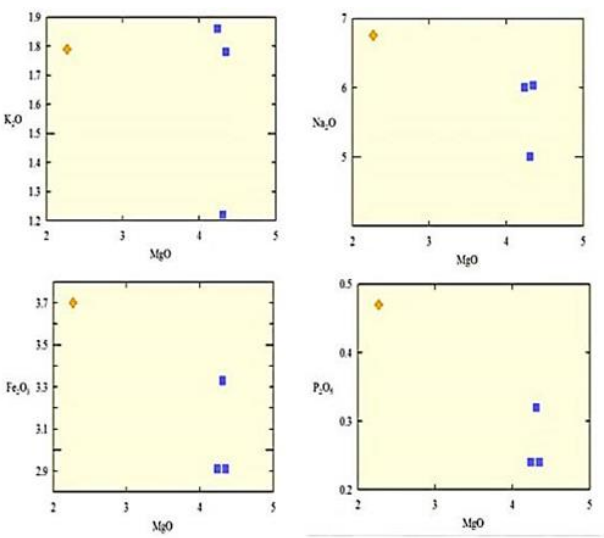


Figure7. the plots of major element oxides-MgO changesin extrusive rock sequence.

Patterns of spider plots normalized to standard chondrite values (Sun andetal, 1989) in the lavas of KhangahOlia Village, show enrichment 30 to 60 times greater than chondrite valueand in the lavas of Akbarabad Village, show enrichment 60 to 110 times greater than chondrite value (Figure8-a). All the samples of light rare earth elements (LREE) enriched to chondrites while the samples of light rare earth elements (LREE) show less enrichment. The patterns of rare earth elements of KhanghaOlia area show significant agreement in the mean ranges of E-MOR and P-MORB. But the lavas of Akbarabad area has an enrichment greater than the mean range of E-MORB and became close to the mean rang of P-MORB (Figure 8-b). Perhaps this enrichment shows the melting of enriched mother rock of the intervention of refractory minerals such as garnet. The samples show positive Eu anomalies due to ferric texture and coarse plagioclase crystals. Placing the samples in different classes may be attributed todifferent degrees of melting of heterogeneous mother rock.Melting of enriched or depleted mantle source is attributed to different degrees of enrichment induced by the fluids from the subducted plate that causes partial melting of mantle wedge metasomatism on the upper part of the plate and its partial melting (Dilek and etal, 2003). Such a wide range of patterns and their position in the orders of 15 to 100, especially in the limited areas on land, is of the features of ophiolites formed in a Supra-subduction environment (Dilek and 2003; Juteaue, T. & Maury, R., 2009).

Patterns of spider plots normalized to standard primitive mantle values show that lavas have clear depletion of elements: Ti, Nb and Sr and enrichment of U and Th elements (figure9). The elements of U and Th enriched more than incompatible elements such as Nb. This can be associated with the enrichment induced by the fluids from the subducted slab and/or dehydration of old oceanic crusts during the subduction that their partial melting may form magma manufacturing the exclusive sequence of ophiolitic complexes (Elliot and etal, 1997). It can be said depletion of HFSE such as Ti and Nb (figure 18-6) reflects the characteristics of their subduction. Such patterns have been reported volcanic arcs such as the South Sandwich Arc Islands (Hawkesworth and etal, 1977), Tongy air arc in New Zealand (Nicholson and etal, 2000) and Ismael ophiolite in Oman (Godard and etal, 2003). About Ismael ophiolite in Oman, despite extensive chemical analysis, there is no consensus on the tectonomagmaticenvironment of their foemation (Godard and etal, 2006), but depletion of HFSEwas widely accepted as an indicator of magmatism in subduction areas. So, according to the depletion of these elements in the patterns normalized to standard primitive mantle values of Miyanrahanaphiolitic complex samples, supra subduction may be supposed as proper tectonomagmatic pattern for the formation of this complex.

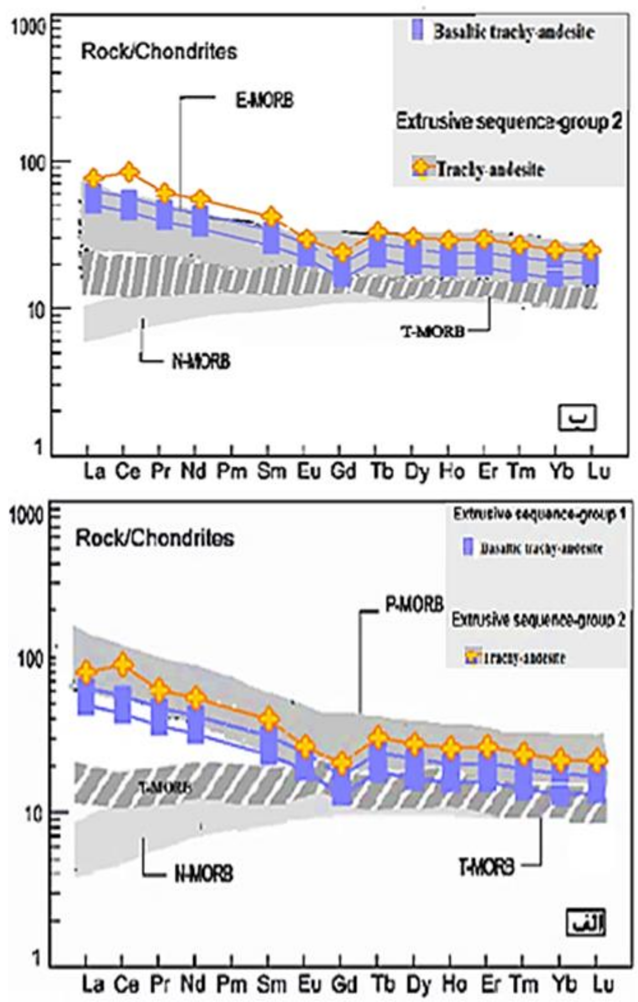


Figure8. Frequency of rare elements in extrusive rock sequence of Mianrahanaphiolitic complex normalized to standard chondrite values (Sun and McDonough, 1989).

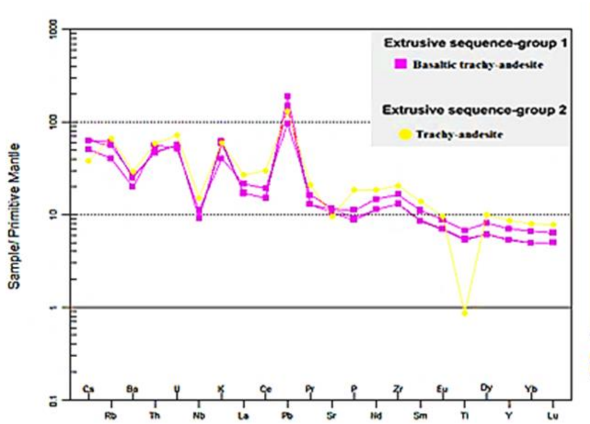


Figure9. Frequency of incompatible elements in extrusive rock sequence of Mianrahanaphiolitic complex normalized to standard primitive mantle values (Sun and McDonough, 1989).

Petrogenesis

Given that basaltic lavas outcropping in the top of the ophiolitic complex have become cold more quickly compared to the underlying plutonic rocks, so, its chemical composition can represent parent magmatic composition of ophiolitic complex. On the other hand, since the top of the rock sequences has been in direct contact with ocean water and exposed to hydrothermal alteration of the seabed, the frequencies of major and stirring rare elements may undergo further changes. So in order to determine the tectonomagmatic environment of extrusive rock sequence formation of Mianrahanaphiolitic complex, the frequencies of rare and sedentary elements of lavas were estimated. The chemical composition of lavas of the studied area is replaced in tectonomagmatic area related to the arc in Y-Nb/Th plot. This indicates the depletion nature of them from Nb. In Zr/Y-Ti/Y changes plot that separate continental basalts from other types of basalts, all samples are replaced in the realm of the basalt on the sheet margin. In Ni/Y plot (Capedri S. 1980), the pillow lavas samples are replaced in the realm of supra-subduction (figure10).

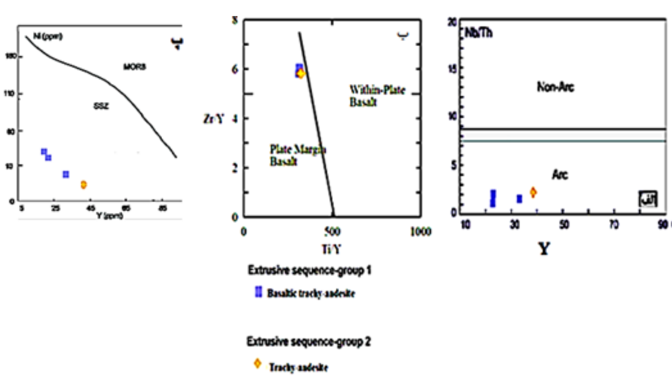


Figure10. The chemical composition of extrusive rock sequence of Mianrahanophiolitic complex on the plots supposed by

A: Jenner et al, 1991 B: Pearce and Gall, 1977 C: Capedri et al, 1980

CONCLUSION

Field observations of the pillow lavas of Mianrahan area show that these rocks have a pillow structure that belongs to the extrusive rock sequence of Kermanshah ophiolitic complex and have been replace on upper Cretaceous limestone.Different shapes and fine and coarse sizes of crystals, microlites, skeletal pyroxene crystals and plagioclase can be associated withhigher speed of nucleation of the crystals compared to their growth speed. Microscopic studies determine basaltic andesite trachyte composition of the pillow lavas in Khanghaholia area and andesite trachyte composition in the samples of Akbarabad area. Magmatic processes I pillow lavas of Miyanrahan area are calc alkaline. Comparing these rocks with primitive mantle show that the samples have clear depletion of elements: Ti, Nb and Sr and enrichment of U and Th elements and comparing them with chondrite show that all the samples of light rare earth elements (LREE) enriched to chondrite while the samples of light rare earth elements (LREE) show less enrichment. Investigating the spider patterns of ofKhanghaOlia village show that the lavas indicate significant agreement in the mean ranges of E-MOR and P-MORB. But the lavas of Akbarabad area has an enrichment greater than the mean range of E-MORB and became close to the mean range of P-MORB. So, according to the depletion of these elements in the patterns normalized to standard primitive mantle values of Mianrahanaphiolitic complex samples, supra subduction may be supposed as proper tectonomagmatic pattern for the formation of this complex.

REFERENCES

1. Berberian, M. & King, G. C. P., 1981- Towards a paleogeography and tectonic evolution of Iran, Can. J. Earth Sciences, 18: 210-265.
2. Capedri S. 1980. Genesis and evolution of a typical Alpine-type peridotite mass under deep-seated conditions (Central Evia, Greece). Boll. Soc. Geol. It., 93, 81-114
3. Coleman R.G., "Ophiolites: Ancient Oceanic Lithosphere", Spinger-Verlag, New York (1977) 229.
4. Dilek Y., Newcomb S., "Ophiolite concept and the evolution of geological thought". Geological Society of America, Special paper (2003) 373-504.
5. Dilek, Y. & Robinson, P. T., 2003- Ophiolites in Earth history: introduction Geological Society, London, Special publication, 218, 1-8.
6. Elliot, A. J., & Sheldon, K, M. 1997. Avoidance achievement motivation: Apersonal goals analysis. Journal of Personality and Social Psychology 3, 171-185.
7. Godard, M., Dautria, J.M., and Perrin, M., 2003, Geochemical variability of the Oman ophiolite lavas: Relationship with spatial distribution and paleomagnetic directions: Geochemistry, Geophysics, Geosystems (G3), v. 4, no. 6, p. 8609. doi:10.1029/2002GC000452
8. Godard, M., Jousselin, D., Bodinier, J.-L., 2006. Relationships between geochemistry and structure beneath a palaeo-spreading centre: a study of the

mantle section in the Oman ophiolite. Earth and Planetary Science Letters, 180(1-2), 133-148.

9. Golonka J., "Plate tectonic map of the phanerozoic", Special publication (SEPM), No 72.
10. Hasti, R., Kerr, A.c., Pearce, J.A. and Mitchell, S.f., 2007. Classification of altered island arc rocks using immobile trace elements: development of Th-Co discrimination diagram", Journal of petrology , v. 48 (12), p.234-235.
11. Hawkesworth, C.J., Kemp, A.I.S., 1977. Evolution of the continental crust. Nature 443, 811e817.
12. Jenner GA, Dunning GR, Malpas J, Brown M, Brace T (1991). Bay of Islands and Little Port complexes, revisited: age, geochemical and isotopic evidence confirm supra-subduction zone origin. Can J Earth Sci 28: 135–162.
13. Juteaue, T. & Maury, R., 2009- La croutOceanique, Petrologie et DynamiqueEndogene. SocieteGeologique de France Vuibert. Paris, Cedex 13, 470pp.
14. LeBas, M.J., LeMaitre, R.W., Streckeisen, A., Zanettin, B., 1986. A chemical classification of volcanic rocks based on the total alkali silica diagram. Journal of Petrology 27, 745–750.
15. Lensch, G., Mihm, A. &Alavi,Tehrani, N., 1977, Petrography and geology of the ophiolite belt of Sabzevar, Khorassan (Iran). NeuesJahrbuch fur Mineralogie, Abhandlungen 131, 156-178.
16. Nabavi, M. H., 1976, An introduction to the geology of Iran. Geological survey of Iran.
17. Nicholson, S.W., Schulz, K.J., Shirey, S.B., and Green, J.C., 2000, Rift-wide correlation of 1.1 Ga Midcontinent rift system basalts: implications for multiple mantle sources during rift development: Canadian Journal of Earth Sciences, V. 34, p. 504-520.
18. Pearce J.A., & Gale G.H., (1977). Identification of ore-deposition environment from trace element geochemistry of association igneous host rocks. Geol. Soc. Spect. Publ., 7, 14- 24.
19. Penrose Conference (participants), "Penrose Field Conference on Ophiolites", Geotimes 1 (1972) 24-25.
20. Rafia'a, R., Shahidi, A.R. (1999) "geological map 1: 100,000 OF Mianrahan sheet", the Geological Survey and Mineral Exploration organization
21. Ricou L.E, " Lemetamorphisme au contact des peridotites de Neyriz (Zagros Interne, Iran)":development de skarns a pyroxene. Bulletin of the Society of Geology 13 (Fr.Seriec , 1971) a, 146-155.
22. Ricou, L. E., 1974- L'etudegeologique de la region de Neyriz (Zagros Iranien) et l'evolutionstructurale des Zagrides. These d'Etat, Orsay,321p.
23. Sabzehei, M., 1974. Les mélanges ophiolitiques de la régiond'Esfandagheh (Iran méridional). Etude pétrologique et structurale. Interprétationdans le cadre iranien. ThèseDoctoratEtat, Grenoble ,* 306p.
24. Stocklin J., 1977. Structural correlation of the Alpine ranges between Iran and Central Asia. Mem. Soc. Geol. France, 8: 333-353.
25. Sun S.-S. and McDonough W.F., 1989. Chemical and isotopic-systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders A.D. and Norry M.J. (Eds.) Magmatism Takashima, I., Nasution, A. and Muraoka, H. (2002) Thermoluminescencedayting of volcanic and altered rocks in the Bajawa geothermal area, central Flores Island, Indoneseia.
26. Takin, M., 1972. Iranian geology and continental drift in the Middle East. Nature 235, 147-150.
27. Thompson, G., 1983. Basalt-seawater interaction, in: P.A. Rona, K.B. Bostrom, L. Laubier, K.L. Smith Jr. (Eds.), Hydrothermal Processes at Seafloor Spreading Centers, Plenum Press, New York, pp. 225-278.