Australian Journal of Basic and Applied Sciences, 5(10): 1062-1073, 2011
ISSN 1991-8178

Petrography, Geochemistry and Origin of Sub-Volcanic Rocks in Tzrj Region

[1]Abadi Hossein Rashidi Ranjbar and [2]Zohreh Hossein Mirzaee Beni

[1]Department of Geology, Khorasgan (Isfahan) Branch, Islamic Azad University, Isfahan, Iran.
[2]Department of Geology, Khorasgan (Isfahan) Branch, Islamic Azad University, Isfahan, Iran.

Abstract: Tzrj region is located in 245 kilometers of Kerman. The study zone is located in central Iran, SE of Urmia girl magmatic belt. Sub-volcanic rocks consist of dacite, andesite and trachy andesite that is belong to Pliocene. Petrological, mineralogical study and geochemical investigations suggest that these rocks belong to sub-alkaline and calc alkaline series. The statistical technique of discriminated analysis shows that these rocks related to volcanic arc active continental margin. And are affected by the phenomenon of subduction. Sub-volcanic rocks with REE fractionation with enrichment of LREE and depleted concentration of elements Ti, Ta, Nb, Y which indicates the presence of garnet, Titany minerals and possibly amphibole in the origin of them.

Key words: Tzrj, volcanic rocks, calc-alkaline, active continental margin.

INTRODUCTION

Study area Zone is located in central Iran, SE of Urmia girl magmatic belt (Fig. 1-1). The study area is located in NW of Shahrbabak, between 245 km of Kerman and 50 km SW of pomegranate and that geographic location is between 55°00 - 55°15 and 30°30 - 30° (Fig. 1-2). Geological map of study area is 1:250 000 of pomegranate. Age of sub-volcanic rocks based on geological maps and works done previously is to Pliocene. (10 , 19). Therefore, to reach the area can use of Bandar Abbas Tehran transit road (Fig. 1-2).

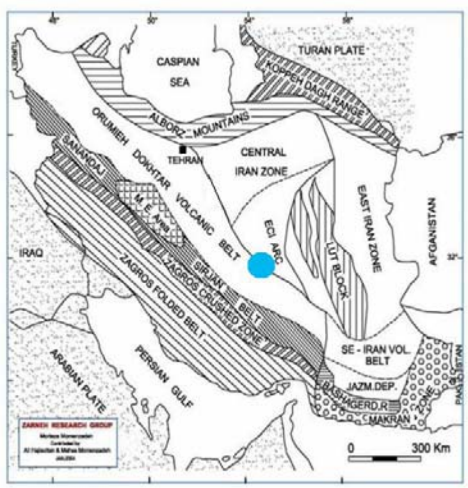


Fig. 1: tecteno magmatic zoning of Iran (31).

Research Methodology :

During the field observations was colected of 60 rock samples from various parts of the study area. After studying the manual sample, 130 thin section preparation and was studied with polarizing microscope. 20 samples with ICP-MS method in ALS chemex was the chemical analysis. Also, different softwares especially Excel, Minpet and Igpet were used for analysis and drawing charts.

Results:

Petrographically, Sub-volcanic rocks are ranged dacite and rhyodacite with bright colors and are fine grain and stream texture. These rocks are age of Late Miocene and Pliocene (19). Sub-volcanic masses generally form the highest elevations. Paint of all weathered volcanic rocks is dark brown or burnt. The darkness of the release of iron from the network of the ferromagnesian minerals in these rocks. Sub-volcanic rocks in the field are common features that including a stratified magma, systems of columnar joints, contraction, magma

Corresponding Author: Abadi Hossein Rashidi Ranjbar, Department of Geology, Khorasgan (Isfahan) Branch, Islamic Azad University, Isfahan, Iran.

contamination and the types of erosion. These rocks have global magma layer that light layers are rich of feldspar and dark layers are rich in ferromagnesian minerals (amphibole, biotite, opaqu) (Fig. 3).

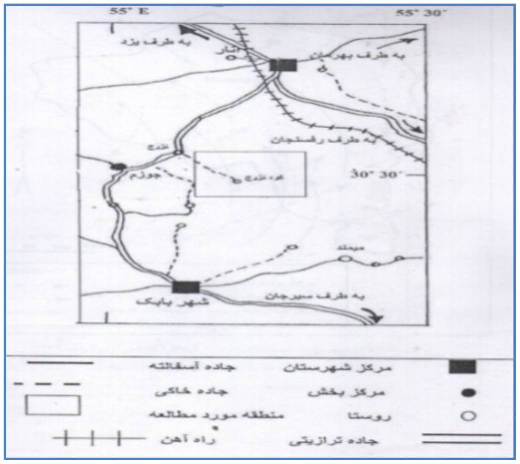


Fig. 2: ways map of the area.

Fig. 3: Global magma layer .

The two joint systems are detectable in the Sub-volcanic rocks in the area. A) The tectonic joints: these joints resulting from tectonic activity, particularly the major and minor faults are seen that cross each other as two sets of fractures (Fig. 4). Acute angle bisector between the two sets of fractures has the highest compressive stress along the North West of region.

Fig. 4: joints caused by tectonic activity.

B) The contraction joints: sub-volcanic masses reduced volume because of located in the earth's surface.

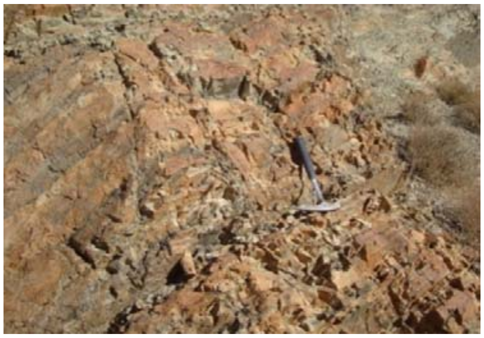


Fig. 5: joints caused by contraction.

Magma contamination:

The masses have been injected into older rocks and pieces of them (enclaves) are in them. Enclaves or xenolies are seen in various sizes in these rocks. Enclaves angled and have changed many times that are visible under the microscope. Sub-volcanic magma rocks due to low temperature can not change them. It must be acknowledged that enclaves are present only in the edge of masses and their upper parts, so have been little change in the composition of the masses (Fig. 6).

Fig. 6: Magma contamination (enclaves) (size between 0.5 to 30 cm and is made of andesite to dacite).

Erosion:

Aquifer due to water absorption, hydrolysis, reduction of various joints and pressure is formed, in some detail, we examined each of them.

A) Erosion of Onion Skin:

This type of weathering is often associated with tensile forces (weathering variable in size), but (20) are discussed weathering in a fixed volume. He noted that in this cases all of the rock to be affected by weathering (Fig. 7).

(a) (b)

Fig. 7: onion skin erosion in dacite rocks, A) rocks have been under the ground and now appeared. B) Weathering of small rocks that are free from all directions.

B) Tafoni Erosion:

One of the most important characteristics of sub-volcanic rocks is tafoni cavities or honeycomb erosion. This type of erosion is seen on slopes and the top mass. (20) noted that tafoni erosion is hole (cave) in very small scales (Fig. 8).

Fig. 8: Tafoni erosion in the dacitic mass.

The size of these holes is of several centimeters to several meters. The more holes shape is elliptical and irregular forms, less spherical. Later wind damaged this tafoni and the shape of the rocks changed. In this area [tofoni] erosion are compound, sculptures and stretches (Fig. 9).

Fig. 9: Tafoni erosion (honeycomb make by water and the particles are carried by the monsoons).

Petrography:

Sub-volcanic and volcanic rocks are generally made of porphyric texture and coarse crystals of feldspar, amphibole, biotite and quartz in some cases. In table 1 is given some details of these rocks.

Studied rocks are exposed as plugs, dikes, volcanic domes and pyroclastic flows. In base classification (TAS) samples placed in the dacite, rhyodacite, andesite, tracy andesite range. Dacite and andesite are exposed as volcanic domes and plugs and most rhyodacite and tracy andesite are exposed as dikes. All samples were formed of the minerals plagioclase, biotite, amphibole (as coarse crystals), quartz and alkaline feldspar. Secondary and minor minerals are zeolite, calcite, apatite, serisit, chlorite, epidote. Plagioclases are the main rock-forming minerals, most acidic and have zoning, dissolution (sieve texture) and twin. Dark minerals were often burned and have become one of the variations of reduced pressure, increased water vapor pressure and increased oxygen in the environment.

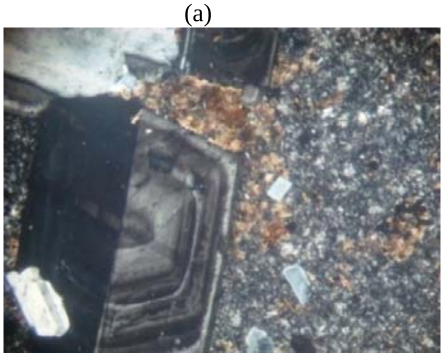
Chemistry of Minerals:

Harker diagrams shows frequency of different elements vs element that most changes in the rocks. K_2O vs. SiO_2 diagram shows an increasing trend and the relatively sparse. This dispersion can be due to the heterogeneous nature of rocks. This inconsistency is the presence of coarse crystals in the rock. This indicated that potassium minerals was crystallized (alkali feldspar) in the late stages of crystallization, during fractionation of a silicate melt at low pressures. MgO vs. SiO_2 shows a decreasing trend from andesite to dacite with increasing SiO2.

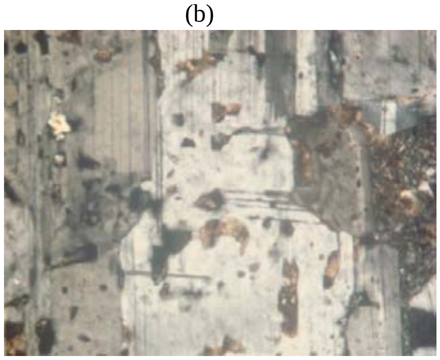
Table 1: petrography of volcanic and sub-volcanic rocks in the study area.

minor minerals	Main minerals	Rock name	Rock texture	The geographical context	Number of rock
Opak	Q	crystal tuff	fine-grained porphyric	N 30^o 33' 86" E 55^o 07' 75"	TH$_1$-1
Apa+opak+amph	Plg+Bi	andesite	porphyric		TH$_1$-2
	Plg+Amph+Bi	andesite	porphyric		TH$_1$-3
Opak+Apa+mus	Plg+Amph+Bi	andesite	porphyric	N 30^o 33' 83" E 55^o 08' 17"	TH$_1$-4
	Plg+Amph+Bi+Q	dacite	porphyric	N 30^o 33' 81" E 55^o 08' 29"	TH$_1$-5
Apa+opak	Plg+Bi+Q	dacite	porphyric	N 30^o 33' 76" E 55^o 08' 39"	TH$_1$-7
Bi+op	Pl+kf+Q	dacite	porphyric		TH$_1$-8
Amph+Apa	Pl+Bi+Q	dacite	porphyric		TH$_1$-9
Amph+Apa	Pl+Q+bi	dacite	porphyric	N 30^o 55' 75" E 55^o 14' 66"	TH$_1$-10
Pyr	Pl+Q+Bi+Amph	dacite	porphyric		TH$_1$-11
Amph+Apa	Pl+Bi+Q	dacite	porphyric		TH$_1$-13
Amph+Apa	Pl+Q+Bi+kf	andesite	porphyric		TH$_1$-14
Q+opak	Plg+Bi	andesite	porphyric	N 30^o 33' 81" E 55^o 08' 08"	TH$_1$-15
Apa+opak	Plg+Q+Bi	dacite	porphyric		TH$_1$-16
Apa+opak	Q+plg+Amph+Bi	dacite	porphyric	N 30^o 33' 98" E 55^o 08' 6"	TH$_1$-18
	Plg+pyr	andesite-basalt	porphyric	N 30^o 35' 92" E 55^o 08' 58"	TH$_2$-1
Apa+opak	Plg	andesite	porphyric	N 30^o 34' 23" E 55^o 10' 43"	TH$_2$-2
Apa+opak	Plg+Q+Amph+Bi	dacite	porphyric	N 30^o 34' 21" E 55^o 10' 11"	TH$_2$-3
serisit+ chlorite	plg+Bi	tracy andesite	microlitic		TH$_2$-4
Opak+ chlorite	Plg	tracy andesite	porphyric	N 30^o 34' 10" E 55^o 10' 76"	TH$_2$-5
Opak	Plg	andesite	porphyric	N 30^o 33' 35" E 55^o 10' 42"	TH$_2$-6
Apa+opak	Plg	andesite	porphyric	N 30^o 33' 21" E 55^o 10' 30"	TH$_2$-8
Opak	Plg+Q+Bi	dacite	porphyric	N 30^o 33' 26" E 55^o 10' 82"	TH$_2$-9
	non-detection of mineral		glass	N 30^o 32' 81" E 55^o 10' 44"	TH$_2$-10
	Plg +Q	dacite	Trachytic	N 30^o 32' 40" E 55^o 09' 73"	TH$_2$-11
Opak	Plg+kf+Amph	andesite	porphyric	N 30^o 32' 18" E 55^o 08' 12"	TH$_2$-12
Opak+Apa	Plg+Bi+Q+Amph	andesite	porphyric	40R 0323135 3383179	TH$_3$-1
Apa+ opak	Plg+Q+kf+Bi+Amph	andesite	porphyric	40R 0323044 3383057	TH$_3$-2
Amph+pyr+Q+mos	Plg+ Bi	andesite	porphyric	40R 0322842 3383087	TH$_3$-3
Amph+Apa+opak	Plg+kf=+Q+Bi	dacite	porphyric	40R 0322734 3383105	TH$_3$-4
Kf+Bi	Plg+Q+	dacite	porphyric	40R 0322703 3383295	TH$_3$-5
Opak+Apa	Plg+Bi+Q+Amph	dacite	porphyric	40R 0322647 3383456	TH$_3$-6

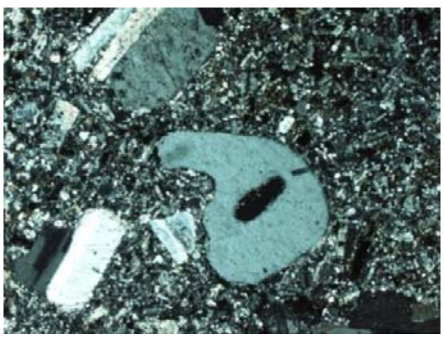
(a)



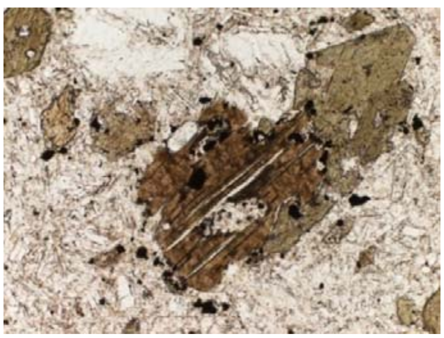
(b)



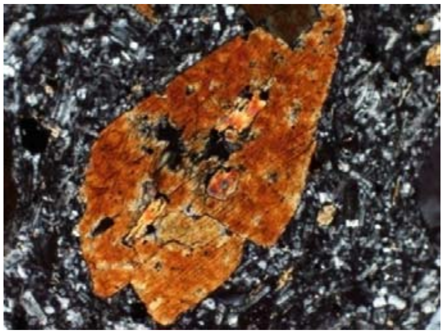
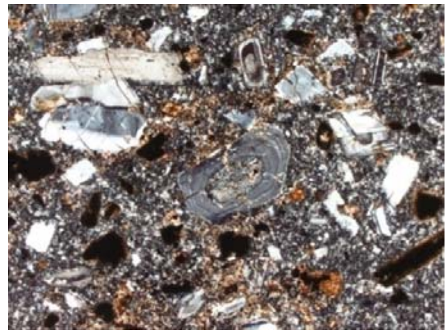
(c)



(d)



(e) (f)

(g) (h)

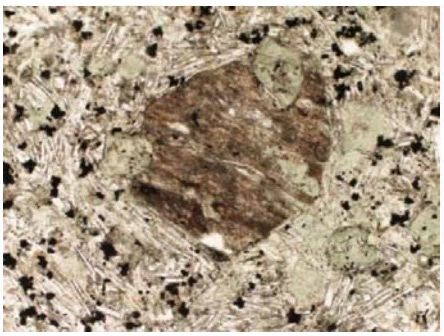
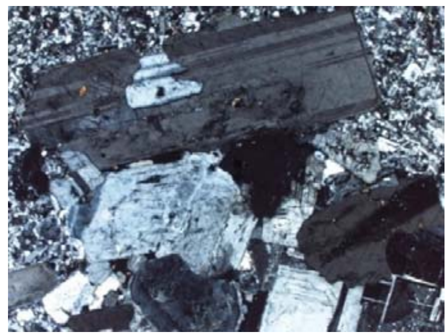
 

Fig. 10: A twin in plagioclase, burned amphibole and alkali feldspar microlitic, B) plagioclase with sieve texture, c) large quartz crystals with smooth margins and Gulf corrosion of in the porphyric tissue, D) burned of amphibole and changed to biotite, E) enclaves of apatite into the biotite, F) plagioclases changed to serisit and complete burned of biotite, G) plagioclases around the biotite that indicating adacites because texture varies and even biotite changed to chlorite, H) two generations of plagioclase with dissolution texture and without it with microlitic alkaline feldspar.

These changes are because of crystallization of minerals and rocks forming. According to the theory of crystallization from a melt, first the ferromagnesian minerals and then plagioclase are crystallized. Magnesium oxide imports ferromagnesian minerals therefore crystallize of these minerals will be reduced magnesium oxide in magma. With increasing silica, CaO is declining in these rocks. FeO to be sparse and this could be due to the heterogeneous nature of rocks. This inconsistency is the presence of coarse crystals in the rock. In sub-volcanic rocks TiO2 is reduced, this reduction is due to crystallization of titaniumagnetite in early steps of magma fractionation and acidic terms will be poor from titanium oxide. Early crystallization of titaniumagnetite related to high pressure of oxygen conditions and the oxidant dominant in the magma reservoir. With increasing silica in rocks, MnO is declining. Manganese oxide sits instead of iron oxide in ferromagnesian minerals and with crystallization of these minerals (amphibole and biotite) comes out from the magma, so in acidic terms (rhyodacite) magma will be poor from this oxide. Minor, trace and rare elements in the Harker charts show different behaviors depending on the ratio of magma storage in sub-volcanic rocks. From dacite to rhyodacite the rubidium and barium is growing and the trend are almost identical. The reaction margins of amphibole and biotite can be involved in distribution of these elements. Reduced of barium in fractionation terms is due to absorption of these elements by alkaline feldspar and biotite. With increasing silica oxide, strontium increase and it due to presence t of calcite, apatite and amphibole in these rocks. Zircon indicates enrichment with increasing of silica in amphibole and magnetite minerals in calc-alkaline series (23). Zircon process has completely dissipated and it due to the presence of the zircon mineral in biotite, ferromagnesian minerals, change percent of zircon mineral in the samples and the apparently low initial concentration of zircon in the magma. Hafnium has a similar trend with zircon (6) (Fig. 11).

Geochemistry of Volcanic Rocks and Sub-Volcanic:

Le Matier (14) (Fig. 12 - a), (3) (Fig. 12 - b) classification volcanic rocks based on SiO_2 vs.Na_2O + K_2O. In this charts, samples placed in the dacite and rhyodacite range. Winchester and Floyd (34) have been used the values of rare and minor elements vs. SiO_2 for classification and naming of volcanic rock. In this chart, samples placed in the andesite, dacite and rhyodacite ranges (Fig. 12-C).

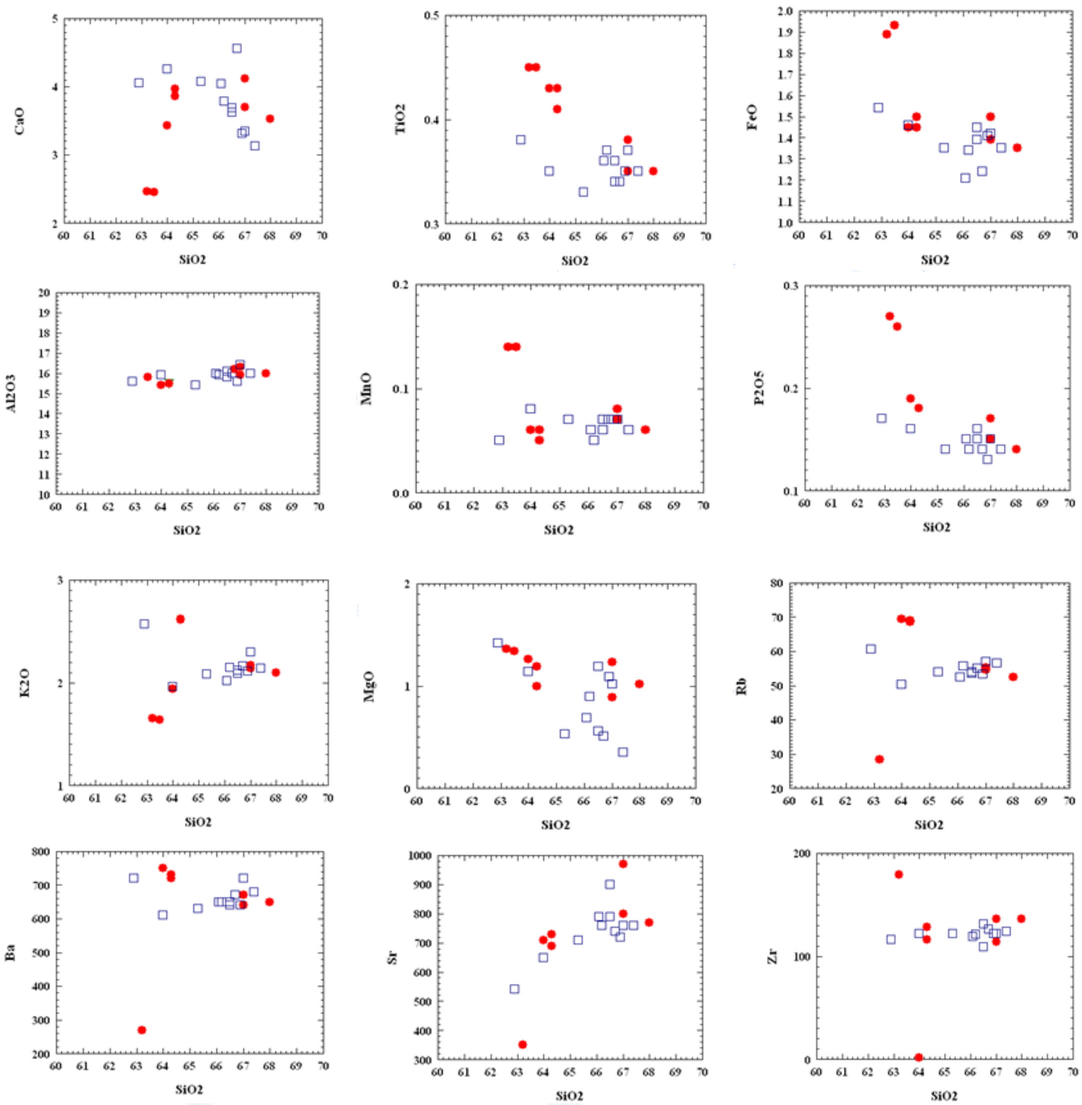


Fig. 11: Harker diagrams.

Lemaître (14) were proposed total alkali vs. silica diagrams for separation alkali rock series from sub-alkaline (Fig. 13-a). Samples of region are showing semi-alkaline or sub-alkaline afiliatly. Diagram of AFM (10) was used to determine the process of igneous series and for separation calc-alkalin magmas from tholeiitique. Samples show calc-alkalin properties (Fig. 13-b).

To determine the tectonomagmatic of sub-volcanic rocks, a variety of diagrams are proposed with researchers. One of the tectenomagmaee diagrams is provided (15) based on K_2O vs. Si_2O and CaO vs. FeO_T + MgO. That separated subduction environments from other tectonic environments. Sub-volcanic rocks in the study area are located on the volcanic arc (Fig. 14).

One of the most common tectenomagmaee diagrams is provided (22). In these diagrams, sample type is not between oceanic ridges (ORG) and within plate (WPG), and their show features volcanic arc (VAG) (Fig. 15).

Spider Diagrams of Sub-Volcanic Rocks:

Spider diagrams have been normalized with conderite and MORB and interpreted the process of magma formation (Fig. 12). All spider diagrams show that, heavy rare-earth elements to light rare-earth elements to generally show rich disruption a lot.

Spider diagrams that normalized with conderite, LREE is riched (Ba, Th, Sr) and HREE is poor. Of course, negative anomaly of Ni is observed (Fig. 12 a). Than MORB elements, Rb, Ba, Th, Sr, Cs (LILE) show enrichment. Instead, negative anomaly of Y, Yb, Ce and Nb is observed (Fig. 12 b). These rocks show strong enrichment in component large ions (LILE) Rb, Ba, Th, Cs. These rocks originated from one parent magma because all samples in parallel and show enrichment in light rare-earth elements especially Sr, Ba and Th.

anomaly of Zr and Nb is observed. Enrichment of Sr is related to the lack of plagioclase in the source of rocks. Negative anomaly of Y, Yb, Ce and Nb is possibly related to amphibole and garnet in the source region. Probably Negative anomaly of Ti related to the presence of ilmenite and titanite in the source region.

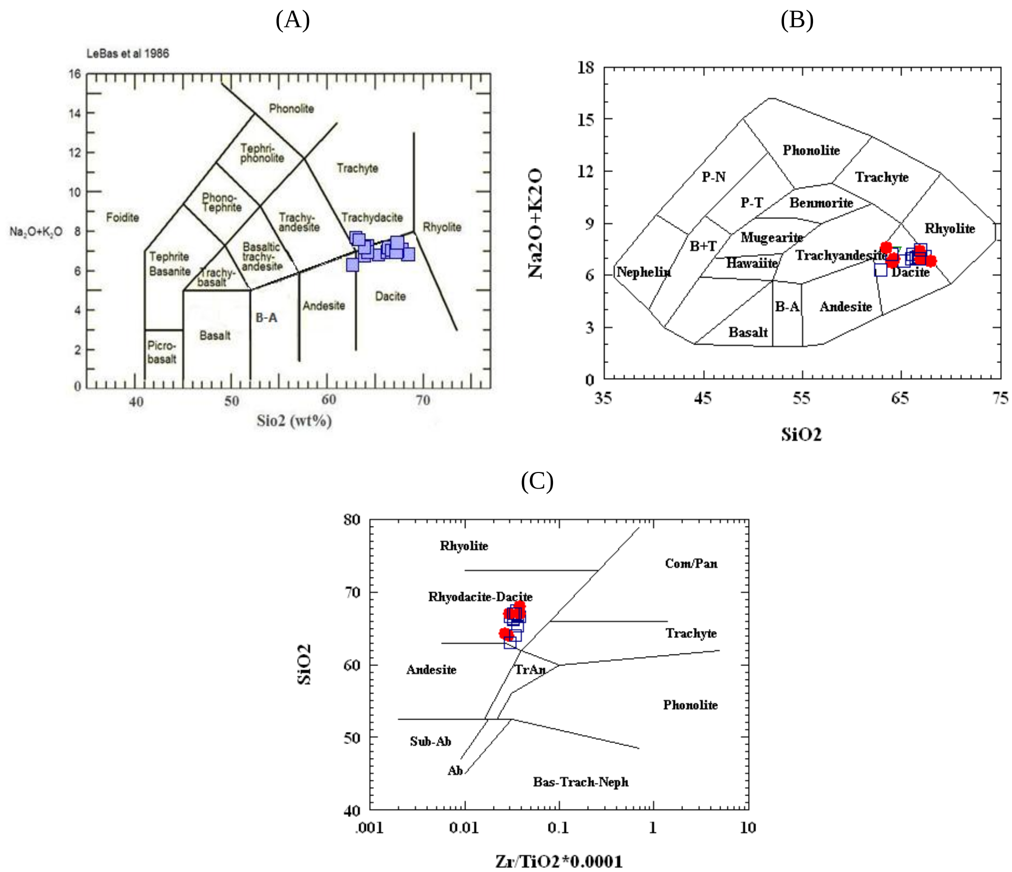


Fig. 12: A) Le Matiere and colleagues (1987) for volcanic rocks B) Cox and colleagues (1979) for volcanic rocks C) the Winchester and Floyd (1977) for classification and naming of volcanic rocks.

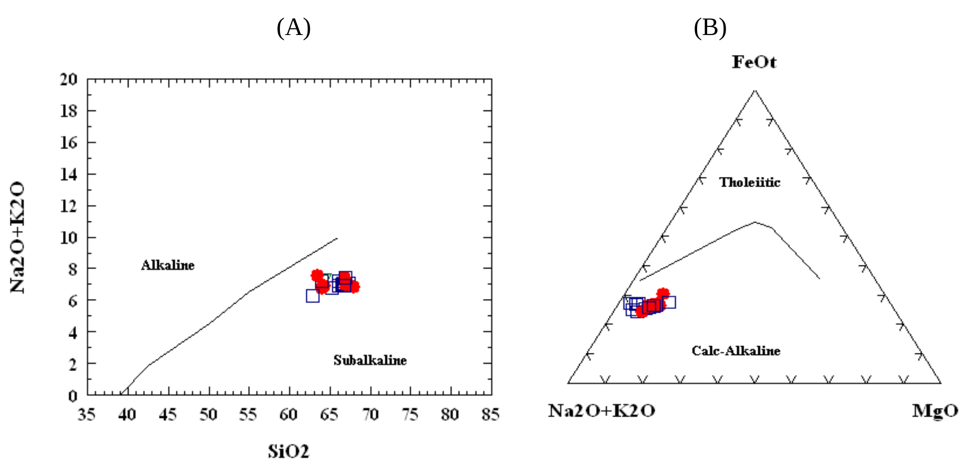


Fig. 13: A) the alkali vs. silica (14) for separation sub-alkaline and alkaline series, B) AFM diagram in which calc-alkaline series are separated from tholeiitique (13).

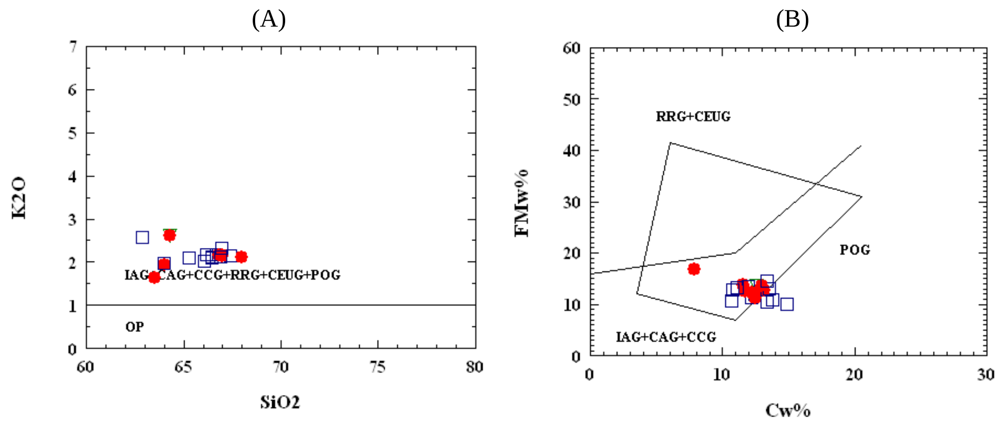


Fig. 14: for separation subduction environments from other tectonic environments (15).

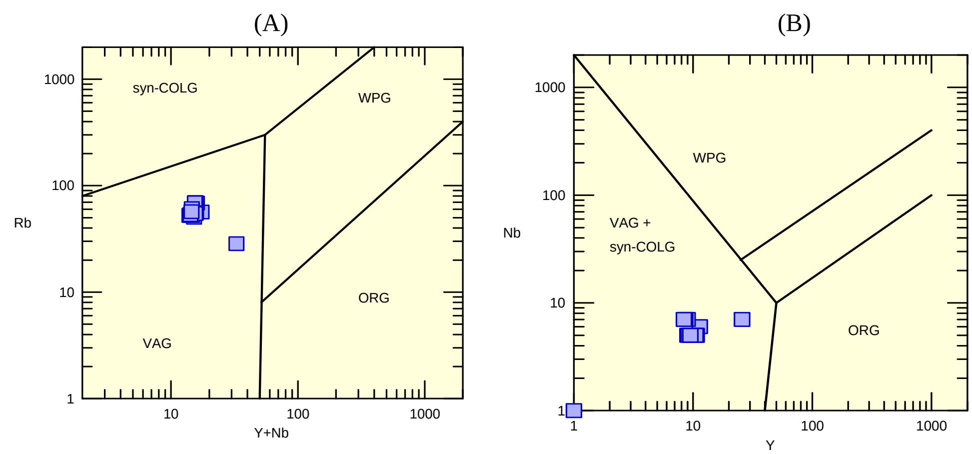


Fig. 15: to determine the tectonomagmatic of sub-volcanic magmas (Pierce and colleagues 1984) based on Rb-Y+Yb (A), based on Nb-Y (B).

Sub-volcanic rocks that have been normalized with conderite show rich disruption in LREE. HREE and MREE are poor, possibly due to the presence of amphibole and garnet in the source area (Fig. 13 a). The pattern of rare earth elements with conderite indicates that subtraction model is heavily in sub volcanic rocks. The rare earth elements is a pattern with high slope for the light rare earth elements, the average slope for medium and almost flat for heavy rare-earth elements. Eu is also a small positive peak, due to the stability of amphibole in the source area (27, 11). The abundance pattern of rare earth elements relative to MORB is also indicative of a pattern of fractionation (Fig. 13 b).

Sub-Volcanic Magma Origin:

There are two sources of magma production in subduction environments. One source mantle and one source MORB from the mid-ocean basalt. Mid-ocean ridge basalt in subduction environments are significantly altered to the garnet amphibolite or amphibole eclogites. For the formation of magma in subduction zones the first possibility is melting of a mantle origin. The peridotite mantle is as the one source of arc basalts (1; 32). Mantle magma sources need to have a 403 to 890 ppm Ni (33; 7) or have at least 200 to 300 ppm Ni, but samples of study area have 8 to 21 ppm Ni that is much lower than the mantle magmas. Mantle magmas sources need to have Yb and Y/2.5 between 6.5 to 25 ppm which are related to upper mantle peridotite origin without the presence of garnet, but samples of study area have Yb and Y/2.5 less than 7.5 ppm (Yb <1ppm, Y <11ppm) and this is related to the stability of garnet in source (29). Therefore, we conclude that the sub-volcanic rocks within the study area is located adakit of world and do not show the origin of mantle and tracy andesite, andesite, dacite, trachy dacite all are in range of adakit (A.V.Z) (5). Most sub-volcanic and volcanic rocks are adakit. Many studies are done under the pressure of water vapor on the molten basalt and amphibolite of the various pressures (less than 10 kbar). Garnet is not stable in these experiments and melts obtained with tonalite composition and rich HREE (28; 2; 12). The geothermal gradient is high enough to melt the oceanic crust.

Because of the greater depth, garnet is stable and plagioclase is unstable. The wedge mantle is thick and it wills reaction with melt (17) and the adakit magma is formed. The sub-volcanic rocks in the study area in charts of Sr / Y vs. Y (21, 4) and La / Yb vs. Yb (16) are in the range adakit (Fig. 19). In addition to the above charts, sub-volcanic rocks in the study area have high amounts of Na2O (3 to 5 %), low K_2O/Na_2O (<0.5 %), high amounts of Sr (Sr >500 ppm), low amounts of Y (Y <18 ppm) and Yb (Yb<1.5ppm).

To clarify the above adakit rocks of the study area, the average chemical composition of sub-volcanic rocks in the study area and the average offered by geologists for adakits is in table 2. With comparing samples, the study area samples are on the world adakit region. The study area adakits are very close to tonalite, granodiorite (30, 24, 25, 26)

(A) (B)

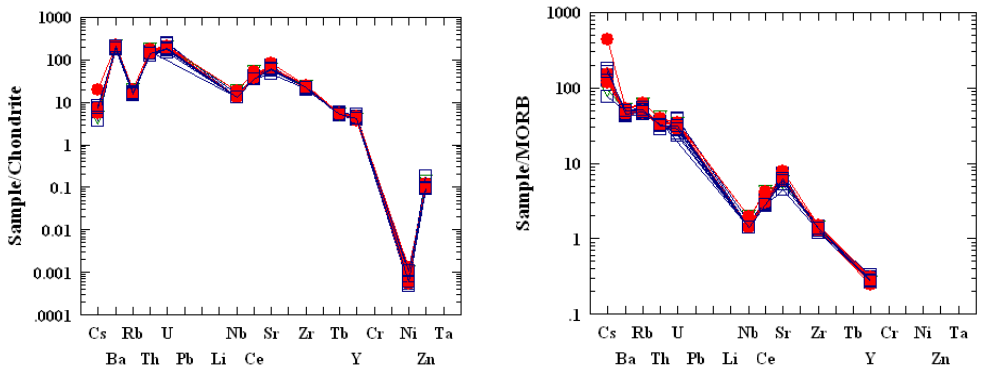


Fig. 16: Spider- diagrams,A) normalized with conderite (18), B) normalized with MORB.

(A) (B)

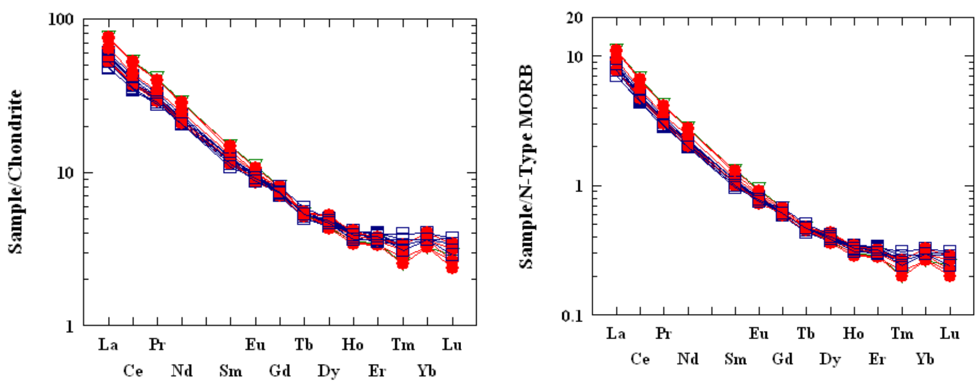


Fig. 17: Rare earth element patterns of sub volcanic rocks,A) normalized with conderite (18), B) normalized with MORB.

(A) (B)

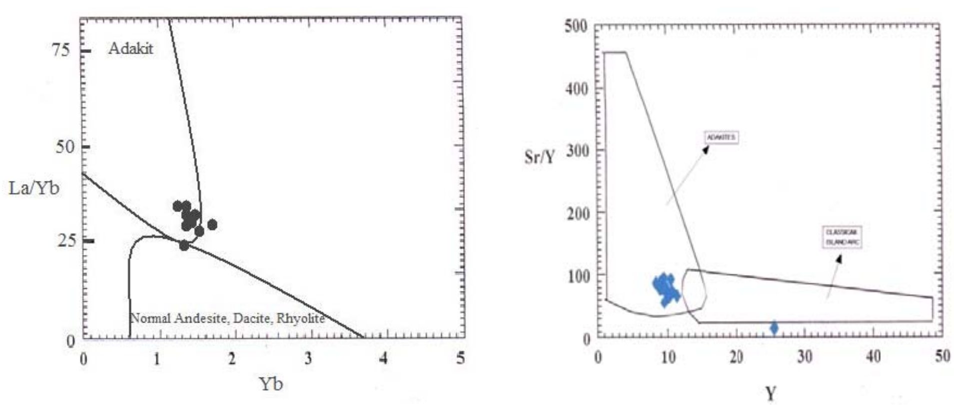


Fig. 18: Diagram for separation calc- alkaline from adakit rocks.

Table 2: Mean chemical composition of granitoid, world adakit and the study area samples.

W %	P.A. n=9, Martin, 1999	V.A. n= 267. Martin,2005	TTG n= 666. Martin,2005	V.A. of S. B.	P.A. of S. B.	E.L.. Martin,2005
SiO_2	67.30	64.80	68.36	63.06	63.94	68.94
Al_2O_3	15.78	16.64	15.52	16.35	16.48	17.70
Fe_2O_3	3.30	4.75	3.27	3.8	3.75	2.42
MnO	0.05	0.08	0.05	0.06	0.06	0.05
MgO	1.96	2.18	1.36	1.56	1.52	0.84
CaO	3.67	4.63	3.23	4.57	4.28	2.06
Na_2O	4.19	4.19	4.70	4.73	4.73	4.92
K_2O	2.15	1.97	2.00	2.14	2.19	2.53
TiO_2	0.54	0.56	0.38	0.48	0.45	0.78
P_2O_5	0.12	0.20	0.15	0.21	0.19	-
ppm	ppm	ppm	ppm	ppm	ppm	Ppm
Rb	-	52	67	46	52	98
Ba	-	721	847	663	730	651
Nb		6	7	6.8	5.6	11.4
Sr	280	565	541	961	864	333
Zr	-	108	154	120	123	196
Y	17	10	11	9	9	11.9
Ni	24	20	21	24.4	20.5	16
Cr	46	41	50	181	158	-
V	-	95	52	85	83	25
La	17.7	19.2	30.8	25.7	25.5	28.65
Ce	-	37.7	58.5	48.1	48.3	53.56
Nd	-	18.2	23.2	19.7	18.01	25.05
Sm	-	3.4	3.5	3.54	3.3	-
Eu	-	0.9	0.9	1.05	1.01	1.23
Gd	-	2.8	2.3	3.11	3.01	-
Dy	-	1.9	1.6	1.94	1.9	2.32
Er	-	0.96	0.75	1	1	1.21
Yb	1.1	0.88	0.63	0.87	0.9	0.94
Lu	-	0.17	0.12	0.13	0.13	-
K_2O/Na_2O	0.51	0.47	0.43	0.45	0.47	0.51
Mg #	0.54	0.48	0.45	0.42	0.42	0.40
Sr/Y	16.5	55.65	51.10	106.8	98.9	28.04
$(La_N/Yb_N)_N$	11	14.44	32.52	21.8	21	20.18

V.A.=Volcanic Adakite P.A.=: Plutonic Adakite Gr: Granodiorite TTG: Tonalite-Trondjimite-Granodiorite E.L.: Experimental liquids S.B.:Share-Babak

Conclusion:

Sub-volcanic and volcanic rocks in mineralogy and geochemical features are classified in dacite, andesite, ryodacite and traciandesite groups in the study area. The main minerals of sub-volcanic rocks include plagioclase, alkaline feldspar, amphibole, biotite and quartz (sometimes) and most porphyric texture. Main oxides including MgO, Al_2O_3, Na_2O, K_2O, CaO, FeO and Si_2O.Sub-volcanic rocks of sub-alkaline geochemical nature are calc-alkaline in the AFM diagram and other diagrams and in the famous diagram of the conventional calc-alkaline and adakit rocks are in range of adakit. These rocks are saturated in the range of aluminum and Meta aluminum. Sub-volcanic rocks are Si_2O>65%, Na_2O Top (3.5-7.5%) and have high Sr (400-800 ppm). Rare earth element patterns are strongly fractionation and HREE has been high, with Y< 11 ppm and Yb <1 ppm. All these features are compatible with the properties of adakit rocks. These rocks are with strong enrichment of Sr and not negative anomaly of Eu. That is related to the lack of plagioclase in the source of rocks. Rocks studied in terms of LREE and LILE elements shows many enriched. Sub-volcanic rocks that have been normalized with conderite and MORB indicate a pattern of fractionation, possibly due to the presence of amphibole and garnet in the source area. Tectonomagmatic diagrams (separation of different tectonic environments) such as rift region, active margins, volcanic arc and continental - continental collision zones are confirmation of an active continental margin environment.

REFERENCES

Arculus, R.J. and R. powell, 1986. Source component mixing in the regions of arc magma generation. J. Geophys. Res., 91: 5913-5926.

Bird, p., 1978. Finite element modeling of Lithosphere deformation: the zagros collision orogeny. Tecktonnophysics, 50: 307-36.

Cox, K.G., J.D. Bell and R.J. Pankhurst, 1979. the interpretation of igneous rocks. George, Allen and Unwin, London.

Drummond, M.S., M.J. Defant, 1990. a model for trondhijemite- tonalite-dacite genesis and crustal growth via slab melting: Archaean to modern comparisons. Journal of Geophysical Research, 95: 21503-21521.

Gill, J.B., 1974. Role of underthurst oscenic crust in the genesis of a Fijian calc –alkaline suite. Contrib. Mineral. Petrol., 43: 29 -45.

Gill, J.B., 1981. Orogenic andesites and plate tectonics, Springer Verlag, Berlin., pp: 390.

Green, T.H., 1989. Anatexis of mafic crust and high pressure crystallization of andesite In: Thorpe RS,ed. Andesites. New York. John Wiley, 465-478.

Harker, A., 1904. The Tertiary igneous Rocks of Sky .Men. Geol. Surv.Uk., pp: 481.

Harker, A., 1909, the natural history of igneous rocks. Methuen London, pp: 527.

Hassanzadeh, J., 1993. Metallogenic and tectonomagmatic events in the SE sector of the Cenozoic active continental margin of Iran (Shahre-Babakarea, kerman province). Unpublished Ph. D thesis, University of California , Los Angeles, pp: 204.

Henderson, P., 1984. Rare earth element geochemistry. Elsevier. Sci. Pub. Co., 510p. His-Lin Tschang, 1975, Geomorphological observations on the Tafoni forms of Hong kong, The Chung Chi Journal. pp: 32-51.

Holloway, J.R., C.W. Burnham, 1972. Melting relations of basalt with equilibrium water pressure less than total pressure. J. Petrol., 13: 1-29.

Irvine, T.N., W.R.A. Baragar, 1971. A guide to the chemical classification of the common volcanic rocks. Canadian Journal of Earth Sciences., 8: 523-548.

Le Maiter, R.W., 1976. the chemical variability of some common ignous rocks, J. Petro., 17(4): 589-637.

Maniar, P.D. and P.M. Piccoli, 1989. Tectonic discrimination of granitoids. Geol. Soc. Am. Bull., 101: 635-643.

Martin, H. and Hugh Rollinson, 2005. Geodynamic controls on adakite. TTG and Sanukitoid genesis: implications for modeles of crust formation, Lithos, 79: 1-4.

Martin, H., 1999. the adakitic magmas: modern analogues of Archaean granitoids. Lithos, 46(3): 411- 429.

McDonough,W.F., S. Sun, A.F. Ringwood, E. Jagoutz, A.W. Hofmann, 1992. Rb and Cs in the earth and moon and evolution of the earths mantle. Geochimica et Cosmochimica Acta, 56(3): 1001-1012.

Moradian, Shahrbabaky A., 1997. Geochemistry, Geochronology and petrography of Feldspathoid Bearing Rocks in Urumieh-Dokhtar Volcanic Belt, Iran Unpublished Ph. D thesis, University of Wollongong, Australia, pp: 412.

Oiller, C., 1971. Geomorphology text, Weathering, pp: 251.

Oyarzun, R., A. Marques, j. Lillo, I. lopez and S. Rivera, 2001. Gant versus small porphyry copper deposits of Cenozoic age in northern chile: adakitic versus normal calc-alkalin magmatism. Mineral. Deposita, 36: 794-798.

Pearce, J.A., 1982. Trace element characteristics of lavas from destructive plate boundaries, In: Trop R.S. Ed. Orogenic andesite and related rocks, pp.524-548. John Wiley and sons chichester.

Pearce, J.A., 1983. Role of the sub-continental lithosphere in magma genesis at destructive plate margins. In: Hawkeswoeth, C.J. and Norry, M.J., (Eds), Continental basalts and Mantle Xenolithes. Nantwich: Shiva, 230-249.

Prouteau, G., R.C. Maury, C. Rangin, E. Suparka, H. Bellon, M. Pubellier, J. Cotton, 1996. Les adakites miocenes du NW Borneo, temoins de la fermenture de la proto-mer de chine. C.R. Acad. Sci. Paris 323 serie IIa, pp: 925-932.

Prouteau, G., B. Scaillet, M. pichavant and R.C. Maury, 1999. Fluid-present melting of ocean crust in subduction zones. Geology, 27: 1111-1114.

Rapp, R.P. and E.B. Watston, 1995. Dehydration melting of metabasalt at 8-32 kbar: implications for continental growth and crust-mantle recycling. J. Petrol., 36: 891-931.

Rollinson, H., 1993. using geochemical data: evaluation presentation, interpretation. New York, Longman, Singapore, pp: 353.

Rushmer, T., 1991. partial melting of two amphibolites: contrasting experimental resultsunder fluid- absent conditions. Contrib. Mineral. Petrol., 107: 41-59.

Schilling, J.G. *et al.*, 1983. Petrologic and geochemical variations along the Mid-Atlantic Ridge from 27 N to 73 N. Am. Jour. Sci., 283: 510-586.

Stern, C.R. and R. Kilian, 1996. Role of the subducted slab, mantle wedge and continental crust in the generation of adakites from the Andean Austral volcanic zone. Contrib. Mineral. Petrol., 123: 263-281.

Stocklin, J., 1974. Possible ancient continental margins in Iran. In: Burk C.A. and Drake C.D. Ed. The geology of continental Margins, pp: 873-888. Sprigerverlag, New York.

Tatsumi, Y., D.L. Hamilton and R.W. Nesbitt, 1986. chemical characteristics of fluid phase released from a subducted lithosphere and origin of aec magmas: evidence from high-pressure experiments and natural rocks.J.Volcan. Geotherm. Res., 29: 293-309.

Wilson, M., 1989. Igneous Petrogenesis: A Global Tectonic Approach. Harper Collins Academic, pp: 466.

Winchester, J.A., P.A. Floyd, 1977. Geochemical discrimination of immobile elements. Chemical Geology 20: 325-343.