Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 6, p. 329-337, 2014
http://www.innspub.net

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RESEARCH PAPER

OPEN ACCESS

Petrography and geochemistry of rhyolite rocks in the Se-Chahun iron oxide deposite, Bafq mining district, Central Iran

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Article published on December 16, 2014

Key words: Geochemistry, Petrography, Rhyolite, I type, Se-Chahun , Bafq.

Abstract

Bafq metallogenic province is located in central Iran about 115 Km Southeast of the Yazd city. This metallogenic province is a narrow paleorift extending northward from south of Bafq to Robat- Posht– Badam and suggested age of 750 – 540 Ma for it. There is an alkaline - calc-alkaline bimodal composition at these environments. Contrary, alkaline-sub alkaline bimodal suites occur in anorogenic continental rift settings. The Se–Chahun Iron Ore mine is containing two major groups of ore bodies called the X and XI anomalies. Volcanic rocks are rhyolite and rhyodacite in composition and the sedimentary rocks are mainly dolomite. These ore bodies are commonly associated with pervasively altered rhyolitic tuffs and sandstones. One of the important volcanic rocks in the study area is rhyolite rocks and are host rocks for Iron mineralization These rocks have a Porphyry texture with micro granular mesostasis. phenocrysts of this rock are quartz and plagioclase. Quartzs are anhedral to subhedral shapes and plagioclases are albite to oligoclase. The properties of these minerals can be mention to albite-pericline and albite-carlsbad twinning. These minerals developed to clay mineral, sericite, chlorite and calcite. Rhyolite mesostasis are containing fine grain quartz and microlitic plagioclase that developed to clay minerals. Accessory minerals in these rocks are opac mineral, calcite and chlorite. In the distinguish diagrams, rhyolite rocks are plotted in the calc-alkaline area. Chemical properties of rhyolites are approaching to I-type. Separation of tectonic environment proposed a range of within plate rocks (WPG) and within place volcanic zone for rhyolite rocks.

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Introduction

Most of the world iron ore production is from banded iron formations (BIF), magnetite-apatite deposits (“Kiruna-type”). An iron oxide copper–gold (IOCG) study widely for the Bafq district deposits (Barton and Johnson, 1996; Williams *et al.,* 2005; Jami *et al.*, 2007; Torab and Lehmann, 2007; Daliran, 2002; Bonyadi, 2010; Stosch *et al.,* 2011).The Bafq mining district is in the Early Cambrian Kashmar-Kerman volcano-plutonic arc in Central Iran and hosts important “Kiruna-type” magnetite-apatite deposits (Torab, 2008).

The Posht-e-Badam Block is a metallogenic/ tectonic province of Infracambrian age, that is located in central Iran about 115 Km Southeast of the Yazd city (55° 15´- 55° 45'E, 31° 30'- 32° 30'N). There are several known iron – phosphate, phosphate, Th-U and Pb-Zn deposits in the region (Fig. 1). Recently, the occurrence of Cu-Au mineralization (probably porphyry in origin) is also reported (Moghtaderi, 2013). According to Forster and Jafarzadeh (1994) and Daliran (2002) Bafq metallogenic province is a narrow paleorift extending northward from south of Bafq to Robat- Posht– Badam.

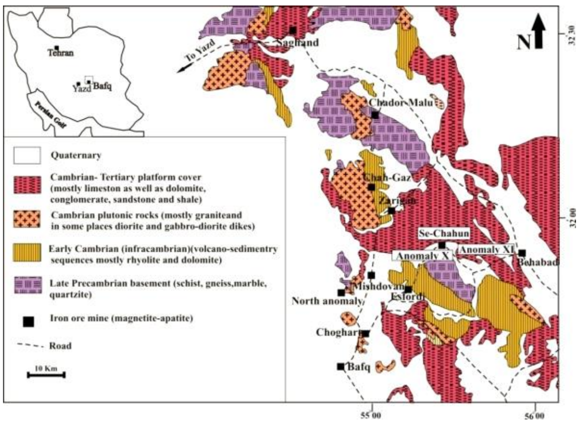

Fig. 1. Simplified geological map of the Bafq mining district and location Se-Chahun ore deposits and igneous rocks (Modified from Torab, 2008).

The age of the paleorift is suggested to be 750 – 540 Ma. New U-Pb ages and geochemical data from magmatic, metamorphic and silisiclastic rocks of the Saqand-Bafq area (Ramazani and Tucker 2003). reveal three main episodes of orogenic activity in the late Neoprotrozoic- Early Cambrian, Late Triassic and Eocene. It is believed that, iron metallogeny occurred in the Early Cambrian (554-531.4 Ma ages). Paleontological evidence also supports a Lower Cambrian age for host rocks at Chadormalu iron oxide deposit (Hamdi, 1995). The association of Bafq iron deposits with nonorogenic magmatism, continental margin or lacustrine halite facies evaporites, and lithological and mineralogical similarity with the red sea aborted rift deposits (Hitzman, 2000), indicate that Bafq iron deposits belong to an ancient failed rift (Moghtaderi, 2013).

An important component of this is the Cambrian Volcanosedimentary Unit (Ramezani, 1997), composed of dolomite, limestone, sandstone, shale and bimodal volcanic rocks. Within this sequence, Samani (1993, 1988) recognized the Saghand Formation and the Rizu to Dezu Series. The volcanism has a predominantly felsic character (rhyolitic to rhyodacitic) with subordinate amounts of andesites and is associated with spilitic basalts,rare undersaturated volcanic rocks of nephelinitic to basanitic composition, small mafic intrusive bodies and late diabase dike swarms, both with alkalic character (Ramazani and Tucker 2003).

The ore bodies of Posht-e-Badam Block are hosted by a lower Cambrian volcano-sedimentary sequence (also known as Saghand Formation) composed of lavas, pyroclastic, epiclesis rocks, intercalated carbonates, associated with number of mafic and felsic intrusions (Jami 2005; Torab 2010). Volcanic rocks are rhyolite and rhyodacite in composition and the sedimentary rocks are mainly dolomite. These ore bodies are commonly associated with pervasively altered rhyolitic tuffs and sandstones.

The Se-Chahun Iron Ore mine is containing two major groups of ore bodies called the X and XI anomalies (NISCO, 1975). Anomaly XI located 3250 m northeast of Anomaly X. Anomaly XI has been explored by geophysical methods and extensive drilling. The deposit is divided into two parts (north and south orebodies) with a total reserve of about 140 Mt low-grade iron ore with an average grade of 36% Fe (Torab, 2008). Although the massive magnetite-actinolite ore in Anomaly X has a higher grade, up to 67% Fe (Bonyadi, 2010).

Rhyolite is host rock in this mine, therefore are important in the study area. The aim of this paper is study mineralogy, petrology, geochemistry and type of rhyolite rocks in the Se-Chahun district. For determine rock groups and magma series.

Research Methodology

The area under study

Igneous rocks are spread in Central Iran. They divide to plutonic and volcanics of Late Precambrian, Infracambrian (recently Cambrian), Mesozoic and Tertiary age. The range of volcanic rocks is acid to basic. This group rocks contain rhyolite, dacite, andesite, basalt and other faceis such as lavas, tuffs, ignimbrites and volcanic detrital rocks (Haghipour *et al.,1* 977).

Research method

Our research includes two parts: field work and laboratory investigations. Field work includes sampling from rhyolite core and rocks for analyzing REEs. In the course 30 thin section preparation and was studied with petrographic polarizing microscope. Some of the fresh rocks selected for ICP-MS and XRF analysis. The analyses were made in Acme Laboratory in Canada.

Results and discussion

Upper Precambrian- Lower Cambrian volcanic rocks in Bafq region are calc alkaline. In the absence of distinguishable contact between Late-Precambrian volcanic evaporate deposits and Early-Cambrian formations Samani (1988), proposed an intra-continental rift facies (Saqand Formation), comprising five members with different lithologies and bimodal volcanism. Momenzadeh (1987) and Feiznia (1993) volcanic activity introduced ions and volatile components in an early rift basin and evaporate deposition occurred during an early to intermediate rifting stage.

The alkaline-sub alkaline volcanism occurred at a later stage. According to Moore and Modabberi (2002) also proposed bimodal volcanism and immature nonmarine clastic sediments in an anorogenic continental rift. Emami (2014), proposed a within plate magmasim at the Se-chahun area. nonorogenic continental rift environment associated with tholeiitic, alkaline-subalkaline or undersaturated -saturated or bimodal volcanism; and enrichment LREE. There is an alkaline - calc-alkaline bimodal composition at these environments. Contrary, alkaline-sub alkaline bimodal suites occur in anorogenic continental rift settings. Volcanic bodies contain rhyolite rocks. The characteristics of some of the more important volcanic rocks in the Se-Chahun mining district are described here.

Petrographic

Fresh and unaltered rhyolite is not found in outcrop of Se-Chahun mine and rhyolite samples were taken from drill core (Fig. 2). Ore mineral in rhyolite rocks are well shown because rhyolites are host rocks for Iron mineralization. In the thin section this rocks have a Porphyry texture with micro granular mesostasis. phenocrysts of this rock are quartz and plagioclase. Quartzs are anhedral to subhedral shapes and have average size 650 µm (Fig. 3).

Plagioclase is euhedral to subhedral shapes. The size of these minerals is 760 µm. Based on the refractive index of the optical properties and composition of the plagioclase is albite to oligoclase. The properties of these minerals can be mention to albite- pericline and albite-carlsbad twinning (Fig. 4). In some cases, plagioclases are strongly altered, so in these cases, is not possible to identify macles. These minerals developed to clay mineral, sericite, chlorite and calcite.

Fig. 2. Hand sample of rhyolite core.

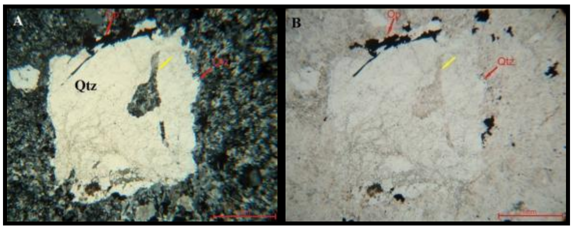

Fig. 3. Photmicrographs of quartz phenocryst in Se-Chahun rhyolites, (A, XPL and B, PPL).

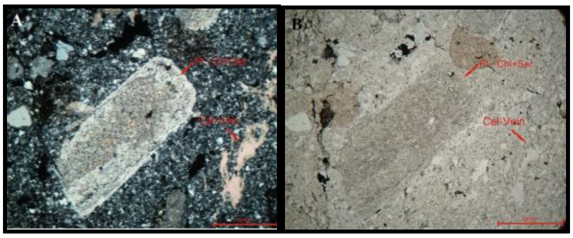

Fig. 4. Photmicrographs of plagioclase phenocryst in rhyolite rocks (A, XPL and B, PPL).

Rhyolite mesostasis are containing fine grain quartz and microlitic plagioclase that developed to clay minerals. Accessory minerals in these rocks are opac mineral, calcite and chlorite. Opac minerals with low frequency are anhedral to subhedral shapes and have average size 720 µm. Calcite has been shaped in anhedral to subhedral shapes and in some cases associated with chlorite and quartz veins. Chlorite has formed in the mesostasis (Fig. 5).

In this rocks silica metasomatism with a large spread occurred and low albite metasomatism observed. In some cases Quartz veins are with calcite and chlorite.

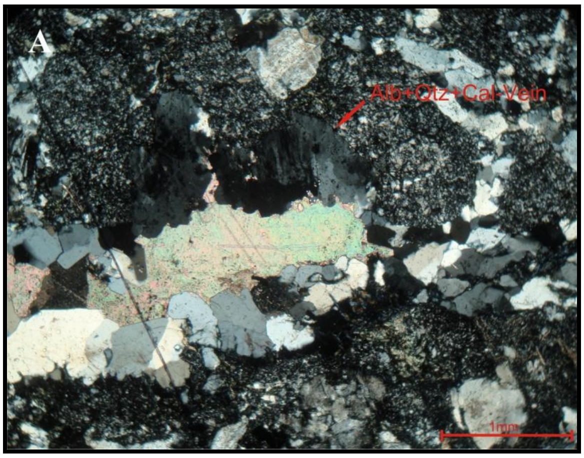

Fig. 5. Photmicrographs of Quartz veins with calcite in Se-Chahun rhyolites.

Geochemistry

Geochemical classification

The result of major and trace element analysis of rhyolite samples are listed in Table 1 and 2. Le Bas *et al.* (1986) and Winchester. & Floyd (1977) diagram distinguish various series of tholeiitic, calc-alkaline and alkaline. Sample rocks are plotted in rhyolite and dacite rocks and show tholeiitic and calc-alkaline series (Fig. 6 and 7). In the AFM plot (Irvine & Baragar, 1971) that distinguish between calc-alkaline and tholeiitic series, that rhyolite rocks are plotted in the calc-alkaline area (Fig. 8).

Table 1. The result of major and trace element analysis of Se-Chahun rhyolites (ICP-MS).

Sample	FeO	CaO	P2O5	MgO	Al2O3	Na2O	K2O	SUM	SiO2
Ry-1	2/14	0/73	0/03	0/70	10/98	4/76	3/32	22/83	77/17
Ry-2	3/15	0/52	0/06	2/60	9/03	2/07	3/88	21/65	78/35
Ry-3	2/70	1/50	0/05	0/90	11/81	5/13	3/58	25/86	74/15
Ry-4	3/40	0/58	0/05	2/81	9/90	2/35	3/90	23/34	76/66
DA	8/61	1/44	0/07	0/81	11/58	1/67	3/55	27/98	72/02
	Cr	**Ba**	**W**	**Zr**	**Sn**	**Be**	**Sc**	**Y**	**Ce**
Ry-1	17/00	319/00	1/20	58/60	3/50	1/00	4/10	21/20	73/65
Ry-2	45/00	777/00	0/80	62/80	2/60	1/00	7/30	24/30	67/14
Ry-3	23/00	410/00	0/90	60/20	2/70	1/00	4/30	22/30	70/54
Ry-4	39/00	620/00	0/80	59/10	3/10	1/00	6/80	23/90	64/64
DA	19/00	74/00	0/30	15/70	1/00	1/00	9/30	5/30	14/34
	Pr	**Nd**	**Sm**	**Eu**	**Gd**	**Mo**	**Cu**	**Pb**	**Zn**
Ry-1	9/80	34/20	7/10	1/30	5/30	1/31	22/10	1/43	12/40

Sample	FeO	CaO	P2O5	MgO	Al2O3	Na2O	K2O	SUM	SiO2
Ry-2	8/70	29/70	6/00	1/10	4/40	0/60	2/81	2/20	58/40
Ry-3	9/16	31/59	6/58	1/21	4/84	1/10	20/80	1/80	15/20
Ry-4	8/39	28/93	6/03	1/11	4/44	0/80	14/20	2/10	32/50
DA	1/80	5/90	1/30	0/70	1/10	1/39	5/17	6/82	29/20
	Ag	**Ni**	**Co**	**Mn**	**As**	**U**	**Dy**	**Ho**	**Er**
Ry-1	20/00	3/30	9/80	112/00	3/00	2/10	4/30	0/80	2/10
Ry-2	20/00	15/90	10/60	463/00	2/30	2/10	4/10	0/80	2/00
Ry-3	20/00	5/40	10/10	135/00	2/60	2/10	4/63	0/88	2/25
Ry-4	21/00	12/30	9/50	240/00	2/90	2/10	4/26	0/81	2/07
DA	148/00	6/70	5/10	8202/00	7/80	0/70	0/80	0/20	0/70
	Th	**Sr**	**Cd**	**Sb**	**Bi**	**V**	**Tm**	**Yb**	**Lu**
Ry-1	12/30	34/00	0/04	0/64	0/12	15/00	0/30	2/00	0/40
Ry-2	10/20	81/00	0/05	0/46	0/04	46/00	0/30	2/10	0/30
Ry-3	11/80	45/00	0/04	0/52	0/09	25/00	0/32	2/00	0/30
Ry-4	10/70	76/00	0/05	0/49	0/06	32/00	0/29	2/00	0/40
DA	1/70	113/00	0/05	3/71	0/08	41/00	0/10	0/50	0/10
	Hf	**Li**	**Rb**	**Ta**	**Nb**	**Cs**	**Ga**	**In**	**Re**
Ry-1	2/35	8/30	68/90	0/40	3/07	0/20	13/16	0/03	0/00
Ry-2	2/27	26/70	96/60	0/40	5/18	0/30	14/79	0/02	0/00
Ry-3	2/29	10/10	70/20	0/40	4/10	0/20	13/40	0/02	0/00
Ry-4	2/32	22/40	88/90	0/40	4/90	0/30	14/20	0/03	0/00
DA	0/51	5/80	85/30	0/10	1/99	1/40	13/92	0/10	0/00
	Se	**Te**	**Ti**	**La**	**Tb**				
Ry-1	0/30	0/08	1030	40/50	0/80				
Ry-2	0/30	0/45	1980	38/40	0/90				
Ry-3	0/30	0/01	1139	39/50	0/88				
Ry-4	0/30	0/20	2098	36/20	0/81				
DA	0/30	0/09	1470	8/00	0/10				

Table 2. The result of major element analysis of Se-Chahun rhyolites (XRF).

Sample	SiO2	Al2O3	Na2O	MgO	K2O	TiO2	MnO	CaO	Fe2O3
monzodiorite	52.26	17.74	3.74	4.61	2.06	1.03	0.11	7.82	8.05
Ryolite	73.32	12.67	4.65	1.02	3.04	0.23	0.03	0.88	2.50
Ryolite1	71.51	10.65	1.96	4.91	3.51	0.32	0.09	0.70	4.00
Ryolite2	60.39	13.44	1.44	0.84	3.54	0.10	1.11	1.58	8.34
	P2O5	**SO3**	**LOI**	**Ba**	**Co**	**Cr**	**Cu**	**Nb**	**Ni**
monzodiorite	1.14	0.00	0.74	3288	9	52	80	28	49
Ryolite	0.04	0.00	1.42	696	N	18	48	2	1
Ryolite1	0.08	0.00	1.96	1381	2	65	N	2	43
Ryolite2	0.08	1.89	6.57	5967	5	21	N	1	N
	U	**Th**	**Ce**	**Cl**	**Pb**	**Rb**	**Sr**	**V**	**Y**
monzodiorite	N	36	33	656	35	46	2057	80	16
Ryolite	1	53	75	551	9	101	42	32	24
Ryolite1	12	68	68	977	14	119	111	40	22
Ryolite2	N	35	1	165	28	95	124	42	18
	Zr	**Zn**	**Mo**						
monzodiorite	383	77	8						
Ryolite	190	28	7						
Ryolite1	173	75	15						
Ryolite2	114	37	13						

According to diagram Zr versus SiO_2 and Zn versus SiO_2 (Collins *et al.* 1982). All samples plotted in the I-type area.

Although in the rift zones typically granite and rhyolites have A type properties, but if in this zone partial melting accurse in igneous crustal rocks, the chemistry of rhyolites are approaching to I-types. In the study area chemical properties of rhyolites are approaching to I-types (Fig. 9).

Geochemistry of trace elements

Minor and trace element abundances plotted in multi-element and rare earth element diagrams. The rhyolite rocks (Fig. 10) is almost enriched than LREE / HREE ratio. This diagram shows negative anomalies of Eu^{2+} and flat pattern of HREE elements. However, have downward sloping curve that indicates the high degree of differentiation. It can be deduced, untile formation of rhyolites, digestion part of old continental crust, shell the changes in the concentrations of trace elements. 90 wt% of Eu^{2+} anomalies control by potassium feldspar and plagioclase, 5 to 7 wt% apatite and monazite and 1-2 wt% control with micas. Thereby, with increasing differentiation of magma, negative anomalies of Eu^{2+} increases.

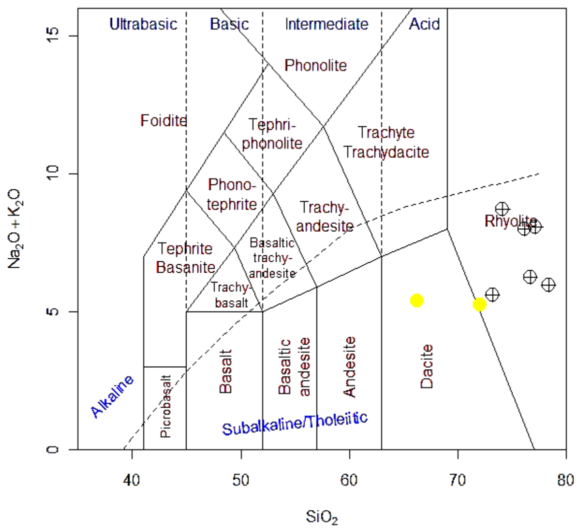

Fig. 6. Classification of rhyolite rocks (Le Bas *et al*, 1986).

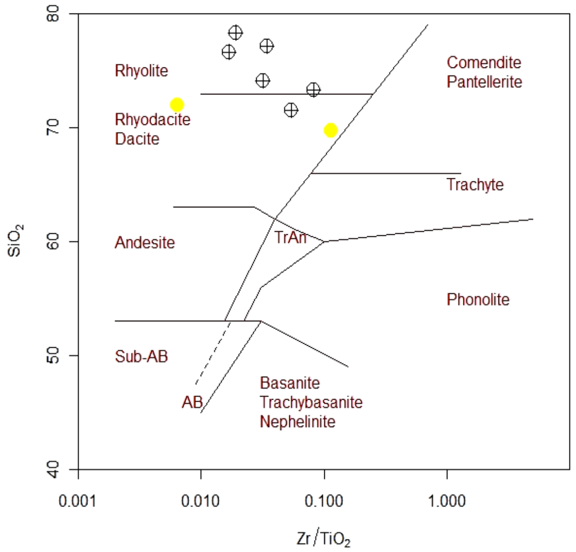

Fig. 7. Classification of rhyolite rocks (Winchester & Floyd, 1977).

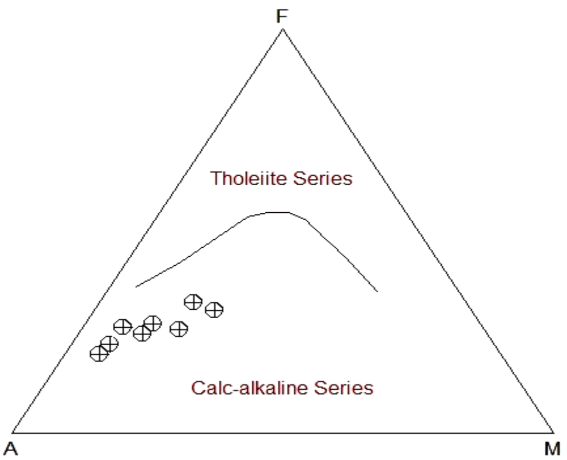

Fig. 8. Discriminant diagram between tholeiitic, calcalkaline series of rhyolite rocks of the Se-Chahun district (Irvine & Baragar, 1971).

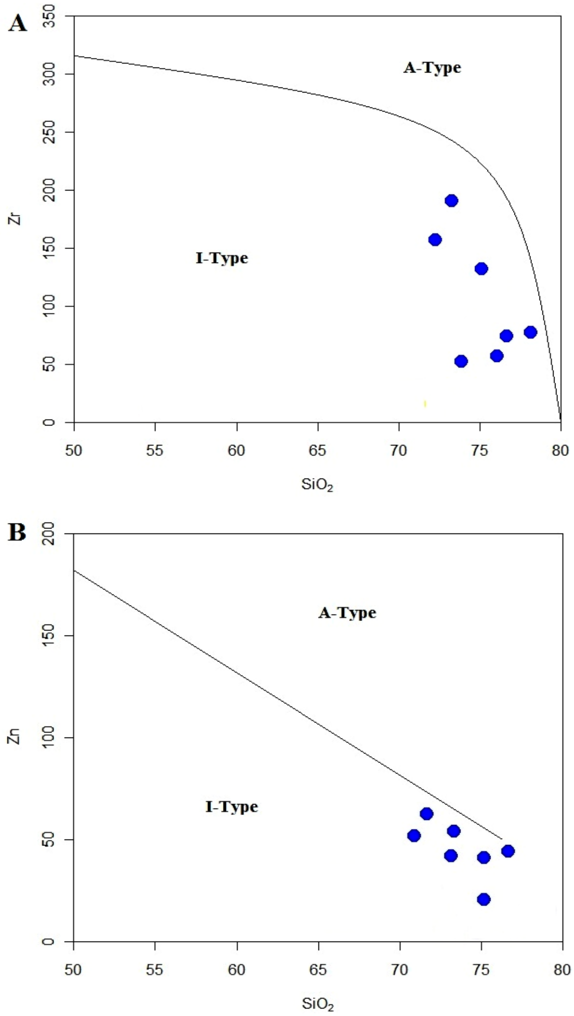

Fig 9. A- Diagram Zr versus SiO2 and B- Zn versus SiO2 (Collins *et al.* 1982). All samples plotted in the I-type area.

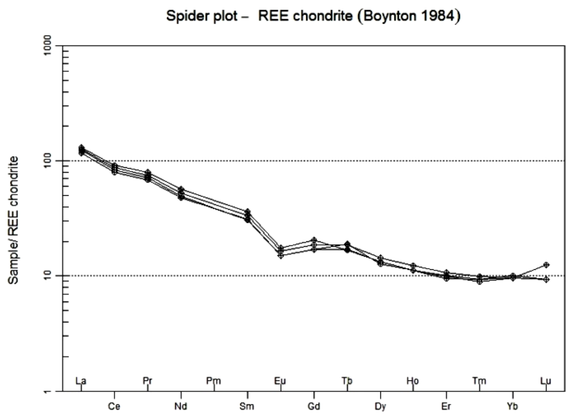

Fig. 10. REE pattern of Se-Chahun rhyolite rocks (Boynton, 1984).

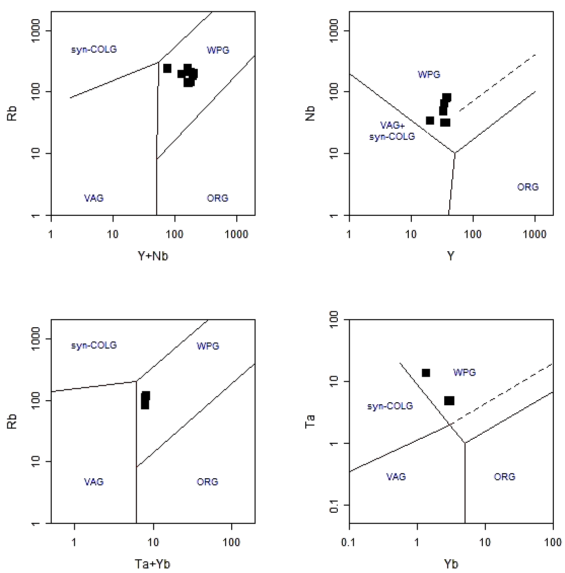

Fig. 11. Graph partitioning the tectonic rhyolite rocks (Pierce *et al.*, 1984).

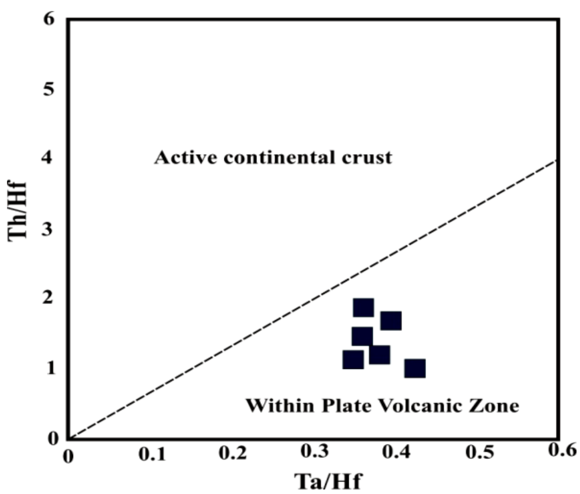

Fig. 12. Tectonic diagrams (Schandl and Gorton, 2002).

Tecnomagnetic setting

Separation of tectonic environment by Pierce *et al* (1983) proposed a range of within plate rocks (WPG) for rhyolite rocks (Fig. 11). In chart that provided by Schandl and Gorton (2002) samples located in the within place volcanic zone (Fig. 12).

Conclusion

Igneous rocks are spread in Central Iran. They divide to plutonic and volcanics of Late Precambrian, Infracambrian (recently Cambrian), Mesozoic and Tertiary age. There is an alkaline - calc-alkaline bimodal composition at these environments. Contrary, alkaline-sub alkaline bimodal suites occur in anorogenic continental rift settings. One of the important volcanics rocks in the study area is rhyolite rocks. Mineral assemblage in these rocks is quartz and plagioclases (phenocryst) and quartz and microlitic plagioclase (mesostasis). Accessory minerals in these rocks are opac mineral, calcite and chlorite. In some cases, plagioclases are strongly altered to clay mineral, sericite, chlorite and calcite. In the distinguish diagrams, rhyolite rocks are plotted in the calc-alkaline area and chemical properties of rhyolites are approaching to I-types. Separation of tectonic environment proposed a range of within plate rocks (WPG) and within place volcanic zone for rhyolite rocks.

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