Geochemical Signatures of Bazman Volcano: Evidence from Makran Subduction Zone, Southeast Iran

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1. Introduction

Bazman is one of the Plio-pleistocene volcanoes in the southeastern Iran. Lavas from its eruptions have covered quaternary sediments adjacent to this volcano. Bazman volcano is located ~420 km northern of coast line of Oman Sea. A crater with 500m diameter and 3400m high has been created on the main summit of this volcano which has been classified as a stratovolcano. This stratovolcano consists of different volcanogenic strata including lavas ranging from basaltic andesite, andesite to dacite and pyroclastic deposits ranging from ash to blocks.

Vicinity of this volcano with active subduction zone, Makran, located in the southeastern Iran indicated that Bazman may be Subduction related volcano. In addition, there are several quaternary volcanos such as Taftan, Shahsavaran (southern Iran) and Soltan (southern Pakistan) which situated along northward of Makran subduction zone as continental arc magmatism.

2. Tectonic setting

Bazman volcano is located north of Jazmurian Depression which is fore arc basin (Shahabpour, 2010). Bazman, Taftan, Shahsavaran (in Iran) and Soltan (in Pakistan) are situated in the active Makran volcanic belt (Biabangard and Moradian, 2008). They form a quaternary volcanic arc on the active continental margin named Baluchestan volcanic arc. Makran accretionary wedge is one of the most extensive accretionary complex on the Earth (Fig. 1). This accretionary wedge grew seaward by accretion of trench fill sediments, and by slope, shelf and coastal plain propagation (Shahbpour, 2010). Northeastern ward of Arabian plate, result of divergent movement of Red Sea, has been collided to southern border line of Eurasian plate (Fig. 1). This collision along the Zagros Fold –thrust belt has been acted as a continent –continent collision but at Makran active subduction zone has been behaved in as an ocean-continent collision. Oceanic lithosphere of Arabian Sea has moved underneath the central Iran (southern Eurasian plate) as long as ~1000km at the rate of ~3.9 cm/y in the Makran subduction zone (Fig. 1). This collision has been started at early Paleocene with moderate slip, and now a day it reveal shallow dip (~5o) (Jacob & Quittmeyer, 1979; White & Louden, 1983; Byrne et al., 1992; Carbon, 1996; Regard et al., 2010) (Fig. 2).

Fig. 1a) Google Earth picture of Arabian, Indian, and Eurasian plates (Plate boundaries from USGS website). Makran Subduction zone indicated by red line in the southern Iran and Pakistan. Seismological evidence indicates that there is a shallow dipping Benioff zone (~5 degrees). Red filled circle is Bazman Volcano

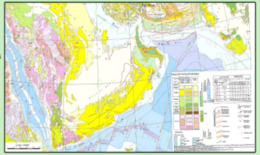

Fig. 1b) Seismotectonic Map of the Middle East. Northward subduction of Arabian oceanic plate at the rate of convergence ~3.9 cm/y has generated volcanic arc in the southern Eurasian plate. Scale: 1/5000,000. (Geological Survey of Iran & Commission for the Geological Map of the World, 1992).

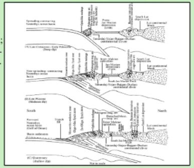

Fig. 2) Scematic illustrations depicting tectonic evolution of the Makran region. Acronyms: EMB, extensional marginal basin; CMB, compressinal marginal basin; Eo-Oligocene, Eocene-Oligocene; EOM, Eocene –Oligocene-Miocene;Meso.mag.arc, Mesozoic-magmatic arc; Mio, Miocene (Shahabpour, 2010).

3. Results

Twenty-four whole-rock samples of volcanic rocks have been analyzed for major and trace elements by ICPMS at the SGS laboratory (Canada). The analyzed samples were collected throughout the whole massif of volcanic area.

3. 1. Major element compositions

The principal major element characteristics were recalculated on volatile-free. Samples with high mg#, MgO and Ni has been selected as primary magma (e.g. sample number 15, 16).On the TAS diagram (Fig. 3) all of the samples plot on the sub-alkaline area and represent andesite and dacite rocks types. On the AFM diagram (Irvin & Baragar, 1971) Bazman samples fall into the field of calc-alkaline series (Fig. 4). On the variation diagrams (Fig. 5) there are strong and meaningful correlations between major oxides such as MgO vs. CaO (r=0.87), MgO vs. SiO2 (r=-0.88) and MgO vs. TiO2 (r=0.93) indicate that this suite is co-magmatic and evolved magma have probably been controlled by fractional crystallization. On the Pearce et al. (1977) diagram all of samples plot on the orogenic field (Fig. 6). SiO2 in the range of 56.1-66.9% (mean=62.19%, median =63.2%) represent high silica content of this suite. The rocks have generally low content of K2O, rang of 0.95-1.87, mean=1.4%, and they have generally high content of Na2O, rang of 3.9-4.5%, mean=4.16%, and Al2O3, rang of 15.9-17.7%, mean=16.8%.

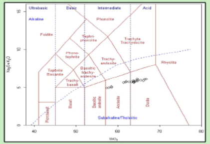

Fig. 3) Total alkaline vs. SiO2 (TAS) diagram (Le Bas et al., 1986), Bazman samples fall into the andesite and dacite area and they show sub alkaline affinity.

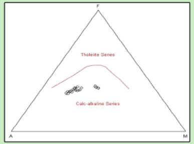

Fig. 4) AFM diagram (Irvin & Baragar, 1971). Bazman rocks plot on Calc-alkaline Series.

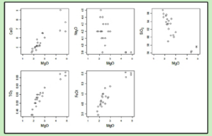

Fig. 5) MgO vs. other major oxides diagrams, there are meaningful correlation between these oxides for Bazman samples.

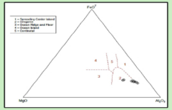

Fig. 6) Bazman volcanic rocks on MgO-Al2O3-FeOT diagram (Pearce et al., 1977) represent orogenic field.

3.2. Trace element compositions

Bazman Samples display high concentration of LIL elements such as U rang of .99-2.17ppm, mean=1.6ppm; Th rang of 3.2-6.3ppm, mean=5ppm; Ba rang of 160-370ppm, mean=265ppm; Sr rang of 350-640ppm, mean=417ppm. Transition metal including Ni (mean=30.5ppm), Cu (mean=33ppm), and Zn (mean=58ppm) have considerably high concentration. In PM normalized pattern (Fig. 7) Bazman samples reveal high concentration of LIL (Ba, Rb, Th, and Sr) and low concentration of Heavy incompatible elements (Tb, Y, and Yb). HFS elements including Nb and Ti strongly represent negative anomalies. However steep REE pattern (Fig. 8) does not show any negative anomalies on Eu.

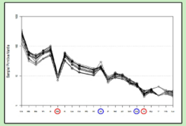

Fig. 7) PM normalized diagram (Sun & McDonough, 1989), Bazman rocks show negative anomalies on Nb and Ti.

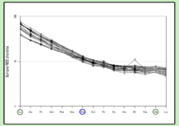

Fig. 8) Bazman samples on Chondrite normalized diagram (Boytone, 1984) with steep REE pattern

4. Discussion and conclusion

4. 1. Fractional Crystallization

Immobile trace elements such as Zr, Ni, and V are not affected by alteration, so their concentrations are mainly controlled by fractional crystallization rather than alteration.

Changing Ni/V versus Zr (Fig. 9) was controlled by fractionation of Olivine, Magnetite, and Pyroxene. During the Olivine or Magnetite fractionation Ni/V ratio decreases whereas Clinopyroxene fractionation just slightly affect Ni/V ratio. Moreover, Plagioclase fractionation has no control on Ni/V ratio; however, it increases the concentration of Ni, V, and Zr in the melt (Reichow et al., 2005). The Bazman samples in Ni/V vs. Zr diagram (Fig. 9), display large variation in Ni/V within narrow Zr rang of 86-129ppm which can be controlled by prominent role of Olivine fractionation from primary magma. Among the Bazman rocks, sample number 15 may represent primary magma character because of high MgO (4.86%), mg# (61), Ni (60ppm), and low LOI (0.94%). Also Fig.9 illustrates fractionation trends of plagioclase, clinopyroxene, and Olivine as cumulate phases which control these trace element concentrations in evolved magmas. The calculations show that this primitive magma may have been experienced ~30% Olivine fractional crystallization to generate more felsic rocks in the Bazman volcanic suite.

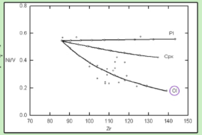

Fig. 9) Variations in Ni/V vs. Zr indicating history of Ol, Cpx, and Plg fractionation. Open circles on trajectories indicate 5% FC intervals. Bazman rocks have been experienced ~30% Olivine Fractionation.

4.2. Petrogenesis

One of the most features in geochemical signatures of Bazman suite is negative anomalies on Nb and Ti. These features have been observed from active subduction related magmas in all of the arc magmatism on the Earth. The origin of the observed Nb deficit in the bulk silicate Earth (BSE) compared to chondritic meteorites constitutes a long-standing problem in geochemistry. The deficit requires a large-scale process fractionating Niobium from Tantalum, and a super-chondritic Nb/Ta reservoir hidden in the deep silicate Earth and/or in the metallic core (Nebel et al., 2010). One possibility in the storage of a high Nb/Ta reservoir in the deep mantle, possibly in the D” layer at the core mantle boundary, as part of the a hidden geochemical reservoir that was proposed on the basis of Neodymium isotopic analysis (Andreasen et al., 2008; Bennett et al., 2007; Boyet and Carlson, 2005; Carlson and Boyet, 2009; Murphy et al., 2009). In this scenario, dense mafic oceanic crust relatively enriched in the Nb-Ta-rich mineral Rutile would be subducted to the core-mantle boundary through the early, hot convecting mantle (Tolstikhin and Hofmann, 2005; Tolstikhin et al., 2006), or continuously stored by subduction thought Earth’s history (Rudnick et al., 2000) and form the missing Nb reservoir. Makran subduction oceanic lithosphere have metasomatized sub-continental mantle wedge underneath the Bazman volcano and this process have produce two component a) subduction derived component (SDC), b) residual slab component (RSC). Differentiation of trace elements operates within the subduction zone environment, resulting in the separation of SDC from subduction oceanic lithosphere, which is recycled back into the mantle as RSC (Saunders et al., 1988). PM and Chondrite-normalized diagrams (Fig. 7-8) for Bazman samples represent steep REE pattern and hence in this suite the concentration of La and Yb are more than those of chondrite by a factor 35 and 3 respectively so the REE and incompatible elements have strongly been fractionated. Depletion in heavy REE and low (Nb/Ta)n ratios, mean=0.59, as well as high (La/Yb)n ratios, mean=9.8, requires that garnet occur in the restite, whereas absence the negative EU anomalies in the REE pattern and high Sr values, mean=417ppm, allow little if any, plagioclase in the restite. Sr is a compatible element in the plagioclase, and hence, the Sr distribution in magma reflects, at least in part, the role of plagioclase fractionation (Ellam and Hawkesworth, 1988; Tarney and Jones, 1994; Martin and Moyen, 2002). The partitioning of Sr into the melt is also related to An content of plagioclase (Foley et al., 2002). Moreover, Bazman rocks show negative anomalies on Nb and Zr as HFS elements similar to those of typical subduction related volcanism.