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Sr isotopic ratios of two magmatic series unraveling the role of crustal contamination in NW Firoozeh, NE Iran

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Abstract

Tertiary basalts of NW Firoozeh in northeastern Iran are alkaline and evolve gradually towards the subalkaline andesites and dacites. Unvariant Sr isotopic ratios in the basalts, andesites and dacites indicate that the evolution of their parental melt towards progressively more differentiated melt occurred in the absence of crustal contamination. On the contrary, progressively higher Sr isotopic ratios in the alkaline basaltic trachyandesites to trachytes from NW Firoozeh suggest that crustal contamination played a significant role in the evolution of the alkaline rocks.

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Keywords: Alkaline; subalkaline; crustal contamination; Sr isotopes; Iran

1. Introduction

Tertiary volcanic rocks are widely distributed in eastern Alborz zone and further toward east in Binaloud zone[1] across northern Iran (Fig. 1). As a portion of the Alpine-Himalayan orogeny, Alborz Mountain Range, which includes the study area, is extended across northern Iran for almost 1500 km. Eastern Alborz Tertiary volcanism is attributed to the northward subduction of the eastern branch of Neotethys[2]. Based on Sr isotope composition of Tertiary volcanic rocks between Sabzevar and Quchan, it was concluded that sialic continental crust has made no

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contribution to the subduction-related magmatism in this area[3]. According to a recent study on the volcanic rocks from NW Firoozeh[4], it is concluded that the subalkaline andesites and dacites are derived from a rather alkaline basaltic melt by two stages of fractional crystallization (FC); 1) a minor olivine+feldspar FC and 2) a major amphibole-dominated mineral assemblage FC; whereas the alkaline basaltic trachyandesites, trachyandesites and trachytes are derived from the same parental melt through assimilation fractional crystallization (AFC) process mainly controlled by olivine + clinopyroxene FC.

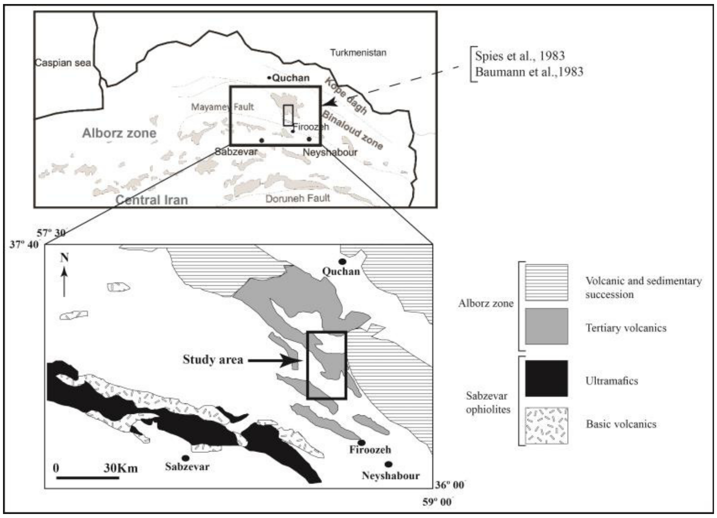

Fig. 1. Location of the study area and the studied region[2,3] shown on a map of Iran with regard to major structural units in NE Iran; Alborz and Binaloud zones as well as Kope dagh.

2. Petrography

Samples of basalts and trachybasalts from the study area show vitrophyric to porphyritic textures. The phenocrysts are mostly fresh euhedral olivine crystals and some feldspars and rare clinopyroxenes. Rock groundmass is vitric or fine-grained mineral assemblage of feldspars + clinopyroxenes + opaque. Basaltic andesites are porphyritic samples which include a phenocryst mineral assemblage dominated by clinopyroxene and feldspar, otherwise look similar to trachybasalts. The andesites and dacites are slightly to moderately porphyritic rocks and are characterized by the following ferromagnesian phenocryst mineral assemblage: amphiboles ± orthopyroxenes ± biotite. Feldspars in the andesites and feldspars ± quartz in the dacites are the ubiquitous phases both as phenocryst and in the groundmass. Opacitized rims for the amphiboles and biotites are common; these are extended to the whole body of phenocrysts in some instances. Volcanic rocks from the alkaline series are mostly vitrophyric or porphyritic. Some pseudomorphs after ferromagnesian minerals (clinopyroxenes?) are present. The vitric groundmass of these samples which have developed perlitic textures in some instances, embrace some feldspar, biotite and quartz phenocrysts. A few of the alkaline rocks show subvolcanic textures.

3. Analytical procedures

Sr isotopic compositions (Table 1) were determined for 15 samples at the DST of the Universita' degli Studi di Firenze following the procedures outlined by Avanzinelli et al.[5]. Although weathering was carefully checked for before sample selection, to avoid possible Sr contamination, rock powders were leached before digestion. Leaching was performed with 1N HCl on a hot plate. Sample powders were digested in a HNO_3-HF-HCl mixture and Sr fractions were collected using standard liquid chromatographic techniques. Sr isotopic compositions were measured by thermal ionization mass spectrometry (TIMS) using a ThermoFinnigan Triton TI in multi-dynamic mode[5]. Strontium selection has been performed using special cation exchange resin (AGW 8X, 200-400 mesh), loading the sample properly re-dissolved into 0.5ml HCl 2.5N acid. Strontium isotopic compositions are exponentially corrected for fractionation to $^{86}Sr/^{88}Sr$ 0.1194.

Table 1. Rb-Sr isotopic composition of the subalkaline and alkaline magmatic series from NW Firoozeh, Iran.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (p)	2se	$^{87}Sr/^{86}Sr$ (20 Ma)
Subalkaline series						
NB48	73.2	387.4	0.5466381	0.705680	± 0.000006	0.705524
NB57	30.4	407.2	0.2159804	0.704098	± 0.000005	0.704036
NB67	32.3	442.7	0.2110773	0.703850	± 0.000005	0.703789
NB85	47.4	544.8	0.2517037	0.704328	± 0.000006	0.704256
NB96	39.2	592.2	0.1914988	0.704209	± 0.000006	0.704154
SN17	42.7	708.2	0.1744297	0.704188	± 0.000005	0.704138
SN32	16.4	520.2	0.0912057	0.703928	± 0.000005	0.703902
SN33	20.6	571.5	0.1042796	0.703867	± 0.000006	0.703837
OP46	39.3	394.6	0.2881270	0.703887	± 0.000006	0.703805
Alkaline series						
OP2	152.2	49.4	8.9132510	0.723900	± 0.000006	0.721368
OP17	188.9	65.6	8.3306052	0.712930	± 0.000006	0.710563
OP18	247.1	70.7	10.111178	0.716634	± 0.000006	0.713761
OP37	98.8	294.9	0.9692384	0.705204	± 0.000005	0.704928
OP38	302.4	40.4	21.654535	0.741821	± 0.000005	0.735669
OP43	272.0	24.3	32.382551	0.749267	± 0.000006	0.740069

4. Subalkaline and alkaline magma series; major, trace and isotope geochemistry

A preliminary examination of the volcanic rocks from NW Firoozeh on Harker variation diagrams, specifically on TAS (total alkalis versus silica) diagram[6] (Fig. 2) indicates the presence of two distinct series. One shows the modest amount of alkaline elements, whereas the other is characteristically enriched in alkaline elements. These are called subalkaline and alkaline series, respectively. Samples from these two series also follow consistent variation trends on other Harker diagrams.

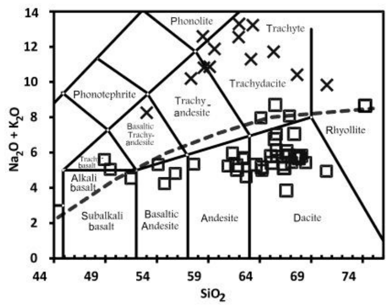

Fig. 2. Total alkalis versus silica (TAS) diagram[6] for alkaline (cross marks) and subalkaline (squares) volcanic rocks from NW Firoozeh. The alkaline-subalkaline boundary is after Miyashiro[7].

On the Harker variation diagrams, data points of the subalkaline series form rather linear trends, though some scatter in data points particularly for Mg, Ca and Al is notable. FeO, MgO and CaO show overall decrease in abundance, while alkalis increase slightly. Decreasing incompatible element abundances such as Y, Zr, Nb, La and Ce with increasing silica in the subalkaline series, particularly in the andesitic-dacitic spectrum are important features with significant petrogenetic implications[4]. Volcanic rocks of the subalkaline series that straddle the alkaline-subalkaline boundary in the basic end of the spectrum and gradually enter the subalkaline domain, mimic the normalized trace element patterns of the Oceanic Island Basalt (OIB).

The alkaline volcanic rocks from the study area are intermediate to felsic and show distinct (if not unique) geochemical characteristics. From major element geochemistry viewpoint, they are strongly enriched in potassium and depleted in Mg[4]. The potassic character of the alkaline volcanic rocks increases with increasing silica. These rocks are severely depleted in compatible trace elements (e.g., Cr, Ni, V, Co) and Sr, whereas they are highly enriched in incompatible trace elements (HFSE, LILE and REE). Alkaline volcanic rocks from the study area constitute a single outcrop (13 x 3 km) which is largely confined to the Firoozeh turquoise mine. It has sharp contact against adjacent subalkaline volcanic rock units. These alkaline rocks are considered as of lower Eocene age on the Mashkan geological map[8] and are older than the subalkaline volcanic succession in the study area. However, a sample from these alkaline volcanic rocks was age-dated by K/Ar method[2] and yielded Oligocene age. The Firoozeh alkaline volcanic rocks cover a rather wide compositional spectrum from basaltic trachyandesite, trachyandesite, alkali trachyte and rhyolite, yet they are uniformly depleted in MgO and highly compatible elements such as Cr and Ni. These alkaline rocks are also highly enriched in incompatible trace elements. The low abundances of highly compatible elements in one hand, and the high values for incompatible trace elements on the other hand, are the major geochemical signatures of both crustal assimilation and fractional crystallization. Strontium isotopic ratios obtained for the volcanic rocks from the NW Firoozeh confirm such petrogenesis. The variation of Sr isotope ratios for the subalkaline series is rather limited, while they vary significantly in the alkaline volcanic rocks (Fig. 3). Progressively higher Sr isotopic ratios in the alkaline basaltic trachyandesites to trachytes from NW Firoozeh suggest that crustal contamination played a significant role in evolution of the alkaline rocks.

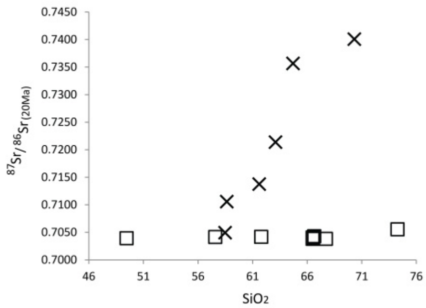

Fig. 3. Strontium isotope composition versus silica content (wt.%) for alkaline (cross marks) and subalkaline (squares) magmatic series from NW Firoozeh.

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