The Nature of Pleistocene Volcanism in the Northeastern Jordan

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Abstract

The Pleistocene volcanicity northeastern of Jordan is represented by basaltic scoria, cones and flows and cover approximately 11.400Km of land area. Geochemical parameters such as Mg value Mg/Mg+Fe^{+2} and high Titanium content indicates that magma is of primary origin.

Trace elements of primary magma show low variable abundances of compatible and incompatible elements which reflect a homogenous source. They are under saturated with respect to its silica content. These volcanic rocks are belonging to alkaline to sub alkaline rocks series. The rocks consist mainly of alkali basalt with 46.10-49.96 Wt.% $Si0_2$, 2.61-4.75 Wt.% alkalis respectively. Mantle xenoliths entrained in late Cenozoic volcanic rocks erupted through out northeastern Jordan provide information about the evolution of Lithospheric mantle, which could represent a potential source for Arabian interaplate volcanism. Xenoliths carried to the surface by magma in Northeast Jordan did not equilibrate with the melts indicating that the transport from the mantle to the surface was rapid.

1-Introduction

During Cenozoic times, basaltic lava poured from vertical fissures and local vents along the Jordan rift mountain ridge in central Jordan and in Northeastern Jordan (Safferini,et.al 1987), (Fediuk & Alfugha 1999).

The Jordanian basalts are part of the Arabian plateau basalt which covers large area in Saudi Arabia, Jordan and Syria. The Cenozoic volcanism in northeastern Jordan has a relatively long period of magmatic sequence extending from the Oligocene to Holocene (Barberi et.al 1979) with an age range from 0.2 to 18.5 Ma. As determined by K-Ar dating (Barberi,et.al 1979 and Moffat,1988).

In general alkai basalts are wide spread in continental plate interiors and are usually associated with continental rifting (Wilson 1989).

The basaltic plateau of northeast Jordan is part of the large intra-continental volcanic province of Harrat Al-Shaam, which cover an area of about 45000km2, and extends continuously in NW-SE trend from the southern rim of Damascus basin in Syria across Jordan into northwestern parts of Saudi Arabia. In Jordan, the volcanic province covers and area about 11.400km2. the exensive volcanism in northeastern Jordan was extruded during faulting epsiodes and predominantly consist of alkali basalts, basanites and Hawaiites (Saffarini- et.al 1987), Barberi et.al.1979) Moffat, 1988,Shaw et-al.2003)

The volcanoes contain upper mantle nodules with composition of spinel lherzolite. Those xenoliths contain olivine, orthpyroxene, clinpryroxene and spinel that could be derived from the upper mantle analogous to worldwide occurrences (white,1966,Frey & Green 1978,as Magurie,1988 and Wilson 1989).

The present work aims at investigating the geochemical mineralogical and petrographical futures. of Pleistocene volcanism of northeast and their origin.

2-Geologic Setting

In north eastern Jordan figure -1-, basalts extend along the east side of the Al-Azraq-Wadi- Sarhan basin.(Bender, 1968) distinguished seven different phases of major volcanic activities in northeastern Jordan based on both field observation and bore hole data.

The thickness of these flows reaches 150m where the upper three phases are exposed at surface between oil pump station H5 and H4, in the central part of the northeastern Jordan plateau.

The volcanoes in the studied area are strato-volvano type (Alfugha 1995.2006), they rise above the surface of the basalt flows by 140m on the slopes of the volcanoes as finely grained ash, angular and spherical pyroclasts of a diameters of less than 0.2 cm and basaltic bombs of different sizes with diameters ranging between 0.5 and 1.5m are exposed basatic layers of blocky lava with an average thickness of 60Cm are also present.

K- Ar. Dates from Harrat Ash Shaam (Ilani et.al.2001) range from 0.05 to 40 Ma. Historical eruption were also recorded in the 17th century (Tarawneh et,al.2000).

The volcanic field comprises series of sub horizontal lava flows<25m thick numerous scoria cones, extensional fault , and large fissure eruption that emanated from dykes<100km in length that strike NW-SE and N-S, forming elongated ridges(Show,et-al.2003).

The tectonic evolution of the Arabian plate is determined by the main regional structures of the region including the Red Sea rift and the dead Sea transform fault, which trends north-south and the net slip along it is about 105km (Garfunkal.et.al-1989) and (weinstein,et.al.2006).

Jordan is part of the Arabian plate, which is drifting to NE, towards the Tauros-Zagros compressional zone. Up lift and tensional depression parallel to the Red sea developed and the most important one is the NE-SE striking Azrag-Sirhan graben structure. The volcanic are aligned NNW-SSE and situated on the east side of a major fault trending NNW-SSE.

These volcanoes of NE which produce a large basaltic plateau lie between the fifth and sixth flow in the basaltic plateau north of the Mafrak-Baghdad road (figure -1).

3-Sampling an Analytical Techniques

Thirty representative rock samples collected from the volcanic cones in northeastern Jordan were crushed and powdered. At mineralogy institute university of stuttgart Germany. Concentration of major and minor elements were determined by

x-ray fluorescence (XRF) type Philips 1404 system.

Concentrations of trace elements were also determined by XRF.Spinel lherzolite minerals were analyzed using EMX- ARI electron microscope. The acceleration potential is ASKW,0.015mA.

Data reduction was done on a computer using Thin section of rock samples was made to be studied in transmitted light at dept. of Geology university of Jordan.(Bence& Ablee 1968).

4- Petrography and Mineralogy

The volcanic rocks of northeast Jordan are mainly composed of cinder cones, scoria and basaltic flow. The basaltic rocks in hand specimen are black to grey in color fine grained,melanocratic typically show porphyritic to glomeroporphyritic texture and are characterized by olivine and plagioclase phenocystes embedded in fine grained groundmass that consist of plagioclase, olivine with glass.

The mineralogical components of the studied basalts are plagioclase, olivine, clinopyroxene apatite and opague minerals. The average modal composition is 54Vol.% plagioclase 25Vol.% olivine,17vol.%clinopyroxene and 4 vol.% accessory minerals.

4.1- Plagioclase occurs in two generation as hypidiomorphic lathgs which form in source structure and as small fine crystal in the ground mass the subhedral plagiclase laths reach 5mm in diameter with composition of An 50-An 60. indicating labradorite composition.

4.2- Olivine

Olivine occurs as phenocrysts and in the groundmass crystlas.they are anhedral to subhedral, fractured, mostly unaltered and reach in length 4mm colourles stopale yellow. A few exception exhibit resorbed embedded margins which is often partly or compeletly replaced by iddingsite.

The olivine phenocrysts are typically more magnesian in the basalt with Fo 75-82.

4.3. clinopyroxene

The type of clinopyroxene is augite which occurs as colorless or pale brown to plale green and occurs as euhedral phenocysts 1-4 mm in length. The groundmass augite show prismatic crystals and asmall a mount of crystals affected by chloritzation where green chlorite is present along fractures, and along crystal rims.

4.4.Accessory

The minerals include apatite occur as a minute needles, magnetite, ilmenite and spinal gererally make up about 4vol% of the basalt composition

4.5 spinel lerzolite

The mineral consist of olivine, orthpyroxene, clinopyroxne and spinel occur as nodules of various sizes (1-7cm) in diameter fragments in the loose pyroclastic material and lava flow.

5- Geochemistry

The Pleistocene alkalibasalt from northeastern Jordan have been analyzed for major, ninor and trace elements, representative data are presented in tables 1,2,3 major elements concentration show a low degree of variabitity. SiO_2 values range from 46.10 to 49.96 wt. %

The AFM variation diagram, figure 2 indicate that the composition of the basaltic rocks from northeastern Jordan falls in the tholeiitic field of Irvine and Baragar (1971) and shows no continuous difference. The SiO_2 values plotted against alkalis in Irvine and Barggar 1971) diagram figure 3 this illustration shows that all rock samples can be assigned to alkaline-subalkaline suites.

Shaw,et.al.(2003) suggested that silica under saturated magma with a high MgO value more that 7wt% and high FeO^{+2} $+Fe_2O_3$>12wt % give evidence of smaller degree of partial melting at high pressure.15-20 Kbar Plotted against the SiO_2 values. The figure 4 shows that Al_20_3 increases with the increase SiO_2 and decreases roughly with the increase of P_2O_5.Total iron and CaO show scattering against SiO_2 content figure 5 & 6.

The Ti richment could be attributed to low degrees of melting of peridotite source (Shehata.et.al 2011)

The total iron (FeO^{+2} $+Fe_2O_3$) show scatter against SiO_2 (figure 7) this could reflect a decreasing degree of partial melting of a relatively homogenous source. The P_2O_5

content of the northeastern basalt varies from 0.22 to 0.53 wt% which agrees with the published data from Jordan result (Saffarini,et.al(1987).

The Ab, An, Or diagram figure 8 the major of samples reflecting the sodic affinity of the rocks.

The Mg-values ($Mg/Mg+Fe^{+2}$) are shown in tables 1.2.3. The ratio range from 0.42 to 0.50. low rate of analyzed samples are due to fractional crystallization of olivine and pyroxene.

The CIPW norm values in table1,2,3) show high anorthite and albite component and the normative percentage of plygioclase (Ab and An) in which An is higher than Ab, Indicated plagioclase calealkalic nature of these rocks Apatite and nephetinite are present in low percentage.

The trace elements data show relatively minor variation in elements. Concentration the strontium and barium concentration represent an enrichment in the melt phase probably due to fractional crystallization. Ni and Cr varies between 105 ppm and 155 ppm 77-164 ppm, suggest some degree of olivine fractionation which tends to increase the incompatible trace element concentration in basaltic, magma. The amount of Rb, Nb, y, Ce, Sc, li and Cd very low in concentration and indicate a low initial mantle concentration while crystallization processes involving olivine and pyroxene are responsible for the distribution of trace elements in basalt, and their absolute content is a reflection of the types and amount of pyroxene and olivine. In figure 9 the SiO_2 value against Sr, with increasing SiO_2 decrease Sr, Cr & Ni decrease with increasing in SiO_2. Rb, y & Nb against SiO_2 show scattering in diagram figure 10.

Discussion and Conclusion

The northeastern basalts are unsaturated with respect to silica content. These rocks are classified as alkali basalts according to (Vanden boom, Suwwan 1966) and (Saffarini et.al. 1987).

The Arabian lithospheric mantle beneath Jordan is chemically and isotopically heterogeneous. According to Shaw, (2003) it is possible that the volcanic rock were sourced from the lower lithosphere depth. (Shaw et.al.2003) suggested that the alkali rocks were probably derived from a mixed asthenospheric source.

Some of the alkali basalt require high pressure >15Kbar (Shervaiset.al.2009). The geochemistry of alkaline basalt indicate source for intraplate volcanism (shaw,et.al.2003). The xenoliths composition are broadly similar to those the source of Arabian intraplate basalt, suggesting that the numerous Cenozoic intraplate volcanic fields throughout Arabia, may be the product melting of uppermantle wedge material fertilized during pan-Afirican subduction and incorporated into the Arabian, Lithospheric mantle (Shaw et.al.2003).

The primary alkali basalts can be formed by an extremely small degree of melting at a pressure as low as 13 kbar .and can fractionate to tholeitic liquids between 4 and 12 kbar pressure (Mysen&kushiro 1977). The alkai basalt melts can be derived in the low velocity zonatan approximate depth of 85-95 km, 30 kbar by a bout 5% partial melting and by about 10% in the lithosphere, at 60-90km (19-27kbar) (Green,1970). Basalt may this be both direct products of mantle partial melting and the differentiates of more primitive picritic partial melts (Aques and Green 1980).

The alkali basalts of Tel-Remah volcano are indicative of primitive upper mantle that hase suffered partial melting at temperature ranging between 930-1075c and pressure around 15-25 Kbar Alfugha(2006).

Based on the prementioned information (Roony,et-al.(2005) that the recent basalt of Ethiopian rift was produced as small degr partial melting peridotite of 15-25kbar. (Thompson-et.al.1980) also suggested that the basalts from central france, which are similar in their mineralogy to those of northeastern of Jordan volcano were produced by partial melting of spinel lherzolite at 16-20 Kbar pressure the investigated volcanoes resulted from magma which is rich in volatile constituents lost explosively from a fissure like eruption and the magma is primary magma reflect the pressure of spinel lherzolite nodules that didn't equilibrate with the melt indicating that the transport from the upper mantle to the surface was rapid spinel-Lherzolite xenoliths were found in volcanos an average chemical analyses are given in table4.

Thus, the consideration of trace elements and mantle xenoliths support the concept that lava from northeastern Jordan has been derived from spinel-lherzolite source in the upper mantle with a low degree of melting<20%.

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Table (1): Chemical Analyses of NE Basalts

	1 NE	2 NE	3 NE	4 NE	5 NE	6 NE	7 NE	8 NE	9 NE
SiO_2	47.22	46.31	46.40	47.47	48.15	49.20	48.80	46.82	47.98
TiO_2	1.62	1.66	2.90	1.70	1.40	1.46	1.42	1.86	1.97
Al_2O_3	14.53	13.35	13.70	14.90	15.28	16.35	14.85	15.45	15.90
Fe_2O_3	3.15	3.15	4.35	3.20	2.90	2.97	2.92	3.36	3.47
FeO	9.13	8.80	8.38	8.08	9.00	9.06	8.52	8.80	7.66
MnO	0.20	0.19	0.21	0.24	0.21	0.19	0.24	0.23	0.20
MgO	8.73	8.50	7.92	6.93	7.15	6.95	6.06	6.94	6.24
CaO	9.50	11.80	9.80	12.21	10.10	9.90	12.46	11.62	11.47
Na_2O	3.45	3.00	3.35	2.80	2.92	2.90	2.51	2.21	2.73
K_2O	0.80	0.73	1.40	0.62	0.65	0.64	0.62	0.68	0.86
P_2O_5	0.37	0.50	0.26	0.21	0.52	0.20	0.22	0.22	0.30
H_2O	1.20	0.98	0.70	0.90	1.07	1.02	0.83	0.96	0.90
Total	99.90	98.97	99.37	99.26	99.35	100.84	99.45	99.15	99.68
$Mg/Mg+Fe^{2+}$	0.49	0.49	0.49	0.46	0.44	0.43	0.42	0.44	0.45

CIPW Norms

Or	4.70	4.47	8.48	3.75	3.85	3.85	3.80	4.04	5.14
Ab	25.50	18.66	21.08	22.40	24.95	24.65	21.40	18.85	23.25
An	21.80	20.84	18.22	20.42	26.75	26.95	27.47	30.50	28.65
Ne	2.00	3.85	4.03	0.78	0.00	0.00	0.00	0.00	0.00
Wo	9.43	14.64	12.11	13.84	8.42	8.71	13.80	10.95	11.40
En	5.80	9.04	8.15	8.35	10.40	12.53	12.00	11.66	9.75
Fs	3.12	4.75	3.08	4.76	7.12	8.72	9.02	7.20	5.22
Fo	11.17	8.70	8.16	6.35	5.29	3.40	2.22	4.05	4.10
Fa	6.66	5.04	3.40	9.99	3.98	2.58	1.85	2.75	2.40
Mt	4.56	4.62	6.40	4.67	4.22	4.31	4.25	4.90	5.05
It	3.14	3.20	5.50	3.28	2.70	2.80	2.72	3.60	3.75
Ap	0.90	1.21	0.68	0.55	1.25	0.46	0.55	0.52	0.70
Or	4.70	4.47	8.49	3.75	3.85	3.85	3.80	4.04	5.15

Trace elements in ppm

Sr	375	435	550	335	365	345	355	370	425
Zn	95	244	91	600	80	80	145	80	70
Ni	160	165	142	107	115	105	105	105	72
Cr	150	155	130	120	125	110	125	130	105
Li	5	10	5	10	5	5	10	10	10
Pb	0	95	100	55	15	75	65	80	55
Cd	10	21	14	10	15	15	10	10	10
Ba	141	124	194	310	75	80	235	140	265
Rb	8	10	12	15	10	10	15	10	12
Nb	21	25	20	40	20	24	25	10	14
Y	17	21	17	25	15	20	15	15	10
Ce	44	70	65	55	45	60	65	46	25
Sc	25	22	24	30	33	20	25	22	25

Table (2): Chemical Analyses of NE Basalts

	10 NE	11 NE	12 NE	13 NE	14 NE	15 NE	16 NE	17 NE	18 NE
SiO_2	48.15	48.35	47.20	47.95	46.65	47.20	47.15	48.25	46.10
TiO_2	1.52	1.47	1.80	1.55	1.72	1.55	1.60	1.55	1.90
Al_2O_2	14.53	13.95	14.40	14.60	14.36	14.65	14.20	15.80	14.65
Fe_2O_3	3.02	2.99	3.30	3.05	3.22	3.05	3.06	3.07	3.40
FeO	9.82	9.62	9.02	9.25	9.25	9.60	9.97	9.05	9.40
MnO	0.20	0.20	0.20	0.20	0.22	0.21	0.21	0.20	0.21
MgO	9.24	9.05	9.00	8.90	8.95	9.25	9.36	8.60	9.38
CaO	9.45	8.90	10.44	10.02	10.35	9.90	9.02	8.48	9.95
Na_2O	3.20	2.59	3.45	3.42	3.45	3.35	3.40	2.87	2.95
K2O	0.87	0.87	0.95	0.90	0.85	0.81	0.85	0.86	0.85
P_2O_5	0.37	0.32	0.60	0.28	0.45	0.27	0.32	0.32	0.28
H_2O	0.40	0.47	0.35	0.37	0.92	0.42	0.38	0.45	0.90
Total	100.77	98.78	100.71	100.49	100.39	100.26	99.52	99.50	99.97
$Mg/Mg+Fe^{2+}$	0.48	0.48	0.50	0.49	0.49	0.49	0.48	0.49	0.50

CIPW Norms

Or	5.16	5.22	5.68	5.28	5.05	4.79	4.97	5.14	5.01
Ab	25.56	27.48	20.94	23.00	20.28	21.69	24.67	24.41	20.55
An	22.35	19.40	20.74	21.70	21.00	22.41	21.09	27.67	24.17
Ne	0.76	1.56	4.30	3.20	4.70	3.51	2.26	0.00	2.44
Wo	9.00	9.51	11.20	10.81	11.30	10.30	9.00	5.13	9.71
En	5.39	5.67	7.02	6.53	6.93	6.21	5.40	10.58	6.04
Fs	3.12	3.31	3.52	3.64	3.63	3.50	3.13	3.87	3.03
Fo	12.20	11.79	10.70	10.74	10.66	11.70	12.55	7.64	12.08
Fa	7.80	7.57	5.91	6.58	6.21	7.22	8.07	4.67	6.68
Mt	4.35	4.31	4.71	4.36	4.64	4.42	4.44	4.43	4.92
It	2.85	2.80	3.35	2.90	3.22	2.94	3.00	2.94	3.59
Ap	2.87	0.77	1.33	0.65	1.06	0.64	0.78	0.77	0.65

Trace elements in ppm

Sr	380	355	370	380	365	370	365	260	365
Zn	104	100	100	100	105	90	90	85	85
Ni	163	164	160	162	160	157	157	160	144
Cr	152	138	137	152	150	137	130	121	137
Li	5	5	10	5	5	5	5	10	10
Pb	140	130	-	80	10	60	100	60	40
Cd	15	15	10	25	15	15	15	20	25
Ba	55	105	45	25	30	10	65	50	50
Rb	10	8	11	15	13	10	7	13	15
Nb	27	25	18	16	15	12	23	15	16
Y	23	17	14	8	12	12	20	17	25
Ce	32	25	35	23	50	43	46	35	25
Sc	28	26	30	17	18	22	21	22	18

Table (3): Chemical Analyses of NE Basalts

	19 NE	20 NE	21 NE	22 NE	23 NE	24 NE
SiO_2	46.20	49.96	49.87	47.37	47.46	49.20
TiO_2	2.12	1.37	1.55	1.47	1.58	1.54
Al_2O_2	14.84	15.83	15.94	14.73	14.63	14.46
Fe_2O_3	3.61	2.86	3.06	2.98	3.08	3.04
FeO	9.01	9.41	8.28	9.61	9.21	9.82
MnO	0.21	0.21	0.21	0.20	0.20	0.21
MgO	9.05	7.33	7.81	9.07	9.00	10.00
CaO	10.09	7.08	8.69	9.81	9.31	7.56
Na_2O	2.71	1.94	2.67	2.80	2.87	3.09
K_2O	0.78	0.67	0.67	0.78	0.76	0.81
P_2O_5	0.31	0.30	0.31	0.29	0.27	0.41
H_2O	1.02	2.04	1.32	0.91	1.03	0.92
Total	99.95	99.00	100.38	100.02	99.50	101.20
$Mg/Mg+Fe^{2+}$	0.50	0.44	0.49	0.49	0.49	0.50

CIPW Norms

Q	0.00	4.89	0.00	0.00	0.00	0.00
Or	4.76	4.05	3.98	4.70	4.54	4.88
Ab	22.33	16.61	21.60	23.80	24.47	26.03
An	25.77	32.73	29.31	25.20	24.83	22.71
Ne	0.43	0.00	0.00	0.00	0.00	0.00
Wo	9.28	0.33	4.78	8.94	8.17	4.82
En	5.92	18.49	19.21	5.91	8.03	11.40
Fs	2.71	13.09	10.34	3.44	4.31	6.07
Fo	11.69	0.00	0.10	11.63	10.13	9.20
Fa	5.91	0.00	0.06	7.50	6.01	5.39
Mt	5.22	4.21	4.39	4.32	4.49	4.33
It	4.01	2.63	2.97	2.79	3.02	2.86
Ap	0.70	0.71	0.77	0.71	0.64	0.99

Trace elements in ppm

Sr	360	600	375	350	355	315
Zn	80	90	95	90	85	85
Ni	145	152	140	150	148	150
Cr	142	120	140	140	140	132
Li	10	10	10	10	10	10
Pb	115	50	95	-	65	20
Cd	20	25	10	10	20	25
Ba	55	85	25	30	40	55
Rb	11	15	10	10	9	11
Nb	12	20	17	25	32	42
Y	12	17	19	13	14	19
Ce	28	24	46	31	42	48
Sc	31	30	27	16	22	26

Table (4):The Avarage of Electron Microprobe Analyses.

	olivines	orthopyroxene	clinopyroxene	spinels
SiO_2	40.34	56.40	53.89	0.07
TiO_2	-	0.00	0.20	0.09
Al_2O_2	-	2.07	4.44	54.75
Cr_2O_3	-	0.50	0.87	14.60
FeO	10.18	6.21	2.62	10.45
MnO	0.13	0.12	0.06	0.09
MgO	49.46	34.12	16.41	20.34
CaO	0.06	0.61	20.77	-
Total	100.17	100.03	99.26	100.39
$Mg/Mg+Fe^{2+}$	**0.829**	**0.846**	**0.862**	**0.661**
Mg/Fe	**4.859**	**5.494**	**6.263**	**1.946**

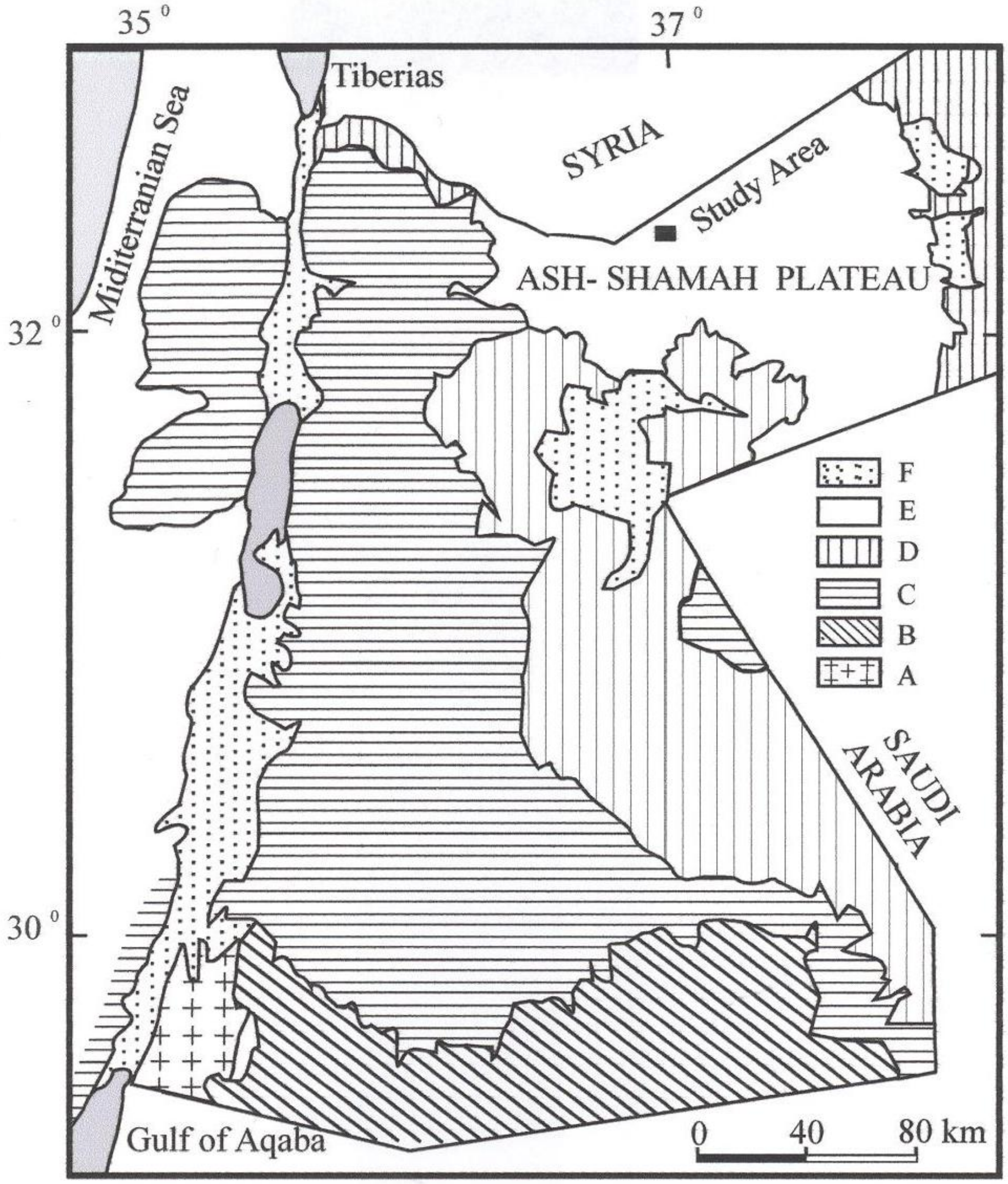

Figure 1: Geological sketch map of Jordan showing location of studied volcano.. A- Precambrian Basement, B- Paleozoic to Cenozoic sediments, C- Jurassic and Cretaceous sediments D- Trertiary sediments, E- Trertiary and Quaternary Sediments F- Quaternary sediments. (Modified after Bender 1968).

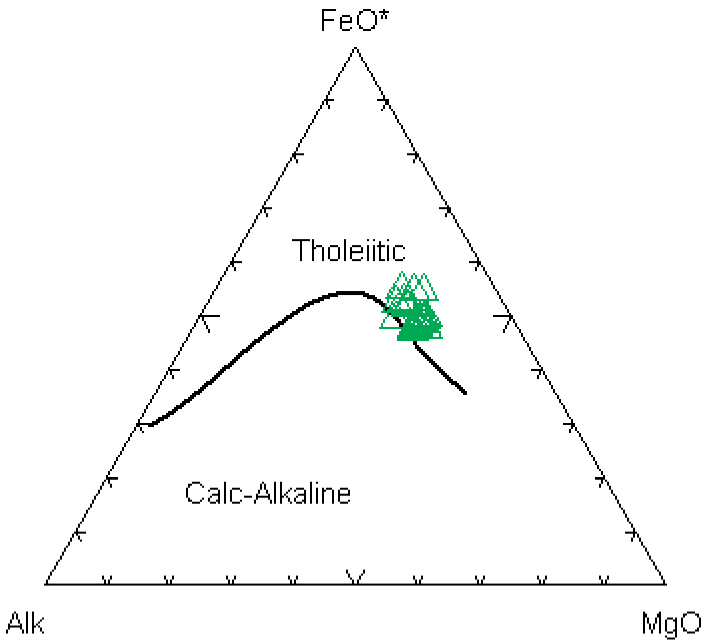

Figure (2): Irvine+Baragar 1971

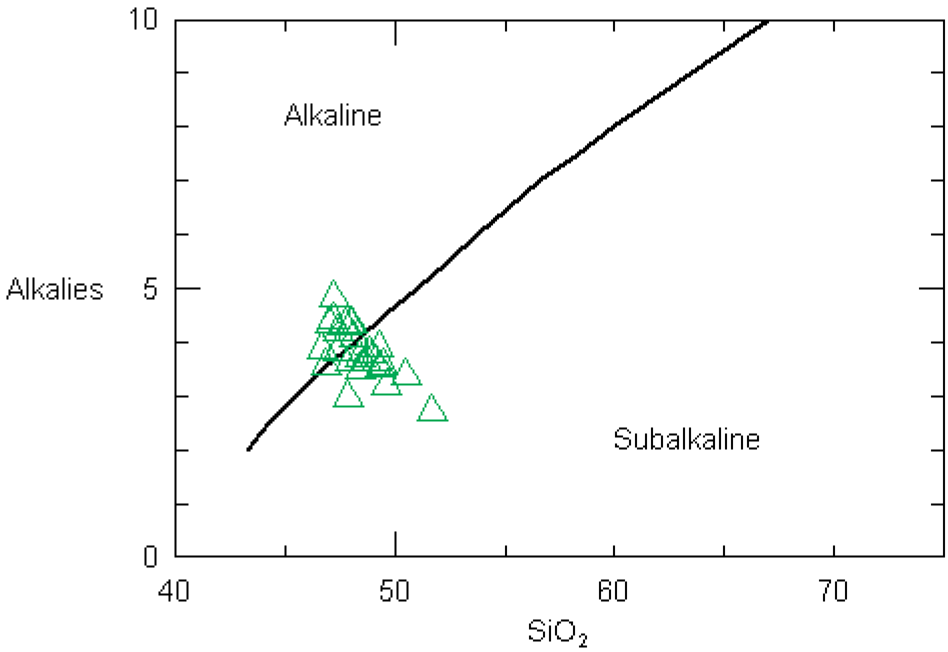

Figure (3): Irvine + Baragar 1971

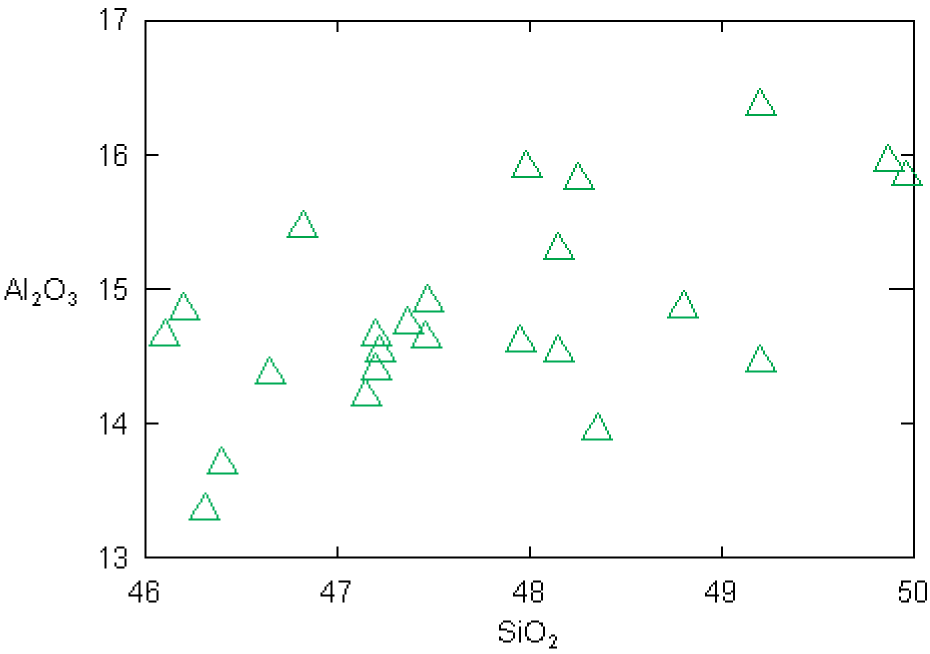

Figure (4): Irvine+Baragar 1971

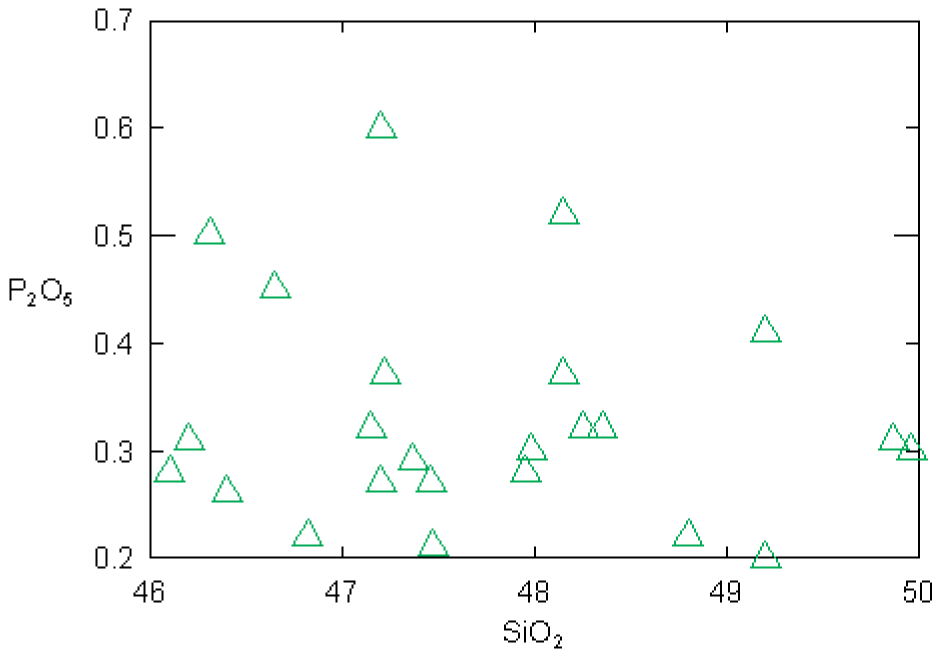

Figure (5): Irvine+Baragar 1971

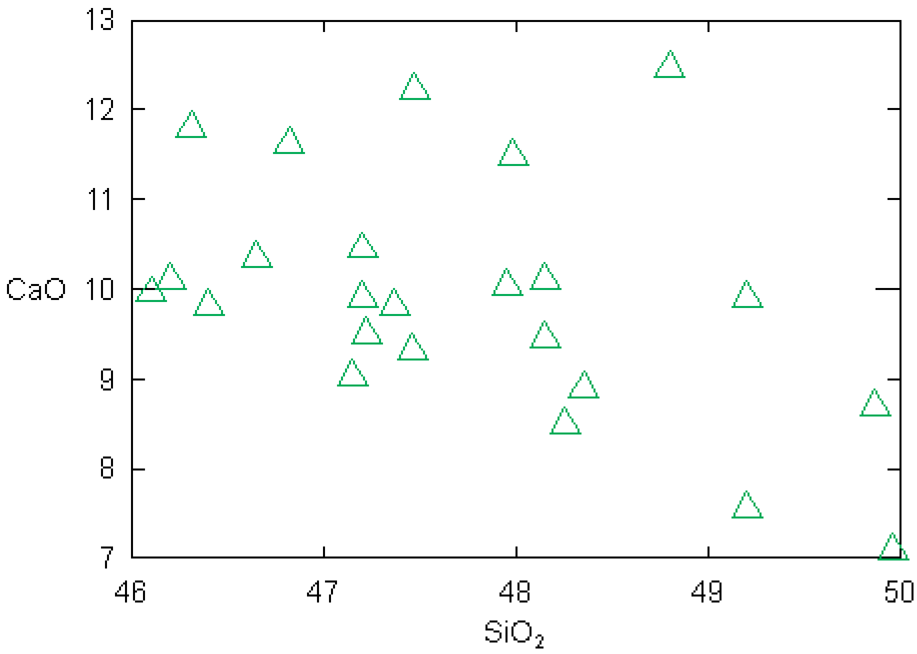

Figure (6): Irvine+Baragar 1971

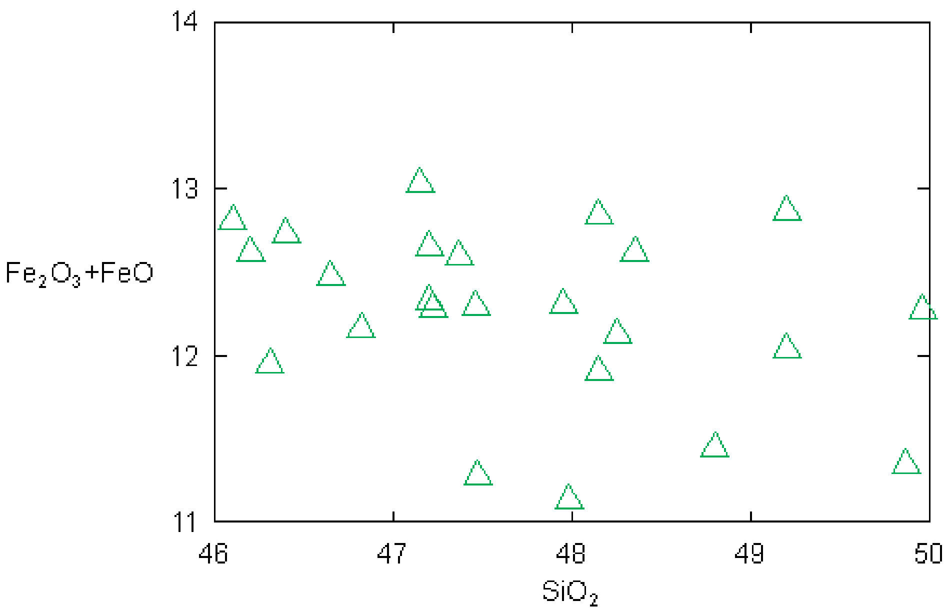

Figure (7): Irvine+Baragar 1971

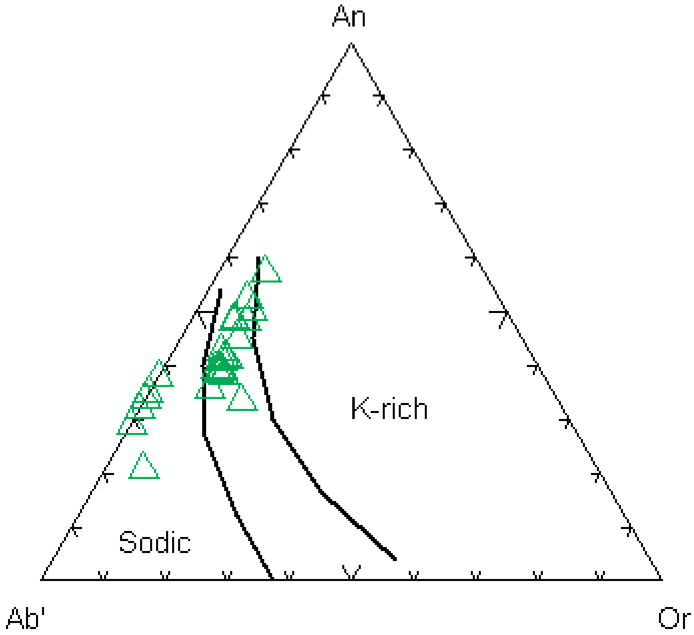

Figure (8): Irvine+Baragar 1971

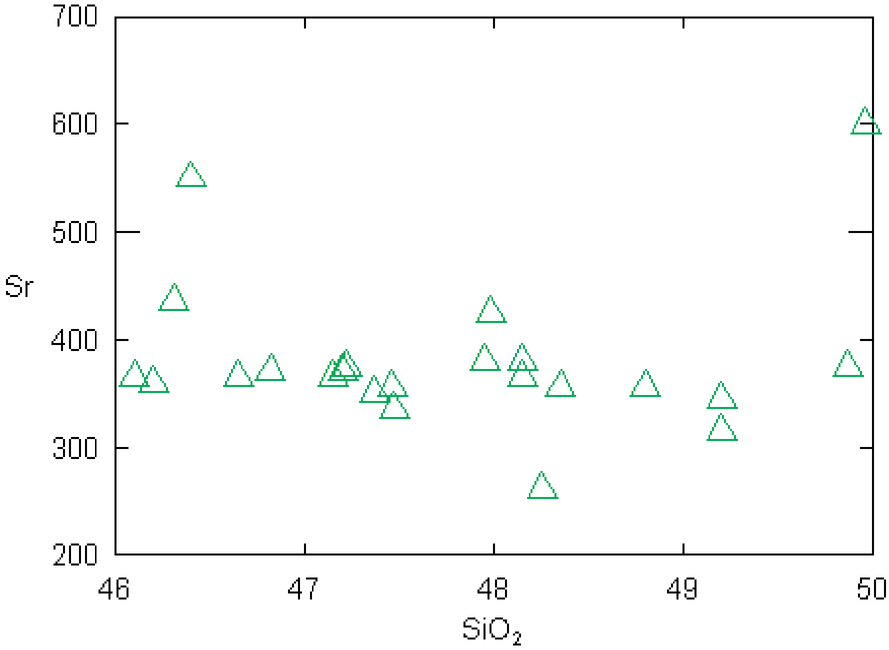

Figure (9): Irvine+Baragar 1971

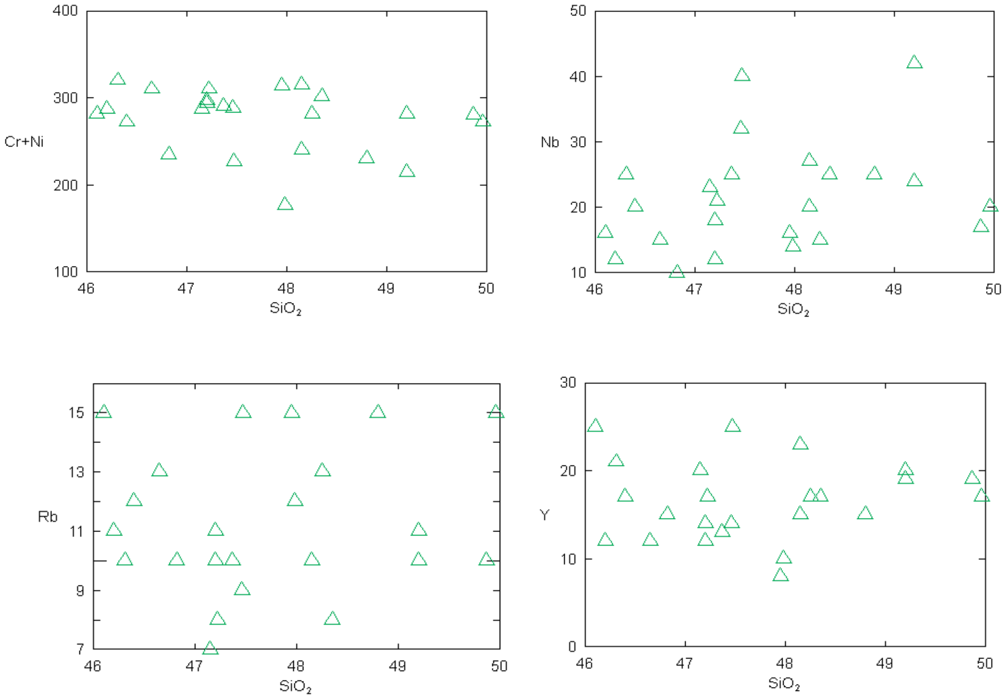

Figure (10): Irvine+Baragar 1971