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ORIGINAL ARTICLE

Petrography and geochemistry of Islam-Abad Ophiolite Complex (SW Iran-Fars Province)

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ABSTRACT
The Islam-Abad Ophiolite Complex as a part of the Tethyan ophiolites is exposed in the south western part of Iran ,Fars Province. This complex extends from the North West to the South East of Iran, along the Neyriz Ophiolitic Complex. Petrography and geochemistry studies of the residual mantle sequence in the Islam-Abad Ophiolitic Complex provide information about the degree of partial melting and deformation in the oceanic mantle lithosphere. The ultramafic and mafic cumulates in this area consist of harzburgite, small lenses of dunite with chromite pods, hornblende gabbro, diabase dikes, and spilitic basalts with pillow structures. These ultramafic tectonites are mainly composed of harzburgite with Al 2O3= 0.25 to 0.61 w%, Ti= 11 to 37 ppm, that are similar to the extremely depleted peridotites in which Ti<50 ppm .The harzburgite contains Cr – rich spinels with a #Cr (Cr#=Cr/[Cr+Al]) of 0.53-0.57and #Mg of 0.58-0.60. This type of peridotite has undergrone >20% partial melting, followed by segregation of basaltic magmas. Discriminat geochemical diagrams based on mineral chemistry of harzburgits indicate a supra-subdution zone (SSZ) to mid-oceanic ridge (MOR)setting for these rocks.
Keywords: *Iran ,Islam Abad, Ophiolite, FARS Province.*

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INTRODUCTION

The Tethyan ophiolites are exposed in the Alpine-Himalayan orogenic belt along the borderlines between the curved gaps, at the junction between the Gondwana (or Gondwanaland) sub-continents. According to the available geochemical evidence, the type of these ophiolites varies from the MORB ophiolites (Alpine-Apennines) in the Western Mediterranean sea to the ophiolites present in the supra subduction zones in Cyprus, Turkey, Iran, and Tibet in the East [8].

The ophiolites placed in Iran have had an important role in the reconstruction of the geodynamic conditions of the Tethyan ophiolite belt. The tectonic history of these ophiolites begins with the separation of Iran central block from Gondwana throughout the Permian to Triassic periods [29; 30]. When the Paleo-Tethys subducted under Eurasia, Iran central block moved northward and the Neo-Tethys ocean lithosphere was created. During the Cimmerian Orogenic stage of the middle Triassic epoch, Iran central block collided with Eurasia and the Neo-Tethys Subduction phase began in the last Triassic and the early Jurassic periods.

The Islam-Abad Ophiolite Complex is part of the Mesozoic Ophiolites that are exposed in North East of Fars province, near Arsanjan district in Iran. These ophiolites reach the Neyriz Ophiolite with a South to East trend (Figure 1).

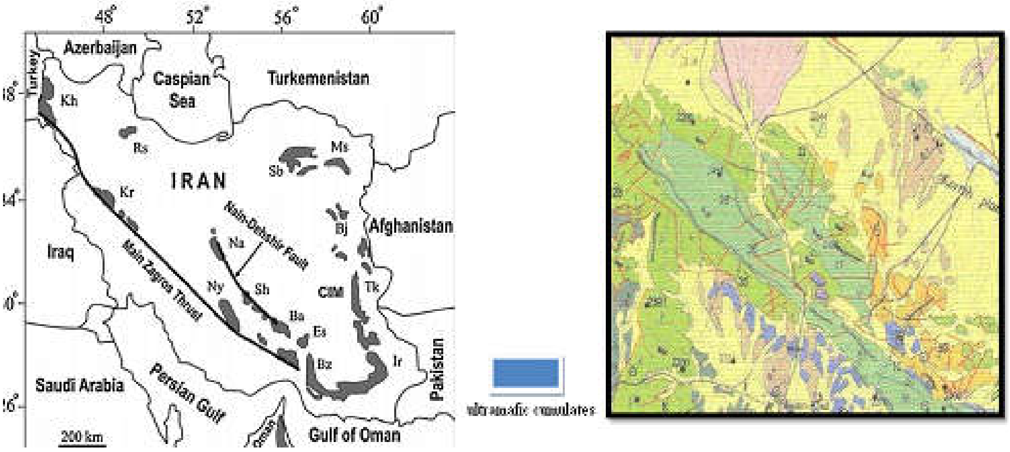


Figure 1: A: Generalized tectonic map showing the distribution of ophiolites along the Tethys suture. Black areas indicate ophiolites and "coloured mélange" zones. From Coleman (1981).B:the geological map of the Islam-Abad ultramafic complex (adopted from Map 1/100000 of Surian)

The mantle cross-section of the Neyriz Ophiolite is one of HOT (Harzburgite Ophiolite Type) type. It is a prominent example of Neo-Tethys oceanic lithospheres that extrude along the Zagros thrust zone [10; 32].

Generally olivines are most abundant constituent phases of mantle rocks that are important from the fabric and chemical composition. We can explain host rock condition ,Based on microscopic evidence such as grain size of olivines and their deformation [19].

In this paper we have carried out a petrographic and petrologic analysis (microscopic study ,XRF and EPM)of the upper-mantle peridotites and the rocks contained in the Islam-Abad Ophiolite Complex.to understand the tectonics.

GEOLOGICAL SETTING AND FIELD OBSERVATIONS

This complex is located in the 29°55' North and 53°36' East,SW Iran (Figure 2). In this region some sequences of mafic and ultramafic rocks, radiolarites, and lime stone are exposed. There are relatively various petrographic units that can be distinguished quite easily. Tectonic connections exist between the petrographic units, which are in some area covered with sediments.

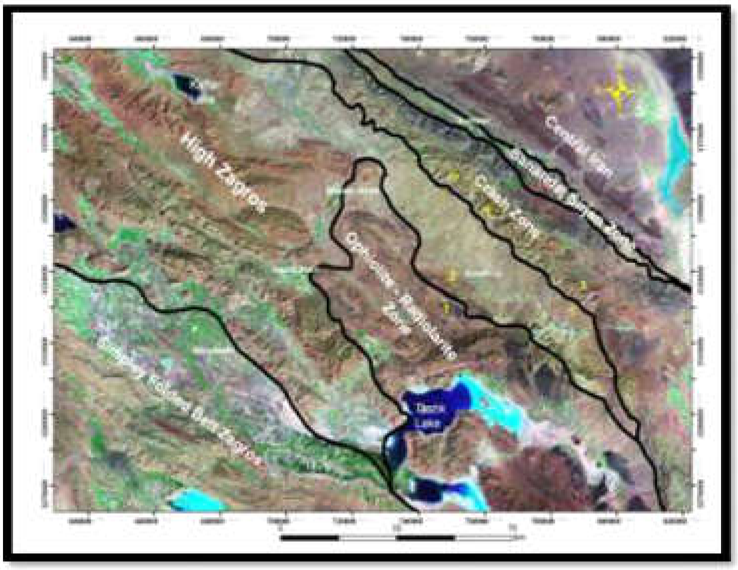
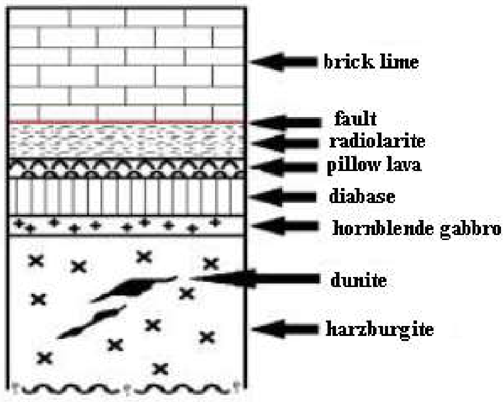


Figure 2: the position of Islam-Abad in the structural zones of Iran [10] this image includes the new changes. Point 1=Islam-Abad.

The radiolarian cherts together with this complex make up the ophiolite complex. The upper layers are also allocated to limestones that cover the layers (Figure 3). Different weathering processes affect the ultramafic rocks and in some areas induce a low-grade metamorphism. The contact respectively between the basalts, radiolarian cherts and limestones are clear and sometimes layers of basalts are emplaced in the limestones. In some sections the limestones are altered by the metamorphosim processes and therefore contain garnet. In the borderline between the ultramafic cumulates and the basalts, semi-deep cumulates with hornblende gabbro combinations are observed, which are extremely altered. bands of chromite are also found within the dunite lenses.

Figure 3: the schematic stratigraphic cross-sections and columns of Islam-Abad region.



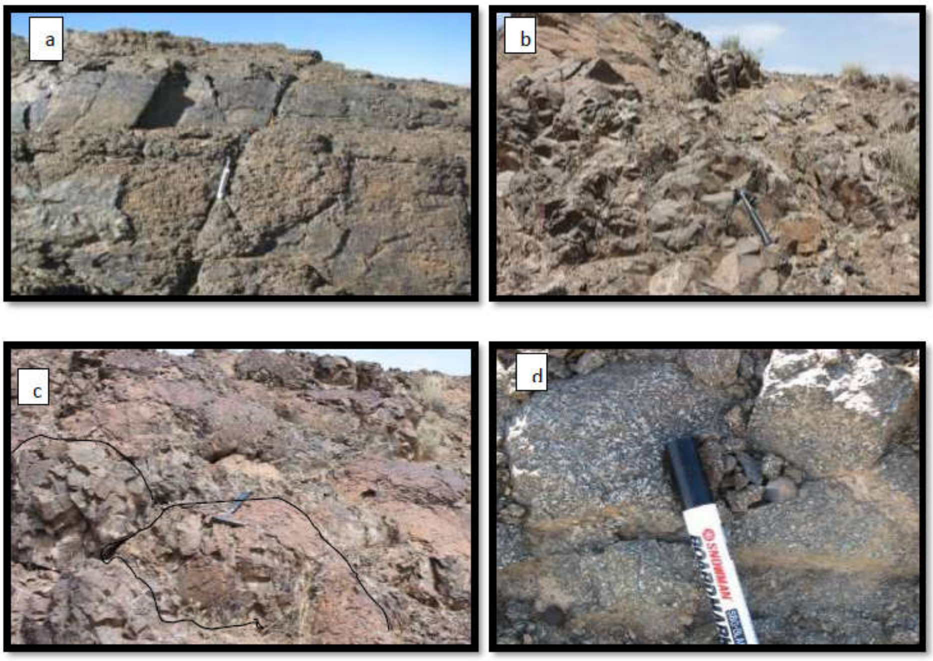
Islam-Abad stratigraphic column

In this area the petrographic units are generally classified into the following categories (Figure 4a,b,c,d).

1. The ultramafic rocks that include serpentinized harzburgite, metamorphosed dunites, chromite pods and serpentines.
2. The mafic rocks that include basalts, diabases, spilits and hornblende gabbros.

The sedimentary rocks that include limestones, radiolarian cherts and dolomites

Figure 4: a) outcrop of ultramafic cumulates; b) diabase rocks; c) spilits with pillow structures; d) hornblende gabbros of Islam-Abad.



Petrography

The peridotites of Islam-Abad region have a low-grade topography than the other rocks in the complex and are found in the form of cumulates with serpentinization. The possibility of serpentinization is higher in the stream bed compared to the other areas. This is associated with the performance of the faults in the region, because the faults that are placed in the stream show a higher level of performance.

A large part of the peridotites that are present in Islam-Abad are harzburgite peridotites that contain small lenses of dunite with pods of chromite.

Harzburgite

harzburgite are green to black holomelanocrate in the hand sample. In microscopic scales, the textures of these rocks are usually found to be proto-granular, porphyroblastic with foliation. This type of foliation is induced in the upper mantle when orthopyroxene and Cr- rich spinel are oriented as a result of high pressure and temperature [27]. foliation and lineation in the ultramafic tectonites are resulted from the flow of plastic in the solidus to sub-solidus temperatures [27]. The ultramafic rocks are extremely metamorphosed and serpentinized. These rocks are bright green with an oily luster in the hand sample. Serpentines have sieve and mesh textures. More than 90 % of the minerals contained in these rocks are classified as lizardite, chrysotile and antigorite minerals.

Orthopyroxene grains contain clinopyroxene exsolution lamellae's along cleavages with an array of discontinuous clinopyroxene lamellae's. Slip along the cleavages led to the formation of clinopyroxene lamellae. The (100) cleavage plane easily slips and forms the bookshelf in orthopyroxene. Clinopyroxene lamellae's are parallel to the cleavage plane.

A small amount of Cr-rich spinel (less than 1%) together with the olivins remains forms the other part of the rock.

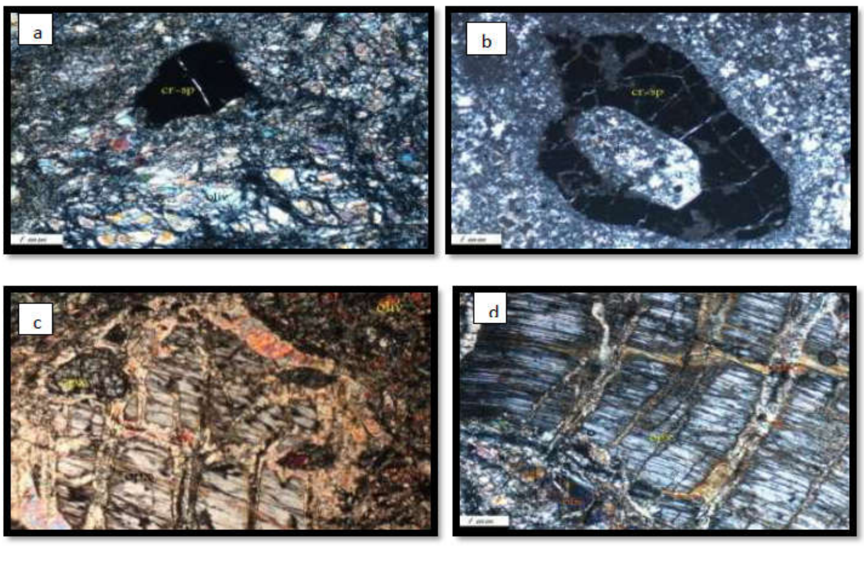
The harzburgite of Islam-Abad contain 65-85 modal% olivine, 10-30 modal % orthopyroxene (enstatite), approximately 1-4modal% Cr-rich spinel, approximately 1-2modal %diopside And 2-7modal %secondary minerals including serpentine, chrysotile and bastite.

Olivine:

Olivines are anhedral with 0.5 to 2 mm dimensions and many fractures. These fractures are replaced with serpentine (chrysotile) and create mesh texture (Figure 5a). Among the other textural characteristics of olivines we can refer to the formation of the Corona texture between the olivine and Cr-rich spinel. This demonstrates the unstability of olivine and suggests that at first the olivines is formed and then it is replaced with Cr-rich spinel. In such cases Cr-rich spinels have rounded margin (Figure 5b).

Orthopyroxenes:

Orthopyroxene are porphyroblastic with 2 to 4 mm dimensions.The porphyroclastics have narrow clinopyroxene exsolution lamellae along the surfaces [10]. Sometimes these surfaces and the exsolution lamellae are bent due to the deformations and kinks are created (Figure 5d). The presence of fine-grained clinopyroxene in low-interference colors (first color system gray), results in the formation of a poikilitic textures in the orthopyroxene (Figure 5c).



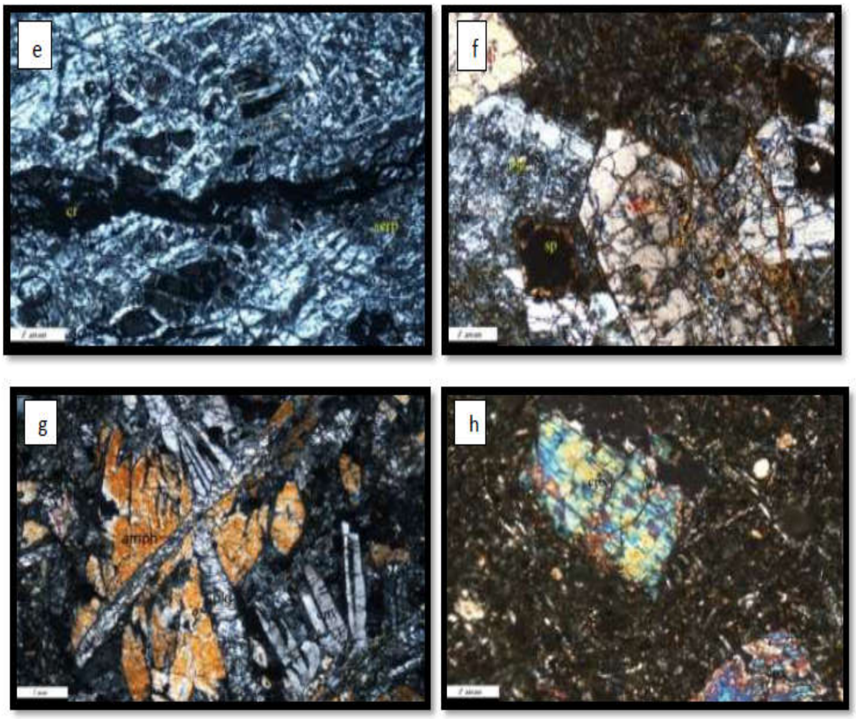


Figure 5: a) the harzburgite of Islam-Abad that are mainly composed of chrysolite and are extremely serpentinized. A chrome spinel crystal can also be seen in this section; b) a rounded chrome spinel crystal in the chrysolites contained in the harzburgite of the region; c) the transverse cross-section of clinopyroxenes (diopsides) with two surfaces perpendicular to each other. These are in the form of poikilitic that is contained in the orthopyroxenes (enstatites) found in the region. Orthopyroxene is turned into bastite; d) the porphyroblastic nstatite orthopyroxenes with bent surfaces, the exsolution clinopyroxenes that are along the surfaces and the process bastitization are shown in this image; e) chromite stripes found in the dunites of Islam-Abad region, which are extremely serpentinized; f) the porphyritic texture of hornblende gabbros found in Islam-Abad; g) the ophitic texture of the diabases of the region. This texture is characterized by its clinopyroxene and plagioclase minerals; h) clinopyroxene augite phenocrysts found in the split basalts of the region.

Cr-rich spinels:

Cr-rich spinels are subhedral with 1 to 2 mm dimensions and are found in reddish-brown to dark-brown colors with pull-apart fractures. These are another evidence for the existence of mantle tectonic conditions or tectonite.

Dunites

Dunites are exposed in the form of small lenses in-between the harzburgite and contain chromitites. These rocks are usually highly metamorphosed to the extent that their chrysotile and pyroxene contents are affected by the serpentinization phenomenon and are contained with black chromite minerals in pods and spherical forms (Figure 5e). In microscopic scales, dunites include the 90modal% Olivine, 5modal%Pyroxene and 5modal% Chromite.

Olivine is anhedral to subhedral. Anhedral chromite grains are between serpentinized olivine and pyroxene grains.

Hornblende gabbro

These rock are dark gray with large amphibole crystals in hand sample and in the form of apophyses with 20 m^2 of dimensions. These are found adjacent to the spilitic basalts and diabase dikes. The minerals contents of this rocks are 40 to 45modal%Plagioclase, 30-40modal%Amphibole (hornblende),and 10modal % of the clinopyroxene (diopside) that has a bright yellow-interference color is occasionally found among the crystals.

Iron oxide, leucoxene, and the secondary minerals chlorite, sericite, calcite, and biotite form less than 5 modal% of the minor minerals.

The dominant texture is the porphyritic texture, which shows that the two-stage of crystallization takes place in the deep and semi-deep areas.

The amphiboles are hornblende type minerals with approximate dimensions of 2 to 4 mm (sometimes 1 cm). They have gradual boundaries with clinopyroxene in some areas and this way form a corona texture.

Plagioclase are normally altered and changed into secondary epidotes and calcites in a way that the twining are lost. The occurrence of this phenomenon shows the presence of hydrothermal solutions in the setting where the minerals are formed. In some cases variolitic textures are formed, which is another reason for the presence of these mineral in the upper zones and for their fast crystallization.
Clinopyroxenes(diopside) are found in small and large dimensions around the auto morph hornblendes where, in some occasions, corona textures are formed (5f).
Biotite as a secondary mineral created by hydrothermal alteration.

Diabases

The diabases recorded in field observations are found in the form of more prominent rocks in relation to the other rocks of the area. The hand sample are black and have textures with the medium grain size. Microscopic-scale studies have shown that the type of their texture ranges from the inter-granular to the sub-ophitic types and that they have the following mineral constituents: 35-40modal%Clinopyroxene (augite), 45-55modal%
Plagioclase (labradorite) And the minor minerals include leucoxene, chlorite and epidote (5modal%) and the secondary minerals include prehnite and pectolite.
Plagioclases are in the form of altered microlites with approximate dimensions of 1 to 2 mm. these are labradorite type and found in ophitic textures with clinopyroxene. These are usually altereted into prehnite ,epidotite and chlorite.
Clinopyroxenes (Augite) have 1 to 3 mm of dimensions. These are mostly turned into chlorite and iron oxide.

Basalts

In a few parts of the study area, the basalts were found to be exposed around the hornblende gabbros, diabases, limestones, and radiolarian cherts. The hand sampels are bright green to black and have vesicular and amygdaloidal textures .
These are usually found in the form of spilitic rocks, but in some outcrops are found as pillow lavas, which are formed as a result of quick cooling of magma in contact with sea water. Making distinction between these rocks is difficult in a field, but in the spilitic basalts cannot be clearly observed pillow shape. This can be caused by the clutter that is induced by tectonic movements. These are usually metamorphosed to chlorite-, epidote-, and sericite. In microscopic studies, these rocks have porphyritic or radial textures with glass in the groundmass (variolitic) that have been alterated in contact with sea water and have been turned into fine-grained complexes of chlorite, actinolite, uralite, epidote, albite and prehnite. We suggests that a hydrothermal (low-grade) metamorphism has occurred in contact with sea water.
In mineralogy terms, basalts contain plagioclase, clinopyroxene, amphibole, minor olivine minerals (serpentine), iron oxide, and secondary minerals (including chlorite, epidote, and calcite). The presence of the vesiculs that are filled with chlorite (it can be pennine type chlorite that fills the vesiculs in a radial form) and calcite suggests that these rocks are spilite type of rocks that have reacted with sea water and hydrothermal solutions.
Anhedral to subhedral Clinopyroxenes (augite) are in the groundmasses of rocks with porphyritic textures. These are turned into uralite because of having contact with sea water or hydrothermal solutions (Figure 5h).
Amphiboles are completely replaced with pseudomorph chlorite crystals. This type of vesicles result from tow stage of alteration,(a)chlorite was formed in the inner part.(b)then Calcite penetrates the holes in the past phase.
The outcrops of the pillow lavas that had been extremely crushed as a result of the performance of the faults of the region have numerous fractures. The results of field studies suggest that the outer surfaces of the pillow lavas have mainly a reddish-brown color, which shows that these rocks are oxidized later in time. These pillows are mostly oval and round and have more vesicles in the upper sections. Radial fractures in the pillows, shows that they are crushed in the contact with sea water. Pillow lavas have vesicular and variolitic textures .these vesicles are filled with calcite, chlorite, and sometimes zeolite.
In thin sections, plagioclase microlites (labradorite – andesine) are formed in the main part of the mesostas of the pillows that are more crystallize. These plagioclases have different degrees of epidote minerals while the plagioclases in the margins of the pillows are found in lamella-shaped and subatuomorphs and in some cases contain epidote and sericite. The length of the plagioclase crystals, the growth of the vacuums in the skeletal crystals and their swallowtail like shape suggest that the lava had been quickly cooled in its contact with sea water (18).
Clinoproxyene(augite)is another type of the phenocrysts that is present in the inner part of the pillows. It has a dimension of 2 to 3 centimeters and can be found in automorph or subautomorphs.Since clinopyroxene(augites) have somewhat a micro-intergranular texture, it can be said that most of the

specimens represent the inner parts of the pillows where the possibility of cooling and crystallization is more. It can also be concluded that the outer parts are ruined under the effects of tectonic factors and erosion.

Geochemistry

Bulk-rock powders for chemical analyses of 18 samples were obtained from Islam-Abbad rock . Major elements and trace elements Rb, Ba, Sr, Zr, Cr and Ni were measured by wavelength dispersive XRF using conventional techniques. The trace elements: Cs, Th, U, Nb, Ta, Hf, Y and REE were analysed by ICP-MS in the Labwest laboratory in Australia(Table1). Two harzburgite samples that were obtained from the area were subjected to electro microprobes. A cameca JXA-860 microprob at Yamagata University,Japan,was employed to obtain mineral chemical data of the studied rocks.The accelerating voltage and beam current were 15 keV and $2*10^{-8}$A ,respectively (Tables 2,3,4,5).The results obtained from these tests were provided in tables and the associated diagrams were later illustrated and interpreted using different software programs such as GCDKit, Minpet and Excel.

Peridotites

Based on the microscopic studies and field observation, these rocks have been through different levels of serpentinization processes and the amount of LOI in these rocks varies from 10.98 to 12.97 wt%. In terms of their main constituents these peridotites have constituents similar to those of the other peridotites(table1). The aluminum oxide content of the peridotites of this ophiolite complex is between 0.25 to 61 wt%. This is similar to the amount of aluminum oxide in the Neyriz Ophiolite, which is between 0.18 to 0.43 wt% (16). Depletion of aluminum oxide (0.61 wt%) and calcium oxide (0.59 wt%) in Islam-Abad peridotites is due to the low amount of clinopyroxene content of these rocks (Table 1).

Table1. Composition of ultramafic and mafic rocks from Islam Abbab Ophiolitic Complex

	E1-B	**E1-G**	**E2-B**	**E2-G**	**E3-B**	**E7-B**	**E8-B**	**E9-B**	**E10-B**	**E11-B**	**E12-B**
SiO_2	94.85	44.27	46.52	42.46	47.58	39.83	39	41.1	40.45	40.47	**45.46**
Al_2O_3	13.29	16.87	13.98	16.05	12.15	0.61	0.31	0.53	0.25	0.35	**15.93**
CaO	12.81	9.65	14.34	11.82	14.69	0.59	0.29	0.6	0.25	0.51	**8.08**
Fe_2O_3	12.03	11.16	11.03	11.56	11.13	7.94	8.62	7.98	7.97	8.14	**10.02**
K_2O	0.4	0.86	0.89	1.54	0.31	0.01	0.01	0.01	0.01	0.01	**4.09**
MgO	4.64	6.87	4.76	7.76	7.82	39.14	38.58	37.56	37.64	38.18	**7.18**
MnO	0.18	0.18	0.16	0.17	0.16	0.11	0.12	0.11	0.11	0.11	**0.24**
Na_2O	2.26	4.01	4.51	2.38	2.09	0.02	0.02	0.04	0.02	0.02	**2.65**
P_2O_5	0.22	0.61	0.15	0.52	0.21	0	0.29	0.01	0.19	0.19	**0.7**
TiO_2	1.88	2.4	1.31	2.71	1.49	1.88	0.03	1.56	1.56	1.56	**2.32**
LOI	1.7	3.68	2.25	3.59	2.52	10.98	11.77	11.21	12.97	11.25	**3.83**

	E14-B	**E16-B**	**E19-B**	**E19-B2**	**E20-B**	**G1-S**	**H3-S**	**R7-S**	**R9-S**	**T1-S**	**T2-S**	**T3-S**
SiO_2	45.57	44.3	44.43	43.1	44.08	38.07	38.4	41.28	38.53	37.95	48.44	**53.67**
Al_2O_3	14.64	16.82	15.16	15.7	16.19	1.4	0.56	0.65	0.34	0.46	1.57	**0.73**
CaO	10.39	10.1	9.39	10.11	10.35	0.2	0.19	0.45	0.14	0.59	15.96	**1.93**
Fe_2O_3	12.01	12.44	12.2	12.07	11.86	8.56	7.61	8.07	7.92	7.67	5.11	**8.25**
K_2O	0.64	0.61	0.83	0.87	1.19	0.02	0.4	0.01	0.8	0.4	0.03	**0.83**
MgO	8.18	7.7	8.7	8.35	8.12	34.89	37.31	36.57	37.27	38.97	22.83	**33.91**
MnO	0.17	0.16	0.18	0.18	0.18	0.08	0.1	0.11	0.11	0.11	0.12	**0.18**
Na_2O	2.49	2.86	2.74	2.9	2.92	3.12	0.08	0.02	0.02	0.08	0.12	**0.03**
P_2O_5	0.28	0.23	0.29	0.28	0.29	0.52	0.22	0.29	0.29	0.22	0.21	**0.29**
TiO_2	1.76	1.67	1.85	1.87	1.85	0.03	1.88	0.03	0.01	1.88	0.04	**0.03**
LOI	2.24	3.18	4.14	4.39	3.63	13.12	15.16	11.78	14.78	12.99	5.24	**1.13**

The CaO/Al_2O_3 ratio is equal to 0.96 to 1.4, which is almost equal to the ratio associated with the peridotites in MORB type depleted mantle layer (DMM) where the CaO/Al_2O_3 ratio is equal to 0.9 (15; 35). The amount of titanite in these rocks is between 11 to 37 ppm. This is similar to the amount of in the extremely depleted peridotites where Ti<50ppm [3]. The amount of chrome in these rocks is between 321 to 910 ppm while the amount of chrome in the mantle peridotites is assumed to be 2200 ppm [4]. The amount of chrome in the Neyriz Ophiolite is 1600 ppm while the chrome content of Oman Ophiolite harzburgite is between 1800 to 4300 ppm [3].

Mineralogic geochemistry of the ultramafic units in the Islam-Abad Ophiolitic Complex Spinel:

The composition of spinel in upper mantle tectonites provides further control on the petrogenesis of the ophiolites.The $Cr^{\#}$ of spinel in abyssal peridotites is a good indicator of the degree of partial melting for the mantle – derived spinel peridotite. Low $Cr^{\#}$ spinels represent less depleted peridotites, whereas high $Cr^{\#}$ spinels highlight more depleted peridoties(Dick and Bullen , 1984 ; Arai,1994).

The harzburgite contains Cr-rich spinel, with a $Cr^{\#}$ in the range of 0.53-0.57. The amount of TiO_2 is 0-0.06wt%(Table 2) .

Table2.Composition of spinels in ultramafic rocks from Islam Abbad region.

		$E_{41}B$-1	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-1	$E_{41}B$-1	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-3
		9	31	32	29	30	10	11	17	18	21
	SiO_2	41.804	38.799	37.096	42.547	42.23	42.146	43.8	41.443	40.628	42.625
	TiO_2	0.013	0.187	0.132	0.011	0.013	0.013	0.00	0.011	0.00	0.00
	Al_2O_3	0.013	1.294	0.880	0.00	0.006	0.00	0.003	0.35	1.536	0.126
	Cr_2O_3	0.00	0.506	0.00	0.002	0.008	0.00	0.007	0.00	0.00	0.032
	FeO	8.227	9.643	8.458	9.083	9.19	8.75	8.896	6.001	6.322	8.755
	MnO	0.068	0.281	0.543	0.149	0.096	0.087	0.131	0.048	0.18	0.142
	NiO	0.413	0.00	0.00	0.416	0.456	0.448	0.507	0.345	0.361	0.383
	CaO	0.025	0.018	0.249	0.016	0.022	0.016	0.04	0.032	0.074	0.00
	MgO	50.577	48.330	51.277	52.028	51.108	50.503	53.311	38.888	35.831	51.057
	Na_2O	0.00	0.393	0.073	0.01	0.00	0.00	0.00	0.00	0.00	0.001
	K_2O	0.00	0.00	0.00	0.013	0.003	0.00	0.014	0.00	0.00	0.004
	Total	101.195	100	100	104.338	103.136	100.75	100.75	87.214	84.982	103.294
	Fo	91.53	89.65	90.72	90.93	90.72	91.04	91.28	91.92	90.64	91.08
	Fa	8.35	10.02	8.42	8.90	9.15	8.85	8.54	7.96	8.97	8.78
	#Mg	0.916	9.926	0.911	0.922	0.911	0.915	0.922	0.920	0.909	0.912

The FeO content is 15.32-16.61wt%.Chemistry of these spinels (Fig.6)

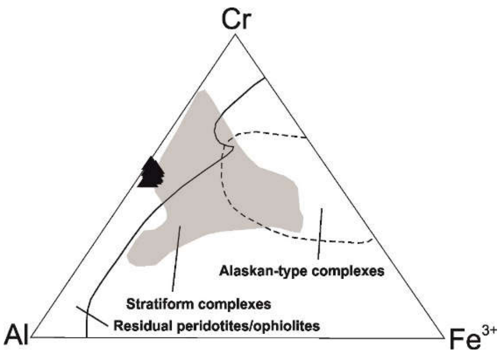


Figure.6.Cr,$Fe^{3+}$and Al relations in spinels from Islam Abad peridotites.The superimposed fields are taken from Jan and Windley (1990).All samples plot in the "residual peridotites or ophiolites" in their field.

Further confirms the ophiolitic origin for the peridotites of Islam Abad. $Mg^{\#}(Mg/[Mg+Fe^{2+}])$ versus $Cr^{\#}$ in spinels is used to distinguish between peridotitic xenoliths in alkaline rocks and ophiolitic peridotite [6].This criterion shows that peridotites from the Islam Abad are ophiolitic peridotites(Fig.7) ,as clearly estabilished by the field relations.Spinels plot in the mantel array field on the Al $_2O_3$ versus Cr $_2O_3$ diagram(Fig.8).

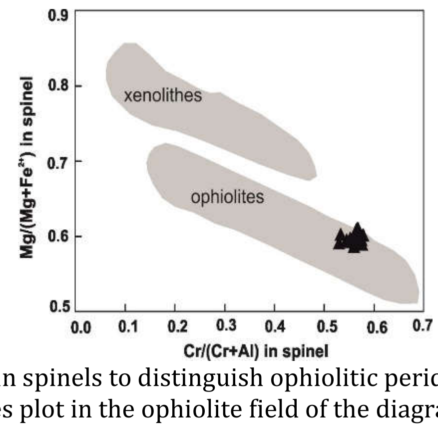


Figure.7.$Mg^{\#}$against $Cr^{\#}$ in spinels to distinguish ophiolitic peridotites from mantle xenolithic peridotites.All analysed samples plot in the ophiolite field of the diagram.Fielda are from Cabanes and Mercier [6].

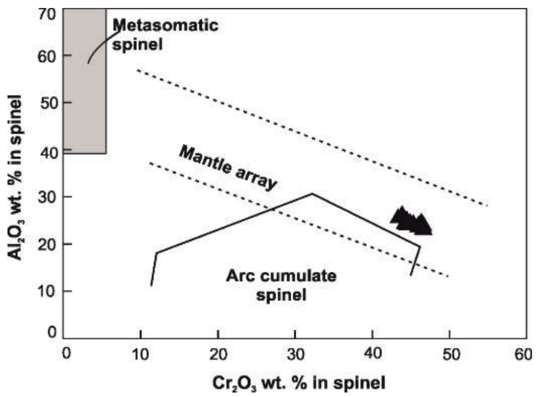


Figure8.Al $_2O_3$ versus Cr $_2O_3$ in the spinels to determine origin of spinel .All samples plot in the mantle array field. The field are from Conrad and Kay [7], Haggerty [12] and Kepezhinskas et al. [21].

Olivine:

The amount of forsterite in the olivine grains contained in the harzburgite of the Islam-Abad mantle sequence is between 89.65 to 91.92%(Table.3). The olivine content of the lherzolites and harzburgite of the mantle sequences is basically composed of forsterite by 89 to 91 % (13) while the amount of this constituent in the Khoy Ophiolite is between 89.3 to 91.22% (26).

	$E_{41}B$-1	$E_{41}B$-1	$E_{41}B$-1	$E_{41}B$-1	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-2	$E_{41}B$-2	$E_{42}B$-1	$E_{42}B$-1	$E_{42}B$-1	$E_{42}B$-1	$E_{42}B$-2	$E_{42}B$-2	$E_{42}B$-2	$E_{42}B$-2	$E_{42}B$-2	$E_{42}B$-2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TiO_2	0.04	0.0	0.01	0.04	0.03	0.05	0.05	0.03	0.0	0.05	0.02	0.05	0.01	0.06	0.05	0.01	0.0	0.06
Al_2O_3	23.17	22.88	22.95	23.58	24.20	23.04	24.17	24.49	24.93	24.43	25.48	23.58	23.60	23.52	23.85	23.82	24.20	26.13
Cr_2O_3	46.62	46.75	46.46	45.93	44.13	44.39	46.21	46.36	44.48	44.89	43.33	45.90	46.29	46.11	45.95	46.63	45.32	43.86
FeO	18.24	16.04	17.26	18.35	18.97	18.99	17.65	18.55	19.27	18.51	18.61	17.15	18.06	16.7	17.89	18.11	18.04	18.68
MnO	0.16	0.26	0.27	0.28	0.30	0.29	0.28	0.29	0.25	0.27	0.26	0.29	0.29	0.29	0.32	0.22	0.32	0.25
MgO	13.11	12.87	12.69	13.23	12.98	12.96	13.01	13.07	13.25	13.18	13.33	13.30	13.26	13.20	13.39	13.58	13.04	13.24
#Mg	59.335	59.901	58.686	59.875	59.109	59.040	58.859	58.386	59.261	59.477	60.009	60.751	60.009	60.542	60.507	60.740	59.304	58.865
#Cr	57.442	57.818	57.592	56.647	55.022	55.434	56.189	55.945	54.481	55.210	53.288	56.631	56.818	56.806	56.378	56.770	55.679	52.963
F%	18.456	18.521	18.482	18.316	18.025	17.9	18.235	18.191	17.926	18.059	17.705	18.313	18.346	18.344	18.269	18.338	18.144	17.644

Table3.Composition of olivins in ultramafic rocks from Islam Abbad region.

Similar to the peridotite cumulates found in the Neyriz Ophiolite Complex, the amount of nickel oxide, as compared to the amount of forsterite, drastically changes in the olivine of Islam-Abad peridotites (16). According to the nickel oxide vs. forsterite diagram and the values associated with the levels of the olivine in the oceanic peridotites and cumulates (9), it is concluded that the olivine are classified as oceanic peridotites and are similar to those found in the Neyriz Ophiolites(Fig,9.A.B).

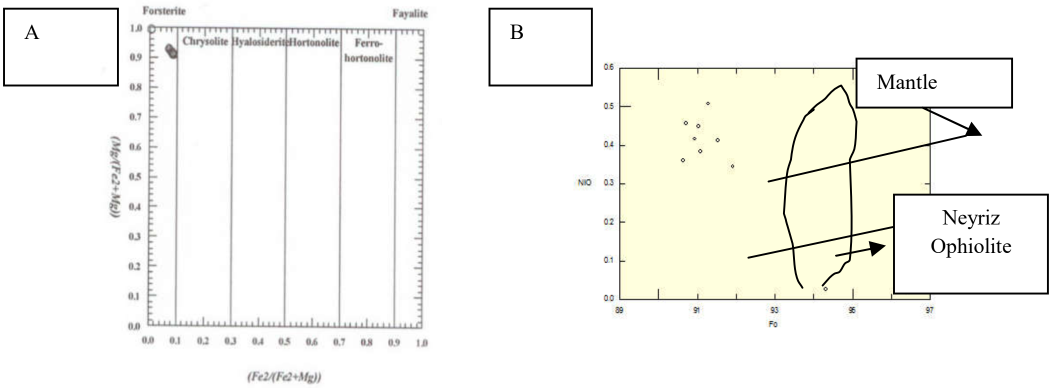


Figure.9.(A). Olivine Composition plot in $Mg^{\#}$vs.$Fe^{\#}$.(B) Olivin composition plot in NiO vs.Fo .fields outline olivin composition in mantle array [34],and Neyriz Ophiolitic Complex (16).

Orthopyroxene:

Orthopyroxene is one of the major minerals in the structure of mantle peridotites the changes in the amount of the major, minor and rare earth elements of which can be used as the yardsticks for measuring the partial melting degree of these rocks. The moral values of these minerals show the extent of depletions or enrichments in the mantle sequences.

The enstatite content of the orthopyroxenes found in the Islam-Abad mantle sequence is between 86 to 91%(Table.4)

Table4-Composition of orthopyroxen in ultramafic rocks from Islam Abbad region

	E_{41}B-1	E_{41}B-1	E_{41}B-1	E_{41}B-1	E_{41}B-1	E_{41}B-1	E_{42}B-2	E_{42}B-2	E_{42}B-2	E_{42}B-3	E_{42}B-3
	1	2	4	5	6	7	12	13	14	19	**20**
SiO_2	58.526	58.763	58.677	58.821	59.087	58.604	58.258	58.279	57.772	50.313	**57.86**
TiO_2	0.001	0.00	0.013	0.013	0.018	0.00	0.018	0.00	0.027	0.00	**0.011**
Al_2O_3	1.817	1.944	1.829	1.803	1.875	1.789	1.737	1.815	1.715	1.714	**1.676**
Cr_2O_3	0.593	0.645	0.625	0.573	0.624	0.601	0.515	0.648	0.619	0.472	**0.644**
FeO	5.163	5.397	5.152	5.65	5.408	5.139	5.764	5.768	5.52	4.177	**5.417**
MnO	0.097	0.181	0.14	0.072	0.194	0.123	0.181	0.131	0.182	0.116	**0.085**
NiO	0.098	0.111	0.045	0.084	0.116	0.089	0.06	0.107	0.06	0.049	**0.106**
CaO	0.827	0.763	0.695	2.215	0.656	2.239	0.613	0.762	3.077	0.517	**0.926**
MgO	34.061	34.569	34.785	34.106	34.821	34.031	35.141	34.662	33.495	29.413	**34.743**
Na_2O	0.014	0.006	0.004	0.005	0.001	0.015	0.00	0.00	0.007	0.003	**0.015**
K_2O	0.022	0.00	0.001	0.00	0.00	0.00	0.012	0.003	0.014	0.00	**0.00**
En	90.70	90.63	91.12	87.75	90.85	88.34	90.53	90.16	86.80	91.55	**90.36**
Fs	7.71	7.94	7.57	8.15	7.92	7.48	8.33	8.42	7.47	7.29	**7.90**
Wo	1.58	1.44	1.31	4.1	1.23	4.18	1.14	1.42	5.73	1.16	**1.73**
#Mg	0.921	0.916	0.923	0.915	0.919	0.921	0.915	0.914	0.920	0.926	**0.919**

(Fig.10)while the enstatite content of the orthopyroxenes contained in the oceanic peridotites of MARK Zone (31) is between 87 to 89%, that of the Khoy Ophiolites is between 81.16 to 90.78% (26), and that of the depleted harzburgite of the Neyriz Ophiolites is between 89 to 93% (16).This is approximately equal to the amount of enstatite found in the Tethyan ophiolites (such as the Marmaris-Fethiye Ophiolite in Turkey), which ranges from 85 to 90% (28) (Fig.11-A,B).

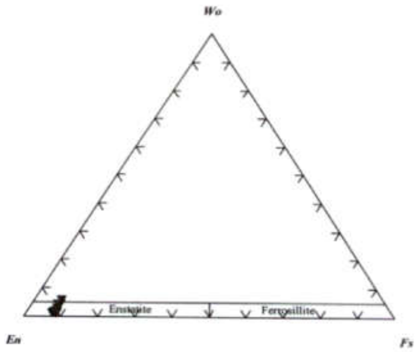


Figure.10.Orthopyroxen Composition in Wo-En-Fs diagram.

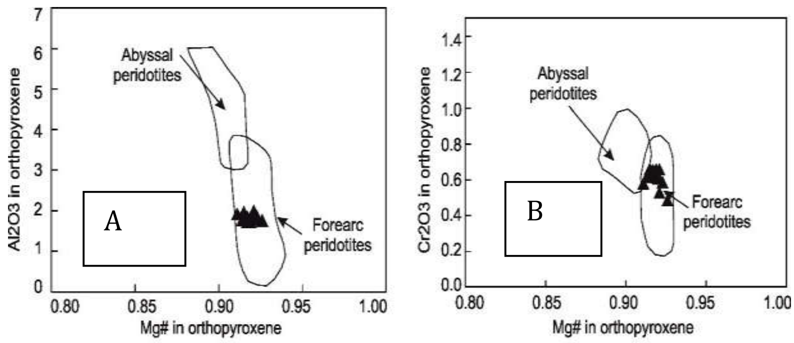


Figure11.orthopyroxen composition plotes for the Islam Abad Ophiolitic Complex peridotites.A: Al_2O_3 vs Mg#,B:Cr_2O_3 TiO_2 vs.Mg#.fields outline orthopyroxen compositions in abyssal peridoties. ,And fore-arc peridoties ,provide for comparison. all samples plot in Fore –arc peridotites.

Clinopyroxene

Clinopyroxenes are highly susceptible to the melting processes, thus the amount of the major, minor and rare earth elements can be used a proper yardstick for estimating the partial melting degree of mantle peridotites. The modal value of this mineral is used to determine the depletion and enrichment levels in the mantle sequence peridotites and ophiolite peridotites. The clinopyroxenes of the harzburgite found in Islam-Abad are diopside type clinopyroxenes (Table 5) (Fig12).

Table5- Composition of clinopyroxen in ultramafic rocks from Islam Abbad region

	E_{41}B-1	E_{41}B-1	E_{42}B-2	E_{42}B-2	E_{42}B-3	E_{42}B-3
	3	8	15	16	23	24
SiO_2	55.219	55.722	55.606	55.176	55.265	55.256
TiO_2	0.033	0	0.032	0.083	0.016	0
Al_2O_3	1.812	1.755	1.573	1.529	1.738	1.312
Cr_2O_3	0.789	0.702	0.633	0.556	0.728	0.482
FeO	1.929	1.866	1.945	2.071	1.804	2.123
MnO	0.066	0.068	0.046	0.055	0.108	0.049
NiO	0.018	0	0.07	0.053	0.045	0.03
CaO	24.201	24.487	24.515	24.481	24.559	24.364
MgO	17.922	18.072	18.151	18.178	17.947	18.46
Na_2O	0.022	0.037	0.026	0.029	0.008	0.031
K_2O	0	0.015	0	0	0	0
Wo	47.79	47.93	47.80	47.66	48.21	47.40
En	49.24	49.22	49.24	49.24	49.02	49.97
Fs	2.97	2.58	2.96	3.10	2.76	2.63
#Mg	0.943	0.945	0.942	0.919	0.946	0.950

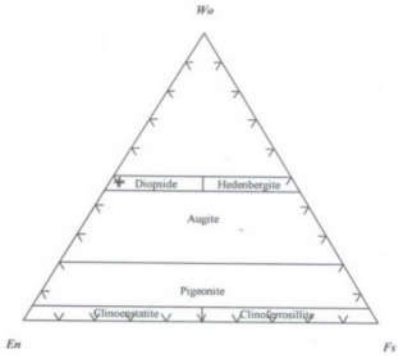


Figure.12.Clinopyroxen composition in Wo-En-Fs diagram

The amount of the aluminum oxide content of these minerals is between 1.312 to 1.812 w% while that of the Oman, Turkey (34; 28) and Neyriz Ophiolites (16) is equal to 3 wt% and that of the harzburgite of MARK Zone is about 5.6 wt% (31). These are aluminum-rich clinopyroxenes while the remaining refractory clinopyroxenes are found within the mantle sequences. Clinopyroxenes with lower amounts of aluminum oxide are probably crystallized out of the extruding magma (34) and have nickel contents of between 0 to 530 ppm. The amount of this element in the Neyriz Ophiolite clinopyroxenes is between 0 to 2400 ppm (16) and between 0 to 800 ppm in the Khoy Ophiolite clinopyroxenes (22). In the Al_2O_3, Cr_2O_3,TiO_2 vs. Magnesium diagram, the amount of this element is found to plot in the fore-arc peridotites fields(Fig.13A,B,C,D).

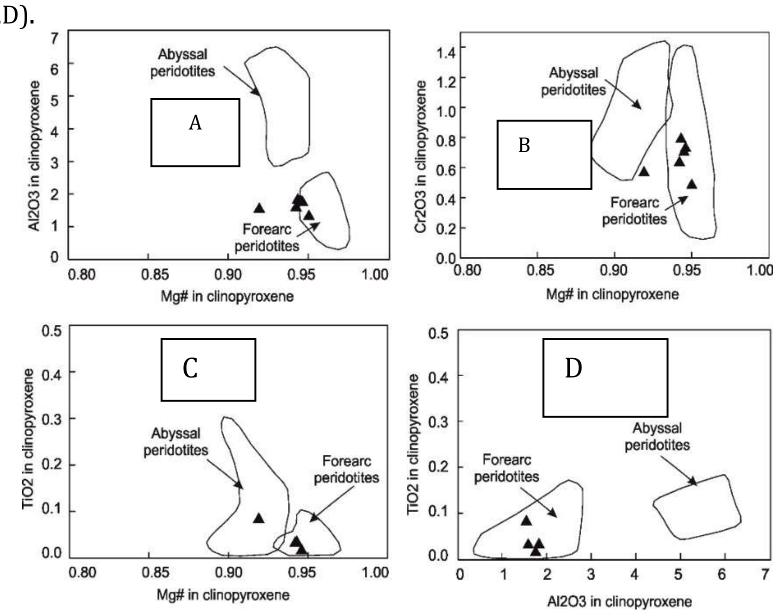


Figure13.Clinopyroxen composition plots for the Islam Abad Ophiolitic Complex peridoties . A:Al_2O_3 vs . Mg#,.B:Cr_2O_3 vs.Mg#,C:TiO_2vs Mg#. D:TiO_2 vs.Al_2O_3.. Fields outline clinopyroxene composition in abyssal peridotites(Johnson et al.,1990),and fore-arc peridotites(Ishii et al.,1992), provided for comparison.

DISCUSSION

Geotectonic setting: The Cr#versus Mg#in spinel diagram can be used to relate peridotites to either Alpine I-type peridotites [7],abyssal peridotites,fore-arc peridotites [33] and back-arc peridotites [25].In this diagram,the harzburgitic samples plot in the SSZ peridotite fields (Fig.14).All the studied samples define Alpine I-type and a back arc setting for the studied peridotites.

Degrees of partial melting obtained from spinel grains, based on calculations made by (14).all sample fall in the field of oceanic supra- subduction-zone peridotites.

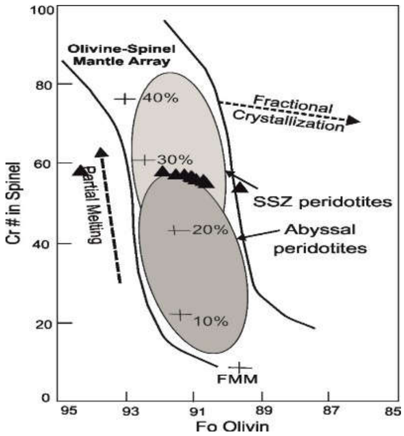


Figure14.Cr# versus Mg# in the studied spinels.Field of abyssal(ocean ridg)peridotite from Dick and Bullen [8], the oceanic supra-subductin zone peridotite,the olivine-spinel mantle array(OSMA) and the melting trend of Arai [1].FMM is fertile MORB mantle.all peridotites fall in the supra-subduction zone with more than20% partial melting.

CONCLUSION

The Islam Abbad Ophiolite is composed chiefly of mantle sequence peridoties (harzburgite and serpentinite). The geochemical results obtained from the studies conducted on the peridotites of Islam-Abbad show that these peridotites are depleted type of peridotites.

The peridotites are ophiolitic peridoties,I-type alpine, originated in the mantle and show about more than 20% partial melting. Peridoties show Cr-rich spinels with Cr numbers of 52.963 -57.818 and Mg numbers varing between58.386- 60.751 ,with a low TiO_2 content(0-0.06).Cr # of spinels indicates an oceanic crust related to a supra-subduction zone. They correspond to depleted abyssal peridoties and magma extraction in a supra-subduction-zone environment.

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