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Genesis of Chromitite in Qalander Area, Northern Iraq Employing Cr-Rich Spinel

Sabah A. Ismail and Sawsan A. Al-Chalabi***
**College of science - Kirkuk university*
***College of science-Sallahadin University, Erbil*

Abstract

The study area is an isolated ultramafic complex composite of harzburgite-dunite-chromitite association in Qalander area, abut 10 km east of Mergesur, Erbil City, northern Iraq. The chromite-bearing rocks are located within lower part of Walash Volcanic Series of Paleocene-Eocene age. They form concordant, podiform bodies with cataclastic and pull-apart texture that occur in two localities (A and B). Electron microprobe and X-ray diffraction analysis indicate that the studied chromites are of alpine-type, Cr-rich in location A and Al-rich in locality B. The disseminated chromites in harzburgite have Cr# of 0.35-0.87 ; and 0.42-0.56 in localities A&B respectively and Cr# rang between 0.38-0.48 in the dunite associates of localities B. The disseminated chromites of both localities are richer in Fe and TiO2 than the associated massive chromite. Olivine and pyroxene are primary inclusions in chromitite, while serpentine, chlorite and calcite represent the secondary inclusions as alteration products of the primary inclusions. The distinctive Cr# displayed by chromitite of two localities (A&B) are attributed to harzburgite from two different tectonic setting. Chromitites, however are formed by wall rock-melt interaction involving refractory harzburgite from different tectonic environment leading to two chemically distinct Cr-rich chromite domains. High Cr# of chromite of locality A, suggest supra-subduction zone environment, indicates genetic linkage with some bonitite, or high-Mg arc tholeiities which are available in supra-subduction zone; lower Cr# in location B suggest mid-oceanic ridge setting.

Introduction

Chromitite refers to a rock rich in spinel (>20% modal ratio), and it can be divided into two types based on their mode of occurrence. The first is the layered type that occurs in the mafic layered intrusions, and the second is the podiform type within the alpine-type peridotite masses or in the ophiolitic complex. The podiform chromitite is usually associated with dunite (Cassard et. al., 1981); it occurs as pod –like bodies with dunite envelopes of mantle origin (Thayer, 1964, Nicolas, 1989). Cr-rich Spinel is a useful petrogenetic indicator for ultramafic and mafic rocks because its composition is changeable, depending on physio-chemical conditions such as pressure, temperature, oxygen fugacity, magma chemistry and bulk rock.

The spinel composition for the Upper Mantle-derived peridotites, may indicate the degree of partial melting and has been used as a guide to classify the peridotite in term of tectonic setting (Dick & Bullen, 1984, Arai, 1994).The purpose of this study is to outline the mineralogy and mineral chemistry of chromitites and associated peridotites, and also to give some constraints on the origin of chromitite and tectonic setting as well as some aspects of the mantle section in the Iraqi Zagros Thrust Zone (IZTZ) .The studied samples weren collected from Qalander area in IZTZ which is located in the northern Iraqi, ~100km northeast of Erbil City and ~10 Km to the east of Mergasur Town (Fig. 1). The chromitite occurrences are denoted as locations A and B, which are ~2 kms apart.

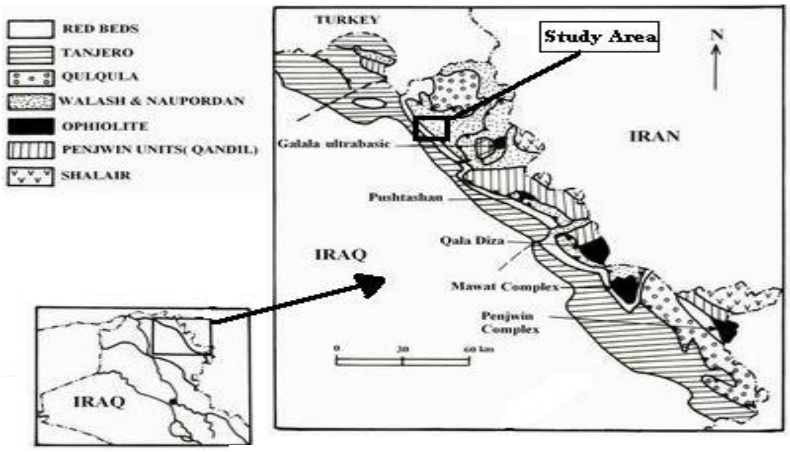


Fig (1)Geologic& Location map of the study area (Budy&Jassim,1987)

Geological setting

The study area is part of the IZTZ, which belongs to the Alpine-Himalayan Orogenic Belt. It is a typical ophiolitic sequences compared to the well known Tethyan belt sequences which extends from Europe to Himalayas. IZTZ represents sites of collision between the Arabian and the Iranian micro-continents in the northeast, and the Arabian and Turkish micro-continents in the north (Searle & Malpas, 1980; Abbotts, 1981; Hall, 1982; & Numan, 1997 & 2001). The IZTZ has been divided into three groups in the form of overthrusted nappes (Bolton 1958; Polinkov &Nikolayev, 1962; Buday, 1973). The *Gimo-Qandil Group* which represents the upper nappe consisiting of regionally metamorphosed rocks with oriented fabrics (slates, phyllites, schists, calc-schists, and marbles) as well as pillow lavas with conglomerates and breccias. The *Walash volcano-sedimentary Group* representing the middle nappe, which is made up of shale, red and green mudstone, slates and phyllites, layered and pillow lavas and agglomerates. *The Naupordan sedimentary Group* represents the lower nappe that is composed of red and green marls, conglomerates, low-grade metamorphic marbles, and layered lavas with few pillows.

The Qalander ultramafic body is situated within the Walash Group of Eocene age (Al-Mehaidi, 1975). This group is a volcano-sedimentary sequence which consists of un metamorphosed basalts (sometimes pillowed), dolerite, andesite, tuff, agglomerate, greywacke, limestone and radiolarian chert. The ultramafic body is a small ophiolitic complex. The studied chromitite occurs as pods in the serpentinized peridotite within the lower part of Walash group(Plate1-A,B). All the studied chromitite pods are relatively deformed and concordant with the structure of the surrounding rocks. (Cassard et al., 1981)

Petrography

Podiform Chromitite : Chromitite pods in Qalander area are composed of coarse-grained aggregates of chromite and silicate minerals (as in matrix and inclusions). The chromite grains are subhedral to euhedral in shape and vary in size from 0.03 to 1 mm (0.3 mm in average) (Plate2-A,B). Most of the chromite grains show marked cataclastic and pull-apart texture(Plate2-D). All chromitite samples contain 2-8 modal percent matrix, which is mainly serpentine, chlorite and sometimes carbonates filling the cracks and the spaces between the chromite grains. The chromite grains contain inclusions of different sizes, shapes and mineralogical composition which can be classified into two groups:

1-Primary inclusions of olivine (Plate1-C), enstatite orthopyroxene and diopside (Plate1-D).

2-Secondary inclusions of serpentine and chlorite (kammererite).They are relatively large in size with rounded shape and traversed and/or connected with matrix by fractures. In some chromitite samples, secondary calcite is also identified as inclusion which was observed only in locality A. The origin of primary inclusions in chromite is accepted as entrapment of silicate melt in spinel structure during magmatic process involving host rock-melt interaction (Mastukage & Arai, 1998). The opening of inclusion to the matrix may causes alteration of primary silicate minerals to secondary minerals during serpentinization and metasomatism.

Host Rock: In locality A dunite occurs as thin envelopes around chromitite pods separating the later from the host rock (harzburgit) in location A but it is a massive body in locality B. The dunites are strongly altered to serpentine and/or chlorite at the expense of the primary olivine grains which are still preserved (Plate2-C); secondary magnetite grains are also formed as a result of serpentinization of olivine and pyroxene along fractures and grain boundaries. Mesh texture is developed in some of dunites as a result of the serpentinzation of the olivines (Plate2-F); the central part of these meshes is filled with nearly isotropic, structureless serpentine. Harzburgite is more dominant than dunite. It is strongly altered to serpentine which can be recognized by basatite psuedomorphs of orthopyroxene with magnetite stringers filling cleavage traces of the original crystals (Plate2-E). Anhedral to subhedral grains of chromite is the main accessory mineral forming ~ 2 %.

Methodology

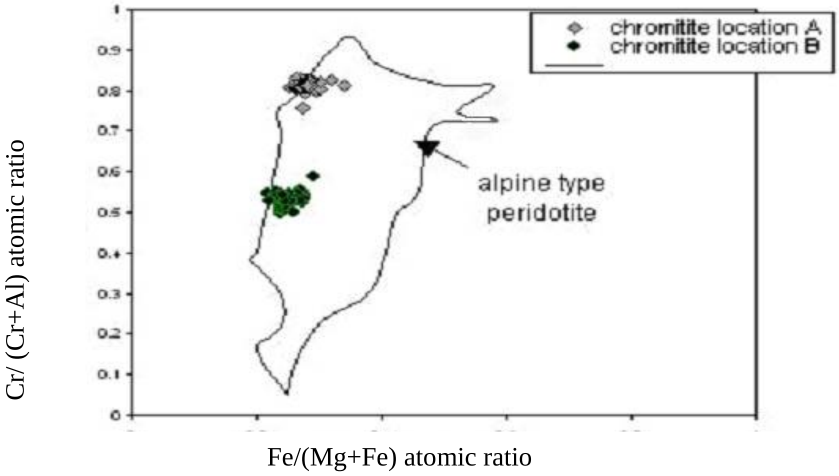
About 500 spot analyses were obtained on sixteen polished thin sections representing samples of both chromitite and host rocks, only fresh spinel is considered in this study , using electron microprobe analyzer JEOL Model, at Kanazawa University, Japan. The analyzed elements are Cr, Al, Fe, Mg, Ti, Si, Ni, Ca, K and Na, and the raw data were corrected using online ZAF program. The Fe^{3+} and Fe^{2+} in spinel were calculated assuming spinel (AB_2O_4) stochiometry

Results

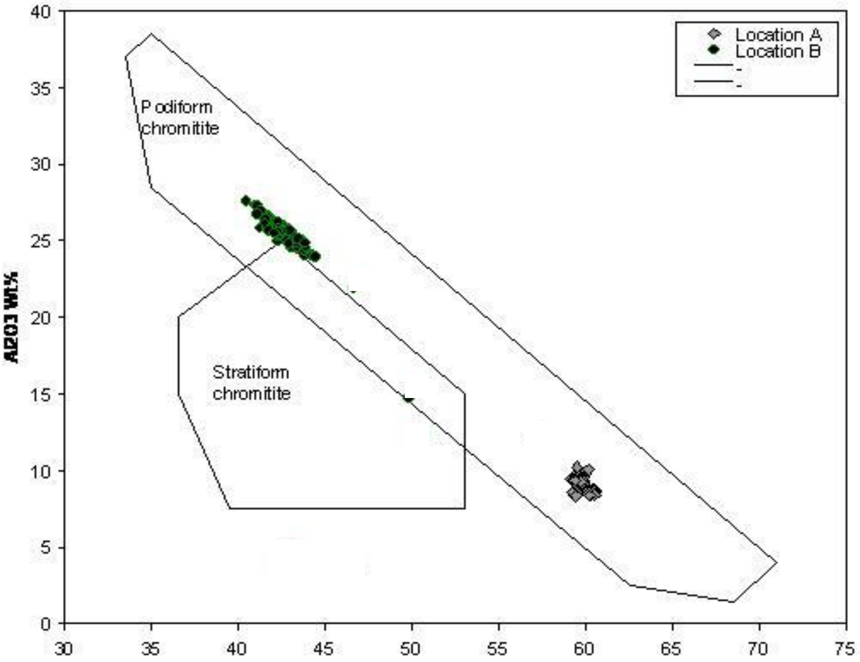
Chromite chemistry

Little compositional variation is noticed in the chromites same locality, but there is a considerable difference between the chromites of localities A and B (Table 1). The Cr_2O_3 content varies between 60.32 – 61.34 wt % in localities A, whereas it varies between 42.23 – 43.05 wt% in locality B. Cr# is 0.8 and 0.5 in localities A and B, receptively and both values lie within field of Alpine type (Fig 2). The Al_2O_3 content ranges between 8.92 – 9.53 wt % in locality A, and 24.82 – 26.10 wt % in locality B; it shows strong correlation with Cr_2O_3 (Fig.3). The Al_2O_3 abundance in podiform chromitite depends on the melt of perodotite composition which is a function of pressure, temperature and the degree of partial melting (Kamentesky et al., 2001).

Therfore the Al_2O_3 or Cr# of disseminated chromospinels is commonly used to elucidate the nature of mantle peridotite source as well as the degree of partial melting (Jaques & Green, 1980; Duncan and Green, 1987). chromitite pods of locality A, and Al-rich ones of locality B do not exceed.The total Fe content of primary chromites in both, the Cr-rich 15.45 wt %. Fe^{3+}# value ranges between 0.03 - 0.07; while the MgO content is limited and does not show wide range of variation, it is about 15 wt% in locality A and 17 wt% in locality B. Mg# ranges between 0.72 - 0.73 and 0.74 - 0.77 in localities A and B, respectively (Table-1). It worth noting that the reaction of chromite with trapped liquid decrease Mg# (Barnes, 1998). TiO_2 content which is used to recognize podiform chromitite from stratiform chromitite is the most important minor oxide in chromite; its content in locality A rarely exceeds 0.2 wt %, whereas the average is 0.34 wt % in locality B. In disseminated chromite within harzburgite TiO_2 content are 0.015 w% and 0.915 w% in both localities A&B respectively while in dunite it is 0.3 wt% in locality B. The TiO_2 content however are low and correlate with level of depletion in mantle. TiO_2 in magmatic spinel clearly dependent on the content of this oxide in the parent melt and thus can be used to discriminate between different magma and their tectonic settings (Arai, 1992; Kamentesky et al.,2001)



Fig(2) Variation of Cr/(Cr+Al) atomic ratio vs. Fe/(Mg+Fe) atomic ratio of chromite in chromitite from both localities A & B . Field of alpine type from Dick & Bullen(1984)



Cr_2O_3

Fig (3) Variation of Cr_2O_3 vs. Al_2O_3 of chromite in the study area's chromitite compositional fields of podiform & stratiform chromitite after Bonavia et al,1993

Chemistry of inclusions

Olivine, clinopyroxene and orthopyroxene are the main mineral inclusions in both localities. Low temperature hydrous minerals (serpentine and chlorite) and carbonate minerals are also present on expense of primary minerals as a result of fluid infiltration through cracks in the host chromite. Chemical analysis of othropyroxene inclusions showed that they are usually enstatite with high Mg# of 0.94 - 0.99, and contain 0.96-1.32 wt % Cr_2O_3 and 0.59-1.93 wt % Al_2O_3. The subsolidus re-equilibration of chromite with Fe-Mg silicate shifts chromite to the lower Mg#, and silicate to be high Mg# (Iriven, 1967). The clinopyroxene inclusions are usually diopside with Mg# is 0.94 - 0.96, and contain 20.5-23.9 wt % CaO, 1.61-1.91 wt % $Cr_2O_{3,}$ 1.45-2.95 wt % $Al_2O_{3,}$ 0.5 wt % Na_2O and 0.27 wt % $TiO_{2;}$ Mg # correlate positively with $Ca/(Ca+Mg+Fe^{2+})$ atomic ratio (r =0.5)

Matrix chemistry

Serpentine and chlorite form the main matrix of chromitite, they fill the fractures and space between chromite grains. Most of the matrix of locality A is serpentine and chlorite forms the matrix in locality B.

Most chlorites in this matrix are penninite and contains >2wt % of Cr_2O_3 and it is rich in magnesia;Mg# is about 0.95-0.99,in locality A SiO_2 content is about 35.41 wt % and it ranges between 28.81-32.43 wt% in locality B. Al_2O_3 content is ranging between 8.2-9.6 wt % in locality A,and about 11.7-16.33 wt % in locality B.Serpentine in the matrix is mainly chrysotile and lizardite. It is rich in magnesium with Mg# [Mg/(Mg+Fe^{2+}) atomic ratio] of 0.98, and poor in Al_2O_3 (<1 wt %). The SiO_2 content is about 37.23.- 41.59 wt %, and that of Cr_2O_3 ranges between 0.56-1.33 wt %.

Carbonate matrix is observed in locality A, it is mainly calcite, CaO is about 49.5-54.97 wt% with low MgO and FeO content. Whereas MnO is 0.53-1.38 wt% (Table 2). The carbonate may have been formed during metasomatism of previously serpentinized rocks, under oxidizing conditions of relatively low fluid rock ratio (Barnes, 2000).

Composition of Primary Cr rich Spinel

A primary chemical composition of Cr-rich spinel in the study area is high Cr_2O_3 content in locality A and high Al_2O_3 content in locality B. This may reflect difference either in melt sources or residual mantle or both that was involved in the formation of chromitite in both locations. The wide compositional range of chromian spinel from chromitite and host rocks indicates pre-metamorphic alteration which may have been produced by reaction with interstitial melt Several studies have shown that cumulus chromite rapidly reacts with the interstitial evolving melt (Handerson and Wood, 1981; Roeder and Campbell, 1985; Barnes, 1998), which results in compositional changes including decrease in Mg, Cr, and Al contents and increase in Fe and Ti contents (Barnes , 1998).

Genesis of Podiform Chromitite

Partial melting in the upper mantle and assimilation of wall rock by primitive melt might have played an essential role in the chromitite formation in the study area. The chemical diversity of chromite between locality A and locality B chromitite is possibly attributed to the difference in the chemistry of the melts evolving in the chromitite formation. Partial melting in the upper mantle produced exotic melt at higher pressure which moved upward,and inevitably interacted incongruently with the harzburgite of the mantle wall to produce dunite and SiO_2-rich secondary melt (Fig.4) by selective consumption of orthopyroxenes (or pyroxenes) of the peridotite wall (Arai & Yurimoto, 1994; Arai, 1997). By releasing latent heat, the melt could necessarily have precipitated olivine (+ chromite), thus promoting the melt - peridotite interaction. The dunite produced by this melt - peridotite interaction should be a mixture of two kinds of olivine the cumulus phase from the melt and residual phase from the peridotite wall. The secondary melt formed could blend with the next inflow of relatively primitive melt and enter primary spinel field (Irvine, 1977).The hybrid melt (secondary Si enriched melt + primitive melt) could precipitate only chromite to make chromite rich cumulates (Arai & Yurimoto,1994). Locality A high Cr# chromitites could have been formed either by relatively high degree of partial melting then consumption of Mg-rich and Al-poor orthopyroxene in wall peridotite by this melt or melt more likely interacted with rather high depleted mantle source under Supra Subduction Zone (SSZ). Locality B however low Cr#, Al-rich chromitites were possibly formed by relatively lower degree of partial melting and consumption of relatively Al-rich orthopyroxene in wall rock by the primitive melt or lower Cr/Al ratio of melt-peridotite system which affiliated to MORB mantle environment .

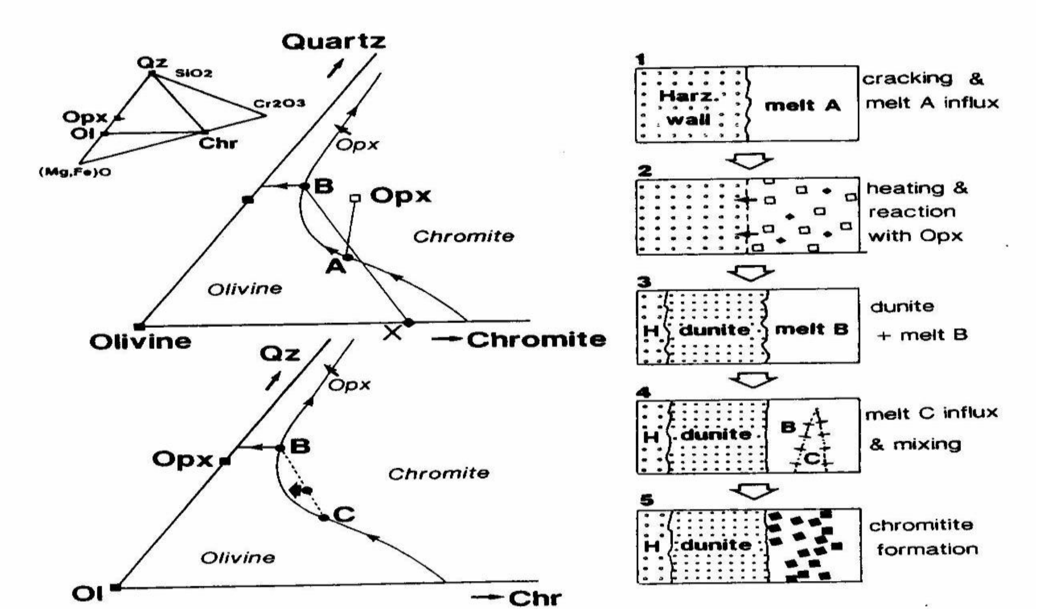
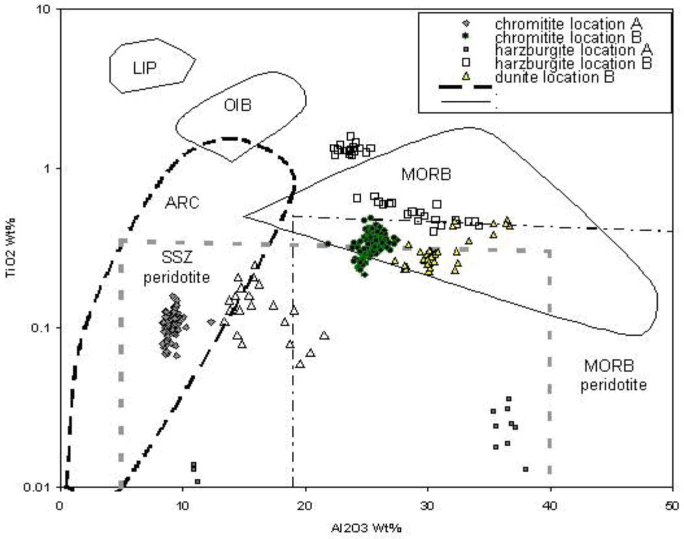


Fig (4) A magma-mixing model for the genesis of podiform chromitite .At the first stage a melt (A) of deep origin is intruded into shallow mantle harzburgite (stage 1) .Melt A reacts with orthopyroxene (open squares) in the harzburgite (stages 2&3) to produce olivine (+ chromite) and secondary Si-rich melt (B),which may precipitate chromite only mixed with successively supplied relatively primitive melt (C) (stages 4&5).Chr= chromite ,Ol = olivine ,Opx = orthopyroxene , Qz = quartz. After Arai & Yurimoto (1994), Phase diagrams modified from Irvine (1977) .

Tectonic implication

Based on the evidence cited above the geological, petrographical and geochemical difference between podiform chromitite of both localities A and B and disseminated chromite in different host rock types (Table 4) suggest that they were generated in two separate environments:

1. Locality A chromitite has high Cr# (0.8). This kind of magma is most easily available at the supra-subduction zone environment (Arai, 1994a). On the other hand, based on TiO_2-Al_2O_3 relation, they lie within the field of supra- subduction zone (Fig 5). The high Cr# low-Ti chromite is linked with some boninites (Mg-rich andesite) or high-Mg arc tholleiite (Arai, 1992, 1994b; Ahmed et al., 2001).
2. Locality B chromitite has lower Cr# of 0.5 and was produced around dunite -harzburgite zone; this may be linked to the formation of residual harzburgite and tholeiitic melt under relatively low degree of partial melting, possibly at mid-ocean ridge setting (Ahmed et al.,2001) since the Cr# of 0.5 is distinct for MORB (Arai,1994b). The absence of primary hydrous mineral inclusions in chromitite, in the study area indicates that they were derived from magma that was poor in incompatible elements or dry magma, which is available beneath MORB environment (Ahmed & Arai, 2002).



Fig(5) Relation between TiO_2 vs. Al_2O_3 of chromite in the study area in both location A and B. SSZ (supra subduction zone),LIP(large igneous province),MORB (mid-ocean ridge basalt),OIB(ocean-island basalt),(Kamenetsky et al.,2001).

Conclusions

1. Podiform chromitites occur in Qalander area in two localities about 2 kms apart, locality A is Cr-rich and locality B is Al-rich.
2. Chemical studies of chromites of both localities indicate that they are of alpine type. The chromitite pods of locality A have relatively high Cr# of 0.8, and low-Al; but the chromitite pods in locality B have lower Cr# of 0.5 and high- Al. The TiO_2 content of chromite from chromitite is usually less than 0.3wt% and the total Fe is ~16 wt % in both localities, whereas MgO is ~15 wt % in location A and ~17 wt % in locality B.
3. All primary silicate minerals of chromitite matrix are altered to serpentine and/or chlorite and sometimes to calcite. The serpentines in the matrix are high in magnesium with Mg# of 0.98, and the Al_2O_3 content is low (<1 wt %). The chlorites are high in magnesium with Mg# of 0.95 - 0.99; Cr_2O_3 content is usually > 2 wt %.
4. Primary inclusions(olivine and pyroxene) and secondary inclusions (serpentine, chlorite and calcite) were identified in chromite grains which did not show any differences in the two studied localities A and B.
5. The diversity of chromitite types in the two localities A and B suggest two different settings of generation. Locality A chromitite with high Cr# was probably generated in supra-suduction zone environment by high degree of partial melting; while locality B chromitite with relatively low Cr# of 0.5 was possibly generated in mid-oceanic ridge setting by a relatively low degree of partial melting.
6. The Qalander chromitite pods are probably a reaction product between exotic melt and intermediately refractory harzburgite and subsequent melt mixing. Due to this process of chromitite formation, it can be concluded that the chromite in harzburgite is a residual phase while in dunite is a cumulate phase.

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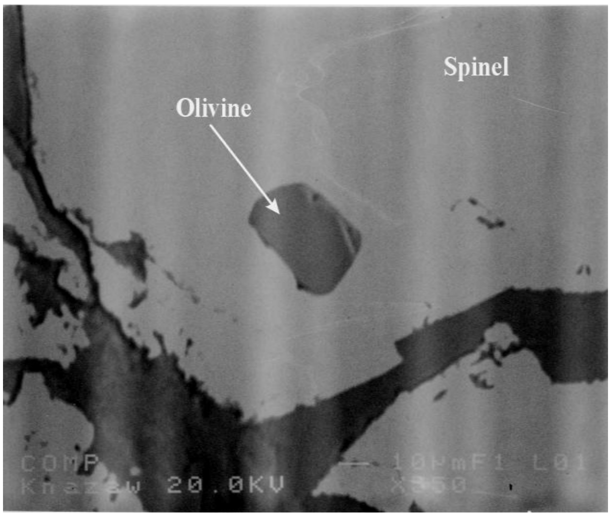
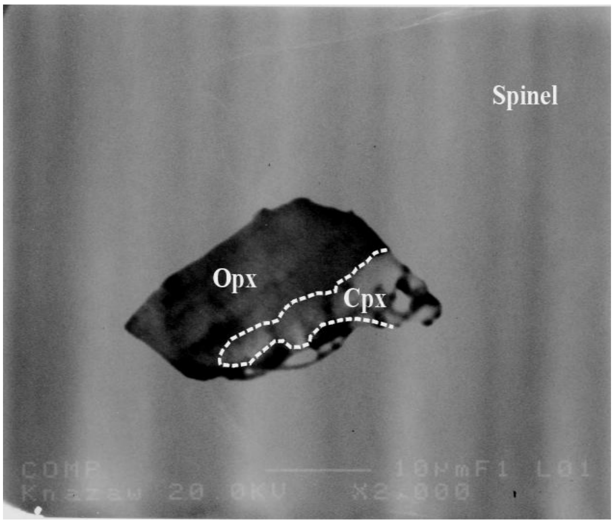
Plate 1

A - Chromitite pod from the studied area .

B -Group of chromitite pods from the studied area .



C -Back scatter electron micrographs of olivine inclusion in chromite from chromitite



D -Back scatter electron micrographs of orthopyroxene (opx) clinopyroxene (cpx)

Plate 2

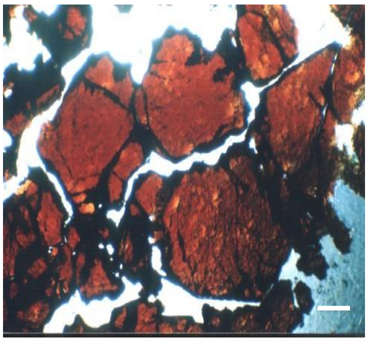


Plate (2-A) Subhedral to euhedral chromite cores with relatively thin opaque rim (transmitted light bar scale 0.16mm).

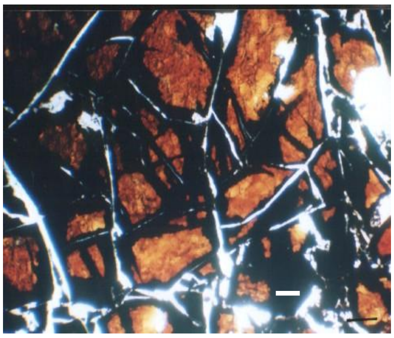


Plate (2-B) Subhedral chromite cores with moderate opaque spinel rim (transmitted light , bar scale 0.1mm).

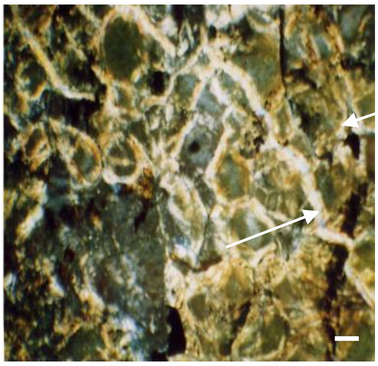


Plate (**2-C**) Pesudomorph of olivine(olv) , arrangement of serpentine reflect the original shape of olivine and form mesh like texture(transmitted light , X-Nicole ,bar scale 0.16mm).

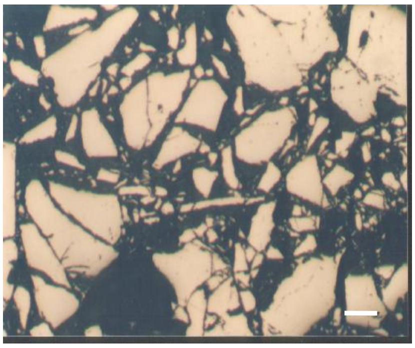
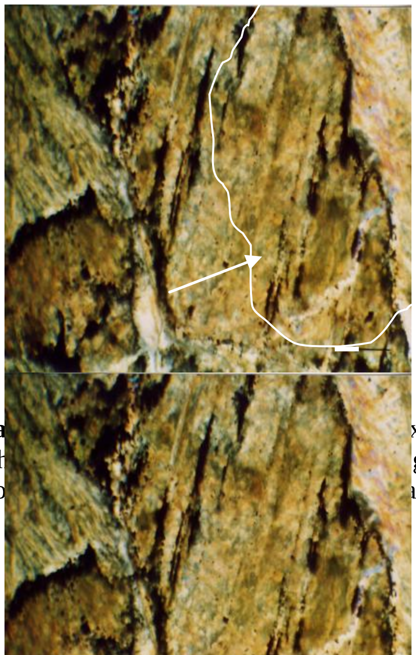


Plate (**2-D**) Marked cataclastic & pull –apart texture in chromitite (reflected light, bar scale 0.1mm).



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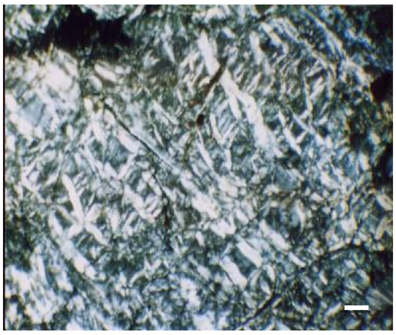


Plant (-F) Mesh texture serpentine in the central part of the mesh is filled with nearly isotropic serpentine (transmitted light, X-Nicols bar scale 0.16mm).

Appendices

Table (1) Average microprobe analyses of chromite from podiform chromitite of both localities (A&B), Cr#:Cr/(Cr+Al)atomic ratio; Mg#:Mg/(Mg+Fe)atomic ratio;Fe^{3+}#:Fe^{3+}/(Fe^{3+}+Al+Cr) atomic ratio ; Fe^{2+}#: Fe^{2+}/(Fe^{2+}+ Mg) atomic ratio .

	Location A			**Location B**				
Sample No.	31A	41A	23A	51B	33B	21B	11B	35B
SiO2	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.04
TiO2	0.12	0.09	0.13	0.21	0.33	0.32	0.33	0.41
Al2O3	9.53	8.92	9.44	24.82	26.10	26.07	25.48	25.79
Cr2O3	60.32	61.34	60.67	42.89	42.23	42.37	43.05	42.47
FeO*	15.45	14.99	14.90	14.22	13.90	14.13	13.97	13.70
MnO	0.25	0.24	0.22	0.18	0.25	0.24	0.34	0.46
MgO	15.16	15.36	15.57	17.00	17.13	16.91	16.99	17.54
CaO	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Na2O	0.00	0.02	0.00	0.00	0.00	0.01	0.03	0.01
K2O	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.01
NiO2	-	-	-	-	-	-	-	0.19
Total	100.99	101.08	101.10	99.52	100.13	100.23	100.38	100.63
O	4	4	4	4	4	4	4	4
Si	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ti	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Al	0.36	0.34	0.36	0.88	0.92	0.92	0.90	0.90
Cr	1.53	1.56	1.54	1.02	1.00	1.00	1.02	1.02
Fe*	0.42	0.40	0.40	0.36	0.35	0.35	0.35	0.35
Fe2+	0.29	0.28	0.27	0.24	0.24	0.25	0.25	0.25
Fe3+	0.13	0.13	0.13	0.11	0.10	0.09	0.09	0.09
Mn	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Mg	0.73	0.74	0.74	0.77	0.76	0.75	0.76	0.76
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
total	3.47	3.46	3.45	3.40	3.37	3.38	3.38	3.38
Fe^{2+}#	0.29	0.28	0.27	0.26	0.25	0.26	0.25	0.23
Fe^{3+}#	0.06	0.07	0.06	0.06	0.05	0.05	0.05	0.05
Mg #	0.71	0.72	0.73	0.74	0.75	0.74	0.75	0.77
Cr #	0.8	0.82	0.81	0.55	0.51	0.53	0.53	0.52

Table (2) Microprobe analyses of matrix mineral from chromitite of both localities (A & B).Mg# :Mg/(Mg+Fe^{2+}) atomic ratio.

Mineral	**chlorite**						**Srepentine**		**calcite**		
Sample No.	31A	23A	51B	51B	51B	33B	41A	41A	41A	23A	23A
SiO_2	35.393	35.428	29.942	32.433	31.931	28.810	41.593	37.231	0.003	0.007	0.036
TiO_2	0.008	0.000	0.000	0.060	0.050	0.015	0.009	0.007	0.001	0.000	0.001
Al_2O_3	8.262	9.615	11.788	15.364	16.337	16.337	0.722	0.260	0.000	0.000	0.027
Cr_2O_3	4.489	4.537	2.777	2.390	1.555	4.123	1.331	0.568	0.085	0.062	0.913
FeO	1.142	0.945	1.005	1.834	1.727	1.243	0.828	1.153	0.048	0.052	0.209
MnO	0.000	0.008	0.000	0.000	0.016	0.026	0.004	0.000	1.383	0.537	0.751
MgO	34.915	33.957	35.177	33.047	32.234	32.291	39.735	27.188	0.206	0.816	1.092
CaO	0.036	0.054	0.019	0.015	0.003	0.013	0.017	0.039	54.978	49.540	52.143
Na_2O	0.008	0.013	0.024	0.019	0.013	0.006	0.024	0.023	0.000	0.533	0.000
K_2O	0.010	0.000	0.021	0.007	0.009	0.008	0.012	0.011	0.000	0.015	0.010
NiO_2	0.226	0.253	0.429	0.115	0.151	0.335	0.100	0.606	0.000	0.000	0.003
Total	84.49	84.81	81.18	85.28	84.03	83.21	84.38	67.09	56.70	51.56	55.19
O ^{atoms}	28	28	28	28	28	28	14	14	3	3	3
Si	6.887	6.849	6.093	6.228	6.198	5.729	3.987	4.435	0.001	0.000	0.002
Ti	0.001	0	0.000	0.009	0.007	0.002	0.001	0.001	0.000	0.000	0.000
Al	1.894	2.19	2.827	3.476	3.737	3.828	0.082	0.036	0.000	0.000	0.002
Cr	0.690	0.693	0.447	0.363	0.238	0.648	0.101	0.053	0.016	0.003	0.036
Fe^{2+}	0.186	0.153	0.171	0.294	0.280	0.207	0.066	0.115	0.009	0.002	0.009
Mn	0.000	0.001	0.000	0.000	0.003	0.004	0.000	0.000	0.271	0.025	0.032
Mg	10.121	9.778	10.663	9.452	9.320	9.564	5.674	4.824	0.071	0.066	0.082
Ca	0.008	0.011	0.004	0.003	0.001	0.003	0.002	0.005	13.624	2.874	2.816
Na	0.003	0.005	0.009	0.007	0.005	0.002	0.004	0.005	0.000	0.056	0.000
K	0.002	0.000	0.005	0.002	0.002	0.002	0.001	0.002	0.000	0.001	0.001
Ni	0.029	0.032	0.058	0.015	0.019	0.044	0.006	0.048	0.000	0.000	0.000
Mg #	0.98	0.98	0.97	0.97	0.95	0.96	0.99	0.98	-	-	-

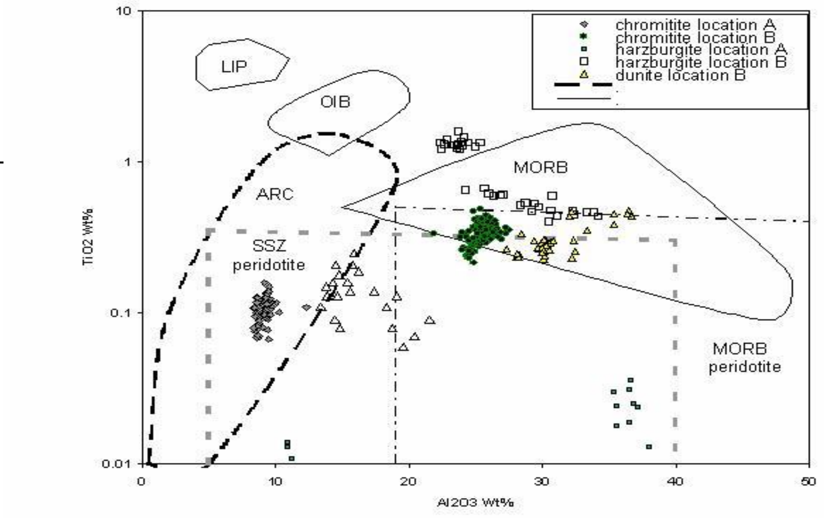
* All Fe assumed to be Fe^{2+}

Table (3) Microprobe analysis of mineral inclusions in chromitite of localities A & B. Opx :orthopyroxene, Cpx :clinopyroxene; Mg #:Mg/(Mg+Fe^{2+}) atomic ratio.

S. No.	23A	23A	51A	33A	33A	35A	35B	23A	35B	35B	35B	33B	33B	33B	23A
Ox.\ min.	Opx	Opx	Opx	Opx	Opx	Opx	Opx	Cpx	Cpx	Cpx	Cpx	olivine	olivine	olivine	calcite
SiO2	62.9	57.5	57.9	57.6	57.1	57.3	57.3	55.6	53.6	54	53.3	41.33	41.99	41.46	0.044
TiO2	0.03	0.06	0.09	0.11	0.09	0.13	0.1	0.08	0.3	0.29	0.28	0.011	0.017	0.02	0.019
Al2O3	0.59	1.61	1.6	1.86	1.53	1.62	1.41	1.45	2.49	2.5	2.95	0.042	0.016	0.018	0.018
Cr2O3	0.97	1.09	1.19	1	1.32	1.01	1	1.8	1.73	1.61	1.63	0.615	0.859	0.792	4.622
FeO	0.39	4.14	4.03	4	3.92	3.86	3.5	1.51	1.84	2.06	2.11	4.78	4.755	4.597	0.302
MnO	0.01	0.07	0.08	0.13	0.15	0.09	0.1	0.05	0.09	0.06	0.03	0.06	0.063	0.062	0.448
MgO	30.7	35.1	35.1	35.9	35.8	36.8	37.6	18.9	18	18.5	17.8	53.27	54.08	53.11	1.315
CaO	0.03	0.81	0.67	0.61	0.54	0.85	0.54	20.5	23.9	23.6	22.7	0.002	0.012	0	49.51
Na2O	0.2	0.01	0.01	0	0.01	0.01	0	0.72	0.41	0.47	0.52	0	0	0.012	0.04
K2O	0.03	0.02	0.01	0.01	0.02	0	0.01	0.02	0.02	0	0.02	0.013	0.006	0.003	0.01
NiO	0.21	0.09	0.09	0.1	0.1	0.12	0.09	0.07	0.05	0.03	0.04	0.533	0.588	0.587	0
Total	96	100	101	101	101	102	102	101	102	103	101	100.7	102.4	100.7	56.33
O atom	3	3	3	3	3	3	3	6	6	6	6	4	4	4	3
Si	1.08	0.98	0.98	0.97	0.97	0.97	0.97	1.98	1.91	1.91	0.89	0.989	0.988	0.991	0.002
Ti	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0.001
Al	0.01	0.03	0.03	0.04	0.03	0.03	0.03	0.06	0.1	0.1	0.03	0.001	0	0.001	0.001
Cr	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.05	0.05	0.05	0.01	0.012	0.016	0.015	0.179
Fe2+	0.01	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.03	0.096	0.094	0.092	0.012
Mn	0	0	0	0	0	0	0	0	0	0	0	0.001	0.001	0.001	0.019
Mg	0.79	0.89	0.89	0.9	0.91	0.92	0.94	1.01	0.95	0.97	0.44	1.898	1.895	1.891	0.096
Ca	0	0.02	0.01	0.01	0.01	0.02	0.01	0.78	0.91	0.89	0.41	0	0	0	2.596
Na	0.01	0	0	0	0	0	0	0.05	0.03	0.03	0.01	0	0	0.001	0.004
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001
Ni	0	0	0	0	0	0	0	0	0	0	0	0.008	0.009	0.009	0
Mg#	0.99	0.94	0.94	0.94	0.94	0.94	0.96	0.96	0.95	0.94	0.95	0.952	0.953	0.954	0.886

Table(4) Average microprope analysis of disseminated chromite from host harzburgite & dunite from both locations A&B.

	Location A		Location B				
	Chromite in Harzburgite				Chromite in Dunite		
Sam. No Ox. wt%	11A	14A	31B	32B	34B	36B	37B
SiO_2	0.01	0.04	0.02	0.02	0.01	0.01	0.03
TiO_2	0.02	0.01	0.52	1.31	0.25	0.38	0.28
Al_2O_3	36.61	11.18	29.48	23.57	28.7	33.32	30.62
Cr_2O_3	32.62	55.94	36.86	41.03	39.61	30.64	34.36
FeO	10.17	12.46	11.21	16.93	9.65	13.94	11.73
Fe_2O_3	2.15	6.08	4.71	4.75	4.9	6.35	7.02
MnO	0.46	0.72	0.4	0.54	0.47	0.4	0.46
MgO	17.69	13.4	16.35	12.42	17.52	14.97	16.24
CaO	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na_2O	0.01	0.01	0	0.01	0.01	0.01	0.01
K_2O	0.01	0.01	0.01	0.02	0.02	0.01	0.01
NiO_2	0.05	0.03	0.13	0.15	0.17	0.19	0.019
Total	99.79	99.89	99.71	100.76	101.31	100.23	100.96
No. atoms for O=4							
Si	0.000	0.001	0.001	0.001	0.000	0.000	0.001
Ti	0.000	0.000	0.012	0.03	0.005	0.008	0.006
Al	1.228	0.431	1.03	0.858	0.988	1.157	1.062
Cr	0.734	1.446	0.866	1.002	0.915	0.716	0.801
Fe^{+2}	0.255	0.366	0.278	0.41	0.245	0.352	0.298
Fe^{+3}	0.048	0.161	0.105	0.103	0.112	0.144	0.161
Mn	0.011	0.02	0.01	0.014	0.012	0.01	0.012
Mg	0.75	0.653	0.723	0.571	0.763	0.656	0.714
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.001	0.000	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.001	0.001	0.001	0.000
Ni	0.001	0.001	0.003	0.003	0.003	0.004	0.004
Fe^{+2}#	0.254	0.359	0.278	0.418	0.243	0.349	0.294
Fe^{+3}#	0.024	0.079	0.052	0.053	0.055	0.071	0.08
Mg#	0.746	0.641	0.722	0.582	0.757	0.651	0.706
Cr#	0.374	0.77	0.457	0.539	0.481	0.382	0.43



Fig(6 Relation between TiO_2 vs. Al_2O_3 of chromite in the study area in both location A and B .SSZ(supra subduction zone), LIP(large igneous province),MORB (mid-ocean ridge basalt), OIB(ocean-island basalt), (Kamenetsky et al.,2001).

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اصل صخور الكروميتايت

سبب

صباح احمد اسماعيل

*كلية العلوم–جامعة كركوك كلية العلوم _جامعة صلاح الدين

الخلاصة

منطقة الدراسة عبارة عن معقدات الصخور القاعدية المعزولة والمتمثلة بتعاقب صخور هارزبروكايت – دنايت وكروميتايت والتي تكون الجزء الاسفل لصخور ولاشن البركاني ذات العمر بليوسين ايوسين (Paleocen–Eocene) والتي تقع ضمن جبل قلندر والتي تبعد ١٠ كم شرق مدينة ميركسور في محافظة اربيل شمال العراق. صخور الكرميتايت تكون على هيئة كتل متوافقة مع الصخور المحيطة(concordant podiform) ولها نسيج (pull – apart) وتظهر في منطقتين سميت A و B . دلت التحاليل لهذه الصخور باستخدام المجهر الالكتروني الدقيق EPM وتقنية حيود الاشعة السينية ، بأنها ذات محتوى عالي لعنصر الكروميوم في منطقة A وانها ذات محتوى عالي لعنصر الالمنيوم في منطقة B بينما معدن الكروميتايت المتواجد على هيئة منتشرة (معادن اضافية) فانها ذات محتوى عالي للحديد والتينانيوم وان لها قيمة الكروم Cr # تتراوح من (٣٥% – ٧٨%) و (٤٢% – ٥٦%) في هارزوكايت في المنطقتين ولها قيمة تتراوح (٣٨% – ٤٢%) في دنايت في منطقة B . هذه المعادن تحتوي على متضمنات لمعادن اوليه والمتمثلة بمعدن اوليفين والبايروكسين وكذلك تحتوي على معادن ثانوية متمثلة بمعادن السيربنتين والكلورايت والكالسايت التي تمثل نواتج عمليات التغيير للمتضمنات .المحتوى العالي لقيمة الكروم(Cr #) في منطقة A دليل على انها تكونت في بيئة supra subduction zone بينما المحتوى الواطىء لقيمة (Cr #) في منطقة B تدل على انها تكونت في بيئة (mide – oceanic ridge) .