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Petrology and Mineralogy of Serpentinite Rock from the Mawat Ophiolite Complex in Zagros Suture Zone, Betwat Area, NE Iraq

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Abstract

This study aims to investigate the serpentinite rocks by combining field observation, petrographic and mineralogical aspects to deduce the mineral composition origin and tectonic setting of the serpentinized ultramafic rocks from Mawat ophiolite complex in Zagros Suture Zone, northern Iraq. The studied rocks are completely serpentinized samples characterized by mineral assemblages consisting of serpentine with relics of the original minerals: olivine and pyroxene, with other subordinate minerals such as amphibole, talc, chlorite, chromite, and magnetite. The serpentine mineral appears in three types (chrysotile, lizardite, and antigorite). The most common mineral is antigorite, which refers to a two-serpentinization stage. The first is retrogression of the original minerals (olivine and pyroxene) by hydrothermal solution to chrysotile and lizardite, and the second stage is a progressive metamorphism, which has recrystallized these minerals into antigorite. The chemistry of the studied minerals reveals that serpentine has a high MgO content, Mg-rich amphibole (type tremolite and actinolite), and chlorite is talc-chlorite type, which indicates a high MgO content. Chromite has elevated Cr2O3 relative to Al2O3 content, which indicates chromitite. Low Al to Cr ratios resemble ophiolitic podiform chromite, especially those seen in dunite. High Cr# and Mg# represent mantle-derived peridotites.

Keywords:

Serpentine, Mineralogy, Ophiolite, Suture Zone, Iraq.

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1. Introduction

Serpentinites are hydrated ultramafic rocks (with H_2O content up to 15–16 wt.%, average of 13 wt.%) that are products as a result of alteration of olivine and pyroxene. These rocks are normally stable at temperatures lower than 650–700 °C (Deschamps et al., 2013). The rocks are almost composed mainly of serpentine group of minerals. Serpentine minerals have a general chemical formula $(Mg, Fe^{2+})_3Si_2O_5(OH)_4$; they are made of equant 1:1 alternating tetrahedral $(Si_2O_5)^{-2}$ and octahedral layers that develop when other cations are bonded to the SiO_4 sheets. They share the apical oxygens and the (OH) ions, which bond to the other cations in octahedral coordination. This forms a layer of cations, usually Fe^{+2}, Mg^{+2}, or Al^{+3}, that occur in octahedral coordination with O and OH ions of the tetrahedral layer (Deer et al., 1992). The three polymorphs of the serpentine group (lizardite, chrysotile, and antigorite) result from different arrangements of these layers. Thus, they form flat layers in lizardite, cylinders in chrysotile, and corrugated modulated structures in antigorite (Wicks and O'Hanley, 1988). Serpentinite rocks have been recently focused on during the last two decades, and interest in these rocks continues unabated. The presence of serpentinite rocks, specifically in subduction zone areas, has important implications for the Earth's dynamic and global geochemical cycle. Processes of serpentinization, which form serpentine minerals, in most cases, are found in the seafloor (near mid-ocean ridges, MOR) and continue during subduction of serpentinites and peridotites; moreover, the fluids that result from the subducting slab lead to mantle wedge serpentinites (Deschamps et al., 2013). Subducted serpentinites are more heterogeneous in terms of timing of serpentinization: they are found mostly in suture zones and associated with high-pressure–low–temperature metamorphic rocks (Aziz et al., 2011). They can originate either from abyssal peridotites hydrated at ridges, trenches, or within the subduction channel, or from the oceanic–continent transition zone (Deschamps et al., 2013). In this study, we try to investigate the serpentinite rocks in the Zagros Suture Zone (ZSZ) by determining the field characteristics of these rocks, the petrography and mineralogy aspects of their mineral composition, as well as the nature of the fluid that led to the formation of these rocks, the intensity of this process, and the type of parent rocks.

2. Geological Setting

Mawat Ophiolite Complex (MOC) is located in the northeastern part of the Kurdistan region in Iraq and approximately 30 km northeast of Al Sulaimani City. Extending for 25 km in length and 12.7 km in width, covering an area of 200 km^2. The study area lies between longitudes (35° 48′ – 35° 50′ N) and latitudes (45° 30′ – 45° 28′ E) in the Mawat area near the village of Betwat (20 km northeast of Sulaymaniyah City) (Fig. 1). The Zagros Mountain Belt represents a typical example of continent – continent collision between the Arabian and Eurasian Plates during the mid–Cenozoic period (Mohammad et al., 2016). Zagros Orogenic Belt belongs to the Alpine – Himalayan Orogenic Belt, which extends from southern Europe to southwest Asia, through the Middle East. The Zagros Suture Zone (ZSZ) has developed in the Neo-Tethys oceanic basin; it thrusts over the Arabian Plate by two distinct events: obduction and collision at Late Cretaceous and Mio - Pliocene times, respectively (Jassim and Goff, 2006). According to Aswad (1999), ZSZ is divided into two allochthonous nappes (Lower and Upper). Jassim et al. (2006) termed as (nappe thrust sheets), where many serpentinite bodies are exposed along the thrust faults. Serpentinites are normally considered as lubricant bodies during tectonic movement and easy to be weathered (Aswad et al., 2011). These rocks play a significant role in understanding subduction and exhumation processes and played an effective role in the tectonics of the ZSZ (Buday and Jassim, 1987). Serpentinites exist in a variety of tectonic settings, and each of these has specific characteristics such as texture, mineral composition, and precursor protoliths (O’Hanley, 1996; Fryer, 2002; Mevél, 2003). Based on mode of occurrence and accompanying lithologies, the serpentinite rocks in Mawat and Betwat areas are found in the field either as serpentinites coupled with ophiolite sequence or as isolated serpentinite bodies associated with the Walash Group of volcano-sedimentary rocks. The selected serpentinite rocks for the present study are isolated bodies associated with the volcano-sedimentary rocks of the Walash Group (Fig. 1). They represent isolated intraformational bodies within the volcano-sedimentary rock unit of the Walash–Naopurdan unit.

The rock samples collected for this work are from an outcrop of 300 to 500 m thick that extends for about 1.5 km, surrounded from all directions by volcanic rocks such as spilites and andesites with sandstone beds of the Walash Formation.

The most common kind in the Mawat area is massive serpentinite (Mohammad, 2011).

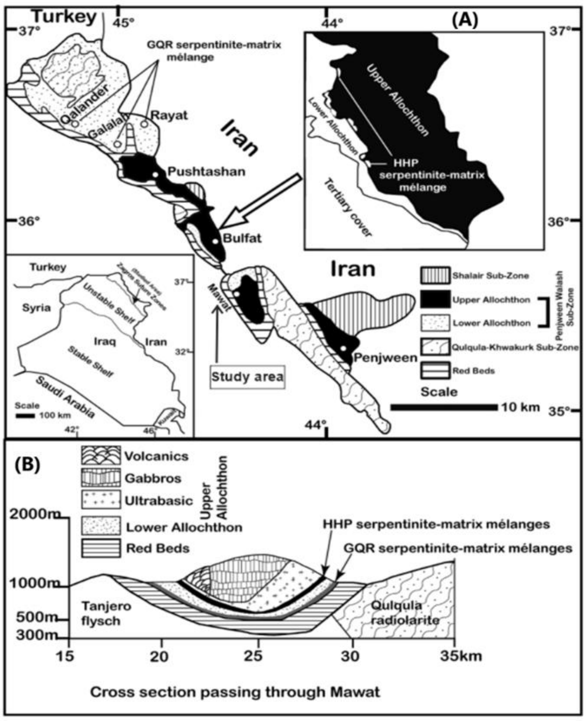

Fig 1: (A): Geological map of NW of ZSZ (Kurdistan Region) illustrating the area of study; (B) Cross section showing the lithology of Mawat ophiolite (after Aziz et al., 2011).

3. Methodology

Field observations

The preservation of most details of the original rock texture implies that serpentinization occurred under static conditions (Aswad et al., 2011). The studied serpentinite rocks of ZSZ include two types, sheared and massive. These rocks are fine-grained, appearing in olive color to black, with fine-grained, often variegated, light- to dark colored zones. Dark or white serpentine results from the alteration of olivine and orthopyroxene crystals. The green color of the studied rock is owing to the presence of iron oxide, which became darker with increased concentration of Fe-element (Mohammad et al., 2016). Transformation of mantle peridotite rocks into serpentinite is observed. This process is accompanied by a noticeable volume increase through the presence of a kernel pattern phenomenon, which is one of the complex periodic patterns of rocks (O'Hanley, 1996). The kernel pattern consists of green belts, highly transformed into serpentinite, surrounding or on the edges of a ring-like form that appears as a cuboid or parallelepiped rock that transformed to serpentinite (Fig. 2). Calcite is associated with some serpentine in veins. The calcite precipitation followed the serpentine formation. It is a dominant vein-filling mineral in the studied rocks. Calcite precipitated from seawater at temperatures around 10°C in open fractures in the peridotites; it is the final stage of hydrous events that occurred in peridotites (Agrinier et al., 1996).

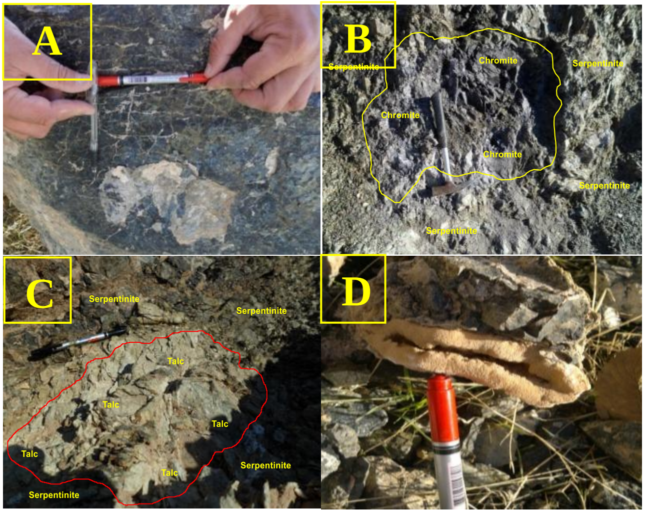

Fig. 2: Field observation. (A) Kernel patterns; (B) Chromite pods; (C) talc veins accompanying serpentinite rocks; (D) Calcite in veins representing secondary deposits.

Analytical techniques

Rock samples of Mawat ophiolite serpentinite rocks are washed with water in the laboratory to remove the altered surface weathering parts. For mineral identification, thin sections for all samples are prepared and investigated petrographically using a polarized microscope. XRD analysis is carried out for (6) selected samples using PAN Analytical's X'Pert PRO MPD device at Acme Lab Canada. Scanning electron microscopy (SEM) and energy-dispersive spectrometry (EDS) are used to determine the chemical composition of minerals for (4) selected samples using MICROSCAN MK5 (ESM/EDS) in the Water and Energy Research Centre, Al Al-Bayt University, Jordan. Operating conditions were 20 kV accelerating potential and 15 nA beam current. Probe size was normally 1–2 micrometers (serpentine 10 micrometers).

4. Petrography and Mineralogy

Thin–section study and XRD analysis are used for the descriptions of petrography and mineral types content in the studied rocks (Figs. 3, 4). Serpentinites are essentially composed of serpentine, as a by-product of altered original rocks (ultramafic rocks), with subordinate amounts of amphibole, talc, and chlorite as well as the relics of the original minerals such as olivine, pyroxene, chromite, and magnetite. Serpentine in the studied samples occurs in three types (antigorite, chrysotile, and lizardite) (Fig. 4). The most common mineral is antigorite. Serpentine has a green color as a result of alteration of precursor minerals (olivine and pyroxene), and appears as fine-grained groundmass containing fine crystals of the original minerals, elongated subhedral to euhedral crystals of pyroxene, and rounded crystals of olivine. Chrysotile has wavy extinction because it is subjected to tectonic processes. Serpentine minerals preserve the shape and arrangement of the original mafic minerals sometime after alteration. Serpentine has developed the well-known mesh texture after the alteration of olivine, which results from pyroxene containing bastite texture type. Amphibole occurs as elongated subhedral crystals that have a bright gray color, wavy extinction, high-order interference color, and cleavage surfaces parallel to the crystal length. The types of amphiboles are recognized as tremolite and anthophyllite (Fig. 4). The presence of amphibole, which results from pyroxene alteration in the groundmass of serpentine, refers to multiple stages of alteration. Fine-grained talc occurs in the groundmass with subhedral shapes, white color or colorless, and of high interference color. The presence of carbonate and talc reflects the presence of a CO2-bearing fluid in the late stage of the serpentinization process (Azer and Khalil, 2005). The opaque minerals in the studied serpentinites are represented mainly by chromite and magnetite. These minerals occur as disseminated subhedral to euhedral fine-grained crystals in the groundmass, showing varying colors of reddish brown.

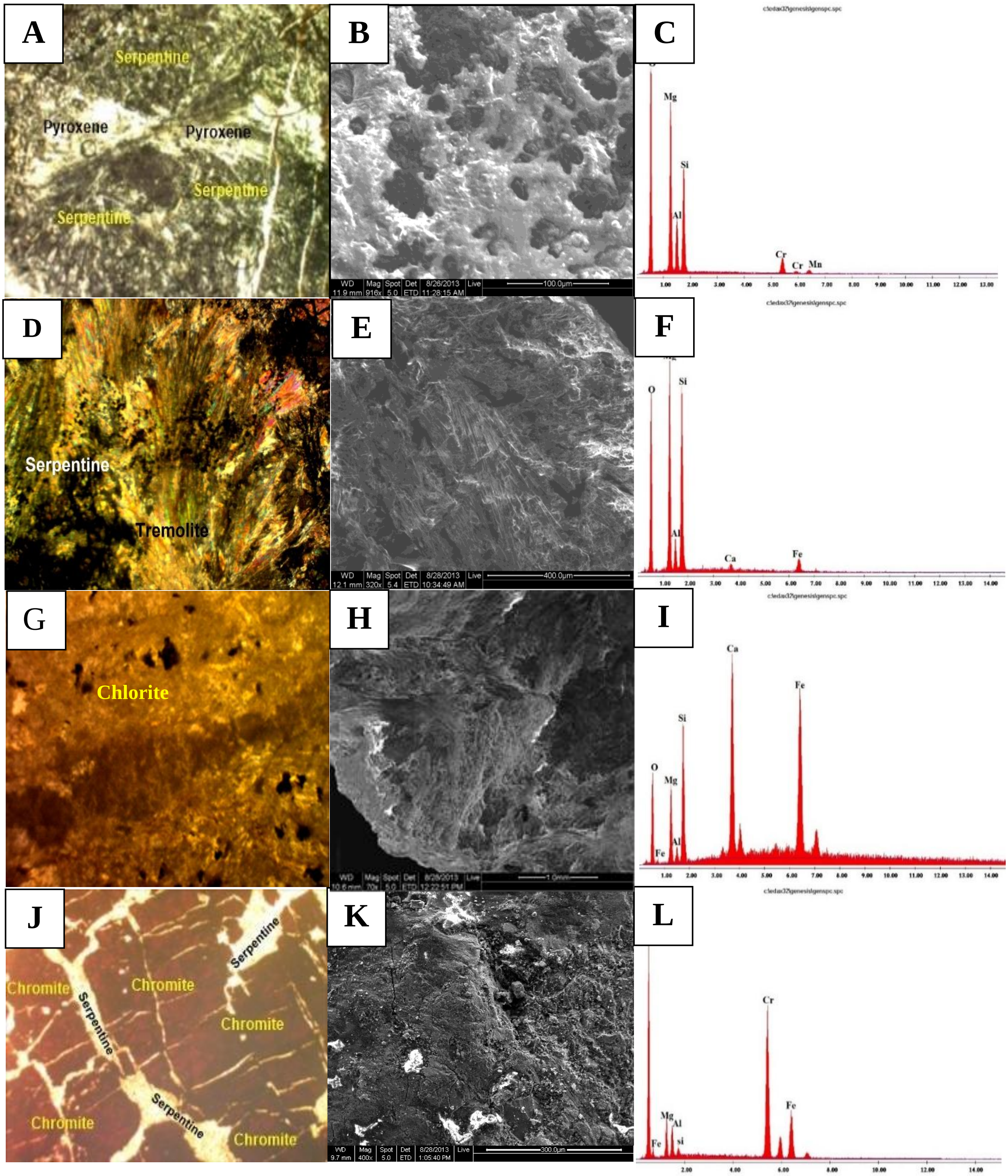

Fig. 3: Photomicrographs (crossed polars) and SEM/EDS patterns. (A, B, C) Serpentine; (D, E, F) Amphibole (tremolite); (G, H, I) Chlorite; (J, K, L) Chromite.

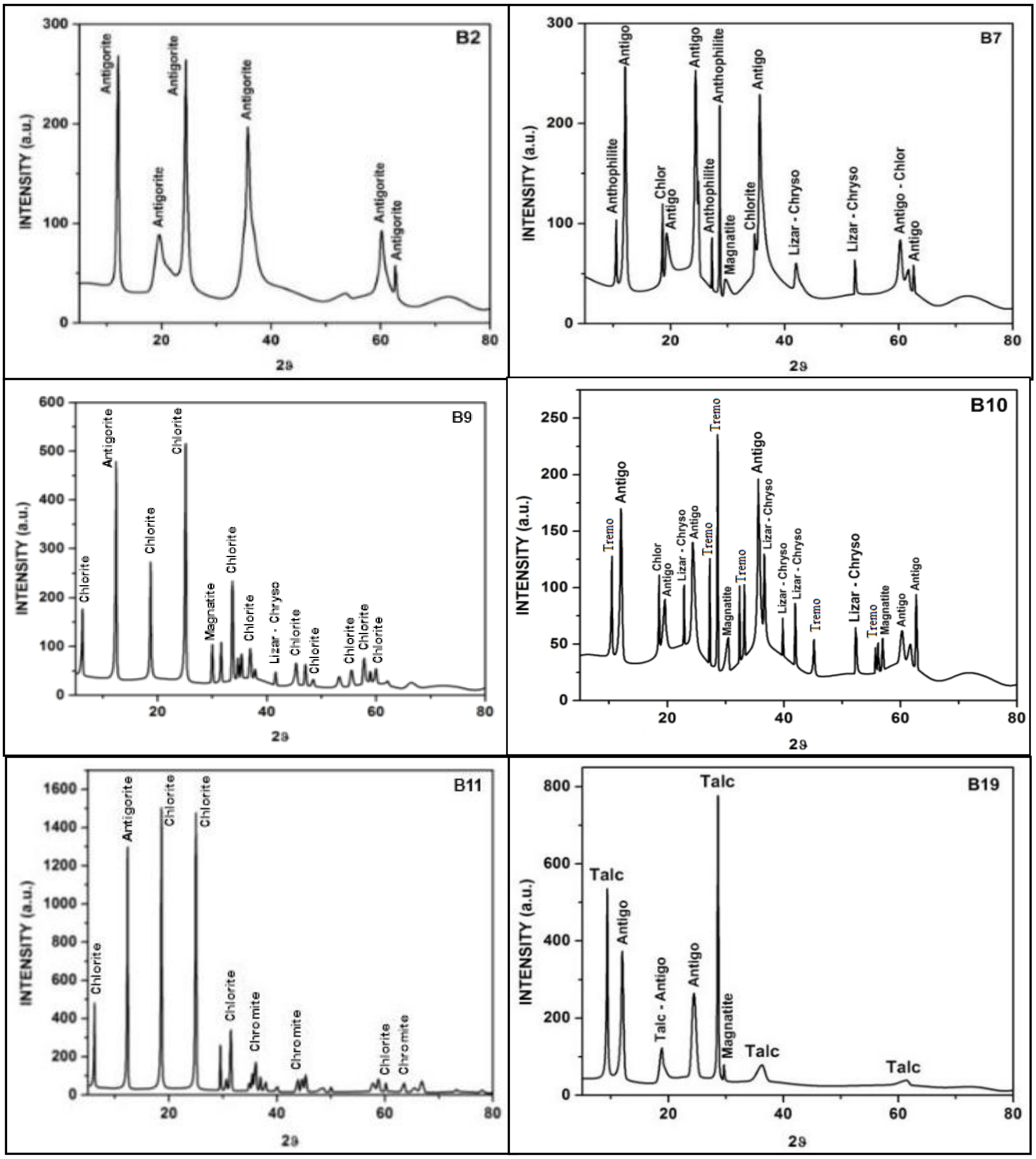

Fig 4: XRD diffractograms of representative serpentinite samples from Mawat complex ophiolite.

5. Mineral Chemistry

Serpentine

The chemical analysis results of the studied serpentine minerals are shown in Table 1. The chemical composition of serpentine minerals is variable because of different generations of serpentinization (Proenza et al., 2004). Analyzed serpentine minerals show high concentrations of SiO_2 and MgO, and low concentrations of other oxides (Table 1). According to Coleman (1971), serpentinite rocks are of two main petrological types: the first type is pseudomorphic serpentinite that contains predominantly lizardite with a smaller amount of chrysotile (developed via retrograde replacement of olivine and pyroxene minerals). The second type is antigorite-rich rocks (formed due to recrystallization of pseudomorphic serpentinites in a successive later progressive metamorphism stage). The binary diagram MgO-SiO_2 (Fig. 5A) shows that the investigated serpentine is a pseudomorphic type, and that refers to retrogressed precursor minerals that formed lizardite and chrysotile; then these minerals recrystallized by a progressive metamorphism process to form antigorite. The studied serpentine is presented on the Cr_2O_3-Al_2O_3 binary diagram (Fig. 5 B) to have various concentrations of Al_2O_3 and Cr_2O_3, which are identical to the Opx-bastite serpentines' constitution. This refers to dunite and harzburgite protolithic rocks. In Figure (5 C), the studied serpentine minerals filled in the prograde metamorphism characteristic that indicated the antigorite serpentine mineral (polymorph).

Table 1: Representative element dispersive spectrometry (EDS) analysis of the serpentine minerals. Chemical formula calculated based on 14 oxygen atoms, general formula (Mg, Fe2+)3Si2O5(OH)4.

Oxides%	B2(P1)	B2(P2)	B2 (P3)	B2(P4)	Average	Elements (*)
SiO_2	40.81	41.76	40.83	41.15	41.14	Si = 4.30
TiO_2	0.00	0.00	0.00	0.00	0.00	Ti = 0.00
Al_2O_3	2.33	2.21	2.28	2.25	2.27	Al = 0.28
Cr_2O_3	0.28	0.33	0.58	0.40	0.40	Cr = 0.03
FeO	3.27	8.06	6.45	5.82	5.90	Fe = 0.52
MnO	0.51	0.13	0.13	0.26	0.26	Mn = 0.02
MgO	39.96	40.93	36.13	38.97	39.00	Mg = 6.08
CaO	0.15	0.10	0.05	0.10	0.10	Ca = 0.01
Na_2O	0.00	0.00	0.00	0.00	0.00	Na = 0.00
K_2O	0.00	0.00	0.00	0.00	0.00	K = 0.00
Total	87.31	93.51	86.45	88.95	89.05	

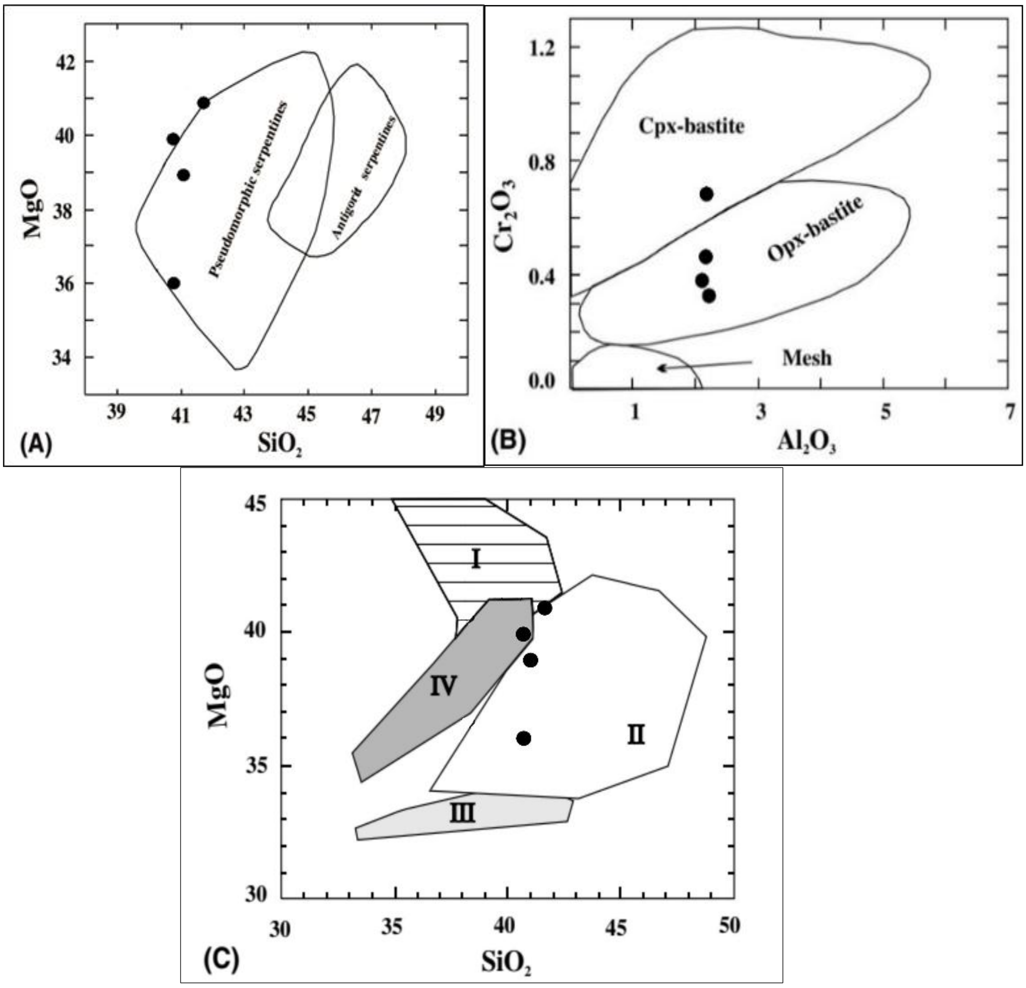

Fig. 5: Studied serpentines binary diagrams. (A) MgO-SiO_2 (Dungan, 1979); (B) Cr_2O_3-Al_2O_3 (Dungan, 1979); (C) MgO-SiO_2 (Wicks and Plant, 1979; I: Lizardite, magmatic olivine, II: Antigorite with interpenetrating texture, III: Antigorite with hourglass texture, IV: Lizardite, metamorphic olivine).

Amphibole

The chemical analysis results of amphibole minerals are shown in Table 2. Amphibole minerals are either primary minerals that crystallize from a magma or as alteration products of pyroxene. The amphibole minerals in the present study are of secondary origin resulting from the alteration of pyroxene. These occur as a minor interstitial phase in ultramafic rock of MOX (Ismail et al., 2010). The analyzed grains are very rich in SiO_2 and MgO. Using Leake et al. (1997) diagram, the amphibole grains are Mg-rich, which are represented by tremolite and magnesiohornblende phases as shown in Figure (6).

Table 2: Representative element dispersive spectrometry (EDS) analyses of the amphibole minerals, chemical formula calculated based on 23 oxygen atoms, general formula $Ca_2Mg_5Si_8O_{22}(OH)_2$.

Oxides	B7(P1)	B7(P2)	B7(P3)	B7(P4)	Average	Elements (*)	B7(P1)	B7(P2)	B7(P3)	B7(P4)	Average
SiO_2	54.94	54.57	56.59	55.54	55.41	Si	7.48	6.52	6.95	7.85	7.20
TiO_2	0.02	0.02	0.02	0.02	0.02	Ti	0.01	0.01	0.01	0.01	0.01
Al_2O_3	1.11	1.15	0.55	2.93	1.44	Al	0.09	0.09	0.04	0.24	0.11
FeO	1.73	1.73	2.17	2.55	2.05	Fe	0.20	0.20	0.24	0.29	0.23
MgO	30.64	32.49	30.90	29.10	30.78	Mg	6.22	6.63	6.21	5.95	6.25
CaO	10.18	7.50	8.47	8.05	8.55	Ca	1.46	1.10	1.22	1.18	1.24
Na_2O	0.00	0.00	0.00	0.00	0.00	Na	0.00	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	K	0.00	0.00	0.00	0.00	0.00
Total	98.62	97.46	98.70	98.19	98.24	Total	15.47	15.48	15.35	15.27	15.39

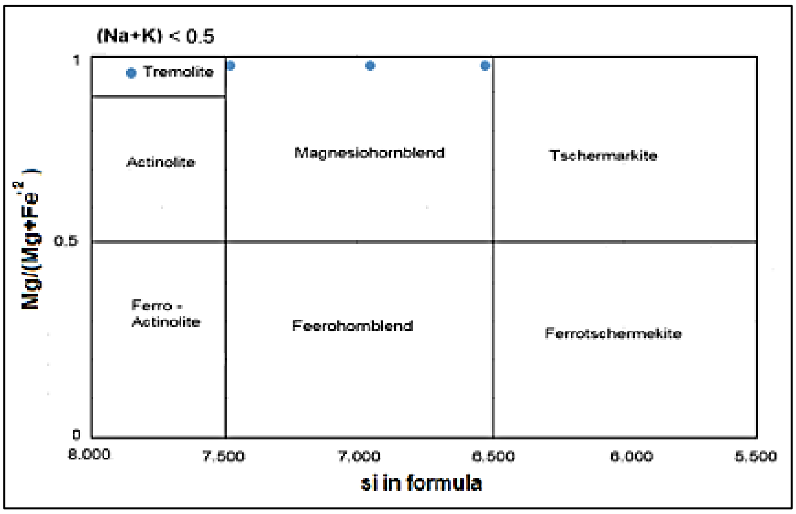

Fig. 6: Amphibole classification chart of serpentinite rock in Mawat Ophiolite (after Leake et al., 1997).

Chlorite

The chemical analysis results of the chlorite mineral are shown in Table (3). Studied chlorite grains are very rich in SiO_2 and MgO. The types of chlorites in the studied rocks are clinochlorite and talc-chlorite (Fig. 7). The Mg-rich chlorites are generally referred to as complete alteration of olivine minerals (Banerjee and Gillis, 2001).

Table 3: Representative element dispersive spectrometry (EDS) analyses of the chlorite minerals, chemical formula calculated based on 18-oxygen atom.

Oxides	B19(P1)	B19(P2)	B19(P3)	Average	Elements (*)	B19(P1)	B19(P2)	B19(P3)	Average
SiO_2	33.35	35.26	36.11	34.91	Si	7.06	7.19	7.36	7.20
TiO_2	0.03	0.03	0.02	0.03	Ti	0.01	0.01	0.01	0.01
Al_2O_3	12.15	12.88	13.12	12.72	Al	1.51	1.55	1.58	1.55
FeO	7.56	2.32	3.59	4.49	Fe	1.34	0.39	0.61	0.78
MgO	30.04	33.31	33.30	32.22	Mg	9.48	10.14	9.82	9.81
CaO	3.53	3.21	2.21	2.98	Ca	0.80	0.77	0.48	0.68
Na_2O	0.00	0.00	0.00	0.00	Na	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	K	0.00	0.00	0.00	0.00
Total	86.62	86.97	88.70	87.43	Total	20.19	20.04	19.85	20.03

(*) atoms per formula unit

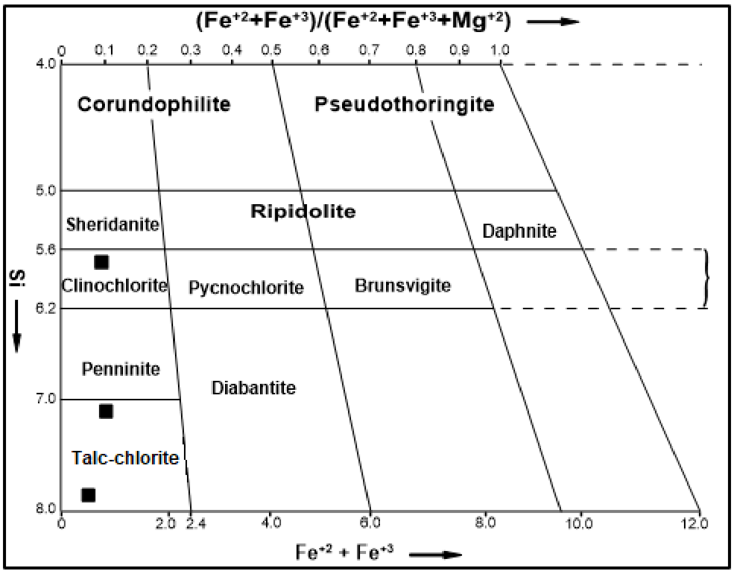

Fig. 7: Classification of chlorite of the present study (after Hey, 1954).

Chromite

Chemical analysis results representing chromite crystals of Betwat are given in Table (4). The chromite that has more than (18.10 wt. % FeO) is considered as ferritchromite (Azer and Khalil, 2005). It can be seen from Table (4) that the present chromite grains are rich in Fe_2O_3 and MgO. Chromites in the studied samples have high Cr_2O_3 relative to Al_2O_3, indicating type podiform chromitite (Fig. 8 A and B). The studied chromites have low amounts of aluminum compared to chromium, similar to ophiolitic podiform chromite, especially to those accompanying the dunite rock (Leblanc et al. 1980; Leblanc and Nicolas, 1992). Chromites in this study have high content of Cr#, indicating chemical compositions similar to chromian spinels in mantle-derived peridotites (Roeder, 1994). The invistigated chromites have high Fe_2O_3 (>21 wt%) and high TiO_2 concentration (>0.28 wt%) which indicate a podiform chromite (Leblanc et al., 1980; Leblanc and Nicolas, 1992) (Fig. 8 A and B).

Table 4: Representative element dispersive spectrometry (EDS) analyses of the chromite minerals, chemical formula calculated based on 4 oxygen atoms, general formula $FeCr_2O_4$.

Oxides	P1	B11(P3)	B11(P2)	Average	Element (*)	P1	B11(P3)	B11(P2)	Average
SiO_2	0.05	0.04	0.06	0.05	Si	0.0019	0.0015	0.0022	0.0019
TiO_2	1.19	1.30	1.18	1.22	Ti	0.0317	0.0352	0.0318	0.0329
Al_2O_3	3.94	3.26	3.13	3.44	Al	0.17	0.14	0.13	0.15
FeO	3.37	2.69	2.63	2.90	Fe^{+3}	4.36	5	5.34	4.86
Fe_2O_3	22.53	21.62	22.09	22.08	Fe^{+2}	0.72	0.69	0.71	0.71
MnO	0.33	0.1958	0.2047	0.2423	Mn	0.0098	0.0059	0.0062	0.0073
MgO	3.67	3.2344	3.3837	3.428	Mg	0.1944	0.173	0.1808	0.1828
CaO	0.02	0.0208	0.0315	0.0243	Ca	0.0008	0.0008	0.0012	0.0009
NiO	0.15	0.2031	0.1071	0.155	Ni	0.0044	0.0059	0.0031	0.0045
Cr_2O_3	66.43	68.6765	68.2751	67.7558	Cr	1.8675	1.948	1.9344	1.9163
Total	101.68	101.25	101.09	101.30	Total	7.3571	7.9993	8.3434	7.8575
			Mg #			0.043	0.033	0.033	
			Cr #			0.917	0.933	0.937	

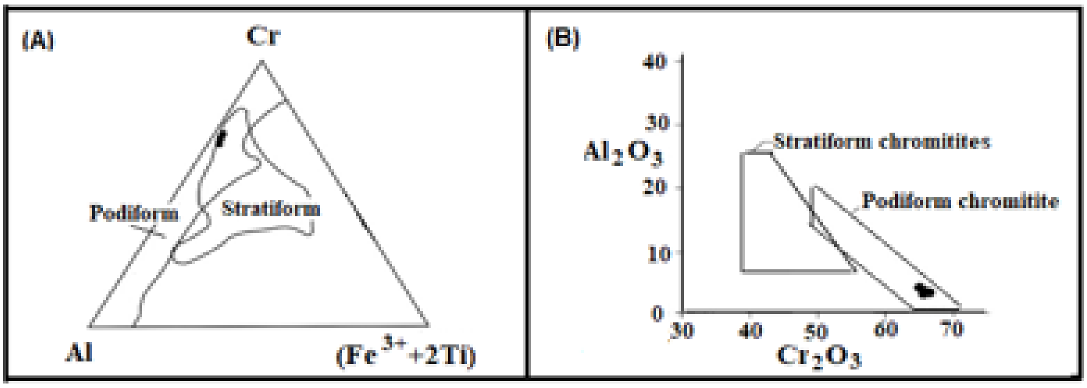

Fig. 8: (A) Cr–(Fe^{3+} + 2Ti)–Al diagram for the analyzed accessory chromite (Jan and Windley, 1990); (B) Al_2O_3 versus Cr_2O_3 for the analyzed accessory chromite.

6. Discussion

Studying serpentinite rocks in ZSZ reveals the relics of the original minerals such as olivine and pyroxene, indicating the ultramafic protoliths of the present serpentine rocks are probably harzburgite, dunite, and to a lesser extent, Iherzolite. The petrographic study of the serpentinite rocks in the study area shows that the secondary processes affected the original ultramafic rocks, represented by decomposition, transformation, and thermal change with different degrees. Some rocks were subjected to distortion or loss of their initial characteristics and the formation of secondary minerals that partially or completely replaced the primary components. The presence of calcite and talc minerals reflects the high CO_2- bearing fluid at the late stage of serpentinization. These observations were also recorded by Azer and Khalil (2005) and Mohammad (2011). The chlorite and amphibole are referred to low-temperature and low-pressure conditions (Deschamps et al., 2013). The alteration to serpentinites happened during many stages. Serpentinites in high–grade metamorphic regions indicate that antigorite is the predominant species in the final stage of serpentinization, where olivine mineral may disappear, and lizardite may be converted in massive serpentinite rock to chrysotile, and in serpentinites altered to antigorite (Mohammad, 2011). Depending on Al_2O_3 content in the mineral chemistry of serpentine, Bonatti and Michael (1989) discriminated the peridotites to different tectonic settings, where serpentinization and metamorphic processes do not significantly affect the aluminum. Al_2O_3 concentration becomes lower in peridotites from intracontinental rift (pre-oceanic) toward passive margins and mature ocean, and to subduction zone area. Investigated serpentinites rock possess low amounts of Al_2O_3 (0.38 – 1.58 wt%). Lizardite and chrysotile are the main polymorph phases that are present in low-grade serpentinites from the oceanic lithosphere and from low-grade metamorphic ophiolites (Schwartz et al., 2012). Experimental studies indicate that antigorite is the stable serpentine phase under high-pressure conditions (Reynard and Wunder, 2006;Schwartz et al., 2012). Lizardite and chrysotile are the main varieties that are present in low-grade serpentinites from the oceanic lithosphere and from low-grade metamorphic ophiolites. Thermodynamic data predict that above 300°C, the antigorite + brucite assemblage is more stable than lizardite, and chrysotile is absent (Evans, 2004). The availability of podiform chromites in the studied rock is typical of supra - subduction ophiolites (Kröner et al., 1987). The composition of chromite indicates the origin of magma, in addition to serving as a discriminator function between different tectonic settings (Ismail et al., 2010). The high Cr# and low TiO_2 content of chromite from the studied Mawat Ophiolite Complex (MOC) rock suggest a supra-subduction tectonic setting, maybe because containing boninite or high-Mg arc tholeiites (Ismail et al. 2010).

7. Conclusion

Based on the data presented in this study, we can infer the origin and nature of the serpentinite rocks in the MOC as a part of ZSZ. Calcite veins indicate high CO_2- bearing fluid in the serpentinization process. Serpentine minerals in the studied samples occur in three types: chrysotile, lizardite, and antigorite; the predominant type is antigorite. Petrologically, two main types are present: the first is a pseudomorphic serpentinite, composed predominantly of lizardite with a smaller amount of chrysotile that developed due to a later retrograde replacement of olivine and pyroxene via hydrothermal solution. The second type is antigorite that resulted from the recrystallization of pseudomorphic serpentinites during progressive metamorphism. The chemistry of serpentine minerals shows high MgO content; amphibole is an Mg-rich type represented in two types (tremolite and anthophyllite). Chlorite is talc-chlorite type with high MgO content. Chromite has high Cr_2O_3 percent relative to Al_2O_3, indicating chromitite. Low Al content compared to Cr is coincident with ophiolitic podiform chromite, especially in those accompanying the dunite rocks. High Cr# and Mg# in the studied sample are considered very likely, as a principal phase, which is identical with the chromian-spinels that are found in mantle-derived peridotites.

8. References

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بتروغرافية ومعدنية صخور السربنتين من معقد ماوات الاوفيولايتي في خط الدرز الزاغروسي، منطقة بيتوات، شمال شرقي العراق

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الملخص

الهدف من هذا البحث هو لدراسة صخور السربنتين في معقد ماوات من خلال استخدام الملاحظات الحقلية والبتروغرافية والمعدنية لتحديد التركيب المعدني والأصل والموضع التكتوني لكتلة الصخور فوق القاعدية من معقد ماوات الاوفيولايتي في منطقة زاغروس شمال شرقي العراق. وكانت عينات الصخور الخاضعة لعملية التحول الى سربنتين بالكامل تتميز بتجمع معدني من السربنتين مع بقايا من المعادن الاصلية مثل الأوليفين والبيروكسين، اضافة الى معادن أخرى ثانوية مثل الأمفيبول والتالك والكلواريت والكرومايت والماكنتايت. يظهر معدن السربنتين في ثلاثة أنواع هي (الكريسوتايل والليزاردايت والأنتيكورايت). المعدن الأكثر شيوعًا هو الأنتيكورايت، والذي يشير إلى مرحلتين من مراحل التحول الى سربنتين. الأولى هي تراجع المعادن الأصلية (الأوليفين والبيروكسين) عن طريق المحلول الحراري المائي إلى الكريسوتايل والليزاردايت، والمرحلة الثانية هي التحول التدريجي والذي أعاد بلورة هذه المعادن إلى أنتيكورايت. بينت كيميائية المعادن المدروسة أن السربنتين يحتوي على نسبة عالية من MgO ، خاصة في الأمفيبول –الغني بالمغنسيوم (نوع تريمولايت وأكتينولايت)، والكلورايت كان من نوع تالك –كلورايت والذي يشير إلى وجود نسبة عالية من أوكسيد المغنسيوم. يحتوي الكرومايت على نسبة مرتفعة من $Cr2O3$ مقارنة بمحتوى $Al2O3$ ، والذي يشير إلى الكروميتايت، وتدل نسب Al إلى Cr المنخفضة الى ان الكرومايت هو من نوع العقدي في معقد الاوفيولايت، خاصة ذلك الذي يظهر في الدونايت. المحتوى العالي من $Cr\#$ و $Mg\#$ يدل على ان البريدوتايت مشتق من الجبة.

الكلمات المفتاحية:

سربنتين، المعدنية، معقد الاوفيولايت، نطاق الالتحام، العراق.

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