

A Survey of the Hydrothermal Fluid Specifications in Ophiolitic Set of Sahneh-Harsin, Using Secondary Minerals for Determining the Metamorphosization-alteration Conditions

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Abstract: Kermanshah Ophiolite is an extremely crushed Ophiolitic complex in which a complete Ophiolitic sequence is not observed. Gabbros, dykes and mostly Serpentinized Peridotites are among the most important constituents of these Ophiolitic set. Peridotites existing in the study area are of metamorphosized types that have been severely affected by the hydrothermal solutions due to their extremely crushed conditions and have tolerated almost a severe alteration. Such decompositions and destructions result in creation of secondary minerals of the Serpentine group (Lizardite, Chrysotile, Antigorite), Talc, Magnesite and Brucite). A survey of the secondary minerals existing in the Peridotite show that the study area has been undergone a low temperature metasomatism at the green schist face level and then the region temperature has risen up to the Amphibiolitic face level due to metamorphosization. In this paper the conditions and the reactions relating to the formation procedure of any of the above said minerals have been surveyed.

Key words: Hydrothermal Fluid • Sahneh-Harsin • Ophiolitic • Serpentine • Peridotite

INTRODUCTION

The Alpine-Himalayan system, having been created in Mesozoic- Cenozoic era, is a classic system of continent junction. This orogeny band has been constituted from numerous Ophiolitic sets that have been identified and studied in Iran and the vicinity areas (Figure 1). The study area is a part of the set renowned as Kermanshah Ophiolite-Radiolite band that starts from the Sahneh-Harsin region, south-east of Kermanshah Province and continuous towards the north-west, running parallel to the Zagros trust. Hence, this section is known also by the independent name of Sahneh Ophiolite.

MATERIALS AND METHODS

Initial field works like preliminary visit and providing photos from the area for better recognition of the region were done. Next, main visits of the whole area under study together with systematic sampling of the specified sections were performed. A number of 65 samples out of

the whole gathered samples were selected and thin sections of them were provided for accurate petrographic studies and determining the ore types existing in the region as well as investigating the secondary minerals contained in them using Polarizing microscope. Finally chemical analyses of 16 samples were carried out using XRF method (In Kansarn Binalood Company and Ferdowsi University of Mashhad) and 2 samples using XRD method (In Geological Survey of Iran and Bu-Ali Sina University). The analysis results then were given to the Newpet and JCD Kit software and the related graphs were produced.

DISCUSSION

Little information exists about the nature of the transfers among the hydrothermal-magma solutions, in oceanic hydrothermal systems and especially in new oceanic crust [2]. Meanwhile petrological and geochemical study of Ophiolites in inter-oceanic mounds is an important key for understanding the alteration/hydrothermal metasomatism processes [3].

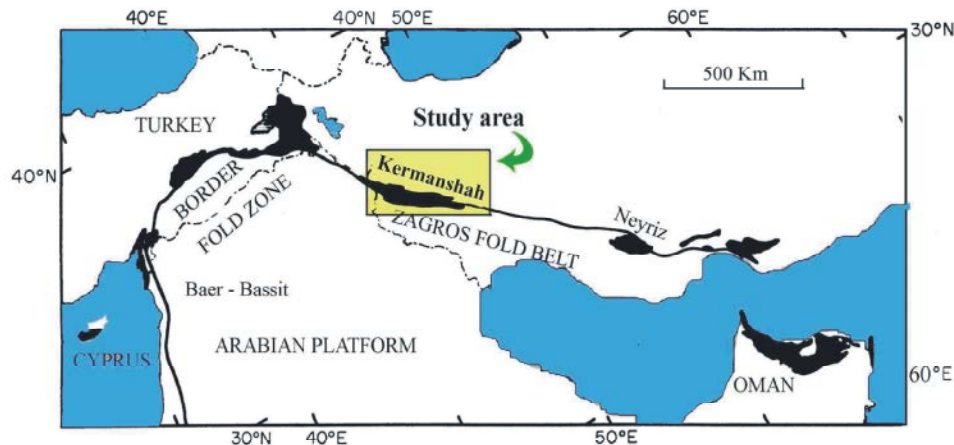


Fig. 1: Scattering map of the Iran Ophiolites and distribution scheme of the cretaceous neotetise Ophiolites running in the direction of Zagros-Betlise zone [1].

Table 1: Main Oxides and rare elements contents in ultramafic samples of Kermanshah Ophiolite sequence (XRF Method has been carried out)

Oxides	7-B-S	5-B-S	24-C-S	4-A-S	16-B-S	4-F-H	21-F-H
SiO ₂	41.39	41.26	39.71	39.67	41.41	37.61	38.13
TiO ₂	0.02	0.01	0.01	0.49	0.01	0.02	0.51
Al ₂ O ₃	0.74	0.11	0.69	4.51	0.33	0.56	3.92
Fe ₂ O ₃	9.71	8.24	7.63	12.41	9.60	8.30	6.18
MgO	34.98	35.94	37.29	27.73	40.65	39.38	36.56
MnO	0.14	0.12	0.11	0.17	0.13	0.11	0.22
CaO	3.25	0.19	0.56	7.52	0.92	1.30	0.86
Na ₂ O	0.01	0.01	0.01	0.41	0.10	0.10	0.08
K ₂ O	0.01	0.01	0.01	0.10	0.01	0.01	0.01
P ₂ O ₅	0.01	0.01	0.00	0.02	-	-	0.01
Trace Element, ppm							
Ni	2432	2744	2339	0.09	-	0.24	0.16
Pb	7	6	3	-	-	-	-
Rb	6	6	3	-	-	-	-
Sr	61	9	9	0.01	-	-	-
V	45	34	42	0.02	-	-	-
W	-	-	-	-	-	-	-
Y	6	6	7	-	-	-	-
Zr	10	8	8	-	-	-	0.02
Zn	47	43	42	0.01	-	-	0.01
Ba	12	-	-	0.08	0.07	0.06	0.06
La	-	-	-	-	-	-	-
Cs	-	-	-	-	-	-	-
Ce	-	29	-	-	-	-	-
Co	84	84	72	0.02	0.02	0.01	0.01
Cr	2441	2166	2315	0.34	0.41	0.33	0.11
Cu	3	-	-	0.01	0.01	0.01	0.01
Nb	0	4	-	-	-	-	-
Mo	4	1	3	-	-	-	-
U	6	5	-	-	-	-	-
Th	-	-	1	-	-	-	-
Cl	70	145	125	0.08	0.03	0.15	0.04

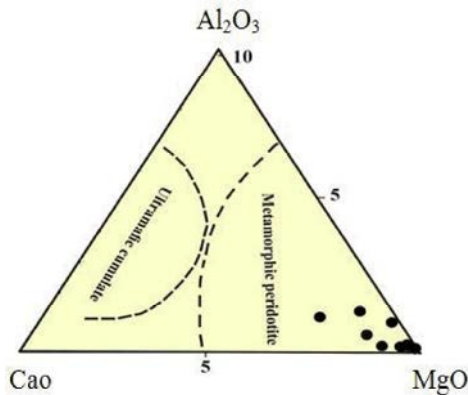


Fig. 2: A graph of (Al₂O₃- MgO- CaO) for studying the Pridotites of the area under study [4]

Ophiolites are important resources of acquiring information about the hydrothermal processes in oceanic crust. Considering the fact that the Ophiolitic set of Iran in most parts, especially in study area is extremely crushed, it has been intensely influenced by the hydrothermal solutions and has tolerated severe alterations. This decompositions and destructions have resulted in creation of secondary ores and minerals. Studying the type and progress of the secondary minerals can help in estimating the alteration and metamorphosization degree of the Ophiolites in the region. The analysis results (Table 1) of the region under study shows that the ultramafic samples are categorized under the metamorphosized category taking notice of the secondary mineralogy combination. These, having been metamorphosized in orogeny regions, are known as Alpine (Figure 2). Based on this, the most important secondary minerals and their chemical properties in

ultramafic ores of the Sahneh-Harsin are studied in this section of the paper for better understanding of the metamorphic processes of the oceanic floor.

Mineralogy and Chemical Properties of the Secondary Minerals: This section deals with the types of secondary minerals and their formation procedure under the static conditions. The predominant minerals of the region include the Serpentine group minerals (Lizardite, Chrysotile, Antigorite) and to a limited extent, other secondary minerals such as Talc, Chlorite, Carbonates and Brucites.

Serpentine: Serpentinites in the region under study are mainly mass Serpentinites relating to the static Serpentinization. The major part of the Serpentinites include Chrysotile and to a lesser extent, Lizardite and Antigorite which is observable in Serpentinite sections of the region, dealt with below in one by one discussion of the minerals.

Table 1- Main Oxides and rare elements contents in ultramafic samples of the area under study (XRF Method).

Lizardite: Lizardites introduce low temperature Serpentinites, usually stable in temperatures below 250°C and frequently visible in low grade metamorphosizations at green schist face level, that transform into high temperature polymorphs (Serpentine) due to progressive metamorphosization, just above the green schist face level. Lizardites in microscopic sections basically appear as disordered layers [5]. In microscopic sections of the study samples also the lizardites can be seen as white layers with little frequency (Figure 3a).

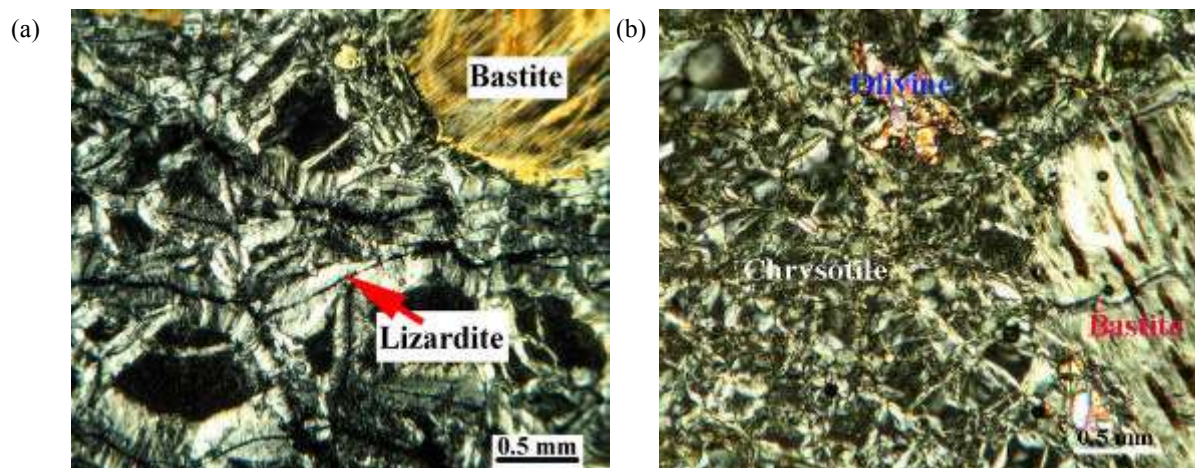


Fig. 3a,b: (a) Microscopic illustration of the Lizardite and, (b) Chrysotile minerals in Serpentinites sections of the study area. The light of microscope is XPL.

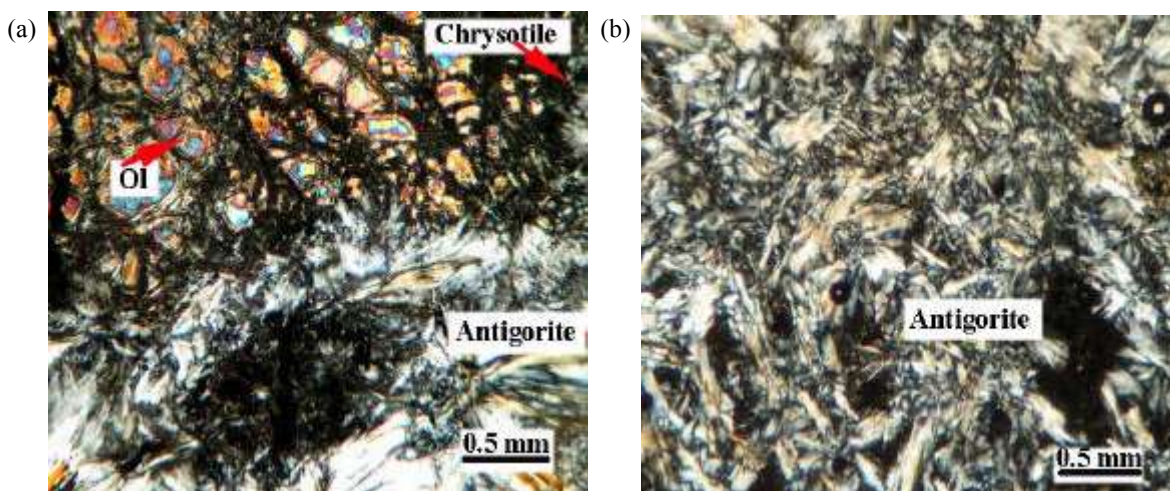
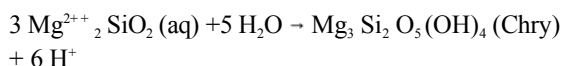
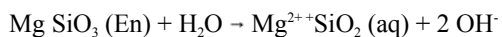
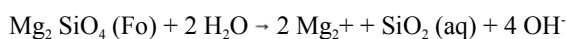


Fig. 4: Microscopic image of the Antigorite mineral in Serpentinites of the region under study. The light of microscope is XPL.

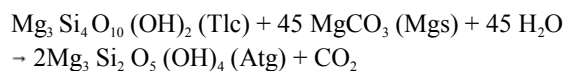
Chrysotile: In thin sections of the samples, the Chrysotile is seen as green crossing fibers, causing a lattice texture. Principally such textures are secondary and have taken form because of re-crystallization (Figure.3b). Chrysotiles also take form in low temperature static alteration process as a result of hydrothermal solutions with mafic minerals like Olivine and pyroxene. Chrysotiles take form under the intermediate green schist face conditions and then create high temperature polymorph of Serpentine (Antigorite) under the progressive alteration up to above green schist face. It must be mentioned that Chrysotiles are the predominant mineral of the mass Serpentinites [5], a fact which is also confirmed in the study area. Considering the point that the predominant Serpentine mineral in the region is Chrysotile, it can be inferred that the temperature in the study area has probably risen up to the green schist face level [6]. Presence of the Chrysotiles in form of crossing fibers in other Serpentine minerals context indicates retardant formation of the Chrysotiles under the static conditions [5] again obviously observable in Serpentinized sections of the region. The following potential reaction is proposed for Chrysotile formation from Olivine and Enstatite in ultramafic ores of the region:



In the above reaction, together with decrease of SiO_2 and increase of PH, the Chrysotile is formed in retardation phase and under the static conditions.

Antigorite: Antigorites shape in high temperature regional metamorphosization; in other words, Antigorite Serpentinization takes place as a result of ultramafic minerals reaction with deep altered hydrothermal solutions [7]. In the area under study the Lizardite and Chrysotile have first been created under low temperature metasomatism at green schist face level and then have been converted into Antigorite due to metamorphosization up to Amphibolite face level [8]. Considering the fact that Serpentinites of the region under study show a lattice and bassetitic texture, it can be inferred that the bedrock of the Serpentinites must be Harzburgite. In Serpentinites with Harzburgite bedrock, the Antigorites are found with lesser frequency; meanwhile the Polymorphic Chrysotiles are predominant in them [9]. In microscopic sections, this mineral is seen as knife and needle shaped white crystals (Figure 4).

The below possible reaction is proposed for Antigorite formation of the study area:



So the Antigorites have taken form in low XCO_2 and water rich fluid conditions in approx. 350°C temperature. As the re-formation of the Forsterites and Enstatites from Antigorites need a temperature more than 350°C and

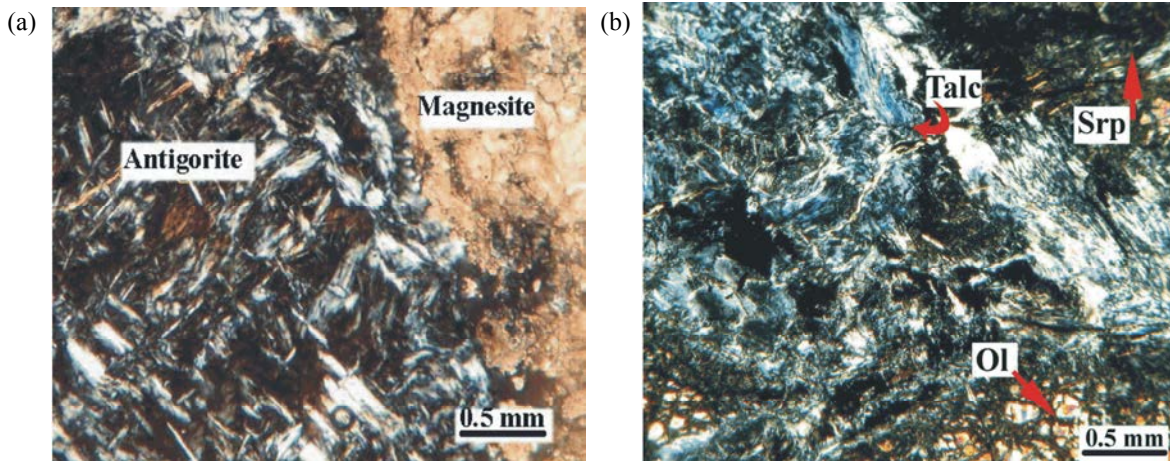
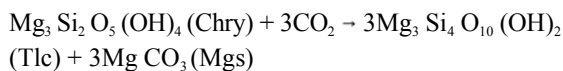


Fig. 5: Microscopic image of the Talc and Magnesite mineral in a Serpentinites sample. The light of microscope is XPL.

because no evidence has been found regarding reformation of such minerals in the region under study, so it can be said that the temperature might not have gone higher than 350°C.

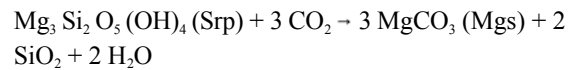
Talc: Talc is an aqueous magnesium silicate. In ultramafic ores of the region under study, the Talc is formed by hydrothermal cycles and under the low temperature conditions up to the green schist face level, mostly in shear zones [10]. In other words, simply as a result of CO₂ addition, the Serpentine set can be converted into Talc. The Talc mineral in microscopic sections of the Serpentinites of the area under study is found in little amount in white laminated form among Serpentine minerals (Fig. 5). The proposed reaction for talk formation in the region is described below:



Carbonate: Carbon mineral in earth mantle exists in the form of hydrothermal fluid solutions that have taken form in upper mantle as the result of interaction between CO₂ existing in these fluids with Silicates and Carbonates which are the most important form of carbon[11]. Ca and Mg rich ores like Pridotites and Serpentinites are needed for producing large amounts of Carbonate minerals; so that ores with high content of MgO are suitable for reaction with CO₂ and producing carbonate minerals [12]. CO₂ rich fluids are altered from the oceanic shell and move in depth towards the Serpentinite mass and react with them. As the Serpentinites are Mg rich ores and have

great potential for reacting with CO₂, they react with CO₂ rich hydrothermal fluids, the most predominant product of which being the Magnesite carbonate minerals visible in the sections of the region under study, especially the Serpentinites (Figure 5).

The following reaction is proposed for Magnesite formation in sections of the study area.



Iddingsite: Iddingsite is among the secondary minerals existing in the study area sections being totally or partially pseudomorph Olivine. Iddingsites in Serpentinite sections are seen in form of thin brown knives with or without average birefringence besides the Antigorites (Figure 6b).

Brucite: Brucite is a secondary mineral which is created because of the alteration process in the Serpentinites, Talc schists and Chlorite schists. The Brucite mineral in the study area has taken form in Serpentinite ores. So the presence of the Brucite is evidence showing that the Serpentinization process takes place at the price of Olivine mineral. The Harzburgite with more Olivine content than the Pyroxene creates some Brucite during Serpentinization [4]. For the same reason in Dunites and Harzburgite, high concentrations of Olivine form the Serpentine-Brucites. Gonarson and *et al.*, determined that the Brucite may take form in thermal range of 5 to 350°C. In Serpentinite sections of the area under study, the Brucite is seen as circular colorless mineral (Figure 7).

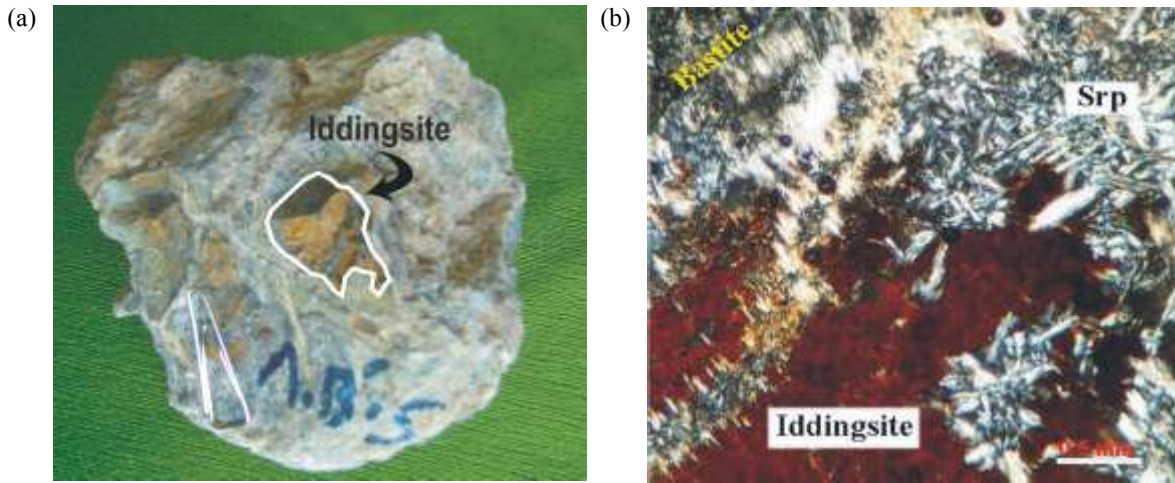


Fig. 6: Macroscopic (a) and microscopic image (b) of the Iddingsite mineral in Serpentine Harzburgite in study area. B: The light of microscope is XPL.

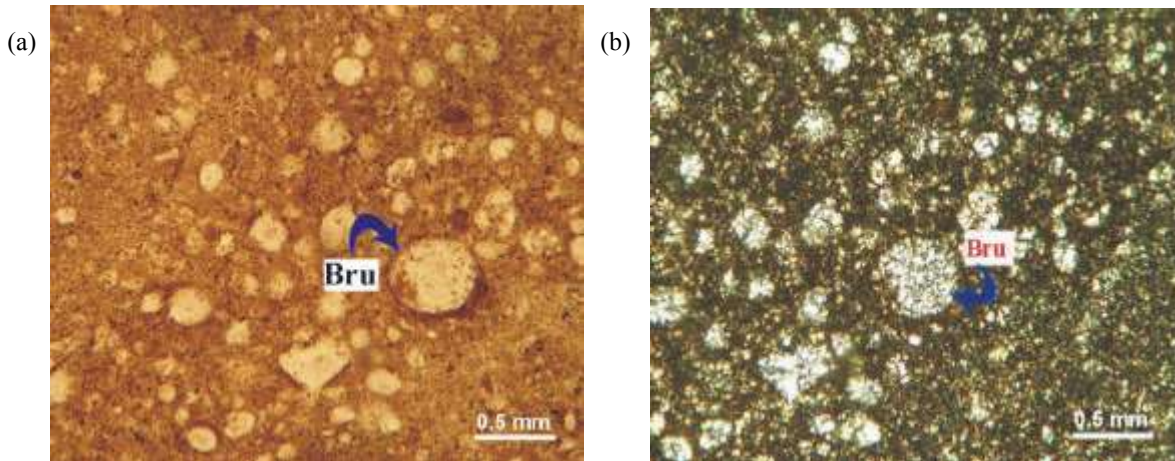


Fig. 7: Microscopic image taken from the Brusite vein in Serpentinites of the area under study; A: The light of microscope is XPL. B: The light of microscope is PPL. (Bru: Brucite)

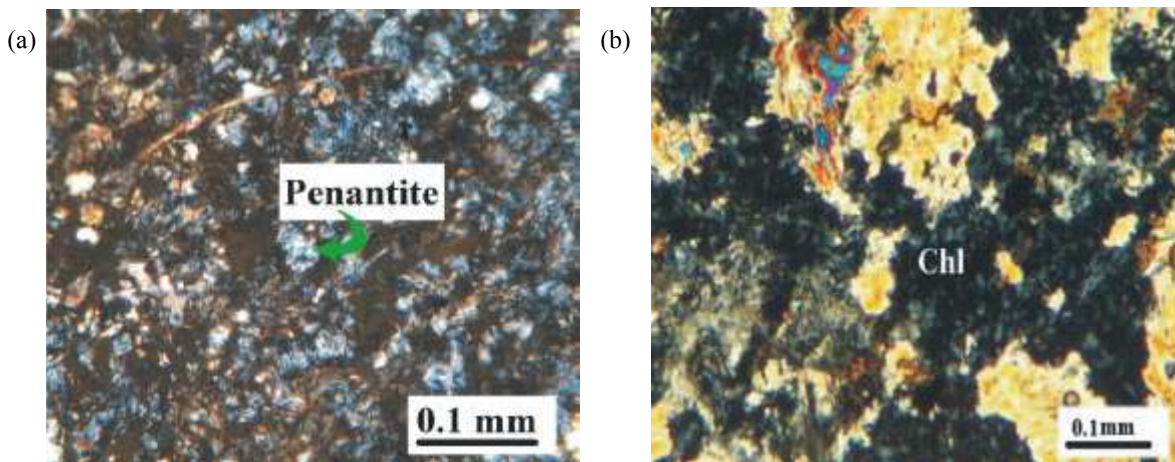
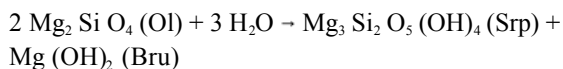


Fig. 8: Microscopic image of the Clinocllore and Penantite in ultramafic ores of the area under study. The light of microscope is XPL.

The following reaction is proposed for Brucite formation in sections of the study area:



Chlorite: Chlorites of the area under study are of Magnesium rich Chlorites like Penantite and Clinoclors (Figure 8). In other words, The Chlorites compounds in ultrabasic ores of the region show that hydrothermal alteration has been occurred under the green schist face conditions in 200-350°C.

CONCLUSIONS

Peridotites existing in the study area are of metamorphosized types that have been severely affected by the hydrothermal solutions due to their extremely crushed conditions and have tolerated almost a severe alteration. Such decompositions and destructions result in creation of secondary minerals including Lizardite, Chrysotile, Antigorite, Talc, Magnesite, Iddingsite and Brucite. A survey of the secondary minerals existing in the Pridotites show that the study area has been undergone a low temperature metasomatism at the green schist face level and then the region temperature has risen up to the Amphibolite level due to metamorphosization, causing formation of high temperature minerals like Antigorite.

REFERENCES

1. Ghazi, M.A. and A.A. Hassanipak, 1999. Geochemistry of Subalkaline and Alkaline extrusives from the Kermanshah Ophiolite, Zagros suture zone, Western Iran: implication for Tethyan plate tectonics, *Journal of Asian Earth Science*, 17: 319-332.
2. Gills, K.M. and M.D. Roberts, 1998. Cracking at the magma-hydro thermal transition; evidence from the Troodos Ophiolite, Cyprus. *Earth and Planetary Sciences letter*, 169: 227-244.
3. Shibuya, T., T. Komiya, R. Anma, T. Ota, S. Omori, Y. Kon, Sh. Yamamoto and Sh. Maruyama, 2007. Progressive metamorphism of the Taitao Ophiolite; evidence for axial and off-axis hydrothermal alteration, *Lithos*, 98: 233-260.
4. Coleman, R.G., 1971. Petrologic and Geophysical nature of serpentinite. *Geology Society of American Bulletin*, 82: 897-918.
5. Azer, M.K. and A.E.S. Khalil, 2005. Petrological and mineralogical studies of Pan-African serpentinites at Bir Al-Edeid area, central Eastern Desert, Egypt. *Journal of African Earth Sciences*, 43: 525-536.
6. Auzende, Al., S. Guillot, B. Bevuard and A. Baronnet, 2006. Serpentinites in an Alpine convergent setting; Effect of metamorphic grade and deformation on microstructures. *European Journal of Mineralogy*, 18: 21-33.
7. Deer, W.A., R.A. Howie and J. Zussman, 1982. *Rock-Forming minerals (Orthosilicates)*. Longman New York
8. Li, X.P., M. Rahn and K. Bucher, 2004. Metamorphic processes in rodingites of the Zermatt-Saas Ophiolites. *International Geological Review*, 46: 28- 51.
9. Gahlan, H.A., Sh. Arai, A.H. Ahmed, Y. Ishida, Y.M. Abdel-Aziz and A. Rahimi, 2006. Origin of magnetite veins in serpentinite from the Late Proterozoic Bou- Azzer Ophiolite, Anti- Atlas, Morocco: An implication for mobility of iron during Serpentinization. *Journal of African Earth Sciences*, 46: 318-330.
10. Boschi, C., G.L. Frush-Green and J. Escartny, Occurrence and significance of Serpentinite-hosted, Talcand Amphibole-rich fault rocks in modern Oceanic settings and Ophiolite Complexes. *Ophiolite*, 31: 129-140.
11. Liu, L.G., 2004. Effect of CO₂ on the phase behavior of the Enstatite- forsterite system at high pressures and temperatures. *Physics of the Earth and Planetary Interiors*, 146: 261-272.
12. Cipolli, F., B. Gambardella, L. Marini, G. Ottonello and M.V. Zuccolini, 2004. Geochemistry of high-PH waters from Serpentinites of the Gruppo di Voltri (Genova, Italy) and reaction path modeling of CO₂ sequestration in serpentinite aquifers. *Applied Geochemistry*, 19: 787-802.