Using secondary minerals in Sahneh ophiolitic complex, west Iran

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Abstract

Kermanshah ophiolite is an extremely crushed ophiolitic complex in which a complete ophiolitic sequence is not observed. Gabbros, deloritc dikes and mostly serpentinized peridotites are among the most important constituents of these ophiolitic set. Pridotites 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), clorite, talc, magnesite, iddingsite and brusite). 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 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.

Keywords: Metamorphosization, Ophiolitic complex, Secondary minerals, Serpentine group.

1- Introduction

The Alpine-Himalayan system, having been created in mesozoic- cenozoic era, is a classic system of continent junction (Yin, 2006). This orogeny band has been constituted from numerous ophiolitic sets that have been identified and studied in Iran and the vicinity areas (Fig. 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.

2- 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 plarizan microscope. Finally chemical analyses of 16 samples were carried out using XRF method and two samples using XRD method . The analysis results then were given to the Newpet and JCD Kit software and the related graphs were produced (Fig. 2).

Little information exists about the nature of the transfers among the hydrothermal-magma solutions, in oceanic hydrothermal systems, and especially in new oceanic crust (Gills and Robert, 1998). Meanwhile petrological and geochemical study of ophiolites in inter-oceanic mounds is an important key for understanding the alteration/hydrothermal metasomatism processes (Shibuya *et al.*, 2007).

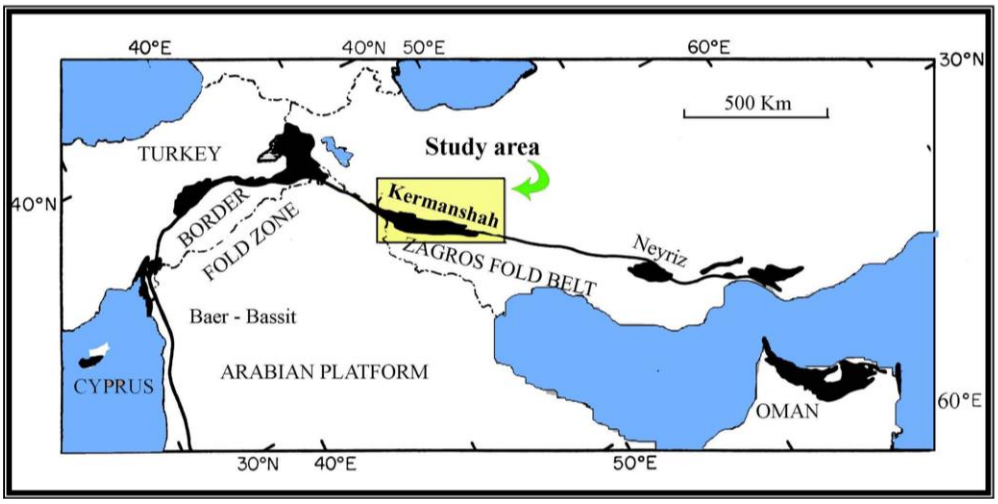

Figure 1) scattering map of the Iran ophiolites and distribution scheme of the cretaceous neotetise ophiolites running in the direction of Zagros-Betlise zone (Modified from Ghazi and Hassani Paak, 2000).

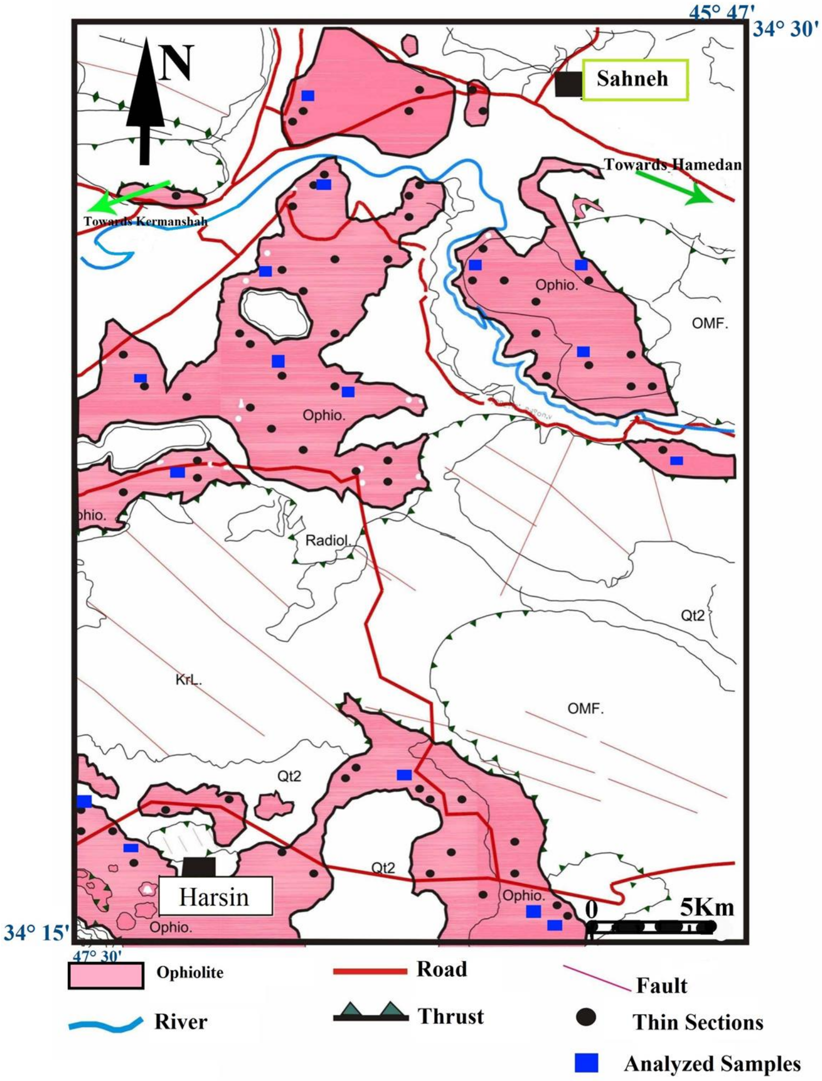

Figure 2) 1:50000 geological map of the study area, sampling points and the analyses performed (Modified from Hosseinidoust, 1385).

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 pridotites of the region under study shows that the ultramafic samples are categorized under the metamorphosized Pridotites category taking notice of the secondary mineralogy combination. These Pridotites, having been metamorphosized in orogeny regions, are known as Alpine Pridotites (Fig. 3). Based on this, the most important secondary minerals and their chemical properties in ultramafic ophiolites ores of the Sahneh-Harsin are studied in this section of the paper for better understanding of the metamorphic processes of the oceanic floor.

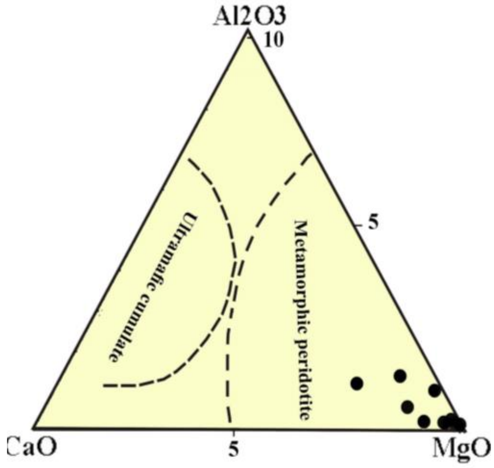

Figure 3) Al_2O_3- MgO- CaO graph for studying the Pridotites of the area under study.

Table 1) Main Oxides and rare elements concentrations in ultramafic samples (XRF).

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_2O_3	0.74	0.11	0.69	4.51	0.33	0.56	3.92
Fe_2O_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_2O	0.01	0.01	0.01	0.41	0.10	0.10	0.08
K_2O	0.01	0.01	0.01	0.10	0.01	0.01	0.01
P_2O_5	0.01	0.01	0.00	0.02	-	-	0.01
LOI	8.64	9.24	9.32	5.51	5.82	9.73	10.5
Total	98.91	95.24	95.34	98.54	98.98	97.12	96.98
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

3- 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, brusites, and iddingsite.

4.1- Serpentine

Serpentinites in the region under study are mainly 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.

4.1.1- 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 mostly appear as disordered layers (Azar and Khalil, 2005). In microscopic sections, lizardites can be seen as white layers with little frequency (Fig. 4a).

4.1.2- chrysotile

In thin sections of the samples, chrysotile is seen as green crossing fibers, causing a lattice texture. Such textures are secondary and have taken form due to recrystallization (Fig. 4b). chrysotiles also take form in low temperature static alteration process because of hydrothermal solutions with mafic minerals like olivine and pyroxene. chrysotiles formed 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 (Ouzbend *et al.*, 2006). It must be mentioned that chrysotiles are the predominant mineral of the mass serpentinites (Azar and Khalil, 2005), 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. Presence of the chrysotiles in form of crossing fibers in other serpentine minerals context indicates retardant formation of the chrysotiles under the static conditions (Azar and Khalil, 2005), again obviously observable in serpentinized sections of the region.

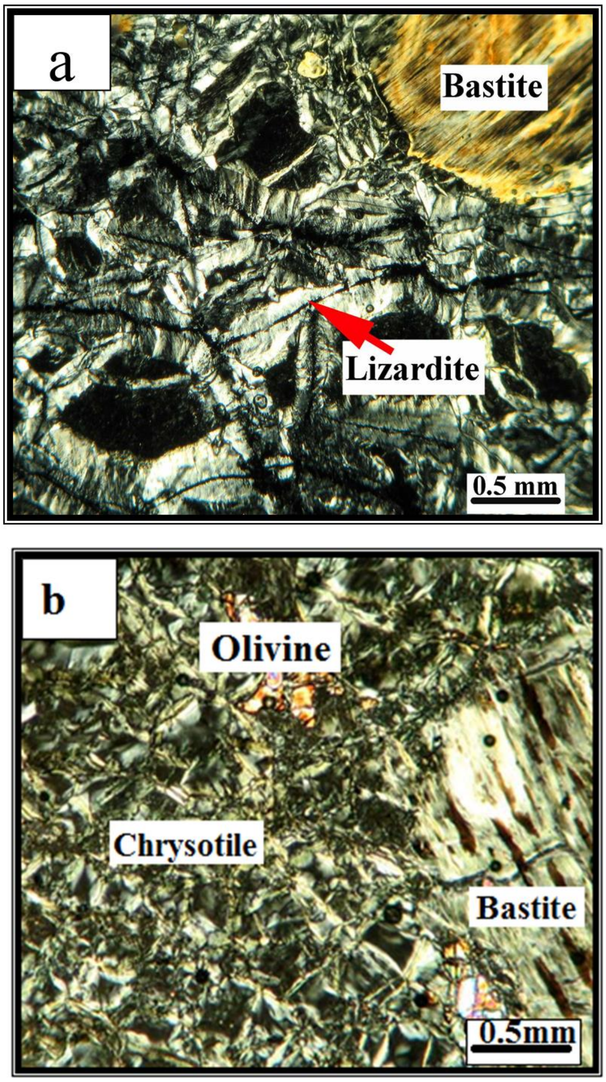

Figure 4) Microscopic illustration a) Lizardite and chrysotile; b) minerals in serpentinites sections of the study area (XPL).

The following potential reactions are proposed for chrysotile formation from olivine and enstatite in ultramafic ores of the region:

1- $Mg_2SiO_4\ (Fo) + 2H_2O \rightarrow 2Mg^{+}_{2} + SiO_2\ (aq) + 4OH^{-}$

2- $MgSiO3\ (En) + H_2O \rightarrow Mg^{+}_{2} + SiO_2\ (aq) + 2OH^{-}$

3- $3Mg^{+}_{2} + 2SiO_2\ (aq) + 5H_2O \rightarrow Mg_3Si_2O_5(OH)_4\ (Chry) + 6H^{+}$

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.

4.1.3- 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 (Dyyre, *et al*., 2004). 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 (Lee *et al*., 2004). Considering the fact that serpentinites of the region under study show a lattice and bassetitic texture, it can be infer 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 (Gehlan *et al*., 2006). In microscopic sections, this mineral is seen as knife and needle shaped white crystals (Fig. 5).

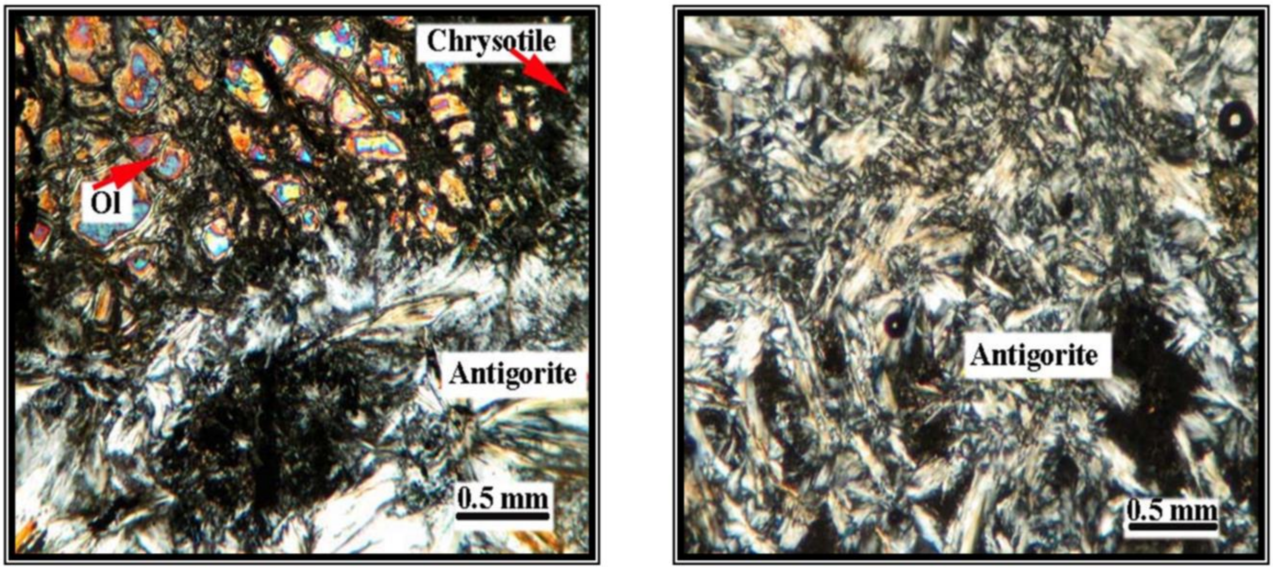

Figure 5) Microscopic image of the antigorite mineral in serpentinites of the region under study (XPL).

The following reaction is proposed for antigorite formation of the study area:

$Mg_3Si_4O_{10}(OH)_2\ (Tlc) + 45MgCO_3(Mgs) + 45H_2O \rightarrow 2Mg_3Si_2O_5(OH)_4\ (Atg) + CO_2$

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

4.2- Talc

Talk is an aqueous magnesium silicate with $Mg_3Si_4O_{10}\ (OH)_2$. In ultramafic ores of the the study area, the talc is formed by hydrothermal cycles and under the low temperature conditions up to the green schist face level, mostly in shear zones (Bouschi *et al*., 2006). In other words, simply as a result of CO_2 addition, the serpentine set can be converted into Talk. The talk 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. 6). The proposed reaction for talk formation in the region is described below:

$Mg_3Si_2O_5(OH)_4$(Chry) + $3CO_2 \rightarrow 3Mg_3Si_4O_{10}(OH)_2$ (Tlc) + $3MgCO_3$ (Mgs)

4.3- Carbonate minerals

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 CO_2 existing in these fluids with silicates and carbonates which are the most important form of carbon (Liu, 2004). 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 CO_2 and producing carbonate minerals (Cipoli *et al.*, 2004). CO_2 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 CO_2, they react with CO_2 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 (Fig. 6).

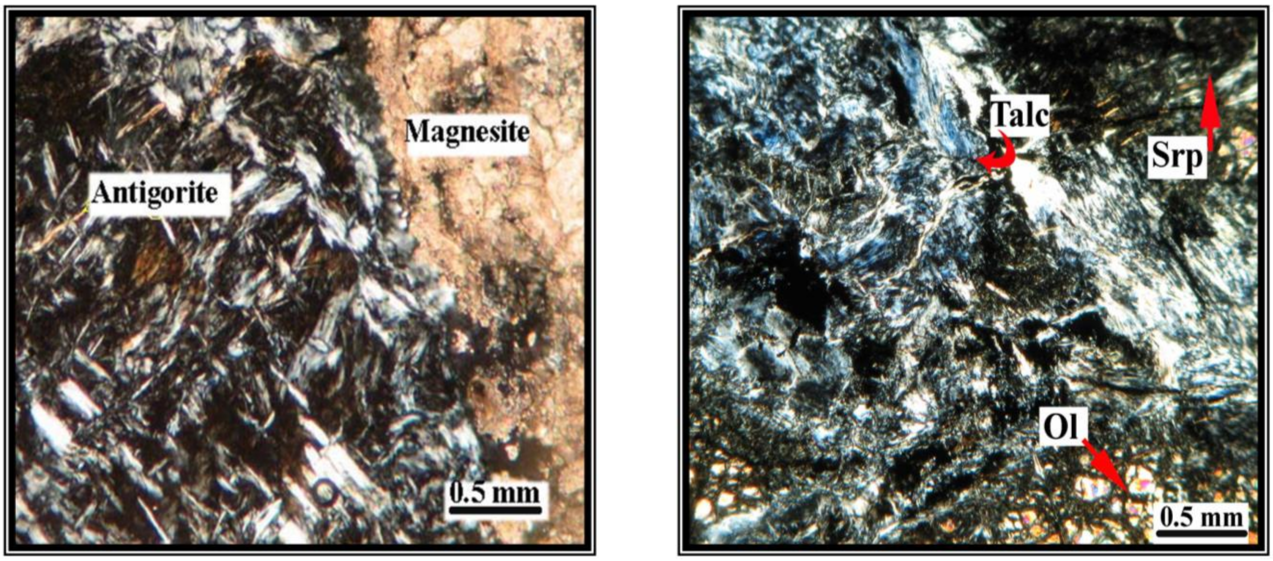

Figure 6) Microscopic image of the talk and magnesite mineral in a serpentinites sample (XPL).

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

$Mg_3Si_2O_5(OH)_4$ (Srp) + $3CO_2 \rightarrow 3MgCO_3$ (Mgs) + $2SiO_2$ + $2H_2O$

4.4- Iddingsite

Iddingsite with Mg, Fe_2O_3, $3SiO_2$, $4H_2O$ formula 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 (Fig. 7b).

4.5- Brucite

Brucite with $Mg(OH)_2$ formula is a secondary mineral which is created because of the alteration process in the serpentinites, Talk schists and chlorite schists (Perkins, 2002). The brucite mineral in the study area has taken form in serpentinite ores. Therefore, 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 (Choleman, 1978). For the same reason in dunites and harzburgite, high concentrations of olivine form the serpentine-brucites (Paoli *et al.*, 2006). Gonarson *et al.*, determined that the brucite may take form in thermal range of 5 to 350ºC. In serpentinite sections of the area under study, the brucite is seen as circular colorless mineral (Fig. 8).

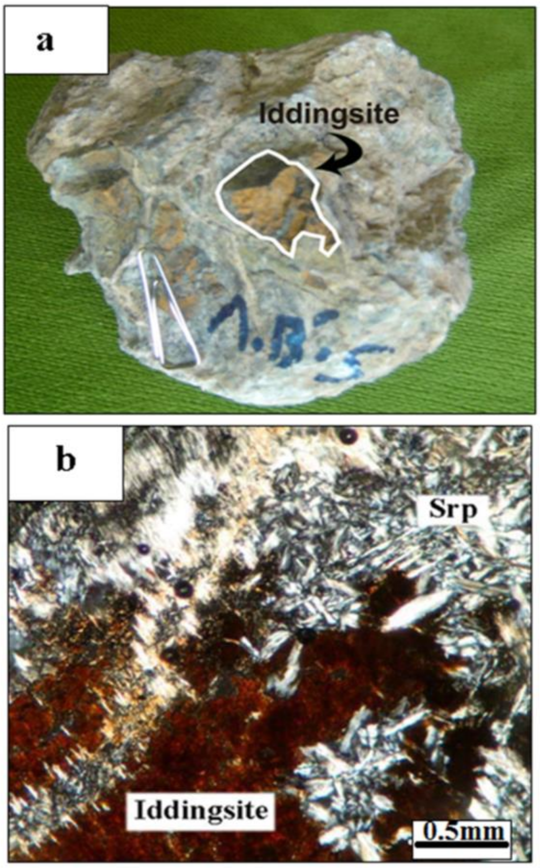

Figure 7) Macroscopic (a) and microscopic image (b) of the Iddingsite mineral in serpentinite harzburgite in study area (XPL).

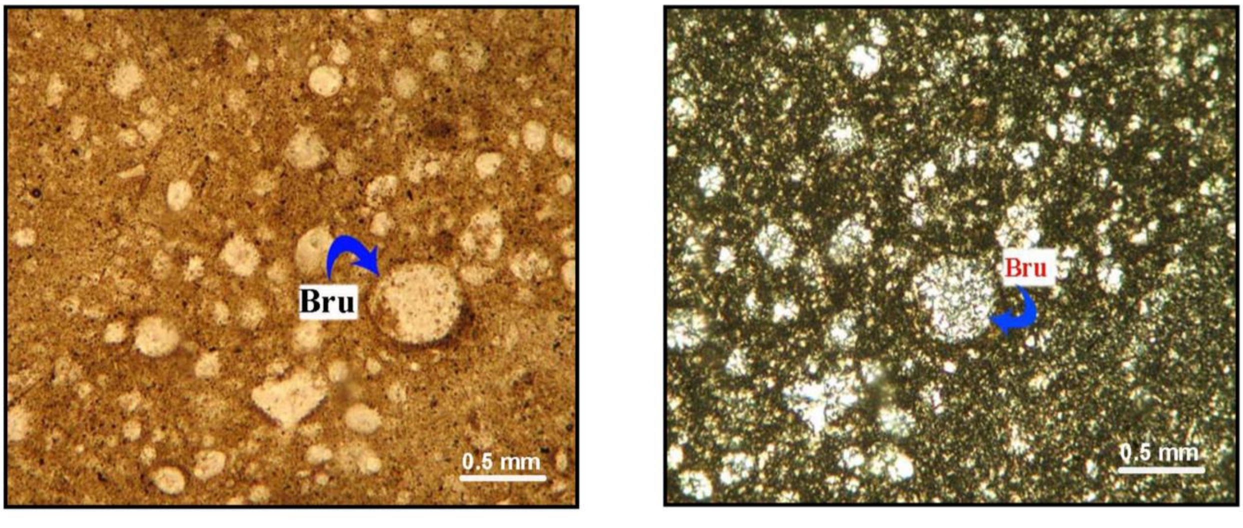

Figure 8) Microscopic image taken from the brusite vein in serpentinites of the area under study (Bru: Brucite, XPL).

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

$2Mg_2SiO_4$ *(Ol)* + $3H_2O \rightarrow Mg_3Si_2O_5(OH)_4$ *(Srp)* + $Mg(OH)_2$ *(Bru)*

4.6- Chlorite

Chlorites of the area under study are of magnesium rich chlorites like penantite and clinochlores (Fig. 9). 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 200-350ºC (Ramadan *et al*., 2004).

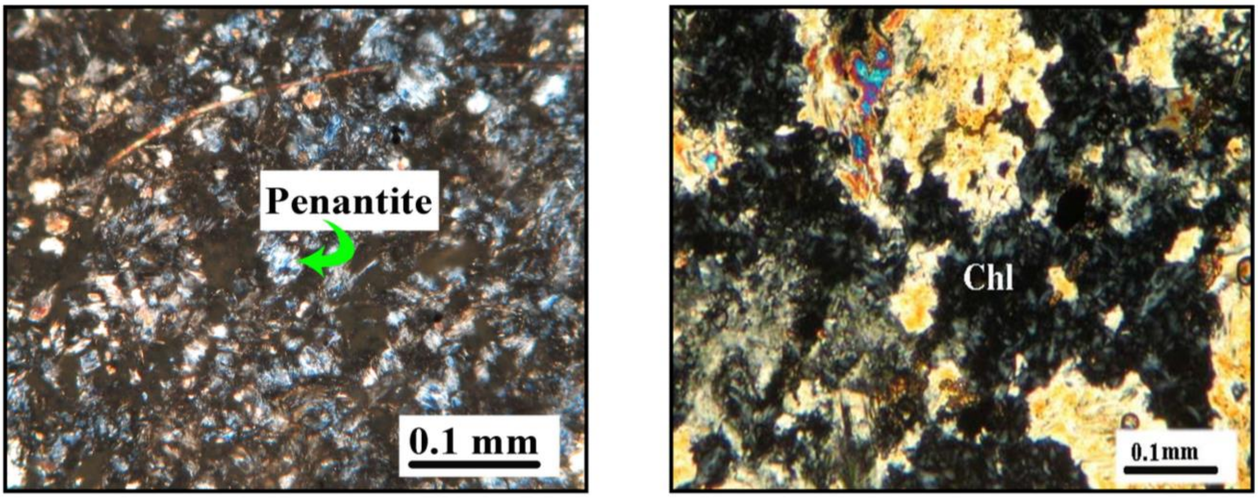

Figure 9) Microscopic images of the clinochlore and penantite in ultramafic ores (XPL).

5- Conclusions

Pridotites 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, clorite, talc, magnesite, iddingsite and brusite. 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.

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