MINERALOGICAL - GEOCHEMICAL CHARACTERISTICS AND GENETIC IMPLICATION OF GUMELI (IVRINDI, BALIKESIR) TALC OCCURRENCES IN THE KARAKAYA COMPLEX (NW TURKEY)

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Abstract

In this study, the mineralogical-geochemical characteristics and genetic implication of various talc occurrences associated with low-graded schists will be explained. Talc outcrops are located in the Karakaya complex, (Ivrindi, Balikesir). Other minerals coexisting with talcs are mainly chlorite, dolomite, magnesite, and magnetite. Geochemically, collected samples are characterized by high iron, magnesium and chrome contents. Talc occurrences have high SiO_2, MgO, Fe_2O_3 and low Al_2O_3, CaO contents. Great Ni (1541 ppm), Co (82 ppm), and Cr (1711 ppm) proportions indicate that talcs were derived from a mafic or ultramafic rock (e.g. serpentinite, dunite, or harzburgite) belonging to the Karakaya complex in terms of parental affinity and should have been formed by the hydrothermal alteration of those rocks.

Keywords: Talc, Karakaya complex, Ivrindi, Balikesir, NW Turkey

Introduction

Talc is an economically important mineral used in ceramics, paint, paper, polymers, plastics and cosmetics industries. Particular attention has been paid to deposits of talc because of its extensive use in nano-composites (Menczel et al., 1983; Ferrage et al., 2002). Talc occurrences have been categorized according to their different lithologies in many different geological environments worldwide. These environments include: retrograde metamorphism and metasomatism of Si-rich dolomites (Moine et al., 1989; Anderson et al., 1990; Schandl et al., 2002), ultramafic associations (Naldrett, 1966; Linder et al., 1992; El-Sharkawy, 2000; Tornos and Spiro, 2000), hydrothermal systems (Huston et al., 1993; Hecht et al., 1999), progressive metamorphism of Mg-rich silicates (Sandrone, 1993), and supergene formations in lateritic rocks (Noack et al., 1986).

The purpose of this paper is to examine the mineralogy and geochemistry of talc mineralization in the Gumeli (Ivrindi, Balikesir) region of Turkey and consider the qualities of the deposit compared to other deposits worldwide. Talc occurrences in this region are found in low-grade metamorphic schists consisting predominantly of Lower Triassic aged pelitic and psammitic rocks from the Karakaya complex in the Ivrindi (Balikesir) region. Previous regional geological studies of the area were carried out by Akyurek and Soysal, 1982; Ercan et al., 1984; Okay et al., 1991; and Coban, 2004.

Materials and Methods

Talc bearing samples were investigated using optical petrographic X-Ray powder diffraction (XRD) scanning electron microscope (SEM), and geochemical techniques. Thin-sections studies were performed using an Olympus CX31 polarizan microscope at the Department of Geological Engineering, Balikesir University (Balikesir, Turkey). Major, trace, and rare earth element (REE) contents of 6 talc and 1 associated rock samples were analyzed by Acme Analytical Laboratories (Canada) by emission spectrometry, using an inductively coupled plasma source and an atomic emission source (ICP–AES) for major elements, and mass spectrometry (ICP-MS) for trace elements. SEM analyses were carried out using an LEO VP-1431 at 15 kV accelerating voltage on samples that were coated with Au-Pd, in the Technology Application and Research Center, Afyon Kocatepe University (Afyonkarahisar, Turkey). The XRD analyses were performed with a SCINTAG XDS 2000 diffractometer (40 kV, 35mA, Co-Kα radiation) in the Geology Department, The University of Georgia (USA).

Results

Geological Settings

The study area is located about 45 km southeast of Balikesir (NW Turkey), and covers an area of approximately 15 km^2 in south of Ivrindi (Fig. 1). The basement rocks are found in the Cavdartepe Formation comprising Lower Triassic metamorphosed psammitic and pelitic rocks, constituting the lower part of the stratigraphic section of the region (Fig. 2).

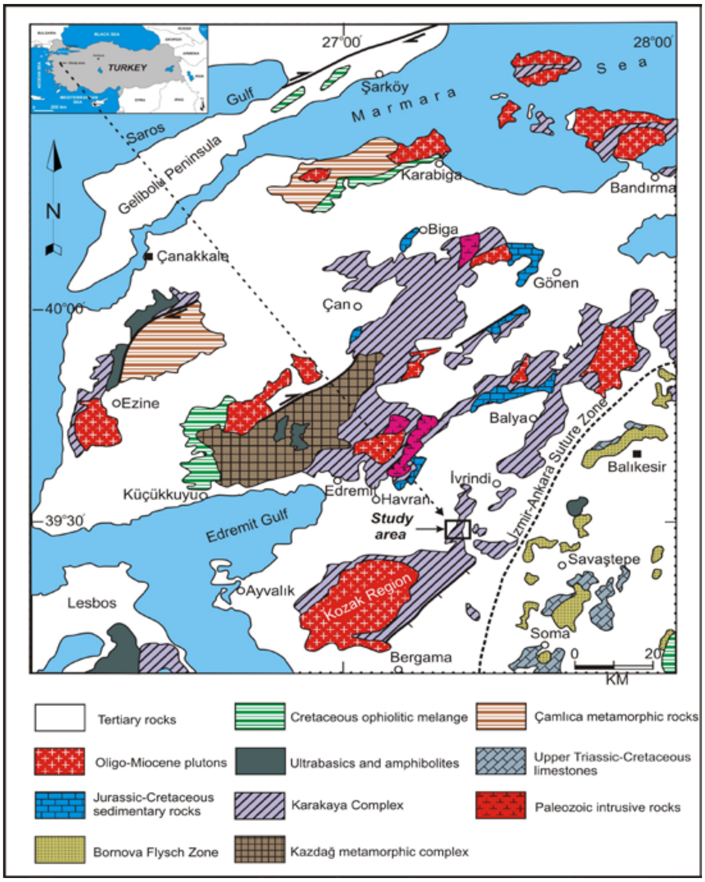

Fig. 1. Simplified geological map of Ivrindi and its surroundings (NW Anatolia), (Modified from Okay and Goncuoglu, 2004).

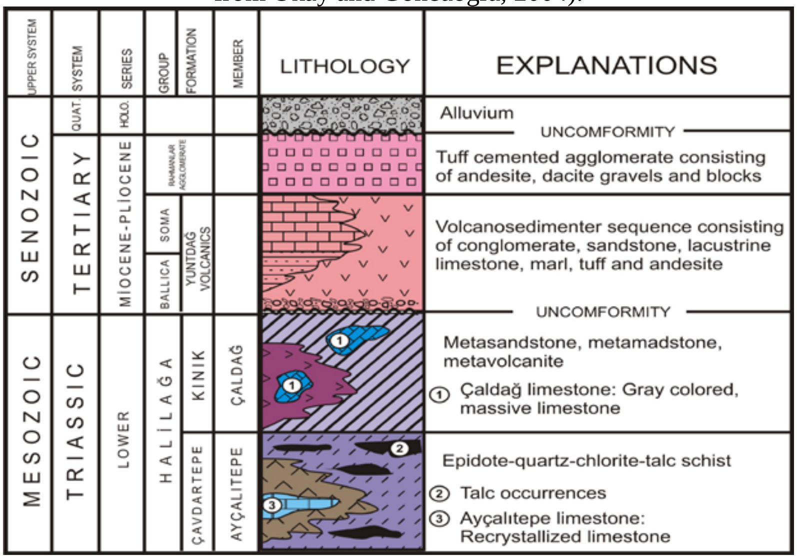

Fig. 2. Generalized stratigraphic columnar section of the study area (Akyurek and Soysal, 1982; Buyukkahraman, 2008).

The unit consists predominantly of quartz schist, quartz-sericite schist, graphite-chlorite-quartz-sericite schist, epidote schist, chlorite schist, and graphite schist. Early Triassic aged Kinik Formation overlies the basement rocks and is mainly characterized by metaconglomerate, metasandstone, and metavolcanics (Akyurek et al., 1984). The Kinik Formation includes a number of large limestone blocks called the Caldag limestone unit of Permian age (Fig. 2-3). Yuntdag volcanic rocks uncomformably overlie the Kinik Formation and are composed of andesite, tuff, silicified tuff, agglomerate and basalt in patches (Ercan et al., 1990). The uppermost unit in the study area is represented by agglomerates and its lower contact is transitive (Fig. 3).

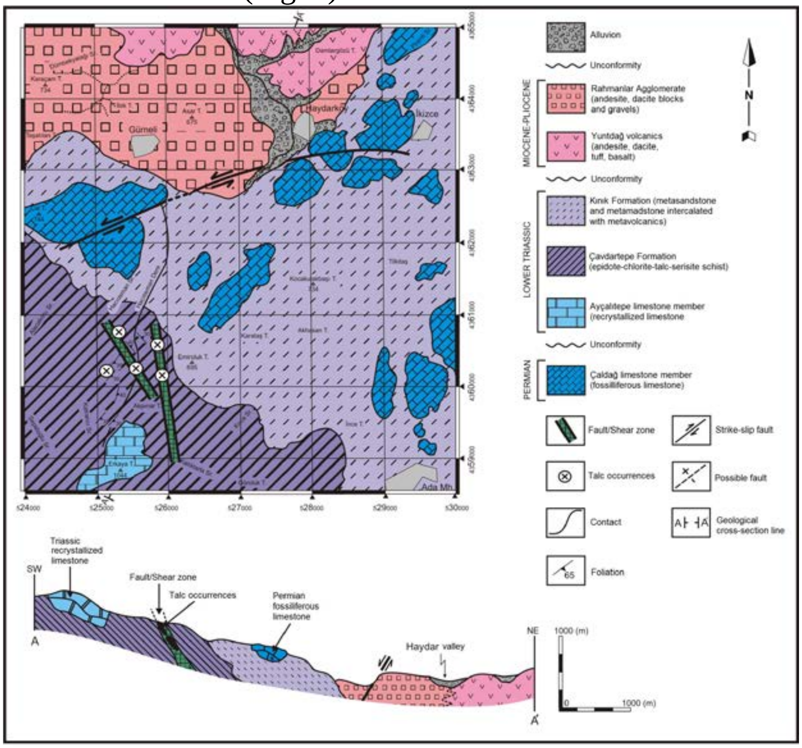

Fig. 3. Geological map and cross-section of the study area (Buyukkahraman, 2008).

Talc Occurrences

The talc schists of the Cavdartepe Formation were quarried by a private company until late 1995 and subsequently all these deposits were abandoned due to the high iron content. Some talc bodies were found along the Haciosman Stream in the study area and classified according to their color, grain size, decomposition, mineral paragenesis and geometry. (Fig. 4a). These occurrences belong to epimetamorphic unit of the Karakaya complex and have lenticular shaped bodies that have different sizes. A decomposition zone was determined along the talc occurrences, which displays accordance with schistosity planes. The size of talc lenses increases from west to east, while grain sizes decrease in the same direction (Coban, 2004). Talc ratio of talc schists increases depending on decomposition in more decomposed fragments and their colors are light grayish-yellowish, while there is a darkening in color (dark green talcs) in the less decomposed fragments. Macroscopically, three types of talcs are recognized: carbonated talcs bearing magnesite, dolomite and calcite (Fig. 4b, d, g), ferrous talcs (Fig. 4c), and pure talcs (Fig. 4e, f, h) (Coban, 2004).

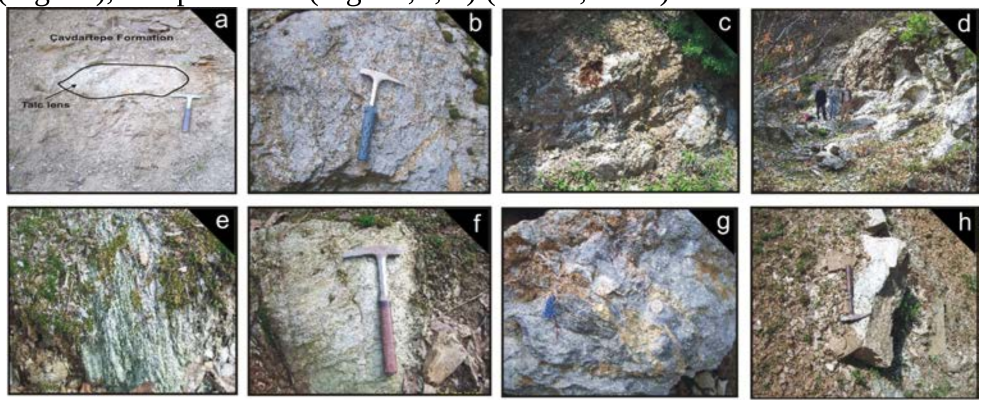

Fig. 4. Field photographs of talc occurrences; (a) lenticular shaped talc, (b,g) carbonated talc, (c) ferrous talc, (d) general appearance of talc outcrops, (e) dark green talc, (f,h) wall rock photograph-talc schist.

Mineralogy-Petrography

Mineral paragenesis of talcs has been determined by mineralogical analyses of the samples collected from different levels of study area talc occurrences and wall rocks (Table 1).

Table 1. Mineral paragenesis of talc samples. (FT: Ferrous talcs; CT: Carbonated talcs; IT: Impure talcs, WR: Wall rock).

Sample No	Mineral Paragenesis
FT-1	Talc + Chlorite + Hematite + Magnetite
CT-1	Talc + Chlorite + Dolomite + Calcite
CT-2	Talc + Chlorite + Magnesite + Dolomite
FT-2	Talc + Chlorite + Hematite + Goethite + Magnetite
IT-1	Talc + Dolomite + Chlorite + Magnetite + Kaolinite + Illite
WR-1	Zoisite + Actinolite + Plagioclase + Quartz + Chlorite ± Calcite ± Opaque mineral

Characteristic peaks belonging to talc in XRD studies are given as 9.33, 4.66, 4.29, 4.12, 4.08, 3.11, 2.60, 2.59, 2.49, 2.33, and 1.55 Å (Evans and Guggenheim, 1988). XRD studies indicate “talc + chlorite” coexistence in almost all levels of the deposit, where towards lower levels dolomite accompanies the “talc + chlorite” assemblage (Fig. 5). Alteration is more extensive to west of Haciosman Stream, therefore alteration zone thickness developing from surface to depth is wider than the upper levels in this location. Dominant mineral paragenesis has been determined with petrographic investigation of talc occurrences (Table 1). Talc generally coexists with chlorite, carbonate minerals (calcite, dolomite, and magnesite), and opaque minerals (magnetite, hematite, and goethite) (Fig. 6). Chlorites are observed as long-rod crystals with talc minerals (Fig. 6a). Dolomites exist in the shape of quite distinctive cleavaged romboedric euhedral crystals (Fig. 6c). Opaque minerals such as magnetite, hematite, and goethite are extensively observed in samples (Fig. 6b) from iron-rich talcs. Petrographic investigations of wall-rocks of talcs reveal zoisite and clinozoisite occurrences (Fig. 6d). SEM investigations show talcs frequently occur as laminas in especially talc-rich rocks (Fig.7a&b). Talc-chlorite coexistence is common (Fig.7d), which suggests that ultramafic parent minerals were subjected to hydrothermal alteration. Dolomite veins are often observed in Gumeli (Ivrindi, Balikesir), and can be seen in SEM studies (Fig. 7c).

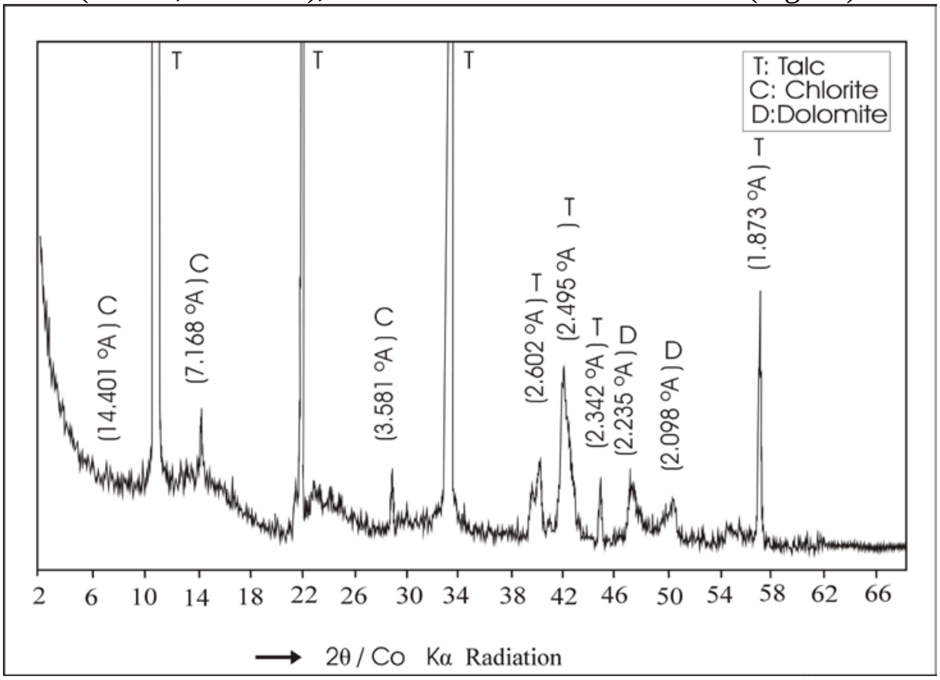

Fig. 5. Representative XRD pattern of carbonated talc sample (Sample no: CT-1).

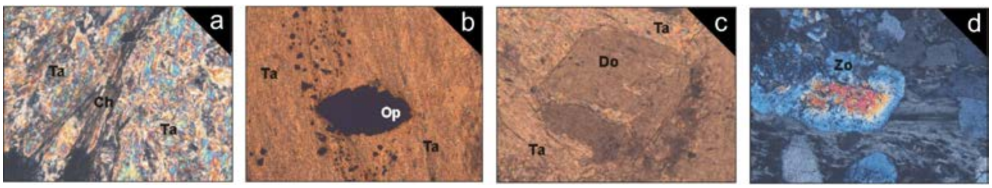

Fig. 6. Optical microscope photographs of talcs and their wall-rocks. (a) Talc-chlorite (b) Talc and opaque mineral (c) Talc-dolomite coexistence (d) Zoisite mineral in wall-rock. Mineral abbreviations: Ta: talc, Ch: chlorite, Do: dolomite, Op: opaque mineral, Zo: zoisite.

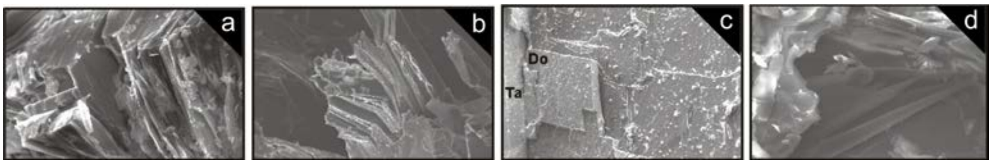

Fig. 7. SEM photographs of talc samples (a, b) Talc laminas, (c) Talc-dolomite transition (d) Talc-chlorite coexistence.

Geochemistry

Talc bearing samples have major compositions that range accordingly: SiO_2 (50.16-55.77%), MgO (30.16-31.92%), Fe_2O_3 (4.41-8.72%), Al_2O_3 (0.62-1.20%) and CaO (0.07-1.63%) (Table 2). Trace elements Ni, Co, Cr, Pb, Cu, Zn, Ta, Th, and U concentrations show some enrichment in talc-bearing rocks. Talcs have high Ni (1541 ppm), Co (82 ppm), Cr (1711 ppm) concentrations and their Mg-number (Mg #) is 92.5. Similar to Gumeli talc occurrences, talc-schists from Boumnyebel (Central Cameroon) also exhibit high Ni (2000±50 ppm), Co (90-100 ppm), and Cr (3600±10 ppm) concentrations (Nkoumbou et al., 2006), (Fig. 8). This suggests that talc formations were derived from a mafic or ultramafic precursor rock.

Discussion

Talc occurrences in the Gumeli (Ivrindi, Balikesir) region are found within the Cavdartepe formation. This assemblage formation suggests that the Cavdartepe reached metamorphism of low-grade green schist facies. Although there is little data available associated with P-T conditions in the study, petrographic mineral paragenesis is one approach to explore the region’s geologic history. Regional metamorphism is represented by zoisite-actinolite schist. Mineral paragenesis, which was obtained from metamorphosed mafic/ultramafic host rock including talc occurrences, is zoisite + actinolite + plagioclase + quartz + chlorite ± calcite ± opaque mineral.

Table 2. Chemical analysis results of Gumeli talc occurrences. (Major, trace, and REE).

Sample	T1	T2	T3	T4	T5	T6	TU
SiO_2	55.54	60.56	59.04	57.86	55.77	54.84	50.16
TiO_2	0.01	< 0.01	0.02	0.01	0.03	0.02	0.81
Al_2O_3	0.75	0.17	0.65	0.6	0.92	1.2	16.17
Fe_2O_3	4.94	2.06	3.76	5.51	6.47	7.51	8.73
MnO	0.01	< 0.01	< 0.01	0.03	0.02	0.01	0.14
MgO	30.16	30.38	28.49	29.97	30.63	30.61	6.54
CaO	0.12	0.05	0.05	0.06	0.30	0.07	6.67
Na_2O	< 0.01	0.01	0.03	0.05	0.03	0.05	2.21
K_2O	< 0.01	0.02	0.05	0.04	0.04	0.04	1.66
P_2O_5	0.007	< 0.01	< 0.01	0.03	0.05	0.04	0.124
Cr_2O_3	0.25	0.19	0.182	0.264	0.268	0.358	0.04
LOI	7.2	6.1	7.1	5.4	5.3	5	6.3
Cr	1711	1300	1246	1807	1827	2450	272
Ni	1541	817	1385	1292	1285	1726	101
Co	81.7	51.9	61.9	55.4	32.7	87.1	36
Ba	31	6	16	8	7	25	313
Nb	1.2	0.2	0.4	1.2	0.2	0.4	9.8
Rb	0.4	0.6	1.4	0.4	0.6	1.4	55.8
Sr	2.2	3.2	4.5	2.2	3.2	4.5	207.9
Th	< 0.2	0.2	< 0.2	< 0.2	0.2	< 0.2	6.5
U	< 0.1	< 0.1	0.2	< 0.1	< 0.1	0.2	1.4
Zr	2.4	1.1	3.5	2.4	1.1	3.5	106.2
Cu	1.7	1.1	3.7	1.7	1.1	3.7	45.1
Pb	0.1	0.3	1.8	0.1	0.3	1.8	2.4
Zn	3	2	8	3	2	8	64
La	0.6	0.2	0.4	0.3	0.5	0.5	18.2
Ce	0.7	0.3	0.6	0.5	0.5	0.5	39.6
Pr	0.08	0.04	0.09	0.14	0.1	0.1	4.62
Nd	< 0.3	< 0.3	0.3	6.6	< 0.7	< 0.8	17.6
Sm	0.05	< 0.05	0.09	3.05	3	3.4	3.45
Eu	< 0.02	< 0.02	< 0.02	0.05	0.05	0.05	0.93
Gd	0.09	< 0.05	0.05	0.09	0.05	0.15	3.34
Tb	0.02	< 0.01	0.01	0.02	0.02	0.02	0.58
Dy	0.07	< 0.05	0.06	0.3	0.35	0.17	3.35
Ho	< 0.02	< 0.02	< 0.02	0.07	0.08	0.09	0.74
Er	0.04	< 0.03	0.04	0.06	0.05	0.05	2.11
Tm	0.01	< 0.01	< 0.01	0.05	0.05	0.05	0.33
Yb	0.06	< 0.05	< 0.05	0.05	0.05	0.05	2.25
Lu	0.01	< 0.01	< 0.01	0.01	0.01	0.01	0.36

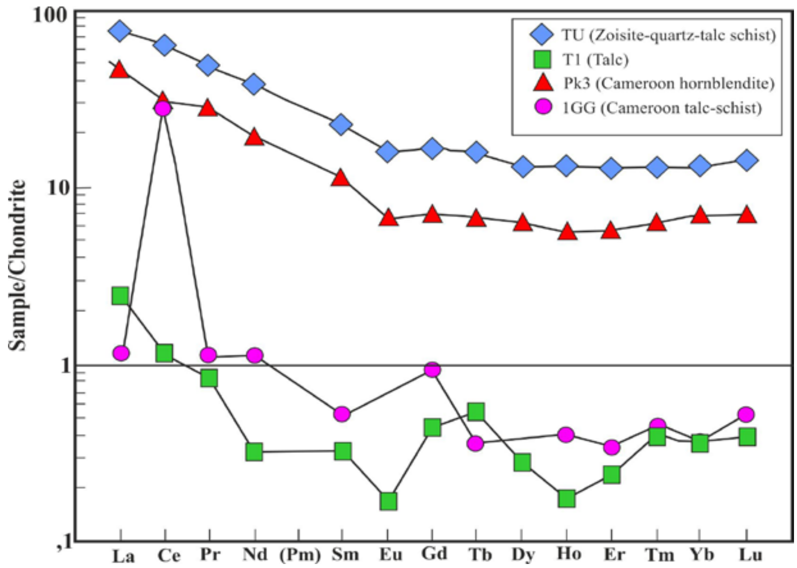

Fig. 8. Chondrite-normalized trace element abundances of talc (T1) and its parent rock (TU). (Normalized values were taken from Sun and McDonough 1989).

Since talc can crystallize in a wide temperature range, it cannot help to constrain temperature (Nkoumbou et al., 2006). Talc formation is controlled by other factors particularly silica activity in the liquid phase (Mével, 2003). In the southern part of the study area, Kozak Pluton is well-exposed. This Pluton has a SW-NE trending ellipsoidal appearance and covers approximately 300 km2 (Fig. 1). Pluton is composed mainly of granodiorite, granite, quartz-diorite and quartz monzonite. The Kozak Pluton contains xenoliths and mafic magma segregations more commonly found on its edge (Altunkaynak and Yilmaz, 1998), where it is intruded into the Cavdartepe Formation. Metamorphism in the region has been effective before hydrothermal activity. Silica-rich solutions derived from Kozak Pluton became rich in some elements (e.g. Na, Rb, K, Ba, U, and Th). Talc occurrences have lower amounts of Ba, Sr, Th, U, Zr, and Y contents and are characteristic in terms of remarkable Ni, Co, and Cr. These occurrences should be related to silica-rich solutions derived from this Pluton due to the fact that talcs in the study area can be seen with siliciferous zones which are followed along a NW/SE trending, 500 m wide, 2 km long fault line in these zones. Tectonic movement is very important in talc formation. Hematite and especially magnetite formations in some talc occurrences support this view (Fig. 9).

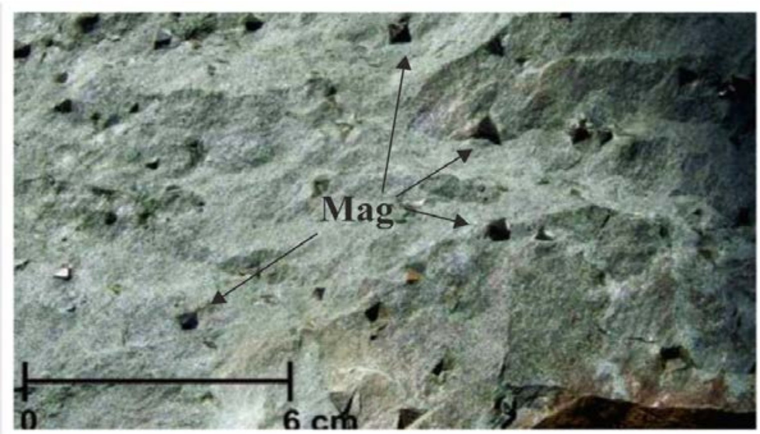

Fig. 9. Octahedral magnetite crystals in Gumeli talc occurrences. Mineral abbreviations: Mag: magnetite.

These minerals (hematite and magnetite) are seen particularly in mineral paragenesis of upper levels of talc occurrences and this condition points out that talcs may be related to Fe-scarn occurrences developed around Kozak Pluton.

Formation of talc by hydration of forsterite and by the alteration of serpentine as follows:

$2Mg_2SiO_4 + 3H_2O = Mg_3Si_2O_5(OH)_4 + Mg(OH)_2$ (Deer et al., 1992) (1)
(forsterite) (water) (serpentine) (brucite)

Fluid coming from the surrounding schists may be rich in dissolved SiO_2;

$$\underset{\text{(serpentine)}}{Mg_3Si_2O_5(OH)_4} + \underset{\text{(fluid)}}{2SiO_2} = \underset{\text{(talc)}}{Mg_3Si_4O_{10}(OH)_2} + \underset{\text{(fluid)}}{H_2O} \quad \text{(Nkoumbou et al., 2006)} \qquad (2)$$

Since the hydrothermal fluid is silica-saturated in the studied case, brucite may be unstable and the possible reactions are shown below:

$$\underset{\text{(serpentine)}}{2Mg_3Si_2O_5(OH)_4} = \underset{\text{(talc)}}{Mg_3Si_4O_{10}(OH)_2} + \underset{\text{(brucite)}}{3Mg(OH)_2} \quad \text{(Nkoumbou et al., 2006)} \qquad (3)$$

$$\underset{\text{(brucite)}}{3Mg(OH)_2} + \underset{\text{(fluid)}}{4SiO_2} = \underset{\text{(talc)}}{Mg_3Si_4O_{10}(OH)_2} + \underset{\text{(fluid)}}{2H_2O} \quad \text{(Nkoumbou et al., 2006)} \qquad (4)$$

Consequently, it can be said that talc occurrences are related to Cavdartepe Formation which occurred in a deep marine environment before the metamorphism following the formation of Karakaya complex in Permo-Triassic and consists of clastic lithology. Being exposed to metamorphism of mafic or ultramafic rocks (e.g. dunite and harzburgite) entered among various levels of this formation, presumably in green schist facies, in addition, decomposition of hydrothermal solutions associated with Kozak Pluton, which is located nearby, to these rocks along fault-related shear zones situated in Cavdartepe Formation were completely effective in formation of talcs.

Conclusions

Talc occurrences found in Karakaya complex (Ivrindi, Balikesir) are related to epimetamorphic rocks which are low-graded metamorphic schists. Some talc bodies were determined along the Haciosman Stream in the study area according to their color, grain size, decomposition, mineral paragenesis and geometry. (Fig. 4a). The talc occurrences have a generally lenticular shape and different sizes in lateral and vertical directions. A decomposition zone was determined along the talc occurrences, which displays accordance with schistosity planes. Talc ratio can increase depending on decomposition in the more decomposed segments (light grayish yellowish colored), while there is a darkening in color (dark green talcs) in the less decomposed segments. Light grayish yellowish colored talc samples can be recognized as ferrous talcs (Fig. 4c), light greenish whitish gray talcs can be recognized as carbonated (magnezite, dolomite, and calcite) talcs (Fig. 4b&g); and dark green talcs can be recognized as the least pure talcs (Coban 2004), (Fig. 4e, f, h). Geochemically, talc occurrences have high SiO_2, MgO, Fe_2O_3 contents and low Al_2O_3 and CaO contents. Mineral paragenesis obtained from metamorphosed mafic/ultramafic host rock including talc occurrences is zoisite + actinolite + plagioclase + quartz + chlorite ± calcite ± opaque mineral. Great Ni (1541 ppm), Co (82 ppm), and Cr (1711 ppm) proportions indicate that talc was derived from a mafic or ultramafic rock (e.g. dunite and harzburgite) in terms of parental affinity. Talcs and their parent rocks are related to ultramafic rocks belonging to the Karakaya complex and were probably formed by hydrothermal alteration of those rocks.

Acknowledgements

This study consists of a part of the MSc thesis of the first author and was financially supported by Coordination of Balikesir University Scientific Research Projects (Project #: 2007/51). The authors greatly appreciate the help of Prof. Dr. Paul A. Schroeder (The University of Georgia, USA) for his helpful criticism and detailed grammatical and scientific suggestions which improved the text.

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