ICOEST

UKRAINE

4th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY

SEPTEMBER 19-23, 2018

BOOK OF PROCEEDINGS

www.icoest.eu

Organized by

Partners

τ0̂È) . 4%2 . ! 4)/ . ! , #/ .&%2% . #% / . % . 6)2 / . - % . 4 ! , 3#)% . #% ! . $
4%# (. / , / ' 9 ɉ)#/%34ɋ
)3" . ωχψζφπυζψρτςφζςζφ
)33 . ςφψχζςτσω

ICOEST UKRAINE
4TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
19-23 September 2018 Kiev

A skark deposit in the Kazdaglari Region: Saricayir (Yenice/Canakkale -Northwest Turkey) Iron-Copper Skarn Deposit

Fetullah Arik[1], Ilknur Akis[2]

Abstract

Saricayir skarn deposit is located around the Saricayir village of Yenice County, 70 km southeast of Canakkale and northeast of the Kazdaglari Region in the northwestern Turkey. Triassic to Oligo-Miocene magmatic, metamorphic and volcanic rocks cropp out in the study area. The Karakaya complex is the structural basement of the study area and represented by the Nilufer and Hodul units which are metamorphosed to green schist facies. While Nilufer unit mostly consists of metabasic rocks, Hodul unit dominated by arkosic sandstones was emplaces over the Nilufer unit. Karakaya complex are cut by Oligocene Karadoru granitoid and Saricayir alkali granites and covered unconformably by the Oligocene Can Volcanics, consist of andesitic pyroclastics and lavas. It is aimed that to explain geological, mineralogical and geochemical properties of the skarn zone between the Karadoru Granitoide and the Karakaya Complex's Nilufer and Hodul units in this study.

Owing to Nilufer and Hodul units were affected by the intrusion of Karadoru Granitoide and Saricayir alkali granite contact metamorphism and skarn zones have been developed between the Karadoru Granitoide and the Nilufer and Hodul units. Contact metamorphism appears to have extended from albite-epidot hornfels to hornblend hornfels facies. Calc-silicate minerals such as garnet, tremolite and epidote were determined in the skarn zone. In addition, pyrite, chalcopyrite, sphalerite, galena, digenite and cinnabar were observed. Chemical data reveal that Fe_2O_3, Pb, Cu, Zn, As, Ag and Au reach up to 57.54% 8101 ppm, 4656 ppm, 3700 ppm, 2500 ppm, 8.3 ppm and 60.6 ppb respectively.

Keywords: Saricayir granite, Skarn-type mineralization, iron, copper, lead, zinc

1. INTRODUCTION

Saricayir skarn deposit is situated 70 km southeast of Canakkale city center and around the Saricayir village of Yenice County (Canakkale-Turkey) northeast of the Kazdaglari Region (Figure 1). Triassic to Oligo-Miocene magmatic, metamorphic and volcanic rocks cropp out in the study area. The Karakaya complex is the structural basement of the study area and represented by the Nilufer and Hodul units and cut by Oligocene Karadoru granitoid and Saricayir alkali granites and covered unconformably by the Oligocene Can Volcanics, consist of andesitic pyroclastics and lavas. Owing to Nilufer and Hodul units were affected by the intrusion of Karadoru Granitoide and Saricayir alkali granite contact metamorphism and skarn zones have been developed between the Karadoru Granitoide and the Nilufer and Hodul units.

Garnet, tremolite and epidote were determined in the skarn zone besides pyrite, chalcopyrite, sphalerite, galena, digenite and cinnabar formations. It is aimed that to explain geological and geochemical properties of the contact metamorphic and skarn zone among the granitoidic rocks and the Nilufer and Hodul units.

[1] *Konya Technical University, Faculty of Engineering and Natural Sciences, Geological Engineering Department, Selcuklu-Konya / TURKEY, farik@selcuk.edu.tr*

[2] *Selcuk University Graduate of Natural and Applied Sciences Geological Engineering Department, katre97@hotmail.com*

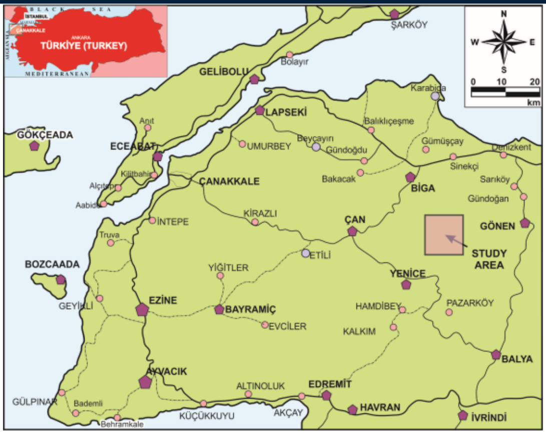

Figure 5. Location map of the study area

2. MATERIAL AND METHODS

In order to determination of geological, mineralogical, petrographical and geochemical characteristics of the units cropp out, field and laboratory studies were carried out in the study area. Formation boundaries were updated and total 90 samples collected from different rock units during the field studies. In order to understand mineralogical petrographic analyzes of rock and ore samples collected during field studies, thin section and polishing section studies were conducted. Samples were classified and prepared for chemical analysis in the Selcuk University and sent to the related laboratories. For petrographic studies, 40 thin sections and 12 polishing sections were prepared. Thin sections were prepared in the Pamukkale University Geological Engineering Department. The polished sections were prepared in the laboratories of the Geological Engineering Department of Istanbul Technical University. Thin and polished sections were examined by a polarizing microscope in the laboratories of the Geological Engineering Department of Istanbul Technical University and Selcuk University Geological Engineering Department.

A total of 45 samples taken from the region and other units which are considered to have skarn mineralization were passed through the crusher for chemical analysis and 50 grams of the ground and grinded samples were taken and placed in plastic bags. The prepared samples were analyzed in ACME (Vancouver-Canada) Laboratories for the determination of the major oxides (SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, Cr_2O_3) and trace elements (Cu, Pb, Zn, Ni, Ga, Nb, Th, V, Zr, Y, Sc). Samples were jaw crushed to 70% passing 10 mesh (2 mm), a 250 g aliquot was riffle split and pulverized to 95% passing 150 mesh (100 µm) in a mild-steel ring-and-puck mill. Samples after thawing process calibration standards, verification standards and reagent blanks were included in the sample sequence. Sample solutions were aspirated into an ICP emission spectrograph (ICP-ES) (Spectro Ciros Vision) for the determination of the major oxides. All geochemical data were evaluated with basic and multivariate statistical methods using student t test, correlation coefficient, cluster analyses, simple regression and scatter diagrams.

3. RESULT AND DISCUSSION

3.1. Geological Settings

In the Biga Peninsula, the Pre-Tertiary rocks are exposed in tectonic and tectonic zones extending from NE-SW. These zones are composed of Izmir-Ankara Zone, Sakarya Zone, Cetmi Melange and Ezine Zones (e.g. [1], [2]). The stratigraphic basement of the Biga Peninsula consists of units belonging to the Sakarya continent. In the study area, the Karakaya complex (e.g. [3]), which is called Sakarya Zone rocks, constitutes the foundation (e.g. [4]). Triassic to Holocene aged metamorphic, magmatic and sedimentary units exposed in the study area (Figure 2) (e.g. [5]-[7]).

Permo-Triassic Nilufer unit (e.g. [8], [9]), which is the most common widespread rock group in the study area, constitutes the lowest structural slice of the Karakaya complex. The unit is mainly represented by dark green, distinctive foliated and fine-grained schists as well as dark gray, lead gray phyllite, sericite-quartz-schist and garnet-schist and gray, blackish gray marble-calcschist block and lenses. The Nilufer unit is exposed to metamorphism in the greenschist facies and the metamorphism grade extends up to the garnet zone, which represents the higher level of the greenschist facies. The green schists in the Nilufer unit were observed to be intensely deformed in the contact zones with the Hodul unit. As a result of metamorphism, schist, Q-schist, garnet schist and epidote schists were formed (e.g. [1], [3]-[4], [7]). Predominantly lepydoblastic, granolepydoblastic, porphyroblastic and occasionally fibroblastic texture development (especially in the external contact zone). According to these properties, the rocks are called phyllite-schist such as epidote-schist, garnet-schist, and quartz-schist. Plagioclases are mostly polygonal grain-shaped and polysynthetic twins. Crystallized limestone and calcschist blocks and lenses located in Karakaya complex are observed to the south of Ortacagil stream and north of Saricayir - Karadoru village road. A marble block within the Nilufer unit to the east of the Karadoru village remained within the Karadoru Granitoide contact metamorphism and skarn zone (e.g. [5]-[7]).

Cretaceous Hodul Unit (e.g. [4], [12]) covers the Nilufer unit with tectonic contact. It has been affected from low grade metamorphism. In the study area, it presents a narrow area spread to the north of Korcesme Hill. Hodul Unit is represented by yellowish gray-brown arkosic conglomerate, sandstone, black greywacke and light green shales (e.g. [5]-[7]). In addition, it contains green colored spyllitic basalt, diabase and recrystallized limestone and chert gravel and blocks. In the petrographic examinations; 30-40% of actinolite, 10-20% of biotite and 30-40% of tremolite have been determined.

Oligocene Karadoru Granitoide is observed South of the Uzunburun Slope to the north of Karadoru village. Granitoide cut the Nilufer and Hodul Units of Karakaya Complex and developed a contact metamorphism and skarn zone in an area of about 7 square kilometers although it has a very narrow area (e.g. [6]). Karadoru Granitoide was cut with hot contact by Saricayir granite. The granitoids are quite cracked and these cracks were filled with secondary quartz (e.g. [13]). Intense clay deposits due to alteration of feldspars in the Karadoru granitoid are exposed on the Karadoru village road (e.g. [7]). 30-50% quartz, 30-50% plagioclase, 10-20% alkali feldspar and 5-8% biotite paragenesis identified in the petrographic examinations of the samples collected from Karadoru granitoid. The holocrystalline, granular textured rock is called granodiorite (e.g. [14]).

Saricayir granite is represented by pinkish-colored, fine-to medium-grained alkali feldspar granite, and aplitic granites (e.g. [15]). In the last phase of the Karadoru granitoid, Oligocene Saricayir granite, which is a granitic and aplitic-looking granite, is settled (e.g. [14]). It was cut by the Can Volcanics developed at the same period. Almost no mafic minerals are contained. The grain size varies between 0.1 and 3 mm. Epidote are observed along the cracks and joint planes. Mainly quartz (15-30%), plagioclase (5-30%) and orthoclase (30-60%) minor amounts biotite and amphibole were observed. The rocks are composed of holocrystalline, grain-like and semi-euhedral crystals. According to these properties, it is in granite composition and it is called alkali granite (e.g. [5]-[7]).

The Miocene Can Volcanics (e.g. [16]) are represented by beige, yellowish beige and pink colored andesite, dacite and rhyodacitic lava, tuff and agglomerates. The tuff and agglomerates are observed to the east of the Patlak Ridge around the Saricayir village (e.g. [5]-[7]). Can Volcanics are generally composed of pyroclastic levels. There are pumice fragments in the tuffs (e.g. [17]). Volcanic glass and plagioclase microliths, as well as large plagioclase phenocrysts, altere amphibole and biotites were observed. The rocks have hypocrystalline porphyric texture are called andesitic tuffs. Iron oxide enrichments were observed somewhere in the tuffs.

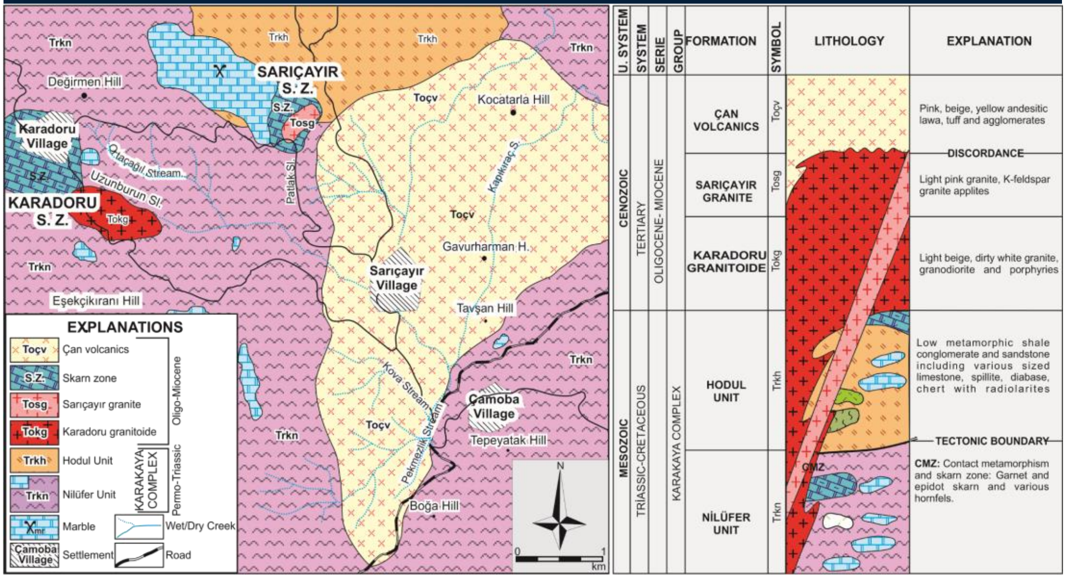

Figure 6. Geological map and tektono-stratigraphical section of the study area (After, Arik ve Akis, 2013

3.2. Skarn Mineralization

Nilufer and Hodul units were affected by the intrusion of Karadoru Granitoide and Saricayir alcali granite. Contact metamorphism and skarn type mineralization were developed adjacent to contacts of granitoids with the carbonate rocks of Nilufer units. Skarn mineralization was approximately 1 km^2 area (e.g. [5], [7]). Garnet - epidote skarn was formed at the contact of granite and marble (Figure 3). Contact metamorphism appears to have extended from albite-epidote hornfels to hornblend hornfels facies. Epidote and quartz fillings are observed within fractures and faults of the Saricayir alcali granite. Garnets have generally andradite-rich composition. As a result of contact metamorphism minor amount of pyrite and magnetite and rarely chalcopyrite was formed in the skarn zone. Garnets are responsible for the iron enrichments while lead and copper enrichments were caused by the epidotes (e.g. [18]).

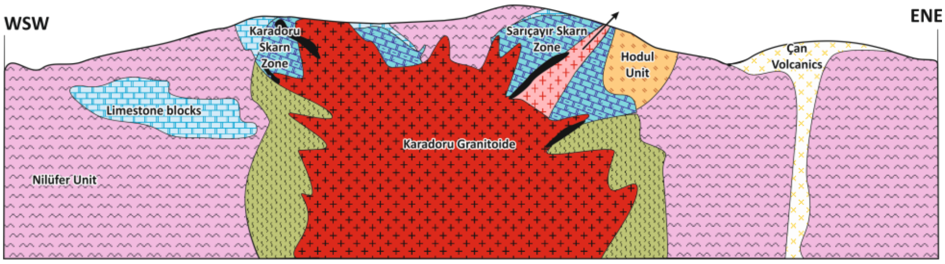

Figure 7. Schematic Cross Section model of Kiziltepe (Aladag) Skarn Zone (Modified from [7]).

The rocks in the Saricayir skarn zone investigated in 3 sections from intrusive rocks to outside zones; 1) Intrusive rocks (granite aplites), 2) skarn zone (epidot, garnet, diopside hornfels) and 3) carbonate rocks of Nilufer Unit (e.g. [5]-[7]).

Garnets (andradite), epidote (epidote and epidote-Pb) and magnetite were identified in the skarn zone (e.g. [18]). In places, K-feldspar is concentrated and these rocks are called K-feldspar-epidote hornfels, garnet-epidote hornfels and garnet-hornfels. The spaces between the large crystal garnets are filled with quartz (e.g. [6], [7]). In the petrographic examinations of the epidote rich samples; epidote, plagioclase, biotite and opaque minerals were observed. These holocrystalline textured rocks are generally called epidote-skarn. Some of the samples were found to be entirely composed of epidote and these rocks are called epidosite (e.g. [6]). Pyrite, (py), Chalcopyrite (cpy), Limonite (lm), Bornite (bn) as well as Magnetite (Mg) were Observed in the skarn zone especially Saricayir Region.

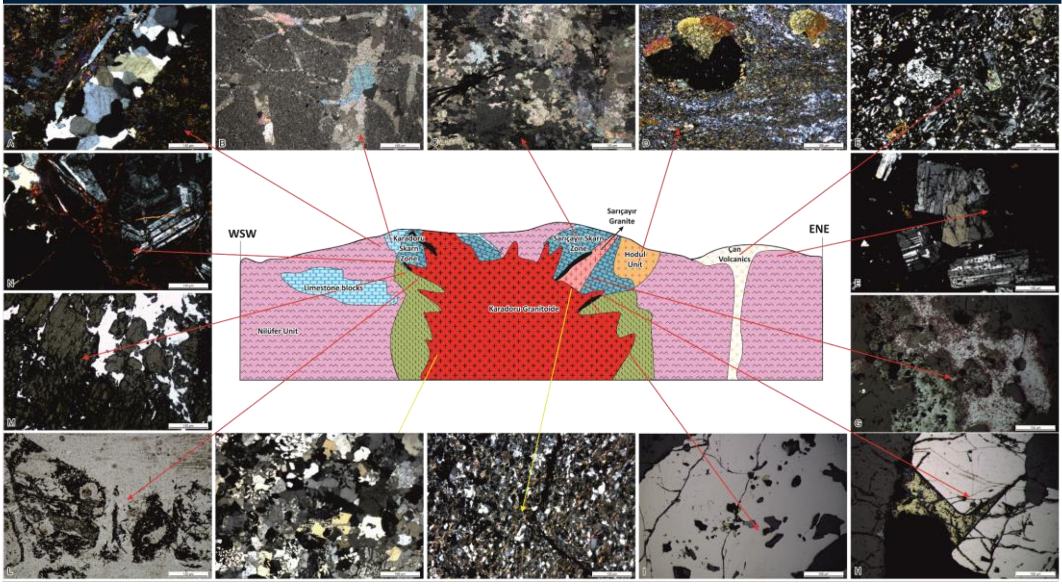

Figure 8. Schematic cross section and mineral paragenesis of the Saricayir and Karadoru skarn mineralization, A: Metabasic rocks and quartz vein of Nilufer Unit, B and C: Calcite and epidote in limestone blocks D: Shale of Hodul Unit, E: Plagioclase phenocrystal and microlites in dough phase of Can Volcanics (Thin section, +N), F: Plagioclase phenocrystals in dough phase of andesitic lava of Can Volcanics (Thin section, +N), G: Magnetite and cinnabar in the skarn zone (Polished section +N), H: Pyrite, chalcopyrite and digenite in the skarn zone (Polished section, +N), I: Pyrite, chalcopyrite, sphalerite and fahlore in the skarn zone (Polished section, +N), J: Granite aplite and FeO veinlets in the Saricayir Granite (Thin section, +N), K: Myrmekitic textured granite of Saricayir Granites (Thin section, +N), L: Cinnabar and magnetite in the skarn zone (Thin section, //N), M : Epidote and garnet and zoned plagioclase in the skarn zone (Thin Section, //N), M: FeO in the fissures in the garnet and zoned plagioclase in the skarn zone (Thin Section, +N) (After [7]).

3.3. Geochemical Features of the Granitoidic Rocks and Skarn Zone

The major oxides and some trace element analysis of the samples taken from the Granitoidic Rocks (Karadoru Granitoide and Saricayir Granites), and skarn zones (Karadoru and Saricayir) (Tables 1 and 3).

Granitoidic Rocks:

The average contents of main oxides such as SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, MnO and Cr_2O_3 were 76%, 11.32%, 2.77%, 0.4%, 1.3 %, 1.32%, 3.61%, 0.4%, 0.001%; while average trace elements such as Ba, V, Mo, Cu, Pb, Zn, As, Sb and Au were 150 ppm, 55 ppm, 1.1 ppm, 22 ppm, 14 ppm, 21 ppm, 40 ppm, 0.7 ppm and 2.4 ppb respectively (e.g. [5]-[7]).

Table 6. Major oxides (%) and some trace element (ppm, Au: ppb) analysis and statistical summaries of the granitoidic rocks (S.D.: Standard deviation, S.E.: Standard error, t_h: Calculated t value: L.L.: The lower limit, U.L.: Upper limit, Sample number: 9, tt: Table t value: 1.86).

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	Ba	Co	Sn	Sr	V	W	Mo	Cu	Pb	Zn	As	Sb	Au	Hg
N8	77.2	12.4	0.7	0.1	0.3	3.01	5.68	0.10	0.01	0.02	0.003	49	0.5	4.0	47	8	2.5	1.1	4	**29**	11	4	0.4	1.1	0.01
N40	75.6	11.8	3.8	0.8	0.1	0.04	3.43	0.42	0.11	0.01	0.005	**513**	1.9	4.0	8	42	2.4	0.4	14	22	45	47	0.3	0.5	0.06
N40-A	89.7	4.7	1.3	0.2	0.0	0.03	1.09	0.05	0.12	0.02	0.003	107	0.6	1.0	3	33	0.6	1.4	6	17	9	71	0.3	1.6	0.01
N41	82.4	9.9	1.0	0.5	0.0	0.03	3.07	0.15	0.13	0.01	0.004	235	0.5	2.0	8	29	0.7	**2.3**	2	7	1	69	0.2	2.2	0.45
N42	57.4	16.2	**11.1**	1.8	0.1	0.04	2.84	2.43	0.22	0.12	0.018	113	**42.3**	2.0	14	**346**	**7.0**	0.7	**130**	3	**94**	**150**	0.5	**7.0**	0.09
N12	77.5	12.3	0.5	0.0	0.6	3.13	5.12	0.08	0.01	0.02	0.002	132	0.3	3.0	62	8	1.7	1.1	5	15	6	3	0.3	5.6	0.01
N12-D	76.8	12.9	0.5	0.1	0.6	2.91	5.21	0.12	0.01	0.01	0.002	37	0.5	5.0	32	8	3.2	0.9	4	17	8	3	0.3	0.5	0.01
N14	75.9	12.7	0.7	0.1	0.9	2.69	5.81	0.14	0.01	0.02	0.002	172	1.1	5.0	77	10	4.8	0.9	28	11	5	7	0.2	2.5	0.36
N16	73.8	9.1	5.3	0.2	9.0	0.02	0.20	0.13	0.02	0.11	0.002	4	1.1	3.0	**433**	10	1.1	1.1	1	2	6	8	**3.7**	0.5	**29.95**
M.	**76.2**	**11.3**	**2.8**	**0.4**	**1.3**	**1.32**	**3.61**	**0.40**	**0.07**	**0.04**	**0.005**	**151**	**5.4**	**3.2**	**76**	**55**	**2.7**	**1.1**	**22**	**14**	**21**	**40**	**0.7**	**2.4**	**3.44**
S.D.	8.5	3.2	3.6	0.6	2.9	1.53	2.03	0.77	0.08	0.04	0.005	153	13.8	1.4	136	110	2.1	0.5	42	9	30	50	1.1	2.4	9.94
S.E.	2.8	1.1	1.2	0.2	1.0	0.51	0.68	0.26	0.03	0.01	0.002	51	4.6	0.5	45	37	0.7	0.2	14	3	10	17	0.4	0.8	3.31

t_c	26.8	10.7	2.3	2.1	1.3	2.59	5.34	1.57	2.78	2.57	2.616	3	1.2	6.9	2	1	3.8	6.2	2	5	2	2	1.8	3.0	1.04
L.L.	69.7	8.9	0.0	0.0	-0.9	0.14	2.05	-0.19	0.01	0.00	0.001	34	-5.2	2.2	-29	-30	1.0	0.7	-10	7	-3	2	-0.2	0.6	-4.20
U.L.	82.8	13.8	5.5	0.9	3.5	2.50	5.16	0.99	0.13	0.07	0.008	269	16.1	4.3	181	139	4.3	1.5	54	20	44	79	1.6	4.2	11.08

In the correlation analysis SiO_2 has strong and weak negative correlation other components. Fe_2O_3; has strong positive correlation with MgO, TiO_2, MnO, Cr_2O_3, Co, V, Cu, Pb and Zn while strong negative correlation with SiO_2. Cu, TiO_2, V, Pb and Zn show strong positive correlation almost all other components except SiO_2. Hg has strong positive correlation together with CaO and Sb (Table 2).

Table 7. Correlation coefficients between the components of the granitoidic rocks

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	Ba	Co	Sn	Sr	V	W	Mo	Cu	Pb	Zn	As	Sb	Au	Hg
SiO_2	1.0	-0.8	-0.8	-0.7	-0.1	0.1	-0.1	-0.9	-0.4	-0.7	-0.8	0.1	-0.8	-0.1	-0.1	-0.8	-0.8	0.5	-0.8	0.4	-0.8	-0.4	-0.2	-0.6	-0.1
Al_2O_3		1.0	0.4	0.5	-0.2	0.4	0.6	0.6	0.1	0.2	0.5	0.1	0.6	0.5	-0.2	0.5	0.8	-0.5	0.6	-0.1	0.6	0.1	-0.2	0.5	-0.3
Fe_2O_3			1.0	0.9	0.2	-0.6	-0.5	0.9	0.7	0.9	0.9	0.0	0.9	-0.3	0.2	0.9	0.6	-0.4	0.8	-0.5	0.9	0.7	0.3	0.5	0.3
MgO				1.0	-0.2	-0.6	-0.3	0.9	0.9	0.6	1.0	0.3	0.9	-0.4	-0.2	0.9	0.6	-0.3	0.9	-0.4	1.0	0.9	-0.1	0.6	-0.2
CaO					1.0	-0.2	-0.6	-0.2	-0.3	0.6	-0.2	-0.4	-0.1	0.0	1.0	-0.2	-0.2	0.0	-0.2	-0.5	-0.2	-0.3	1.0	-0.3	1.0
Na_2O						1.0	0.9	-0.4	-0.8	-0.4	-0.4	-0.3	-0.3	0.7	-0.2	-0.4	0.1	-0.2	-0.3	0.5	-0.4	-0.7	-0.3	0.0	-0.3
K_2O							1.0	-0.1	-0.4	-0.5	-0.2	0.1	-0.1	0.7	-0.5	-0.2	0.4	-0.2	-0.1	0.5	-0.1	-0.4	-0.6	0.1	-0.6
TiO_2								1.0	0.8	0.7	1.0	0.0	1.0	-0.3	-0.2	1.0	0.8	-0.3	1.0	-0.4	0.9	0.8	-0.1	0.7	-0.1
P_2O_5									1.0	0.4	0.8	0.3	0.7	-0.7	-0.4	0.8	0.3	0.1	0.7	-0.3	0.8	1.0	-0.2	0.4	-0.2
MnO					**Strong negative**					1.0	0.6	-0.4	0.7	-0.3	0.6	0.7	0.4	-0.2	0.6	-0.7	0.6	0.5	0.7	0.4	0.6
Cr_2O_3											1.0	0.1	1.0	-0.4	-0.2	1.0	0.7	-0.3	1.0	-0.4	1.0	0.9	-0.1	0.7	-0.2
Ba					**Weak Negative**							1.0	-0.1	0.1	-0.4	0.0	0.0	-0.2	0.0	0.2	0.3	0.2	-0.4	-0.1	-0.4
Co													1.0	-0.3	-0.2	1.0	0.8	-0.3	1.0	-0.4	0.9	0.8	-0.1	0.7	-0.1
Sn					**No correlation**									1.0	0.1	-0.4	0.3	-0.5	-0.2	0.3	-0.2	-0.7	-0.1	-0.4	-0.1
Sr															1.0	-0.2	-0.2	0.0	-0.2	-0.5	-0.2	-0.4	1.0	-0.3	1.0
V					**Weak positive**											1.0	0.7	-0.3	1.0	-0.4	0.9	0.9	-0.1	0.7	-0.2
W																	1.0	-0.6	0.9	-0.2	0.7	0.4	-0.2	0.5	-0.3
Mo					**Strong positive**													1.0	-0.4	-0.2	-0.5	0.0	0.0	-0.1	0.0
Cu																			1.0	-0.4	0.9	0.8	-0.1	0.7	-0.2
Pb																				1.0	-0.2	-0.4	-0.5	-0.4	-0.5
Zn																					1.0	0.8	-0.1	0.6	-0.2
As																						1.0	-0.2	0.5	-0.2
Sb																							1.0	-0.3	1.0
Au																								1.0	-0.3
Hg																									1.0

Skarn Zone

Average Fe_2O_3, Co, Sn, Cu, Pb, Zn, As, Sb and Au 19.6%, 46 ppm, 29 ppm, 364 ppm, 401 ppm, 205 ppm, 343 ppm, 4.3 ppm and 12 ppb respectively (e.g. [5]-[7]). Some samples have reached up 321 ppm for Sn, 382 ppm for W, 4656 ppm for Cu, 8101 ppm for Pb, 3692 ppm for Zn, 2463 ppm for As and100 ppm for Hg (Table 3).

Table 8. Major oxides (%) and some trace element (ppm, Au: ppb) analysis and statistical summaries of the granitoidic rocks (M: Mean, S.S.: Standard deviation, S.E.: Standard error, t_c: Calculated t value: L.L: The lower limit, U.L: Upper limit, Sample number: 22, tt: Table t value: 1.72).

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	Cr_2O_3	Ba	Co	Sn	Sr	V	W	Mo	Cu	Pb	Zn	As	Sb	Au	Hg
N6	**98.5**	0.3	0.7	0.02	0.03	0.03	0.05	0.01	0.01	0.002	16	1	1	2	8	1	1.0	2	2	2	1	0.1	0.5	0.01
N9	40.7	0.7	26.1	0.49	28.76	0.01	0.01	0.01	0.54	0.002	32	19	1	24	10	201	2.4	5	167	14	539	1.2	48.1	0.02
N10-B	85.0	0.7	4.3	1.12	2.15	0.03	0.07	0.01	2.38	0.003	70	31	1	13	12	4	1.7	98	**8101**	**3692**	17	2.0	1.2	0.04
N11	50.1	1.0	13.4	6.86	19.78	0.12	0.03	0.01	3.65	0.002	8	104	1	34	20	10	0.4	324	8	114	26	1.4	0.5	0.01
N13	10.5	0.4	55.6	0.12	8.19	0.01	0.01	0.01	0.13	0.003	1	**524**	54	1	8	102	9.1	**4656**	81	21	**2463**	0.4	**60.6**	0.01
N13-A	33.7	1.9	32.4	0.18	28.49	0.01	0.01	0.01	0.71	0.003	4	1	**321**	1	17	**382**	**14.5**	428	11	3	1348	0.8	11.7	0.04
N13-C	36.6	0.2	30.5	0.01	31.17	0.01	0.01	0.01	0.72	0.003	2	45	24	1	8	254	2.5	50	246	62	259	0.5	6.9	0.01
N13-D	18.8	1.2	**57.5**	0.05	16.34	0.01	0.01	0.01	0.33	0.003	3	27	31	3	10	187	3.1	259	23	11	496	0.9	11.2	0.02
N13-E	26.8	0.9	39.2	0.04	23.79	0.01	0.01	0.01	0.32	0.003	3	53	28	1	8	213	3.1	1898	40	3	781	0.7	55.2	0.01
N14-A	88.6	0.3	8.2	0.01	0.13	0.01	0.02	0.01	0.08	0.003	30	23	1	9	8	36	2.9	9	55	101	385	**78.1**	40.5	**100.0**
N15	39.0	6.4	22.8	0.59	29.24	0.01	0.01	0.10	0.47	0.004	23	5	3	2	26	84	1.6	11	3	6	253	0.4	0.7	7.30
N16-A	33.2	12.3	13.8	1.57	28.69	0.01	0.15	0.19	0.67	0.004	5	9	3	**402**	18	10	0.9	1	7	29	18	1.5	0.5	2.71
N17	47.9	1.3	15.3	**8.04**	23.18	0.06	0.01	0.01	2.23	0.002	23	76	1	26	8	21	0.5	3	2	31	132	1.7	0.5	1.03

N19	35.6	0.4	30.9	0.04	32.07	0.01	0.01	0.01	0.29	0.002	3	5	1	1	8	301	0.8	7	8	2	223	0.3	1.8	0.07
N20	37.0	0.0	1.3	0.73	**39.02**	0.01	0.02	0.01	**4.48**	0.002	2	10	1	48	8	1	0.7	1	19	11	27	0.5	0.7	0.68
N22-A	34.7	0.3	34.7	0.74	28.56	0.01	0.01	0.01	0.34	0.002	9	14	41	1	8	67	1.1	49	2	4	460	0.4	1.3	0.37
N23	74.5	12.2	4.1	1.20	0.42	0.68	**3.30**	0.42	0.16	0.006	**385**	14	2	49	64	3	0.8	45	22	28	45	1.1	2.2	0.22
N24	46.8	2.6	22.9	2.74	19.81	0.07	0.02	**0.66**	1.82	**0.008**	20	26	92	136	**99**	2	0.2	118	6	245	10	1.0	3.9	0.24
N25	46.7	**18.0**	10.3	2.30	18.32	**1.08**	0.17	0.54	0.89	**0.008**	25	10	33	307	63	2	0.9	2	6	28	57	1.1	1.8	0.88
N34-A	95.8	1.5	1.0	0.09	0.18	0.23	0.20	0.03	0.05	0.002	65	2	1	17	8	1	0.7	8	6	12	3	0.1	2.1	0.20
N45	95.0	0.8	2.6	0.06	0.03	0.01	0.04	0.01	0.01	0.002	8	0	1	2	24	1	0.7	11	1	8	6	0.5	3.6	0.33
N45-A	81.4	7.6	4.4	1.00	0.12	0.04	0.52	0.22	0.62	0.005	83	16	1	24	45	1	0.6	15	27	86	6	0.1	3.5	0.09
M.	**52.6**	**3.2**	**19.6**	**1.27**	**17.20**	**0.11**	**0.21**	**0.11**	**0.95**	**0.003**	**37**	**46**	**29**	**50**	**22**	**86**	**2.3**	**364**	**402**	**205**	**343**	**4.3**	**11.8**	**5.2**
S.D.	27.0	4.9	17.1	2.15	13.28	0.26	0.70	0.19	1.22	0.002	81	110	69	104	24	116	3.3	1041	1721	781	577	16.5	19.5	21.2
S.E.	5.7	1.1	3.7	0.46	2.83	0.06	0.15	0.04	0.26	0.000	17	23	15	22	5	25	0.7	222	367	166	123	3.5	4.2	4.5
t_c	9.1	3.1	5.4	2.78	6.07	2.02	1.43	2.59	3.66	8.541	2	2	2	2	4	3	3.2	2	1	1	3	1.2	2.8	1.1
L.L.	40.6	1.0	12.0	0.32	11.31	0.00	-0.10	0.02	0.41	0.003	1	-3	-1	4	11	34	0.8	-98	-361	-141	87	-3.0	3.1	-4.2
U.L.	64.5	5.4	27.2	2.22	23.09	0.23	0.52	0.19	1.49	0.004	73	95	60	96	33	137	3.8	825	1165	551	599	11.6	20.4	14.6

In the correlation analysis SiO_2 has strong and weak negative correlation with Fe_2O_3 and CaO. Fe_2O_3; has strong positive correlation with W, and As while strong negative correlation with SiO_2. Pb and Zn have not got any correlation with others. Hg has strong positive correlation with Sb; Au has strong positive correlation with Cu and As. According to these results SiO_2 shows different behavior in the geochemical process (Table 4).

Table 9. Correlation coefficients between the components of the skarn samples

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	Cr_2O_3	Ba	Co	Sn	Sr	V	W	Mo	Cu	Pb	Zn	As	Sb	Au	Hg
SiO_2	1.0	0.0	-0.8	-0.1	-0.8	0.1	0.2	0.0	-0.1	0.0	0.4	-0.4	-0.3	-0.1	0.1	-0.5	-0.4	-0.4	0.3	0.3	-0.5	0.3	-0.3	0.3
Al_2O_3		1.0	-0.3	0.1	-0.1	0.8	0.5	0.7	-0.1	0.7	0.4	-0.2	-0.1	0.8	0.6	-0.3	-0.2	-0.2	-0.1	-0.1	-0.3	-0.1	-0.3	-0.1
Fe_2O_3			1.0	-0.2	0.4	-0.3	-0.3	-0.2	-0.3	-0.1	-0.3	0.5	0.3	-0.2	-0.2	0.7	0.5	0.6	-0.2	-0.2	0.7	-0.2	0.5	-0.2
MgO				1.0	0.1	0.2	0.0	0.2	0.6	0.1	0.0	0.1	-0.1	0.2	0.2	-0.3	-0.3	-0.1	0.0	0.0	-0.3	-0.1	-0.3	-0.1
CaO					1.0	-0.2	-0.3	-0.1	0.4	-0.1	-0.4	-0.1	0.2	0.2	-0.2	0.5	0.1	-0.1	-0.2	-0.3	0.1	-0.3	0.0	-0.3
Na_2O						1.0	0.5	0.7	-0.1	0.7	0.5	-0.1	-0.1	0.5	0.5	-0.3	-0.2	-0.1	-0.1	-0.1	-0.2	-0.1	-0.2	-0.1
K_2O							1.0	0.4	-0.2	0.4	1.0	-0.1	-0.1	0.0	0.4	-0.2	-0.1	-0.1	0.0	0.0	-0.2	-0.1	-0.1	-0.1
TiO_2								1.0	0.0	1.0	0.4	-0.1	0.1	0.6	1.0	-0.4	-0.3	-0.2	-0.1	-0.1	-0.3	-0.1	-0.2	-0.1
MnO					**Strong negative**				1.0	-0.1	-0.1	0.0	-0.1	0.1	0.0	-0.3	-0.2	-0.2	0.3	0.3	-0.3	-0.1	-0.3	-0.2
Cr_2O_3										1.0	0.4	-0.1	0.1	0.6	0.9	-0.3	-0.1	-0.1	0.0	0.0	-0.2	0.0	-0.1	0.0
Ba					**Weak Negative**						1.0	-0.1	-0.2	0.0	0.4	-0.3	-0.2	-0.1	0.1	0.1	-0.2	0.0	-0.2	0.0
Co												1.0	0.0	-0.1	-0.2	0.0	0.4	0.9	0.0	0.0	0.8	0.0	0.6	-0.1
Sn					**No correlation**								1.0	0.0	0.1	0.6	0.8	0.2	-0.1	-0.1	0.5	-0.1	0.1	-0.1
Sr														1.0	0.4	-0.3	-0.2	-0.2	-0.1	-0.1	-0.3	-0.1	-0.2	-0.1
V					**Weak positive**										1.0	-0.3	-0.2	-0.2	-0.1	0.0	-0.3	-0.1	-0.3	-0.1
W																1.0	0.6	0.2	-0.1	-0.2	0.5	-0.1	0.3	-0.1
Mo					**Strong positive**												1.0	0.5	0.0	-0.1	0.8	0.0	0.4	0.0
Cu																		1.0	-0.1	-0.1	0.9	-0.1	0.7	-0.1
Pb																			1.0	1.0	-0.1	0.0	-0.1	-0.1
Zn																				1.0	-0.1	0.0	-0.1	0.0
As																					1.0	0.0	0.7	0.0
Sb																						1.0	0.3	1.0
Au																							1.0	0.3
Hg																								1.0

4. CONCLUSIONS

Triassic to Holocene aged metamorphic, magmatic and sedimentary units exposed in the study area. Permo-Triassic Nilufer unit was formed by metamorphic detritic and carbonate rocks in the greenschist facies, constitutes the lowest structural slice of the Karakaya complex. Cretaceous, low grade metamorphic Hodul Unit covers the Nilufer unit with tectonic contact. Oligocene Karadoru Granitoide cut the Nilufer and Hodul Units. Oligocene Saricayir granite is represented by pinkish-colored, fine-to medium-grained alkali feldspar granite, and aplitic granites. Miocene Can Volcanics represented by beige, yellowish beige and pink colored andesite, dacite and rhyodacitic lava, tuff and agglomerates.

Nilufer and Hodul units were affected by the intrusion of Karadoru Granitoide and Saricayir alcali granite. Contact metamorphism and skarn type mineralization were developed adjacent to contacts of granitoids with the carbonate rocks of Nilufer units. Garnet - epidote skarn was formed at the contact of granite and marble and epidote skarn in the clastic rocks. Contact metamorphism appears to have extended from albite-epidote hornfels to hornblend hornfels facies. As a result of contact metamorphism minor amount of pyrite and magnetite and rarely chalcopyrite were formed in the skarn zone. Garnets are responsible for the iron enrichments while lead and copper enrichments were caused by the epidotes. Average Fe_2O_3 20%, Sn 29 ppm, Cu 364 ppm, Pb 400 ppm, Zn 205 ppm, As 343 ppm, Sb 4 ppm, Au 12 ppb and Hg 5 ppm. Some samples have reached up 320 ppm for Sn, 380 ppm for W, 4660 ppm for Cu, 8100 ppm for Pb, 3700 ppm for Zn, 2500 ppm for As and above 100 ppm for Hg. According to the findings obtained from the field, mineralogical, petrographical, geochemical and statistical studies performed in the Karadoru and Saricayir Skarn deposits, granitoidic rocks of the Karadoru Granitoide and Saricayir Granites intruded into the clastic and carbonate rocks of the Bozalan formation and the Hodul Units, formed a contact metamorphic zone in this region. Karadoru and Saricayir Skarn Deposits and their near environs should be detailed investigate for copper, lead, zinc and iron formations.

ACKNOWLEDGMENT

The Authors wish to thank Scientific Research Project Coordination Unit of Selcuk University for supports timely (BAP Project Numbers: 09201131 and 12701434).

REFERENCES

[1]. Duru, M., Pehlivan, S., Senturk, Y., Yavas, F. and Kar, H., 2004. New results on the lithostratigraphy of the Kazdag massif in Northwest Turkey. Turkish Journal of Earth Science, 13, 2, 177-186.
[2]. Donmez, M., Akcay, A.E., Genc, S.C. and Acar, S., 2005, Middle-Upper Eocene volcanism and marine ignimbrites of Biga Peninsula, Journal of Min. Res. Expl. Inst. of Turkey, 131 49-61.
[3]. Bingol, E., Akyurek, B., Korkmazer, B., 1973, Geology of Biga Peninsula and Karakaya formation characteristics. 50th Anniversary Geology Congress of Republic's, 1973, Ankara.
[4]. Okay, A. I., Siyako, M., and Burkan K. A., 1990, Geology and tectonic evolution of Biga Peninsula, Bulletin of Turkey Petroleum Geologist Association, 2/1 83-121.
[5]. Akis, I., 2011, Geological and geochemical features of the skarn deposits around the Saricayir (Yenice-Canakkale), MSc thesis Selcuk University, Graduate Natural and Applied Sciences, Geological Engineering Main Science Branch 108 pp.
[6]. Arik, F., 2011, Geological and geochemical characteristics of the skarn deposits around the Saricayir (Yenice-Canakkale), Selcuk University Scientific Research Projects Coordination Unit 09201045, 117 pp.
[7]. Arik, F. and Akis, I., 2013, Geological and geochemical features of the Saricayir (Yenice/Canakkale) Skarn deposits, Goldschmidt2013 Conference Abstracts, 614.
[8]. Genc, S.C., Donmez, M., Akcay, A.E. and Altunkaynak, S., 2004, The middle Eocene to late Miocene magmatic evolution of the Biga Peninsula, NW Turkey. *32nd. IGC Florence 2004 –Sci. Sess.*: Abstracts (part 2) -1298.
[9]. Robertson, A.H.F., Ustaomer, T., Pickett, E.A., Collins, A.S., Andrew, T., Dixon, J.E., (2004), Testing models of Late Paleozoic – Early Mesozoic orogeny in Western Turkey: support for an evolving open – *Tethys model. Journal of Geological Society, London, Vol. 161,* pp. 501–511.
[10]. Okay, A.I., Satir, M., Maluski, H., Siyako, M., Monie, P., Metzger, R. and Akyuz, S., 1996, Paleo-and Neotethyan events in *northwest* Turkey. In: Yin A, Harrison M(eds) Tectonics of Asia. Cambridge University Press, Cambridge, 420-441.
[11]. Okay, A.I., and Satir, M., 2000, Coeval plutonism and metamorphism in a latest Oligocene metamorphic core complex in Northwest Turkey. Geological Magazine, 137, 495-516.
[12]. Okay, A.I., ve Goncuoglu, M.C., 2004, The Karakaya Complex: A Review of data and concepts. *Turkish Journal of Earth Sciences,* Vol.13, pp. 77-95
[13]. Ongen, S., 1982, Petrology of the Yenice (Canakkale) granitoids and wall rocks, Istanbul Univ. Graduate Natural and Applied Science Institute, Associate Professor Thesis, 234 pp.
[14]. Aysal, N. 2005, Petrology of the Mesozoic-Tertiary Magmatism and Metamorphism East of Biga (Canakkale) PhD. Thesis, Istanbul Univ. Graduate Natural and Applied Science Institute, 195 pp.
[15]. Ongen, S., Azaz, D. and Aysal, N., 2002, Petrography of the Oligocene aged Namazgah Granitoide and vessel rocks Yenice (Canakkale). 55th. Turkey Geological Congress, Proceedings, 204- 206.
[16]. Ercan, T., Satir, M., Steinitz, G., Dora, A., Sarifakioglu, E., Adis, C., Walter, H.J. and Yildirim, T., 1995. NW Anatolia Tertiary volcanism in Biga Peninsula, Gokceada, Bozcaada and Tavsan peninsulas characteristics, Journal of Min. Res. Expl. Inst. of Turkey, Ankara, 117, 55-87.
[17]. Lacin, D., 2003, Formation, mineralogical and deposition features of the halloysites of the Biga Peninsula (Canakkale-Balikesir) PhD. Thesis, Istanbul Univ. Graduate Natural and Applied Science Institute 162 pp.
[18]. Aysal, N., Ongen, S. and Hanilci, N., 2006, Petrography of the Karadoru Granitoid Pluton and its wall rocks and characteristics of the skarn zone (Yenice-Canakkale), *Istanbul Univ. Engineering Faculty, Journal of Geosciences* 19, (2), 183-194.