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Research Article

Geochemistry and Mineralization Potential of the Ophiolitic Rocks in Konya Region

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Abstract

Geochemical studies performed in ophiolitic rocks and placers located in three different regions around Konya (Hatıp-Çayırbağı, Altınekin, Yükselen) show that the average Si and Al in both rocks and placers are lower than the earth crust. On the other hand, the average Fe, Cr, Mg, Co, Ni and Ti contents are higher than the average amounts in the earth's crust. While Cu content of Hatıp-Çayırbağı ophiolitic rocks is at high values, Pb and Zn contents are observed at high values in the Altınekin region. While Cr_2O_3 in Hatıp-Çayırbağı region shows 5 times enrichment in placers compared to rocks, it shows approximately 4 times enrichment in the Yükselen region. In the Altınekin region, Au shows five times more enrichment. Light Rare Earth Elements (LREE) are highly enriched in all regions. According to the simple correlation and cluster analysis of the components analyzed in all three regions, it is revealed that the examined ophiolitic rocks were formed by similar processes. In the three different regions, ophiolitic rocks and placers are rich in Fe, Cu, Pb, Zn, Cr, Co, Ni and Ti.

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Konya Bölgesindeki Ofiyolitik Kayaçların Jeokimyası ve Cevherleşme Potansiyeli

Özet

Konya çevresinde üç farklı bölgede (Hatıp-Çayırbağı, Altınekin, Yükselen) bulunan ofiyolitik kayaçlar ile plaserler üzerinde gerçekleştirilen jeokimyasal incelemelerde, hem kayaçlarda hem de plaserlerde ortalama Si ve Al'un yer kabuğundan daha düşük değerlerde olduğunu göstermektedir. Bunun yanı sıra ortalama Fe, Cr, Mg, Co, Ni ve Ti içerikleri yer kabuğundaki ortalama miktarlara göre daha yüksektir. Hatıp-Çayırbağı ofiyolitik kayaçlarında Cu içeriği yüksek değerde iken Altınekin bölgesinde Pb ve Zn içerikleri yüksek değerlerde gözlenmektedir. Hatıp-Çayırbağı bölgesinde Cr_2O_3, plaserlerde kayaçlara göre 5 kat zenginleşme gösterirken, Yükselen bölgesinde yaklaşık 4 kat zenginleşme göstermektedir. Altınekin bölgesinde, Au beş kat daha fazla zenginleşme göstermektedir. Hafif Nadir Toprak Elementleri (REE) tüm bölgelerde oldukça zenginleşmiştir. Her üç bölgede de bileşenlerin basit korelasyon ve küme analizine göre incelenen ofiyolitik kayaçların birbirlerine benzer süreçlerle oluştuğu ortaya çıkmaktadır. Üç bölgede de ofiyolitik kayaçlar ve plaserler, Fe, Cu, Pb, Zn, Cr, Co, Ni ve Ti bakımından zengindir.

Anahtar Kelimeler
Jeokimya
Ofiyolit
Altınekin
Yükselen
Hatıp-Çayırbağı
Konya

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INTRODUCTION

Alpine-Himalayan orogenic belt includes tectonic forces of the Neotethyan ocean. The ophiolites were formed by the closure of the Late Permian and Late Triassic Neotethys Ocean in the Upper Cretaceous.

Ophiolites are the continental remnants of the oceanic lithosphere and are formed in a tectonic zone represented by the subduction zone [1-4]. Geological and geochemical studies on ophiolites (e.g. [5,6]) show wide geochemical characteristics of the ophiolitic rocks.

Ophiolitic rocks, which are exposed in large areas in Turkey, are used both during their formation and the changes they undergo after their formation, especially precious (PGM and Au) and heavy metals (Cr, Co, Ti, Ni, Fe) and industrial raw materials (olivine, magnesite, talc, sepiolite, etc.) and are rich in natural structure and coating materials. Central Anatolia is an important metallogenic provenance in which numerous industrial raw material formations and metallic mineralizations associated with ophiolitic rocks are observed [7].

Stream sediments give information about mineral composition, sources of ore material, lithodynamic events, paleotectonic, lithofacies properties and concentration change during transport, as well as economic value and technological properties of placers [8]. As placer samples help in solving problems related to bedrock geochemistry and in the discovery of anomaly related to mineralization [9], these sediments are the most effective sampling tools used in exploration of mineral deposits [10,11].

Previously, many studies have been conducted in Konya and its surroundings about ophiolitic complexes [12-16], and there are no detailed studies on the genesis and metal enrichment in ophiolitic rocks and related placers. Within the scope of this study, it was aimed to determine the origin and metallic enrichment of ophiolitic rocks and placers in three different regions by using geological, geochemical and geostatistical features (1. Hatıp-Çayırbağı, 2. Altınekin, 3. Yükselen; Fig. 1). The detailed geochemistry and geostatistical studies of heavy and precious metals in the ophiolitic rocks and placers in the regions were attempted to reveal their geochemical properties and the results obtained in each region were compared with each other.

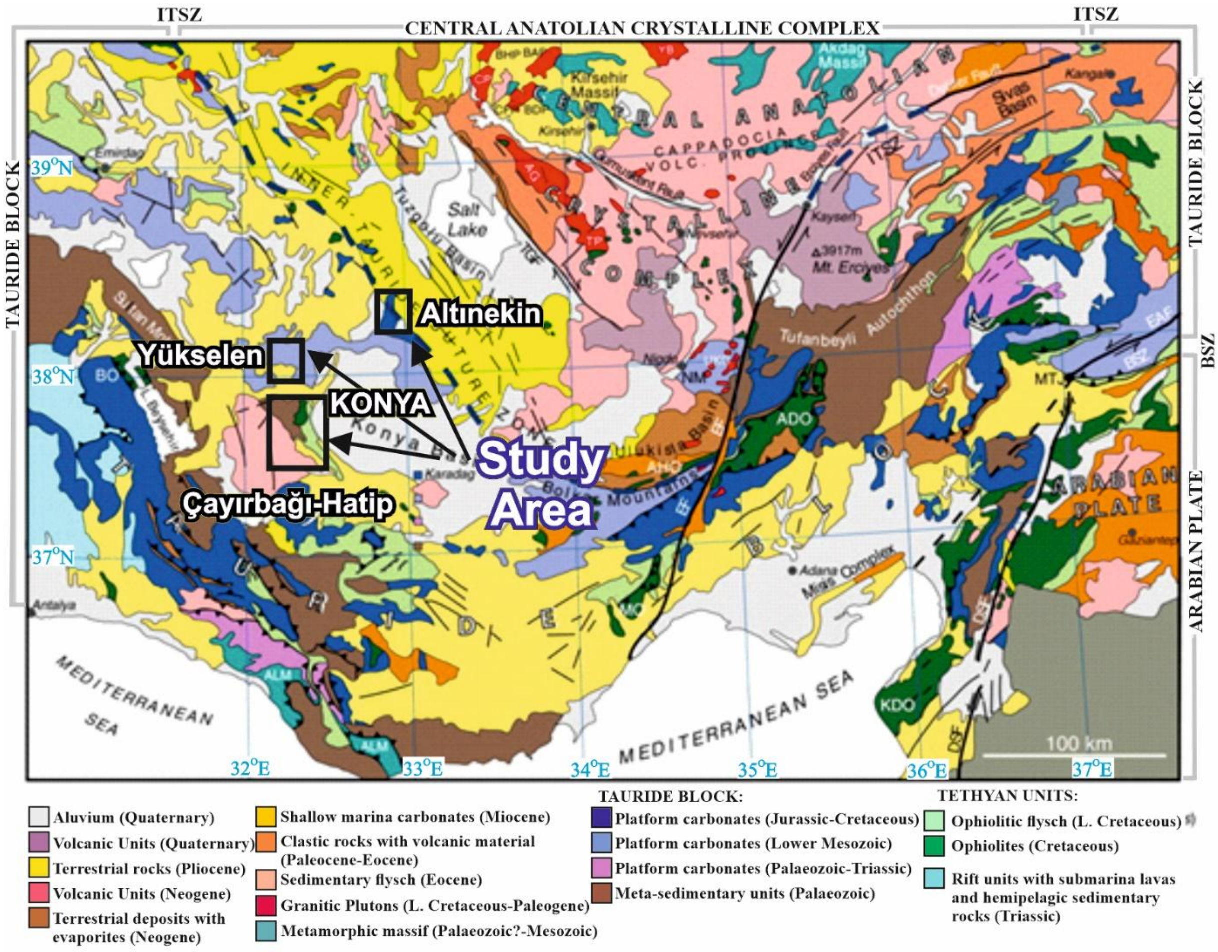

Figure 1. Investigated regions in geological map (modified from [17])

MATERIAL AND METHOD

A detailed and systematic sampling study was carried out from ophiolites and wall rocks for rock-ore petrography and chemical analysis (major oxide, trace element, rare earth elements) within the scope of this study which conducted in three different regions (Hatıp-Çayırbağı, Altınekin, Yükselen). For this purpose, a total of 85 ophiolitic rock samples, 33 from the Hatıp-Çayırbağı region, 25 from the Yükselen region, 27 from the Altınekin region, and 24 placer samples were taken. Major oxide, trace element and rare earth element analyzes were carried out in Bureau Veritas Acme Laboratories (Canada) in order to determine the chemical composition of these samples. For these investigations, rocks and ores were first passed through a jaw crusher in Selçuk University Laboratories, then ground in a 4-mesh ball milling machine and powder rock / ore samples weighing about 20 grams were brought to 90 µ size and numbered and bagged. For the analysis of trace elements and rare earths, samples which weighing 0.5 g are processed in a solution prepared from a mixture of 3 ml HCl-HNO_3-H_2O for one hour at ~ 95 °C, completed to 10 ml and by making final filtration the sample is made ready for analysis. Chemical analyzes were performed at ACME Laboratories (Canada) using the ICP-MS (Inductively Coupled Plasma Mass Spectrometry) method. In these rock samples, from 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; from trace elements Pb, Zn, Cu, Sb, Au, Ag, Sn, Mo, W, Ni, Ba, Sr, V, Zr, Y, Sc, Se and from Rare Earth Elements, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu contents were determined.

Major oxide, trace element and rare earth elements obtained by chemical analysis were evaluated, and measures of variability such as average and enrichment ratios were determined. In order to determine the conformity of the chemical analysis results to normal distribution, normal and logarithmic classifications were made on some major oxides and trace elements that were thought to be enriched by the same processes in the region and it was determined that they were suitable for normal distribution.

Correlation and cluster analyzes were performed to determine the shape, direction and strength of the relationship between the analyzed components. Interpretation of the relations of metals in the field with each other and their wall rocks was made using all the data obtained as a result of field, laboratory and statistical analyzes.

RESULTS

Regional Geology

Hatıp-Çayırbağı Region

At the base of the Hatıp-Çayırbağı region, Lorasdağı formation is located which consisting of Late Triassic-Early Cretaceous aged recrystallized limestone, dolomitic limestone and dolomites. The Midostepe formation, consisting of Late Cretaceous aged dark pink clayey limestone and gray colored chert nodular pelagic limestone, overlies this formation with lateral vertical transition. This unit is overlain by a tectonic contact with the Hatıp ophiolite complex consisting of Late Cretaceous serpentinite, ophiolitic mélange and limestones with intermediate levels. Late Cretaceous aged İkisivritepe olistoliths are found in the Hatıp ophiolite complex. The Çayırbağı formation, consisting of the Late Cretaceous aged dark bright green and locally brown serpentinized peridotites, lies on the Hatıp ophiolite complex with tectonic contact. Erenlerdağı volcanics which consisting of Neogene aged dacites and gray and greenish colored andesites with an angled unconformity overlying this unit. Quaternary aged Alluvium which consisting of clay, silt, sand and pebbles covers all units with an angled unconformity [7].

Altınekin Region

The oldest unit in the Altınekin region is the Nuras formation containing the Early Triassic-Late Cretaceous aged whitish-beige, cream-colored crystallized limestones, and the Milis formation containing Late Cretaceous aged schists, calcschists, metasandstones and metaconglomerates comes on top with lateral vertical transition. The Koçyaka ophiolite, which contains Late Cretaceous aged marble, radiolarite blocks and diorite-diabase dykes, overlies the underlying units with tectonic contact. The Aktepe ophiolite, which contains Late Cretaceous aged serpentinite, peridotite, gabbro and diabase dykes, overlies the underlying units with tectonic contact. The Ulumuhsine formation, which contains white, cream and yellow colored limestone, marl and mudstone of Late Miocene-Early Pliocene aged, unconformably overlies the other units. The Karakaya volcanite, which contains the late Miocene-Early Pliocene aged brown, reddish yellow-gray volcanics that lost their primary texture, cuts out the underlying units and the alluvium covers all these units unconformably [7].

Yükselen Region

Studies have conducted in the Yükselen region and its surrounding [18-32], there is no common opinion about the stratigraphic development of the region.

The Ladik Metamorphics, which form the basis of the Bozdağlar Massif, are located at the bottom of the Mesozoic-aged Yükselen ophiolite, above which is the Silurian (?) - Devonian Permian aged Bozdağ formation, Bağrıkurt formation, Karadağ metamagmatics and the Permo (?) - Mesozoic aged Bahçecik and Ertuğrul formations that cover them in an angle unconformity [21].

At the base of the study area; there is the Yükselen Ophiolite, which is composed of rocks such as diabase, gabbro, serpentinite and surfaced within the tectonic window. Bozdağ formation consisting of recrystallized limestone, dolomitic limestone and dolomites overlies this unit; Bağrıkurt formation consisting of phyllite, methasandstone, recrystallized limestone, metachert, schist and metacarbonate olistoliths and Upper Carboniferous-Lower Permian aged Karadağ metamagmatics, which are observed as dykes in places at intermediate levels. The units overlying these formations unconformably at the bottom are the Bahçecik formation represented by metaconglomerate, phyllite methacumstone and slightly recrystallized limestones, and the Ertuğrul formation in the form of metacarbonate and metaclastics. All these units are covered unconformably by the Quaternary-Current aged Topraklı formation and alluvium, which are widely observed in the region [7].

Geochemistry

Ophiolitic rock geochemistry

According to the chemical analysis results of ophiolitic rocks in three different regions, these ophiolitic rocks are classified as ultramafic and mafic rocks, mostly gabbro-norite, in the R1-R2 discriminant diagram (Fig. 2a) proposed by [33]. In the Th/Yb - Nb/Yb graph proposed by [34], ophiolites in the examined regions did not form very distinct clusters and are seen as scattered in the continental crust region, volcanic arc region and ocean island arc basalt regions (Fig. 2b). However, the ophiolites have a subduction component are displaced to higher Th/Yb values (Fig. 2b). In the TiO_2-V classification diagram prepared by [35]; comparing the Central Anatolian ophiolites (Çiçekdağı ophiolite and Sarıkaraman ophiolite) with the ophiolitic rock samples in the study area, it was determined that Çiçekdağı and Sarıkaraman ophiolites showed the dominant island basalt feature, but the ophiolites in the examined regions showed both the island basalt and the mid-ocean ridge basalt feature (Fig. 2c). Altınekin ophiolite is displaced near the MORB–OIB array and weak subduction influence (Fig. 2b). Hatıp-Çayırbağı ophiolite plots predominantly between the volcanic arc array and MORB–OIB array and MORB-OIB array (Fig. 2b). Yükselen ophiolite display higher Th/Yb values and plots predominantly in the field of island arc tholeiite (Fig. 2d).

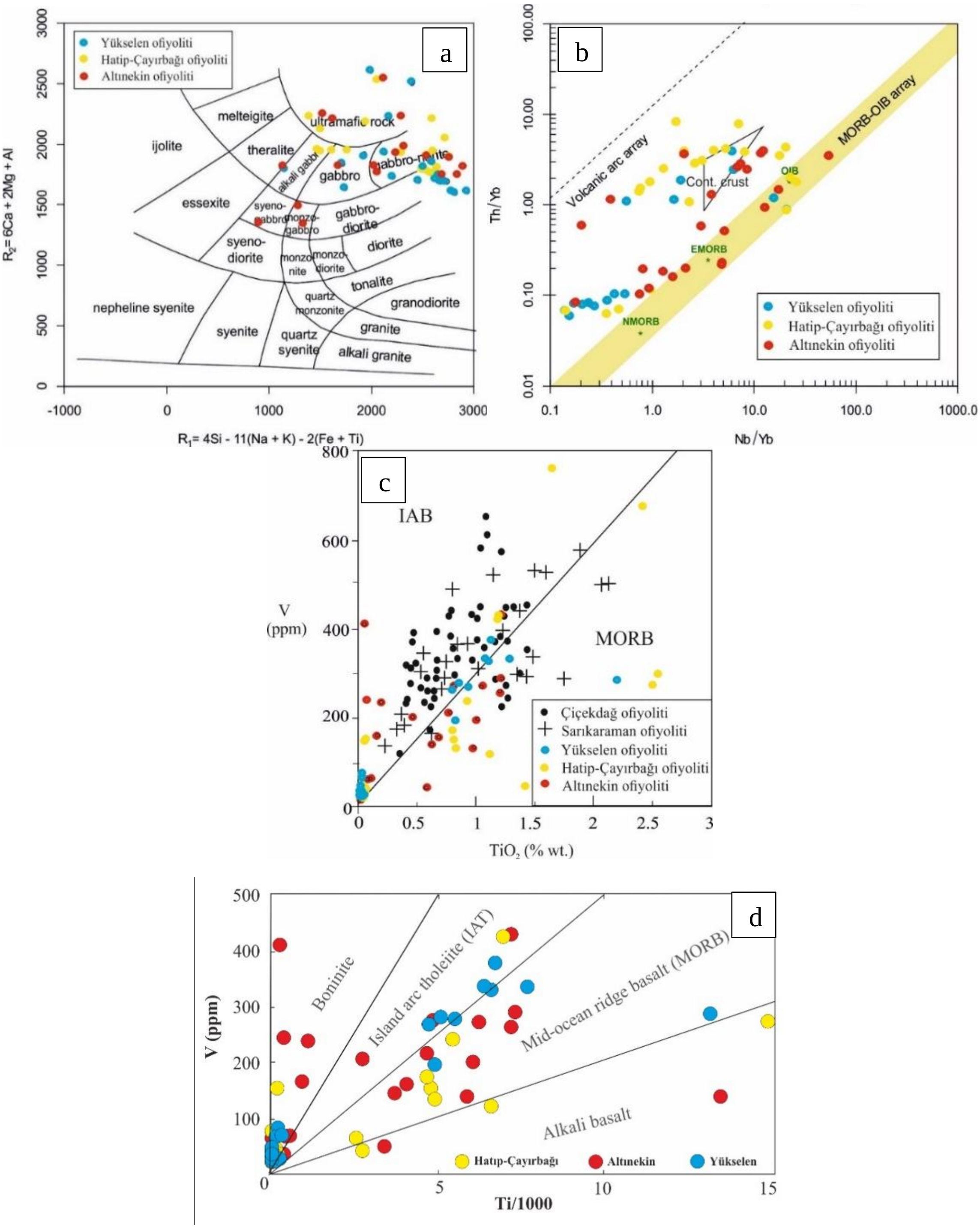

Figure 2. a. Classification chart [33]; **b.** Classification diagram according to Nb / Yb-Th / Yb values [34]. **c.** TiO_2-V classification diagram and comparison with other Central Anatolian ophiolites (Çiçekdağı ophiolite and Sarıkaraman ophiolite, [35]; IAB: Island arc basalt; MORB: Mid-ocean ridge basalt), **d.** Ti / 1000-V diagram [36, 37] of the ophiolitic rock samples in the study area.

The SiO_2 content of 33 ophiolitic rock samples collected from the *Hatıp-Çayırbağı region* is on average 48.62%, and in other samples with the same number of samples to be collected from the ophiolitic rocks from which these rocks are taken, SiO_2 is expected between 44.13% and 53.11% with a 95% probability. The Hatıp-Çayırbağı ophiolites contain average of 19.70% MgO, 10.50% Fe_2O_3, 5.9% Al_2O_3 and 5.1% CaO. These rocks are rich in elements such as Cu, Zn, Ni, Co, Zr, Ba and Sr, and the samples examined draw attention with an average of 90.8 ppm Zr, 4.38 ppm Sr, 106.1 ppm Ba and 1145.5 ppm Ni (Table 1).

The average SiO_2 content of 27 ophiolitic rock samples collected from the *Altınekin region* is 46.58%, and the average SiO_2 content in the ophiolitic rocks from which these samples were taken is expected to be between 39.09% and 46.75%. Altınekin ophiolites contain average of 9.90% Fe_2O_3, 16.24% MgO, 8.9% Al_2O_3 and 5.36% CaO (Table 1). The Altınekin region ophiolites are rich in elements such as Cu, Pb, Zn, Ni, As, Co, Zr, Ba and Sr, and the placers which examined include average of 43.03 ppm Zr, 102.6 ppm Sr, 99.2 ppm Ba and 650.9 ppm Ni (Table 1).

Table 1. Major oxide, trace element and rare earth element analysis results and statistical analysis summaries of the ophiolitic rocks belonging to Hatıp-Çayırbağı, Altınekin and Yükselen regions (major oxides are expressed as % and Au as ppb and other elements as ppm)

	Hatıp-Çayırbağı (n=33)			**Altınekin (n=27)**			**Yükselen (n=25)**		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
SiO_2	22.56	83.95	48.62	9.53	88.96	46.58	31.95	75.18	45.34
Al_2O_3	0.16	18.34	5.91	0.38	18.24	8.91	0.09	14.56	5.12
Fe_2O_3	2.88	55.65	10.50	4.34	21.78	9.90	5.20	13.62	8.50
MgO	0.70	42.62	19.70	0.23	38.21	16.24	1.20	37.11	19.72
CaO	0.12	20.03	5.09	0.02	15.12	5.36	0.09	29.58	7.11
Na_2O	0.01	5.00	0.80	0.01	5.44	1.36	0.01	3.35	0.65
K_2O	0.01	4.14	0.64	0.01	1.77	0.30	0.01	2.01	0.14
TiO_2	0.01	3.66	0.67	0.01	2.24	0.50	0.01	2.19	0.42
P_2O_5	0.01	0.74	0.14	0.01	0.99	0.14	0.01	0.23	0.04
MnO	0.02	0.48	0.15	0.02	0.98	0.27	0.04	0.45	0.14
Cr_2O_3	0.01	0.50	0.21	0.00	17.18	1.43	0.01	0.48	0.19
Ni	28.95	2572.50	1145.46	38.60	2735.75	650.86	33.35	2599.85	1327.05
Sc	3.00	56.00	18.45	1.00	116.00	22.04	3.00	49.00	18.04
Ba	1.00	816.00	106.09	1.00	855.00	99.15	2.00	563.00	46.64
Co	6.80	549.20	90.23	5.10	423.20	82.01	34.50	131.40	77.09
Cs	0.1	6.80	0.76	0.10	6.30	0.92	0.10	3.40	0.83
Ga	0.50	22.00	7.10	0.50	20.80	7.74	0.50	15.20	4.94
Hf	0.10	11.90	2.41	0.10	5.00	1.19	0.10	3.20	0.73
Nb	0.10	83.90	9.67	0.10	42.70	4.85	0.10	25.40	1.39
Rb	0.10	153.20	19.32	0.10	49.00	8.95	0.10	21.60	1.95
Sr	0.50	515.80	74.38	0.50	461.20	102.62	2.70	311.90	73.11
Ta	0.10	5.30	0.69	0.10	1.70	0.29	0.02	39.40	4.26
Th	0.20	18.80	3.15	0.20	6.10	1.04	0.20	2.00	0.31
U	0.10	7.40	1.12	0.10	1.80	0.45	0.10	3.40	0.50
V	20.00	766.00	149.58	24.00	427.00	156.48	21.00	376.00	131.72
W	0.50	3.40	0.81	0.50	3.50	0.81	0.05	1.55	0.25
Zr	0.10	436.30	90.78	0.30	181.50	43.03	0.30	117.40	24.26
Y	0.10	73.70	13.62	0.10	34.20	10.35	0.10	28.80	8.38
La	0.20	77.40	15.28	0.10	57.50	7.04	0.10	19.40	2.06
Ce	0.10	151.70	31.21	0.10	44.90	10.84	0.10	39.40	4.49
Pr	0.02	17.04	3.53	0.02	15.63	1.93	0.02	5.11	0.65
Nd	0.30	65.00	13.94	0.30	68.40	8.70	0.30	21.70	3.31
Sm	0.05	13.33	2.75	0.05	14.50	2.03	0.05	4.77	0.95
Eu	0.02	3.41	0.80	0.02	3.13	0.61	0.02	1.55	0.35
Gd	0.05	14.25	2.82	0.05	13.02	2.23	0.05	4.37	1.29
Tb	0.01	2.31	0.43	0.01	1.58	0.35	0.01	0.82	0.24
Dy	0.05	13.58	2.57	0.05	7.36	2.05	0.05	5.14	1.51
Ho	0.02	2.65	0.51	0.02	1.39	0.41	0.02	1.08	0.33
Er	0.03	7.31	1.42	0.03	3.62	1.15	0.03	3.29	0.97
Tm	0.01	1.02	0.20	0.01	0.52	0.17	0.01	0.48	0.14
Yb	0.05	6.32	1.30	0.05	3.29	1.05	0.05	3.30	0.94
Lu	0.01	0.95	0.20	0.01	0.51	0.16	0.01	0.49	0.14
Mo	0.10	23.70	2.32	0.10	3.30	0.36	0.10	4.4	0.17
Cu	1.50	5457.80	192.81	3.20	151.90	45.80	3.30	217.40	37.28
Pb	0.10	78.50	6.88	0.30	3752.20	171.79	0.10	8.50	1.84
Zn	5.00	427.00	61.61	8.00	402.00	74.07	7.00	89.00	43.84
As	0.50	49.10	4.56	0.50	906.10	51.73	0.50	468.70	20.92
Sb	0.10	3.30	0.29	0.10	46.70	2.69	0.1	0.5	0.15
Au	0.50	17.50	1.49	0.50	11.20	1.52	0.50	9.10	1.10

The SiO_2 content of 25 ophiolitic rock samples collected from the *Yükselen region* is on average 45.34%, and SiO_2 is expected between 41.83% and 48.86% in all samples (Table 1). The ophiolites collected from the Yükselen region have an average of 8.5% Fe_2O_3, 19.72% MgO, 7.11% CaO and 5.1% Al_2O_3. Ophiolites in the Yükselen region are rich in elements such as Ni, V, Co, Cu, Zn and Sr. Among the Yükselen ophiolites, the average contents of 1327 ppm Ni, 131.7 ppm V, 77.1 ppm Co, 77.1 ppm Sr draws attention (Table 1).

The average Si and Al contents of the ophiolitic rocks in the *Hatıp-Çayırbağı region* are lower than the earth crust's value, and the Fe value is close to the earth crust's value. The Mg ratio in the ophiolitic rocks collected from the *Hatıp-Çayırbağı region* is quite high (Table 2) and is associated with the serpentinites representing the majority of the ophiolitic rocks. Cr content in ophiolitic rocks in the Hatıp-Çayırbağı region is similar to that in ultramafic rocks (Table 2), and it can be said that Cr content is related to the presence of serpentinite and serpentinized dunites. Co content in ophiolitic rocks in the *Hatıp-Çayırbağı region* is lower than ultramafic rocks' value, Ni value is close to ultramafic rocks' values and Ti value is close to the earth's crust average.

In the ophiolitic rocks from the *Altınekin region*, Si and Al are lower than the earth crust's value, and the Fe value is close to the earth crust's value. The high Mg content in Altınekin ophiolites is associated with the serpentinites observed commonly in the region. In the serpentinized peridotites in the Hatıp-Çayırbağı area in the southwest of the study area, there are widespread magnesite formations in the form of stock veins. Magnesite formations observed in some thin sections in Altınekin region indicate the presence of magnesite formations in this region as well. Accordingly, magnesite occurrences have become in Altınekin region under atmospheric conditions. The Cr amount reaching a level close to 1% depends on the Cr_2O_3 content of 17.18% and 16.98% measured in two samples. When these samples are excluded, the average decreases to 0.2%, and this amount is very close to the average values in ultramafic rocks. However, the region of these two samples with high Cr_2O_3 content should be investigated in detail in terms of Cr. The Cr content in ophiolitic rocks depends on the presence of serpentinized peridotites. The Co content in ophiolitic rocks in the Altınekin region is lower than ultramafic rocks', but rather higher than others. While the average Ni value is lower than the ultramafic rocks' values, it is higher than the other average values.

It is seen that the average Si in the ophiolitic rocks located in the *Yükselen region* is lower than the earth crust's value, and the Fe value is close to the amount in the earth's crust. The Mg ratio in these rocks is quite high and is caused by serpentinites, which are common in the region and represent the majority of the studied ophiolitic rocks. The average Ti content in the examined rocks is close to the average amount in the earth's crust, the Cr content is close to the Cr content in the ultramafic rocks and much higher than the other values. It can be said that the high Cr content in the studied samples is related to the presence of serpentinized dunites. The average Co content of the ophiolitic rocks in the region is lower than that of ultramafic rocks, and Ni content is close to the average Ni content in ultramafic rocks.

Table 2. Comparison of mean major and trace element values in ophiolitic rocks belonging to Hatıp-Çayırbağı, Altınekin and Yükselen regions with "global mean element concentrations" (MORB: Mid-ocean ridge basalt, OIT: Ocean island tholeiite, IAT: Island arc tholeiite, CFT: Tholeiitic basalt)

	Location	**Si (%)**	**Al (%)**	**Fe (%)**	**Mg (%)**	**Ti**	**Co (ppm)**	**Ni (ppm)**	**Cr (%)**
Mean	**Hatıp-Çayırbağı**	22.73	3.13	7.34	11.88	0.40	90	1146	0.21
	Altınekin	21.77	4.72	6.92	9.79	0.30	82	651	0.98
	Yükselen	21.19	2.71	5.95	11.89	0.25	77	1327	0.13
Earth crust		27.72*	8.13**	5**	2.09**	0.44**	23	80	0.02
MORB			8.25***	7.13***, I	4.64***, I	0.86			0.029III
OIT			7.12***	8.23***, I	4.47***, I	1.57			
IAT			8.47***	6.92***, I	4.08***, I	0.48			
CFT			9.04***	7.24***, I	4.73***, I	0.6			
Ultramafic rocks				9.43***, I			110****, II	2000	0.2
Mafic rocks				8.65***, I		0.5****	48****, II	130	0.03****, II

*[38, 39], **[39, 40], ***[41], ****[42], I [43], II[44], III[45]

Simple correlation analyzes were carried out in order to determine the shape, direction and strength of the relationships between the analyzed major oxide, trace element, and Rare Earth Elements (REEs).

Examined the correlation table consisting of major oxide, trace element and REE of the ophiolite in *Hatıp-Çayırbağı region*, Fe_2O_3 shows a very positive relationship with Cu and Au and shows a strong positive relationship with Co, V, MnO and Zn. MgO, which has an important role in the ophiolites of the region shows a very strong positive relationship with Ni and a strong positive relationship with Cr_2O_3. While Co shows a very strong positive correlation relationship with Cu and Au, Zr has a very strong positive correlation with LREE, and all REEs among themselves.

In the correlation analysis performed on samples collected from *Altınekin region*, it can be said that many components have different behaviors with others. According to the correlation analysis, the high positive correlation between REEs is noteworthy. Al, Ca, Na and Cs, which are among the other components, also have strong positive correlations with REE. Fe_2O_3 analyzed in the ophiolites in the Altınekin region shows very strongly positive relationship with V, Y and usually HREE; it shows a strong positive relationship with Co, V, MnO and Zn. MgO in the samples has a strong positive relationship with Ni and Co, and a very strong negative relationship with Ni and HREEs. MgO has a very strong positive correlation with Zr, TiO_2, P_2O_5, Al_2O_3 and REE. It has no significant correlation with any component other than SiO_2 and Mo. Al_2O_3 shows strong positive correlation relationship with CaO, TiO_2, Sc, Ga, Hf, V, Zr, Y, HREE and Cu in the ophiolitic rocks in *Altınekin region*.

Fe_2O_3 in the ophiolites in the *Yükselen region* show very strongly positive correlation relationship with V, Y and usually HREE and shows strong positive relationship with Co, V, MnO and Zn. MgO, which has an important role in the ophiolites of the region, has a strong positive relationship with Ni and Co. Ni shows a very strong negative relationship with HREEs. They have very strong positive correlations with Zr, TiO_2, P_2O_5, Al_2O_3 and all REE. REE also shows a very strong positive correlation between itself.

In the cluster analysis dendrogram which prepared using the common correlation coefficients of the components of the ophiolitic rocks in the *Hatıp-Çayırbağı region*, seven distinct groups emerged (Figure 3). The first group consist of HREE, Y and Al_2O_3 and it is seen that they move together. The second group consists of HREE, (Zr-Hf) and Th. The third group includes (Pb-As-Mo), (K_2O-Rb), Nb, Ba, U and W. In the fourth group, it is seen that SiO_2 is added to (Na_2O-Sr) and (TiO_2-P_2O_5) pairs with a very low coefficient, which indicates the secondary action of SiO_2. In the fifth group, it is seen that Fe_2O_3, Co, Zn and MnO-V pairs are added to Cu-Au pair, respectively. The sixth group consisting of CaO-Sc pair is also associated with other previous groups, and in the last group, Ni, Cr_2O_3, MgO, which also represent magnesite and chromite in ophiolitic rocks, can be said to show a weathering.

Two distinct groups emerged in the dendrogram which prepared using the correlation coefficients of the components of the ophiolitic rocks in the *Altınekin region* (Fig. 3). In the cluster analysis dendrogram, the first group was determined as the main components and REE group, except SiO_2 and MgO. The second main group is named as Si-Mg-trace element group. The main components-REE group is represented by two subgroups within itself. The first subgroup of the main components-REE group constitutes (Hf-Zr) -TiO_2 and (Al_2O_3-Ga), which are added to the HREE-Y group, respectively, and this group is named HREE-Al-Ti subgroup. The second subgroup is the LREE-Na subgroup, which includes HREE with strong positive correlations and Na_2O is added remotely. These two important subgroups of the main constituent group are weakly positively combined, and (CaO-Cu) -Sr, Sc-V, K_2O-Rb, ((Nb-Ta)-Ce)-P_2O_5)-Th)) subgroup and (MnO-Cr_2O_3)-Fe_2O_3 subgroup has been added to these groups. The second main group in the cluster analysis dendrogram of *Altınekin ophiolites* is the Si-Mg-trace elements group and this group is represented by two distinct subgroups. The first subgroup of the Si-Mg-Trace elements group consists of the (MgO-Ni)-W assembly remotely added to the Pb-Zn pair, and this subgroup is named as the Mg-Ni-Pb-Zn subgroup. The second subgroup of the Si-Mg-Trace elements group is represented by the SiO_2-U pair added to the ((Ba-Mo)-C-Cs group remotely added to the As-Sb pair. Unlike other main components, Si and Mg, the presence of trace elements such as Pb, Zn, As, Sb, Mo, Co and Ni together reflects the metamorphism that took place in the region after the formation of ophiolitic rocks and the extreme changes in these components with the effect of young volcanics. Therefore, changes have occurred in *Altınekin ophiolites* with the effects of both surface alteration and hydrothermal alteration.

In the cluster analysis dendrogram of the ophiolitic rock samples collected from the *Yükselen region*, five distinct groups are emerged (Fig. 3). In the dendrogram, the first group is consists of HREE, Y, V and Al_2O_3 and it is seen that they move together. Addition of Sc and Fe_2O_3 remotely to these shows that Fe_2O_3 comes as weathering from rocks. In the dendrogram, it is seen that in the second group, Zr, TiO_2 and HREE move together and Cu is added to the group later. The third group includes K_2O, Nb, Ba, Rb, La and Th, and Sr is added to this group with a low coefficient. The fourth group includes Ni, Co, MgO and Cr_2O_3, which also represent magnesite and chromite in ophiolitic rocks, and show a superficial weathering. In the last group, (U-As), SiO_2 and (Pb-Zn) are added with a low coefficient, and the addition of SiO_2 to the (U-As) pair with a low coefficient may indicate a secondary silicification. The fact that Pb and Zn move together with low coefficients indicates the presence of superficial alteration rather than hydrothermal alteration (Fig. 3).

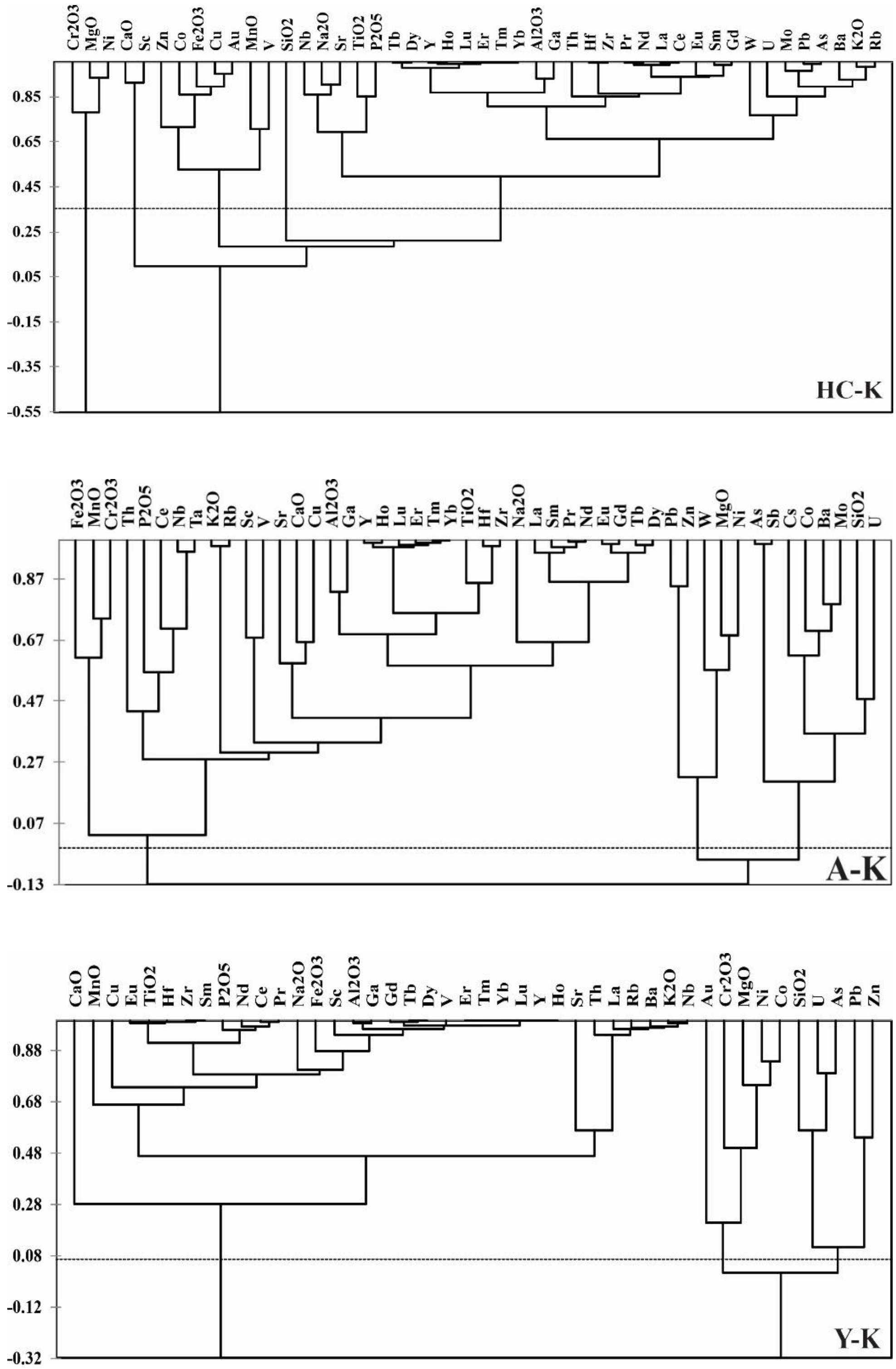

Figure 3. Dendrogram of cluster analysis according to coefitic correlation coefficients of ophiolitic rocks collected from Hatıp-Çayırbağı (HC-K), Altınekin (A-K) and Yükselen (Y-K) regions.

Placer Geochemistry

The average SiO_2 content of 9 placer samples collected from the common streams and their immediate surroundings in the *Hatıp-Çayırbağı region* is 43.33%, and SiO_2 is expected between 39.92% and 46.75% in all placers. In Hatıp-Çayırbağı placers, there is an average of 10.44% Fe_2O_3 and the highest Fe_2O_3 amount determined in placers is 12.6%. The other major oxides MgO, Al_2O_3 and CaO values in the region placers are respectively 16%, 8.7% and 7.9% (Table 4). The placers of Hatıp-Çayırbağı region are rich in elements such as

Cu, Zn, Ni, Co, Zr, Ba and Sr, and the placers examined have an average of 207.1 ppm Zr, 251.4 ppm Sr and 236.4 Ba (Table 3).

The average amount of SiO_2 of 7 placer samples collected from *Altınekin region* is 44.84%, and SiO_2 is expected between 37.37% and 52.31% in all placers (Table 3). In the placers of the region, Fe_2O_3 is found at an average rate of 7.24% and the highest Fe_2O_3 amount determined is 9.22%. The ratios of MgO, Al_2O_3 and CaO among other major oxides in placers are 7.89%, 7.24%, 13.28%, respectively. Placers in Altınekin region are rich in elements such as Cu, Zn, Ni, Co, Zr, Ba and Sr, and placers examined have an average of 192 ppm Zr, 386 ppm Sr, 239 ppm Ba, and 468 ppm Ni (Table 3).

The SiO_2 content of 8 placer samples collected from the *Yükselen region* is on average 36.6%, and SiO_2 is expected between 31.7% and 41.6% in all placers. There is an average of 11.20% Fe_2O_3 in the Yükselen placers and the highest Fe_2O_3 amount determined is 16.24%. Other major oxides MgO, CaO and Al_2O_3 in the region placers are respectively 16.4%, 11.1% and 5.9% (Table 3). Placers of the Yükselen region are rich in elements such as Cu, Pb, Ni, Co, Zr, Ba and Sr, and the placers examined have an average of 207.1 ppm Zr, 149.0 ppm Sr, 199.5 ppm Ba and 1001.8 ppm Ni (Table 3).

In placers located in *Hatıp-Çayırbağı region*, while average Si and Al are low, Fe content is quite high compared to the average of the earth's crust. The presence of rocks such as gabbro and diabase rich in magnetite and hematite minerals in the area where the samples were collected caused an increase in the Fe content (Table 4). The contents of Mg, Ni, Co and Cr in the ophiolitic samples are also higher than the average of the earth's crust. It shows that these components have been enriched due to the superficial weathering of gabbro, diabase, spilite and serpentinites in the region.

In *Altınekin region* placers, Si and Al content is lower than the average value of earth crust, and Fe content is close to the values of mafic rocks (Table 4). While the average amount of Mg in the samples is higher than that of the earth's crust, it is close to basaltic rocks and tholeiites. The high amount of Ti and Cr in the placers in the study area originates from the ophiolitic rocks in the region and can be attributed to the weathering of the serpentinized peridotites. Co content in placers in the study area is lower than ultramafic rocks, and Ni content is close to ultramafic rocks (Table 4).

Table 3. Major oxide, trace element and rare earth element analysis results and statistical analysis summaries of placers belonging to Hatıp-Çayırbağı, Altınekin and Yükselen regions (major oxides are expressed as %, Au as ppb, and other elements as ppm).

	Hatıp-Çayırbağı (n=9)			Altınekin (n=7)			Yükselen (n=8)		
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
SiO_2	37.77	52.33	43.23	34.21	54.25	44.84	28.59	45.47	36.69
Al_2O_3	2.36	20.95	8.76	6.05	9.22	7.24	1.68	9.50	5.72
Fe_2O_3	7.75	12.61	10.25	7.18	13.09	9.41	7.85	16.24	11.20
MgO	2.65	35.09	15.84	5.60	11.59	7.89	8.64	29.04	16.34
CaO	0.64	15.10	7.79	6.02	18.60	13.28	2.67	17.40	11.22
Na_2O	0.02	1.55	0.88	0.51	1.39	1.04	0.07	1.08	0.58
K_2O	0.03	5.80	1.19	0.15	1.01	0.61	0.06	1.30	0.48
TiO_2	0.06	2.52	1.02	0.65	1.21	0.94	0.20	1.60	0.92
P_2O_5	0.01	0.26	0.11	0.04	0.39	0.14	0.02	0.32	0.10
MnO	0.13	0.33	0.19	0.12	0.22	0.17	0.15	0.23	0.18
Cr_2O_3	0.02	2.79	1.14	0.12	1.31	0.42	0.44	1.11	0.71
Ni	110.00	2140.00	909.44	238.90	916.25	468.27	471.40	1996.90	1001.94
Sc	8.00	29.00	18.56	10.00	25.00	17.14	10.00	21.00	16.63
Ba	25.00	631.00	236.44	152.00	336.00	239.00	24.00	673.00	199.50
Co	49.90	156.20	84.07	25.90	76.60	52.63	49.10	169.40	97.66
Cs	0.10	10.00	1.78	0.50	2.50	1.49	0.10	7.90	1.83
Ga	2.50	26.60	10.61	7.10	11.80	8.30	3.40	10.20	5.64
Hf	0.40	9.30	4.74	2.30	6.80	4.34	0.70	14.30	4.88
Nb	1.00	45.80	19.61	4.20	22.90	14.64	1.10	24.50	8.71
Rb	1.90	222.30	38.49	4.20	25.80	18.63	2.70	44.10	13.89
Sr	18.30	642.10	251.44	236.40	553.40	385.93	69.80	336.00	148.94
Ta	0.10	3.00	1.29	0.30	1.30	0.94	0.10	1.50	0.53
Th	1.00	21.00	8.36	2.30	15.50	8.11	0.30	11.60	4.05
U	0.10	5.60	2.34	0.90	3.20	1.97	0.30	2.80	1.09
V	103.00	316.00	199.22	90.00	226.00	157.00	69.00	268.00	167.13
W	0.50	2.70	0.88	0.50	1.80	1.16	0.50	1.70	0.78
Zr	21.90	418.30	207.09	92.50	307.10	192.23	21.90	624.70	207.00

Y	1.30	48.70	19.92	14.70	30.80	21.20	3.20	21.80	12.40
La	8.90	75.70	36.74	9.00	54.80	34.29	2.00	53.80	16.71
Ce	14.20	153.10	71.28	15.90	99.00	62.63	3.60	95.80	31.08
Pr	1.25	16.83	7.99	2.03	10.61	6.77	0.46	10.50	3.52
Nd	3.60	62.70	30.31	8.90	39.10	25.40	1.90	38.60	13.16
Sm	0.43	11.71	5.47	2.16	6.69	4.60	0.53	6.68	2.57
Eu	0.10	2.46	1.36	0.58	1.86	1.18	0.14	1.46	0.66
Gd	0.34	9.91	4.64	2.25	6.70	4.33	0.56	5.31	2.45
Tb	0.05	1.51	0.67	0.41	1.05	0.65	0.09	0.73	0.36
Dy	0.21	9.35	3.90	2.55	5.81	3.80	0.59	4.38	2.29
Ho	0.04	1.70	0.73	0.58	1.21	0.78	0.10	0.78	0.43
Er	0.14	4.90	1.95	1.56	3.24	2.19	0.32	2.43	1.32
Tm	0.02	0.71	0.30	0.22	0.47	0.33	0.05	0.33	0.19
Yb	0.14	4.60	1.86	1.37	2.82	2.04	0.36	2.19	1.30
Lu	0.01	0.72	0.29	0.22	0.39	0.31	0.06	0.38	0.20
Mo	0.10	6.60	0.94	0.20	0.70	0.36	0.20	0.40	0.33
Cu	5.70	57.70	29.21	20.30	69.60	42.51	18.20	109.10	41.06
Pb	1.50	30.80	7.32	6.20	27.60	12.16	1.20	9.40	4.00
Zn	34.00	151.00	61.89	36.00	203.00	82.57	40.00	84.00	50.38
As	0.60	19.10	3.92	5.70	15.80	10.46	1.00	6.40	3.49
Sb	0.10	0.60	0.20	0.10	0.80	0.44	0.10	4.20	0.69
Au	1.00	4.20	2.84	0.80	11.20	3.54	0.50	2.80	1.69
Pt	-	-	-	6.80	1.29	12.31	-	-	-
Pd	-	-	-	8.40	0	18.51	-	-	-

While the average amounts of Si and Al in the placer samples in the *Yükselen region* are low, the average Fe ratio is quite high compared to the average values of the earth's crust, and the presence of rocks such as gabbro, diabase and etc. rich in magnetite and hematite minerals in the area where the samples were collected caused an increase in Fe content. Average Ti content is close to mafic rocks, Mg and Cr content is higher than the earth's crust average. Especially the prevalence of ophiolitic rocks in the region caused an increase in the amount of Mg in placer samples. It shows that excessive amounts of Mg and Cr come from basic and ultrabasic rocks in the region to placers. The average Co and Ni content in the placers in the study area is also high, and it can be said that this situation is due to the weathering of the gabbro, diabase, serpentinite and spilite in the region.

Table 4. Comparison of mean major and trace element values in placers of Hatıp-Çayırbağı, Altınekin and Yükselen regions with "global mean element concentrations" (MORB: Mid-ocean ridge basalt, OIT: Ocean island tholeiite, IAT: Island arc tholeiite, CFT: Tholeitic basalt)

	Location	Si (%)	Al (%)	Fe (%)	Mg (%)	Ti (%)	Co (ppm)	Ni (ppm)	Cr (%)
Mean	**Hatıp-Çayırbağı**	20.25	4.59	8.12	9.65	0.67	84	877	0.78
	Altınekin	20.96	3.83	6.58	4.76	0.60	52.71	468.27	0.29
	Yükselen	17.75	3.02	7.83	9.85	0.55	97.63	1001.75	0.49
Earth crust		27.72[*]	8.13[**]	5[**]	2.09[**]	0.44[**]	23	80	0.02
MORB			8.25[***]	7.13[***, I]	4.64[***, I]	0.86			0.029[III]
OIT			7.12[***]	8.23[***, I]	4.47[***, I]	1.57			
IAT			8.47[***]	6.92[***, I]	4.08[***, I]	0.48			
CFT			9.04[***]	7.24[***, I]	4.73[***, I]	0.6			
Ultramafic rocks				9.43[***, I]			110[****, II]	2000	0.2
Mafic rocks				8.65[***, I]		0.5[****]	48[****, II]	130	0.03[****, II]

[*][38, 39], [**][39, 40], [***][41], [****][42], [I] [43], [II][44], [III][45]

In the correlation analysis prepared from major oxide, trace element and REE in placers located in *Hatıp-Çayırbağı region*, MgO shows a very strong negative correlation with Co and Ni. While Zr has a very strong positive correlation with U and Hf, REE has a very strong positive correlation with each other. While all elements except Fe_2O_3, MgO, CaO, Cr_2O_3, Co, Sr, V, Zr, Ni, As and Au have strong and very strong positive correlations with each other, these elements also show strong and very strong positive correlations within themselves. Therefore, in placers, Fe, Ca, Cr, Co, Sr, V, Zr, Ni, As and Au behave differently than other components. The average values of these components being higher than the reference rocks show that the components released from the weathered ophiolitic rocks are enriched in the placers.

A very strong positive correlation is observed between Cr_2O_3-Au, MgO-Ni and Zr-Hf-REE in the placers of *Altınekin region*. Ni shows a very strong negative relationship with HREEs.

It is seen that Co, Cs, Ga, Hf, Nb, Sr, Th, U, Zr, Y and REE have very strong positive correlations with each other in the placers of the *Yükselen region*. SiO_2, Fe_2O_3, CaO, MnO, Cr_2O_3, TiO_2, Sc, V, Mo, Cu and Zn do not show significant correlations with any components other than a few components. Al_2O_3 has a strong and very strong positive correlation with many components other than the components mentioned above. MgO, Co and Ni have negative correlations with the majority of the components.

Based on the relationships that emerged in the simple correlation analysis of the components analyzed in all placers, 6 distinct groups emerged in Hatıp - Çayırbağı placers according to cluster analysis and dendrograms using common correlation coefficients in order to identify significant clusters between these components. In the cluster analysis dendrogram in Hatıp - Çayırbağı region, the first group is represented by the MnO-Eu pair added to the Al_2O_3-REE group in which the entire REE is located together with Al_2O_3-Ga (Fig. 4a). This group shows that as a result of the weathering of the serpentinized peridotites, Al, Mn and REE are generally deposited in the furthest regions from the bedrock. The second group in placers is represented by Ba, Cu and SiO_2 added to the K_2O-Pb-Cs-Rb-As-Zn group. This group, which is called the K-Trace element-Si group, reached the streams as a result of the relatively high proportion of components in placers carried more than the first group. The third group in the dendrogram is the (Hf-Zr) - (Th-U) group, and the elements belonging to this group have accumulated in regions closer to the main rocks. In the cluster analysis dendrogram, the fourth group is represented by (TiO_2-Nb)-P_2O_5 added to the Na_2O-Sc pair. The fifth group is the (CaO-Sr) - (Fe_2O_3-V) group, and the components in this group have been enriched very close to the source. In the cluster analysis dendrogram, the sixth group is represented by Co and Cr_2O_3 added to the MgO-Ni pair and is named as the Mg-Cr group.

In the cluster analysis dendrogram of the placers in the *Altınekin region*, the first main group is the Main Components-REE-Trace Elements Group, which includes SiO_2, K_2O, Al_2O_3, Na_2O, Fe_2O_3, P_2O_5 and MgO (Fig. 4b). This group is divided into four subgroups. The main components are REE- the first subgroup of the trace elements group [(Eu-Gd-Sm)-SiO_2] - (La-Pr-Nd-Sb)] added to the community [(Hf-Zr) - (K_2O-Th)] and to this group represented by the attached ensemble {[(Nb-Ta) -Rb]-Cs}, which is called the subgroup SiO_2-K_2O-LREE. LREE with close ion radius with SiO_2 took place together in this group. The second subgroup of the main components REE-trace elements group is represented by (Al_2O_3-Ga) added to the HREE and Na_2O and Fe_2O_3 added to this group respectively. This subgroup is named as HREE-Al-Fe subgroup. In Altınekin placers, the main components are represented by REE-Third subgroup of the trace elements group (Sr-U)-Ba assembled by {[(Sn-Pb) -P_2O_5] -Mo} and Be and Zn remotely added to this group, and Sr-Ba It is named the Sn-Pb-Mo group.

The last group of the main components REE-trace elements group is represented by As and W added to the MgO-Ni pair, and this group is named as the Mg-Ni-As-W group. The second main group in Altinekin placers is named Cr-Ti-Mn-Au group and is represented by the {[(Cr_2O_3 Au)-Co]-(CaO-Cu)} community, which joins with the [(Sc-V)-(TiO_2-MnO)] community. The presence of CaO and Au in this group shows that listvenitization occurs as a result of hydrothermal alteration in ophiolitic rocks and these components move together in the weathering environment.

In the cluster analysis dendrogram of the placers in the *Yükselen region*, four groups can be distinguished, and the first group is represented by P_2O_5-Ba-Hf-Zr-U-Nb, which is closely added to the K_2O-Rb-Gd-Cs-LREE assembly, and Th added to this group. This group is named as K-LREE-Heavy element group, and a cluster has been formed due to the separation of alkali minerals in the rocks (Fig. 4c). In the cluster analysis dendrogram, the second group is represented by Ga-Pb, which is closely added to the Al_2O_3-Na_2O-HREE assembly, and As-Au and SiO_2 remotely added to the group. This group shows that Al and Na, which are released due to the weathering of feldspars, move jointly with the HREE. The addition of Si to this group remotely shows that Si also moves together with the HREE, although its concentration changes with subsequent changes. The third group in the placers of the Yükselen region is {[(TiO_2-V) -Sc] -MnO} group and it explains the TiO_2 accumulations due to the weathering of ophiolitic rocks of these components, which do not have strong positive correlations with other components in the correlation table. The last group in the placers of the Yükselen region is {[((MgO-Ni)-Co)-Fe_2O_3]-(Cr_2O_3-Mo)} group and consists of the components commonly found in ophiolitic rocks, which are the dominant host rocks of these placers. Therefore, this group shows that ophiolitic rocks were incorporated into placers as a result of surface weathering.

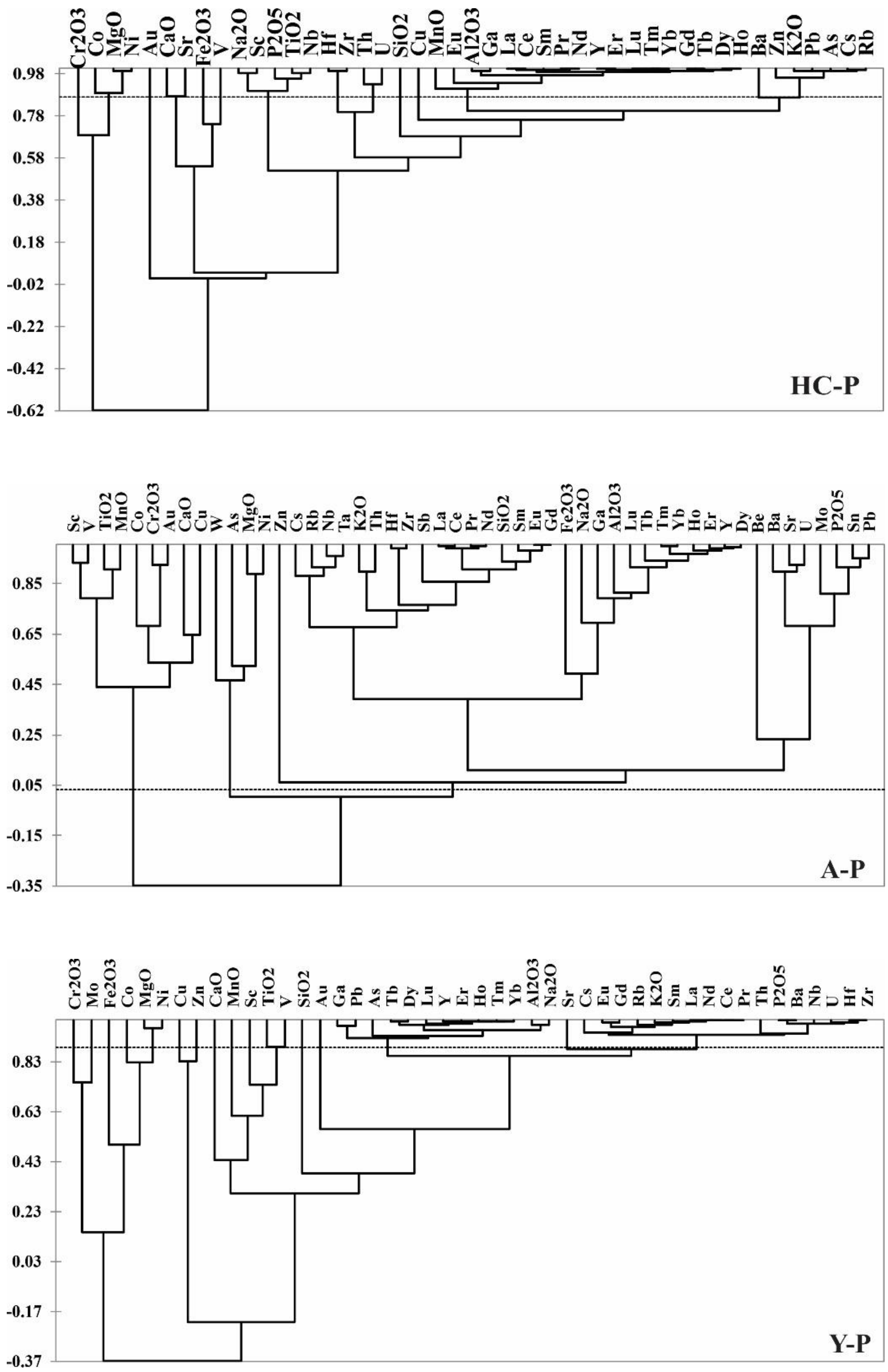

Figure 4. Dendrogram of cluster analysis prepared according to common correlation coefficients of placer samples collected from Hatıp-Çayırbağı (HC-P), Altınekin (A-P) and Yükselen (Y-P) regions.

DISCUSSION AND CONCLUSION

The ophiolites in the three different studied regions show geochemically similar characteristics to each other. Considering the dominance in the geochemical distribution of the samples in each region, the ophiolites in Altınekin and Hatıp-Çayırbağı regions show similar to MORB type ophiolite, the ophiolite in Yükselen region show similar to island arc tholeiite.

While the fact that Pb and Zn move together with low coefficients indicates the presence of superficial alteration rather than a hydrothermal alteration in the Yükselen ophiolites, the presence and moved together of trace elements such as Pb, Zn, As, Sb, Mo, Co and Ni in Altınekin ophiolites reflects the metamorphism that took place in the region after the formation of ophiolitic rocks and the extreme changes in these components with the effect of young volcanics. Therefore, it can be suggested that both superficial alteration and hydrothermal alteration had an effect on Altınekin ophiolites.

The most important factor for changes within a storage or placer site is related to the mineral composition of the ore in the source. This composition changes during weathering and this is reflected in the placers [37]. According to correlation and cluster analyses, the fact that the components (Ni, Co, Fe_2O_3, Cr_2O_3, MgO, TiO_2, etc.) commonly found in ophiolitic rocks commonly highly existed and move together in placers in the studied regions is a result of the superficial weathering of ophiolitic rocks (gabbro, diabase, serpentinite, spilite, etc.). The average values of Fe, Ca, Cr, Co, Sr, V, Zr, Ni, As and Au being higher than the reference rocks show that the components released from the weathered ophiolitic rocks are enriched in the placers.

In all studied regions, SiO_2, MgO and Na_2O are relatively poor in placers compared to rocks, and again, the amount of Ni in all regions shows an equal (0.7-fold) decrease in placers. However, while Cr_2O_3 increases 5 times in placers compared to the rocks in Hatıp-Çayırbağı region, it has approximately 4 times enrichment in the Yükselen region. Au, on the other hand, shows enrichment five times in Altınekin region. It is seen that LREE is enriched very high in all regions (Table 5). In the simple correlation analysis performed in the three regions, the combined movement and enrichment of "MgO, Ni and Co" and "Al_2O_3, Y and REE" indicate that the studied ophiolitic rocks were formed by a similar process. This study shows that the main oxides, Ni, Co, Ba, Sr, V, W, Y, Sc and HREE values of both ophiolitic rocks and placers in each of the studied three regions are quite similar to each other.

Table 5. Comparison of the average chemical content of ophiolitic rocks and placers in the study area and the status of enrichment rates in placers with respect to rocks

Component	Ophiolitic rock			Placer			Rate of enrichment		
	Hatıp-Çayırbağı	Yükselen	Altınekin	Hatıp-Çayırbağı	Yükselen	Altınekin	Hatıp-Çayırbağı	Yükselen	Altınekin
SiO_2	48.62	45.34	46.58	43.23	36.69	44.84	0.89	0.81	0.96
Al_2O_3	5.91	5.12	8.91	8.76	5.72	7.24	1.48	1.12	0.81
Fe_2O_3	10.50	8.50	9.90	10.25	11.20	9.41	0.98	1.32	0.95
MgO	19.70	19.72	16.24	15.84	16.34	7.89	0.80	0.83	0.49
CaO	5.09	7.11	5.36	7.79	11.22	13.28	1.53	1.58	2.48
Na_2O	0.80	0.65	1.36	0.88	0.58	1.04	1.10	0.89	0.76
K_2O	0.64	0.14	0.30	1.19	0.48	0.61	1.86	3.43	2.03
TiO_2	0.67	0.42	0.50	1.02	0.92	0.94	1.52	2.19	1.88
P_2O5	0.14	0.04	0.14	0.11	0.10	0.14	0.79	2.50	1.00
MnO	0.15	0.14	0.27	0.19	0.18	0.17	1.27	1.29	0.63
Cr_2O_3	0.21	0.19	1.43	1.14	0.71	0.42	5.43	3.74	0.29
Ni	1145.46	1327.05	650.86	877.33	1001.90	468.27	0.77	0.75	0.72
Sc	18.45	18.04	22.04	18.56	16.63	17.14	1.01	0.92	0.78
Ba	106.09	46.64	99.15	236.44	199.50	239	2.23	4.28	2.41
Co	90.23	77.09	82.01	84.07	97.66	52.63	0.93	1.27	0.64
Ga	7.10	4.94	7.74	10.61	5.64	8.3	1.49	1.14	1.07
Hf	2.41	0.73	1.19	4.74	4.88	4.34	1.97	6.68	3.65
Nb	9.67	1.39	4.85	19.61	8.71	14.64	2.03	6.27	3.02
Rb	19.32	1.95	8.95	38.49	13.89	18.63	1.99	7.12	2.08
Sr	74.38	73.11	102.62	251.44	148.90	385.93	3.38	2.04	3.76
Th	3.15	0.31	1.04	8.36	4.13	8.11	2.65	13.32	7.80
U	1.12	0.50	0.45	2.34	1.09	1.97	2.09	2.18	4.38
V	149.58	131.72	156.48	199.22	167.13	157	1.33	1.27	1.00
W	0.81	0.30	0.81	0.88	0.78	1.16	1.09	2.60	1.43
Zr	90.78	24.26	43.03	207.09	207.00	192.23	2.28	8.53	4.47
Y	13.62	8.38	10.35	19.92	12.40	21.2	1.46	1.48	2.05
La	15.28	2.06	7.04	36.74	16.71	34.29	2.40	8.11	4.87
Ce	31.21	4.49	10.84	71.28	31.08	62.63	2.28	6.92	5.78
Pr	3.53	0.65	1.93	7.99	3.52	6.77	2.26	5.42	3.51
Nd	13.94	3.31	8.70	30.31	13.16	25.4	2.17	3.98	2.92
Sm	2.75	0.95	2.03	5.47	2.57	4.6	1.99	2.71	2.27
Eu	0.80	0.35	0.61	1.36	0.66	1.18	1.70	1.89	1.93
Gd	2.82	1.29	2.23	4.64	2.45	4.33	1.65	1.90	1.94
Tb	0.43	0.24	0.35	0.67	0.36	0.65	1.56	1.50	1.86
Dy	2.57	1.51	2.05	3.90	2.29	3.8	1.52	1.52	1.85
Ho	0.51	0.33	0.41	0.73	0.43	0.78	1.43	1.30	1.90
Er	1.42	0.97	1.15	1.95	1.32	2.19	1.37	1.36	1.90

Tm	0.20	0.14	0.17	0.30	0.19	0.33	1.50	1.36	1.94
Yb	1.30	0.94	1.05	1.86	1.30	2.04	1.43	1.38	1.94
Lu	0.20	0.14	0.16	0.29	0.20	0.31	1.45	1.43	1.94
Mo	2.32	0.10	0.36	0.94	0.33	0.36	0.41	3.30	1.00
Cu	192.81	37.28	45.80	29.21	41.06	42.51	0.15	1.10	0.93
Pb	6.88	1.84	171.79	7.32	4.00	12.16	1.06	2.17	0.07
Zn	61.61	43.84	74.07	61.89	50.38	82.57	1.00	1.15	1.11
As	4.56	20.92	51.73	3.92	3.49	10.46	0.86	0.17	0.20
Au	1.49	1.10	0.70	2.84	1.69	3.54	1.91	1.54	5.06

In this study, the major oxide, trace element and rare earth element analysis results of samples collected from ophiolitic rocks and placers show very close values in all regions these samples belong.

Ophiolites and placers in studied three different regions are rich in Fe, Cr, Cu, Pb, Zn, Co, Ni and Ti and should be investigated more comprehensively.

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