ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCE

MASTER THESIS

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MINERALOGY AND POTENTIAL CHARACTERISTIC OF CHROMITE OF HAMIDIYE/GAZIANTEP

DEPARTMENT OF MINING ENGINEERING

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MSc THESIS

DEPARTMENT OF MINING ENGINEERING

We certify that the thesis titled above was reviewed and approved for the award of degree of the Master of Science by the board of jury on 28/06/2019.

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ÖZ

YÜKSEK LİSANS TEZİ

HAMİDİYE/ GAZİANTEP BÖLGESİ KROM CEVHERLEŞMELERİNİN MİNERALOJİSİ VE POTANSİYEL ÖZELLİKLERİ

Gael Calo-sinda NGBANGANDIMBO

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: Prof. Dr. Özen KILIÇ
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Çalışma konusunu oluşturan kromit cevherleşmesi, Islahiye Bölgesi sınırlarında N37 c3 paftasında içerisinde bulunan Alt Kretase yaşlı ‘Ofiyolit nap’ı olarak değerlendirilmiş birim içerisinde bulunmaktadır. Kromittler, Dünit, ve harzburjitlerden oluşan tektonitler içerisinde faylara bağlı merceksi, ince tabakamsı olarak masif, saçınımlı nodüler yapıda bulunmaktadır. Yapılan çoklu sondaj verilerinden alınan kayaç ve kromit örneklerinde Pt, Pd, Rh ve Au için ICP-MS yöntemi ile, kromitlerde iz element içerikleri analiz edilmiştir. Kimyasal analiz sonuçlarına göre kromit %Cr_2O_3 42,03-52,1, Cr/Fe oanı 3,794- 4,216 arasında, PGE içeriklerinde; Ru oranı 90 ile 130 ppb, Ir oranı 24 ile 40 ppb, Os oranı 13 ile 50 ppb ve Rh oranı 6 ile 11 ppb arasında değişmektedir.

Çalışma alanı cevherleşmelerinin, Plütonik kromitler ile NATO podiform kromitleri arasında bir değer sunmakta olduğu ve Manto podiform kromitleri alanına daha yakın bir alana düştüğü tespit edilmiştir. Tespit edilen koordinatlarda yapılmış sondaj verilerine göre 10,350 tonluk muhtemel rezerv hesap edilmiştir.

Anahtar Kelimeler: Kromit, PGE, Hamidiye/Gaziantep/Türkiye

ABSTRACT

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The chromite mineralization being studied is located in the unit that is assessed as the "Lower Cretaceous Induced Iterite Water Table" in the N37c3 section of the Ilahiye area. In tectonites consisting of dunite and harzburgites, a massive nodular structure with a thin layer and a disseminated layer is present. Rock and chromite samples obtained from multiple drill data were analyzed by the ICP-MS method for Pt, Pd, Rh and Au. According to the results of the chemical analysis, the $\%Cr_2O_3$ is between 42.03-52.1 and the Cr/Fe ratio is between 3.79-4.21. The PGE contents, the Ru ratio is from 90 to 130 ppb, the Ir ratio from 24 to 40 ppb, the bone ratio from 13 to 50 ppb and Rh from 6 to 11 ppb.

Mineralization in the study area has been found to have a value between the plutonic chromites and the podiform chromites of NATO and has been found to be closer to the podiform chromite region of Manto. The probable reserve of 10 350 tonnes was calculated based on drilling data at the determined coordinates.

Key words: Chromite, PGE, Hamidiye/Gaziantep/Turkey

EXTENDED SUMMARY

Chromites are minerals of great economic value, their value is even more important that they are often associated with enrichment in PGM (platinum group elements: Os, Ir, Ru, Rh, Pt, and Pd). PGEs are highly sought after for their exceptional physicochemical properties. Moreover, this demand is reflected in strong price growth in recent years. So the search for new deposits and the development of new extraction technologies are increasing.

Over the last three decades, ophiolitic chromitites have become a potential target for recovery of platinum group elements (PGEs). Turkey is one of the countries where natural resources are important for the development of the country. The Turkish chromitites have been poorly studied regarding chromite composition and PGE abundances and mineralogy. In this contribution, we are going to make mineralogical and chemical investigations of Islahiye chromites in order to evaluate the economic potential in PGE. The present work is part of this general trend. It aimed to study the mineralogy and concentration of platinum group elements in the chromites at Islahiye (Gaziantep).

Turkey is a structurally complex area where two major oceans have closed with a superimposed structural deformation. The chromite mineralization was installed as a result of plate tectonics and their formation was completed in a regional tectonic setting. The study area covers an area of about 40 km² near Islahiye/Hamidiye, in the province of Gaziantep in south-eastern Anatolia. It is completely in the peridotites 90 km west of Gaziantep.

The mineralization of chromite ore, which forms the basis of the study, is located in the lower Cretaceous ophiolite layer unit on the N37 c3 map. The ophiolite layer is completely stabilized by tectonic movements and forms podiform chromite deposits in its tectonites. As a result of field observations, a geological map was developed based on tectonic and mineralized outcrops. Dunite and harzburgite as the dominant lithology form the major part of the study area. Outcrop and 8 whole data were used to reveal the paragenesis of rocks and ores.

The faults are NE-SW oriented and the mineralization has been displaced in the region due to these faults. The mineralization is irregular and semi-organized, lenticular, massive, nodular and striated. Chromite and rock samples were collected from outcrops (8 samples) in the study area. 8 specimens were drilled in the study area at a depth of 20 to 125 m in order to determine the concentration of platinum group elements contained in the chromite by a mineralogical process. Samples for the chromite and platinum group analysis were prepared in a mining engineering laboratory and sent to ACME/Canada. According to the results of the chemical analysis of chromite ores; Cr_2O_3 = 42.03-52.1%, MgO = 11.08-30.48%, Al_2O_3 = 10.09-18%, 57%, Fe_2O_3 = 10.49-12%, 85% were recorded.

The results of the polished section microscopy and the XRD analysis of the ore are as follows; chromite, lepidocrosite, forsterite, millerite, principal paragenesis of magnetite have been determined.

According to the results of the elemental analysis, the Cr/Fe ratio was 3.78. There is a negative correlation between the positive diagrams Cr_2O_3-Al_2O_3 and Cr_2O_3-FeO and Cr_2O_3-MgO in the% oxide values of the XRF factor analysis results.

The PGE cotent of samples taken from Islahiye chromitites was low and ranged from 138 to 214 ppb in total.

The PGE content of samples taken from Islahiye chromitites was low and ranged from 138 to 214 ppb in total. The mineral content, Laurite, Ruarsite were determined.

Occurrences and chromite faults in the vicinity of faults are different and affect the formation of chromite fusions. The fault zones are composed of highly serpentinized and brecciated colors of yellow, green and mylonite.

The thickness of the fault zone can be between 4 and 6 m or a few centimeters. According to the measured values taken in the majority of chromite ores, the dominant directions of the chromite formations are N35-45°E, the dominant tilt directions (60-75°) SW and the tilt angles are between 50° and 60°.

The fact that the mineralization is due to faults and lenticular settlement near the surface varies greatly in thickness over short distances. The content does not change much.

The fact that mineralization is more underground means that mining should be considered underground. Surface geological observations and outcrops of mineralization can be predicted much higher by taking into account the movement of fault.

GENİŞLETİLMİŞ ÖZET

Kromitler, ekonomik değeri çok büyük olan ve değerleri PGM (Platin Grubu Mineraller; Os, Ir, Ru, Rh, Pt, and Pd) içeriklerinden dolayı artan önemli minerallerdendir. Platin Grubu Mineraller (PGE) fizikokimyasal özellikleri nedeniyle endüstriyel alanda önemli bir yere sahiptir.

Son otuz yılda, ofiyolitik kromititler, platin grubu elementlerinin geri kazanımı için potansiyel bir hedef haline gelmiştir. Türkiye, doğal kaynakların ülkenin kalkınması için önemli olduğu ülkelerden biridir. Türk kromititlerinde, kromit kompozisyonu, bolluğu ve PGE'lerin mineralojisi bakımından yetersiz araştırma bulunmaktadır. Bu çalışmada, Hamidiye bölgesi kromitlerin mineralojik ve kimyasal incelemeleri ile PGE (Platin Grubu Mineraller)' in ekonomik potansiyeli değerlendirilmiştir.

Türkiye, yapısal olarak oldukça karmaşık bir bölgedir. Kromit cevherleşmeleri plaka tektoniği sonucu yerleşmiş ve oluşumunu bölgesel anlamda tektonik çerçevede tamamlamıştır.

Çalışma alanı Güneydoğu Anadolu bölgesinde Gaziantep iline bağlı Islahiye/Hamidiye yerleşim alanlarına yakın yaklaşık 40 km²'lik bir alanı kaplamaktadır. Gaziantep'in 90 km batısında tamamen peridotitler içerisinde bulunmaktadır.

Çalışmanın temelini oluşturan kromit cevher mineralizasyonu, N37 c3 haritasında Alt Kretase yaşlı ofiyolit nap ünitesinde bulunmaktadır. Ofiyolit tabakası tamamen tektonik hareketlerle bölgeye yerleşmiş ve tektonitlerinde podiform kromit yataklarını oluşturmuştur. Saha gözlemleri sonucunda, bölgesel jeolojik haritası yapılmış, dünit-harzburjit kayaç ayırımı gerçekleştirilmiştir. Kayaç ve cevher mineral parajenezlerinin ortaya çıkarmak amacı ile yüzey ve 8 adet sondaj verilerinden yararlanılmıştır.

Bölgesel alanda cevherleşmeyi tetikleyen faylar NE-SW doğrultuludur. Cevherleşme düzensiz ve yarı düzenli yapıda, merceksi, massif, nodüler, bantlı yapıda bulunmaktadır.

Kromitlerde platin grubu elementlerinin konsantrasyonunu ile mineralojik, kimyasal özelliklerinin tespiti için 8 adet kayaç ve mineral analiz için açılan sondajlara ek olarak kromit anamolisi tespit edilen 20 ile 125 m derinlikte 8 sondaj numunesi daha elde edilmiştir. Sondaj verilerinden kromit ve platin grubu analizleri için maden Mühendisliği laboratuvarında örnekler hazırlanmış, ACME/ Kanada'ya gönderilmiştir. Kromit cevherlerinin kimyasal analiz sonuçlarına göre; Cr_2O=%42,03-52,1, MgO=%11,08-30,48, Al_2O_3=%10,09-18,57, Fe_2O_3 =%10,49-12,85 bulunmuştur.

Cevher analizi için parlak kesit mikroskobik ve XRD analiz sonuçları çalışmalar sonucunda; kromit, lepidokrozit, forsterit, millerit, manyetit ana mineral parajenezleri tespit edilmiştir.

Element analizinin sonuçlarına göre, Cr/Fe oranı ortalama 3,78 olarak bulunmuştur. Yine Ana kayaç XRF analiz sonuçlarının % oksit değerlerinde Cr_2O_3-Al_2O_3 ve Cr_2O_3-FeO olan diyagramlarında pozitif ve Cr_2O_3-MgO arasında ise negatif bir korelasyon görülmüştür.

PGE (Platin Grubu Mineraller) tespiti amacı ile kromititlerden alınan örneklerde PGE içerikleri düşük olup, 138 ile 214 ppb arasında değişmektedir.

Ru oranı 90 ila 130 ppb arasında, Ir oranı 3 ila 40 ppb arasında, Os oranı 9 ila 50 ppb arasında ve Rh oranı 6 ila 11 ppb arasında bulunmuştur. Mineral içeriği olarak, Laurit, Ruarsit tespit edilmiştir.

Kromit oluşumları ve yakın çevresinde yer alan faylar atımları farklı olan ve kromit oluşumlarını etkileyen faylardır. Fay zonları ileri derecede serpantinleşmiş, breşleşmiş renkleri sarı, yeşil tonlrında oluşmuş milonitlerden oluşmuşlardır.

Fay zonu kalınlıkları 4-6 m aralığında olabileceği gibi bir kaç santimetre arasında da gözlenmektedir.

Mostralardaki kromit cevherlerinden alınan ölçüm değerlerine gore kromit oluşumlarının egemen doğrultuları N35-45°E, egemen eğim yönleri (60-75°) SW ve eğim açıları 50°-60° olarak belirlenmiştir. 5 adet mostra ve 8 adet sondaj sonuçlarına göre rezerv muhtemel olarak hesaplanmıştır. 10,350 ton'luk muhtemel rezerv hesap edilmiştir.

Cevherleşmenin faylanmalara bağlı olması ve yüzeye yakın yerlerde merceksel yerleşim kalınlık yönünden kısa mesafelerde büyük farklılıklar göstermektedir. Tenör fazla değişmemektedir.

Cevherleşmenin daha çok yealtına doğru olması madenciliğin yeraltı işletmesi olarak değerlendirilmesini gerekli kılmaktadır. Yapılan yüzey jeolojisi gözlemleri ve cevherleşmelerin mostra verileri fayların hareketi göz önüne alınarak rezevin çok daha fazla olduğu öngörülebilir.

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LISTE OF ABBREVIATIONS

PGE	: Platinum Group Element
ICP-MS	: Inductively Coupled Plasma – Mass Spectrometer
XRF	: X-ray fluorescence Spectrometer
XRD	: X-Ray Diffraction Spectrometer
OS	: Osmium
Ir	: Iridium
Ru	: Ruthenium
Rh	: Rhodium
Pd	: Palladium
Pt	: Platinum
PGM	: Platinum Group Metal
ALS	: Analytical Laboratories LTD
Fig	: Figure
Ppm	: part per million

1. INTRODUCTION

Chromium is the 24th element on the periodic table and is what makes steel stainless. It was about 1760 when the chromium-bearing mineral crocoite from deposits in the Ural Mountains was recognized in Europe. However, it was not until 1797-98 that chromium was isolated by Nicolas Louis Vauquelin, a professor of chemistry at the Paris Ecole des Mines. Chromium was discovered later than other metals because it does not appear terrestrially as a native metal, and it is strongly bonded in the minerals in which it occurs. The wide variety of colorful compounds derivable from crocoite led Vauquelin to name the newly discovered element chromium, the name was derived from chroma, the Greek name for color. Crocoite, also is called Siberian red lead, was found to produce a yellow pigment that became popular. Thus paint became the first commercial application of chromium. Chromium was soon discovered in chromite, a much more common mineral, also from the Ural Mountains.

Chromium is primarily used in the metallurgical industry as an alloying element in steel. Chromium confers properties on the alloy that are not achievable with base metals alone. The most common use of chromium is with iron to make stainless steel, an iron-chromium alloy. Chromium confers oxidation resistance to stainless steel, making it "stainless". Stainless steel, in addition to being commonly found in home as kitchens utensils, is an important engineering alloy used throughout industry in machinery, containers, and pipes. Chromium is also used in chemicals for a variety of purposes. Chromite, the mineral from which chromium is extracted for using in the metallurgical and chemical industries, is used directly by the refractory industry to produce heat, spalling, corrosion and abrasion resistant bricks for metallurgical and high-temperature industrial mineral processing applications. Chromite is not mined domestically; thus, the United States is 100% dependent on imports to meet domestic chromite demand. Domestic chromium demand is met by import of chromite ore, chromium ferroalloys, chromium metal and chemicals and by recycling.

Ninety percent of the chromite mined across the world is converted into ferrochrome for use in stainless steel production. Ferrochrome is an alloy composed of iron and chromium, created in an electric arc furnace when processing chromite ore. The importance of ferrochrome lies in the fact that there is no substitute for it. Mined chromite is also used to manufacture refractory bricks, furnace linings, and foundry sand. It is used in these objects because it has a very high melting point and can withstand very high temperatures.

The global resources of chromite are recognized to be adequate for the needs of the world for many more years, with world reserves being estimated at 7,600 million tonnes. South Africa, the dominant chromite ore supplier, is expected to hold its 35% share in the supply, with some marginal increases expected in Turkey, Russia, and Zimbabwe (Golder Associates, 2011).

Chromium is a strategic and critical metal in industrial development. Commercial sources of Cr are limited to relatively few countries and the current and projected demand for the metal is growing. The industrial nations that lack identified economic resources of the metal, yet require it, and the developing nations that need nontraditional strong value exports with established future markets, should explore for chromite mineral deposits, determine their potential, and plan for their development. The metals heavily used in industry such as Cr, Ni, Co and Mn should be high-priority commodities in the exploration for mineral deposits. With the ever-increasing demand for mineral-based raw materials for the development of new economies such as China and India, the discovery of new deposits is necessary. Chromites are minerals of high economic value, their value is all the more important as they are often associated with enrichment in PGM (Platinum Group Elements: Os, Ir, Ru, Rh, Pt, and Pd). A large majority of the world's produced Cr (70%) is derived from chromite (chromitite) enriched levels of large intrusions, while the remaining 30% is from ophiolitic chromitites (Cawthorne et al., 2005).

Traditionally, ophiolites as a whole have never been recognized for their potential in platinum group elements. According to Oshinet Crocket, who have made a detailed geochemical and petrological study of the distribution of platinum group elements (PGE) in Thetford Mines' pyrolite, this lack of potential could only be apparent, as tends to to prove the presence of platinum in the gold-bearing gravels, near certain ophiolites as in Ural or Beauce (Logan, 1864). In several places in the world, ultramafic rocks and, in particular, chromitites of ophiolitic complexes have been the subject of research for PGE. For example, the work of Stockman and Hlava (1984), Page et al. (1986), Talkington (1986), Johan (1986), Prichard and al. (1986) et Nilsson (1989). The first precise descriptions of platinum-palladium mineralization in the chromitites of an ophiolite come from Shetland ophiolite. The ophiolitic complexes of Thetford Mines and Asbestos are not left behind since, since 1986, most of the former chromite farms of Estrie and Beauce, in southern Quebec, have been the subject of a series of chemical analyzes which revealed, in certain cases, strong positive anomalies in PGE. The main objective of the present study is precisely to try to better recognize these anomalies and to explain them from geochemical, petrological and mineralogical points of view.

Turkey is one of the countries where natural resources are important for the development of the country. The Ottoman period, one of the periods of traditional exports of chrome ore from Turkey in recent years, has gained importance for the Republic, the first year and in the meantime it has continued to increase despite some drop of taken. If we leave aside the boron mines, the other mines will not even reach the mid-size reserves. However, Turkey is a country characterized by a fairly rich mineral diversity. In other words, Turkey is a country with low mineral reserves and mineralization in many varieties. The Turkish chromitites have been poorly studied regarding chromite composition and PGE abundances and mineralogy. In this contribution we have summarized the results of mineralogical and geochemical investigations on several Turkish podiform chromitites with the aim of evaluating them as potential economic sources.

World Resources

Total (non 43-101 compliant) resource estimated ((USGS) (Figure 1.1));

- South Africa: 2,910 mt
- Kazakhstan: 1,11 mt
- India: 1,090 mt
- Russia: 291 mt
- Zimbabwe: 215 mt
- Turkey: 208 mt
- Brazil: 190 mt
- Finland: 174 mt
- Oman: 102 mt

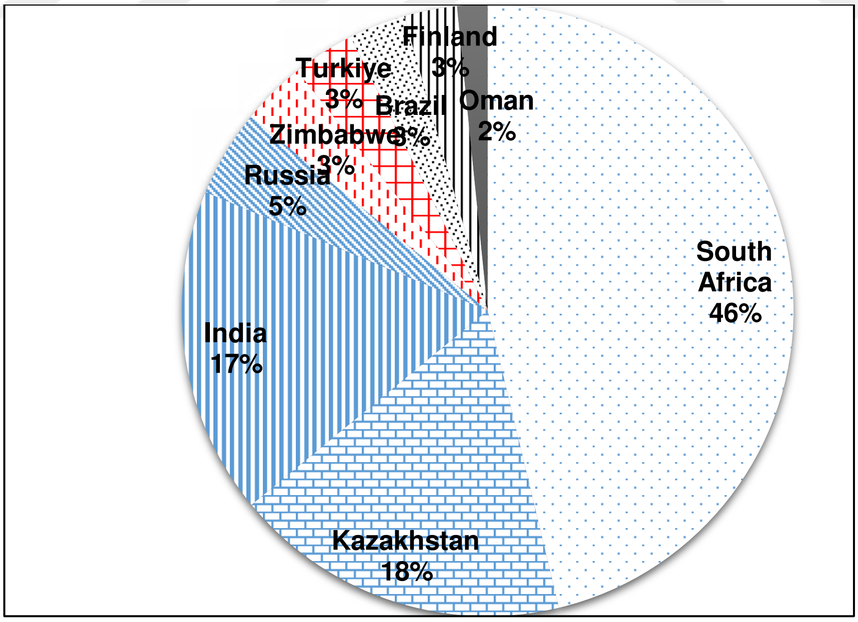

Figure 1.1. Global chrome reserve (Chrome Workshop, 2018)

1.1. Chromite Formation

Many minerals contain chromium as a major element, and many minerals contain 10 percent of chromium. However, only the mineral chromite occurs in large enough quantities to be a commercial source of chromium. Chromite can be found in many different rock types, but the host rocks for economically important chromite deposits are called peridotite and norite. These are distinctive rocks composed mainly of the minerals olivine and pyroxene (peridotite) and pyroxene and plagioclase (norite). These rocks occur primarily in two types of geologic settings, layered intrusions, which are large bodies of layered igneous rock that cooled very slowly in large underground chambers of molten rock, and ophiolites. Ophiolites are large pieces of the oceanic crust and mantle that have been thrust over continental rocks by the same tectonic forces that cause continental drift. Because chromite deposits in layered intrusions tend to be tabular in form they are known as stratiform deposits, while those in ophiolites are typically pod-like or irregular in form, are known as podiform deposits. Other sources of chromite are beach sands derived from chromite-containing rocks and laterites that are weathering products of peridotite. Laterites are more widely known as sources of nickel and cobalt. Beach sands and laterites have historically been a minor source of chromite.

In terms of origin, geological location, mineralogy, texture and chemical properties, chromite deposits are divided into three types (Thayer, 1960). These are;

- Stratiform chromite deposits due to basic intrusions into continents,
- alpine or podiform type chromite deposits associated with assemblages of ultrabasic basic rocks (ophiolites) along alpine mountain ranges,
- Chromite deposits related to assemblages of ultrabasic rocks with concentric inner planes.

1.1.1. Stratiform Deposits

Chromites are more subject to magma than they do. Therefore, like other premature minerals, it settles at the bottom of the magma chamber layer by layer. In many stratiform complexes, compaction and crystallization of magma occurred in stray cratonic environments. For this reason, all primary magmatic features are preserved. These were later installed in the upper shell.

This solid was formed by the removal of the lithostatic pressure increased sharply and through deep fractures formed in the cratonic interior regions with significant differentiation of the molten sheath material which is the stratiform name in the upper level of the ultramafic rock base containing various types of rocks ranging from the composition of average gabbroic granotoid, the internal structure in layers are massive masses Precambrian massive. The largest stratiform deposits in the world are the Bushveld and Stillwater complexes.

Chromite stratiform is very small chromite crystals in the layer % of Fe_2O_3 content of high (10-24%),% Al_2O_3 content is too low, % MgO /% FeO rate is low (between 1.1 and 3.5)% Cr_2O_3 /% Low Fe_2O_3,% Cr_2O_3/Characterized by high %Al_2O_3.

1.1.2. Podiform Deposits

Localization in ophiolite. In all these opinions can occur Moho podiform body of chromite in the area under tectonites, were the main point of the common theory. However, Oman Ophiolite, which is known as the most studied ophiolite in the world, 2004, reported masses of podiform chromite in the region between the plate dikes and the upper gabbro zone. The authors call the chromites found here "Podiform Chromatite of the Upper Crustale".

There are different opinions on the formation of podiform chromite masses in tectonites. When cumulative processes and geosynclinal theory related to the formation of stratiform-type chromite deposits are applied to podiform-type chromite deposits, podiform chromite beds, the upper mantle in the partial melting of super-complex base-formed magma Magma level of the chamber formed in the upper part of the density of mantle differentiation as in stratiform intrusion occurs in the form of group results. The formation of chromite bands during the crystallization of basal magma differentiation describes the sudden pressure drop of the melt with respect to the Cr becoming too saturated. These differentiated units are thought to be inserted into the shell in the form of hot pots (Thayer, 1969).

During reinstallation, the solid chromite bands separate and gain their new position in the formed structures. Silicate minerals such as olivine and pyroxene are recrystallized and the texture of the mosaic grows. There are deformation bands in the olivines and bending bands in the pyroxenes. Chromites cause cataclasis. When this training model is adapted to the model of propagation of the ocean floor, ocean floor spreading partial fusion of the upper mantle Centers sub-chromite body in the obtained magma chamber, the base of the process chromite crystal magma chamber accumulate the deposits (crystal deposit) at the conclusion that occur. Here, chromite masses coexist with dunites. This model leads to partial melting by the presence of large chromite primary mass tectonites commonly associated harzburgites in mineralogy are theoretically described.

By tectonites harzburgites chromite bed in the presence of dunite, bands and lenses contained therein is the chromite body and the zone were formed in the upper cumulates. Because of the irregularities at the bottom of the magma chamber, the dunite and the chromites undergo a simultaneous deformation with deposit of crystals. In the chamber of magma in which process of plastic deformation that cumulates the bottom of the pile and the advent of the mantle of closed deep fold residues affecting harzburgites and closed deep folds and develop in the upper part of dunite cumulate and chromite deposits in harzburgites.

Peridotite enters diapir with basaltic magma filling the space in the walls of the cavity, in which the convection current develops due to the difference in temperature. The course of grains crystallized on the developing convection current will be different because of the difference in weight. This causes the grains to collide with each other. Thus, chromite grains that come into contact with each other grow from the corner and edge of appropriate crystals, and the grain community or nodules come to the fore. The accumulation of chromite grains, in which the shape of the cavity in which they constitute an appropriate mass like chromite.

1.1.3. Beach Sands

Oman ophiolite is composed of the MORB (open ocean-crest-ocean) and SSZ (supra-subduction zone) components. The upper crustal section of the chromite mass is found in the upper rocks of intrusive dunites (Arai et al., 2004).

Arai et al., (2004) reported that there is a podiform type chromite mass as a new type in the study of Oman ophiolite. According to the authors, the general characteristics of these masses of chromite are:

- Between the plate dike system and the upper gabbro zone;
- Podiform chromite masses 30 cm small irregularly rounded structures shape;
- Chromite masses occur in dunitic rocks surrounded by the net structure of gabbroic rocks;
- Inside the chromite masses, the stratification and gradation structures are not observed;
- They are located very close to the roof of ophiolites compared to other podiform masses below the MOHO area;
- The mass of chromite is in dunite with minerals forming gabbroic rocks;
- While the stratiform chromite masses produce matrix plagioclase and clinoproxene, the podiform chromitin matrix forming the dunite is also present as inclusions in the chromite crystals;
- Crustal chromites are similar to stratiform chromites in this respect;

- The chromite mineral values (average, $Cr_2O_3 + Al_2O_3 = 58.08\%$) are quite low compared to normal mantle chromite values (Manto chromites are on average $Cr_2O_3 + Al_2O_3 = 69.01\%$);
- the Cr / (Cr + Al) ratio is about 0.6;
- They report that the TiO_2 content in the chromite crystal varies from 1 to 3%.

1.2. Turkey Chromium Deposits and Reserves

Peridotite general name in which said chromium bearing ultrabasic rocks, large areas are covered in turkey. A significant distribution scheme chrome deposits in Turkey are spread across the country in showing the Peridot cost. Turkey's convenience chromium and chromium bearing ore occurrence singly or in groups of 1.600.

MTA study made by operators as a result of the evaluation of the collected data and information it obtained limited results from the establishment of more than 20% Cr_2O_3 content of chromium reserves, Turkey is given as approximately 26 tons of million. On the other hand, the total amount of chromium ore depositors reported to the Istanbul Mine Exporters Association is about 39 million tons for the beds where some organizations own licenses.

Chrome mining in 150 years of history in Turkey, in the high-grade nature directly sold 30% Cr_2O_3) Most of the layers was consumed. Nowadays, production has to be made in deeper and / or lower grade bearings which have not attracted much in the past. According to MTA data known Turkey's chrome resources (137 layers detected resources) it is due to total 242.341 million tons. 83% of this source comes from less than 10% Cr_2O_3 bearing grades (Figure 1.2). Only 5% (13.087.000 tons) of a total of 242.341.000 tons of resources are directly sold.

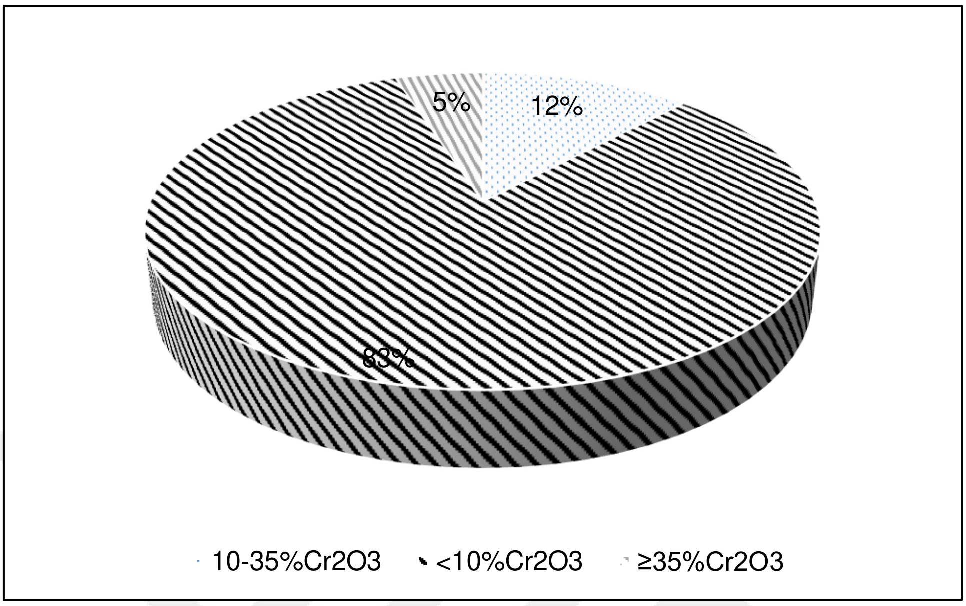

Figure 1.2. Classification of chromium in Turkey (Chrome Workshop, 2018)

Areas where outcrops of ophiolite in Turkey is around 20.000 km^2. It can be assumed that 63% of these are peridotites. Because, in the five major ophiolite complexes, 63% of the outcrops were found to be composed of ultramafic rocks (Colman 1997). As a result, it is estimated to 12.600 km^2 area of favorable formation of chromium deposits in Turkey. On the other hand, low-grade chromite resources are best in terms of 5-6% Cr_2O_3 in the total 231.25 million tons of ophiolite Aladag searched the sources identified cases in Turkey.

Geographically, it is possible to collect chromium deposits in 6 regions (Figure 1.3). Elazığ-Guleman region is the most important region of the country in terms of potential and production. Nearly half of the chromite ore, Turkey Elazığ-in Guleman (Alacakaya) available.

Guleman (Elazığ Region): Western Kef (6.8 million, 33%), eastern Kef (500.000 tons, 40-45%), sori quarries (2.5 million tons, 42-48%), capin (700.000 tons, 43 to 47%).

Fethiye-Köyceğiz-Denizli Region: Karaismailler (800.000 tons, 30-38%), Üzümlü-Sazl 100.000 tons, 36%), Biticealan (102.000 tons, 44-48%), Kazandere (236.000 tons, 37.5%), Kandak (100.000 tons, 40-46%).

Bursa-Kütahya-Eskişehir Region: Harmancık-Başlan (163.000 tons, 20%), Ömeraltı-Kınalıbatak (100.000 tons, 23%), Miran-Border-Koca Ocaklar (120.000 tons, 43%), Orhaneli-Karacaören (35.000 tons, 15-45%, Eskişehir-Karaburhan (1.800.000 tons, 22-26%), poplar chrome (1 million tons, 30-45%).

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Mersin-Adana-Kayseri Region: Adana-Aladağ (230 million tons, 5.3%), Kayseri-Pınarbaşı (1.000.000 tons, 20-48%), Field Farm (3000.000 tons, 30-45%). İskenderun-Kahramanmaraş Region: Hatay-Kızıldağ (117.000 tons, 34-44%).

It is known that there are some scattered chrome layered and occurrences outside these six regions.

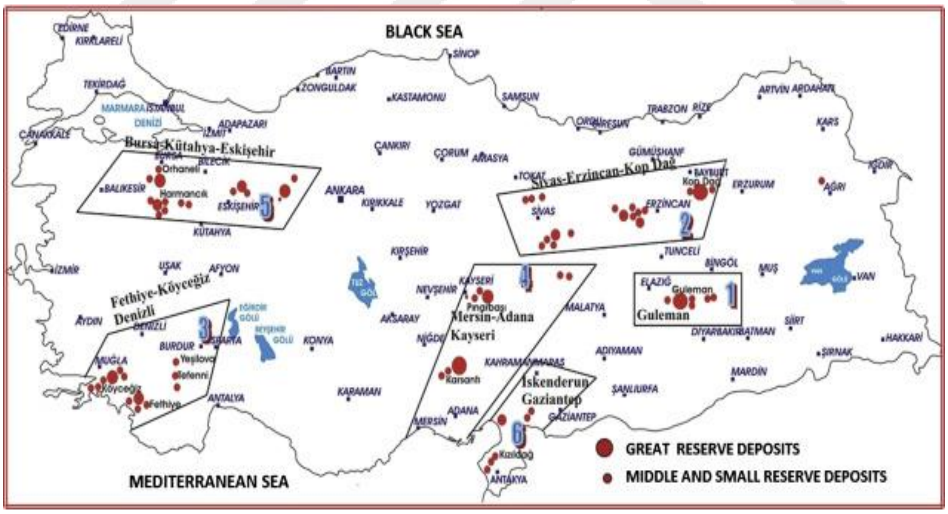


Figure 1.3. Chromite deposits located in six major areas in Turkey (Red Points) Data from Mineral Research & amp; Exploration General Directorate (MTA); Chromite deposits in Turkey. Available at: http://www.mta.gov.tr/v2.0/images/turkiye_maden/maden_yataklari/b_h/krom.jpg (accessed 10.08.15.)

1.3. Platinum Group Elements

1.3.1. Definition and Properties of Platinum Group Elements

Platinum group elements (PGE) mainly comprise the following six elements of the periodic table: platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru). These metals have several highly desirable characteristics such as good corrosion resistance, high melting point, chemical inertness, excellent catalytic capacity as well as good thermoelectric and mechanical properties. This explains why they are used in many situations in the form of alloys or in pure form. Their lustrous metallic appearance similar to silver, hence the origin of the word platinum, as well as their rarity make precious metals prized by jewelers. Their primary utility is undoubtedly due to their good catalytic property. From the mechanical point of view, they generally have a face-centered cubic structure with the exception of ruthenium and osmium, which have a compact hexagonal structure. These last two are besides very difficult to work in the pure state even at high temperature (Cabri, 1981). In contrast, platinum and palladium are the most malleable and ductile platinum group metals. On the other hand, the iridium has a low ductility even in pure form and the rhodium can be rolled into sheets from 350 °C. The latter form a ductile metal and very resistant when they are alloyed with platinum and palladium.

PGEs also have good chemical resistance to common aqueous reagents (Carbi, 1981). To dissolve these elements, it is better to use strong acid mixtures such as aqua regia. This mixture is effective to solubilize the six elements, however it forms a volatile oxide with osmium. It is therefore necessary to be very careful with this method of dissolution because of the osmium losses it can cause. Aqua regia owes its ability to attack PGE thanks to the strong oxidizing power of chlorine and formed nitric chlorides, but also because hydrochloric acid becomes more complex with metal ions to form very stable corrosion products.

Some specialists classify PGEs in two groups relative to their respective densities, the heavier than gold (PGE-heavy), including osmium, iridium and platinum, and the lightest (PGE-light), then gathering ruthenium, rhodium and palladium. The specific gravity of PGE-light varies between 12.0 and 12.4 whereas that of PGE-heavy varies rather between 21.0 and 22.5 (Cabri, 1981). However, the commonly used classification is based on their common geochemical behavior. We then distinguish the group of iridium (I-PGE) including Ir, Os and Ru and the group of palladium (P-PGE) consisting of Pd, Pt and Rh. Some complexes correspond this subdivision, others much less (Houle, 2000).

1.3.2. History and Impacts of Platinum Group Metals

It was at the end of the 19th century that the platinum market expanded with Russia as the largest producer and the United States as the largest consumer. After the abandonment of the industry by the Russians, Colombia became again the first producer of platinum. The resource was then exclusively from alluvial deposits. The First World War also marks the beginning of the Canadian platinum industry with the opening of several nickel mines in which platinum group metals were by-products of extraction. At that time, the two largest producers were none other than Mond Nickel Co. (INCO) and Falconbridge Nickel Mines. The increase in global platinum demand has enabled South Africa to become a major producer with the discovery of numerous deposits associated with the Bushveld Complex and more specifically the renowned Merensky Reef (1925). Since the Second World War, this country has become the largest producer of platinum group metals in the world. Nowadays, the second largest producer is Russia. In addition, this country is the largest producer of palladium. With the operation of the Stillwater Complex, the United States ranks 4th, just ahead of Canada where primary PMF production was 18.5 tons in 2003. In 2016, Canadian mines produced approximately 903.000 troy ounces of PGM as concentrates. Although no PGMs are refined in Canada, they are recovered from eight active mines located in four Canadian provinces: Newfoundland and Labrador, Quebec, Ontario and Manitoba.

In 2017, Canada was the third largest producer of PGM in the world. 70% of Canadian PGM exports went to the United States. Globally in 2017, approximately 18.4 million tons of PGM came from sources of metals that were mined and recycled (Figure 1.4). The following graphs show the evolution of platinum group metal production by country in 2017, and the global production of platinum group metals for the years 2008 to 2017 (Figure 1.5).

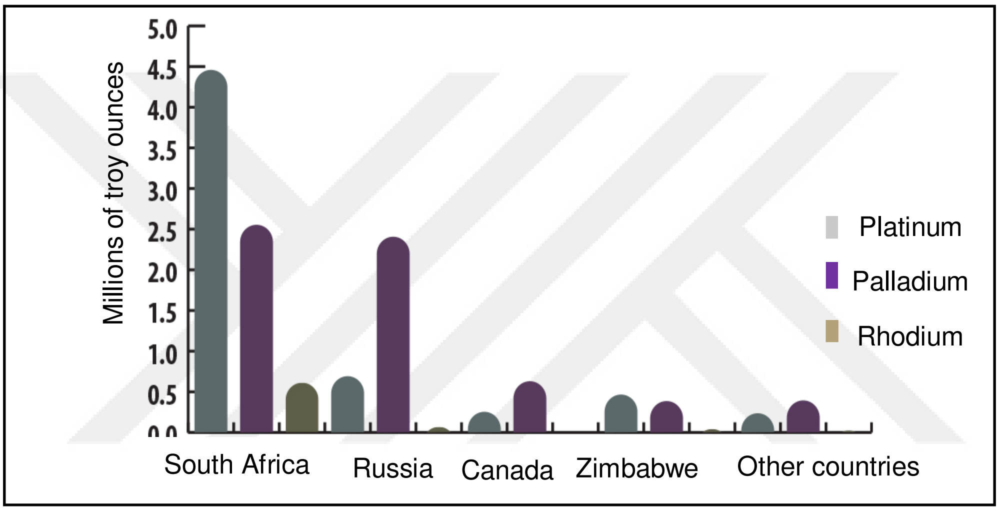


Figure 1.4. Global mining of platinum group metals by country in 2017 (Dpr) (Natural Resources Canada, 2017)

This bar graph illustrates the annual global production of platinum group metals (PGM) from 2008 to 2017. Production totaled 16.9 million tons in 2008 and 18.4 million tons in 2017 (Figure 1.6).

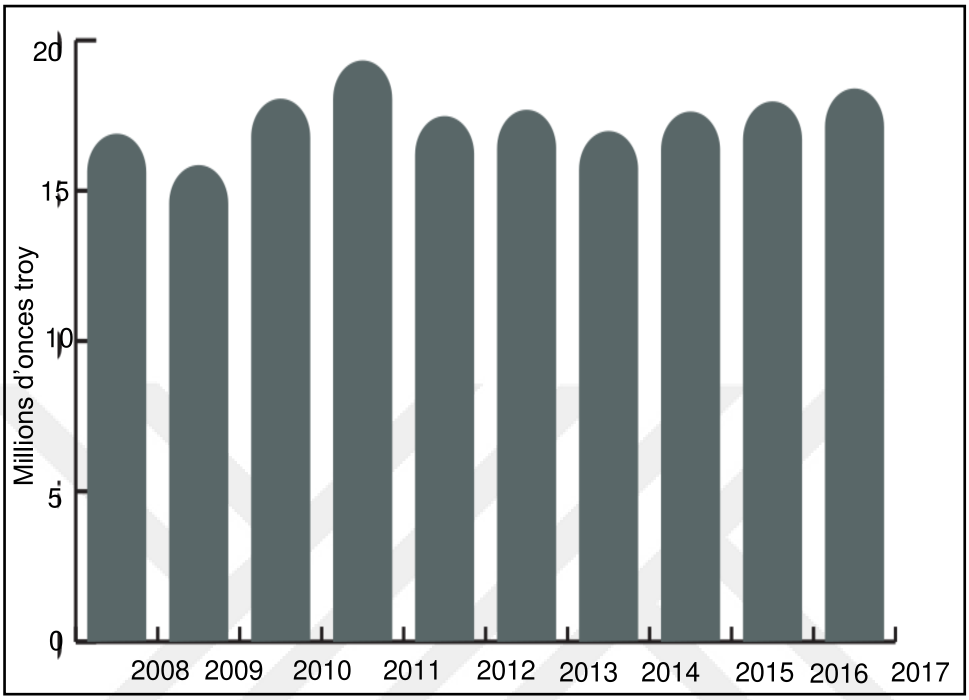


Figure 1.5. Global production of platinum group metals, 2008 to 2017 (Natural Resources Canada, 2017)

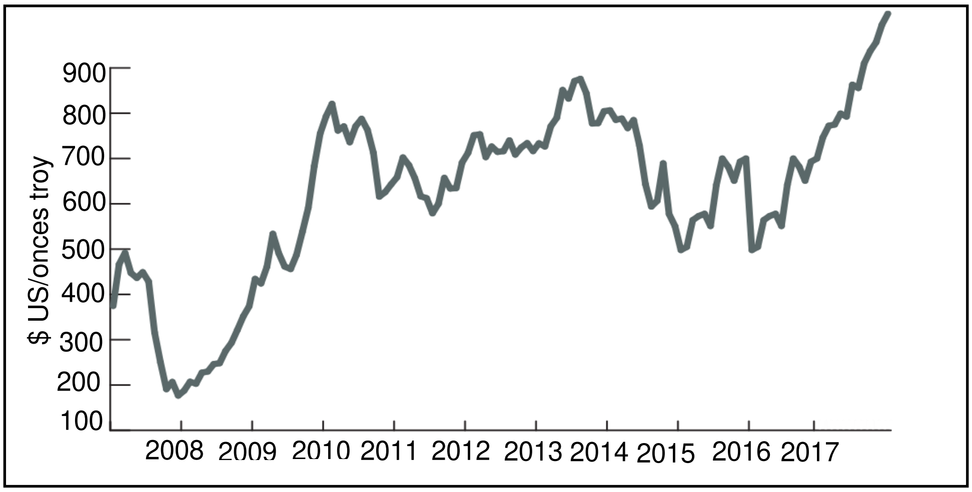


Figure 1.6. Palladium quoted prices in the morning monthly average from 2008 to 2017 (Natural Resources Canada, 2017)

1.3.3. Uses, Applications, and Consumption

The PGEs possess excellent catalytic and stable electrical properties. PGEs are also highly resistant to wear, tarnishing, and chemical attack, and can withstand high temperatures, making them indispensable to many industrial applications. Their leading use is as catalysts for oxidation and reduction reactions that decrease hydrocarbon, carbon monoxide, and nitrous oxide emissions in automobile exhaust (Figure 1.7). The chemical industry requires either platinum or platinum- rhodium alloy to manufacture nitric oxide, which is a raw material used to manufacture explosives, fertilizers, and nitric acid. PGEs are also used in the production of specialty silicones, which, in turn, have many uses, such as in coating son automobile airbags, water repellent coatings, and adhesives for sticky notes. In the petrochemical industry, platinum- supported catalysts are needed to refine crude oil and to produce high-octane gasoline and aromatic compounds.

Alloys of PGEs are exceptionally hard and durable, making them the best known coating for industrial crucibles used in the manufacture of chemicals and synthetic materials, such as high-purity single crystals used in the production of light-emitting diodes (LEDs). PGEs are used by the glass manufacturing industry in the production of fiberglass and flat-panel and liquid crystal displays. In the electronics industry, PGEs are used in computer hard disks to increase storage capacity, and they are ubiquitous in electronic devices, hybridized integrated circuits, and multilayer ceramic capacitors. Platinum does not corrode inside the body, and allergic reactions to platinum are extremely rare; therefore, it is used in medical implants, such as pacemakers. PGEs are also used in cancer-fighting drugs. Other uses of PGEs include gas sensors in automobiles and homes, spark plug tips, and additives to super alloys.

Their white color, strength, and resistance to tarnish make platinum alloys an ideal choice for jewelry. In parts of Ecuador and Colombia before the Spanish conquest, platinum was used by indigenous peoples for the fabrication of small objects, as well as sintered with gold, and incorporated into bimetallic and platinum-clad articles. Their master- works reflect a high degree of technical innovation because the high melting temperature of platinum (1.769 degrees Celsius [ºC]) requires sophisticated manufacturing techniques and craftsmanship. The modern tradition of using platinum for jewelry began in Europe in the 18th century.

The works produced by Cartier and Tiffany in the late 19th century and early 20th century created interest in platinum jewelry, particularly in the United States. The Great Depression of the 1930s and the advent of World War II suppressed the platinum jewelry market in the United States. In the 1960s, demand for platinum jewelry in Japan surged, followed by a surge in demand in China in the mid-1990s.

Platinum, palladium, and rhodium are also used for investment in the form of physical or financial assets. Physical assets include platinum and palladium as collectible coins, or as bullion coins, bars, or wafers.

Financial assets include stocks, mutual funds, and exchange-traded funds. Financial assets allow investors to own platinum, palladium, and rhodium without the difficulties associated with physically holding the metal.

PGMs are also used as investment vehicles by investors wishing to hold precious metals in their portfolios.

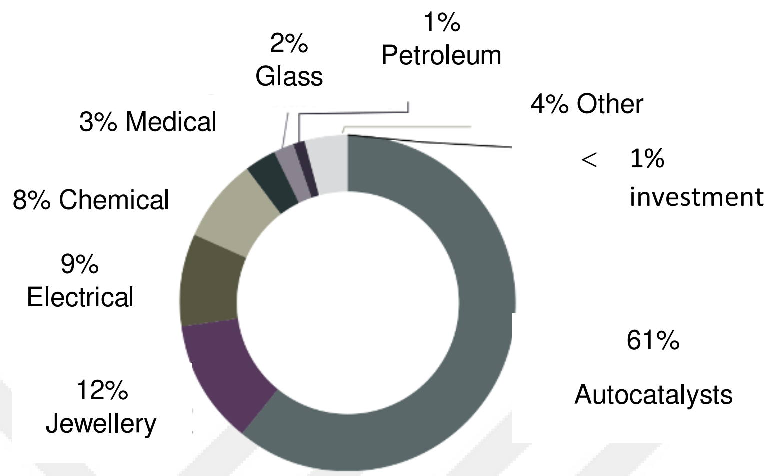


Figure 1.7. Uses of platinum group metals globally in 2017 (Natural Resources Canada, 2017)

1.4. Purpose of Study

Turkey is a major chromium province southwestern Anatolia and Fethiye Koycegiz (Mugla) Chrome Zone and Northwest Anatolian chromite deposits in the cliffs, received a preliminary examination, some (especially the region Fethiye reads Harmancık) PGE showed significant abnormalities.

As part of the study, the careers of Harmancık, Dikmen, Yolocak, Rozocak, Keserali, Atbaşı and Sinekli around Fethiye, in southwestern Anatolia; The quarries of Ilıkdere, Kaymakam, Sivaş around Köyceğiz; Kazandere's career around Marmaris; In the vicinity of Acipayam in Denizli, the quarries Aslan, Karaismailler-Diamonds have been the subject of a research on the mineralogical and geochemical aspects in terms of PGE potential. All the rock chemical data obtained from the deposits studied indicate that chemical PGE values of the southwestern Anatolian chromitites are generally low.

However, at Islahiye/Hamidiye in the southern part of Ganziantep, a chromite deposit has been searched for several years for possible exploitation. Thus, the purpose of our work is to determine the economic potential of chromite deposit in terms of platinum group elements (PGE) in this area. It is at the end of our research work to perform sampling, and chemical and mineralogical analysis of samples to find the percentage of platinum group elements in chromite.

2. PREVIOUS STUDIES

Geochemical, mineralogical and chemical studies on PGE formations in our country have been revealed by very few researchers, these are;

Economou-Eliopoulos, (1996), Compilation of some new data on ophiolites for Greece and Yugoslavia, and published data from previous studies, indicate that platinum-group element (PGE) and gold concentrations in chromite ores are generally low, ranging from less than 100 ppb to a few hundred ppb. However, samples from several ophiolite complexes exhibit an enrichment (of a few ppm) (a) only in Os, Ir and Ru, (b) only in Pt and/or Pd or (c) in all PGE. This enrichment (up to 10s ppm) is mainly related with chromitites hosted in supra-Moho dunites and dunites of the uppermost stratigraphic levels of the mantle sequence and it seems to be local, independent of the chromitite major element composition and the chromite potential of the ophiolite complexes.

Ciftci, (2002), in his study Refahiye (Kızıldağ) PGE ophiolites indicate different behaviors according to the primitive mantle values, Os and Ru in terms of enrichment observed in some ratios, Ir, Rh and Pt suggested that observed.

Uysal, (2008), all PGE levels (Os, Ir, Ru, Rh, Pt, Pd) were determined for selected chromite samples in the Kahramanmaraş and Kop regions. PGE levels are low and range from 28 to 541 ppb. PGE distributions in the chromitites studied have properties similar to those of many mantle chromitites and offer Ru+Os+Ir enrichment for Rh+Pt+Pd values. In addition, low Pt and Pd enrichments were observed in Kahramanmaraş and Ortaca chromitites, respectively.

Günay and Çolakoğlu, (2011), geochemical properties and platinum group element (PGE) contents of eastern Turkey (Van Area) Chromitite. Eastern Anatolia (Van) chromite deposits are associated with an east-west trending units of peridotite in the Eastern Anatolia Accretionary Complex (EAAC). The samples taken from four different areas were analyzed for their trace, major oxides and PGE contents. The average content of chromite ore as follows: Mehmetalan n=11) 45.3

wt. % Cr_2O_3, Mollatopuz (n=15) 31 wt. % Cr_2O_3, Yukarıbalçıklı area (n=12) 43 wt. % Cr_2O_3 and Alabayır (n=4) 36.5 wt. % Cr_2O_3. The average of PGE results of same group samples contain 194 ppb, 86 ppb, 287 ppb, and 122 ppb respectively. Ir group (Ir, Os, and Ru) elements show significantly enrichement compare to Pd group elements (Pd, Rh, Pt). IPGE of chromitites host in ultramafic tectonits are much more abundant compared to banded chromitite host in cumulates. This results are comparable with all Turkey chromitite ore. In Yukarıbalçıklı area, both existence of abundant cataclastic zones in the polished sections and boudin shaped ore within shear zones contain high IPGE values (e.g. Sample No: YB-CO_2; 627 ppb). This enrichment indicate that multi stage of deformation might have been effected for PGE enrichment.

Uçurum, (2006), chromite in Turkey have a low grade and PGE Au and some PGE and are enrichments, mineral solution and hydrothermal chromite for micro-fissures and fractures in rocks is reported to be associated with development sulphide minerals.

Kozlu, (2007), stated that chromitites enriched in Pt and Pd were enriched in base metals, in accordance with bedrock. It has been found that the mechanism of melt impregnation during enrichment of some NTE-PGE and some base metals may be the cause of chromitites rather than bedrock. Primary and secondary data indicate that the magma, where the bedrock is, indicates that a magma such as lherzolite can form in the tectonic environment of the partial melting subduction zone

Tsoupas et Economou-Eliopoulos (2008), point out that the most important chromite sites for platinoids (PGM) are the particularly sheared fault zones within the ophiolite complexes.

Kurtuluş (2011), in his study in the Van region, the EGP content obtained in this case is not economical in the current results. However, results obtained in fault zones in smaller pods with deformed mineralized bodies have a higher content of PGE in this study is a result obtained. He stated.

Akmaz, (2012), according to Turkey's southern Ophiolitic Berit chromitites Mountain-Göksun regions, Afşin (Kahramanmaras) Islahiye (Gaziantep), and Dogansehir (Malatya) located in the impoverished mantle peridotites (harzburgites and dunite) in the veins and lenticulars located in a structure. SE Turkey ophiolitic chromites PGE content are generally low (42-348 ppb, average 126 parts per billion) and all the chromitites IPGE (Os+Ir+Ru) content PPGE (Rh+Pt+Pd) offers significant enrichment by their abundance. In addition, a significant increase in the total PGE content of 13 ppm and 2.8 ppm was observed in samples taken at Islahiye and Doğanşehir. Total PGE content of Cr-rich chromitites (mean chrome PGE = 529 ppb) relative to Al-rich chromitites (mean PGE = 87 ppb) is quite high and Pd / Ir ratios are low (0.115 for Cr-rich chromites), Al while in rich chromitites 0.632).

Uysal et Aiglsperger, (2012), One chromitite sample from the Islahiye ophiolite (Gaziantep, SE Turkey), characterized by high platinum group elements (PGE) concentrantions (up to 13 ppm total PGE), have been studied for the mineralogy of PGE. About 200 platinum group minerals (PGM) were found in heavy concentrates obtained using the electric pulse disintegration (EPD) and hydro-separation (HS) techniques. Subsequently the PGM have been invesigated by electron microprobe. Two different types of PGM have been found with the same proportion: 1) PGM included in chromite crystal, less than 10 µm in size and 2) free grains with a size variable from 20 up to more than 100 µm. Laurite, with few irarsite, is the most abundant PGM found included in chromite. It occurs as single phase or associated with Ni-sulphides, chalcopyrite and silicates. Single phase laurite is also the most common free PGM, accompanied by abundant Ru-Os-Ir oxides. Laurite rimmed by Ru-Os-Ir oxides, associated with sulpharsenides (irarsite, hollingworthite and platariste) and with Ru-Ni arsenides, has been also recognized as free grains. Free awaruite crystals contain small PGM (less than 5 µm) composed of ruthenium and Pd-Pt-Rh-Cu-Sb. The composition of the two types of laurite, included in chromite or free grains, have the same concentration of

Ru-Os-Ir. The Ru-Os-Ir oxides composition, in terms of Ru-Os-Ir, overlaps the field of the analyzed laurite. This observation supports the conclusion that the oxidized PGE compounds derived from desulphurization of magmatic laurite at low temperature, with substitution of the removed S by O. The data presented in this work suggest that the EPD and HS techniques are very efficient to concentrate PGM. However, PGM with a size less than 10 µm and occurring included in fresh chromite are not liberated from their host mineral.

Akmaz, et al, (2013), Chromitites, associated with upper mantle peridotites of ophiolites from southeastern Turkey, are lenticular bodies or veinlets made up of massive, banded and disseminated chromite. Chromite shows a wide range of Cr# [Cr/ (Cr + Al)] varying between 0.42 and 0.81, and Mg# [Mg/ (Mg + Fe^2+)] of 0.45 to 0.75. Geochemically, they are divided into two compositional groups, such as high-Cr (Cr# ≥ 0.7) and high-Al (Cr# b 0.6). The contents of the platinum-group elements (PGE) in high-Cr chromitites range between 42 and 348 ppb (average 158 ppb), whereas high-Al ones are represented by a lower total PGE, ranging between 70 and 94 ppb (average 84 ppb). However, two high-Cr chromitite samples showed significant enrichments especially of Ir-subgroup of PGE (IPGE: Os, Ir, Ru) with total PGE contents reaching up to 2.7 ppm. The chromitites mostly contain tiny inclusions (b5 µm) of platinum-group minerals (PGM).

Kozlu et al (2014)**,** the high-Al chromitite-bearing stratigraphic levels (Cr# ranges from 0.38 to 0.47) are located at the mantle/crust transition zone (MTZ) and in the cumulate dunites in the Berit ophiolite in SE Turkey. Iridium group elements IPGE (Ir, Os and Ru) and related mineralisation were previously reported from ophiolitic high-Cr chromitites in the Berit–Elbistan area. Palladium group elements -PPGE (Pt, Pd and Rh) and associated mineralisation are predominantly found in the high-Al chromitites and they are presented in this study for the first time. Our results indicate that IPGE-enriched phases of the PGMs such as laurite are present in both the PPGE-enriched and the PPGE-poor chromitites in Berit. The high-Al chromitite chondrite normalised patterns in the Berit ophiolite show an enrichment of PPGE, with values of up to 1700 ppb Pt and up to 4469 ppb Pd.

Özek et al., (2016), platin Group Elements (PGE) Contents and Interpretation Geochemistry of Chromite Deposits with Host Rocks in Guleman (Elazığ) Region Guleman ophiolite made up of tectonites which comprises dunite and chromite bearing harzburgites and cumulates which contain dunites, wehrlite, clinopyroxenite, gabbros, diabase dykes, sheeted dyke complex and basic volcanites are other constituents of the ophiolite. Rocks samples and chromite ore samples were analyzed for Pt, Pd, Rh and Au using ICP-MS and for Ir and trace elements using Neutron Activation Methods. The analytical data are normalized for primitive mantle and used in spider diagrams. These diagrams illustrate that the rocks have negative anomalies for Rh, Pt is close to mantle values, Pd close or show enrichment and Au is enriched in comparison to the mantle. The PGE contents of ore samples vary. Ir shows positive anomaly, Rh negative, Pt and Pd are close to or richer, and Au is richer than the mantle values. Samples are determined as Irarsite, according to Ir ratio 45-550 wt% - Rh ratio of 0.05-5.56 wt%- Pt ratio also 0, 1-23 wt% and Chromites have the asthenospheric composition with reference to PGE data.

The 10 major research projects carried out in the area are summarized in Table 2.1.

Table 2.1. PGE includes in chromite in Turkey

	Ir (ppb)	Os (ppb)	Pd (ppb)	Pt (ppb)	Rh (ppb)	Ru (ppb)
Chromitites of Mersin (Kozlu, 2006)	10,3-45	19-40	0,72-28	1,2-81,2	6,4-19,6	32,8-90
Adana- Pozantı-Karsantı (Kozlu, 2006)	14-90	0,18-0,21	144-6877	50-1390	50-150	0,68-0,70
Kızılyüksek (Adana) (Avcı, 2015)	3,27-72,47	3,55-61,55	0-5,95	0,18-57,24	0,10-17,50	0-44,80
Kahramanmaraş / Kop and Ortaca Complexes (Uysal, 2008)	2,64-18,17	1,82-7,90	0,07-0,15	<2	0,15-10,36	5,81-50,19
Southwest (ophiolite of Marmaris) (Akbulut, 2009)	0,02-5,77	3,69-32,93	0,13-97,61	0,08-0,2	0,99-2,85	14,67-51,59
Eastern Turkey (VAN) (Günay , 2011)	11-105	20-170	<20	<20-60	<50-22	<50-280
Ophiolite of Sivas-Refahiye (çiftçi , 2002)	<2-23	<5-37	<1-7	<1-10	<1-4	<5-19
Ophiolite of Guleman (Özek, 2016)	45-440	<2-25	5,5-24	0,1-23	0,05-5,56	5-32
Elekdagi's Ophiolite (Kastomonu) (Donmez, et al, 2014)	19-290	11-279	<2-10	<2-10	4-18	43-863
Berit Ophiolite (Kahramanmaras) (H., Kozlu, 2007)	6-286	5-523	14-4469	14-1700	6-31	11-1275
Complexe d'agglomération (Van) (Günay, Çolakoğlu, A.R., 2011)	11-105	20-170	<20-40	<20-90	<5-22	<50-280

3. MATERIALS AND METHODS

The study of the thesis was conducted as part of a program covering field work, laboratory and office work.

3.1. Materials

3.1.1. Generalities on the Study Area

İslahiye is a town and district of Gaziantep province in southeastern Turkey. It is a railway border crossing into Syria. Its geographical coordinates are 37 ° 1 '30 "North, 36 ° 37' 50" East and is located west of Gaziantep, about 90 km from the center of the province. Its area is 1.513 km², in the middle of a fertile crescent area, in a strategic location and on a flat plain. It is one of the oldest settlement areas in the province of Gaziantep, and it is quite rich in terms of history and tourism. Its population is 67.714 in 2017. The study area is located on map N37c3 and the nearest settlement is Çakmak district of Yeniceli village. The flying distance from Çakmak is 2800 m (Figure 3.1.).

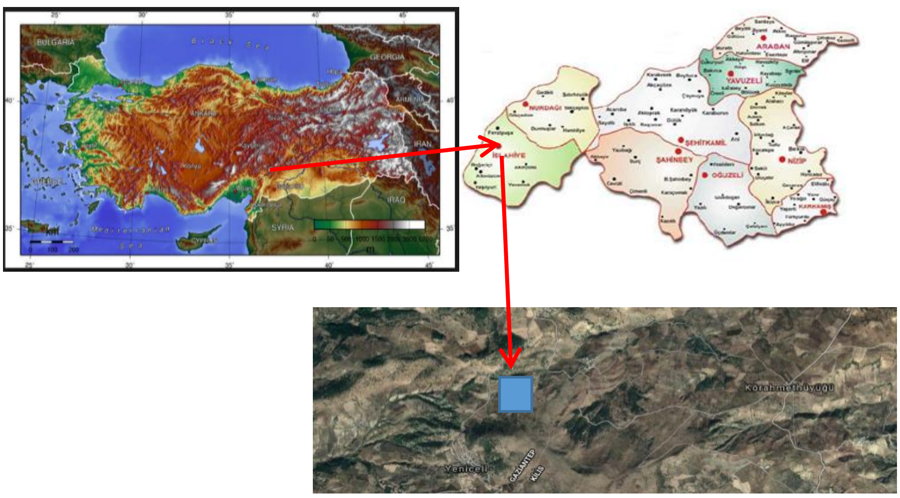


Figure 3.1. Geographic location map

3.1.2. Geological Setting

Turkey is a structurally complex area where two major oceans have closed with a superimposed structural deformation. Part is geologically located on the northernmost edge of the Arabian plate as a passive margin (Southeast Anatolia) on one side, and the southern part of the Eurasian plate as a passive margin (part of the region of the Black Sea) Paleozoic and early Mesozoic. These two main plates collided at the end of the Cretaceous until the Eocene, and the Anatolian plateau is sandwiched between these continents. The collision created two important suture zones, and different basins were formed in front of and between the suture areas. The stratigraphy of these areas differs markedly from each other. In southeastern Turkey, where the study area covers an area of 1.513 km², 90 km west of Gaziantep is entirely made up of peridotites. However, it is not possible to distinguish these rocks as different lithological units according to their chemical and mineralogical characteristics, because they cannot see the primary properties of these peridotites (magmatic bands, lineation, foliation, etc.). These peridotitic rocks containing occurrences of chromite are serpentinized in almost all parts of the study area and occurrences of chromite can be observed in two different locations. The ophiloitic rocks include, from bottom to top, metamorphic soil (plagioclase-amphibole schist and plagioclase amphibolite), mantle tectonites (serpentinized dunite and harzburgite), ultramafic cumulates (mainly websterite), mafic cumulates (olivine gabbro, gabbro, and olivine gabbronorite) and isotropic gabbros (olivine gabbronorite).

The Amanos Mountains, attracting attention with its rather complicated structure in the western part of the Eastern Taurus, which includes the Amanos ascension and the Karasu-Hatay Graben . The allochthonous and autokontainers representing the infra-fluid-quaternary interval of the Anatolit-Tauride Platform and the Arab Plate (Okay et al., 2001), the Antalya-Misis association and the Southeastern Anatolia Plate located tectono-stratigraphic units. The Amanos Mountains are located within the eastern Taurus belt, which emerges between the Turkoğlu-İslahiye-Bahçe-Düziçi districts (Kahramanmaraş). Paleozoic-Early

Mesozoic volcano-sedimentary and epiclastic rocks, late cretaceous ophiolite complexes, late cretaceous and younger post-collisional rocks.

The ophiolites observed throughout the Alpine-Himalayan orogenic belt are gathered in two groups, namely the Western Alps and the Eastern Mediterranean ophiolites, in terms of geodynamic environment in terms of their age of occurrence. On the Bat Alps, there are ophiolites west of Albania, Helenids and Dinarids. These ophiolites are of Jurassic age and formed in the Oceanic Ridge (MORB) (Koller and Höck, 1990). In the Eastern Mediterranean zone Pindos, Vourinos, Troodos, all of the ophiolite in Turkey, there Baer-Bassit and more towards the southeast of Oman ophiolite. These ophiolites are of Upper Cretaceous age and formed on the intra-oceanic subduction zone (SSZ-type) (Pearce et al., 1984) (Figure 3.2).

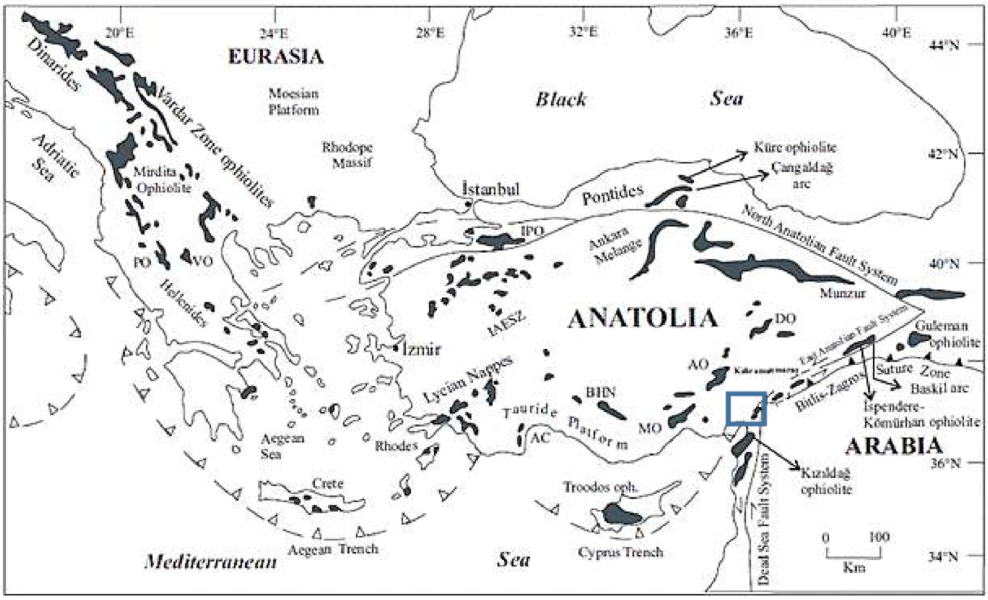


Figure 3.2. Distribution of the neotethyan ophiolites and major tectonic features in the eastern mediterranean region (from Dilek and Flower 2003). AC: Antalya Complex; IPO: Intra Pontide Ophiolites; BHN: Beyşehir-Hoyran Nappes; İAESZ: İzmir-Ankara-Erzincan Suture Zone; MO: Mersin Ophiolite; PO: Pindos Ophiolite; VO: Vourinous Ophiolite; AO: Aladağ Ophiolite; DO: Divriği Ophiolite.

Ophiolites in Turkey contain significant podiform chromitite deposits hosted by harzburgites in the form of massive, nodular, banded, disseminated and orbicular occurrences, exhibiting physical and chemical characteristics typical of Alpine-type chromium deposits .

The southern belt, geographically enters Turkey from the north of Syria (Baer-Bassit area) and extends from Antakya to Elazığ Soridağ. It enters Iran (Zagros range) through Oman (Oman ophiolite). It incorporates some of the most well-known ophiolite complexes, such as the Troodos (Cyprus), Kızıldağ (Turkey), and Semail Nappes (Oman). The allochthonous Kızıldağ ophiolite exposes the complete ophiolite sequence. Aproximately 200 economic scale individual podiform chromite ore bodies are observed on Kızıldağ Mountain (Kızıldağ ophiolite) and Balıkalan, Türkoğlu village (Islahiye ophiolite). Generally the podiform chromite bodies are clustered near the cumulate/harzburgite boundary.

The southern Kahramanmaraş region, evaluated in this study, is located in the actively deforming East Anatolian fault zone, where a long-lived triple junction (the Maraş Triple Junction) evolved as a result of the Alpine Orogeny. The geological units of this region are classified into three groups.

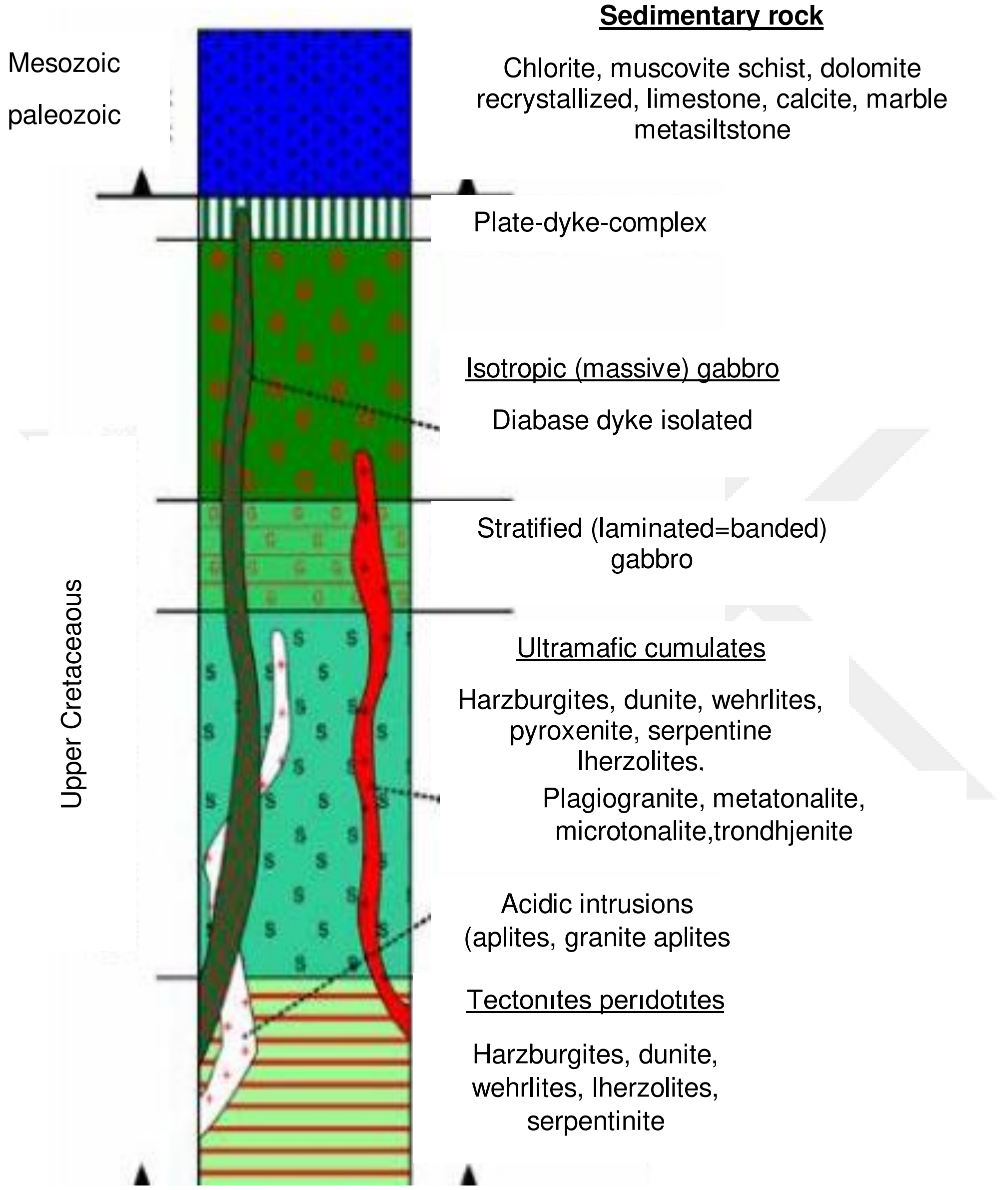
These are: 1) autochthonous Arabian Platform, 2) Ophiolite Nappes and 3) Tertiary Cover Units. The Autochthonous Arabian Platform contains Lower Cambrian to Upper Ordovician limestone, with a sandstone, quartzite and shale alternation at its base. These basement rocks are unconformable overlain by Upper Triassic-Lower Cretaceous dolomite and dolomitic limestone. The ophiolite nappes consist of three slabs that have tectonic contacts with each other.

The basement of the geological units in the region is represented by Lower Cambrian–Upper Ordovician Arabian autochthonous units consisting of alternation of limestone, sandstone, quartzite and shale (Tanırlı and Rızaoğlu 2016). This basement unit is uncorfomably overlain by the Upper Triassic–Lower Cretaceous carbonates.

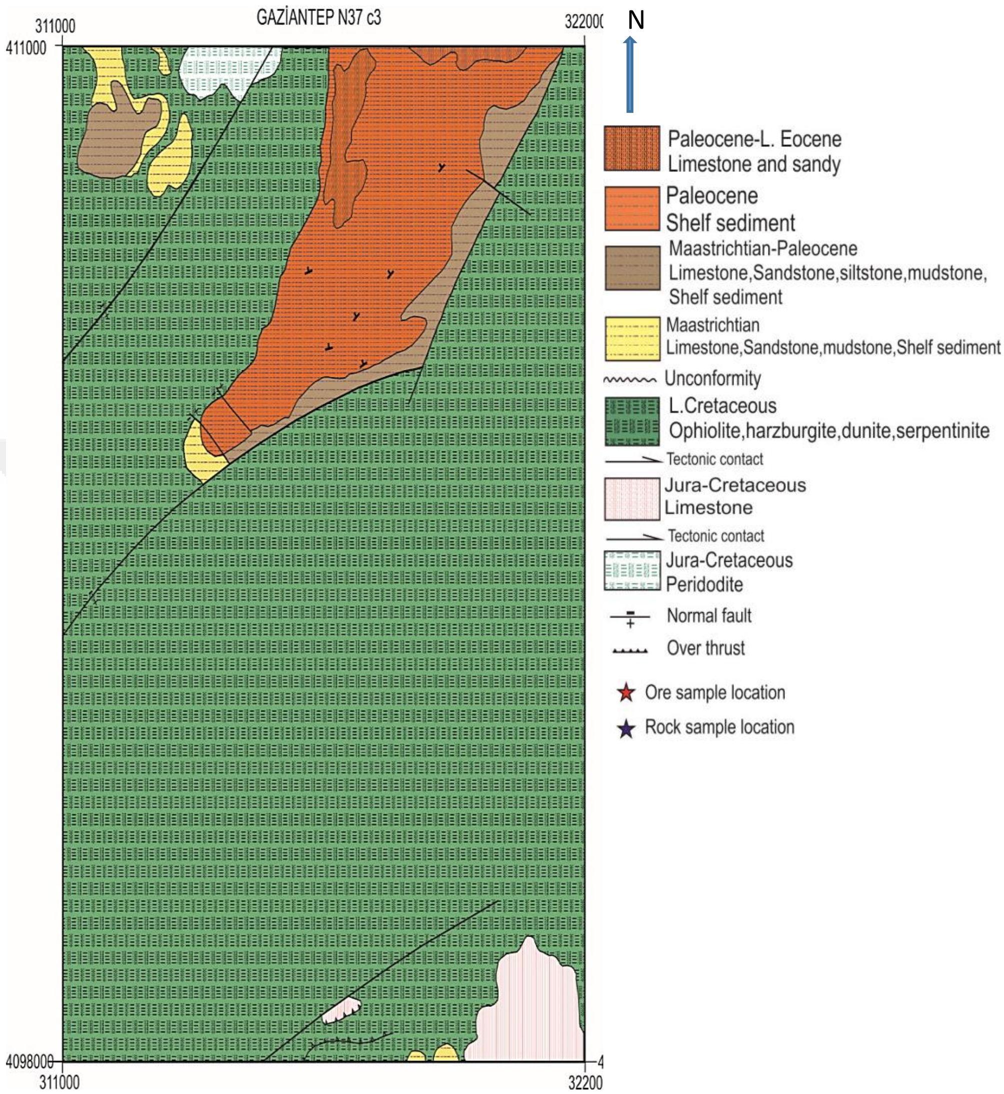
The ophiolitic rocks in the region start at the bottom with the metamorphic sole rocks. The metmorphic sole rocks are metamorphosed from green schist to amphibolite facies. Then the unit passes into the mantle tectonites, ultramafic to mafic cumulates and isotropic gabbros. The contacts between the subunits of the ophiolite are tectonic. The Upper Paleocene-Miocene sedimentary units unconformably overlie the older units in the region (Bagci, 2013).

The ophiolitic rocks from the southern Kahramanmaraş region are highly dismembered and composed of undifferentiated mantle tectonites and gabbroic rocks (Bagci, 2013). Cropping out throughout the study area, the highly serpentinized mantle tectonites are composed mainly of dunite and harzburgite, and display foliation and lineation, which reflect plastic deformation. Pyroxenite dykes, ranging in thickness from 10 to 40 cm, cut the mantle tectonites. The chromitites display a great variety of textures: massive, nodular, schlieren and disseminated (Uysal et al, 2007; Uysal, 2008) (Figure 3.3).

The study area is entirely composed of peridotites. However, in this area where tectonic movements are highly effective, primary characteristics of peridotites (magmatic banding, lineation, foliation, etc.) cannot be seen and there is no possibility to differentiate these rocks into different lithological units according to their chemical and mineralogical properties. These peridotitic rocks, which contain chromite formations in places, were serpentinized in almost every part of the study area and chromite formations could be observed in two different positions.


Sedimentary rock
Mesozoic
paleozoic
Chlorite, muscovite schist, dolomite recrystallized, limestone, calcite, marble metasiltstone
Plate-dyke-complex
Isotropic (massive) gabbro
Diabase dyke isolated
Stratified (laminated=banded) gabbro
Upper Cretaceaous
Ultramafic cumulates
Harzburgites, dunite, wehrlites, pyroxenite, serpentine lherzolites.
Plagiogranite, metatonalite, microtonalite,trondhjenite
Acidic intrusions (aplites, granite aplites
Tectonıtes perıdotıtes
Harzburgites, dunite, wehrlites, lherzolites, serpentinite

(A)



(B)

Figure 3.3. Vertical stratigraphic section (A) and geological map of Islahiye (B) (MTA, 2015).

1. Initially speckled type chromite formations 2. Massive higher grade chromite formations in the fault zones the small faults in the N-S direction and the faults in the E-W direction cutting these faults are evident. The important chromite

formations in the study area were exposed in fault zones in E-W direction. These outcrops are shaped as islands and show openings in places.

3.2. Methods

The location, the reserve of this ore widely used in the industry is classically identified by field observation and drilling, and the grade is determined by laboratory analysis of samples from field work. The study area covers some areas where the ophiolites of Kahramanmaraş and Gaziantep are located in the Eastern Mediterranean Region. This section is a summary of the methods used to arrive at objectives that we had previously set ourselves. Full details about preliminary studies, fieldwork, laboratory work, assessment and writing.

3.2.1. Field Work

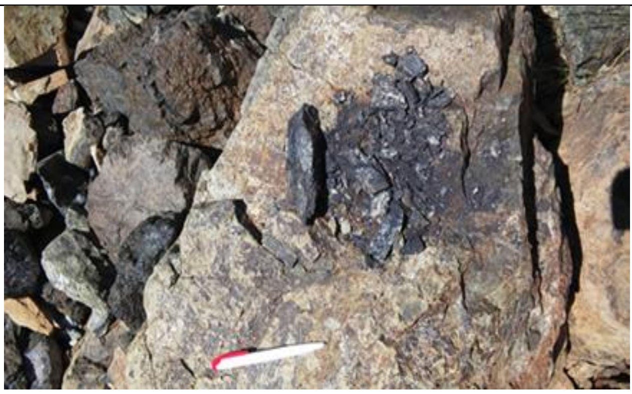
- **Outcrops samples**

For the fieldwork, we sampled where we took the rock samples. The samples were considered to be the least representative of the level of separation, indicating the representative nature of the samples and the greater diversity of rocks. During the field studies, the GPS (Global Positioning System) was used to take the coordinates of the sampling points. Photographs of various macroscopic geological features have been taken.

8 rock samples were taken from the outcrop. The coordinates of the samples and the images collected on the site are in the following Table 3.1.

Table 3.1.Coordinates and images of sampling points

POINTS	Coordinates X/Y	Images
A	37,0316573 40,99305	
B	37,0316634 40,99341	
C	37,0316627 40,99319	

POINTS	Coordinates X/Y	Images
D	37,0316611 40,99321	
E	37,3165915 40,99272	
F	37,0316775 40,99387	

POINTS	Coordinates X/Y	Images
G	37,0316331 40,99130	
H	37,0316317 40,99100	
I	37,0316218 40,99025	

- **Drill cores**

A total of 8 specimens of cores were drilled in the study area at a depth of 20 to 125 m to determine the concentration of platinum group elements contained in chromite by a mineralogical process Table 3.2.

Table 3.2.Coordinates and images of the drilling points

Coordinates	Images
316163.194 4099156.828	
316188.006 4099172.861	

Coordinates	Images
316205.250 4099180.133	
316216.125 4099182.644	

Coordinates	Images
316227.719 4099188.460	
316235.467 4099195.269	

Coordinates	Images
316244.634 4099208.583	
316320.932 4099300.299	

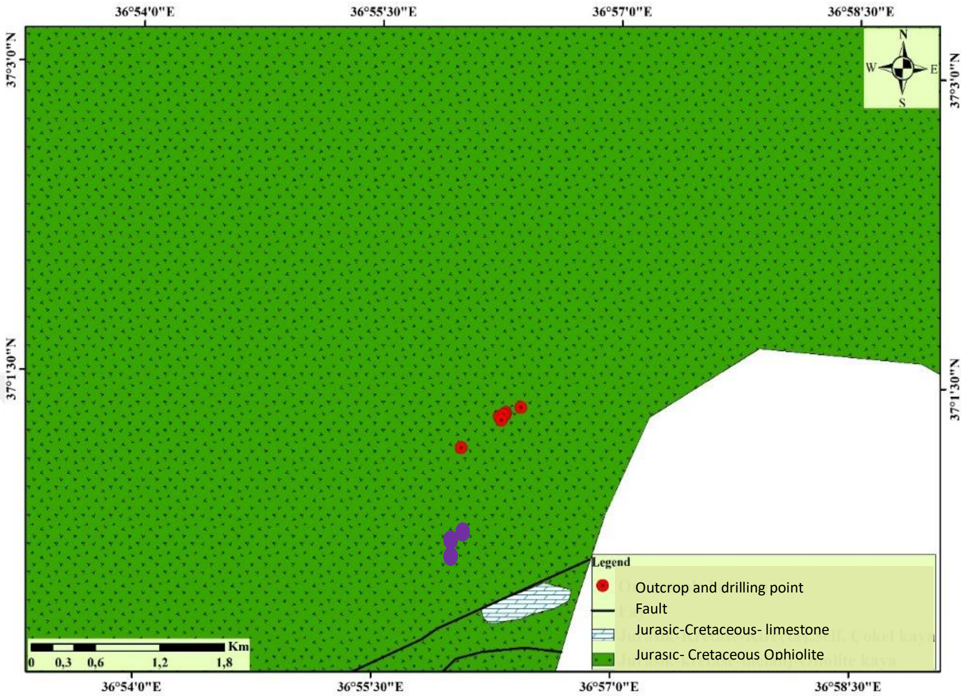


Figure 3.4. Map of sampling

3.2.2. Laboratory Work

3.2.2.1. Samples Preparation

After sampling in the study area, samples were taken to the Çukurova University laboratory to be prepared accordingly for analysis. A jaw crusher eventually crushes all samples to very small particles. Using a microscope we selected 8 chromite samples and 4 samples rock. Each sample is placed in a pouch and weighs 25 g. Then the samples are sent to Canada for analysis (Figure 3.5).

Figure 3.5. Sample preparation

3.2.2.2. Analysis

Field samples were brought ınto the Çukurova University Mining Engineering Laboratory to prepare and send to Canada for analysis. This analysis is aimed at XRD, XRF, PGE microscopic analysis of mineral and rock.

At this stage of the work, thin sections of hand specimens compiled from the ground will be prepared and mineral names will be made by using the diagrams published by the International Union of Geological Sciences (IUGS) and observing mineralogical and petrographic aspects under polarizing microscope.

Appropriate sections from thin sections will be imaged under a polarizing microscope. The main element and trace element analysis of chromite samples are ALS (Analytical Laboratories LTD). Analysis will be done in the Canadian laboratories. Mineralogical analysis and ranking of the survey data will be performed.

3.2.2.2.1. Chemical Analysis

Mineral chemistry analysis were conducted on 4 rock and 8 mineral chromite samples at ALS (Analytical Laboratories LTD) in Canada.

All samples were subjected to a series of in situ total and mineral rock analyzes. Total rock analysis include X-ray fluorescence (XRF, X-Ray Fluorescence) and ICP-MS analysis to determine major and trace element composition, respectively, as well as to determine the PGE content of the samples. For mineral analyzes, these include ICP-MS analysis to determine the major element composition of minerals such as olivine and chromite, as well as LA-ICP-MS analysis for compositional determination in trace elements of chromites.

X-ray fluorescence (XRF) analysis of samples prepared from bulk, nodular, dispersed, and striped chromite ore collected from underground and outcrop areas of the study area were performed using a semi-quantitative method.

3.2.2.2.2. Petrographic Study

All samples were used to make thin, polished slides to perform detailed petrographic study under the microscope. This study includes: (1) identification and characterization of the minerals constituting the phenocristic and matrix portions of samples; (2) the determination of the modal proportions of each species of phenocrysts and micro-phenocrysts; (3) the characterization of the global textures of samples, and; (4) the characterization of chromite-specific textures. The blades samples of 8 samples were also studied at scanning electron microscope (SEM) to verify if grains of PGM are present in association with chromite. Information provided by the petrographic study were related to the results chemical to facilitate the interpretation of the data set and thus achieve formal conclusion

4. RESULTS AND DISCUSSION

In this section, the geological map of the area with the various drill points have been made and mineralogical and petrographic characteristics of chromite mineralization in ophiolites were examined. The chemical properties of rock, chomite and PGE were examined. Finally the potential evaluation in PGE. The chromite ore mineralization, which forms the basis of the study, is located within the unit of the Lower Cretaceous aged 'Ophiolite nap' within the N37 c3 map sheet. The ophiolite layer is located in the region with completely tectonic movements.

The ore in the region is composed of podiform chromite deposits in the tectonites of ophiolite. As a result of observations made in the field, a geological map was drawn according to tectonic and ore and rock outcrops (Figure 4.1). Dunite and harzburgite as dominant lithology form the major part of the study area. The presence of the Dunite, Harzburgite, mineralization and drill points are shown on the map. Containing chromite occurrences are serpentinized in almost all parts of the study area harzburgite and dunite can be observed in different locations.

Large faults and a small NE-SW fault are apparent. The faults in the region were completely associated with the formation of mineralization and caused semi-regular and irregular mineralization. There is a deposit of ore located between the first two major faults that cut the area. Significant occurrences of chromite in the study area were flush between the first 3 major faults in the area. Among several drill points made, two points show the significant presence of chromite. In the study area, podiform chromite deposits are mainly hosted by dunites and harburgites at the coverage area.

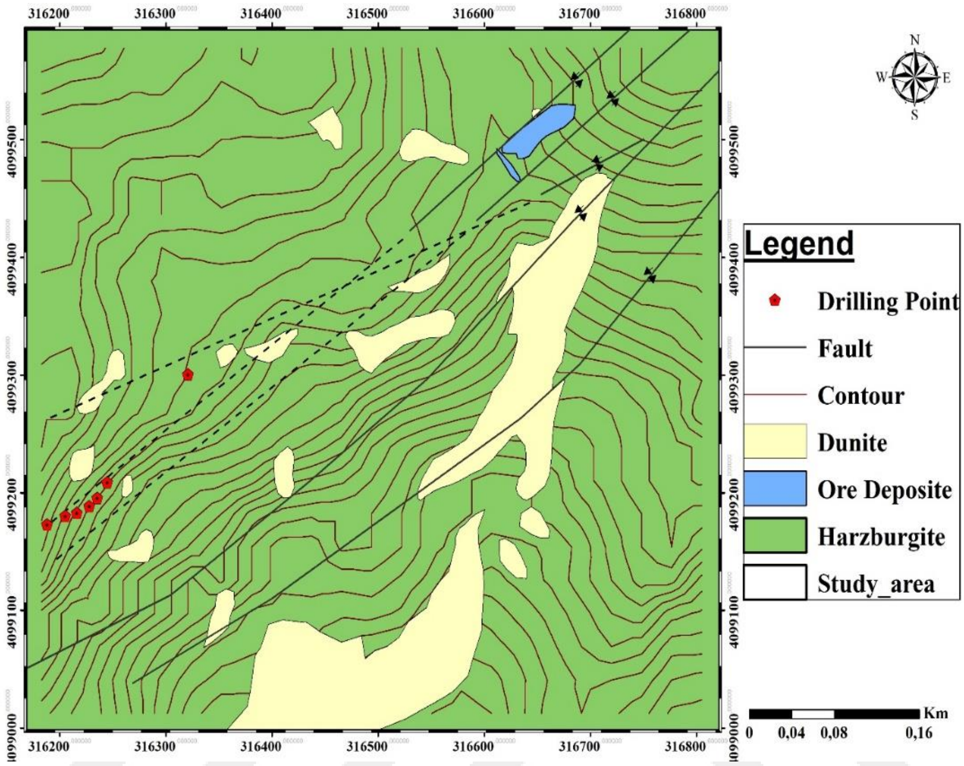


Figure 4.1.Geological and drilling map of ophiolitic rocks

4.1. Mineralogical and Petrographic Studies

The purpose of this section is to provide an overview about petrographic nature and mineralogical composition of the main rock types encountered in the area. Samples of each type of rock encountered were examined in thin and polished section. The major and minor minerals present in the ore quantified as well as the PGE content in chromite.

4.1.1. Petrographic Studies

The ophiolitic rocks in the study area are composed of peridotites consisting of dunite and harzburgites. Ophiolitic rocks L. Cretaceous aged mantle tectonites are the most extensive rocks within the ophiolites in the region and are composed of dunite, serpentinized dunite, serpentinized harzburgite, and serpentinite (Figure 4.2).

Figure 4.2.The ophiolite units observed in the study area

4.1.1.1. Peridotites

In the study area, tectonite composed of dunite and harzburgite with a peridotite composition.

a) Harzburgites

The lithology of the area is dominated by harzburgites. The harzburgites, less clastic and less fragmented than the dunites, are distinguished by color changes due to the fact that the dunites present monochrome tones such as pistachio green and dark blue. They are mainly related between dunites. As it is closer to the dunite unit, the average amount of pyroxene increases. The modified harzburgites were serpentinized. Their colors become light green, yellow, and brown.

Mineralogical Properties of Harzburgites:

Microscopic examination of the thin sections of the rocks shows the presence of olivine, orthopyroxene, pyroxene clino and major chromite paragenesis. Quantities of thin sections.

The serpentinized harzburgites exhibit granular to mesh textures, and are composed of olivine (~80 vol. %), orthopyroxene (~15 vol. %) and opaque minerals (magnetite and chromite) (Figure 4.3). The serpentinites are represented mainly composed of serpentine group minerals (chrysotile and bastite) (Figure 4.4). The ultramafic cumulates consist of serpentinized harzburgite, and websterite.

Figure 4.3. Serpentinized harzburgites observed in the field

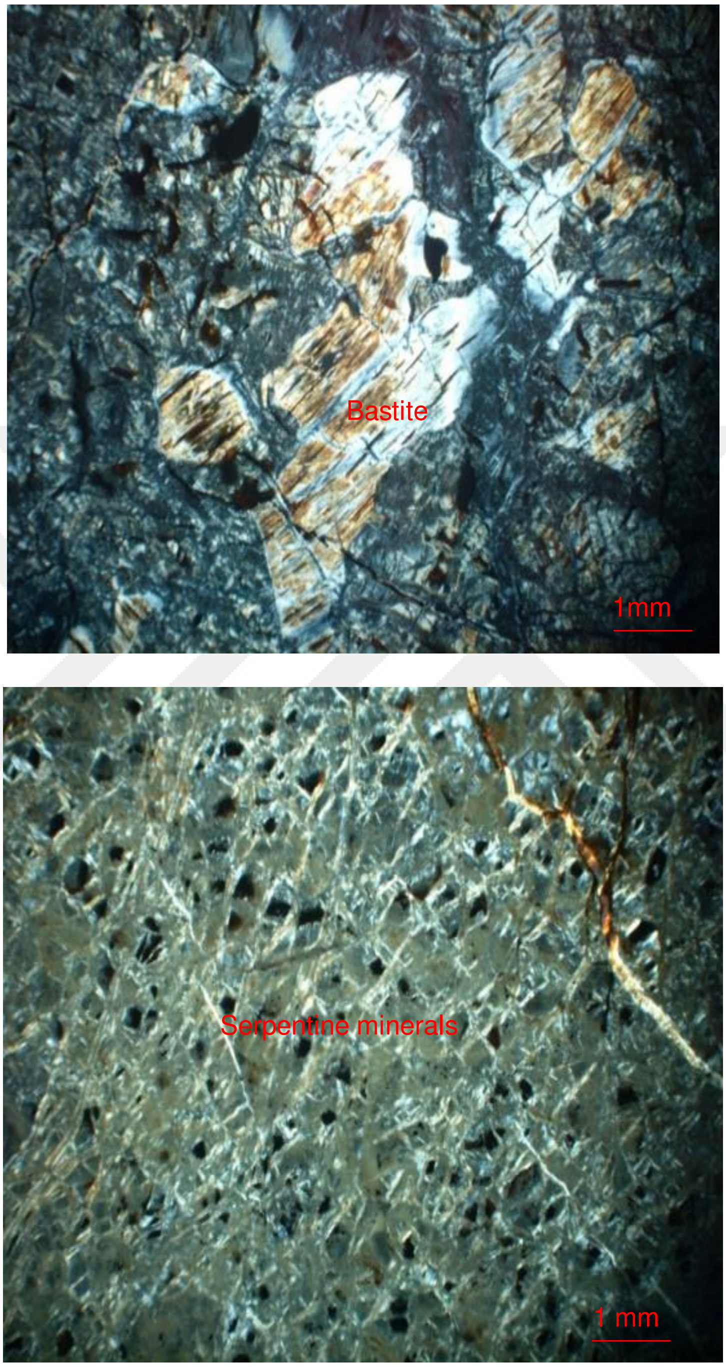


Figure 4.4. Thin section investigation, chrysotile and bastite

b) Dunites

It is less in the study area compared to harzburgites. In most places, it was completely serpentinized and mineral transformations were made. The rock was accompanied by chromite enrichments, outcropping in 7 to 8 regions, and the study area was indicated on the geological map.

Mineralogical Properties of Dunites

The dunites show granular texture and are composed of olivine (97–98 vol. %) and rare chromite crystals are set in partly serpentinized olivines and orthopyroxenes (Figure 4.5). The serpentinized dunites show mesh to granular textures and are mainly composed of olivine (90–95 vol. %), clinopyroxene (1–2 vol. %) and chromite. Olivines are made of forsterite minerals.

The serpentinized olivines are surrounded by a serpentine band. In some sections, they are very deformed under the effect of cataclasis.

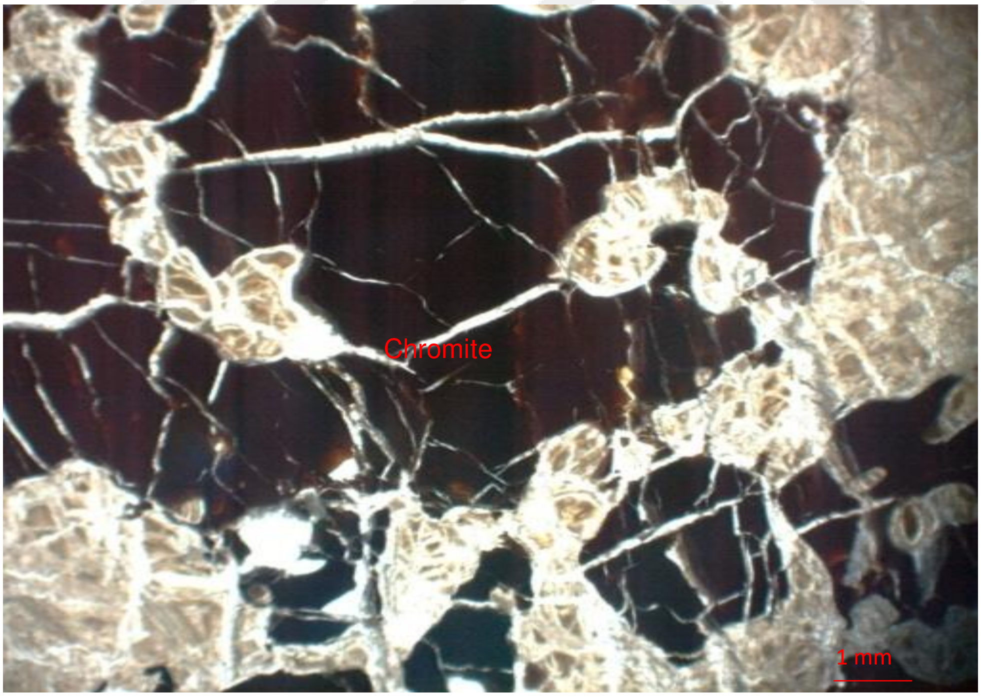


Figure 4.5. Fine section of dunite rich in chromite

On the outer surfaces of the chromite mineralization, there is a dunite rock in the form of envelopes, and the mineralization has developed as a function of this rock (Figure 4.6).The transition contact between the Harzburgite and dunite units represents the outer part of the lithology and the inner part of the harzburgite. In cases where the fresh dunite samples are not altered, it is sometimes difficult to differentiate the foliation plans.

Figure 4.6. Chromite ore surrounded by dunites

4.2. Mineralization

4.2.1. Chromite Mineralization

Mineralization in the study area is composed of dunitic sheaths and podiform chromites in harzburgites.

The mineralization in the area is related to tectonic movements and the outcrop points are very few. The faults are oriented NE-SW and the mineralization has been displaced in the region due to these faults. The fault has resulted in an irregular distribution of mineralization in the area, so that the presence of ore and the determination of reserves have resulted in a very difficult process (Figure 4.7.). In the region 2 fronts were opened, 8 holes were drilled and the ore and mineral rock content was determined (Figure 4.8 and 4.9).

Figure 4.7.The faults of mineralization

Figure 4.8. Irregular chromite mineralization

The contact between the chromite ore and the harzburgites in which the ore is located is tectonic, creating a brieved transition zone between the ore and the harzburgites. There are problems of fragmentation and ore loss in areas where the ore occurs. tectonism is high. There are lenticular chromitic formations. It is difficult to see all the massive, scattered, nodular and banded chromite ores in the same regions (Figure 4.10 and 4.11). Structural irregularities are related to the change in physicochemical conditions in the ophiolite magma chamber and to the conditions of the ophiolite surge on the continent.

In the study area, open pit factories were discovered and the ore was tested by underground mining. Production did not continue due to the loss of ore. In this study, the mineralization of the region was followed by drilling and new occurrences of ore were revealed.

Figure 4.9. Band chromite surrounded by a dunitic envelope at the entrance of the underground mine

Figure 4.10. Massive chromite

Figure 4.11. Scattered chromite band

The chromitites observed in the mantle portion of the ophiolitic sequence are represented by massive textures, while the chromitites observed near the mantle in the crust transition zone, closer to the crust of rocks and representing the shallower parts of the crustal zone. Coat, generally have a structure dispersed in bands (Figure 4.12).

4.2.1.1. Microscopic Study of Chromite Ore

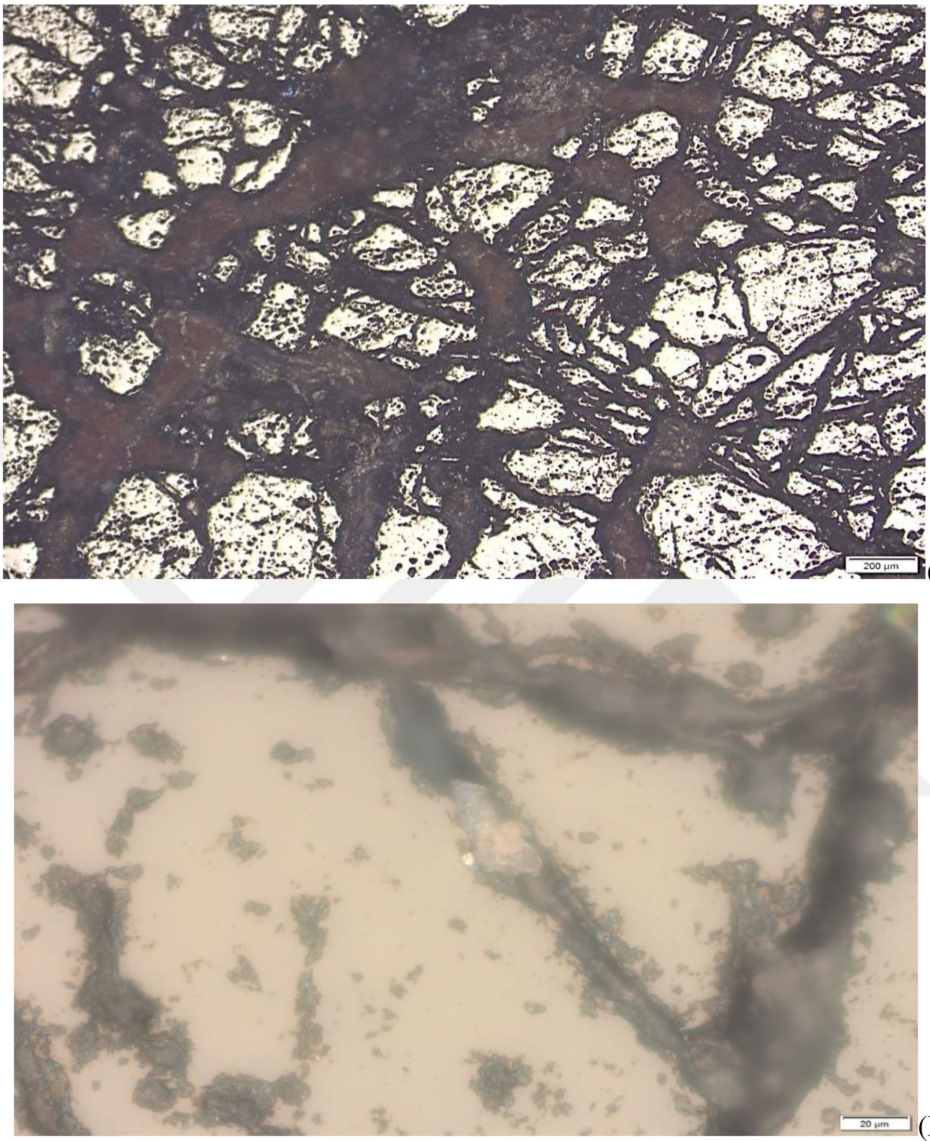
Polished section microscopic studies were performed from serially produced samples of nodular chromite ore. The main minerals composed of chromite, nickel and magnetite were observed in the sections.

Chromites have cataclastic properties due to intense deformation. Rock forming minerals have been observed as gangue minerals in fracture systems. It has been found that olivine in thin section studies of gangue minerals.

Figure 4.12.Harzburgite and disperse chromite ore boundary

Durind serpentinization, the Fe^{3+} cation was transformed into lizardite, antigorite minerals, some of which form magnetite (Figure 4.13).

The NiS mineral has been observed in millite crystals. Its shiny appearance is evident by its needle-like extension. Intensified deformations of chromite revealed cataclastic characteristics in the sections studied, slip planes were formed between the fracture systems and pieces of chromite were divided into small blocks and spacer structures were formed.



(A)

(B)

Figure 4.13. Chromite polished section

Silicate minerals forming rocks are frequently observed in the crystals. The silicate minerals were observed to be olivine and then converted to serpentine minerals in thin sections.

The primary sulfur mineral, pentlantite [$(Fe, Ni)_9 S_8$], is found in small crystals of chromite and matrix crystals. It was distinguished from other nickel minerals by its pale white color and anisotropy.

4.2.1.2. Chromite Ore XRD Analysis

In the chromite ore samples taken from the study area, XRD analysis were performed to determine the minerals contained in the ore samples. According to the graph, the mineral analysis are presented in the (Figure 4.14). Forsterite, klinokrozite, Millerit and chromite were detected as main minerals.

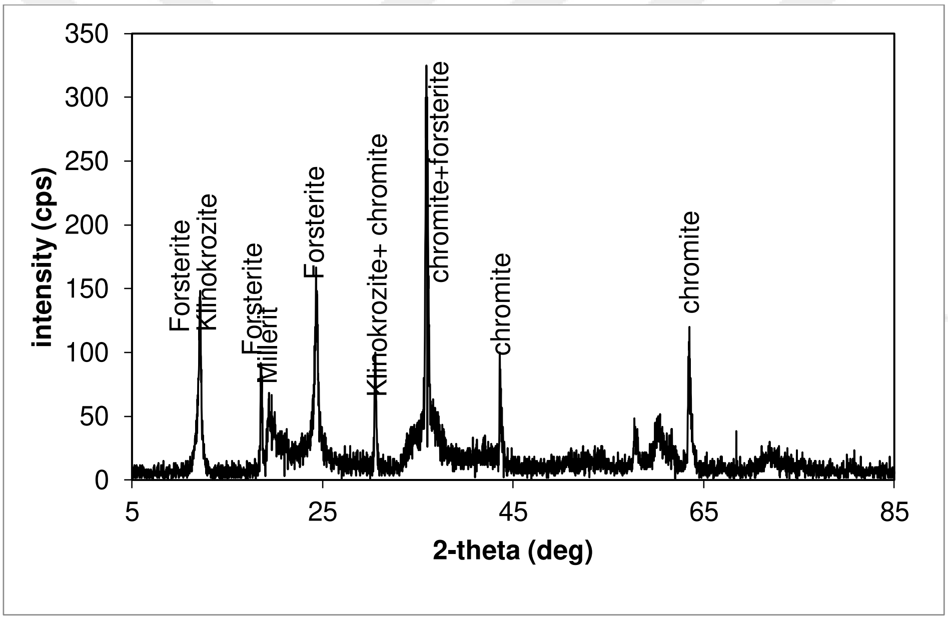


Figure 4.14. X-Ray diagram of a nodular chromite sample

4.2.1.3. Chromite Ore XRF Analysis

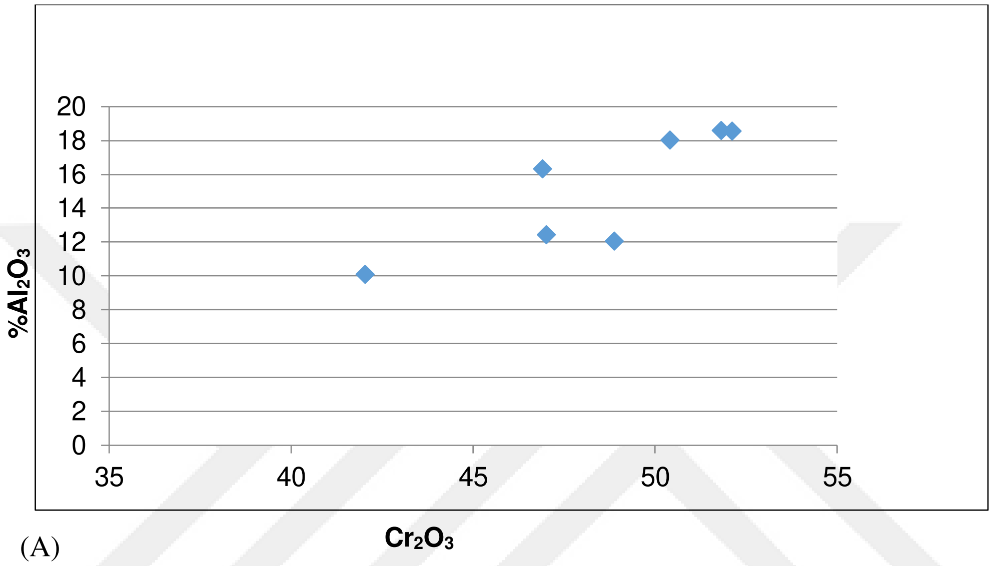
X-ray fluorescence (XRF) analysis of 7 samples prepared from massive, nodular, scattered and ribboned chromite ore collected from underground and outcrop of the study area. The semi-quantitative method was used in the laboratory of the mines department. Results of the X-ray fluorescence analysis the main distributions of oxidized elements in the ore are presented in Table 4.1.

The chromite grains exhibit a wide range of compositional variations (Cr_2O = 42.03-52.1 wt %, MgO = 11.08-30, 48 wt %, Al_2O_3 = 10.09-18, 57 wt %, Fe_2O_3 = 10.49-12, 85 wt %) which lie in the opiate-shaped Islahiye podiform chromitite field. According to the results of the elemental analysis, the Cr/Fe ratio was 3.78.

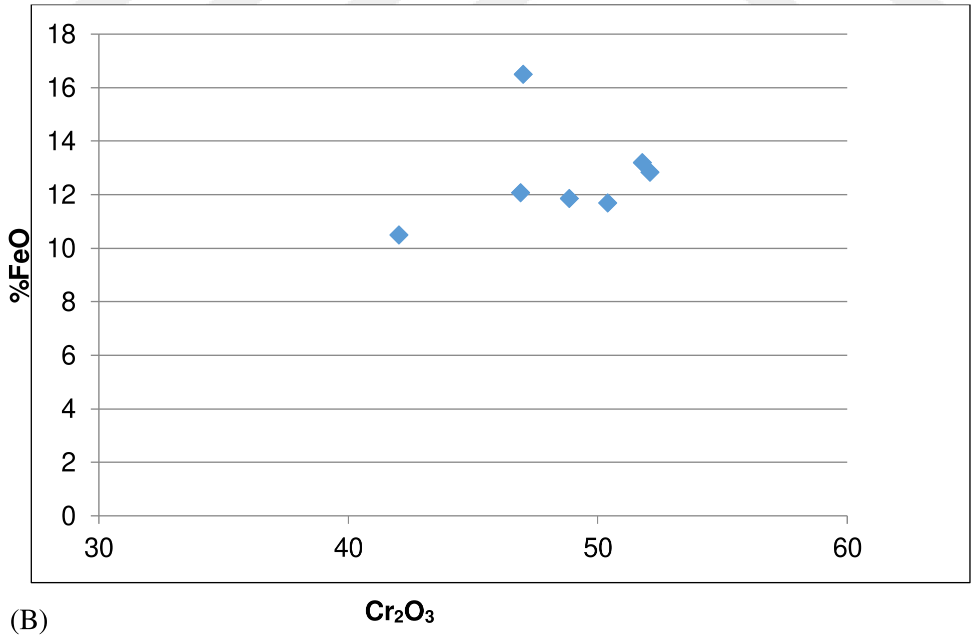
Table 4.1. Major and trace element contents of the massive chromite.

%	S1	S 2	S3	S4	S5	S6	S7
Cr_2O_3	42.03	48.87	52.1	50.4	51.8	46.9	47.01
SiO_2	4.14	5.57	3.78	4.09	2.03	2.32	2.14
MgO	30.48	19.01	11.08	13.52	12.06	20.05	19.17
Al_2O_3	10,09	12.05	18.55	18.01	18.57	16.31	12.44
Fe_2O_3	10.49	11.87	12.85	11.68	13.20	12.08	16.51
CaO	0.63	0.32	0.29	0.21	0.27	0.26	0.26
SO_3	0.98	1.06	0.73	0.96	0.78	0.85	1.10
TiO_2	0.085	0.052	0.036	0.3	0.106	0.099	0.26
V_2O_5	-	-	-	-	0.096	0.081	0.05
MnO	-	-	-	-			
NiO	0.740	0.650	0,452	0, 621	0,613	0,20	0, 450
CuO	-	-	-	-	0,073	0,078	0,089
ZnO	-	-	-	-	0,076	0,078	0,074
As_2O_3	-	-	-	-	0,091	0,078	-
SeO_2	-	-	-	-	0,04	-	-
Re_2O_7		-	-	-	0.07	0.07	0.1
Bi_2O_3	-	-	-	-	0.01	0	0
Pr_2O_3	-	-	-	-	-	-	0.01
Cr	28.75	33.43	35.64	34.47	35.43	32.08	32.15
Fe	7.343	8.309	8.995	8.176	9.24	8.456	11.557
Cr/Fe	3.915	4.023	3.962	4.216	3.835	3.794	2.782

There is a negative correlation between the positive diagrams Cr_2O_3-Al_2O_3 and Cr_2O_3-FeO (Figure 4.15 A-B) and Cr_2O_3-MgO (Figure 4.15 C) in the percentage of oxide values of the XRF factor analysis results (Figure 4.15).



(A)



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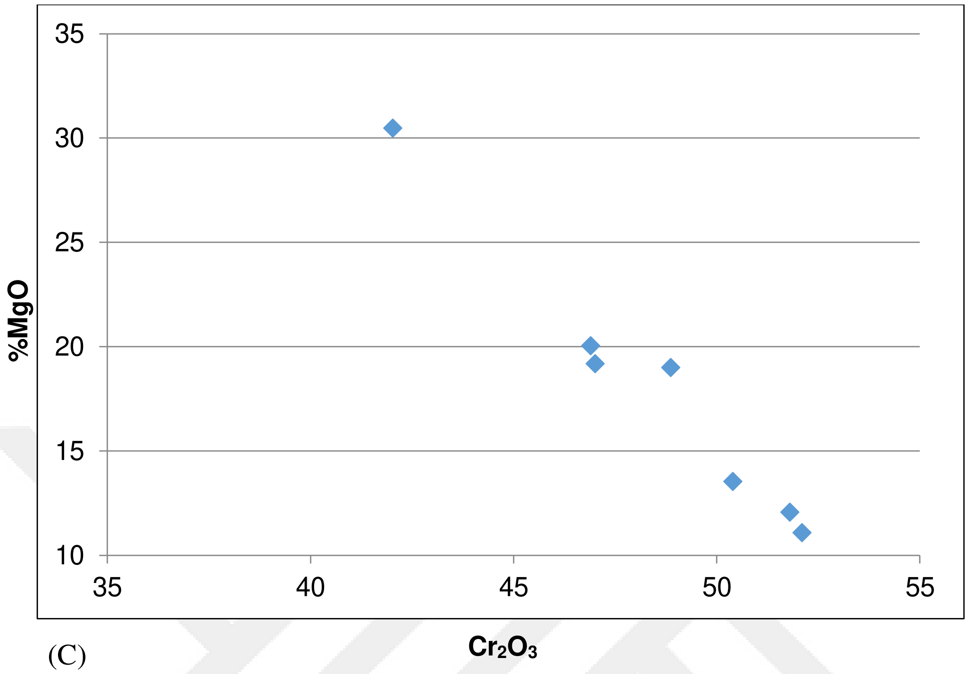


(C)

Figure 4.15.XRF analysis of chromite ore

4.3. Whole Rock Chemistry

Mineral chemistry of ophiolite rock has been investigated with X-ray fluorescence (XRF) analysis. Four rocks samples were analysed to know the chemistry composition. The results are presented in the following Table 4.2.

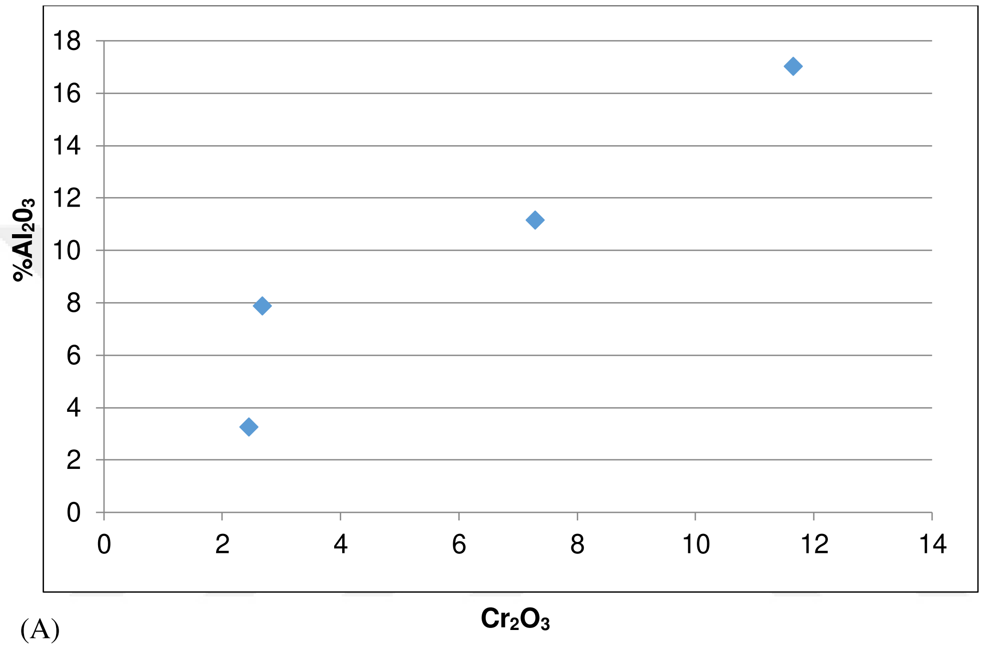
Table 4.2. Presents the major contents and trace of the chemical elements contained in the ophiolitic rocks of Hamidiye/Islahiye. The main elements are expressed as percentage by weight (% by weight) while the trace elements are in part per million (ppm).

Analyte	Unit	R1 Rock Pulp	R2 Rock Pulp	R3 Rock Pulp	R4 Rock Pulp
SiO_2	%	18.64	24.44	38.08	3.34
Al_2O_3	%	7.29	2.68	2.45	11.65
Fe_2O_3	%	9.60	7.95	7.47	11.86
MgO	%	22.51	30.78	33.46	13.19
CaO	%	0.09	0.15	0.58	0.12
Na_2O	%	<0.01	<0.01	0.01	<0.01
K_2O	%	<0.01	<0.01	<0.01	<0.01
TiO_2	%	0.06	0.02	0.02	0.06
P_2O_5	%	0.02	0.02	<0.01	<0.01
MnO	%	0.12	0.10	0.10	0.14
Cr_2O_3	%	11.166	7.880	3.245	17.063
Ba	ppm	25	20	15	27
Ni	ppm	1390	2063	1680	862
Sc	ppm	8	5	9	8
LOI	%	7.5	12.8	13.8	1.7
Sum	%	77.14	87.07	99.40	59.17
Be	ppm	<1	<1	<1	<1
Co	ppm	115.1	106.2	93.3	138.6
Cs	ppm	<0.1	<0.1	<0.1	<0.1
Ga	ppm	8.4	3.2	3.9	13.8
Hf	ppm	<0.1	<0.1	<0.1	<0.1
Nb	ppm	0.1	<0.1	<0.1	<0.1
Rb	ppm	4.8	3.6	1.5	8.2
Sn	ppm	<1	<1	<1	<1
Sr	ppm	0.7	<0.5	2.2	2.2
Ta	ppm	<0.1	<0.1	<0.1	<0.1
Th	ppm	<0.2	<0.2	<0.2	<0.2
U	ppm	<0.1	<0.1	<0.1	<0.1
V	ppm	286	122	92	473
W	ppm	<0.5	<0.5	<0.5	<0.5

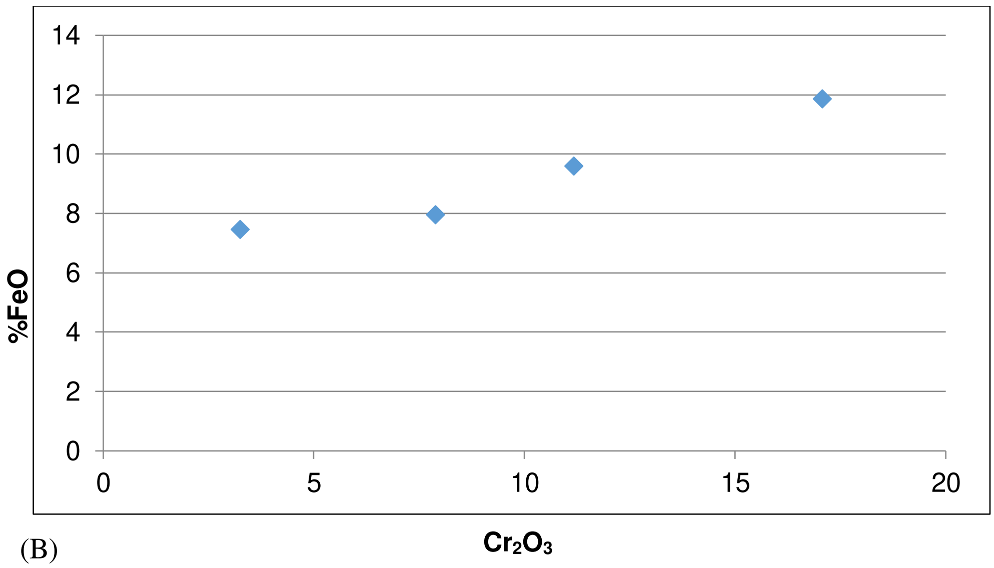
Analyte	Unit	R1 Rock Pulp	R2 Rock Pulp	R3 Rock Pulp	R4 Rock Pulp
Zr	ppm	1.4	0.9	0.4	0.9
Y	ppm	0.3	0.3	0.4	0.2
La	ppm	0.5	0.2	0.4	0.2
Ce	ppm	0.2	0.1	0.1	0.1
Pr	ppm	0.02	<0.02	<0.02	<0.02
Nd	ppm	<0.3	<0.3	<0.3	<0.3
Sm	ppm	<0.05	<0.05	<0.05	<0.05
Eu	ppm	<0.02	<0.02	<0.02	0.02
Gd	ppm	<0.05	<0.05	<0.05	0.19
Tb	ppm	0.02	<0.01	<0.01	<0.01
Dy	ppm	0.09	<0.05	0.07	<0.05
Ho	ppm	0.03	<0.02	<0.02	0.03
Er	ppm	0.04	<0.03	0.07	0.03
Tm	ppm	0.02	<0.01	0.01	0.01
Yb	ppm	0.05	<0.05	0.08	<0.05
Lu	ppm	0.01	<0.01	0.01	<0.01
TOT/C	%	0.06	0.22	0.17	0.03
TOT/S	%	<0.02	<0.02	<0.02	<0.02
Mo	ppm	<0.1	0.3	0.1	<0.1
Cu	ppm	3.0	0.9	10.6	1.1
Pb	ppm	3.7	4.9	0.7	2.9
Zn	ppm	7	14	22	3
Ni	ppm	1218.7	2040.2	1726.8	207.4
As	ppm	<0.5	<0.5	<0.5	<0.5
Cd	ppm	<0.1	<0.1	<0.1	<0.1
Sb	ppm	<0.1	<0.1	<0.1	<0.1
Bi	ppm	<0.1	<0.1	<0.1	<0.1
Ag	ppm	<0.1	<0.1	<0.1	<0.1
Au	ppb	<0.5	<0.5	<0.5	<0.5
Hg	ppm	<0.01	<0.01	<0.01	<0.01
Tl	ppm	<0.1	<0.1	<0.1	<0.1
Se	ppm	<0.5	<0.5	<0.5	<0.5

A high percentage of SiO_2 (3.38 to 38.08) and MgO (13.19 to 33.46) were found in the ophiolitic rocks of Islahiye. The Cr_2O_3 were found between 3.245 and

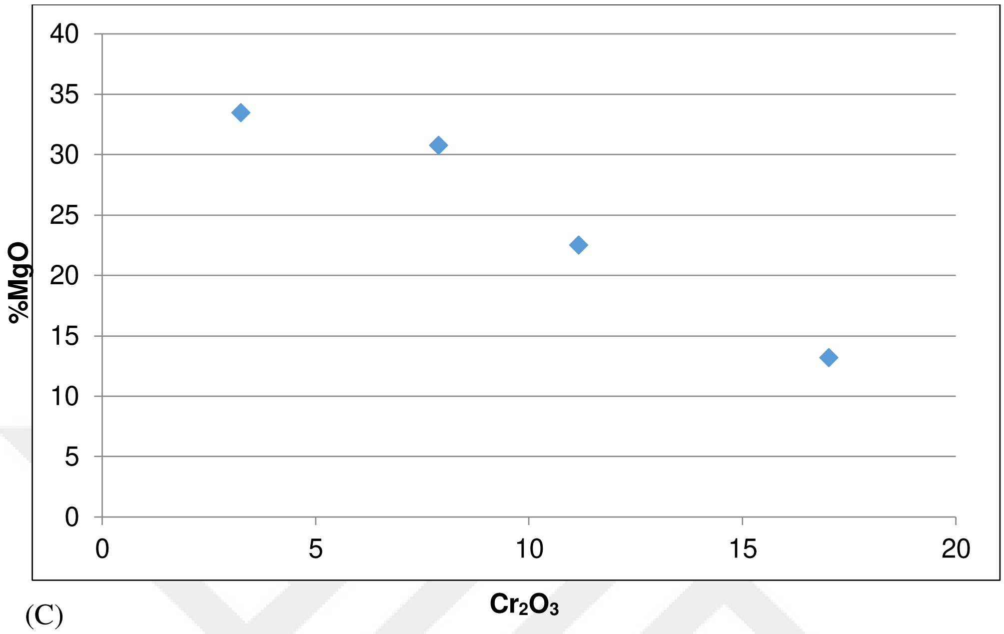
17.063%. There is also a negative correlation between the positive diagrams Cr_2O_3-Al_2O_3 and Cr_2O_3-FeO (Figure 4.16 A-B) and Cr_2O_3-MgO (Figure 4.16 C) in the oxide values of the XRF analysis results of the main rock (Figure 4.16).



(A)



(B)



(C)

Figure 4.16. XR-F analysis of the comparison % oxide rock

4.3.1. Chemical Analysis of Olivine Mineral

Representative olivine analysis from rocks (calcite, dolomite, and magnesite) are shown in Table 4.3. Olivine is represented by a low content of A.Za (<0.05-2.45%), CO_2 (<0.05-0.25), CaO (0.5-1.30%), Al_2O_3 (1.10-1.40%), Fe_2O_3 (8.35-9.10%) and a high MgO content (42.90-43.50%), SiO_2 (43.05-44.40%) contents (Table 4.3).

It was observed that olivines were composed of forsterit minerals (Mg_2SiO_4) depending on their chemical content.

The density of olivine varies between 3.22 and 4.40 g/cm^3 depending on the amount of Fe. The average concentration of olivine in the study area is about 3.20-3.30 around. As the density difference between chromite and olivine increases during ore beneficiation processes, ore gain increases and cost decreases.

Table 4.3.Analysis of the mineral olivine.

Bar code	Marked sample	LOI %	Al_2O_3 %	CO_2 %	CaO %	FeO_3 %	MgO %	SiO_2 %
18-H-008298	ISK-KA-20/1	2.45	1.10	0.25	0.50	8.35	43.50	43.05
18-H-008300	ISK-KA-21/2	<0.05	1.40	<0.05	1.30	9.10	42.90	44.40

4.3.2. XRD Results

According to the results of XRD analysis of rock samples, main paragenesis; Forsterite, klinokrozite, chromite (Figure 4.17).

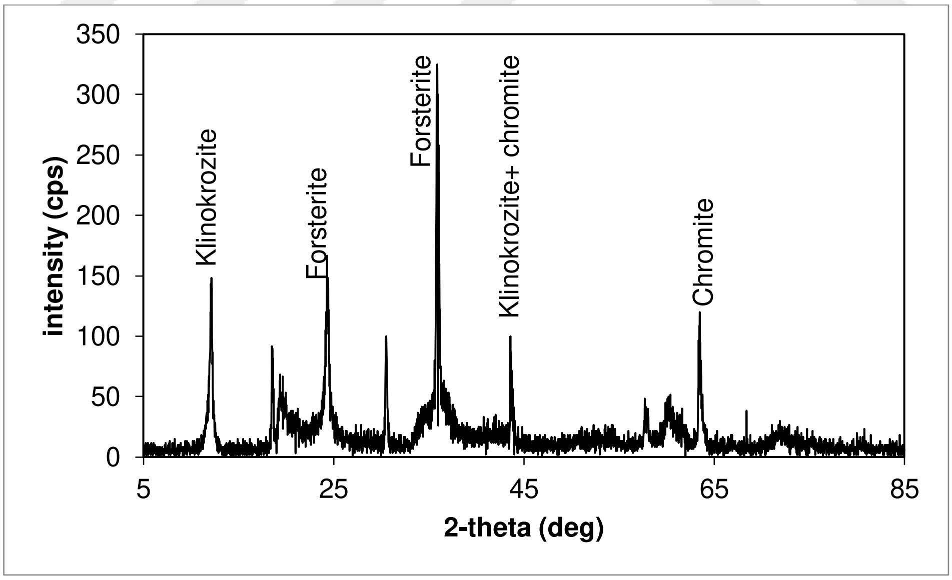


Figure 4.17. XRF patern graphic in rocks

4.4. PGE Analysis

The PGE content of samples taken from Islahiye chromitites was low and ranged from 138 to 214 ppb in total.

A total of 8 samples of whole chromite ores were analyzed for PGE presence.The results of PGE analysis for Islahiye chromitites are shown in Table 4.4. In the samples examined, the Ru ratio is between 90 and 130 ppb, the Ir ratio is between 3 and 40 ppb, the ratio of Os is between 9 and 50 ppb and the Rh ratio is between 6 and 11 ppb. Chromitites show an enrichment in IPGE with the occasional presence of Ru and Ir and Os higher in chromite. In addition, we found no PGM associated with the serpentinized silicate matrix of this sample, which would have also indicated secondary enrichment in PGE.

Table 4.4.The PGE in chromite

	Au (ppb)	Ir(ppb)	Os(ppb)	Pd(ppb)	Pt(ppb)	Rh(ppb)	Ru(ppb)
PGE1	-	40	33	-	-	11	130
PGE2	-	38	22	-	-	11	120
PGE3	-	37	50	-	-	6	120
PGE4	-	24	13	-	-	9	92
PGE5	-	32	24	-	-	8	90
PGE6	5	27	14	-	-	8	91
PGE7	5	3	9	100	20	7	48
PGE8	-	38	35	-		10	127

The analysis results are normalized to the Primitive Mantle (PM) values and the results are evaluated in spider diagrams (Figure 4.18). The standardized chondrite spider pattern of PGE analysis obtained from chromites was presented in Figure 4.19 and compared to other world chromite samples.

The chromites obtained from the Gaziantep region are similar to PGE profiles similar to chromites in relation to the world.

Accordingly, the PGE profiles show a negative trend towards positive Ru to Rh in general, and show a near-horizon trend from Os to Ir.

The PGE samples fall into the laurite subfield, whereas in the Ru-Rh-Ir triple diagram, the samples obtained from the region are called as ruarsit.

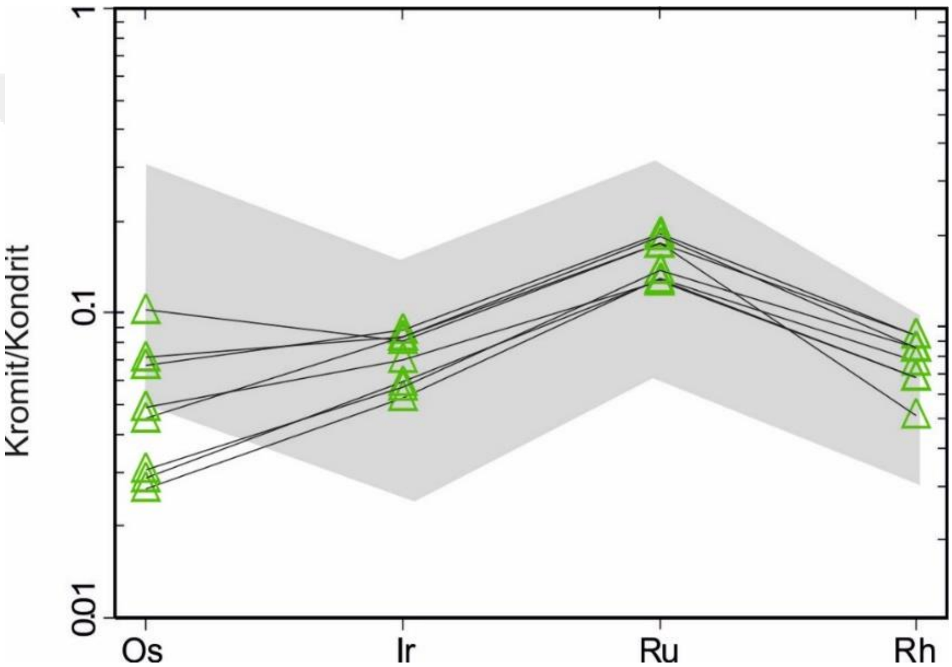


Figure 4.18. Spider web diagram showing the comparison of mantle peridotites and chromites with the PGE content of chromites from the Gaziantep region. Gray area page et al. (1982), Bacuta et al. (1990), Bonavia et al. (1993), Yang and Seccombe (1993), Augé and Maurizot (1995), Leblanc (1995), Graham et al. (1996), Zhou et al. (1996, 1998), Cliff et al. (2000, 2006), Uysal et al. (2005, 2007a, b, 2009a) and Prichard et al. (2008).

Samples obtained from PGE samples collected in the Gaziantep region show a positive correlation between Ir, Ru and Rh and Os, and Rh again shows a positive correlation with Ru, Rh and Ru. Samples taken from the region show a value between plutonic chromites and podiform chromites of NATO and fall closer to the podiform chromite zone of the mantle (Figure 4.19).

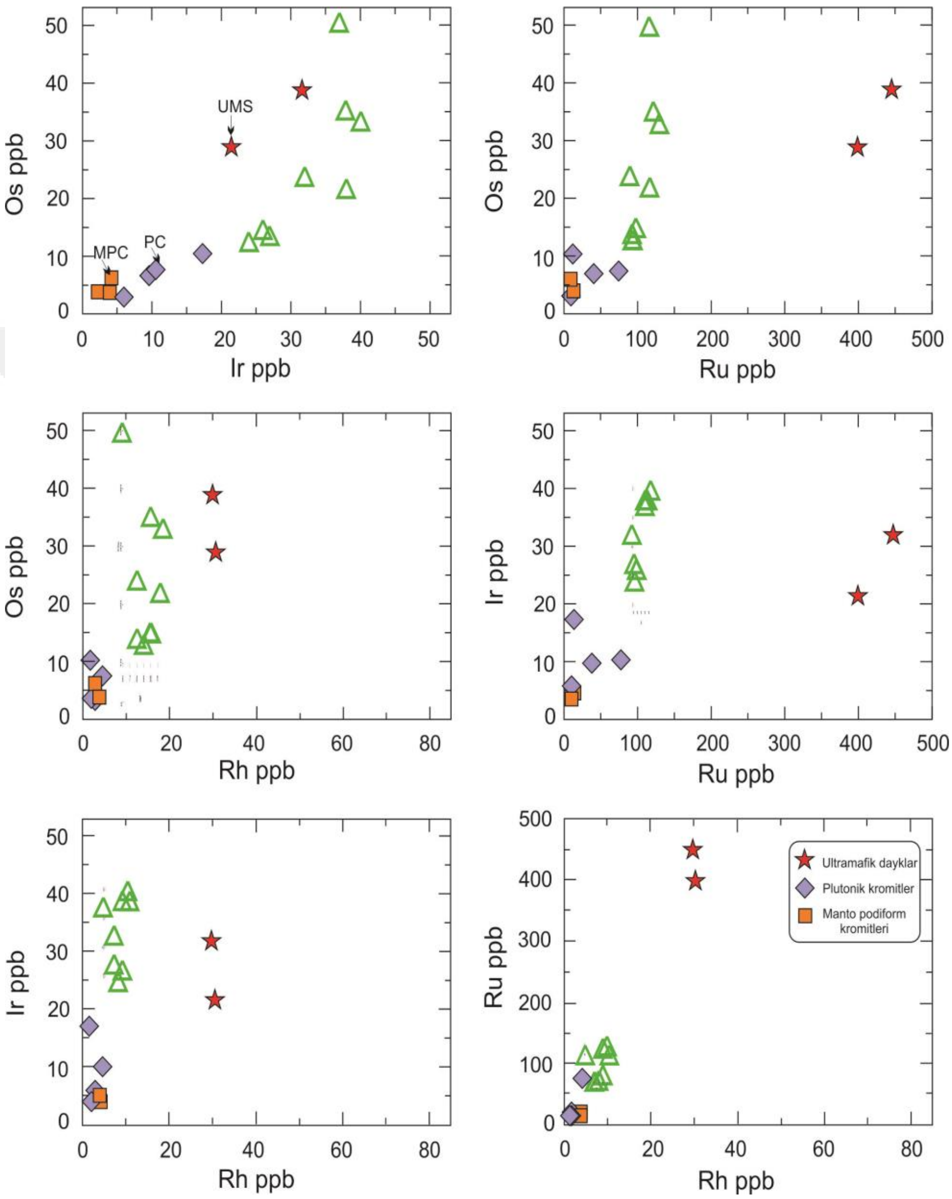


Figure 4.19. Diagram Os, Ir, Ru, Rh / Ir, Rh, Ru and Ru versus Rh shows the location of the PGE sample chart comparison values were obtained from Page et al. 2008 and Hirose and Kawamoto, 1995.

4.4.1. Mineralogy of the Platinum Group Elements

PGE samples enter the laurite subfield, while in the Ru-Rh-Ir triple chart, samples obtained from the region are called ruarsit. Ir, Ru, Rh have a positive correlation against Os and Ir against Ru, Rh and Ru against also a positive correlation with Rh. Laurite is the most abundant PGM among the chromites samples studied, as is commonly seen in other ophiolitic drugs. Chromites, which in some cases, irarsit and the Os - Ir alloy have been found to be associated with laurit. The laurite grains in chromites with high Cr content are richer in Ru content (Figure 4.20).

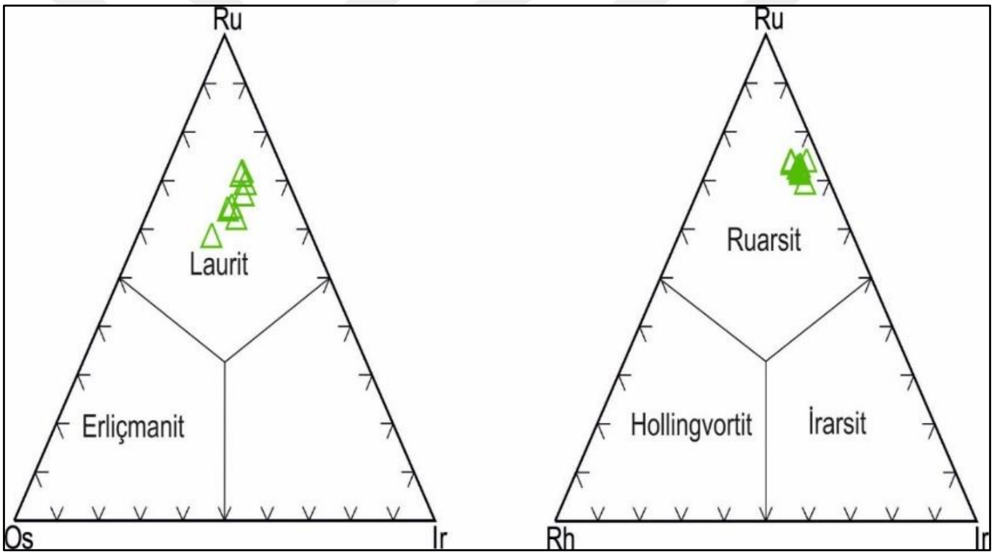


Figure 4.20.PGE mineral diagrams

4.4.2. XRD PGE Results

XRD patern according to the results of the main paragenesis; Chromite, Klinokrozite, Millerite, Forsterite, Laurit, Irarsit (Figure 4.21).

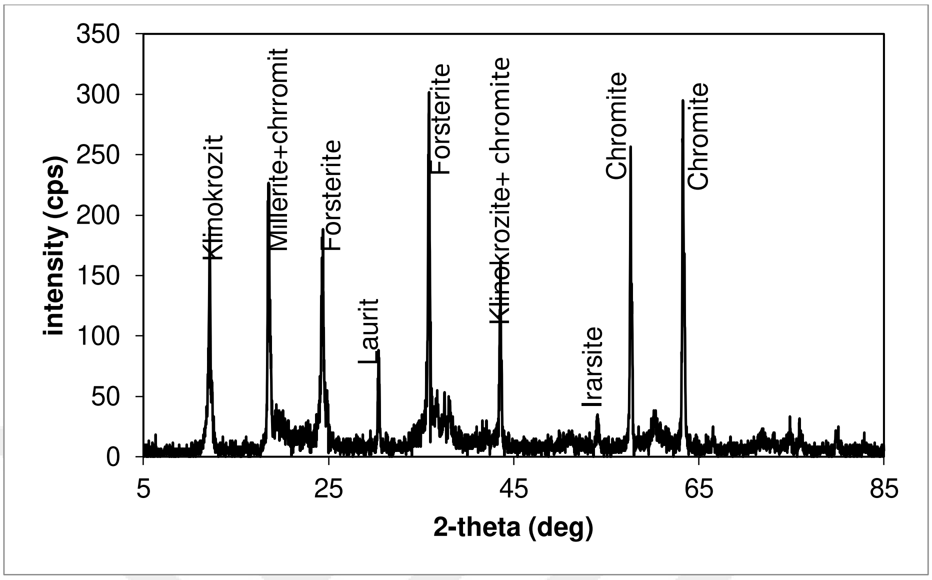


Figure 4.21.PGE XRD diagram

4.5. Economic Potential of Chromite

Occurrences and chromite faults in the vicinity of faults are different and affect the formation of chromite fusions. The fault zones are composed of highly serpentinized and brecciated colors of yellow, green and mylonite.

The thickness of the fault zone can be between 4 and 6 m or a few centimeters. According to the measured values taken in the majority of chromite ores, the dominant directions of the chromite formations are N35-45°E, the dominant tilt directions (60-75°) SW and the tilt angles are between 50° and 60°. During the field surveys, 8 drill locations were determined taking into account the outcrops and faults observed. These 8 drill samples and the 5 outcrop coordinates for the ore exploration were examined on the map (Figure 4.22, Table 4.5 and 4.6).

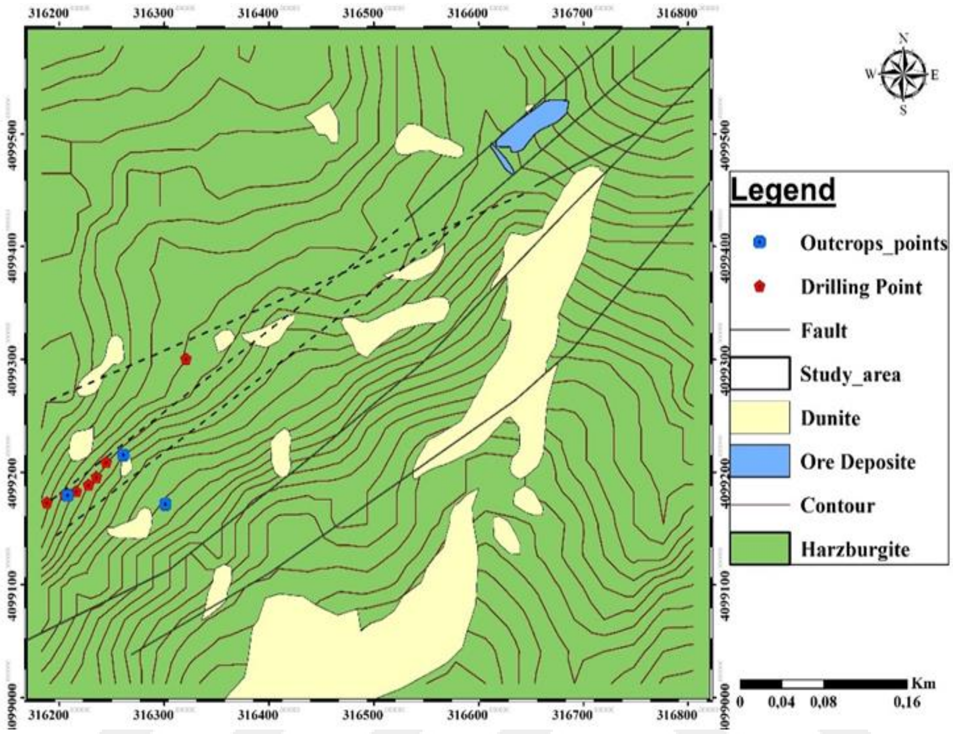


Figure 4.22. Map of drilling and outcrops points

Table 4.5. Outcrop points

Points (Outcrop)	**Y**	**X**	Z
O1	316146.853	4099055.448	931.682
O2	316301.047	4099171.468	976.354
O3	316260.972	4099215.217	986.174
O4	316207.762	4099179.323	989.059
O5	316131.363	4099066.472	941.132

Table 4.6. Drilling points

points	Y	X	Z	commentary
D1	316163.194	4099156.828	982.803	In a total of 63 m of drilling, harzburgite and dunite were cut between 41.90 and 42.40 m.
D2	316188.006	4099172.861	987.916	A total of 45 m of drilling was done with harzburgite, crushed dunite and the mines were cut between 40.90 and 42.50 m.
D 3	316205.250	4099180.133	989.850	Drilling was completed at 100 m and the harzburgite was cut.
D 4	316216.125	4099182.644	990.624	Drilling was completed at 117 m and harzburgite was discontinued.
D5	316227.719	4099188.460	992.298	Harzburgite, crushed dunite and mines were drilled between 41.90 and 44.10 totaling 75 m.
D 6	316235.467	4099195.269	992.608	A total of 80 m of drilling, harzburgite, crushed dunite and veins of 30 to 40 cm were dug in mines.
D 7	316244.634	4099208.583	993.488	In a total of 100 m of drilling, harzburgite, crushed dunite and mines were cut from 45 to 60 cm.
D 8	316320.932	4099300.299	983.866	Out of a total of 110 m of drilling, harzburgite mines, crushed dunite mines and thin strips were cut.

The reserve was calculated based on 5 outcrop samples and 8 drill samples results. Based on drill points at close coordinates, the average depth of 40 to 44 m of ore was determined at drill points 1, 2, 5, 6, 7, 8 and the possible thickness was estimated at 1.5 m. The length of the outcrop points based on the calculation of the minimum possible length of more than 100 m has been determined.

Content = 46/100

Density: 4.5 tones/m^3

Thickness: 1.5 m

Surface area: 10,000 m^2

Reserve= $\frac{\textbf{(Surface area (m}^2\textbf{) xthickness (m) xdensity (ton/m}^3\textbf{)*ore surface ratio 46/100)}}{\textbf{3}}$

As a result, a probable reserve of 10 350 tones was found.

The result of the quantity of the surveys estimates that there are more reserves in the region.

The fact that the mineralization is due to faults and lenticular settlement near the surface varies greatly in thickness over short distances. The content does not change much.

The fact that mineralization is more underground means that mining should be considered underground.

For effective mining activity on such a bed of chrome, a quarry design must be designed and a project design must be prepared taking into account the distribution of the thickness and the content determined by the bulk model method.

Although the regional chromium mineralization is economic, it has been shown to contribute to our national economy by activating our unused national resources.

Although the regional chromium mineralization is economic, it has been shown to contribute to our national economy by activating our national resources.

Surface geological observations and outcrops of mineralization can be predicted much higher by taking into account the movement of fault.

5. CONCLUSION

The aim of this thesis was to define the mineralogical and potential characteristics of chromite ore concentrations in terms of platinum group elements in Islahiye ophiolites. To achieve this, we have set the following objectives: to make a petrographic and mineralogical study of rock and chromite samples taken from the study area. Then perform a chemical analysis of these samples to determine the PGE content in the chromite. At the end of this work, data on platinum group elements (PGE) combined with petrographic and chemical data lead to the following conclusions:

- Field and laboratory studies indicate that ophiolitic rocks in the study area are composed of peridotites consisting of dunite and harzburgites. Mantle tectonites are the most extensive ophiolite rocks in the region and consist of dunite, serpentinized dunite, serpentinized harzburgite and serpentinite. The ophiolite layer is located in the region with completely tectonic movements.
- As a result of the chromite microscopic study, the main minerals composed of chromite, nickel and magnetite were observed in the sections. Chromites have cataclastic properties due to intense deformation. The chromite crystals have serpentinized olivine inclusions.
- The result of XRD analysis shows that forsterite, klinokrozite and chromite were detected as main chromite minerals. XRF analysis of chromites was evaluated in% oxide diagrams. There is a negative correlation between the positive diagrams Cr_2O_3-Al_2O_3 and Cr_2O_3-FeO and Cr_2O_3-MgO in the values in % of oxide.
- The Islahiye chromites show an enrichment in IPGE with the occasional presence of Ru and Ir and higher Os in chromite. In addition, we found no

PGM associated with the serpentine silicate matrix of this sample, which would have also indicated secondary enrichment in PGE.

- A probable reserve of 10 350 tonnes has been estimated. The result of the quantity of the 8 surveys estimates that there are more reserves in the region. The PGE content of samples taken from Islahiye chromitites was low and ranged from 138 to 214 ppb in total.
- The Islahiye chromites have no potential in terms of PGE

The results obtained in the framework of this work constitute data that cannot bring definitive results concerning the non-potentiality of the PGEs in the chromite of the region and in all Turkey. To this end, it would be desirable for further studies to be made in this region and the whole Turkey in order to better know and draw a definitive conclusion on the non-potentiality of PGEs in chromites in Turkey.

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