Chapter 3
Chromitite Deposits of Turkey in Tethyan Ophiolites

Yahya Çiftçi, Cahit Dönmez, Osman Parlak, and Kurtuluş Günay

Abstract Some parts of the Tethyan ophiolites of Alpine-Himalayan suture belt are located within Turkey. The Tethyan belt splits into two branches in Turkey. The northern branch follows the İzmir-Ankara-Erzincan Zone, while the southern branch extends along the Anatolide-Tauride and Bitlis-Zagros suture zone. The subsections of the latter reach Iran in the east and Oman ophiolites in the south east. These ophiolites are also the only environments in which chromitite deposits occur. Consequently, the ophiolites in Turkey are significantly rich in terms of Alpine type chromitite occurrences and they are the oldest metallic mine products.

There has been chromitite ore production in Turkey since the nineteenth century. With their refractory quality, chromitite produced in Turkey has always had a good standing in the market. Chromitite, which was exported as lump ore until mid-twentieth century, started to be used in the domestic market as the country's industry developed, but still, even today an important part of the production is exported. In addition, since the chromitite developments near to the surface are almost completely exhausted, the chromitite ore production in the country has evolved to concentrated ore obtained from low grade deposits, through beneficiation. Although there are many active beneficiation plants in various parts of the country, there is still a significant amount of concentrate ore production; especially in the deposits of Adana-Aladağ region.

In this chapter, the mentioned chromitite occurrences are discussed in a specific order from west to east, taking into account the ophiolite sequences to which they belong. The North Anatolian Ophiolites are introduced in the first three sections whereas the other three sections present the chromitite deposits of the South Anatolian Ophiolites. Nevertheless, considering the historical records and future production potentials, Turkey's most important chromitite production regions could be listed in order of priority as Guleman (Elazığ), Kopdağ region (Erzincan),

Y. Çiftçi (✉) · C. Dönmez · K. Günay
Department of Mineral Research and Exploration, General Directorate of Mineral Research and Exploration, Ankara, Turkey
e-mail: redaksiyon@mta.gov.tr

O. Parlak
Engineering Faculty, Geological Engineering Department, Çukurova University, Adana, Turkey

F. Pirajno et al. (eds.), *Mineral Resources of Turkey*, Modern Approaches in Solid Earth Sciences 16, https://doi.org/10.1007/978-3-030-02950-0_3

Muğla-Fethiye region, Aladağ-Pınarbaşı (Adana-Kayseri), Orhaneli-Harmancık (Bursa)-Eskişehir region and Hatay. It is clear that these should all be taken into consideration for further prospecting targeting.

3.1 Introduction

This chapter has been prepared by making use of the wide literature on Turkish chromitites. The "Turkish Chromitite Inventory" project, which is being prepared using the Chrome-Nickel Prospecting reports, has been worked on by the General Directorate of Mineral Research and Exploration for many years. Most of the presented data (tables and maps) were derived from these prospecting reports. In the first part we provide brief information about Tethyan ophiolites of the Eastern Mediterranean. The second part includes general information about chromitites and general features of chromitites in Turkey. A summary of petrogenetic studies regarding ophiolites in Turkey is also presented here. The third part is the main body of this chapter. Chromitite occurrences of Turkey presented here are based on an inventory format in accordance with County administrative requirements in Turkey. In this way, related ophiolite sequences can be described in more detail.

This Chapter aims to work through the chromite occurrences associated with the Tethys Ophiolites, thereby becoming an essential overview and a guide for new scientific studies. We also hope to have opened a new window for our colleagues and students who are studying and working on mineral systems.

3.2 Tethyan Ophiolites of the Eastern Mediterranean

The Mesozoic Tethyan ophiolites of the Alpine-Himalayan orogenic belt include the Mid-Late Jurassic ophiolites of the Dinarides, Albanides and Hellenides in the western region and the Late Cretaceous ophiolites of Turkey, Troodos, Baer-Bassit, Khoy, Kermansah, Neyriz, and Oman in the eastern region (Fig. 3.1). The Mid to Late Jurassic ophiolites in the western region formed in a transitional tectonic settings from MORB to SSZ (Bebien et al. 1998; Bortolotti et al. 2002; Robertson 2002, 2012; Robertson and Shallo 2000; Höck et al. 2002; Dilek and Flower 2003; Saccani et al. 2004; Dilek et al. 2005, 2008; Tremblay et al. 2009), whereas the late Cretaceous ophiolites in the eastern region, from Turkey to Oman, are supra-subduction zone (SSZ) type (Aktaş and Robertson 1984; Pearce et al. 1984; Hebert and Laurent 1990; Lytwyn and Casey 1993; Yalınız et al. 1996; Collins and Robertson 1998; Dilek et al. 1999; Floyd et al. 2000; Parlak et al. 1996, 2000, 2002, 2004, 2009, 2013a; Al-Riyami et al. 2002; Robertson 2002; Robertson et al. 2006, 2007; Flower and Dilek 2003; Dilek and Thy 2009; Dilek and Furnes 2009).

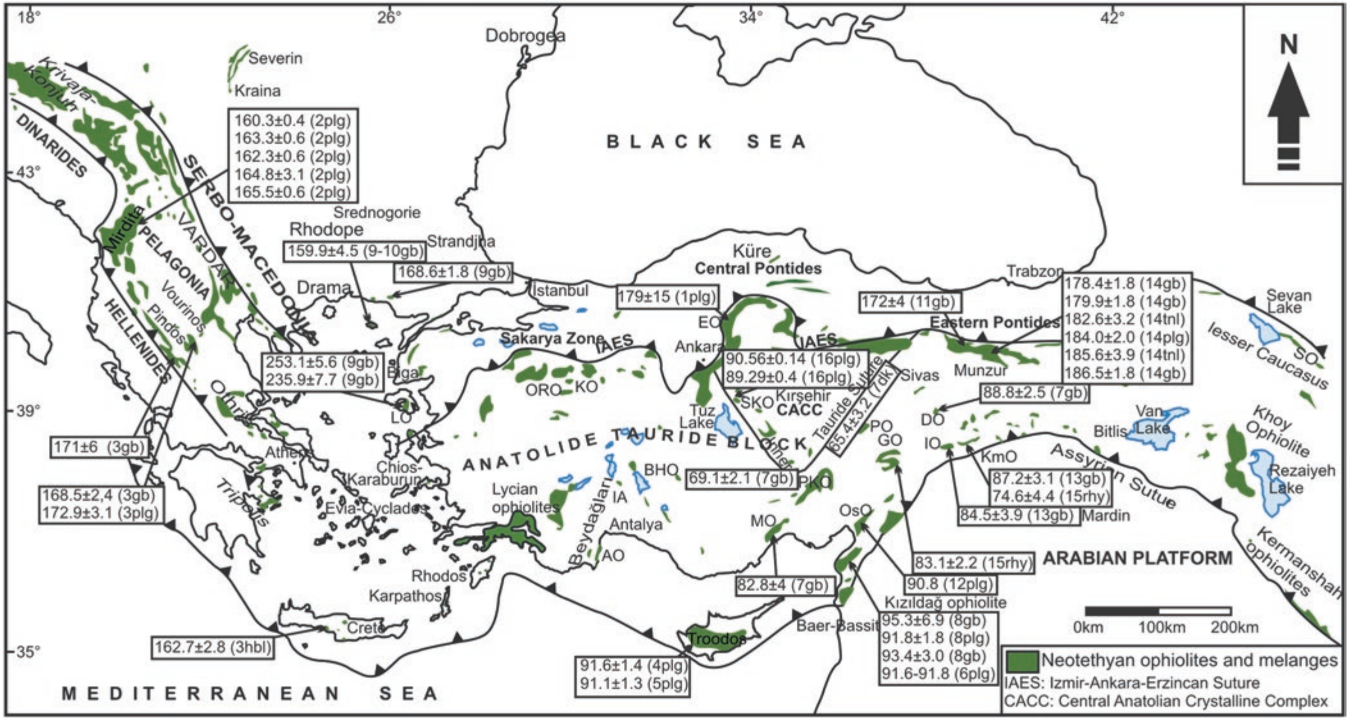


Fig. 3.1 U-Pb ages of the Tethyan ophiolites in Turkey and surrounding areas (Data are from (1) Dilek and Thy (2006), (2) Dilek et al. (2008), (3) Liati et al. (2004), (4) Mukasa and Ludden (1987), (5) Konstantinou et al. (2007), (6) Dilek and Thy (2009), (7) Parlak et al. (2013a), (8) Karaoğlan et al. (2013a), (9) Koglin (2008), (10) Koglin et al. (2009), (11) Topuz et al. (2012), (12) Sarıfakıoğlu et al. (2012), (13) Karaoğlan (2012), (14) Robertson et al. (2013b), (15) Karaoğlan et al. (2013b)). *LO* Lesvos Ophiolite, *AO* Antalya Ophiolite, *BHO* Beyşehir-Hoyran Ophiolite, *ORO* Orhaneli Ophiolite, *KO* Kınık Ophiolite, *EO* Eldivan Ophiolite, *MO* Mersin Ophiolite, *PKO* Pozantı-Karsantı Ophiolite, *OsO* Osmaniye Ophiolite, *GO* Göksun Ophiolite, *PO* Pınarbaşı Ophiolite, *IO* Ispendere Ophiolite, *DO* Divriği Ophiolite, *KmO* Kömürhan Ophiolite, *SO* Sevan Ophiolite, *plg* plagiogranite, *gb* gabbro, *dk* dyke, *tnl* tonalite, *rhy* rhyolite. (Map modified after Dilek and Flower 2003; Çelik et al. 2011)

Neotethyan ophiolites in Anatolia are located along several east-west trending suture zones separated by continental blocks, metamorphic core complexes and sedimentary basins (Şengör and Yılmaz 1981; Robertson and Dixon 1984; Robertson 2002, 2006; Okay and Tüysüz 1999; Okay 2008). These suture zones are marked by ophiolites, ophiolitic melanges and ophiolite-related metamorphic rocks (Okay 1986, 1989; Parlak et al. 1995, 2006, 2009; Önen and Hall 2000; Vergili and Parlak 2005; Robertson et al. 2009; Pourteau et al. 2010; Okay and Whitney 2010; Dilek and Furnes 2011). These tectonic units were emplaced in the Late Cretaceous as a result of series of collisions of intra-oceanic arc-trench systems with the continental margins (Robertson 2002, 2004, 2006, 2007; Flower and Dilek 2003; Dilek and Flower 2003; Dilek et al. 2007; Dilek and Thy 2009; Dilek and Furnes 2009; Okay and Şahintürk 1997; Okay et al. 2006; Okay 1989).

The ophiolites in northern Anatolia occur in the İzmir-Ankara-Erzincan suture (Fig. 3.1), cropping out in western, central and northeastern Anatolia. The ophiolites are incompletely preserved, and crustal units display a supra-subduction zone geochemical character. In western Turkey, the ophiolites were emplaced over a subducted and exhumed passive margin of the Tauride-Anatolide platform in the Campanian (Okay 1989; Yılmaz et al. 1997a, b; Göncüoğlu et al. 2000; Robertson 2002; Robertson et al. 2009). The Late Cretaceous dismembered ophiolites above the Kırşehir/Niğde metamorphic massifs, and within the Ankara Melange are interpreted mainly as remnants of SSZ-type ophiolites formed in the Late Cretaceous within a northerly Neotethyan oceanic basin. The felsic intrusives and the volcaniclastics of Middle Turonian-Early Santonian age are indicative of contemporaneous arc volcanism (Yalınız et al. 1996; Yalınız and Göncüoğlu 1998). The Late Cretaceous Central Anatolian ophiolite was emplaced southwards from the Ankara-Erzincan suture zone onto the Kırşehir/Niğde metamorphic basement before latest Maastrichtian time. However, Early-Middle Jurassic isotopic ages were reported from the Ankara melange (Dilek and Thy 2006; Çelik et al. 2011). The Ankara-Erzincan suture zone includes large bodies of ophiolites and ophiolitic melanges in northeastern Anatolia (Rice et al. 2006, 2009; Sarıfakıoğlu et al. 2009; Parlak et al. 2013b; Topuz et al. 2013). These ophiolitic units display well-preserved oceanic lithospheric sections and accretionary melanges with local blueschist assemblages. Southward-emplacement onto the Tauride passive margin and northward emplacement onto the Pontide active margin has been proposed during Late Cretaceous-Early Tertiary (Okay and Şahintürk 1997; Yılmaz et al. 1997a, b; Rice et al. 2006, 2009). These ophiolitic units are unconformably overlain by Campanian-Maastrichtian sediments that were, in turn, imbricated with the ophiolitic rocks (Okay and Şahintürk 1997; Rice et al. 2006, 2009).

The Tauride belt ophiolites start with the Lycian nappes to the west and end with the Divriği ophiolite to the east. These ophiolites (Lycian nappes, Antalya, Beyşehir-Hoyran nappes, Mersin, Pozantı-Karsantı, Pınarbaşı and Divriği) are situated either on the northern or on the southern flank of the E-W trending Tauride carbonate platform axis (Juteau 1980). They mainly consist of three tectonic units namely, in ascending order, ophiolitic mélange, sub-ophiolitic metamorphic sole and oceanic lithospheric remnants. The ophiolitic mélange in tectonic contact with the underlying platform carbonates, is composed of ophiolitic rock fragments, limestone blocks ranging in age from Permian to Late Cretaceous, radiolarites, shale, and fragments of metamorphic rocks. This unit is, in turn, tectonically overlain by thin sheets of metamorphic rocks that display inverted metamorphic zonation from upper amphibolite to greenschist facies. The mantle tectonites, dominated by harzburgite, tectonically rest on the deformed metamorphic sole rocks. Well-preserved ultramafic and mafic cumulates are the most conspicuous features all over the Tauride belt ophiolites (Juteau 1980). The plutonic sections and the metamorphic soles of the Tauride ophiolites are crossed by numerous isolated diabase dykes at different structural levels. The dykes are not deformed, indicating that they were emplaced after the deformation of metamorphic soles, but they do not extend into the underlying melanges. Sheeted dyke complexes and volcanic sections are rarely present in some of the ophiolites such as Antalya, Mersin and Pozantı-Karsantı (Juteau et al. 1977; Parlak 1996; Parlak et al. 2001). The geochemistry of crustal rocks indicates SSZ origin for the Tauride ophiolites (Collins and Robertson 1998; Parlak et al. 1996, 2000, 2002, 2006; Andrew and Robertson 2002; Vergili and Parlak 2005; Çelik and Delaloye 2003; Çelik and Chiaradia 2008; Çelik 2007).

Two subparallel, NE-SW-trending belts of Upper Cretaceous ophiolitic rocks transect southern Turkey, extending through northern Syria, Cyprus and intervening offshore areas (Robertson 2002; Parlak et al. 2009). The southern belt includes the Troodos ophiolite (Cyprus), the Baer–Bassit ophiolite (northern Syria) and the Antalya (Tekirova and Gödene), Hatay, Amanos and Koçali ophiolites (southern Turkey). Geophysical evidence indicates that a submarine connection existed between the Troodos and Levant margin ophiolites (Baer-Bassit and Hatay ophiolites) via the Latakia Ridge (Ben-Avraham et al. 2006; Roberts and Pearce 2007; Bowman 2011). These ophiolites originated within the Southern Neotethys. Regional comparisons show that the Kızıldağ ophiolite has similar petrological and geochemical features to the Baer–Bassit and Troodos ophiolites. The Baer–Bassit ophiolite is the leading edge of a vast ophiolite that was emplaced southwards from the southerly Neotethyan Ocean in latest Cretaceous (Maastrichtian) time. The Kızıldag ophiolite to the north represents the undeformed, more northerly part of the same thrust sheet (Robertson 1986a, b, 2002; Al-Riyami and Robertson 2002; Al-Riyami et al. 2002). There are a number of similarities between the two ophiolites. Despite the strongly dismembered nature of the Baer-Bassit ophiolite, it can be reconstructed as a single complete ophiolite sequence from bottom to top, like the Kızıldag ophiolite (Robertson 1986a, b; Al-Riyami et al. 2002). The plutonic section of the Kızıldag ophiolite is lithologically similar to that of the Baer–Bassit ophiolite (Bağcı et al. 2005, 2008; Al-Riyami et al. 2002). Both ophiolites have well developed sheeted dyke complexes. The extrusive rocks in both ophiolites are mostly depleted and exhibit the geochemical features of island arc tholeiites (IAT) (Al-Riyami et al. 2002; Bağcı et al. 2008).

The more northerly belt includes the North Berit (Göksun) ophiolite, the İspendere ophiolite, the Kömürhan ophiolite, the Guleman ophiolite and the Killan ophiolite. These ophiolites originated from an ocean basin, here termed the Berit ocean, that was located between the Malatya-Keban platform to the north and the

Bitlis and Pütürge continental units to the south (Robertson et al. 2012a, b). The SE Anatolian ophiolites are tectonically overlain by the Malatya-Keban platform and all intruded by late Cretaceous granitoid (Parlak 2006; Rızaoğlu et al. 2009). These ophiolites were thrust over the Maden Group at the end of Middle Eocene time. They include differentiated rock units in both the plutonic (quartz diorites) and the volcanic sections (i.e. basalt to rhyolite). They are also overlain by volcanic arc units (i.e. Elazığ Unit, Yüksekova Complex), suggesting that SSZ-type crust evolved into an ensimatic island arc as subduction continued (Rızaoğlu et al. 2006; Parlak et al. 2009; Karaoğlan et al. 2013b). The Guleman ophiolite shows similar features to the Kömürhan, İspendere and Göksun ophiolites. Although it was also accreted to the base of the Malatya-Keban platform during the Late Cretaceous, it was not affected by the intrusion of the granitoid. All of the evidence suggests that the Göksun, İspendere, Kömürhan, Guleman ophiolites and the North Berit (Göksun) ophiolite were related to the northern margin of the southern Neotethys (i.e. the Malatya–Keban Platform), whereas the Kızıldağ (Hatay) ophiolite was attached to the southern margin (i.e. the Arabian Platform) of the southern Neotethys in the latest Cretaceous time (Robertson et al. 2006, 2007; Parlak et al. 2009, 2013a).

U-Pb ages of the oceanic magmatism (gabbro) reported from the Western and Central Alps range from 164 to 158 Ma (Rubatto et al. 1998; Rubatto and Scambelluri 2003; Kaczmarek et al. 2008). But the youngest oceanic magmatism was reported as 93 Ma by Liati et al. (2003) in the Central Alps. Similar Middle to Late Jurassic crystallization ages were also documented from the Mirdita (plagiogranite: 165–160 Ma), in Albania (Dilek et al. 2008); Vourinos (plagiogranite: 172.9 ± 3.1 and gabbro: 168.5 ± 2.4 Ma), Pindos (gabbro:171 ± 3 Ma), Samothraki (gabbro: 159.9 ± 4.5 Ma), Evros (gabbro: 168.6 ± 1.8 Ma), Crete (gabbro/hornblendite: 162.7 ± 2.8 Ma) ophiolites in Greece (Liati et al. 2004; Koglin 2008); and Ankara melange (plagiogranite: 179 ± 15 Ma) in northern Turkey (Dilek and Thy 2006) (Fig. 3.1). In contrast, Late Cretaceous crystallization age of the oceanic crust is well documented in the Eastern Mediterranean region, including Troodos (plagiogranite: 90–91 Ma; Mukassa and Ludden 1987; Konstantinou et al. 2007), Kızıldağ (plagiogranite and gabbro: 93–91 Ma), Divriği (88.8 ± 2.5 Ma), Mersin (gabbro: 82.8 ± 4 Ma), Pozantı-Karsantı (Gabbro: 69.1 ± 2.1 Ma), Pınarbaşı (Isolated dike: 65.4 ± 3.2 Ma) ophiolites in Turkey (Dilek and Thy 2009; Karaoğlan et al. 2013a; Parlak et al. 2013a) and the Semail ophiolite (plagiogranite: 95 Ma) in Oman (Tilton et al. 1981; Warren et al. 2005).

3.3 Chromitites: Types, Occurrences, Petrological Features

3.3.1 Types of Chromitite Deposits

Chromitite deposits are usually associated with ultramafic rocks. Generally they are divided into three main types based on their origin, geological setting, mineralogy, texture, and chemical characteristics (Thayer 1960; Jackson and Thayer 1972)

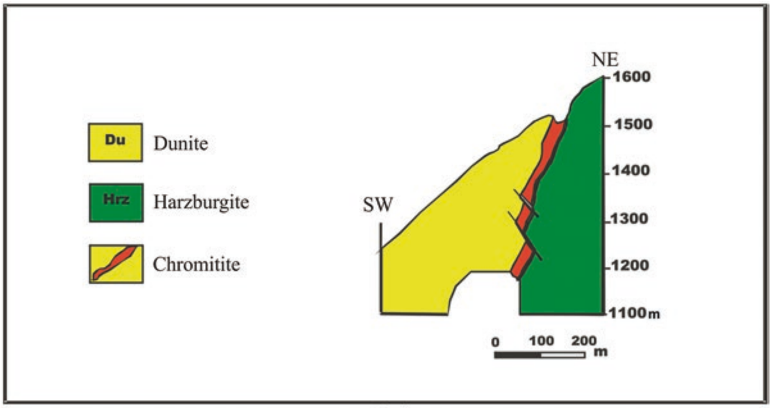
(a) Stratiform chromite deposits generally occur in mafic-ultramafic intrusions in stable continental regions: these are continuous deposits that usually have large reserves and show consistency in dip and strike, small grain size, smooth crystal shape (idiomorph), cumulate textures, high iron content, low Cr/Fe ratio. The most typical examples are deposits in the Bushveld (South Africa; Cawthorn 2015), and Stillwater (USA; McCallum 1996) complexes.
(b) Alpine (podiform) chromite deposits: these consist of lenses or irregularly shaped chromitite masses, with limited continuity in strike and dip, widely varying Cr content, and their reserves usually do not exceed a few hundred thousand tonnes. The chromite is coarse-grained, with irregular crystallinity and Cr/Fe ratios are generally high. Such deposits are usually found in countries located on the Alpine mountain belt such as the Former Yugoslavia, Albania, Greece, Turkey, Cyprus, Iran and Pakistan. Also, Kazakhstan, India, the Philippines and New Caledonia as well as some other countries where similar types of chromitite deposits are located.
(c) Chromitite (and magnetite) deposits that have a concentric internal order, related to mafic-ultramafic rock assemblages: This type of chromite formation has no economic significance. The most typical examples exist in Alaska and are known as Alaskan-type intrusions (Johan 2002).

3.3.2 General Characteristics of the Turkish Chromitites

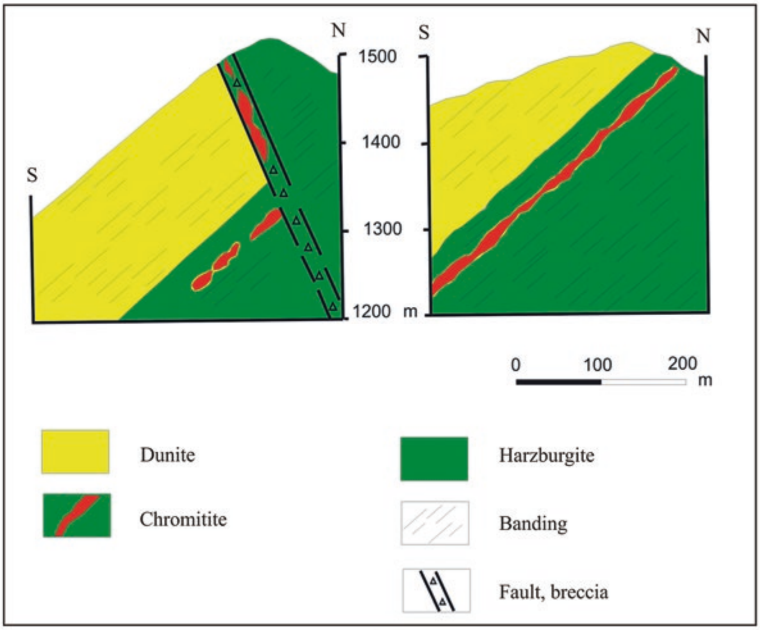
The chromitite deposits of Turkey are classified as “Alpine-Type” deposits. Thicknesses usually vary between 10 cm and 10 m with lengths of 100–200 m. However, in the Guleman (Elazığ) region, 1500 m long bodies were observed, boudinaged along strike, in the Uzun Damar and Ayı Damar ore deposits. Although the thicknesses of chromite masses can reach up to 50 m, it usually does not exceed a few meters.

The chromite mineralisation in Turkey can be found in the ultramafic rocks of both the cumulate and tectonite sections of the ophiolites and can be grouped according to their tectono-stratigraphic location (Engin et al. 1985). The chromite bodies of harzburgites (tectonites) are surrounded by dunite envelopes ranging in thickness from a few centimetres to a few meters (Fig. 3.2).

(a) Chromitites within the deeper part of the mantle, harzburgites could be seen as in Ayıdamar and Uzun Damar deposits in Guleman (Elazığ) region,
(b) Chromitites located below the tectonite-cumulate transition zone as in the Koca Ocak and Kıran Ocak in Harmancık (Bursa) region,
(c) Chromitites located along the tectonite-cumulate transition zone as in Batı Kef Mine in Guleman (Elazığ) region,
(d) Chromitites hosted in ultramafic zones (dunite), as in Pütyan Mine of Gölalan - Guleman (Elazığ) and Kızılyüksek (Pozantı-Karsantı) regions (Fig. 3.3).



2a-1



2a-2

Fig. 3.2 Location of chromitites in Turkey. (After Engin et al. 1985)

The structural relationships of the chromitite bodies with the host peridotites are shown in Fig. 3.4. Chromite deposits in Turkey are mostly concordant with the foliation fabric of the peridotites (Fig. 3.4a). Although some deviations are possible due to the shape of the chromitite bodies, in general, the orientation of the chromite lenses and the foliation pattern in the peridotite are parallel to each other (Fig. 3.4a, b). However, later tectonics may have affected this primary fabric and the position of the chromitites (Fig. 3.4c–e).

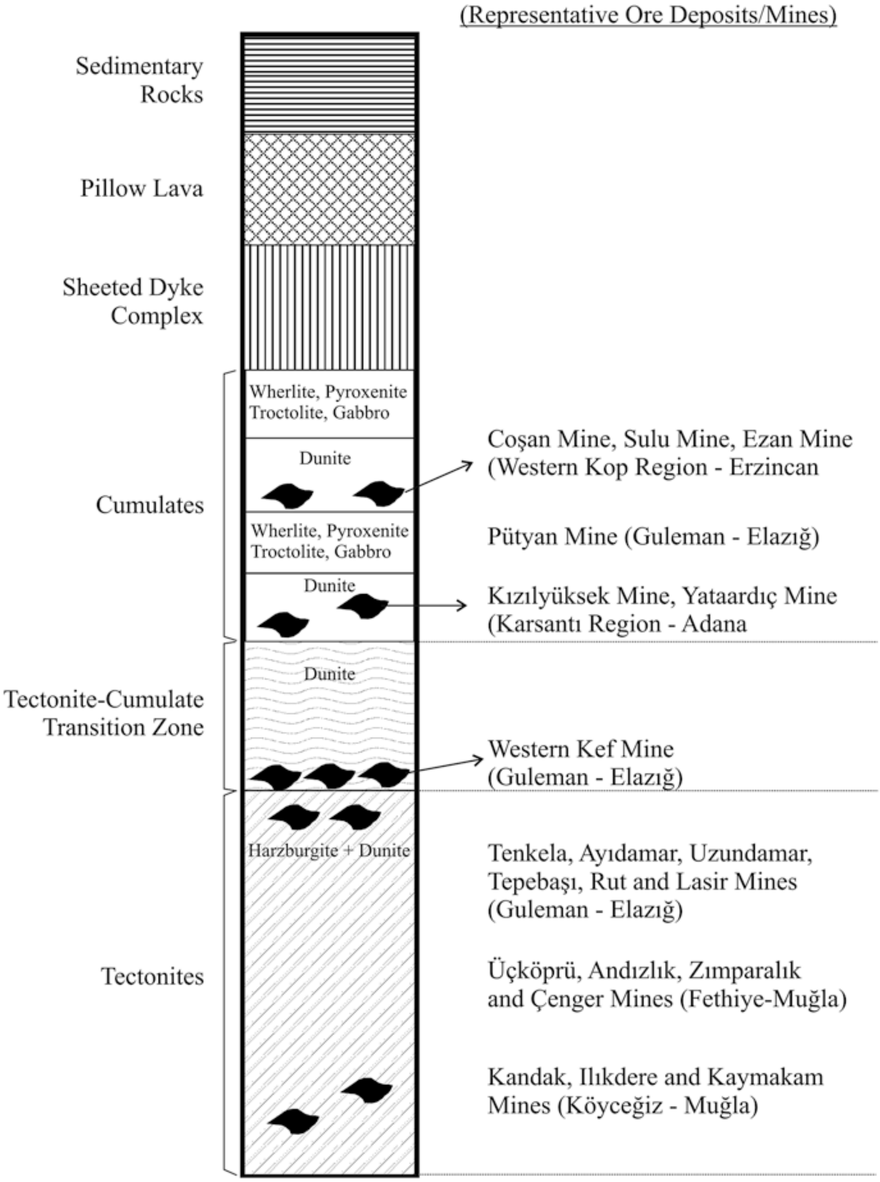


Fig. 3.3 Chromitites in Turkish ophiolites and representative ore deposits/mines. (After Engin et al. 1985)

Chromitites cutting the structural fabric of peridotites, are mainly located along fault zones (Fig. 3.4c). Some chromitite deposits although initially elongated along the foliation fabrics of peridotite, as a result of tectonic transportation and deformation, actually cut through the foliation planes (Fig. 3.4c), or are locally folded with

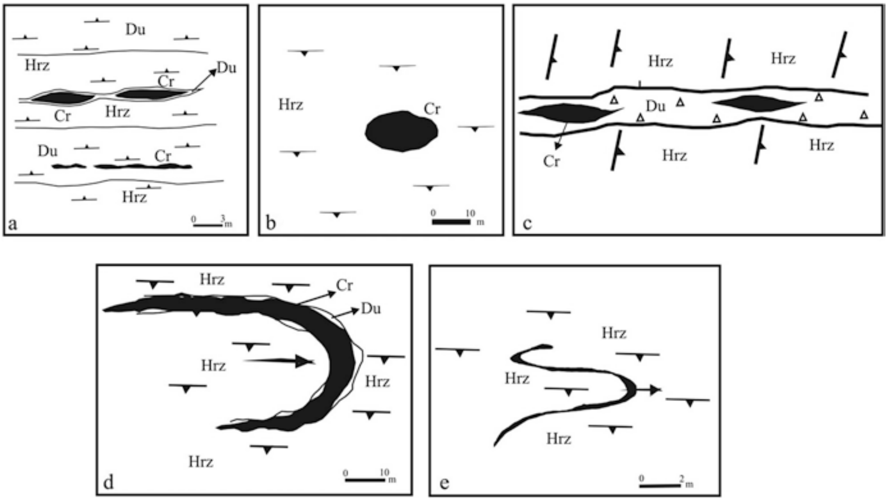


Fig. 3.4 Wallrock/chromitite ores relationship typically found in Turkey: (**a**, **b**) chromitite bodies are concordant with the internal structure of the peridotite (Uzundamar and Western Kef Mines, Guleman-Elazığ; length of the orebody in dip direction is more than ten times than strike direction (Anik Mine, Fethiye); (**c**) Structural fabric of the orebodies in the fault zone are concordant with this fault zone, but they cut the internal structure of peridotite in a diagonal direction (Eastern Kef and Kapin Mines, Guleman); (**d**, **e**) Folded chromitite bodies in peridotite; chromitite bodies are plunging, foliation of the peridotite at the fold apex diagonally intersects these fabrics of the orebody (Kandak and Biticealan Mines, Köyceğiz-Muğla). (Redrawn after Engin et al. 1985)

the wall-rock ultramafics (Fig. 3.4d, e). These types of chromitites, as shown in Fig. 3.4, have been described only in few areas, such as Kavak-Bahtiyar (Eskişehir) and Guleman (Elazığ) regions (Engin et al. 1980–1981) in Turkey, but well studied in New Caledonian ophiolites (Cassard et al. 1981).

3.3.3 Geochemical Features of Turkish Chromitites and Platinum Group Element (PGE) Contents

Apart from whole rock geochemical features available through chromite mining operations, information related to chromite mineral chemistry and PGE contents of chromites was reviewed from published articles, post-graduate theses and public reports.

As mentioned above, Turkish chromitites typically are Alpine type (podiform) deposits. These deposits are characterized by high Cr_2O_3, Al_2O_3, Cr/Fe and MgO, and low FeO and Fe_2O_3 contents. Although the Turkish chromitites are generally of economic grade, their wide range of chemistry enables their use in the refractory and chemistry industries. The average wt% Cr_2O_3 grade of deposits ranges between 5% and 45%, with a maximum of about 58 wt% Cr_2O_3. Average grades of less than

40% Cr_2O_3 are accepted as "third quality"; 40–46% is accepted as "second quality", and over 46% is accepted as "first quality" chromite ore in the market. In this regard, Turkish chromitites which are used in refractory industry should have approximately 30–40 wt% Cr_2O_3, 25–32 wt% Al_2O_3, >10 wt% SiO_2. On the other hand, the metallurgical industry needs at least 34–48 wt% Cr_2O_3, 8–15 wt% Al_2O_3, 8–12 wt% SiO_2, 16–22 wt% MgO. For the industry, average compositions should be at least 48 wt% Cr_2O_3 (base), 6–7 wt% SiO_2 and Cr/Fe rate should be 3/1 (typical) (Çiftçi et al. 2017; DPT 2001).

The chemistry of chrome spinel minerals in chromitites provides important data for genetic models of chromite formation and also for classification of chromite-bearing ophiolites. Chemistry of chrome spinels of Turkish chromitites varies significantly, and in this chapter, the average values of chrome spinel compositions are used.

Data of chrome spinel chemistry demonstrates classic features of these spinels. Turkish chromitites can generally be classified as Mg-Chromite/Chromite, according to their chromium and magnesium numbers; 0.5< Cr# (Cr/[Cr+Al], atomic ratio) and 0.4–0.8 <Mg# [100 Mg/(Mg + Fe), atomic ratio] (Fig. 3.5a) (Dönmez et al. 2014 and the references therein). Al_2O_3 wt% and Cr_2O_3 wt% contents support the podiform type generation of Turkish chromitites (Fig. 3.5b). Chrome spinels in Alpine type Turkish podiform chromitites have highly variable Cr# ranging from 0.2 to 0.9.

This compositional difference in chromitites, were reported by many researchers in the last decade and chromitites were divided into two groups according to their Cr# value intervals as high-Cr type (Cr# >0.6) and high-Al type chromitites (González-Jiménez et al. 2011; Pal 2011; Rollinson 2008; Uysal et al. 2009a, b; Zaccarini et al. 2011). Both types can exist in the same mantle source. The occurrences of high-Cr and high-Al types are still debated. Here, features that have a general consensus are addressed. In recent years, as a result of studies on Turkish chromitites, similar results were obtained about chromitites related to Muğla, Kastamonu and Van Ophiolites (Uysal et al. 2009b; Dönmez et al. 2014; Günay and Çolakoğlu 2011, 2016).

Turkish chromitites hosted in ultramafic tectonites, which dominantly consist of harzburgites and dunites. In these upper mantle rocks, chromite formations are strongly related to mantle stratigraphy. Stratigraphic levels of chromitites in an ophiolitic sequence, also appear to determine their chemistry. In this aspect, chromitites can be classified in an effective way on Rammlmair's (1986) Cr# versus Cr/Fe diagram presented in Fig. 3.5c. It is clearly seen in this figure that Turkish chromitites mainly plot within (I) and (II) areas. These areas were defined as ultramafic tectonite (mantle peridotites) and are also consistent with their geological features. However, the chromitites related to ultramafic cumulate rocks that plot within (III) and (IV) areas, are bands which are also consistent with these rocks and their occurrences are highly limited.

Turkish chromitites that mainly occur in mantle peridotites, do not contain economic quantities of PGE. Chromitites in Turkey generally have low PGE content, ranging between 200 and 350 ppb. However, it was reported that elements such as

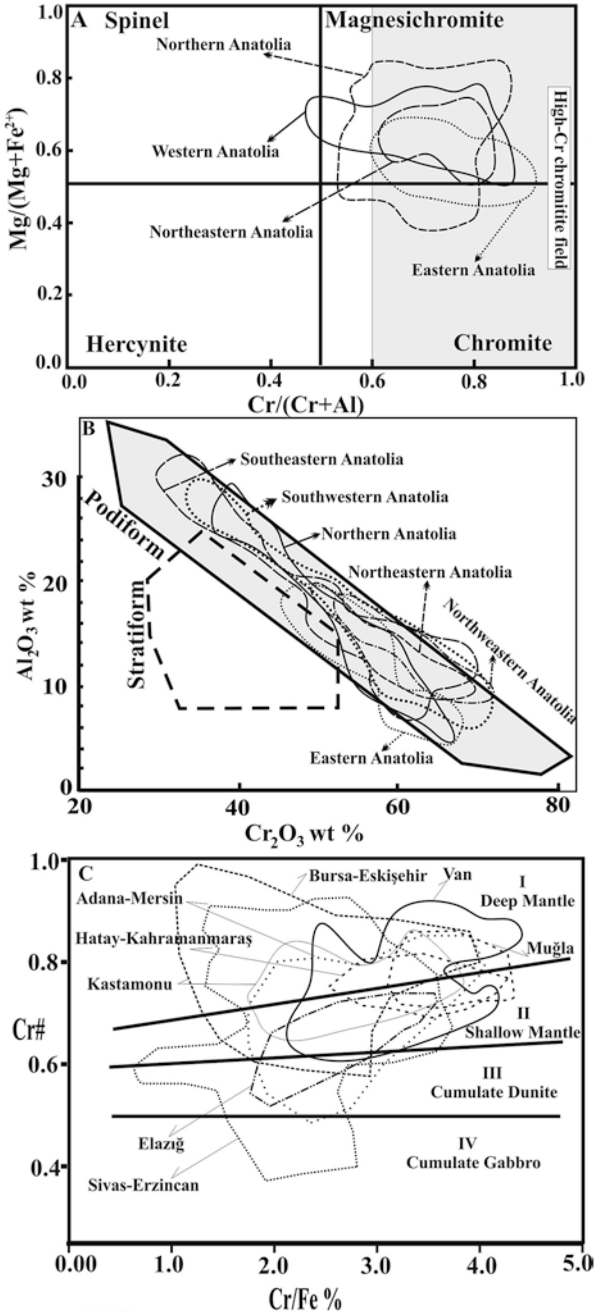


Fig. 3.5 Geochemical properties of Turkish chromitites (explanations in text)

Pt and Pd are locally enriched over 1 ppm in a few areas such as Muğla Ophiolite (Harmancık area; Uçurum and Koptagel 2006) and Kahramanmaraş Ophiolite (Berit area; Kozlu et al. 2014). There is no relation between whole-rock PGE contents of chromitites and mineral chemistry. In general, it is accepted that ophiolitic chromitites have high IPGE/PPGE (IPGE= Ru-Os-Ir; PPGE= Rh-Pt-Pd) ratios and low PGE contents (Economou-Eliopoulos 1996; Zhou et al. 1998; Proenza et al. 1998; Melcher et al. 1999; Ahmet and Arai 2002; Garuti 2004; Uysal et al. 2009a, b; González-Jiménez et al. 2011; Zaccarini et al. 2011). Turkish podiform chromite deposits exhibit enrichment in Ru-Os-Ir relative to Rh-Pt-Pd elements (Fig. 3.6a), similar to the PGE content of other ophiolitic chromitites around the World.

On the basis of their PGE contents, Turkish chromitites show similar features with geochemical behaviours of PGE's of ophiolitic chromitites in petrological processes. Total PGE contents of Turkish chromitites negatively correlating with $PPGE_N/IPGE_N$, are consistent with ophiolitic trends around the world (Fig. 3.6b; Melcher et al. 1999). In addition to this, Turkish chromitites display a trend compatible with partial melting rather than being fractionated in Pd/Ir versus Pt/Pt*$[=Pt_N/(Rh_N{}^*Pd_N)^{1/2}]$ diagram (Fig. 3.6c; Garuti et al. 1997). It can be concluded that during the crystallization of chromites related to partial melting processes, Ir-group elements preferred chromite as the primary phase when compared to Pd-group elements.

3.4 Geological Properties of Chromitites in Turkey

Tethyan ophiolites located within the borders of Turkey are exposed mainly along the İzmir – Ankara – Erzincan, Inner Taurid and Bitlis – Zagros Suture Belt (Okay and Tüysüz 1999) (Figs. 3.1 and 3.7) and their principal features are discussed in Sect. 3.2. Chromitites, which are entirely related to these rocks, are considered in six related groups (Çiftçi et al. 2017) (Fig. 3.7). In this study, the chromite deposits of Turkey are introduced, together with the related ophiolite sequence, on the basis of this grouping, as follows:

Region 1: NW Anatolian Region: (Balıkesir, Bursa, Eskişehir and Kütahya).
Region 2: North Anatolian Region (Çankırı, Çorum, Kastamonu, Sinop, Tokat and Yozgat).
Region 3: NE Anatolian Region (Sivas, Bayburt, Erzincan, Erzurum).
Region 4: SW Anatolian Region (Antalya, Burdur, Denizli, Isparta, Konya and Muğla).
Region 5: Central Anatolian Region (İçel, Adana, Kayseri).
Region 6: SE Anatolian Region (Hatay, Osmaniye, Kahramanmaraş, Gaziantep, Elazığ, Malatya, Adıyaman, Diyarbakır, Siirt, Van, Hakkari).

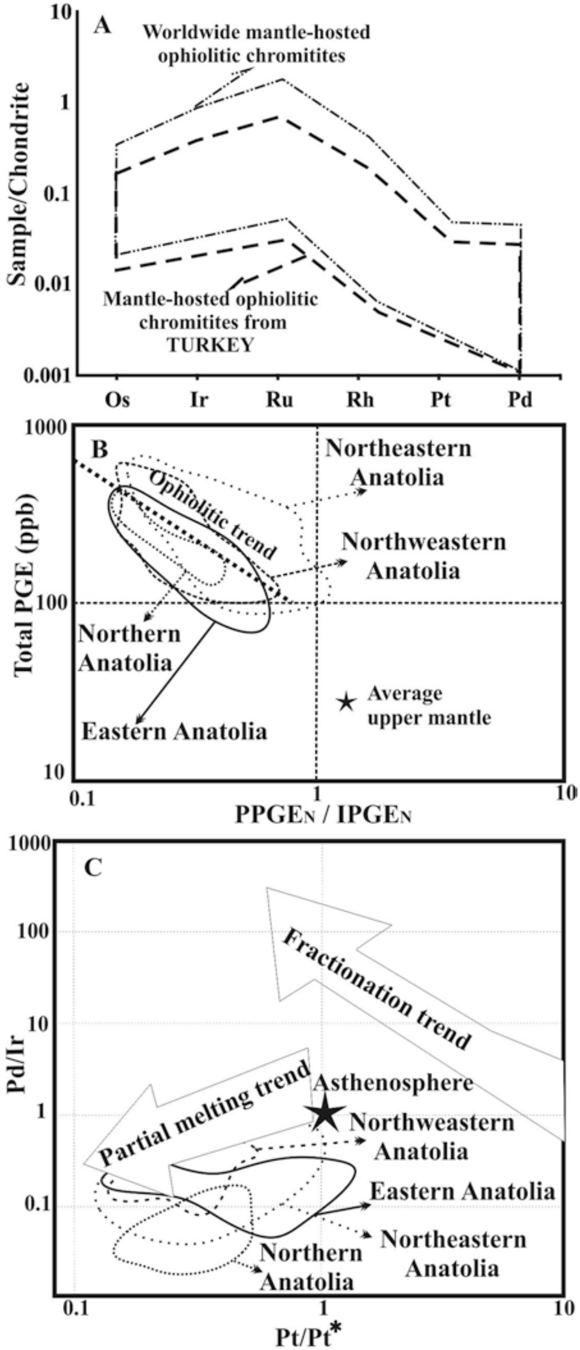


Fig. 3.6 PGE content and properties of chromitites in Turkey (explanations in the text)

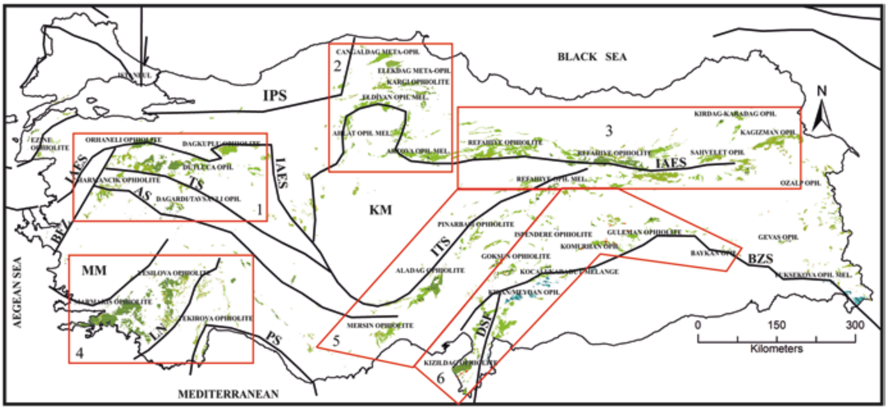


Fig. 3.7 Major structural elements of Turkey; distribution of ophiolites and related chromitites (*1*: NW Anatolian; *2*: North Anatolian; *3*: NE Anatolian; *4*: SW Anatolian; *5*: Middle Anatolian; *6*: SE Anatolian Sub-Regions). (*IAES* İzmir-Ankara-Erzincan Suture, *TS* Tavşanlı Suture, *AS* Afyon Suture, *BFZ* Bornova Flysh Zone, *MM* Menderes Massif, *KM* Kırşehir Massif, *PS* Pamphylian Suture, *ITS* Inner Tauride Suture, *IPS* Inner Pontide Suture, *BZS* Bitlis-Zagros Suture (Assyrian Suture), *DSF* Dead Sea Fault). (Modified After Okay and Tüysüz 1999) (Modified after MTA 2002)

Although the regional characteristics and the main features are discussed in the first section, it is necessary to describe them in more detail in terms of petrological and structural features because they are the primary wall-rock of chromitite ore deposits.

3.4.1 Region One: NW Anatolian (Balıkesir, Bursa, Eskişehir and Kütahya) Ophiolites and Related Chromitite Deposits

Ophiolitic rocks in this region and surrounding areas remain within İzmir-Ankara suture zone ophiolites (Fig. 3.7). The ophiolites that occur in the eastern border of Balıkesir province are part of the Yayla Melange (Ergül et al. 1980) and rocks belonging to the same section were examined under the Eydemirçay Formation towards the south (Konak and et al. 1980). In general, multi-colored units with different lithologies are in tectonic contact and form large and small blocks interpreted as ophiolitic melange (Pehlivan et al. 2007). The lithologies belonging to the Yayla Melange, which rests tectonically on the Bornova flysh, are also defined as a part of the Bornova flysch by other researchers (Ergül et al. 1980; Okay and Siyako 1993).

The chromite occurrences in the Balıkesir area are contained in harzburgites and dunites of the Harmancık Ophiolite, which is entirely composed of ultramafic tectonites. These units were cut partly by diabase dykes at different structural levels (Fig. 3.8).

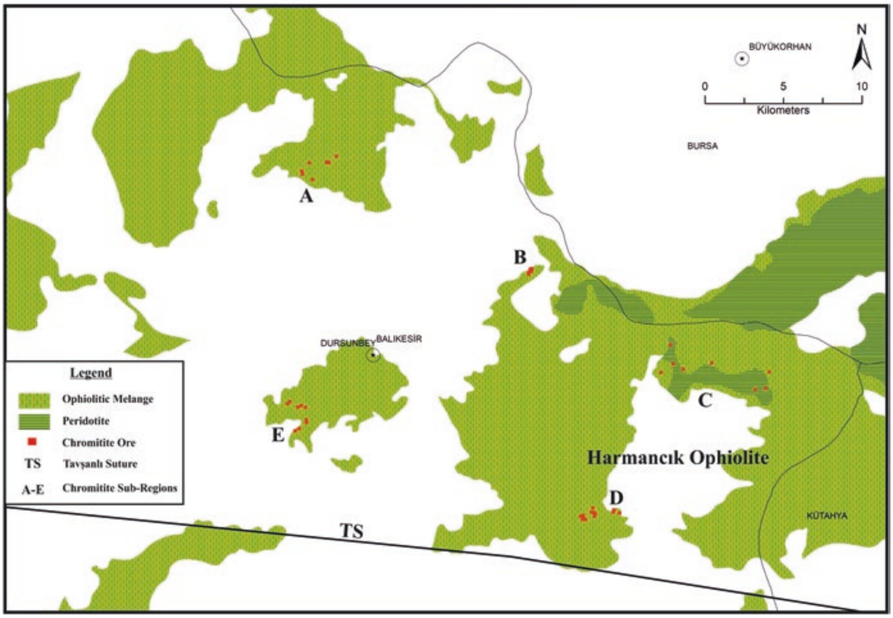


Fig. 3.8 Distribution of the chromitite occurrences in Balıkesir segment: (*a*) Karacabayır hill; (*b*) Adaören; (*c*) Akçaalan-Sağir; (*d*) Boyalıca and (*e*) Çatalçam sub-regions. (Simplified and modified after MTA 2002)

Chromitite occurrences in Bursa province are associated with approximately E–W trending Orhaneli Ophiolite or Harmancık Ophiolite (Figs. 3.9 and 3.10). While the Orhaneli ophiolites are generally represented by ultramafic to mafic cumulates, the Harmancık ophiolite is usually characterized by variably serpentinized harzburgitic to dunitic mantle tectonites (MTA 2002; Sayak et al. 2009; Ortalan et al. 1984; Bacak and Uz 2003).

The ophiolites outcropping around Kütahya, have been studied by many researchers (Arni 1942; Holzer 1954; Brinkmann 1972; Okay 1981, 2011; Konak 2002; Önen and Hall 1993; MTA 2002; Önen 2003). In the Tavşanlı Zone they display an internally coherent unit, the Tavşanlı Ophiolite, and a disordered melange, the Dağardı Melange. The Tavşanlı ophiolite is located in the north of Tavşanlı village as an E–W trending tectonic unit which is underlain by the Dağardı Melange (Fig. 3.11).

Tavşanlı zone ophiolites rest tectonically on the Ovacik Complex and Orhaneli group in the region (Okay 2011). They comprise peridotites, gabbro, pyroxenite, and diabase dykes. These ophiolitic rocks were named as “Dağardı Ophiolite” by Bacak and Uz (2003) and this ophiolite section is known as the eastern extension of the Harmancık (Bursa) Ophiolite.

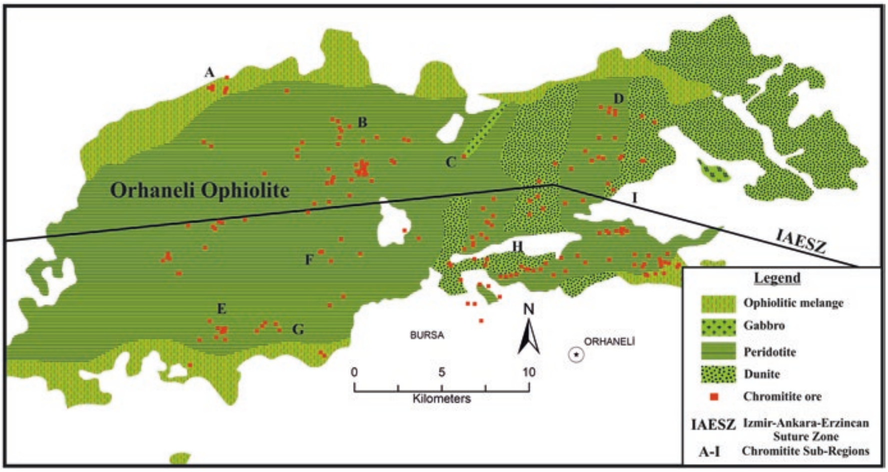


Fig. 3.9 Orhaneli sub-region and related chromitite occurrences and segments (A: Eskikızılelma; B: Çınarcık; C: Göktepe; D: Şeytanbudakköy; E: Çiviliçam; F: Ömeraltı; G: Letafet Köyü; H: Akçabük; I: Göynükbelen segments). (Simplified and modified after MTA 2002)

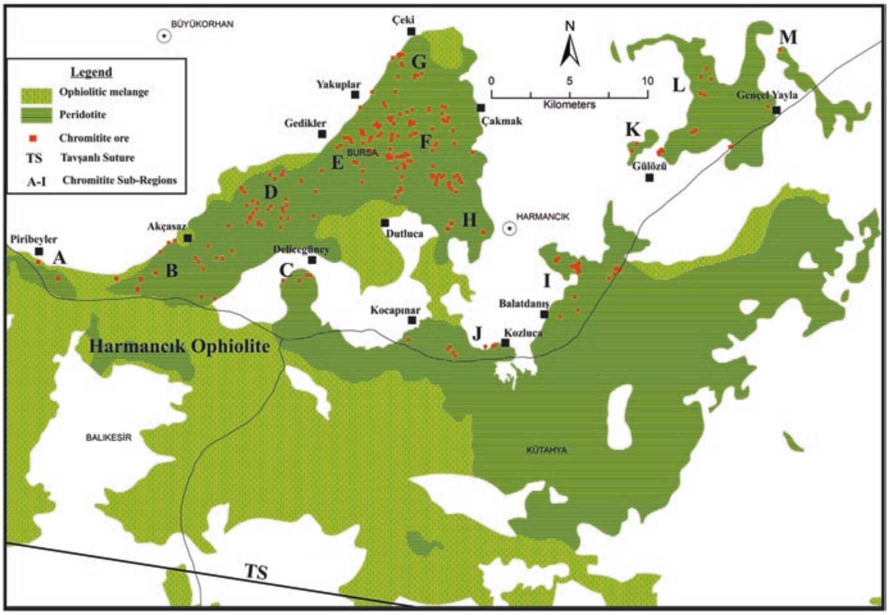


Fig. 3.10 Harmancık (Bursa) sub-region and related chromitite occurrences and segments (A: Piribeyler, B: Akçasaz, C: Delicegüney, D: Kınık, E: Yakuplar, F: Çakmak, G: Çeki Köyü, H: Harmancık, I: Balatdanış, J: Kocapınar-Kozluca, K: Eşen, L: Fındıcak, M: Gençel segments). (Simplified and modified after MTA 2002)

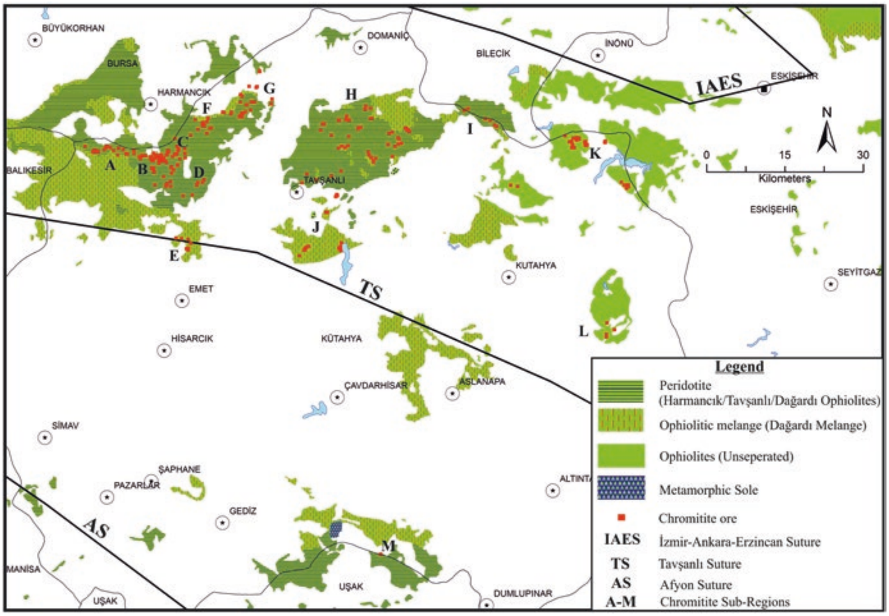


Fig. 3.11 Chromitite occurrences of Kütahya region and its segments (A: Uluçam; B: Madanlar; C: Çamalan; D: Kargılı; E: Dereli; F: Nusretler; G: Karakaya; H: Elmalı; I: Karsak; J; Tavşanlı; K: Sobran; L: Muhatboğaz; M: Çukurören segments). (Simplified after MTA 2002)

The Dağardı Melange covers a wide area between the Tavşanlı and Emet regions and consists of metamorphics, mafic to ultramafic magmatic and sedimentary rock assemblages trending NW-SE which are unconformably overlain by Tertiary sediments.

In Eskişehir province, ophiolitic units outcrop in three regions (Fig. 3.12). The first starts in the north of Eskişehir and ends in Sarıcakaya region as an E-W trending zone, and is named as Dağküplü Ophiolite. The second is Sivrihisar-Karaburhan Ophiolite Nappe outcropping in the north of Sivrihisar, and the third, the Dutluca Ophiolite, outcrops around Dutluca village. The ophiolitic rocks are made up of imbricated slices, and the assemblage from bottom to top is ophiolitic melange, mafic to ultramafic cumulates and tectonites (Özen et al. 2011).

3.4.1.1 Balıkesir Region Chromite Deposits

The chromite deposits and formations in the Balıkesir province are located within the borders of Dursunbey District (Fig. 3.8). General features of the chromitites in Balıkesir Region are given in Table 3.1. As shown in this table, chromitite ores in the region are generally limited in shape and reserve, and do not have economic importance, although chromitite ore in Turkey was first mined in this region.

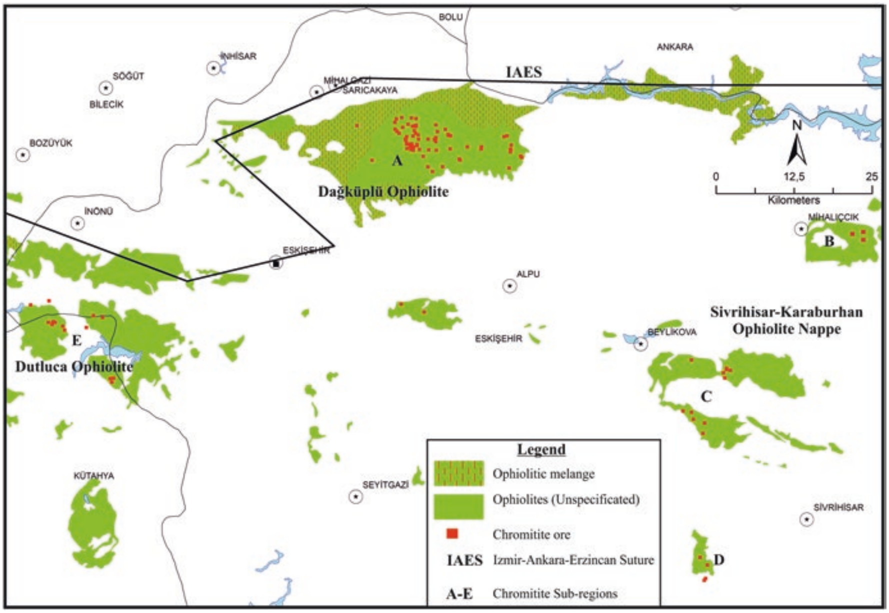


Fig. 3.12 Chromitite occurrences of Eskişehir region and its sub-regions (**A**: Dağküplü; **B**: Kavak-Bahtiyar; **C**: Sivrihisar-Karaburhan; **D**: Bahçecik; **E**: Dutluca). (Simplified and modified after MTA 2002)

3.4.1.2 Bursa Region Chromite Deposits

3.4.1.2.1 Orhaneli Sub-region

Chromitite formations in this area are largely located in Eskikızılelma, Çınarcık, Göktepe, Şeytanbudakköy, Çiviliçam, Ömeraltı, Letafet Village, Akçabük and Göynükbelen sectors. These sub-regions correspond to the zones lettered from A to I in Fig. 3.9.

The chromitite ore is generally observed in highly fractured/crushed serpentinized dunites. It can be seen in dunites, alternating with wherlite and pyroxenites as in Göktepe Sub-Region (Fig. 3.9C), but can also occurs in sheared serpentinite zones as massive, disseminated and banded zones like in the Şeytanbudakköy Sub-Region (Fig. 3.9D). There are pyroxenites and diabases around Ömeraltı Village (Fig. 3.9F). Harzburgites and dunites are partly/completely serpentinized in this region. Chromitite ores are sometimes located in cumulate dunite sections, including wherlite and clinopyroxenite layers (Fig. 3.9G–I). Also, ophiolitic rocks around the Dağgüney region display a mélange character (Fig. 3.9I).

Although Orhaneli Sub-Region is characterised mainly by disseminated ore, occurrences of several other types (massive, nodules) also exist and alternate with disseminated ore as banded layers. These ore-zones exhibit quite different

Table 3.1 General features of the chromitites in Balıkesir region

Region	Province/ophiolite	Sub-region/deposit name	Type[a]	Thickness/ length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region One (NW Anatolia)	Balıkesir/ Harmancık ophiolite	Karacabayır Tepe	Disseminated; partly massive banded	0.8–1.5/3–40	Hbj, Dn	15–25	Fig. 3.8a
		Adaören	Massive, disseminated, nodular	1–5/40–250	Hbj, Dn	30	Fig. 3.8b
		Akçaalan Sagir, Çamharmanı, Kuzköy, Çaltıcak	Brecciated, banded, disseminated	0.6–1.5/10–30	Hbj, Dn	25–40	Fig. 3.8c
		Boyalıca	Massive, lensoidal	10–90	Hbj, Dn	10–40	Fig. 3.8d
		Çatalçam	Massive banded, disseminated	1–20	Hbj, Dn	15–40	Fig. 3.8e

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite

thicknesses varying from few centimetres to tens of metres. The lengths of these deposits are usually quite short because they are cut by several faults and thrusts, but some deposits are up to 100 and 150 m in length. The average grade of the chromitite ore in Orhaneli Region is around 20 and 30 wt% Cr_2O_3, but can reach up to 50% Cr_2O_3 in massive and banded sections.

3.4.1.2.2 Harmancık Sub-Region

The chromite deposits and occurrences in the lower part of Harmancık (Bursa) are shown in Fig. 3.10 and their features are summarised in Table 3.2. All chromite deposits and occurrences in this sub-region are related to the harzburgite and dunite levels of the ophiolitic rocks, which are described as "Harmancık Peridotite Massif". These units are partly intruded by diabase dykes. According to Table 3.2, chromitite ores in this region have quite different shapes and dimensions, and include some large reserves. Since the nineteenth century it has included the most famous chromitite ore deposits in Turkey.

3.4.1.3 Kütahya Region

Kütahya province chromitite formations were mainly observed within the Tavşanlı (Dağardı) ophiolite. This ophiolite body has been described above and interpreted as the eastern extension of the Harmancık peridotite. There are no notable chromitite occurrence within Dağardı Melange (Fig. 3.11).

Chromite and magmatic bands in this section of the Dağardı Ophiolite are coherent and oriented NW – SE (Ortalan et al. 1984). The SW section of the ophiolite, east of Tavşanlı and E-SE of Çamalan Village in the north of Emet, is lateritic in character, and post-ophiolite-emplacement magmatism in the region had partly altered ophiolitic rocks through silicification and listwanitization. Chromite textures indicate a tectonic origin for this section of Tavşanlı Ophiolite (Ortalan et al. 1984).

In general, chromite mineralisation in this region has similarities with the Bursa-Harmancık region. Mineralization is usually banded and disseminated, but massive and nodular types are also present. Mineralized zones have variable thickness of between a few cm and a few meters and the Cr_2O_3 grade of ore varies between 20% and 45%. Mining activities in this region were by open pit and underground mining. General features of the chromitites in Kütahya Region are given in Table 3.3.

3.4.1.4 Eskişehir Region

Other ophiolites around the Dağküplü Ophiolite are related to the North Anatolian Ophiolite Belt. These rocks are emplaced as imbricated slices of ophiolitic mélange, mafic and ultramafic cumulates and tectonites (Fig. 3.12). Chromitite ores are

Table 3.2 General features of the chromitite deposits in Bursa region

Region	Province/ophiolite	Sub-region/ deposit name	Type[a]	Thickness/ length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region One (NW Anatolian regions)	Bursa/Orhaneli ophiolite	Eskikızılelma	Disseminated, nodular, banded	1–4/12–40	Dn	25–40	Fig. 3.9A
		Çınarcık	Banded	1.5–2/2–12	Dn	25–48	Fig. 3.9B
		Göktepe	Banded, nodular	3–5/10–120	Wh-Px-Dn	15–30	Fig. 3.9C
		Şeytanbudakköy	Massive, banded, disseminated	1–1.5/4–110	Dn	12–46	Fig. 3.9D
		Çiviliçam	Disseminated, partly massive banded	0.8–5/1–150	Wh-Px-Dn	20–50	Fig. 3.9E
		Ömeraltı	Disseminated, banded, nodular	1–8/5–50	Hbj-Dn	20–45	Fig. 3.9F
		Letafet	Disseminated, banded	1–12/10–300	Wh-Px-Dn	20–30	Fig. 3.9G
		Akçabük	Banded, disseminated, massive	0.5–3/1–100	Wh-Px-Dn	20–35	Fig. 3.9H
		Göynükbelen	Banded	1–3/1–100	Wh-Px-Dn	20–30	Fig. 3.9I
	Bursa/Harmancık Ophiolite	Piribeyler	Disseminated, banded, massive	0.1–2.0/7–250	Hbj-Dn	5–34	Fig. 3.10
		Akçasaz	Disseminated, massive, nodular, spotted	0.2–2.0/1.0–40	Hbj-Dn	20–40	Fig. 3.10B
		Delicegüney	Banded, disseminated, nodular	0.3–2.5/1.0–20	Hbj-Dn	10–35	Fig. 3.10C
		Kınık	Banded, disseminated, spotted, massive	0.1–4.0/1.0–15	Hbj-Dn	10–35	Fig. 3.10D
		Yakuplar	Massive, disseminated, spotted	0.1–2.0/5–500	Hbj-Dn	20–30	Fig. 3.10E
		Çakmak	Massive, disseminated, nodular	0.1–1.5/5–60	Hbj-Dn	20–30	Fig. 3.10F
		Çeki Köyü	Disseminated, massive, nodular	0.2–1.5/1–5	Hbj-Dn	30–40	Fig. 3.10G
		Harmancık	Disseminated, massive, nodular	2–10/20–30	Hbj-Dn	20–40	Fig. 3.10H
		Balatdanış	Disseminated, spotted, massive	0.2–4.0/10–85	Hbj-Dn	25–40	Fig. 3.10I
		Kocapınar-Kozluca	Massive, banded, disseminated	02–4.0/10–60	Hbj-Dn	15–30	Fig. 3.10J
		Eşen	Banded, disseminated, spotted, nodular	0.2–2.0/10–30	Hbj-Dn	20–45	Fig. 3.10K
		Fındıcak	Massive, spotted, disseminated	0.1–1.5/5–35	Hbj-Dn	30–40	Fig. 3.10L
		Gençel	Massive	0.1–0.3/1–5	Hbj-Dn	20–30	Fig. 3.10M

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite; Wh: Wehrlite; Px: Pyroxenite

Table 3.3 General features of chromite deposits in Kütahya region

Region	County/ophiolite name	Sub-region/ deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region One (NW Anatolian region)	Kütahya/Harmancık (Dağardı-Tavşanlı) ophiolite	Uluçam	Banded, disseminated	0.2–1.5/1–10	Hbj-Dn	20–30	Fig. 3.11A
		Madanlar	Banded, disseminated	0.3–3.0/1–80	Hbj-Dn	10–40	Fig. 3.11B
		Çamalan	Massive, banded, disseminated, spotted	0.1–1.5/1–70	Hbj-Dn	25–40	Fig. 3.11C
		Kargılı	Massive, disseminated, nodular	0.2–1.0/1–10	Hbj-Dn	30–45	Fig. 3.11D
		Dereli	Massive, disseminated	0.5–1.0/1–2	Hbj-Dn	20–40	Fig. 3.11E
		Nusretler	Massive, disseminated, spotted	0.1–0.7/1–10	Hbj-Dn	20–45	Fig. 3.11F
		Karakaya	Massive, nodular, disseminated	0.2–1.5/1–90	Hbj-Dn	40–50	Fig. 3.11G
		Elmalı	Banded, disseminated, nodular	0.2–2.0/1–20	Hbj-Dn	20–30	Fig. 3.11H
		Karsak	Banded, massive, disseminated, nodular	0.1–1.0/1–2	Hbj-Dn	30–35	Fig. 3.11I
		Tavşanlı	Massive, disseminated, nodular	0.2–0.8/1–12	Hbj-Dn	40–50	Fig. 3.11J
		Sobran	Massive, disseminated	0.1–1.2/1–16	Hbj-Dn	35–45	Fig. 3.11K
		Muhatboğaz	–	–	Hbj-Dn	–	Fig. 3.11L
	Dağardı Melange	Çukurören	Massive, disseminated	15 × 1 × 4	Hbj-Dn	45–50	Fig. 3.11M

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite

located within the harzburgitic and dunitic tectonites as well as within cumulate dunites. Ophiolites are strongly serpentinized and partly listwanitized in the region.

Chromite formations of Eskişehir are mostly located in Dağküplü, Sivrihisar-Karaburun, Dutluca and Kavak-Bahtiyar sub-regions (Fig. 3.12). Their general features are summarised in Table 3.4, in which it can be seen that no economically viable chromitite reserves exist in the region, except of the pipe shaped Kavak-Bahtiyar chromitite deposit. This deposit is one of the oldest chromitite mine in Turkey and operated since 1930s by Türk Maadin Company. According to the information given in the companies web-page, total production of chromitite ore (both massive and concentrated) is about 2.5 Mt and this is one of the deepest mine in the World (TMS 2017).

3.4.2 Region Two: North Anatolian (Çankırı, Çorum, Kastamonu, Sinop, Tokat and Yozgat) Ophiolites and Related Chromitite Deposits

3.4.2.1 Çankırı Region

3.4.2.1.1 Çankırı Ophiolites

Ophiolites around Çankırı and Çorum are examined under two names or labels in the literature. The first includes Eldivan Ophiolite Complex/Kargı Ophiolite Unit/Artova Ophiolite Complex (Özcan et al. 1980). The second is the Ahlat Ophiolitic Melange. The chromitite formations in the region are associated with peridotites of the Eldivan Ophiolite (Akın 1995). Akyürek et al. (1980) stated that the unit defined as Eldivan Ophiolite Complex, was emplaced as tectonic slices of oceanic crustal materials and upper mantle, separated by low angle overthrust planes (Hakyemez et al. 1986). The Complex consists of peridotite dunite, harzburgite and pyroxenite in the lower section; followed by oceanic crustal material consisting of gabbro, diabase dyke complex, pillow lava and pelagic sediment in the upper section (Akyürek 1981; Akın 1995). The internal structure of the Eldivan Ophiolite Complex is only partly known.

3.4.2.1.2 Çankırı Region Chromitites

Chromitite occurrences in Çankırı region are found in five areas: Eldivan Mountain, Çaparkayı, Sani Plateau, Yukarıöz Village and Gök Tepe sub-regions (Fig. 3.13). These occurrences are mostly in the eastern section of Eldivan County; a few are in the Northern sections of Korgun and Yapraklı Counties. General features of the chromitites in the Çankırı Region are given in Table 3.5.

Table 3.4 General features of the chromitite occurrences in Eskişehir region

Region	County/Ophiolite name	Sub-region/deposit name	Type[a]	Thickness/ Lenght (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region one (NW Anatolian regions)	Eskişehir/ Dağküplü Ophiolite	Dağküplü	Banded, disseminated, massive	0.1–3.0/0.5–5	Dn	20–30	Fig. 3.12-A
		Gündüzler-1	Massive, disseminated	0.5–4.0/2–50	Dn	20–40	Fig. 3.12-A
		Gündüzler-2	Banded, disseminated, massive	0.2–2.5/5–20	Dn	20–40	Fig. 3.12-A
		Gündüzler-3	Banded, disseminated	0.5–2.5/1–12	Dn	10–30	Fig. 3.12-A
		Sepetçi-1	Banded, disseminated, nodular, massive	0.5–2.5/10–50	Dn	30–40	Fig. 3.12-A
		Sepetçi-2	Banded, disseminated	0.2–2.5/5–60	Dn	20-40	Fig. 3.12-A
		Margı	Massive, disseminated	0.5–5.5/1–10	Dn	30-45	Fig. 3.12-A
		Taycılar-Başören	Banded, disseminated	0.2–2.0/10–50	Dn	20–35	Fig. 3.12-A
	Eskişehir/Sivrihisar-Karaburhan Ophiolite Nappe	Kavak-Bahtiyar	Massive, banded, disseminated	1.0–20/1–2.5	Dn	20–45	Fig. 3.12-B
		İmikler	Massive, banded	0.1–0.3/0.5–1.5	Hbj-Dn	30–45	Fig. 3.12-C
		Süleymaniye	Massive, banded	0.1–1.0/1–5	Hbj-Dn	30–45	Fig. 3.12-C
		Karaçam	Massive lens	0.2x0.25	Hbj-Dn	40–45	Fig. 3.12-C
		Okçu-Karaburhan	Banded, disseminated, Massive	0.1–1.0/1–40	Hbj-Dn	5–30	Fig. 3.12-C
		Bahçecik	Massive, banded	0.01–0.2/1–30	Hbj-Dn	30–40	Fig. 3.12-D
	Eskişehir/Dutluca Ophiolite	Aşağıkuzfındık	Banded, disseminated	0.3–1.5/5–15	Dn	30–45	Fig. 3.12-E
		Ballık	Massive, disseminated	0.1–0.5/1–5	Dn	30–40	Fig. 3.12-E
		Eski Sobran	Massive, disseminated	0.5–1.0/1–5	Dn	30–40	Fig. 3.12-E

[a]Starts from most abundant type; Hbj: Harzburgite; Dn: Dunite

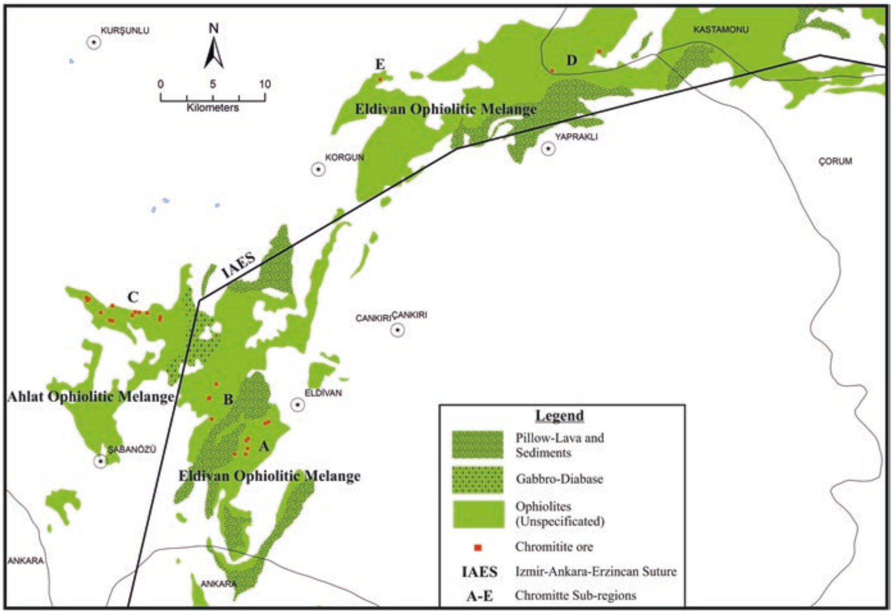


Fig. 3.13 Chromitite occurrences of Çankırı region and its sub-regions (A: Eldivan Dağı; B: Çaparkayı; C: Sani Yaylası; D: Yukarıöz Köyü; E: Göktepe). (Simplified and modified after MTA 2002)

3.4.2.2 Çorum Region

3.4.2.2.1 Çorum Region Chromitites

Chromitites of Çorum Region are observed within dunitic and harzburgitic mantle tectonites (Ortalan and Taşan 1997). These occurrences, except for the Morsümbül Stream deposit, crop out along a tectonic lineament about 25 km NW of Çorum province (Fig. 3.14, Table 3.5).

Sub-economic chromitite occurrences was exposed in open pits within serpentinized dunites and harzburgites, and included massive ore fragments, with high Cr_2O_3 grades.. Most chromite occurrences are in breccia zones along faults, and as veneers on fault walls.

3.4.2.3 Kastamonu and Sinop Regions

As chromitites in Kastamonu and Sinop regions are observed in the same ophiolite body they are both introduced in this section.

Table 3.5 General features of chromitites in Çankırı and Çorum regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Two (North Anatolian region)	Çankırı/Eldivan ophiolitic melange	Eldivan Mountain	Banded, disseminated, massive	0.01–0.4/1–3	Dn	30–40	Fig. 3.13A
	Çankırı/Ahlat ophiolitic melange	Çaparkayı	Disseminated, banded, massive	0.1–1.6/1–116	Dn	33–45	Fig. 3.13B
		Sani Yaylası	Disseminated, banded, massive	0.05–0.4 (zone)	Dn	5–25	Fig. 3.13C
		Yukarıöz	Massive	–	Dn	42	Fig. 3.13D
		Gök Tepe	Massive	0.5–1.0/1–5	Dn	45–52	Fig. 3.13E
	Çorum/Artova ophiolitic complex	Uçarlık Tepe	Massive[b]	–	Dn	42–48	Fig. 3.14A
		Güllük Dere	Massive[b]	–	Dn	30–35	Fig. 3.14B
		Göl Sırtı	Massive[b]	–	Dn	30–40	Fig. 3.14C
		Yavşanlı Tepe	Disseminated, banded[b]	–	Dn	40–48	Fig. 3.14D
		Derinseki	Disseminated[b]	–	Hbj-Dn	20–30	Fig. 3.14E
		Tekçam Tepe	Massive[b]	–	Hbj-Dn	42–45	Fig. 3.14F
		Morsümbül	Massive, lens shaped	0.2–0.5/0.5–1	Hbj-Dn	38–42	Fig. 3.14G

[a]From the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]No primary occurrence observed, chromitite rubbles in excavation

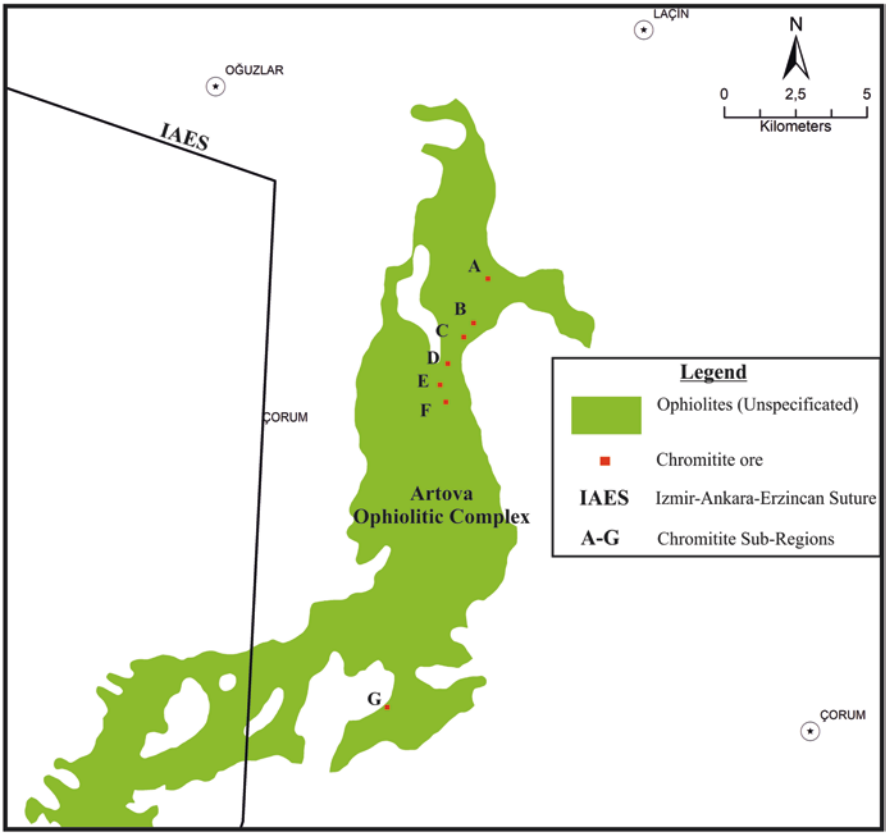


Fig. 3.14 Ophiolites and chromitite occurrences of Çorum region (A: Uçarlık Tepe; B: Güllük Dere; C: Göl Sırtı; D: Yavşanlı Tepe; E: Derinseki; F: Tekçam Tepe and G: Morsümbül Dere chromitite occurrences). (Simplified and modified after MTA 2002)

3.4.2.3.1 Kastamonu and Sinop Ophiolites

Ophiolitic rocks in the region mainly consists of eclogite-bearing ultramafics, peridotite, serpentinite, gabbro, diabase, basaltic lava, chert, radiolarite and mudstones. Although these rocks were defined under different names by several researchers, we will follow the "Elekdağ Meta-ophiolite" name used by Yılmaz and Tüysüz (1984).

According to Yılmaz and Tüysüz (1984), meta-ophiolites in Elekdağ have a "complete ophiolite section" along the long axis of the Elekdağ Mountain. Ultramafic rocks are seen in lower levels and pass upwards into layered peridotite. Serpentinite is the most common lithology and can be foliated along shear planes. Mesh texture is common in serpentinites hosting chromite mineralisation.

Peridotite and serpentinites are overlain by gabbro and diabases. Traces of high-pressure metamorphism are observed in many places within the diabases. At the highest levels, basaltic pillow lavas, mudstone and cherts are observed.

3.4.2.3.2 Kastamonu and Sinop Region Chromitites

Chromitite occurrences in this region are concentrated in meta-ophiolite that was called "Elekdağ Meta-ophiolite", and located mainly in Taşköprü territory (Fig. 3.15). The chromitite mineralisation occurs in ultramafic tectonites (harzburgite, dunite) and forms small bodies with little continuity and no economic potential. General features of the chromitites in Kastamonu and Sinop Regions are given in Table 3.6.

3.4.2.4 Tokat and Yozgat Regions

3.4.2.4.1 Tokat-Yozgat Ophiolites

Two different ophiolites were identified around Tokat and Yozgat. The first one consists of mafic and ultramafic rock slices within a Permo-Triassic metamorphic sequence. The Tokat Massif or Turhal Group, as known in the literature, can be correlated with the Kargı Ophiolite association exposed around Çorum. These rocks are named as "Artova Ophiolite Complex" (Aktimur et al. 1990). The other one is "Tekelidağ Complex" and "Refahiye Ophiolite" consisting of epi-ophiolitic sediments and oceanic crustal components that partly have a melange character, exposed in the southern part of Tokat (Yılmaz 1981, 1985; Aktimur 1986).

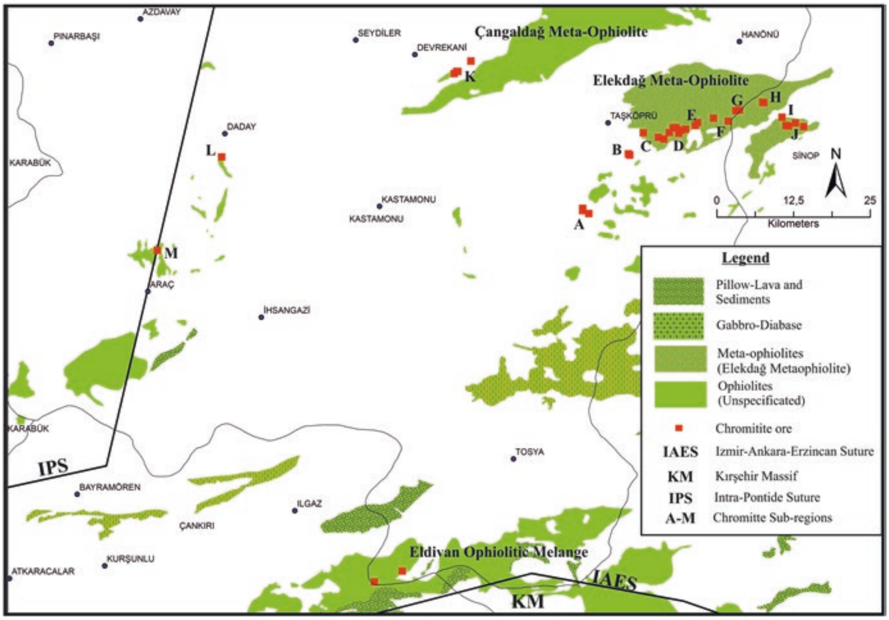


Fig. 3.15 Kastamonu (Elekdağ) chromitites and sub-regions (A: Olukbaşı; B: Belören; C: Çambaşı; D: Hacıali; E: Gündoğdu/Esentepe; F: Karapınar; G: Kovaçayır-Alıç; H: Kovaçayır-Türbe Tepe; I: Kovaçayır-Göçük Tepe; J: (Kovaçayır Alıç); K: (Örenbaşı); L: (Daday Hacıağa) ve M: (Araç Kavacık)). (Simplified and modified after MTA 2002)

Table 3.6 General features of chromitite occurences in Kastamonu-Sinop regions

Region	County/ Ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region two (North Anatolian Region)	Kastamonu/ Elekdağ Meta-Ophiolite	Çekiç	Massive	Small blocks	Hbj-Dn	38–48	Fig. 3.15-A
		Olukbaşı	Massive, nodular	0.2–1.5/1–20	Hbj-Dn	35–40	Fig. 3.15-B
		Belören-Bardakçı	Massive, disseminated, nodular	0.1–1.5	Hbj-Dn	35–40	Fig. 3.15-C
		Çambaşı	Massive, nodular	1.0–1.5	Hbj-Dn	40–45	Fig. 3.15-D
		Hacıali	Massive, nodular, lens shape	0.5x0.5	Hbj-Dn	40–45	Fig. 3.15-E
		Gündoğdu/ EsenHill	Nodular, massive, lens shape	0.5x0.5	Hbj-Dn	40–45	Fig. 3.15-F
		Karapınar River	Massive, nodular	0.2–0.5	Hbj-Dn	45–50	Fig. 3.15-G
	Sinop/Elekdağ Meta-Ophiolite	Kovaçayır-Göçük Hill	Massive, lens shape	0.05–0.1/10	Hbj-Dn	44–48	Fig. 3.15-H
		Kovaçayır-Türbe Hill	Massive, banded	0.05–0.1 (Massive band); 5–6 (zone)	Hbj-Dn	42–44	Fig. 3.15-I
		Kovaçayır-Alıç	Massive, banded	0.05-0.5	Hbj-Dn	40–44	Fig. 3.15-J
	Kastamonu/ Çangaldağ Meta-Ophiolite	Örenbaşı	Disseminated/massive banded	25 (zone)	Dn	38–40	Fig. 3.15-K
		Daday-Hacıağa	Massif blocks	0.1–0.2	Dn	42–44	Fig. 3.15-L
		Araç-Kavacık	Massif blocks	0.1–0.2	Dn	44–48	Fig. 3.15-M

[a]Starts from most abundant type; Hbj: Harzburgite; Dn: Dunite

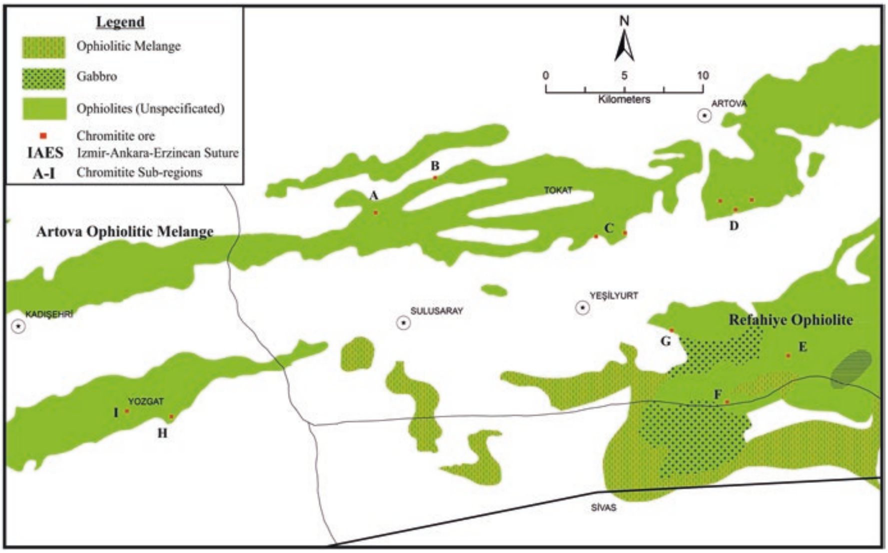


Fig. 3.16 Tokat and Yozgat chromitites (A: Arpacıkaraçay; B: Eşmebaşı; C: Doğlacık-Yağmur; D: Artova-Kazbayırdere-Demirci; E: Yamaç; F: Ağılın Tepe; G: Artova Tepe; H: Bozsırt; I: Deveçıkmazı). (Simplified and modified after MTA 2002)

3.4.2.4.2 Tokat and Yozgat Regions Chromitites

Some of the chromitite ores are located in the Artova Ophiolitic Melange, whilst others are in the Refahiye Ophiolite (Fig. 3.16). Key features of these deposits are summarised in Table 3.7. Around Arpacıkaraçay Village (A), Eşmebaşı Steam and Çukurtepe (B), and close to Doğlacık and Yağmur Village (C), occurrences of banded and disseminated chromite mineralization of no economic importance were observed.

3.4.3 Region Three: NE Anatolian (Sivas, Bayburt, Erzincan, and Erzurum) Ophiolites and Related Chromitite Deposits

3.4.3.1 Sivas Region

3.4.3.1.1 Sivas Ophiolites

Ophiolitic rocks are exposed in three different areas around the Sivas province. These ophiolite sequences include different oceanic crustal components and cover sediments, and they are partly melange in character. In the literature, they are known

Table 3.7 General features of chromitite occurrences in Tokat and Yozgat regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Two (North Anatolian region)	Yozgat/Artova ophiolite	Deveçıkmazı	Massive, disseminated	0.5–1.0/2–8	Dn	40	Fig. 3.16I
		Bozsırt	Massive, disseminated	0.3–0.5/0.6–1.0	Dn	35–40	Fig. 3.16H
		Arpacıkaraçay	Banded, disseminated	–	Dn	–	Fig. 3.16A
		Eşmebaşı	Banded, disseminated	0.05–0.1/2 (zone)	Dn	45	Fig. 3.16B
		Doğlacık-Yağmur	Massive, disseminated	0.01–0.02/0.5–1.0	Dn	45	Fig. 3.16C
		Artova	Massive lenses	0.05–0.2/10–75	Dn	48	Fig. 3.16D
	Tokat/Refahiye ophiolite	Yamaç	Disseminated, spotted	0.5–1.0/1–5	Dn	30–35	Fig. 3.16E
		Ağın Tepe	Massive lenses	0.1–0.9	Dn	35–40	Fig. 3.16F
		Artova Tepe	Disseminated, massive	1–5/10–650	Dn	5–48	Fig. 3.16G

[a]Starts from the most abundant type; Dn: Dunite

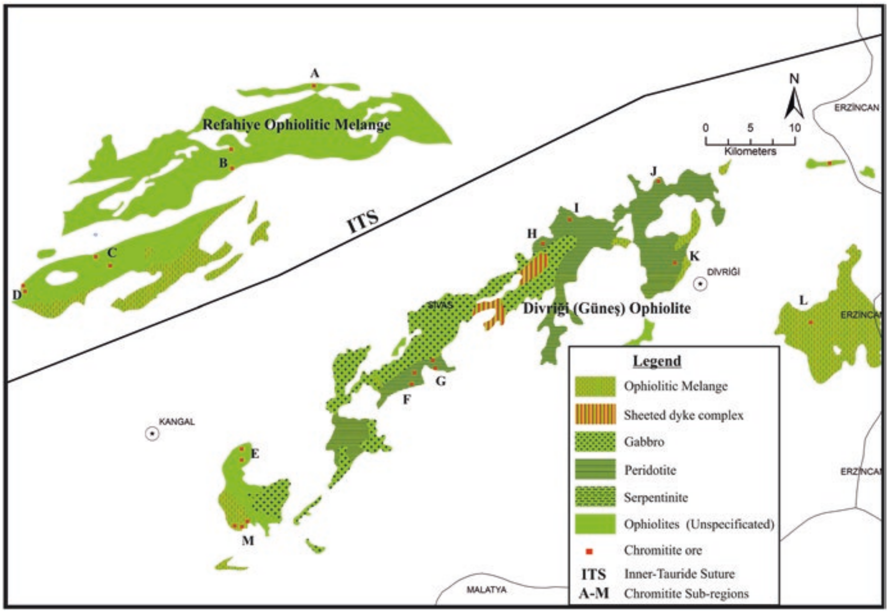


Fig. 3.17 Chromitite occurrences of Divriği and Kangal (Sivas) regions (A: Gürgen Ağılı; B:Gülkanat; C: Sivritaştepe; D: Başçayır; E: Ortadağ; F: Bostan Dere; G: Çamlıburun; H: Galin; I: Karakuz; J: Kayabaşı; K: Karatepe; L: Asmalı Dere). (Simplified and modified after MTA 2002)

as "Refahiye Ophiolite" that occur along the İzmir-Erzincan suture zone and were emplaced in the Late Cretaceous (Yılmaz 1985; Aktimur 1986, Aktimur et al. 1988) (Fig. 3.17). But the ophiolitic rocks cropping out in the north part of Kangal and west part of Divriği, are called "Divriği (Güneş) Ophiolite", and are interpreted as products of the Inner Tauride Ocean (Bayhan 1980).

3.4.3.1.2 Sivas Region Chromitites

Numerous chromite occurrences in ophiolites of Sivas province were derived from both the Ankara-Erzincan Ocean and the Inner Tauride Ocean. Chromitite occurrences in the north have a genetic link with the Erzincan region ophiolites and are explained together with occurrences in Erzincan province. Whereas the chromite occurrences observed in the south, around Kangal and Divriği regions, as shown in Fig. 3.17, occur in disseminated and massive forms hosted in dunites. These chromitites are partly hosted in Refahiye Ophiolite and partly in Divriği Ophiolite, and are summarised in Table 3.8.

Table 3.8 General features of chromitite occurrences in Sivas region

Region	County/Ophiolite name	Sub-Region/ Deposit name	Type[a]	Thickness/Lenght (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region three (NE Anatolian Region)	Sivas/ Refahiye Ophiolite	Gürgen Ağılı	Massif lensler	0.01–2.5/1–5	Hbj-Dn	40–48	Fig. 3.17-A
		Gülkanat	Banded, Massive	2–8 (zone)/40–70	Hbj-Dn	30–40	Fig. 3.17-B
		Sivritaş Tepe	Banded, disseminated	0.1–1.0/1–17	Hbj-Dn	30–40	Fig. 3.17-C
		Başçayır	Banded	0.05–0.5/20–30	Hbj-Dn	15–20	Fig. 3.17-D
	Sivas/Divriği Ophiolite	Ortadağ	banded	0.01–0.1/4–5(zone)	Dn	5–10	Fig. 3.17-E
		Bostan Dere	Disseminated, banded	2–5/60–70	Dn	20–30	Fig. 3.17-F
		Çamlıburun	Disseminated, banded	0.8–1.0/10–50	Dn	1*–30	Fig. 3.17-G
		Galin	Massive, disseminated, banded	2–10 (zone)	Dn	35–48	Fig. 3.17-H
		Karakuz	Disseminated, massive lensler	0.2–0.4/5–10	Dn	25–30	Fig. 3.17-I
		Kayabaşı	Disseminated, massive	0.5–2.5 (zone)/10–50	Dn	20–30	Fig. 3.17-J
		Kara Tepe	Massive banded	0.1–0.3 (zone)/20–100	Dn	40–45	Fig. 3.17-K
		Asmalıdere	Disseminated, massive banded	0.1–1.5/1–5	Dn	38–50	Fig. 3.17-L
		Seçenyurdu	Disseminated, massive banded	2.5–6.0/0.5–0.8	Hbj-Dn	25–30	Fig. 3.17-M

[a]Starts from most abundant type; Hbj: Harzburgite; Dn: Dunite

3.4.3.2 Erzincan Region

The Erzincan Region is located on the Eurasian plate (Pontides) and Anatolian plate suture zone, along the "İzmir-Ankara-Erzincan Suture Zone" that was defined by Brinkmann (1966, 1968). The ophiolitic rocks along this suture zone are named as Refahiye Ophiolite and the defining unit (Refahiye Ophiolitic Complex, Yılmaz 1985) is exposed in the north of Erzincan and continues toward Mercan, Tercan and Çayırlı territories (Özen et al. 2008).

From its beginning north-northeast of Erzincan, along the Keşiş Mountains that extend eastward, the ophiolitic sequence consists of mantle tectonites (harzburgite and dunite), ultramafic to mafic cumulates (wherlite, dunite, pyroxenite, gabbro), isotropic gabbro, and sheeted dyke complex (Özen et al. 2008).

3.4.3.2.1 Erzincan Region Chromitites

There are numerous chromitite mines, quarries, open pits and outcrops of various size in Erzincan region (Fig. 3.18). These and some other occurrences to the NE of Sivas, that share the same features, are summarised below.

Ores in the Erzincan region (Fig. 3.18) are banded and lens shaped, and have mineralization styles of massive, spotted, disseminated and nodular type. The contacts between ore bands and lenses and wall rock dunite are generally primary, but structural in some cases. The chromitite bands and lenses are either primary or

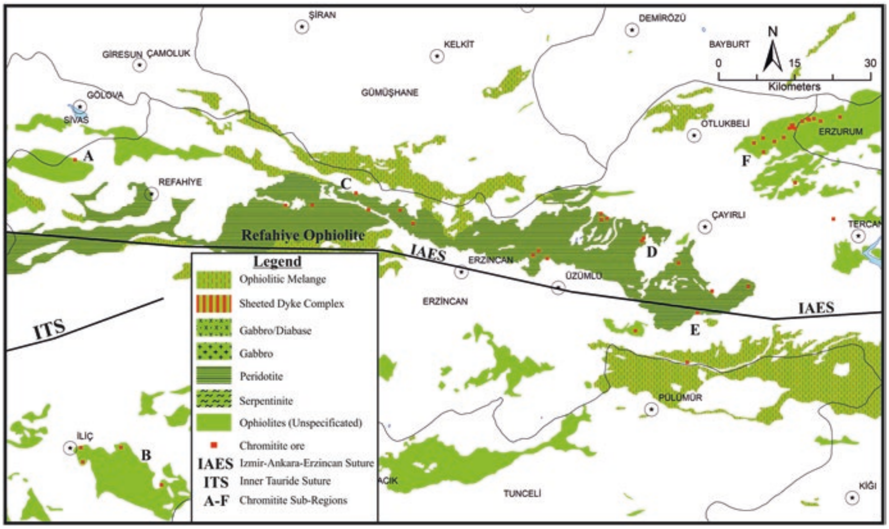


Fig. 3.18 Chromitite occurrences and sub-regions of Erzincan region (A: Refahiye; B: İliç-Kemah; C: NW of Erzincan; D: Üzümlü-Çayırlı; E: Pülümür; F: Otlukbeli-Tercan). (Simplified and modified after MTA 2002)

structural, and usually conformable with the internal structure of the peridotites. Mineralization in cumulate dunites is generally low grade (10–30% Cr_2O_3), whereas mineralization in tectonite dunites have relatively higher Cr_2O_3 grade (42–48% and above). In terms of their chemical components, they have good metallurgical characteristics (Cr/Fe ratios are high).

Chromitites in Erzincan region can be grouped in six sub-regions. These are Refahiye, İliç-Kemah, NW of Erzincan, Üzümlü-Çayırlı, Pülümür and Otlukbeli-Tercan (Fig. 3.18). The general features of these chromitites are given in Table 3.9.

3.4.3.3 Erzurum and Bayburt Regions

These are located to the east of Erzincan and its border region (Fig. 3.19). Ophiolite sequences are located in Horasan and Narman regions, north and east of Tekman and outside of the Refahiye Ophiolite Complex exposures that line up to North of Aşkale in the west of the province. Ophiolitic rocks that lie between Tekman and Pasinler were defined as "Şahvelet Ophiolite". This ophiolite sequence, from bottom to top, consists of ophiolite melange, tectonites and cumulates (Özen et al. 2008).

Ophiolite melange at the bottom is characterised by podiform chromite mineralization within harzburgites, and dunites to a lesser extent. The tectonites consist mainly of dunites and harzburgites intruded by doleritic dykes. The cumulate sequence consists mainly of gabbros, and dunite with relatively lesser amounts of wherlite and clinopyroxenite. Moreover, the ophiolitic mélange unit also contains tectonites and cumulates around Karayazı region. The cumulate rocks in the region are characterised by dunite, wherlite, clinopyroxenite and gabbro alternations. The tectonites comprise harzburgite and dunites. The chromitite quarries, open pits and outcrops in this region occur in tectonite or tectonite-cumulate transition zones, but do not have economic potential when compared to chromite mineralisations between Pasinler and Tekman regions.

There is an ophiolitic melange at the base of the ultramafic rocks in Horasan region (Çolakoğlu et al. 2014). Above this melange, spilitic basalts with cover sediments come onto the cumulate section. Two different mélange units, namely Örükyayla and Gezenek Melanges, are observed in Kırdağ (Oltu-Erzurum) region and in successions overlain by ophiolitic units from bottom to top: cumulates, isotropic gabbros and epi-ophiolitic sediments with pillow lavas in the upper part.

3.4.3.3.1 Erzurum Region Chromitites

Ophiolites of Erzurum region are exposed mainly in four regions (Fig. 3.19), and seven groups have been recognised. A small part of ophiolites to the NW of Aşkale are located in the Bayburt province border and the "Kopdağ Chromitites" is one of the most important chromitite mines of Turkey. These occurrences are interpreted as part of the Refahiye ophiolite.

Table 3.9 General Features of chromitites in Erzincan region

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Three (NE Anatolian region)	Erzincan/Refahiye ophiolite	Refahiye-Mağara Tepe	Disseminated, banded	0.2–0.5/1–2	Dn	30 (zone)	Fig. 3.18A
		Kemah-İliç	Massive, banded, disseminated	0.3–0.5/2–5	Dn	20–45	Fig. 3.18B
		NW-Erzincan	Massive, disseminated	0.3–0.5/1–5	Dn	40–45	Fig. 3.18C
		Üzümlü-Çayırlı[b]	Massive, disseminated	5–12/90–350	Dn	45–55	Fig. 3.18D
		Pülümür	Massive (brecciated)	0.04–0.15/1–15	Dn	55–18	Fig. 3.18E
		Otlukbeli-Tercan[b]	Massive	1–10/20–60	Dn	35–45	Fig. 3.18F

[a]Starts from the most abundant type; Dn: Dunite
[b]The most important chromite deposits of Turkey

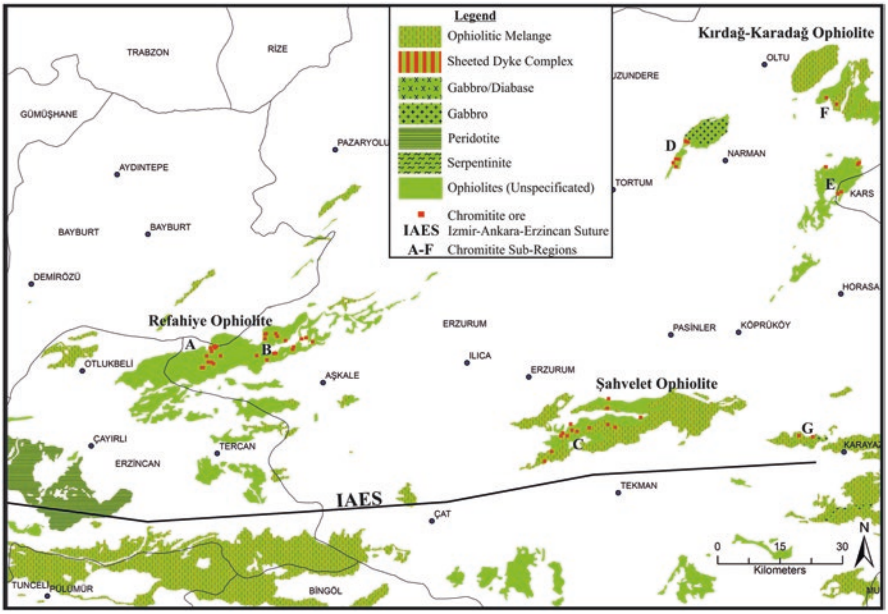


Fig. 3.19 Ophiolites, chromitite occurrences and sub-regions of Erzurum region (A: Kopdağ; B: Aşkale; C: Tekman; D: Narman; E: Horasan; F: Şenkaya; G: Karayazı). (Simplified and modified after MTA 2002)

The second group of chromitites, close to the Kopdağ Deposit, is situated in the Erzurum province borders. These are known as "*Aşkale West Chromitites*". They outcrop in an E–W trending belt. The Şahvelet Ophiolite, between the center of Erzurum province and Tekman, are considered as the third group under the name of "Tekman Chromitites". On the other hand, the chromite occurrences hosted in dunitic-harzburgitic mantle west of Narman are the fourth sub-group: the "Narman Chromitites". The fifth group was defined as "Horasan Chromitites"; the sixth group was defined as "Şenkaya Chromitites"; the seventh group was defined under "Karayazı Chromitites" in the west of Karayazı close to SE border of province. General features of the chromitites in Erzurum and Bayburt Regions are given in Table 3.10.

3.4.4 Region Four: SW Anatolia (Muğla, Denizli, Burdur, Isparta, Konya, and Antalya) Ophiolites and Related Chromitite Deposits

3.4.4.1 Muğla, Denizli and Burdur Regions

The Muğla region is located in SW Anatolia (Figs. 3.1 and 3.7). This region is at the south of the Menderes Massif and it is widely covered by metamorphic and oceanic crustal rocks.

Table 3.10 General features of chromitites between Erzurum ve Bayburt regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Three (NE Anatolian region)	Erzurum/Refahiye ophiolite	Kopdağ[b]	Disseminated, banded	1–4/1000 (zone)	Dn	20–40	Fig. 3.19A
		Aşkale-West	Disseminated, banded	1–3/10–70	Dn	30–40	Fig. 3.19B
	Erzurum/Şahvelet ophiolite	Tekman	Massive lenses	0.3 × 0.6/1–2	Hbj-Dn	40–50	Fig. 3.19C
		Narman	Massive, lenses, boulders	0.1 × 0.3/0.5–1.0	Hbj-Dn	40–50	Fig. 3.19D
		Horasan	Massive, lenses, boulders	0.2 × 0.4/0.5–1.0	Hbj-Dn	40–50	Fig. 3.19E
		Şenkaya	Massive and banded	0.2–1.0/5–50	Hbj-Dn	20–30	Fig. 3.19F
		Karayazı	Massive	0.2–0.5/3–5	Hbj-Dn	30–45	Fig. 3.19G

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]One of the important deposits of Turkey

3.4.4.1.1 Muğla-Denizli-Burdur Region Ophiolites

The distribution of ophiolitic rocks from Muğla to Burdur through Denizli, are shown on Figs. 3.1 and 3.20. Ophiolites in this area were defined as "Marmaris Ophiolite Nappe" (Şenel 1997a) and "Likya Ophiolite" (Şenel 2004). Their thicknesses are more than 2 km, and spread over a 45,000 km^2 area (Collins and Robertson 1997, 1998). Ophiolite units consist of serpentinized harzburgite, and lesser pyroxenite, podiform chromite and gabbro cutting by altered diabase dykes at different structural levels.

The Menderes Massif consists mainly of tectonite peridotites with the plutonic section completely eroded. Harzburgite is the most common rock type. Massive harzburgites exhibit foliation patterns on higher levels (Erendil 2002). Banding is defined by harzburgite-dunite or harzburgite-orthopyroxenite alternations. Banding planes are almost horizontal and it may indicate that the ophiolite nappe is close to the horizontal position.

The tectonites of Marmaris ophiolites are cut by isolated diabase and gabbroic dykes compared to the Yeşilova Ophiolite in NE areas. From the character of these isolated dykes, it was suggested that deeper sections of mantle are exposed in the massif (Reuber et al. 1984). The mantle peridotites are underlain by subophiolitic metamorphic rocks.

In the Denizli and Burdur Regions, ophiolitic rock groups are classified as Marmaris Ophiolite in the West and Yeşilova Ophiolite in the east, with the former discussed above. The general characteristics of the Yeşilova Ophiolite are as follows, the serpentinized ophiolitic rocks rich in chromite mineralization are located along the Çavdır-Tefenni-Yeşilova line. The ophiolites in this area are defined as

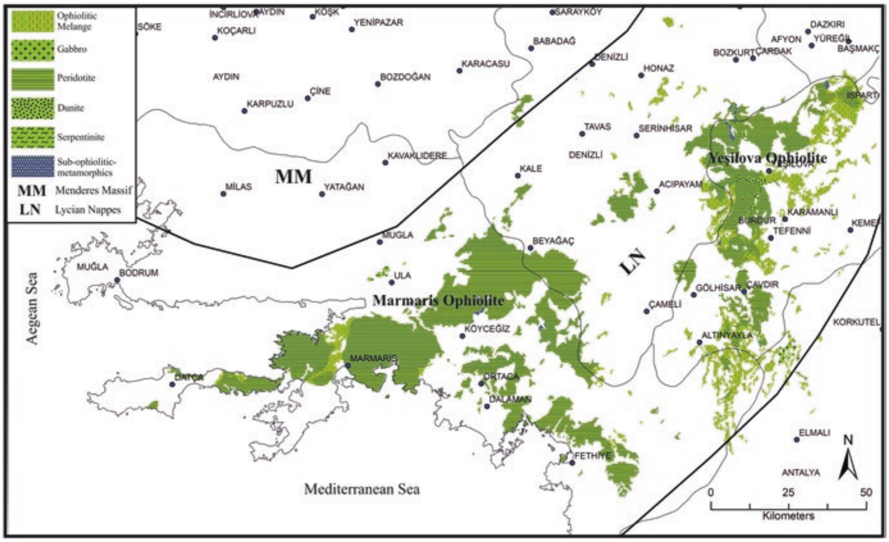


Fig. 3.20 Distribution of SW Anatolian Ophiolites (Marmaris and Yeşilova). (Simplified and modified after MTA 2002)

"Marmaris Ophiolite Nappe" (Şenel 1997a) and "Likya Ophiolite" (Şenel 2004). The ophiolites that outcrop around Çavdır-Tefenni-Yeşilova were firstly defined as "Yeşilova Ophiolite" by Sarp (1976). Rock units within the ophiolitic sequence in Yeşilova region from bottom to top consist of tectonites, cumulates, dyke rocks and volcanic rocks (Döyen 1995). The tectonites are represented mainly by harzburgites and dunites. The chromites are enveloped by dunites. In mantle tectonites, beside harzburgite, lherzolite and wherlite are also observed (Döyen 1995).

Cumulate sections of Yeşilova Ophiolite, crop out in south and western part of Yeşilova Village. Dykes are generally represented by diabase. It is suggested that these isolated dykes cutting the Yeşilova opholites, can be interpreted as big dykes in tectonites (Reuber et al. 1984). The sheeted dyke complex could not be observed, instead mafic sills and basaltic volcanics were discovered by Koralay (2000).

3.4.4.1.2 Muğla Chromitites

Chromitites in the Muğla region are found in the Marmaris Ophiolite. Although these occurrences are less common in the Marmaris sub-region, there are numerous chromite quarries in the Köyceğiz, Dalaman and Fethiye areas, where significant Cr production has been recorded (Fig. 3.21). A number of quarries and open pits contain these chromites in Nergislidüz, Kazandere, Ilıkdere-Suçıktı, Sülek, Andızlık-Meşebükü-Erengediği, Dalaman-Ortaca and east of Fethiye (Fig. 3.21). The main features of these chromitite deposits are briefly explained in Table 3.11. Although this region is one of the major chromitite mining areas in Turkey, these deposits were almost mined out at shallow depths at the beginning of the twentieth century.

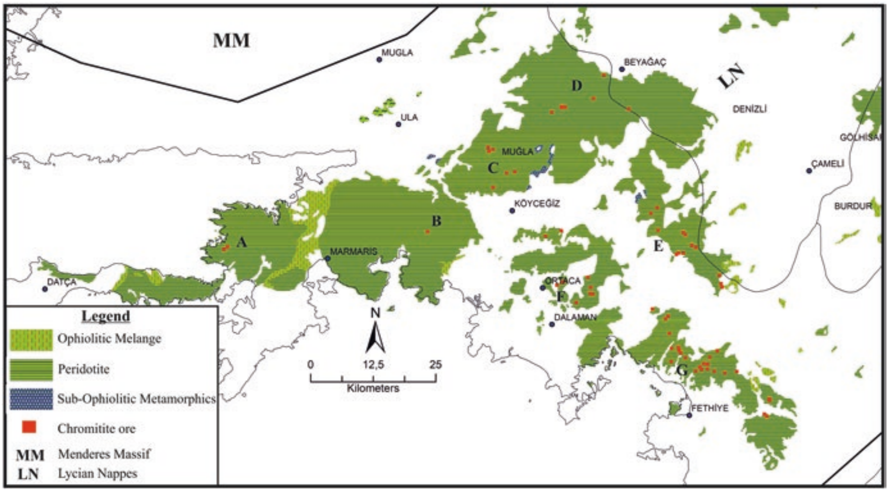


Fig. 3.21 Chromitite occurrences and sub-regions of Muğla region (A: Nergislidüz; B: Kazandere; C: Ilıkdere-Suçıktı; D: Akçaalan-Sülek; E: Andızlık-Meşebükü; F: Dalaman-Ortaca; G: Fethiye). (Simplified and modified after MTA 2002)

Table 3.11 General features of chromitite occurrences in Muğla, Denizli and Burdur regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Four (SW Anatolian region)	Muğla/Marmaris ophiolite	Nergislidüz	Massive, nodular, lensoidal	1–5.5/5–25	Dn	30–45	Fig. 3.21A
		Kazandere	Massive, nodular, lensoidal	1–4/10–20	Dn	30–40	Fig. 3.21B
		Ilıkdere-Suçıktı	Banded, disseminated, massive	0.01–05/20–100	Dn	30–50	Fig. 3.21C
		Akçaalan-Sülek	Massive, lensoidal	0.1–0.3/1–5	Dn	40–50	Fig. 3.21D
		Andızlık-Meşebükü	Massive, lens/ boulder shaped	1–2/10–100	Dn	30–40	Fig. 3.21E
		Dalaman-Ortaca	Massive, lens	0.1–0.8/10–100	Dn	35–45	Fig. 3.21F
		Fethiye[b]	Massive, nodular	0.3–7.0	Dn	40–50	Fig. 3.21G
	Denizli/Marmaris ophiolite	Efekli	Massive, nodular, disseminated	0.5–1.5/5–15	Dn	35–45	Fig. 3.22A
		Topuklu	Massive banded	2 (zone)/5–25	Hbj-Dn	15–35	Fig. 3.22B
		Karanfil	Massive, disseminated, lens	1–8/10–60	Dn	30–40	Fig. 3.22C
		Çatak	Nodular, massive, disseminated	1–7/1000 (zone)	Dn	35–45	Fig. 3.22D
		Horozköy	Disseminated, massive banded	0.1–0.8/1–5	Dn	30–40	Fig. 3.22E
	Burdur/Yeşilova ophiolite	Gölhisar	Massive, banded	0.5–0.7/10–25	Dn	20–40	Fig. 3.23A
		Çavdır	Massive, nodular	0.1–0.6/1–3	Dn	30–45	Fig. 3.23B
		Tefenni	Banded, massive	0.1–0.4/1–4	Dn	30–45	Fig. 3.23C
		SW of Yeşilova	Banded, disseminated, leopar patterned	0.15–1.0/1–6	Dn	35–50	Fig. 3.23D
		West of Yeşilova	Disseminated, banded, massive, lensoidal	0.1–0.3/1–10	Dn	20–40-55	Fig. 3.23E
		NW of Yeşilova	Massive, disseminated	0.1–0.6/1–35	Dn	20–45	Fig. 3.23F
		N and NE of Yeşilova	Massive, banded	0.05–0.3/1–25	Dn	30–42	Fig. 3.23G

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]An important deposit in Turkey

This area was taken into consideration because of its economic potential and currently new exploration continues in deeper sections of the ancient ore deposits by using new methods and production technologies.

3.4.4.1.3 Denizli Chromitites

Chromitites in Denizli Region, as in the Muğla Region, are located within mantle tectonites, along the harzburgite-dunite level of Marmaris Ophiolite (Fig. 3.22). The chromite occurrences are mainly situated in the west and east sections of Beyağaç and Acıpayam. These occurrences are briefly introduced below (Fig. 3.22). The main Sub-Regions of the Denizli Region are Efekli, Topuklu, Karanfil, Çatak and Horozköy and the main features of chromitite deposits are briefly explained in Table 3.11. This region is much less active in terms of chromitite mining compared to the Muğla Region.

3.4.4.1.4 Burdur Region Chromitites

Distribution of ophiolitic rocks and chromitite deposits in Burdur region is shown in Figs. 3.21 and 3.23, respectively.

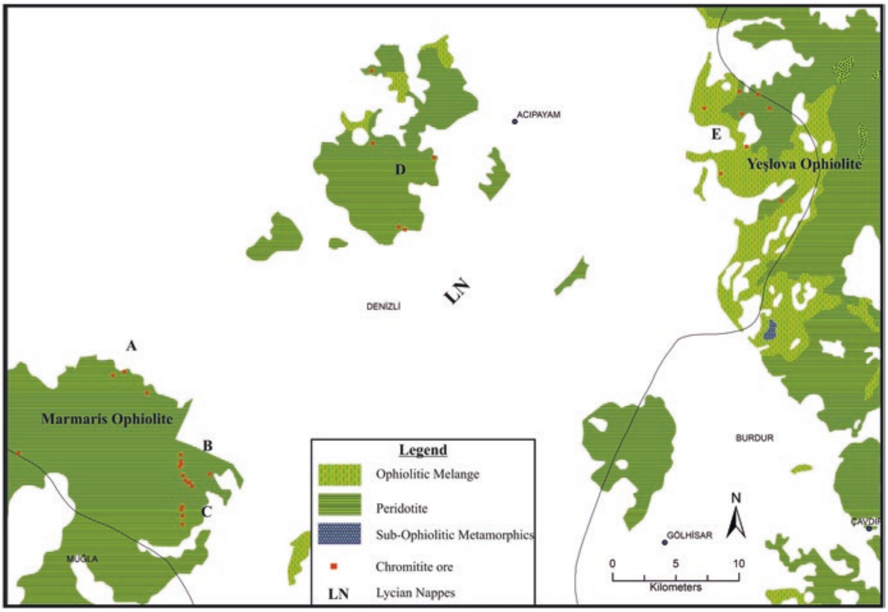


Fig. 3.22 Chromitite occurrences and sub-regions of Denizli region (A: Efekli; B: Topuklu; C: Karanfil; D: Çatak ve E: Horozköy). (Simplified and modified after MTA 2002)

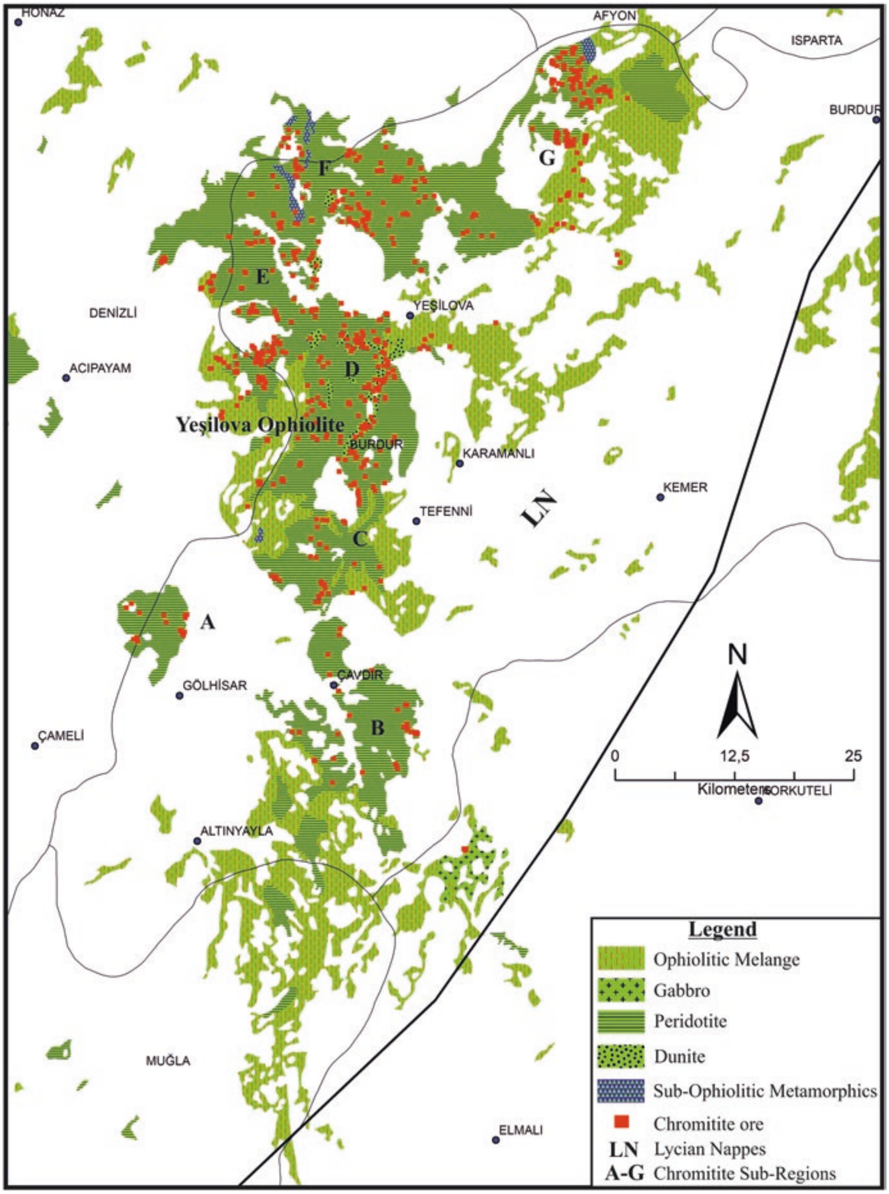


Fig. 3.23 Chromitite occurrences and sub-regions of Burdur region (A: Gölhisar; B: Çavdır; C: Tefenni; D: SW Yeşilova; E: Western of Yeşilova; F: NW of Yeşilova KB, and G: N and NE of Yeşilova). (Simplified and modified after MTA 2002)

The first chromitite prospecting in the region was done by Alpay (1951) around Salda, Horozköy, Bahtiyar and Işıklar Village of Yeşilova district. This was followed by large scale studies of Borchert (1960, 1962) and Denkel (1972). The chromite occurrences were studied in detail by Sarıkaya and Seyrek (1976) and Yıldız et al. (1976). Boyalı (1996) studied some occurrences in the north of Salda Lake, Antalya and Isparta provinces. Renewed studies were carried out by MTA (Mineral Research and Exploration Institute) in 1991, and the findings from these studies are reported here. It can be concluded that the ophiolites in the eastern section of the province are generally mélange in character and not related with chromitite occurrences (Fig. 3.23). The ophiolites which are important in terms of chromitites are serpentinized peridotites that belong to Marmaris Ophiolite along the Çavdır-Tefenni-Yeşilova line. Chromitite deposits in this region are significantly different in type and size (Fig. 3.23).

Chromite deposits in the Burdur region can be divided into six sub-regions. In each sub-region, features of a few representative and important deposits are given in Table 3.11. Chromitite mining has been stopped for a long time in the Burdur and Denizli Regions, but is still active in the Muğla Region.

3.4.4.2 Isparta-Konya-Antalya Regions

3.4.4.2.1 Isparta-Konya-Antalya Ophiolites

Isparta ophiolites generally consist of ophiolitic melange and peridotite bodies. The ophiolites from SE to NW reach the Sütçüler district, eventually ending to the S in the Serik (Antalya) district. These are parts of ophiolitic imbricates related to Antalya Nappes (Fig. 3.24).

Peridotites exposed within the Isparta province, contain chromitites in the western part of Aksu district and of Şarkikaraağaç. The peridotites are accepted as a part of Beyşehir-Hoyran nappes that outcrop around Beyşehir (Konya) towards the SE of the Province. These ophiolite piles are part of the nappe beneath the Beyşehir nappes (Mackintosh and Robertson 2009). This structural imbrication is consistent with the nappe tectonics of the Taurides (Fig. 3.24).

To the southeast of Beyşehir Lake, metamorphic sole and ophiolitic rocks were observed. The mélange unit is mostly seen in the eastern part of the Middle Taurus Mountains (Özgül 1997). Also in this region, Mesozoic Taurus platform carbonates are tectonically overlain by the Late Cretaceous mélange unit. The melange unit comprises serpentinite blocks, basalt, chert and pelagic sediments. Regionally, the Beyşehir-Hoyran ophiolite nappe was obducted towards the south over the Taurus carbonate platform in Late Cretaceous. Later on, in the Late Eocene period, the ophiolitic rocks and the Mesozoic carbonate platform thrust southward due to closing of the suture (Andres and Robertson 2002; Mackintosh and Robertson 2009).

In Antalya nappes, a number of ophiolitic melange slices of different size are present. The melange unit within the Antalya nappes generally consists of serpentinites. Within the mélange unit, large blocks derived from harzburgite, dunite,

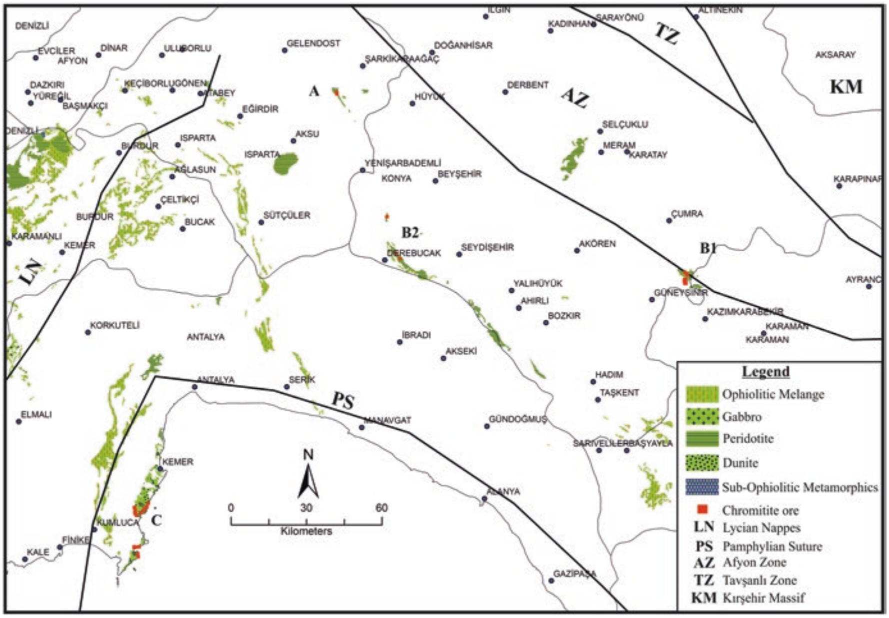


Fig. 3.24 Isparta-Konya-Antalya ophiolites and locations of chromitite occurrences. (Simplified and modified after MTA 2002)

wherlite, gabbro, amphibolite are also present (Şenel 1997b). Late Cretaceous Tekirova (Antalya) ophiolite is one of the largest nappes in Antalya of the Western Taurus and is represented by, from bottom to top, harzburgitic tectonites, ultramafic-mafic cumulates, isotropic gabbros and sheeted dyke complex (Bağcı 2004). In Tekirova (Antalya) ophiolite, volcanic complex was not preserved and rocks which belong to the metamorphic sole are seen as tectonic slices within the tectonites (harzburgite). A number of isolated dykes, and rarely pegmatitic gabbro dykes, cut the whole ophiolitic section (Fig. 3.25, Bağcı 2004).

3.4.4.2.2 Isparta Region Chromitites

Chromite deposits and occurrences in the Isparta province are shown in Fig. 3.24A. Peridotite bodies are located around Sipahiler-Yuvalı-Bağıllı-Kocular in the south; around Belceğiz-Yenicekale-Salur-Çeltek and Yaniköy areas in the east; and around Atabey-Kapıcak-Barla areas in the west. General characteristics of chromite occurrences are summarized in Table 3.12. These chromitites have no economic importance in the Turkish chromite mining sector.

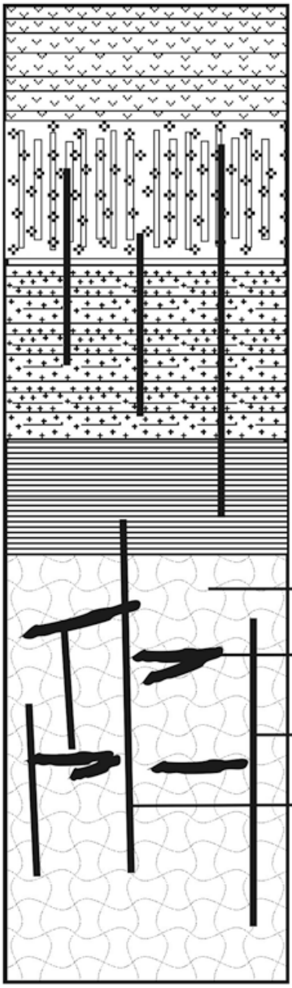


Fig. 3.25 Tectono-stratigraphic column of Antalya (Tekirova) ophiolites. (Revised after Bağcı et al. 2006)

3.4.4.2.3 Konya Region Chromitites

In the Konya region, chromite occurrences are found in two districts. The first is situated to the south of Çumra district (Fig. 3.24B1) and the second is located to the west of Seydişehir district (Fig. 3.24B2). Details of these deposits are summarized in Table 3.12. These chromitites also have no economic importance in the Turkish chromite mining sector.

Table 3.12 General features of chromitite occurrences in Isparta, Konya and Antalya regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Four (SW Anatolian region)	Isparta/Antalya Nappes (Tekirova ophiolite)	Şarkikaraağaç Belceğiz-1	Spotted, massive, banded	0.4–0.6/1–5	Dn	40–50	Fig. 3.24A
		Şarkikaraağaç Belceğiz-2	Disseminated, nodular, massive banded	0.2–0.3/1–4	Dn	20–30	Fig. 3.24A
	Konya/Antalya Nappes (Tekirova ophiolite)	B1 (Eren Tepe, Tekke Tepe)	Disseminated, massive	0.05–0.5/1–10	Dn	20–48	Fig. 3.24B1
		B2 -Dedecik Tepe)	Disseminated, nodular, massive	0.1–0.7/10–70	Hbj-Dn	25–42	Fig. 3.24B2
		B2-Bayıroluk Tepe	Massive	0.1–0.7	Dn	42–48	Fig. 3.24B2
		B2-Tekke Tepe	Disseminated, massive	0.1–1.0/1–7	Dn	20–40	Fig. 3.24B2
	Antalya/Antalya Nappes (Tekirova ophiolite)	Atbükü-Tatlısu Bay	Disseminated, spotted, massive	0.2–1.0/10–30	Hbj-Dn	15–35	Fig. 3.24C
		Atbükü-Yanartaş	Massive banded	0.1–0.7	Hbj-Dn	40–48	Fig. 3.24C
		Atbükü-Atbükü Bay	Disseminated, massive banded	0.5–0.7	Hbj-Dn	30–35	Fig. 3.24C
		Kumluca-Adrasan Bay	Massive, disseminated, banded	0.2–0.5/1–5	Dn	25–44	Fig. 3.24C
		Kumluca-Kızıldağ	Disseminated, massive, spotted, banded	0.2–0.3/1–25	Dn	40–50	Fig. 3.24C

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite

3.4.4.2.4 Antalya Region Chromitites

Chromitite deposits and occurrences in Antalya are generally exposed to the SW of Antalya province center (Fig. 3.24C). One group of chromite occurrences belonging to dunite sections occur around Atbükü-Kemer and to the SE of Çavuş Village, and another group of chromite occurrences related to different sizes of dunites within harzburgites occur around Kumluca. A total of 19 chromitite occurrences occur in the Kemer and Kumluca districts. These chromitites also have no economic importance in the Turkish chromite mining sector.

All these chromitite ores and occurrences of the three Regions are summarized in Table 3.12.

3.4.5 Region Five: Central Anatolian (Mersin, Adana, Kayseri) Ophiolites and Related Chromitite Deposits

Thin slices of ophiolites from Mersin merge with the ophiolites of the IAEZ (Izmir-Ankara-Erzincan Zone) around Refahiye (Erzincan). These ophiolite slices in the eastern part of the Inner Tauride suture are discussed in the first section. Ophiolites related to this zone begin from the Mersin Ophiolite and continue to the NE as the Kızıltepe Ophiolite, Alihoca Ophiolite, Pozantı-Karsantı Ophiolite, Pınarbaşı Ophiolite and Divriği/Güneş Ophiolite (Fig. 3.26).

Although the Sivas Region ophiolites are associated with this suture zone, they are interpreted as part of the NE Anatolian Division. In this chapter, mainly chromitite deposits and related ophiolite sequences in Mersin, Adana and Kayseri provinces will be introduced.

3.4.5.1 Mersin Region

According to the map in Fig. 3.26, the ophiolites that cover the most SW part of the region are defined as the Mersin Opholite (Fig. 3.27).

3.4.5.1.1 Mersin Ophiolites

Mersin Ophiolite, exposed beneath a thick Miocene cover at the westernmost end of the Eastern Taurus Mountain, forms a large massif at the southern flank of the Bolkar Mountains. This ophiolite body rests tectonically on top of an ophiolitic mélange, named Aslanköy formation (Demirtaşlı 1984), and is covered by Eocene sediments in the north section (Ternek 1957; Demirtaşlı et al. 1975; Demirtaşlı 1984; Özgül 1976; Gedik et al. 1979) and partly by Oligocene conglomerates. Pillow lavas, volcanic breccias, hyaloclastics, radiolarites, pelagic limestones with lava intercalations (possible Triassic in age: Juteau 1979, 1980; Çapan 1980),

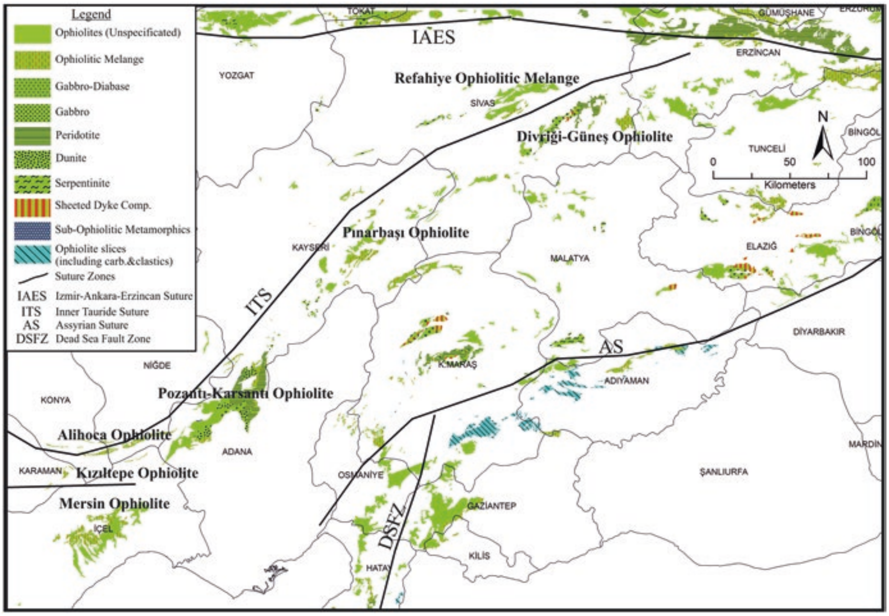


Fig. 3.26 Ophiolites and chromitite occurrences of Mersin-Adana-Kayseri and Sivas Regions (*IAESZ* Izmir-Ankara-Erzincan Suture Zone, *IPSZ* Inner Pontide Suture Zone, *BZSZ* Bitlis-Zağros Suture Zone, *DSFZ* Dead Sea Fault Zone). (Simplified and modified from MTA 2002; Suture Zones are adapted from Okay and Tüysüz 1999)

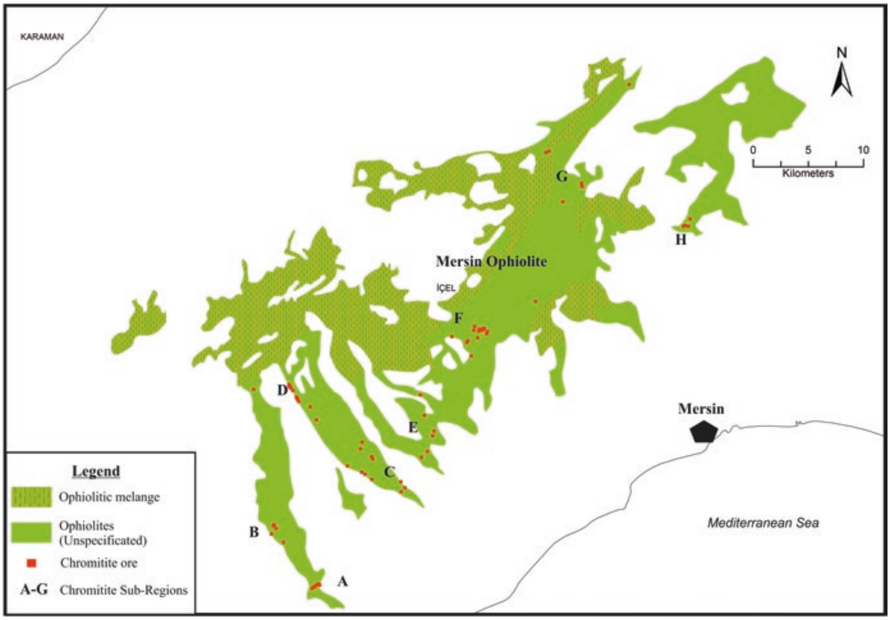


Fig. 3.27 Chromitite occurrences and sub-regions of Mersin ophiolite (A: Kösbucağı; B: Köserelli; C: Sıraç – Yassıtaş – Mühlü; D: Poyrazlı – Hacıalanı; E: Avrangedik; F: Takanlı – Akarca – Demirışık – Yeniköy; G: Horozlu – Kızılbağ; H: Musalı). (Simplified and modified after MTA 2002)

limestones (Maastrichtian; Gedik et al. 1979) and serpentinite-gabbro blocks are the typical rock association within the ophiolitic mélange that was emplaced onto the Jurassic-Cretaceous carbonate platform (Erendil 2002).

The Mersin ophiolite represents an oceanic lithospheric section, about 6 km thick, which from bottom to top consists of; a metamorphic sole, harzburgitic mantle tectonites, ultramafic to mafic cumulates, basaltic pillow lavas (Parlak et al. 1996). Metamorphic sole rocks form a thin slice, 50–70 m thick, beneath the harzburgitic tectonites. It generally consists of amphibolite, mica-schist, amphibolite-schist and marble (Parlak et al. 1995, 1996). The mantle tectonites are represented by harzburgite and dunite. The cumulate rocks start with ultramafic units, namely wherlite, pyroxenite, dunite at the bottom, passing upwards into mafic units such as olivine gabbro, gabbro norite, troctolite and anorthosite at the top (Parlak et al. 1996). The volcanics are characterized by pillow basalts and basaltic lava flows. The metamorphic sole, mantle tectonites and cumulate rocks were intruded by numerous diabase dykes (Parlak and Delaloye 1996).

3.4.5.1.2 Mersin Chromitite Occurrences

The general distribution of chromitite occurrences in ultramafic rocks of the Mersin Ophiolite was given in Fig. 3.27. These occurrences are within eight sub-regions: Kösbucağı, Köserelli, Sıraç – Yassıtaş – Mühlü, Poyrazlı – Hacıalanı, Avrangedik, Takanlı – Akarca – Demirışık – Yeniköy, Horozlu – Kızılbağ and Musalı sub-regions and summarized in Table 3.13. Although several chromitite deposits are present in the Mersin Region, they are mostly small and almost totally mined-out.

3.4.5.2 Adana Region

3.4.5.2.1 Adana Ophiolites

In Adana province, ophiolitic rocks form an important part of Aladağ Tectonic Unit that forms a belt through to the SE from Pozantı. These rocks extend to the northern borders of the province, and for about 30 km in the same strike on Kayseri province (Fig. 3.26). The most comprehensive studies about ophiolites in the region were conducted by Tekeli et al. (1984).

Pozantı-Karsantı Ophiolite or "Aladağ Ophiolite" has a nappe character sequence that includes metamorphic rocks at its base and ultramafic-mafic rocks. It is divided into two groups, based on the rock association. The first was defined as "tectonite" and is an ultramafic rock association with metamorphic texture, derived from the upper mantle. The other group is a cumulate type rock association, represented by ultramafic to mafic rocks (Fig. 3.28).

The Aladağ Ophiolite Complex consists of three units defined by rock types, structural features and location. These are, from bottom to top, ophiolite melange, metamorphic sole and oceanic lithospheric section (Tekeli et al. 1981; Çakır 1978;

Table 3.13 General features of the chromitite occurrences in Mersin, Adana and Kayseri regions

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Five (Middle Anatolian region)	Mersin/Mersin ophiolite	Kösbucağı	Disseminated, massive, banded-lensoidal	6 (zone)/10–80	Dn	15–20	Fig. 3.27A
		Köserelli	Disseminated, massive, banded-lensoidal	1–3 (zone)/10–30	Dn	15–35	Fig. 3.27B
		Sıraç-Yassıtaş-Mühlü	Disseminated, nodular, banded	0.1–0.2/1–10	Hbj-Dn	15–20	Fig. 3.27C
		Poyrazlı-Hacıalanı	Disseminated, massive, banded-lensoidal	1–3 (zone)/10–300	Dn	10–20/30	Fig. 3.27D
		Avrangedik	Massive, disseminated	0.3–1.0/20–30	Dn	35–50	Fig. 3.27E
		Takanlı – Akarca – Demirışık – Yeniköy	Disseminated, massive, nodular, banded	0.5–4.0/10–100	Dn	10–20	Fig. 3.27F
		Horozlu – Kızılbağ	Disseminated, massive, thin banded	0.2–1.0/1–4	Dn	25–40	Fig. 3.27G
		Musalı	Disseminated, banded	0.05–0.1/10–40	Dn	25–40	Fig. 3.27H
	Adana/Aladağ ophiolite	Dereyurt Dere – Gerdağı-Beyçamı Tepe	Disseminated, nodular, massive, banded	0.6–2.5/2–20	Hbj-Dn	20–45	Fig. 3.29A
		Cehennemdere – Kırcakatran	Massive, disseminated, banded	1–2 (zone)/10–60	Hbj-Dn	30–50	Fig. 3.29B
		Gerdibi – Deveboynu-Kaklık Dere	Massive, disseminated, banded	0.5–2.0 (zone)/2–30	Dn	30–48	Fig. 3.29C
		Sivişli – Mencek Tepe – Çötlük Tepe – Badırıklı Tepe	Disseminated, banded	30–80 (zone)/100–450	Dn	2–5	Fig. 3.29D
		Kütüklü Tepe – Tozlu Tepe-Kartalkale Tepe-Gavurgeri Tepe	Disseminated, massive, banded	2–3 (zone)/80–200	Hbj-Dn	20–40	Fig. 3.29E

		Ziyaret Dağı-Kaltar Dağı-Duvarlı Tepe-Keşgöz Tepe	Disseminated, banded	0.5–8 (zone)/40–80	Dn	10–25	Fig. 3.29F
		Çanakpınarı Tepe – Kızılyüksek-Yataardıç[b]	Disseminated, nodular, massive banded	1–10 (zone)/10–220	Hbj-Dn	5–(40)[c]	Fig. 3.29G
		Darılık Köyü-Akinek Dağı-Yapraklı Tepe	Disseminated, banded	10–22 (zone)/25–250	Hbj-Dn	15–30 (40–50[c])	Fig. 3.29H
		Hova Tepe-Sulukerer Tepe-Üçsivri Tepe	Massive, banded, lensoidal	1–5/20–80	Hbj-Dn	40–50	Fig. 3.29I
	Kayseri/Pınarbaşı ophiolite	Sarıtaş Tepe	Disseminated, nodular, banded	0.2–1/2–36	Hbj-Dn	40–48	Fig. 3.30A
		Tatlar-Kanlıpınar-Zorkunlu Dere	Disseminated, massive, banded	0.7–3.5 (zone)/10–85	Hbj-Dn	10–30 (52[c])	Fig. 3.30B
		Divrikçakırı	Disseminated, massive, banded	0.1–1.0 (zone)/5–35	Hbj-Dn	25–40	Fig. 3.30C
		Ademi Mah.-Asar Tepe-Melengeçli Tepe-Delialiuşağı-Aşağı Delialiuşağı	Disseminated, massive, nodular, banded	0.4–2 (zone)/8–60	Hbj-Dn	15–20 (44[c])	Fig. 3.30D
		Kadılı-Kızılören-Artmak, Avşarsöğütlü, Toklar	Massive, disseminated;	5–20 (zone)/15–180	Hbj-Dn	10–25	Fig. 3.30E
			Lensoidal	0.7 × 17		55	
		Kaman and Dilciler	Disseminated, banded	1–3 (zone)/9–45	Hbj-Dn	5–15	Fig. 3.30F
		Kırımuşağı, Pulpınar, Demirci County, Kireçlikyayla	Disseminated, banded	1–3 (zone)/10–60	Hbj-Dn	10–20	Fig. 3.30G
		Yusuflar, Bahçecik, Emeğil, Solaklar, Büyükpotuklu	Disseminated, banded	0.1–0.3/2–200	Dn	20–30	Fig. 3.30H
		Üçsivri Tepe	Massive; banded	0.2–1.0/1–5	Hbj-Dn	40–45	Fig. 3.30I

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]One of the important deposits of Turkey
[c]Massive and banded grades

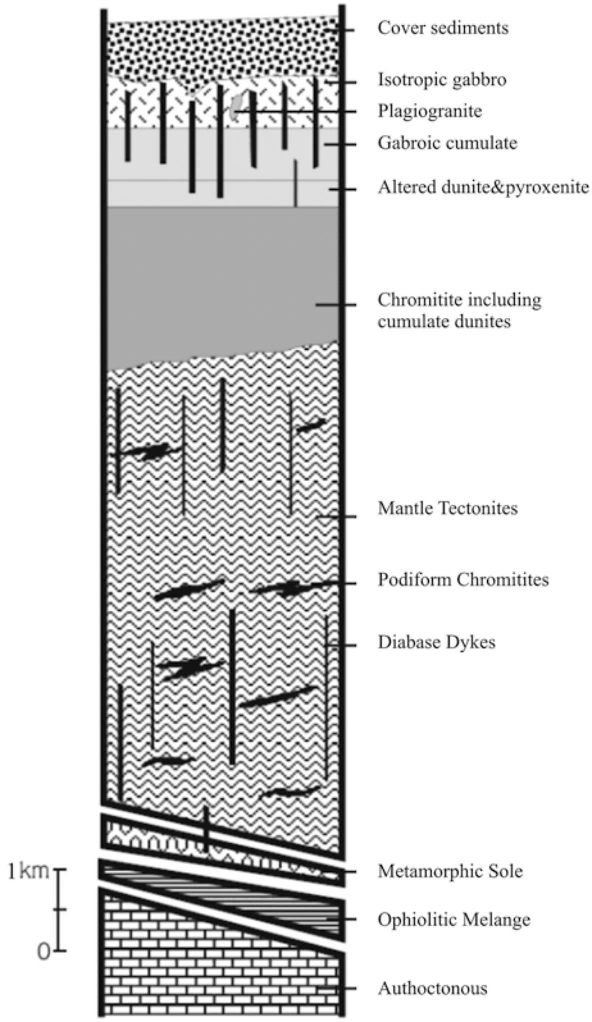


Fig. 3.28 Generalized lithostratigraphy of Aladağ ophiolite. (Re-constructed after Tekeli 1981; Çakır 1978; Bingöl 1978; Çapan 1980; Çataklı 1983)

Bingöl 1978; Çapan 1980; Çataklı 1983) (Fig. 3.28). The mantle tectonites are rich in chromitite mineralization. Even though the chromite occurrences in this area, firstly reported by MTA, are of low grade, they form one of the important chromite mineralisation regions in the world, at least in terms of mineral resources.

3.4.5.2.2 Adana Chromitites

Adana province is a region where low grade, large scale chromitite deposits occur. The Kızılyüksek-Yataardıç chromitite deposits (Table 3.13) are 200 m long with an average grade of 5.35% Cr_2O_3, according to MTA estimation. In addition, there are

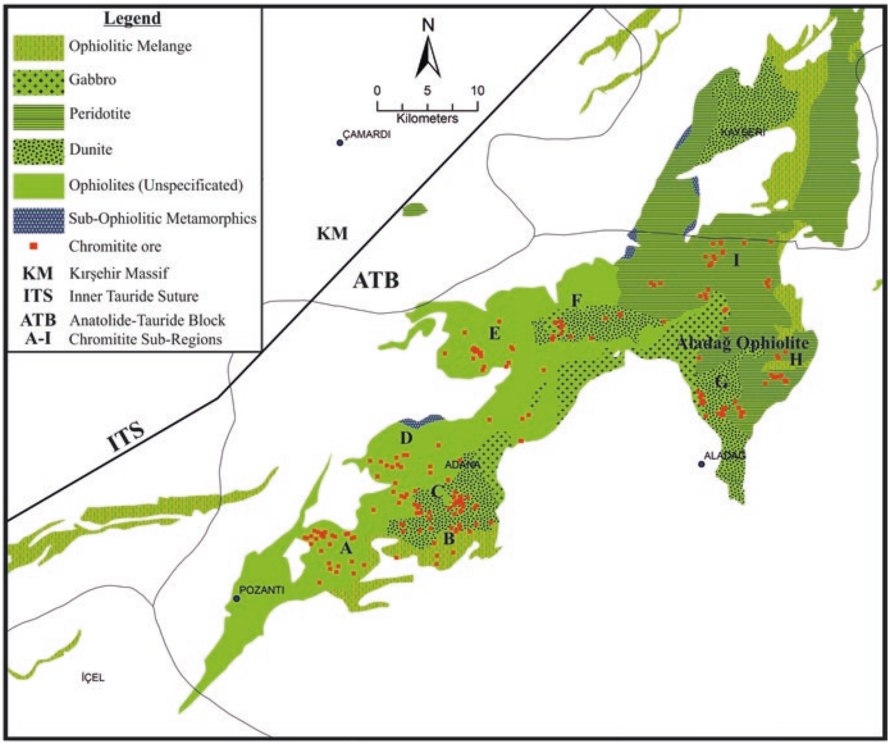


Fig. 3.29 Chromitite occurrences and sub-regions of Aladağ (Adana) region (A: Dereyurt -Gerdağı-Beyçamı; B: Cehennemdere-Kırcakatran; C: Gerdibi-Deveboynu-Kaklık Dere; D: Sivişli-Mencektepe-Çötlüktepe-Badırıklıtepe; E: Kütüklütepe-Tozlutepe-Kartalkale Tepe-Gavurgeri Tepe; F: Ziyaret Dağı-Kaltar Dağı-Duvarlı Tepe-Keşgöz Tepe; G: Çanakpınarı Tepe-Kızılyüksek-Yataardıç; H: Darılık Köyü-Akinek Dağı-Yapraklıtepe; I: Hova Tepe-Sulukerer Tepe-Üçsivri Tepe). (Simplified and modified after MTA 2002)

low grade chromitite deposits with reserves that vary between a few millions of tonnes and a few tens of millions of tonnes, embedded within cumulate dunites in this region. Rising demand for chromitite ore in the last decade has improved the economics of large, low grade deposits. Thus, Adana province is an important region in Turkey for low grade chromitite deposits, especially in terms of production capacity and potential.

The Adana chromitite deposits are shown on Fig. 3.29. The sub-regions are; Dereyurt-Gerdağı-Beyçamı, Cehennemdere-Kırcakatran, Gerdibi-Deveboynu-Kaklık Dere, Sivişli-Mencektepe-Çötlüktepe-Badırıklıtepe, Kütüklütepe-Tozlutepe-Kartalkale Tepe-Gavurgeri Tepe, Ziyaret Dağı-Kaltar Dağı-Duvarlı Tepe-Keşgöz Tepe, Çanakpınarı Tepe -Kızılyüksek-Yataardıç, Darılık Köyü-Akinek Dağı-Yapraklıtepe and Hova Tepe-Sulukerer Tepe-Üçsivri Tepe; and their characteristics are also summarized in Table 3.13.

3.4.5.3 Kayseri Region

3.4.5.3.1 Kayseri Ophiolites

Kayseri province ophiolitic sequences outcrop in two regions as shown in Fig. 3.30. One of them is located in the SW border of the province and this a NE extension of Aladağ Ophiolite.

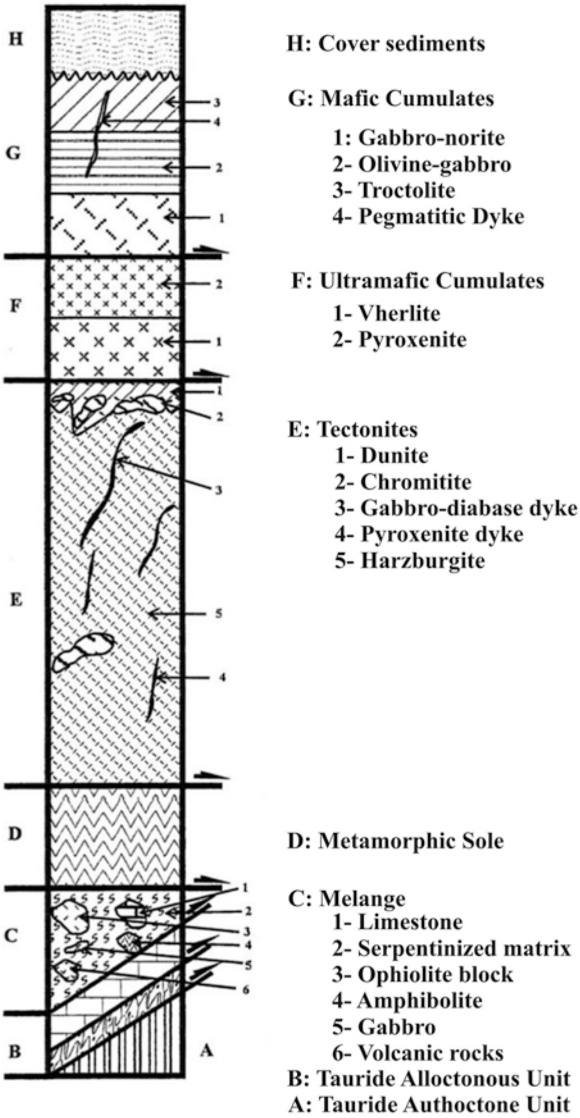


Fig. 3.30 Tectono-stratigraphic section of Pınarbaşı ophiolite. (Modifies after Vergili and Parlak 2005)

The second ophiolitic sequence in Kayseri province is the **Pınarbaşı Ophiolite** that forms a belt with a NE-SW extension around Pınarbaşı (Fig. 3.30). According to Vergili and Parlak (2005), these ophiolites are allochthonous slices emplaced onto the Eastern Taurus Autochthonous. The ophiolitic rocks mainly consist of three different rock associations, such as ophiolitic melange, metamorphic sole and a regular opholite sequence (Fig. 3.30).

3.4.5.3.2 Kayseri Chromitite Occurrences

Some of the chromitite occurrences in Kayseri province are observed in the SW, in Aladağ Ophiolite (A, B, C, D). The other important part is seen in Pınarbaşı Ophiolite (E, F, G, H and I in Fig. 3.31). Table 3.13 presents the main characteristics of the chromitite deposits in Mersin, Adana and Kayseri regions.

3.4.6 Region Six: SE Anatolian (Hatay, Osmaniye, Gaziantep, Kahramanmaraş, Adıyaman, Elazığ, Siirt, Van, Hakkari) Ophiolites and Related Chromitite Deposits

Ophiolite sections of the SE Anatolian Region extend along the Bitlis-Zağros Suture Zone (BZSZ) and are named "SE Anatolian Ophiolite Belt" (Fig. 3.32). Some of the ophiolite sections, namely the Göksun Ophiolite, Berit Metaophiolite, İspendere Ophiolite, Kömürhan Ophiolite, Guleman Ophiolite, Baykan Ophiolite, and Gevaş Ophiolite, were accreted to the metamorphic Tauride platform (Malatya-Keban platform) in the north. Other ophiolites are situated on the top of the Arabian platform in the south. These are Kızıldağ Ophiolite, Kılan/Meydan Ophiolite, Koçali-Karadut Complex and Yüksekova Complex (Sarıfakıoğlu et al. 2014) (Fig. 3.32).

Although some of these ophiolitic sequences are very fertile in terms of chromite mineralisation, like the Guleman ophiolite, they generally lackchromitite deposits.

3.4.6.1 Hatay-Osmaniye-Gaziantep-Kahramanmaraş Regions

3.4.6.1.1 Hatay Region

Kızıldağ Ophiolite

The Kızıldağ Ophiolite is exposed at the south-western end of the Amanos Mountains and consists of ultramafic and mafic rocks in a NE-SW tectonic lineament (Fig. 3.32). It displays a well-preserved oceanic lithospheric section in southern Turkey, from bottom to top: mantle tectonites, ultramafic-mafic cumulates, isotropic gabbros, sheeted dykes, volcanic rocks and cover sediments. The Kızıldağ Ophiolite is located in the Mediterranean coastline and covers a wide area.

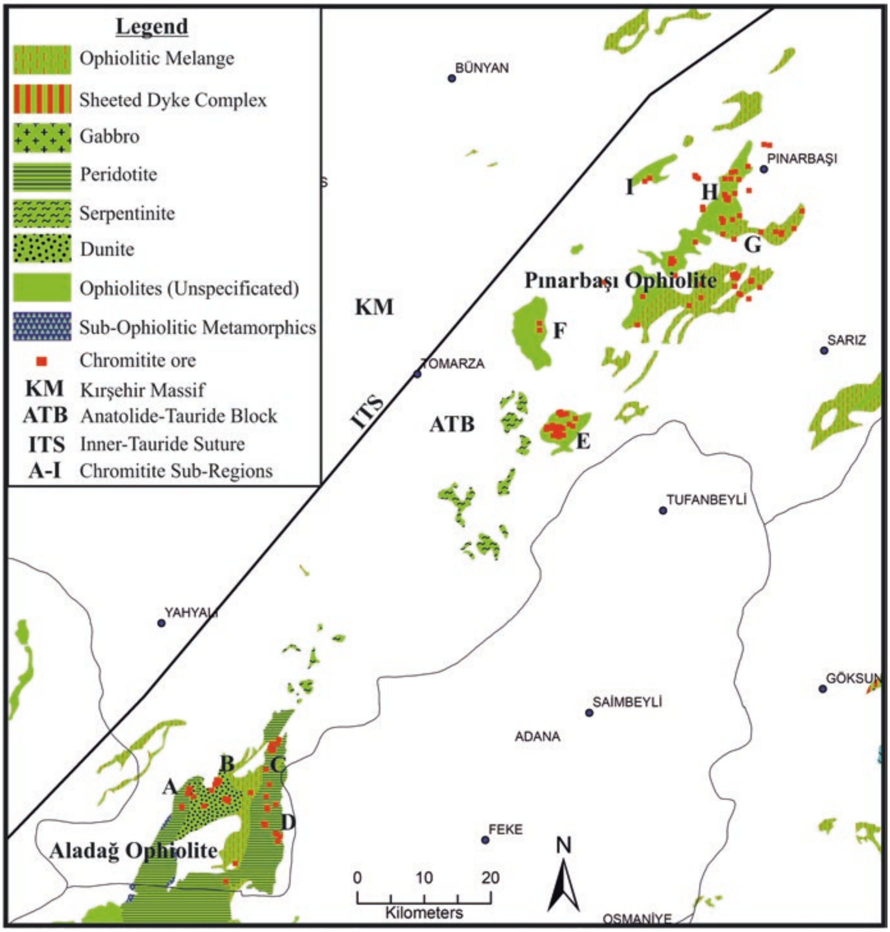


Fig. 3.31 Chromitite occurrences and sub-regions of Pınarbaşı ophiolite (Kayseri) (A: Sarıtaş Tepe; B: Tatlar-Kanlıpınar-Zorkunlu Dere; C: Divrikçakırı; D: Ademi Mah.-Asar Tepe-Melengeçli Tepe-Delialiuşağı-Aşağı Delialiuşağı; E: Kadılı-Kızılören-Artmak, Avşarsöğütlü, Toklar; F: Kaman ve Diliciler; G: Kırımuşağı, Pulpınar, Demircili-Kireçlikyayla; H: Yusuflar, Bahçecik, Emeğil, Solaklar, Büyükpotuklu; I: Üçsivri Tepe). (Simplified and modified after MTA 2002)

The mantle tectonites mainly consist of harzburgites, dunite with lesser amounts of lherzolite and wherlite. They are cut by number of dykes such as pyroxenite, pegmatite gabbro and rodingitized diabase dykes with chilled margins (Bağcı 2004). The harzburgites form 70% of the tectonites and, together with the dunites, weather to a brown colour. Both of these rocks are dark green-black in unweathered outcrops. The less common Lherzolites are mainly seen along the transition zone into the cumulate rocks.

The ultramafic and mafic cumulates form the lowest level of oceanic crust within Kızıldağ Ophiolite and are exposed along the southern flank of the Kızıldağ massif.

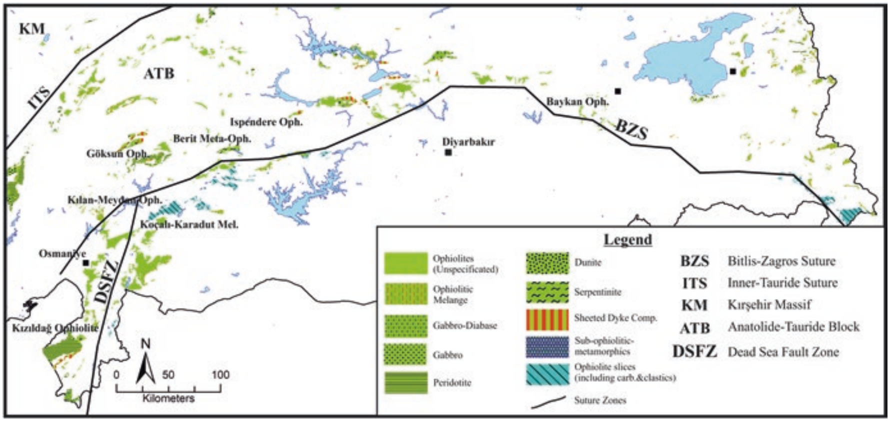


Fig. 3.32 Ophiolites in SE Anatolia along Bitlis-Zagros-Suture (BZS) Belt. (Simplified and modified after MTA 2002)

The cumulates taper from southeast to northeast, are emplaced tectonically on tectonites at the base, and exhibit a transitional contact with isotropic gabbros in their upper levels (Bağcı 2004). The cumulate rocks are cut by diabase and pegmatitic gabbro dykes, ranging in thickness from 2 to 60 cm (Bağcı et al. 2005).

Hatay Chromitites

Chromite deposits in Hatay Region are located mainly in the central part of the Kızıldağ Ophiolite, in the area at the west of Belen and in the NE section of Dörtyol district. Most of these deposits and occurrences are hosted within ultramafic tectonites. Chromitite occurrences in Kızıldağ centre are mainly located in Çerçikaya, Aşağı Zorkum, Yukarı Zorkum, Sarıgöl, Gümüşoluk and Arapgediği quarries (Fig. 3.33A1). Chromite occurrences close to the NE of Dörtyol district (Fig. 3.33A2) mainly occur in Emirali Damları and Şehmahmut Pleateu/Yanık Hill areas (see Table 3.14).

3.4.6.1.2 Osmaniye Ophiolites

Ophiolitic sequences in this region were emplaced during Late Cretaceous onto the Mesozoic Carbonate platform (Yılmaz 1984) (Fig. 3.32). They have characteristics similar to the Kızıldağ Ophiolite in the NE. Yılmaz (1984) considered these ophiolite sequences under different names based on their composition and tectonic position, with the Zorkun Ophiolitic Melange, Yarpuz Ophiolitic Melange, Tozaklı Ophiolite, Ispirler Meta-Ophiolitic Melange and Berke Ophiolite being the main sequences. The internal structures of these ophiolites are not considered in this section of Chap. 3.

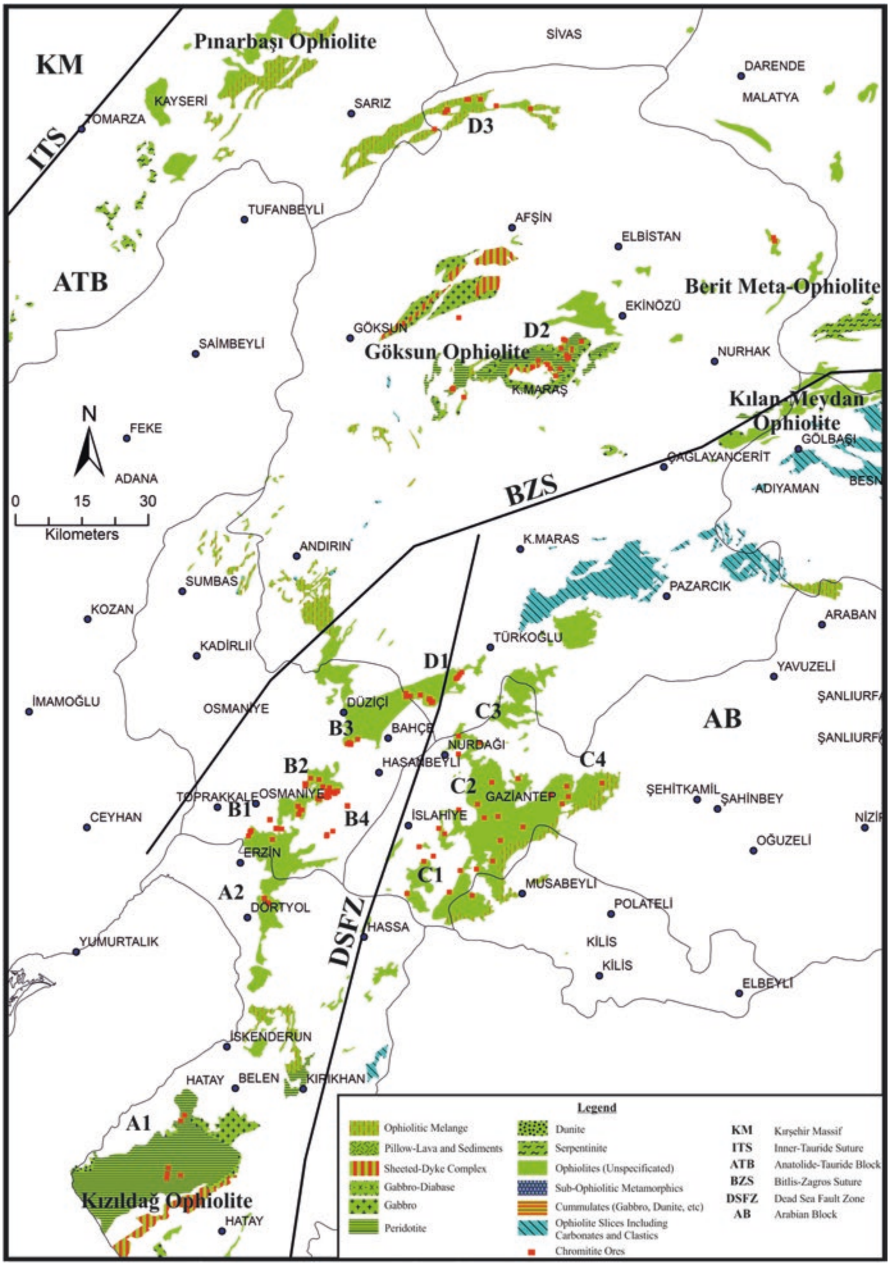


Fig. 3.33 Chromitite occurrences of Hatay, Osmaniye, Gaziantep and Kahramanmaraş (A: Hatay Region; B: Osmaniye Region; C: Gaziantep Region; D: Kahramanmaraş Region). (Simplified and modified after MTA 2002)

Table 3.14 General features of chromitite occurrences in Hatay and Osmaniye regions

Region	County/ ophiolite name	Sub-region/deposit name		Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	Hatay/Kızıldağ ophiolite	A1	Çerçikaya	Massive, brecciated	–	Hbj-Dn	35–40	Fig. 3.33A1
			Aşağı Zorkum	Disseminated, massive, banded	1–2 (zone)/20–30	Hbj-Dn	25–40	
			Yukarı Zorkum	Disseminated, massive, banded	0.1–0.5/50	Dn	25–47	
			Sarıgöl	Massive, disseminated, banded	0.1–0.7/10–50	Hbj-Dn	37–42	
			Gümüşoluk	Disseminated, banded	0.2–0.5/1–5	Dn	15–20	
			Arapgediği	Massive, brecciated	0.5–0.6/1–5	Dn	30–40	
		A2	Emirali Damları	Massive, lens/boulder shaped	0.2 × 0.5	Hbj-Dn	40–50	Fig. 3.33A2
			Şehmahmut Yayla					
	Osmaniye/ Kızıldağ ophiolite	B1	Kanlıkoz yayla, Harak yayla, Ürün Mahallesi-Armuttarla	Disseminated, massive, banded	0.3–1.5/few meters	Dn	35–40	Fig. 3.33B1
			Konak Sırtı ve Aşağıbağ	Massive, lensoidal	Variable	Dn	48–52	
			Çamlık Sırtı – Karacaüstü	Massive, nodular, brecciated	0.2–0.4/few meters		35–42	
			Cevizlik Tepe	Massive, nodular; brecciated	0.2–0.5/few meters		35–40	
		B2	Kayalı	Massive, lens, banded	Irregular	Dn-Wh-Px	48	Fig. 3.33B2
			Issızca	Massive, nodular, lensoidal	0.4 × 3.0		30–40	
			Davutlar	Massive, lensoidal	Irregular	Hbj-Dn	45	
		B3	Burgaçlı-Arıklıtaş	Disseminated, massive, nodular, banded	0.1–0.2/few meters	Hbj-Dn	44	Fig. 3.33B3
		B4	Beşağaç Tepe, Mezar Tepe, Gördüktarla, Çamdenizi	Massive, lensoidal	Irregular	Hbj-Dn	30–40	Fig. 3.33B4

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite; Wh: Wehrlite; Px: Pyroxenite

Osmaniye Chromitites

The distribution of Osmaniye region chromitite occurrences is shown on Fig. 3.33B. They will be presented under four main groupings: Kanlıkoz Yayla – Kıvrıkoğlu Yayla, Konak Sırtı, Aşağıbağ Mevkii, Çamlık Sırtı – Karacaüstü, Ürün Mahallesi – Armuttarla Mevkii, Cevizlik Tepe (B1); Kayalı, Issızca, Davutlar, Çulhalı, Karayiğit (B2); Burgaçlı – Arıklıtaş (B3); and Beşağaç Tepe, Mezar Tepe, Gördüktarla ve Çamdenizi (B4), which are summarised in Table 3.14.

3.4.6.1.3 Gaziantep Region

Gaziantep Ophiolites

Ophiolites that were defined as "Allochthonous Series" and exposed in the west of the province, are mainly the Upper Jurassic-Early Cretaceous Koçali Complex, the Early-Middle Maastrichthian Karadut Complex, and the Middle-Late Maastrichtian Ophiolite Nappe (Fig. 3.32). These ophiolitic sequences were emplaced along the suture zone at different times and alternate with several magmatic and volcanic rocks of the Tethyan closure. Here we discuss only the chromitite deposits and not these ophiolitic sequences.

Gaziantep Chromitites

Chromite occurrences in Gaziantep province are generally centred in the Islahiye region (Fig. 3.33C1–C4). Ultramafic tectonites and cumulates of the Islahiye Ophiolite Nappe have small chromitite occurrences, reported by MTA in 1999 during chromitite-nickel prospecting surveys.

Little chromite was extracted from exploration quarries and no more than five deposits achieved a few thousand tonnes of production. The grade of chromite ores hosted in cumulate dunites, ranges from 10% to 30% Cr_2O_3 and many of these occurrences and deposits are not suitable for mining. The grade of chromitite occurrences in ultramafic tectonite basal dunite zones varies between 40% and 52% Cr_2O_3 and these higher grades have enabled a limited amount of production during periods of high demands and higher prices. The Gaziantep province chromitites and occurrences are shown as "Serial C" on Fig. 3.33. The general features of these chromitite deposits are given in Table 3.15.

3.4.6.1.4 Kahramanmaraş Region

Ophiolites

There are many lithological associations that consist of ophiolite components in the Kahramanmaraş province and these are exposed in Malatya-Bitlis ophiolites group (Erendil 2002). Ophiolites of this belt occur as tectonic slices sandwiched between

Table 3.15 General features of chromitite occurrences in Gaziantep region

Region	County/ophiolite name	Sub-region/deposit name		Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	Gaziantep/Koçali and Karadut complex islahiye ophiolite nappe	C1	Tilmenhüyük-Karapolat	Nodular, disseminated, massive banded and lenses	0.05–0.15/1–10	Hbj-Dn	35–40	Fig. 3.33C1
			Kırkpınar – Kuzoluk – Bakırcan		0.05–0.15/10–200		30–35	
			Yukarı ve Aşağı Şerikanlı, Dilan	Massive, disseminated, banded	0.2–0.5/10–40		10–20	
			Alaca – Çıbık	Massive, nodular, disseminated	Few cm/10–150		30–40	
			Yesemek	Massive, banded	0.5–1.0/5–20		20–30	
		C2	Soğucak-Fizge-Çakmak-Terken	Massive ore blocks in quarry excavations		Hbj-Dn	30–40	Fig. 3.33C2
			Toplamalar-Katrancı	Massive, banded	0.01–0.1/irregular		20–30	
			Durmuş-Kırkpınar-Ökkeşbaba Tepe-Çatal Tepe	Massive	0.5–1.0/variable		Up to 48	
			BayrakHill-Hudut Çiftliği	Disseminated, massive, nodular, banded	0.2–0.5/variable		10–20	
			Kürdikanlı – Arabuşağı	Disseminated, massive, banded	0.05–0.35/10–50		30–40	
		C3	Tepkanlı Köyü	Noduled, disseminated, banded	0.02–0.1/variable		20–25	Fig. 3.33C3
			Tandırlı-Keloso-Hamidiye	Massive, nodular, disseminated, banded	0.2–0.4/10–200		20–30	
		C4	Kartal-Terken-Sarıkaya-Şemlik	Massive banded	–		10–20	Fig. 3.33C4
			Hasancalı	Massive, disseminated	0.1–0.3/10–20		30–40	

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite

metamorphic massifs or unmetamorphosed younger deposits (Erendil 2002). Ophiolite slices of the Taurus Belt and Arabian Platform are shown in Fig. 3.32.

To the north of Afşin and Kayseri border; the Göksun Ophiolite and the Berit Ophiolite are exposed between Andırın and Türkoğlu and can be described together. They consist of slices that were emplaced in the region at different times by over-thrust nappe tectonics.

Chromite mineralisation in the region, occurs mostly in small deposits (Fig. 3.33D1–D3) which have been occasionally exploited with small-scale production.

In the Dağlıca Melange exposed between Afşin and Sarız, marketable chromitites occur in small deposits. To the south of Ekinözü, in the Berit Ophiolite, low Cr_2O_3 grade occurrences were identified with the "high aluminium" content depending on dunite abundance in the ultramafic cumulate units. The general features of these chromitite deposits of the Kahramanmaraş region are given in Table 3.16.

3.4.6.2 Adıyaman and Elazığ Regions

3.4.6.2.1 Adıyaman Region

Ophiolite sequences in the Adıyaman province are defined as the Karadut Complex, the Koçali Complex and the Opholite Nappe (Fig. 3.32).

Chromitites

Chromite deposits and chromitite occurrences in this region are located in the Ophiolite Nappe, within a sequence of peridotites referred as the Koçali Complex in previous studies (Yoldemir 1987).

The early chromite exploration programs in this region were carried out by MTA in 1973. Since 1989, information about chromitite occurrences in Adıyaman region was updated by field studies, and they are located mainly in Gölbaşı, Besni, and Tut central districts (Fig. 3.34). Within the framework of the data obtained during prospecting work, it can be concluded that the chromite deposits and occurrences in the Adıyaman territory are small with a potential of between a few hundred and a few thousand tonnes. The general features of these chromitite deposits in the Adıyaman region are given in Table 3.17.

3.4.6.2.2 Elazığ Region

The Elazığ-Alacakaya (Guleman) territory has the largest chromite resources and production in Turkey and accounts for about 45% of the total chromite resources. Mining in the Elazığ-Alacakaya territory started in 1936 and still operates today. Many scientific studies were conducted in the region aimed at the understanding the mechanism of chromitite genesis in order to improve exploration studies (Kovenko

Table 3.16 General features of chromitite occurrences in Kahramanmaraş region

Region	County/ophiolite name	Sub-region/deposit name		Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	K.Maraş/ Göksun, Berit, Tozaklı ophiolites	Türkoğlu	Küçük İmalı Köyü	Massive, lenses, nodular	Variable	Hbj-Dn	Up to 48	Fig. 3.33D1
			Kaledibi Köyü	Massive, disseminated, lensoidal	Variable		Up to 44	
		Elbistan	Süleymanlı Köyü	Disseminated, banded	0.1–0.4/1–15	Dn	20	Fig. 3.33D2
			Sarıgüzel Köyü		0.2–2.5/1–15		30	
			Kabak Tepe Köyü	Disseminated, massive, banded	Thin		40[b]	
			Kandilköy-Çıtak	Massive, banded	0.05–0.1/1–2		40	
			Demirlik Köyü	Disseminated, banded	0.5–1.0/10–35		20–25 (40[b])	
		Afşin	Sergen Mahallesi	Massive, disseminated	0.2–0.6/1–23		40	Fig. 3.33D3
			Armutalanı	Massive, lensoidal	Irregular		40	

[a]Starts from the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]Massif band grades

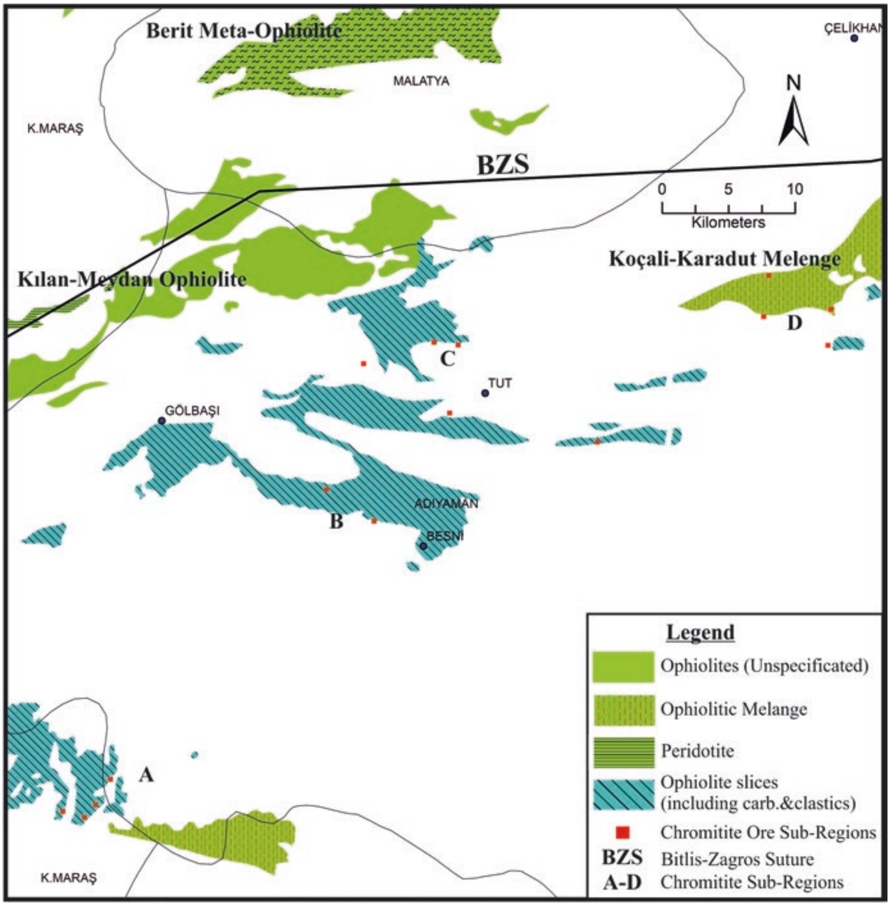


Fig. 3.34 Chromitites of Adıyaman region and sub-regions (A: Harmancık ve Çorak; B: Besni; C: Tut; D: Yazıbaşı-Akçalı-Kotur). (Simplified and modified after MTA 2002)

1940; Borchert 1952; Ercan et al. 1970; İskit 1973; İzmir and Koç 1977; Ortalan and Erdem 1977; Özkan 1977, 1982a, b; Özkan and Sümer 1986, 1987; Engin et al. 1980–1981, 1987; Balcı 1986; Engin 1986; Engin and Sümer 1987).

The Guleman ophiolite unit covers an area of 200 km^2. About 65% of the unit is represented by tectonite and the rest is cumulate rocks (Fig. 3.35). The cumulate rocks are located within the tectonites, or generally surround them. Although there are chromite deposits in both rock groups, those in tectonites are more important.

The dunite unit in Kef territory, is considered as a transition zone between tectonites and cumulates and the major Western Kef Deposit is exposed at the base of this dunite unit. Some other chromite deposits in the region occur in thin dunite envelopes within harzburgites.

Table 3.17 General features of the chromitite occurrences in Adıyaman region

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	Adıyaman/Koçalı and Karadut complex	Harmancık and Çorak Köyleri	Massive, boulder/lensoidal	Variable	Hbj-Dn	30–55	Fig. 3.34A
		Besni	Disseminated, banded, brecciated	0.1–0.2/1–1.5	Hbj-Dn	20–48	Fig. 3.34B
		Tut	Disseminated, massive, banded	0.1–0.15/ 1–1.5	Hbj-Dn	25–50[b]	Fig. 3.34C
		Yazıbaşı-Akçalı-Kotur	Massive, disseminated, lens, boulder	0.3 × 0.1/1–2	Dn	15–20 (48)	Fig. 3.34D

[a]From the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]Massif band grades

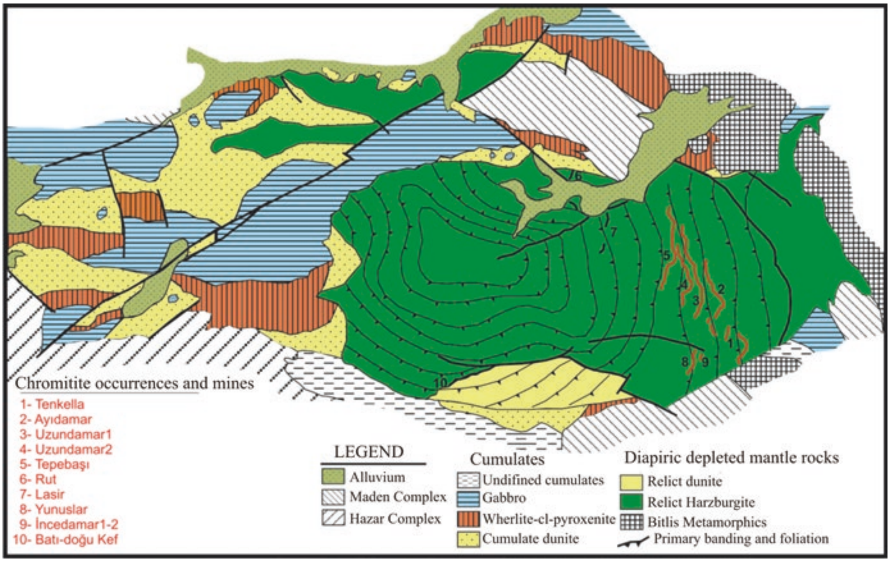


Fig. 3.35 Geology of Guleman ophiolite and major chromitite deposits. (Modified after Özkan 1982b)

Although the Guleman chromite deposits are classified as Alpine type, their continuity in terms of strike and dip directions make these deposits quite special. A large component of chromite mineralization is concordant with the internal structure of the host rocks. Figure 3.35 shows the major deposits in Guleman where mining was carried out by both open pit and underground mining operations. The principal features of these deposits are summarised in Table 3.18.

3.4.6.3 Siirt-Van-Hakkari Regions Chromite Deposits

3.4.6.3.1 Siirt Region

Ophiolites

The Siirt ophiolites are part of the Bitlis Metamorphic Massif and occur as tectonic slices within this Massif. They are generally distributed around Baykan and Şirvan and rarely NE of Pervari (Fig. 3.32). The ultramafic unit was named Guleman ultramafics by Sungurlu (1974), whereas Perinçek (1978) referred to it as the Guleman group. The best outcrop of the unit is north of the Guleman settlement area in the east of Elazığ province, Maden district (Şenel 2007). This ophiolitic sequence was examined under different names, such as Guleman Group, Şimsin Formation (Açıkbaş and Baştuğ 1975); Guleman Metamorphics (Perinçek 1978); Guleman Peridotite Unit (Engin et al. 1980–1981); Guleman Ophiolite (Özkan 1981–1982, 1983) (Fig. 3.36).

Table 3.18 General features of chromitite occurrences in Elazığ (Guleman) Region

Region	County/ophiolite name	Sub-region/deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (% Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	Elazığ/Guleman ophiolite	Western Kef[b]	Disseminated, banded	10–50/1000	Dn	20–44	Fig. 3.35
		Eastern Kef[b]	Disseminated, massive, banded, lensoidal, brecciated	5–8/50–100		26–46	
		Altındağ-Spotted Vein-Kapin-Şabate[b]	Disseminated, massive, banded, lensoidal, brecciated	10–25/50–110	Hbj-Dn	30–45	
		Rut-Taşlı Tepe (Sori Part)[b]	Disseminated, massive, banded, lensoidal	0.1–3.5/100–1600	Hbj-Dn	30–50	
		Gölalan, Tosinler, Sitealtı, Aşağı ve Yukarı Kündikan[b]	Disseminated, massive; banded, lensoidal	Many podiform lenses/boulder	Hbj-Dn	40–53	

[a]From the most abundant type; Hbj: Harzburgite; Dn: Dunite
[b]One of the important deposits of Turkey

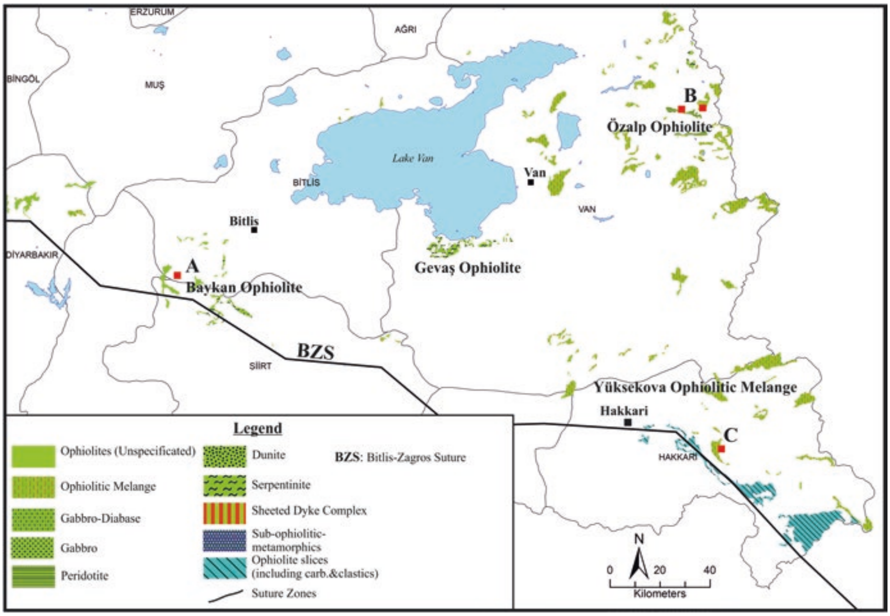


Fig. 3.36 Ophiolites of SE Anatolia and major chromitite deposits (A: Siirt Region; B: Van-Özalp Region; C: Hakkari Region). (Simplified and modified after MTA 2002)

Chromitites

In the Siirt province, at Büzügan section, 41 chromitite outcrops have been identified. They occur mostly in serpentinized harzburgites in a melange environment, And exhibit limited continuity in both strike and dip (Fig. 3.36A).

Information for this region, is largely based on prospecting work conducted by MTA in 1974. Private companies subsequently carried out both exploration and production however, considering the geological structure of the region, the potential for substantial chromite production is considered limited.le.

3.4.6.3.2 Van Region

The Gevaş Ophiolite around Gevaş and the Özalp Ophiolite around Özalp and Saray areas, are the main ophiolitic sequences in the Van region. All chromitite occurrences in the region are located in the Özalp Ophiolite.

Özalp Ophiolite

This ophiolite outcrops in a wide region from Van in the centre to the east, near the Iran border (Fig. 3.36). Ophiolitic complex (melange) forms a layered structure around Özalp and Saray districts, consisting of basic components like deep-sea lavas (mostly spilitic), serpentinites and diabases, radiolarites-limestones-multicolored shales and marls (Ketin 1977). The Özalp Ophiolite is overlain by Neogene age sediments, suggesting that it was emplaced in Late Cretaceous-Paleocene time. The ophiolitic sequence is represented mostly by upper mantle harzburgites and minor amounts of gabbros. The tectonite peridotites are cut partly, or completely, by rodingitised diabase dykes (Günay et al. 2012).

Van Region Chromitites

Chromitite occurrences in Van Region are located in Özalp and Saray Villages, along the Land Border of Iran and Turkey (Fig. 3.36B). The main features of these chromitite deposits are summarized in Table 3.19. According to this table, chromitites in Özalp region are mainly in massive character, lens shaped, and banded in lesser amount. In contrast, the character of chromitites in eastern and SE part of Özalp Village are disseminated and they are mostly brecciated, partly lens shaped. Dimensions are also quite limited in both section, means that no significant chromite reserve has expected in the region.

3.4.6.3.3 Hakkari Region

The ophiolites that are common in the Hakkari region (Fig. 3.36) are known as Yüksekova Complex and outcrop around Cilo Mountain of Hakkari and Yüksekova along the Bitlis –Zagros Suture Zone (Perinçek 1989). The Yüksekova Complex is mainly represented by spilitic basalt, agglomerate, volcanic sandstone, conglomerate, limestone, chert, granite, granodiorite, quartz diorite, tonalite and flysch facies rocks and in lesser amounts serpentinite, gabbro and diabase units (Sungurlu et al. 1985).

Hakkari Chromitites

Ophiolite occurrences in the Hakkari region are generally of melange character and they exhibit an orderly internal structure, belonging to a cumulate group, they show alternation of serpentinized dunite, wherlite and gabbro. In the ophiolitic melange extending for about 15 km SW of Yüksekova district in an approximate N-S direction, these bodies contain localised with chromitite occurrences. Due to lack of prospecting activity of the ophiolitic melange units to the east and NE sections of Yüksekova district, there is no detailed information about the structure of these sections (Boyalı and Sayın 1974; Sümer and Artan 1983).

Some prospecting and mineral exploration was conducted by MTA in 1983 in the Hakkari-Yüksekova Complex, with the specific aim of assessing the potential of the chromitites. This work showed that the chromitite mineralization is mainly associated with dunites in ultramafic cumulate units. Chromitites in peridotites are highly cataclastic and occur as discontinuous lens-shaped masses. The general features and potential for chromititite occurrences in the territory are presented below.

Table 3.19 General features of chromitite occurrences in Van region

Region	County/ophiolite name	Sub-region/ deposit name	Type[a]	Thickness/length (meters)	Wall-rock	Grade (%Cr_2O_3)	Map Nr. and sign
Region Six (SE Anatolian region)	Van/Gevaş ve Özalp ophiolite; Yüksekova complex	Aşağı Dikme	Massive, lens	0.5 × 3.5	Hbj-Dn	30–45	Fig. 3.36B
		Yukarı Balıkçı	Massive, lens, boulder	0.4–0.6 × 0.8–4.0			
		Çavuşlar	Massive, banded, lens, boulder	0.5–1.5 × 1–7.5			
		Savatlı	Massive, lens, boulder	0.8–1.6 × 0.9–2.8			
		Karaharabe Tepe	Disseminated, brecciated, lens	1.2 × 6.4			
		Bot Tepe	Disseminated, brecciated, lens	0.1–0.5/30 (zone)			
		Söylemez Tepe	Disseminated, brecciated, lens	0.9–1.5 × 3.2–10			
		Öküzyolu Tepe	Disseminated, brecciated, lens	0.5–1.1 × 2–5			
		Saray-1	Disseminated, banded	1–2/20–25			
		Saray-2	Disseminated, brecciated, lens	0.5-1 × 1–2			

[a]From the most abundant type; Hbj: Harzburgite; Dn: Dunite

Ophiolite rocks in the Kışlacık village section in the Cilo Mountains are located in an area with a NW-SE trend in a 600–1000 m wide belt of cumulates alternating with dunite, wherlite and gabbro.

They are generally melange in character, but retain much of their internal structures. Chromitite lenses in serpentinized dunites, generally show a parallel sequence to ophiolite-limestone. Here, chromitites can be grouped as those between Kışlacık Village and Görhele Hill (2.718 m) and the ones between Alakan Village and Öküzölen Hill (2200 m).

Between Kışlacık Village and Görhele Hill, the serpentinized cumulate dunites, host about 24 chromitite lenses in 8 groups that have a general N-S trend. These lenses are generally in structural contact with serpentinized dunites, and are between 1 and 13 m long, with thicknesses varying between 0.5 and 7 m. The strike of these chromitite lenses is generally N60–65°E or 50–55°SE, but they have limited continuity along strike and down dip. Chromitites also occur in the form of large tectonic blocks. Chemical analysis of samples from chromitite lenses, indicate Cr_2O_3 grades of between 17.86% and 47.45% Cr_2O_3; SiO_2 content is between 1.66% and 17.74%. The dominant Cr_2O_3 content is around 30–35% (Sümer and Artan 1983).

Lens shaped chromitite bodies located mostly on the SW side of Öküzölen Hill (2.200 m, a.s.l.), SW of the Alakan Village, consist of two sequences, with a stratigraphic separation of 30 m, that continue in parallel, but with similar interruptions, for 400 m.

The chromitite lenses are between 0.5 and 30 m long and between 0.2 and 4 m thick. Strikes and dips are N25E, 40° SE; N55E, 46°SE and N50W, 42°SW. Chemical analysis of samples taken from chromitites in Öküzölen Hill, where disseminated chromitites are dominant, indicate that the Cr_2O_3 grade varies between 5.30% and 20.55%; SiO_2 content varies between 13.65% and 20.45% (Sümer and Artan 1983).

3.5 Conclusions

The demand from metallurgy and chemistry industries in Turkey are not sufficient to influence the chromitite market prices. As this sector is highly dependent in exploration, the fluctuations in the global market tend to affect Turkey's chromitite production as well. Nevertheless, as the chromitite occurrences near the surface began to run out, junior mining companies in the country started to close down with the market scene being left to the larger companies with greater investment capabilities. In this circumstances, unless there is a global economic crisis, Turkey's chromitite production may be stabilised. But, this would have a negative effect on a high number of employees who work for the junior mining companies, as they would be forced to find another sources of income.

In terms of high quality steel production, chrome is still an unmatched resource today. Therefore, chromitite as a metallic ore will always have a global demand in the short and medium term. All the same, it is evident that producing chromitite from shallow depths using traditional methods will soon no longer be desirable in

Turkey. Aiming for deeper targets makes it necessary to invest more for research and exploration. Necessary operations have started in Turkey by using more sophisticated software technologies and modelling, more geological and geophysical data which can be helpful in reaching deeper levels of these ore deposits,. Historical mining activities and their records serve as a guiding source for these operations. In addition to this some important deposits which were abandoned without being processed before, are today being considered for producing concentrated ore. This can be taken as a hopeful development, paving the way for new opportunities in the chromitite mining sector in Turkey.

Acknowledgements This chapter includes valuable data from prospecting reports of MTA, accrued during many years, resulting from long-lived studies. Dr. Tandoğan Engin, Dr. Yusuf Ziya Özkan, Bayazıt Erdem, Ali Kemal Akın and İlhan Odabaşı should be mentioned first. A. Olcay Çolakoğlu, Aytekin Türkel and Serdar Keskin were also active prospectors for these Projects. We have to present our gratitude to all prospectors in the past and the present, for their enormous efforts and contribution to the mining sector.

References

Açıkbaş D, Baştuğ C (1975) V. Bölge Cacas-Hani yöresi kuzey sahalarının jeoloji raporu ve petrol olanakları [Geology report and petroleum resources of 5th Region, Cacas-Hani Region]. Report No: 917. TPAO, Ankara (in Turkish, unpublished)

Ahmet AH, Arai S (2002) Unexpectedly high-PGE chromitite from the deeper mantle section of the northern Oman ophiolite and its tectonic implications. Contrib Mineral Petrol 143:263–278

Akın AK (1995) Kurşunlu-Ilgaz-Çankırı-Araç-Tosya-Kastamonu-Kargı-Çorum ve çevresinin krom prospeksiyon raporu [Chromite prospecting report of Kurşunlu-Ilgaz-Çankırı-Araç-Tosya-Kastamonu-Kargı-Çorum and related area]. Report No: 9886. MTA, Ankara (in Turkish, unpublished)

Aktaş G, Robertson AHF (1984) The Maden Complex, SE Turkey: evolution of a Neotethyan continental margin. In: Dixon JE, Robertson, AHF (eds) The geological evolution of the Eastern Mediterranean, Geological Society special publications, vol 17. Geological Society, London, pp 375–402

Aktimur HT (1986) Erzincan, Refahiye ve Kemah dolayının jeolojisi [Geology of Erzincan-Kemah region]. Report No: 7932. MTA, Ankara (in Turkish, unpublished)

Aktimur HT, Atalay Z, Ateş Ş, Tekirli ME, Yurdakul ME (1988). Munzur Dağları ile Çavuşdağ arasının jeolojisi [Geology between Munzur and Çavuş Mountains]. Report No: 8320. MTA, Ankara (in Turkish, unpublished)

Aktimur HT, Tekirli ME, Yurdakul ME (1990) 1:100.000 ölçekli, açınsama nitelikli Türkiye Jeoloji Haritaları Serisi, Tokat D22 (UTM: G 36) Paftası [Geology of Turkey, 1:100.000 scale exploration map series, G36 sheet]. MTA, Ankara (in Turkish, with English abstract)

Akyürek (1981) Ankara-Elmadağ-Kalecik dolayının jeolojisi [Geology of Ankara-Elmadağ-Kalecik region]. Report No: 7298. MTA (in Turkish, unpublished)

Akyürek B, Bilginer E, Çatal E, Dağer Z, Soysal Y, Sunu O (1980) Eldivan-Şabanözü (Çankırı) Hasayaz-Çandır (Kalecik-Ankara) dolayının jeolojisi [Geology of Eldivan-Şabanözü (Çankırı) Hasayaz-Çandır (Kalecik-Ankara) region]. Report No: 6741. MTA (in Turkish, Unpublished)

Alpay B (1951) Burdur İli'nin Yeşilova ilçesine bağlı Salda, Horozköy, Bahyar ve Işıklar köyleri hudutları içinde bulunup Rıfat Kasanoğlu ve Mehmet Erkazancı ortaklığına ait ruhsatname sahalarında yapılan taharriyat hakkında fen raporu [Prospecting report of Burdur-Yeşilova-

Salda–Horozköy-Bahtiyar and Işıklar Villages, licensed to Rıfat Kasanoğlu and Mehmet Erkazancı corporation]. Report No: 3809. MTA Ankara (in Turkish, unpublished)
Alriyami K, Robertson AHF (2002) Mesozoic sedimentary and magmatic evolution of the Arabian continental margin, northern Syria: evidence from the Baer-Bassit Melange. Geol Mag 139:395–420
Alriyami K, Robertson AHF, Dixon J, Xenophontos C (2002) Origin and emplacement of the Late Cretaceous Baer-Bassit ophiolite and its metamorphic sole in NW Syria. Lithos 65:225–260
Andrew T, Robertson AHF (2002) The Beyşehir–Hoyran–Hadim Nappes: genesis and emplacement of Mesozoic marginal and oceanic units of the northern Neotethys in southern Turkey. J Geol Soc Lond 159:529–543
Arni P (1942) Tavşanlı (Kütahya) Linyit Yatakları Raporu [Tavşanlı (Kütahya) lignite report]. Report No:1373. MTA Ankara (in Turkish, unpublished)
Bacak G, Uz B (2003) Dağardı güneyi (Kütahya) ofiyolitinin jeolojisi ve jeokimyasal Özellikleri [Geology and geochemical properties of Dağardı South (Kütahya) ophiolite]. J Istanbul Tech Univ 2(4):86–98
Bağcı U (2004) Kızıldağ (Hatay) ve Tekirova (Antalya) Ofiyolitlerinin Jeokimyası ve Petrolojisi [Geochemistry and petrology of Kızıldağ (Hayat) and Tekirova (Antalya) ophiolites]. PhD thesis, Çukurova Univ Institute of Science, 383 p (in Turkish with English abstract, unpublished)
Bağcı U, Parlak O, Höck V (2005) Whole rock and mineral chemistry of cumulates from the Kızıldağ (Hatay) ophiolite (Turkey): clues for multiple magma generation during crustal accretion in the Southern Neotethyan Ocean. Min Mag 69:53–76
Bağcı U, Parlak O, Höck V (2006) Geochemical character and tectonic environment of ultramafic to mafic cumulate rocks from the Tekirova (Antalya) ophiolite (southern Turkey). Geol J 41(2):193–219
Bağcı U, Parlak O, Höck V (2008) Geochemistry and tectonic environment of diverse magma generations forming the crustal units of the Kızıldağ (Hatay) ophiolite southern Turkey. Turk J Earth Sci 17:43–71
Balcı M (1986) Rut-Taşlıtepe (Guleman-Elazığ) yöresi krom yataklarının jeolojisi [Geology of chromite deposits in Rut-Taşlıtepe (Elazığ) region]. Report no: 7909. MTA, Ankara (in Turkish, unpublished)
Bébien J, Shallo M, Manika K, Gega D (1998) The Shebenik Massif (Albania): a link between MOR- and SSZ-type ophiolites. Ofioliti 23:7–15
Ben-avraham Z, Woodside J, Lodolo E, Gardosh M, Grasso M, Camerlenghi A, Vai GB (2006) Eastern Mediterranean basin systems. In: Gee DE, Stephenson RA (eds) European lithosphere dynamics, Memories, vol 32. Geol Society, London, pp 263–276
Bingöl AF (1978) Pétrologie du massif ophiolitique de Pozantı-Karsantı (Taurus Cilicien, Turquie); étude de la partie orientale: thèse de spécialité (3 ème cycle). Univ. Louis Pasteur, Strasbourg (unpublished)
Borchert H (1952) Etibank Şark kromları mıntıkasında krom cevheri yataklarında yapılan jeolojik tetkik hakkında rapor [Report of the geological prospectivity on chromite deposits in Etibank eastern chromite region]. Report No: 2082. MTA, Ankara (in Turkish, unpublished)
Borchert H (1960) Yeşilova – Burdur havalisindeki kromit yatakları [Chromite ores around Yeşilova-Burdur region]. Report No: 3245. MTA, Ankara (in Turkish, unpublished)
Borchert H (1962) Tefenni (Vilayeti Burdur) peridotit massifindeki kromit zuhurları [Chromite occurrences of the Tefenni (Burdur) peridotite massif]. Report No: 260. MTA, Ankara (in Turkish, unpublished)
Bortolotti V, Marroni M, Pandolfi L, Principi G, Saccani E (2002) Interaction between mid-ocean ridge and subduction magmatism in Albanian ophiolites. J Geol 110:561–576
Boyalı İ (1996) Salda Gölü Kuzeyi (Yeşilova-Burdur), Eğridir-Sütçüler (Isparta), Serik (Antalya) Çevresi Krom Prospeksiyon Raporu [Chromite prospectivity report of northern of Salda Lake (Yeşilova-Burdur), Eğridir-Sütçüler (Isparta) and Serik (Antalya) region]. Report No: 6336. MTA, Ankara (in Turkish, unpublished)

Boyalı İ, Sayın A (1974) Van-Özalp civarındaki peridotitlerde krom prospeksiyon raporu [Chromite prospectivity report of peridotites around Özalp-Van region]. Report No: 5457. MTA, Ankara (in Turkish, unpublished)
Brinkmann R (1966) Geotektonische Gliederung von Westanatolien. N Jb Geol Paleo, Stuttgart, pp 603–618
Brinkmann R (1968) Einige geologische Leitlinien von Anatolien. Geol Paleontol 2:111–119
Çakır Ü (1978) Petrologie du massif de Pozantı – Karsantı (Taurus Cilicien, Turquie): Etude de la partie centrals, These 3 eme cyl, 251. Strasbourg
Çapan UZ (1980) Toros kuşağı ofiyolit Massiflerinin (Marmaris, Mersin, Pozantı, Pınarbaşı ve Divriği) iç yapıları, petroloji ve petrokimyalarına yaklaşımlar [Approaches to the internal structures, petrology and petrochemistry of the Tauride belt ophiolite massifs (Marmaris, Mersin, Pozantı, Pınarbaşı and Divriği)]. PhD thesis, HU Institute of Science (in Turkish, unpublished)
Çataklı AS (1983) Assemblage ophiolitique et roches associees de la partie occidentale du Massif de Pozantı-Karsantı (Taurus Cilicien, Turquie). These d'Etat, Universite de Nancy I
Cawthorn RG (2015) The Bushveld complex, South Africa. In: Charlier B, Namur O, Latypov R, Tegner C (eds) Layered intrusions. Springer, Dordrecht, pp 517–588
Çelik ÖF (2007) Metamorphic sole rocks and their mafic dykes in the eastern Tauride belt ophiolites (southern Turkey): Implications for OIB-type magma generation following slab break-off. Geol Mag 144:849–866
Çelik ÖF, Chiaradia M (2008) Geochemical and petrological aspects of dike intrusions in the Lycian ophiolites (SW Turkey): a case study for the dike emplacement along the Tauride Belt Ophiolites. Int J Earth Sci 97:1151–1164
Çelik ÖF, Delaloye M (2003) Origin of metamorphic soles and their post-kinematic mafic dykes swarms in the Antalya and Lycian ophiolites, SW Turkey. Geol J 38:235–256
Çelik ÖF, Marzoli A, Marschik R, Chiaradia M, Neubauer F, Öz I (2011) Early–Middle Jurassic intra-oceanic subduction in the İzmir-Ankara-Erzincan Ocean, Northern Turkey. Tectonophysics 509(1–2):120–134
Çiftçi Y, Dönmez C, Çolakoğlu AO, Odabaşı İ (2017). Türkiye Krom Envanteri 1. ve 2. Bölüm [Chrome inventory of Turkey: part 1 and 2]. MTA Inventory Series: 205. Ankara
Çolakoğlu AO, Dönmez C, Çiftçi Y, Sayak H, Türkel A (2014) Oltu-Narman-Horasan (Erzurum) Yöreleri Krom-Nikel Prospeksiyon Raporu [Cr-Ni Prospectivity report of Oltu-Narman-Horasan (Erzurum) region]. Report No: 11730. MTA, Ankara (in Turkish, unpublished)
Collins AS, Robertson AHF (1997) Lycian melange, southwestern Turkey: an emplaced Late Cretaceous accretionary complex. Geology 25:255–258
Collins AS, Robertson AHF (1998) Processes of Late Cretaceous to Late Miocene episodic thrust sheet translation in the Lycian Taurides, SW Turkey. J Geol Soc Lond 155:759–772
Demirtaşlı E (1984) Stratigraphy and tectonics of the area between Silifke and Anamur, Central Taurus Mountains. In: Tekeli O, Göncüoğlu MC (eds) Proceeding of the int symp on the geology of the Taurus Belt, 26–29 September, MTA, Ankara, pp 101–118
Demirtaşlı E, Bilgin AZ, Erenler W, Işıklar S, Sanlı DY, Selim M, Turhan N (1975) Geology of the Bolkar mountains. In: Alpan S (ed) Congress of earth sciences, 50th year of the republic. MTA Special Publ, Ankara, pp 42–57
Denkel U (1972) GB Anadolu kromit yatakları hakkında bazı ekonomik mülahazalar [Some economic aspects of SW Anatolian chromite ores]. Report No: 3550. MTA (in Turkish, unpublished)
Dilek Y, Flower MFJ (2003) Arc-trench rollback and forearc accretion: 2. A model template for ophiolites in Albania, Cyprus, and Oman. Geol Soc Lond Spec Publ 218:43–68
Dilek Y, Furnes H (2009) Structure and geochemistry of Tethyan ophiolites and their petrogenesis in subduction rollback systems. Lithos 113(1–2):1–20
Dilek Y, Furnes H (2011) Ophiolite genesis and global tectonics: geochemical and tectonic fingerprinting of ancient oceanic lithosphere. GSA Bull 123(3–4):387–411
Dilek Y, Thy P (2006) Age and petrogenesis of plagiogranite intrusions in the Ankara melange, central Turkey. Island Arc 15(1):44–57

Dilek Y, Thy P (2009) Island arc tholeiite to boninitic melt evolution of the Cretaceous Kizildag (Turkey) ophiolite: model for multi-stage early arc-forearc magmatism in Tethyan subduction factories. Lithos 113(1–2):68–87

Dilek Y, Thy P, Hacker B, Grundvig S (1999) Structure and petrology of Tauride ophiolites and mafic dyke intrusions (Turkey): implications for the Neotethyan ocean. GSA Bull 111:1192–1216

Dilek Y, Shallo M, Furnes H (2005) Rift-drift, seafloor spreading and subduction tectonics of Albanian ophiolites. Int Geol Rev 46:147–176

Dilek Y, Furnes H, Shallo M (2007) Suprasubduction zone ophiolite formation along the periphery of Mesozoic Gondwana. Gondwana Res 11:453–475

Dilek Y, Furnes H, Shallo M (2008) Geochemistry of the Jurassic Mirdita Ophiolite (Albania) and the MORB to SSZ evolution of a marginal basin oceanic crust. Lithos 100:174–209

Dönmez C, Keskin S, Günay K, Çolakoğlu AO, Çiftçi Y, Uysal İ, Türkel A, Yıldırım N (2014) Chromite and PGE geochemistry of the Elekdağ Ophiolite (Kastamonu, Northern Turkey): implications for deep magmatic processes in a supra-subduction zone setting. Ore Geol Rev 57:216–228

Döyen A (1995) Yeşilova (Burdur) civarı kromit yataklarının mineralojik, petrografik ve jeokimyasal incelemesi [Mineralogical, petrographical and geochemical prospection of chromite deposits around Yeşilova (Burdur) region]. PhD thesis, SU Institute of Science, (in Turkish, unpublished)

DPT (2001) Sekizinci Beş Yıllık Kalkınma Planı, Madencilik Özel İhtisas Komisyonu, Metal Madenler Alt Komisyonu, Krom Çalışma Grubu Raporu [8th five years development plan, commission of mines, chrome sub-commission report]. DPT: 2626-ÖİK: 637, 66p

Economou-Eliopoulos M (1996) Platinum-group elements distribution in chromite ores from ophiolite complexes: implications for their exploration. Ore Geol Rev 11:363–381

Engin T (1986) Petrology of the peridotite and structural setting of the Batı Kef-Doğu Kef chromite deposits, Guleman-Elazığ, eastern Turkey. In: Gallagher JM, Ischer RA, Neary CR, Prichard HM (eds) Metallogeny of basic and ultrabasic rocks. British IMM, London, pp 229–240

Engin T, Sümer Y (1987) Kefdağ-Kapin (Guleman-Elazığ) yöresinin jeolojisi, Batı Kef-Doğu Kef krom yataklarının maden jeolojisi [Geology of Kefdağ-Kapin (Guleman-Elazığ) and mining geology of West and East Kef chromite deposits]. Report No: 8123. MTA (in Turkish, unpublished)

Engin T, Balcı M, Sümer Y, Özkan YZ (1980–1981) General geological setting and the structural features the Guleman Peridotite unit and the chromite deposits (Elazıg, Eastern Turkey). Bull Min Res Exp 95(96):34–56

Engin T, Özkan YZ, Balcı M (1985) Türkiye Krom Yatakları ve MTA'nın Krom Aramacılığındaki Yeri [Chromite ore deposits of Turkey and the role of the MTA in chromite exploration]. 50th Year Symposium Abstracts Ankara, MTA

Engin T, Özkoçak O, Artan Ü (1987) General geological setting and character of chromite deposits in Turkey: in evolution of chromium ore fields. In: Stowe CXW (ed) Evolution of chromium fields. Von Nostrand Reinhold Company, New York, pp 195–219

Ercan T, Soykal T, Pehlivanoğlu H (1970) Elazığ-Diyarbakır (Maden-Ergani-Guleman) bölgesi jeolojisi [Geologyof Elazığ-Diyarbakır (Maden-Ergani-Guleman) region]. Report No: 5038. MTA, (in Turkish, unpublished)

Erendil M (2002) Türkiye Ofiyolitleri [Ophiolites of Turkey]. Seminar Notes, MTA publ. (in Turkish, unpublished)

Ergül E, Öztürk Z, Akçaören F, Gözler MZ (1980) Balıkesir İli-Marmara Denizi arasının jeolojisi [Geology between Balıkesir and Marmara Sea] Report No: 6760. MTA, (in Turkish, unpublished)

Flower MFJ, Dilek Y (2003) Arc-trench rollback and forearc accretion: 1.A collosion-induced mantle flow model for Tethyan ophiolites. In: Dilek Y, Robinson PT (eds) Ophiolites in earth history, vol 218. Geol Soc, London Sp Public. pp 21–41

Floyd PA, Winchester JA, Seston R, Kryza R, Crowley QG (2000) Review of geochemical variation in Lower Palaeozoic metabasites from the NE Bohemian Massif: intracratonic rifting and plume-ridge interaction. In: Franke W, Haak V, Oncken O, Tanner D (eds) Orogenic processes: quantification and modelling in the Variscan Belt, vol 179. Geological Society special publication, Geological Society, London, pp 155–174

Garuti G (2004) Chromite-platinum group element magmatic deposits. In: De Vivo B, Stüwe K (eds) Geology, encyclopedia of life support systems (EOLSS). UNESCO, EOLSS Publisher, Oxford. http://www.eolss.net

Garuti G, Fershtater G, Bea F, Montero PG, Pushkarev EV, Zaccarini F (1997) Platinum-group element distribution in mafic-ultramafic complexes of central and southern Urals: preliminary results. Tectonophysics 276:181–194

Gedik A, Birgili Ş, Yılmaz H, Yoldaş R (1979) Mut – Ermenek – Silifke yöresinin jeolojisi ve petrol olanakları [Geology and petroleum resources of Mut-Ermenek-Silifke region]. Bull Geol Soc Turk 22:7–26 (in Turkish with English abstract)

Göncüoğlu MC, Turhan N, Şentürk K, Özcan A, Uysal S, Yalınız MK (2000). A geotraverse across northwestern Turkey: tectonic units of the Sakarya region and their tectonic evolution. In: Bozkurt E, Winchester JA, Piper JDA (eds) Tectonics and magmatism in Turkey and the surrounding area, vol 173. Geol Soc of London, Sp Public. pp 139–161

González-Jiménez JM, Proenza JA, Gervilla F, Melgarejo JC, Blanco-Moreno JA, Ruiz-Sánchez R, Griffin WL (2011) High-Cr and High-Al chromitites from the Sagua de Tánamo district, Mayarí-Cristal ophiolitic massif (eastern Cuba): constraints on their origin from mineralogy and geochemistry of chromian spinel and platinum-group elements. Lithos 125(1):101–121

Günay K, Çolakoğlu AR (2011) Geochemical properties and platinum group element (PGE) contents of Eastern Turkey (Van Area) chromitite. Geol Bull Turk 54(1–2):1–24

Günay K, Çolakoğlu AR (2016) Spinel compositions of mantle-hosted chromitite from the Eastern Anatolian ophiolite body, Turkey: implications for deep and shallow magmatic processes. Ore Geol Rev 73(1):29–41

Günay K, Çolakoğlu AR, Çakır Ü (2012) Geochemical properties and rodingitization of diabase dykes cutting peridotites in Yüksekova complex (Özalp, Van – Turkey). Bull Min Res Exp 144:1–22

Hakyemez Y, Barkut MY, Bilginer E, Pehlivan Ş, Can B, Dağer Z, Sözeri B (1986) Yapraklı-Ilgaz-Çankırı-Çandır dolayının jeolojisi [Geology of Yapraklı-Ilgaz-Çankırı-Çandır region]. Report No: 7966. MTA (in Turkish, unpublished)

Hébert R, Laurent R (1990) Mineral chemistry of the plutonic section of the Troodos ophiolite: new constraints for genesis of arc-related ophiolites. In: Malpas J, Moores E, Panayiotou A, Xenophontos C (eds) Proceedings of Troodos ophiolite symposium, geological survey, Cyprus, pp 149–163

Höck V, Koller F, Meisel T, Onuzi K, Kneringer E (2002) The Jurassic South Albanian ophiolites: MOR- vs SSZ-type ophiolites. Lithos 65:143–164

Holzer H (1954) Beyce 54-1 ve Simav 71-2 Paftalarının Jeoloji Raporu [Geology report of the Beyce 54-1 and Simav 71-2 sheets]. Report No: 2366. MTA (in Turkish, unpublished)

İskit M (1973) Etibank Şark kromları Kef Dağı krom yatakları arama raporu [Prospectivity report of the Kef Dağı chromite deposits in eastern chromites of Etibank]. Etibank Report

İzmir M, Koç İ (1977) Pütyan-Bişeran (Guleman-Elazığ) yöresi, Pütyan krom ocakları çevresinin jeolojisi raporu [Geology report of Pütyan-Bişeran (Guleman-Elazığ), Pütyan chromite deposit and adjacent areas]. Report No: 6603. MTA, Ankara (in Turkish, unpublished)

Jackson ED, Thayer TP (1972) Some criteria for distinguishing between stratiform, concentric and alpine type peridotite-gabbro complexes. In: Proceeding of international geological Congress 24th, Montreal, vol 2, pp 280–296

Juteau T (1979) Ophiolites des Taurides: Essai sur leurhistorie oceanique. Rev Geol Dyn Geogr Phys 21(3):191–214 Paris

Juteau T (1980) Ophiolites of Turkey. Ofioliti 2:199–237

Juteau T, Nicolas A, Dubessy J, Fruchard JC, Bouchez JL (1977) Structural relationships in the Antalya ophiolite complex, Turkey: possible model for an oceanic ridge. GSA Bull 88:1740–1748

Kaczmarek MA, Müntener O, Rubatto D (2008) Trace element chemistry and U-Pb dating of zircons from oceanic gabbros and their relationship with whole rock composition (Lanzo, Italian Alps). Contrib Mineral Petrol 155:295–312

Karaoğlan F (2012) Geochronology of the ophiolitic and granitic rocks along the SE Anatolian orogen. PhD thesis. Çukurova University, Adana, (in Turkish with English abstract)

Karaoğlan F, Parlak O, Klötzli U, Thönim, Koller F (2013a) U–Pb and Sm–Nd geochronology of the Kızıldağ (Hatay, Turkey) ophiolite: implications for the timing and duration of suprasubduction zone type oceanic crust formation in the southern Neotethys. Geol Mag 150(2):283–299

Karaoğlan F, Parlak O, Klötzli U, Koller F, Rizaoğlu T (2013b) Age and duration of intra-oceanic arc volcanism built on a suprasubduction zone type oceanic crust in Southern Neotethys, SE Anatolia. Geosci Front 4(4):399–408

Ketin İ (1977) Van Gölü ile Iran sınırı arasındaki bölgede yapılan jeoloji gözlemlerinin sonuçları hakkında kısa bir açıklama [Short explanatory notes about the results of the survey between Van Lake and Iran–Turkey state border]. Bull Geol Soc Turk 20:79–85 (in Turkish with English abstract)

Koglin N (2008) Geochemistry, petrogenesis and tectonic setting of ophiolites and mafic-ultramafic complexes in the Northeastern Aegean region: new trace-element, isotopic and age constraints. PhD thesis, Department of Chemistry, Pharmacy and Geosciences of the Johannes Gutenberg University

Koglin N, Kostopoulos D, Reichmann T (2009) Geochemistry, petrogenesis and tectonic setting of the Samothraki mafic suite, NE Greece: trace-element, isotopic and zircon age constraints. Tectonophysics 473:53–68

Konak N (2002) Türkiye Jeoloji Haritası, İzmir Paftası 1/500.000 [Geological Map of Turkey, Izmir sheet in 1:500.000 scale] MTA (in Turkish with English abstract)

Konak N, Akdeniz N, Armağan F (1980) Akhisar-Gölmarmara-Gördes-Sındırgı dolaylarının jeolojisi [Geology of Akhisar-Gölmarmara-Gördes-Sındırgı region]. Report No: 6916. MTA, Ankara (in Turkish, unpublished)

Konstantinou A, Wirth KR, Vervoort J (2007) U-Pb isotopic dating of Troodos plagiogranite, Cyprus by LA-ICP-MS. In: 2007 GSA Denver Annual Meeting (28-31 October 2007) Paper No. 143–16

Koralay T (2000) Niyazlar Köyü (Yesilova–Burdur) ile Tefenni Yaylası (Tefenni–Burdur) Ofiyolitlerinin Jeolojik, Petrografik ve Petrokimyasal incelenmesi [Geological, petrographical and petrochemical investigation of Niyazlar Village (Yeşilova-Burdur) and Tefenni Highland (Tefenni-Burdur) ophiolites]. MSc thesis, PU Institute of Science (in Turkish with English abstract, unpublished)

Kovenko V (1940) Soridağ mıntıkası krom yataklarına yapılan ziyaret hakkında rapor [Report about the visit of Soridağ chromite deposits]. Report No: 1024. MTA (in Turkish, unpublished)

Kozlu H, Prichard H, Melcher F, Fisher P, Brough, Stueben D (2014) Platinum group element (PGE) mineralisation and chromite geochemistry in the Berit ophiolite (Elbistan/Kahramanmaraş), SE Turkey. Ore Geol Rev 60:97–111

Liati A, Gebauer D, Fanning CM (2003) The youngest basic oceanic magmatism in the Alps (Late Cretaceous; Chiavenna unit, Central Alps): geochronological constraints and geodynamic significance. Contrib Mineral Petrol 146:144–158

Liati A, Gebauer D, Fanning CM (2004) The age of ophiolitic rocks of the Hellenides (Vourinos, Pindos, Crete): first U-Pb ion microprobe (SHRIMP) zircon ages. Chem Geol 207:171–188

Lytwyn JN, Casey JF (1993) The geochemistry and petrogenesis of volcanics and sheeted dikes from the Hatay (Kızıldağ) ophiolite, southern Turkey: possible formation with the Troodos ophiolite, Cyprus, along fore-arc spreading centers. Tectonophysics 232:237–272

Mackintosh PW, Robertson AHF (2009) Structural and sedimentary evidence from the northern margin of the Tauride platform in south central Turkey used to test alternative models of Tethys during Early Mesozoic time. Tectonophysics 473:149–172

McCallum IS (1996) The stillwater complex. In: Cawthorn RG (ed) Layered intrusions, developments in petrology. Elsevier, Amsterdam, pp 441–484

Melcher F, Grum W, Thalhammer TV, Thalhammer OAR (1999) The giant chromite deposits at Kempirsai, Urals: constraints from trace element (PGE, REE) and isotope data. Mineral Depos 34:250–272

MTA (2002) 1:500,000 scale geology map of Turkey. General Directorate of Mineral Research and Exploration, Ankara

Mukasa SB, Ludden JN (1987) Uranium–lead ages of plagiogranites from the Troodos ophiolite, Cyprus, and their tectonic significance. Geology 1:825–828

Okay AI (1981) The geology and blueschist metamorphism of the ophiolites in Northwest Turkey (Tavşanlı – Kütahya). Bull Geol Soc Turk 24:85–95 (in Turkish with English abstract)

Okay AI (1986) High pressure/low temperature metamorphic rocks of Turkey. In: Evans BW, Brown EH (eds) Blueschists and eclogites, vol 164. GSA Memoir, pp 333–348

Okay AI (1989) Alpine-Himalayan blueschists. Annu Rev Earth Planet Sci 17:55–87

Okay AI (2008) Geology of Turkey: a synopsis. Anschnitt 21:19–42

Okay AI (2011) Tavşanli zone: the northern subducted margin of the Anatolide Tauride block. Bull Min Res Exp 142:191–211

Okay AI, Şahintürk Ö (1997) Geology of the Eastern Pontides. In: Robinson AG (ed) Regional and petroleum geology of the Black sea and surrounding region, vol 68. AAPG, pp 291–311

Okay AI, Siyako M (1993) İzmir-Balıkesir arasında İzmir-Ankara Neo-Tetis kenedinin yeni konumu. Türkiye ve çevresinin tektoniği-petrol potansiyeli [The new position of Izmir-Ankara Neo-Tethyan suture between Izmir and Ankara. Tectonics and petroleum potential of Turkey and surroundings)]. In: Turgur S (eds) Ozan Sungurlu Semposium, Abstract Book. pp 333–355

Okay AI, Tüysüz O (1999) Tethyan sutures of northern Turkey. In: Durand B et al (eds) The Mediterranean Basins: tertiary extension within the Alpine Orogen, vol 156. Geol Soc of London. pp 475–515

Okay AI, Whitney DL (2010) Blueschists, ophiolites and suture zones in northwest Turkey. In: Field trip guide book of Pre-Congress Excursion 1-3.10.2010, Tectonic Crossroads: evolving Orogens of Eurasia-Africa-Arabia, Geological Society of America, Ankara, 4–8 October 2010

Okay AI, Tüysüz O, Satır M, Özkan-Altıner S, Altıner D, Sherlock S, Eren RH (2006) Cretaceous and Triassic subduction-accretion, HP/LT metamorphism and continental growth in the central Pontides, Turkey. GSA Bull 118:1247–1269

Önen AP (2003) Neotethyan ophiolitic rocks of the Anatolides of NW Turkey and comparison with Tauride ophiolites. J Geol Soc Lond 160:947–962

Önen AP, Hall R (1993) Ophiolites and related metamorphic rocks from the Kütahya region, north-west Turkey. Geol J 28:399–412

Önen AP, Hall R (2000) Sub-ophiolite metamorphic rocks from NW Anatolia, Turkey. J Metamorph Geol 18:483–495

Ortalan F, Erdem B (1977) Kelhasi-Beyazkaya (Guleman-Elazığ) Gölalan, Tasinler, Sitealtı, Kündikan krom ocaklarının jeolojisi raporu [Geology report of the Kelhasi-Beyazkaya-Gölalan-Tasinler-Sitealtı and Kündikan (Guleman-Elazığ) chromite ore deposits]. Report No: 6579. MTA, Ankara (in Turkish, unpublished)

Ortalan F, Taşan N (1997) Çorum, Laçin, Sungurlu, Alaca, Ortaköy, Mecitözü (Çorum) arasında yüzeyleyen ofiyolitlerin krom prospeksiyon raporu [Cr-prospection report of Laçin-Sungurlu-Alaca-Ortaköy-Mecitözü (Çorum) ophiolites]. Report No: 10011. MTA, (in Turkish, unpublished)

Ortalan F, Seçer Y, Özen H (1984) Harmancık-Orhaneli (Bursa), Tavşanlı-Emet (Kütahya), Dursunbey (Balıkesir) yöresinde krom prospeksiyonu [Cr-prospectivity report of Harmancık–Orhaneli (Bursa), Tavşanlı-Emet (Kütahya) and Dursunbey (Balıkesir) region]. Report No: 7640. MTA (in Turkish, unpublished)

Özcan A, Akın E, Keskin E, Oral A, Sümengen M, Tekeli O (1980) Kuzey Anadolu Fayı-Kırşehir Massifi Arasının Temel Jeolojisi [Basic geology of North Anatolian Fault and Kırşehir Massif]. Report No: 6722. MTA (in Turkish, unpublished)

Özen H, Çolakoğlu A, Sayak H, Dönmez C, Türkel A, Odabaşı İ (2008). Erzincan-Tercan-Çayırlı Yöresi Ofiyolit Jeolojisi ve Krom-Nikel Prospeksiyon Raporu [Cr-Ni prospection report and

geology of ophiolites around Erzincan-Tercan-Çayırlı region]. Rep.No: 11050. MTA (in Turkish, unpublished)
Özen H, Gültaşlı ÖF, Çolakoğlu A (2011) Sivrihisar-Beylikova-Mihaliççik-Sarıcakaya (Eskişehir) yörelerindeki ofiyolitlerin jeolojisi ve metalojenezi [Geology and metallogenesis of the ophiolites in Sivrihisar-Beylikova-Mihaliçikik-Sarıcakaya (Eskişehir) regions]. Report No: (11458). MTA (In Turkish, unpublished)
Özgül N (1976) Toroslar'ın bazı temel jeolojik özellikleri [Some geological aspects of the Taurus Orogenic Belt (Turkey)]. Bull Geol Soc Turk 19(l):65–78 (in Turkish with English abstract)
Özgül N (1997) Bozkır-Hadim-Taşkent (Orta Toroslar'ın kuzey kesimi) dolayında yer alan tektonostratigrafik birliklerin stratigrafisi [Stratigraphy of the tectonostratigraphic units around Hadim-Bozkır-Taşkent Region (northern part of the Central Taurides, Turkey)]. Bull Min Res Exp 119:113–174 (in Turkish with English abstract)
Özkan YZ (1977) Kunt-Cordik-Genepi köyleri (Elazığ-Maden) arasında görülen krom oluşumları hakkında jeoloji raporu [Geology report about chromite occurrences around Kunt-Cordik-Genepi villages (Maden-Elazığ)]. Report No: 6955. MTA (in Turkish, unpublished)
Özkan YZ (1981–1982) Structural investigation of Guleman (Elazığ) ophiolite. Bull Min Res Exp 97(98):32–39
Özkan YZ (1982a) Guleman (Elazığ) Ofiyolitlerinin jeolojisi ve petrolojisi [Geology and petrology of Guleman (Elazığ) ophiolites]. PhD thesis, IU Earth Science Faculty, (in Turkish, unpublished)
Özkan YZ (1982b) Guleman-Elazığ Ofiyolitlerinin Jeoloji ve Petrolojisi [Geology and petrology of Guleman (Elazığ) ophiolites]. Ist J Earth Sci 3–4(6):33–39 (in Turkish with English abstract)
Özkan YZ (1983) Effects of metamorphism in the Guleman ophiolite. In: Tekeli O, Göncüoğlu MC (eds) Proceeding of the int symp on the geology of the Taurus belt, MTA, Ankara. p 87
Özkan YZ, Sümer Y (1986) Rut, Orta Lasir ve Yeni Lasir ocakları maden jeolojisi raporu [Mining geology report of Rut, Middle Lasir and New Lasir mines]. Report No: 8030. MTA (in Turkish, unpublished)
Özkan YZ, Sümer Y (1987) Uzundamar-2 ve Uzundamar-1 Ocakları (Guleman-Elazığ) jeolojisi raporu [Geology report of Uzundamar 1 and Uzundamar-2 mines (Guleman-Elazığ)]. Report No: 8278 MTA, Ankara (unpublished)
Pal T (2011) Petrology and geochemistry of the Andaman ophiolite: melt–rock interaction in a suprasubduction-zone setting. J Geol Soc 168(4):1031–1045
Parlak O (1996) Geochemistry and geochronology of the Mersin ophiolite within the eastern Mediterranean tectonic frame. PhD thesis, Terre and Environnement 6, University of Geneva, Switzerland
Parlak O (2006) Geodynamic significance of granitoid magmatism in the Southeast Anatolian Orogen: geochemical and geochronogical evidence from Göksun-Afşin (Kahramanmaraş, Turkey) region. Int J Earth Sci 95:609–627
Parlak O, Delaloye M (1996) Geochemistry and timing of postmetamorphic dike emplacement in the Mersin ophiolite (southern Turkey): new age constraints from $^{40}Ar/^{39}Ar$ geochronology. Terra Nova 8:585–592
Parlak O, Delaloye M, Bingöl E (1995) Origin of subophiolitic metamorphic rocks beneath the Mersin ophiolite, southern Turkey. Ofioliti 20(2):97–110
Parlak O, Delaloye M, Bingöl E (1996) Mineral chemistry of ultramafic and mafic cumulates as an indicator of the arc–related origin of the Mersín ophiolite (southern Turkey). Geol Rundsch 85:647–661
Parlak O, Höck V, Delaloye M (2000) Supra-subduction zone origin of the Pozantı-Karsantı ophiolite (Southern Turkey) deduced from whole rock and mineral chemistry of the gabbroic cumulates. In: Bozkurt E, Winchester JA, Piper J (eds) Tectonics and magmatism in Turkey and its surroundings, Geological Society special publications, vol 173. Geological Society, London, pp 219–234
Parlak O, Delaloye M, Demirkol C, Ünlügenç UC (2001) Geochemistry of Pliocene/Pleistocene basalts along the central Anatolian fault zone (CAFZ), Turkey. Geodin Acta 14:159–167

Parlak O, Höck V, Delaloye M (2002) The suprasubduction zone Pozantı-Karsantı ophiolite, southern Turkey: evidence for high-pressure crystal fractionation of ultramafic cumulates. Lithos 65:205–224

Parlak O, Höck V, Kozlu H, Delaloye M (2004) Oceanic crust generation in an island arc tectonic setting, SE Anatolian Orogenic Belt (Turkey). Geol Mag 141:583–603

Parlak O, Delaloye M, Kozlu H, Rizaoğlu T, Bağci U (2006) The petrography and the geochemistry of the tectono-magmatic units outcropped around the Baskil and Sivrice (Elazığ) regions. Project Report No: YDABÇAG-102Y041 Scientific & Technological Research Council of Turkey (TÜBITAK), Ankara

Parlak O, Rizaoğlu T, Bağci U, Karaoğlan F, Höck V (2009) Tectonic significance of the geochemistry and petrology of ophiolites in southeast Anatolia, Turkey. Tectonophysics 473(1–2):173–187

Parlak O, Karaoğlan F, Rızaoğlu T, Klötzli U, Koller F, Billor Z (2013a) U-Pb and $^{40}Ar/^{39}Ar$ geochronology of the Ophiolites and Granitoids from the Tauride Belt: implications for the evolution of the inner Tauride suture. J Geodyn 65:22–37

Parlak O, Çolakoğlu A, Dönmez C, Sayak H, Yildirim N, Türkel A, Odabaşı İ (2013b) Geochemistry and tectonic significance of ophiolites along the İzmir–Ankara–Erzincan Suture Zone in northeastern Anatolia. Geol Soc Lond Spec Publ 372:75–105

Pearce JA, Harris NBW, Tindle AG (1984) Trace element discrimination diagram for the tectonic interpretation of Granitic rocks. J Petrol 25:956–983

Pehlivan Ş, Duru M, Dönmez M, Ilgar A, Akçay AE, Erdoğan K, Özer D (2007) 1:100.000 Ölçekli Türkiye Jeoloji Haritaları, Balıkesir İ-19 Paftası [Geology maps of Turkey in 1:100.000 scale: I–19 sheet]. No: 96. MTA Publ (in Turkish with English abstract)

Perinçek D (1978) Çelikhan-Sincik-Koçali (Adıyaman) alanının jeolojik incelemesi ve petrol olanaklarının araştırılması [Geology and petroleum resources of Çelikhan-Sincik-Koçali (Adıyaman) region] PhD thesis, IU Science Faculty, Applied Geology Chair, İstanbul (in Turkish, unpublished)

Perinçek D (1989) Hakkari İli ve Dolayının Stratigrafisi, Yapısal Özellikleri, Petrol İmkanları [Stratigraphy, structural elements and petroleum resources of Hakkari region]. Report No: 2545. TPAO, Ankara (in Turkish, unpublished)

Pourteau A, Candan O, Oberhanslı R (2010) High-pressure metasediments in central Turkey: constraints on the Neotethyan closure history. Tectonics 29:TC5004

Proenza JA, Gervilla F, Melgarejo JC, Reve D, Rodríguez YG (1998) Ophiolitic chromitites from the Mercedita deposit (Cuba). Example of Al-rich chromites at the mantle-crust transition zone. Acta Geol Hisp 33:179–212

Rammlmair D (1986) Chromite in the Philippines and the tectonic setting of the host ophiolites: case examples Zambales and Palawan. In: Monography on chromite deposits. IGCP project 197, Theophrastus publications. pp 285–309

Reuber I, Juteau T, Whitechurch H (1984) Genese en cotexte transformant des ophiolites d'Antalya (Turquie). Bull Soc Geol Fr 26:945–954

Rice SP, Robertson AHF, Ustaomer T (2006) Late-Cretaceous-Early Cenozoic tectonic evolution of the Eurasian active margin in the central and eastern Pontides, northern Turkey. In: Robertson AHF, Mountrakis D (eds) Tectonic development of the Eastern mediterranean region, vol 260. Geol Soc, London, pp 413–445

Rice SP, Robertson AHF, Ustaomer T, İnan T, Tasli K (2009) Late Cretaceous–Early Eocene tectonic development of the Tethyan suture zone in the Erzincan area, eastern Pontides, Turkey. Geol Mag 146(4):567–590

Rızaoğlu T, Parlak O, Höck V, İşler F (2006) Nature and significance of Late Cretaceous ophiolitic rocks and its relation to the Baskil granitoid in Elazığ region, SE Turkey. In: Robertson AHF, Mountrakis D (eds) Tectonic development of the Eastern Mediterranean region, vol 260. Geol Soc, London, pp 327–350

Rızaoğlu T, Parlak O, Höck V, Koller F, Hames WE, Billor Z (2009) Andean-type active margin formation in the eastern Taurides: Geochemical and geochronogical evidence from the Baskil granitoid (Elaziğ, SE Turkey). Tectonophysics 473:188–207

Roberts G, Pearce D (2007) Hydrocarbon plays and prospectivity of the Levantine Basin, offshore Lebanon and Syria from modern seismic data. Geo Arab 12:99–124
Robertson AHF (1986a) Geochemistry and tectonic implications of metalliferous and volcaniclastic sedimentary rocks associated with late ophiolitic extrusives in the Hatay area, southern Turkey. Ofioliti 11:121–140
Robertson AHF (1986b) The Hatay ophiolite (southern Turkey) in its Eastern Mediterranean tectonic context: a report on some aspects of the field excursion. Ofioliti 11(2):105–119
Robertson AHF (2002) Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. Lithos 65:1–67
Robertson AHF (2004) Development of concepts concerning the genesis and emplacement of Tethyan ophiolites in the Eastern Mediterranean and Oman regions. Earth Sci Rev 66:331–387
Robertson AHF (2006) Contrasting modes of ophiolite emplacement in the Eastern Mediterranean region. Geol Soc Lond Mem 32:235–261
Robertson AHF (2007) Overview of tectonic settings related to the rifting and opening of Mesozoic ocean basins in the Eastern Tethys: Oman, Himalayas and Eastern Mediterranean regions. In: Karner G, Manatschal G, Pinheiro LM (eds) Imaging, mapping and modelling continental lithosphere extension and breakup, Geological Society special publications, vol 282. Geological Society London, pp 325–389
Robertson AHF, Dixon JE (1984) Introduction: aspects of the geological evolution of the Eastern Mediterranean. In: Robertson AHF, Dixon JE (eds) The geological evolution of the Eastern Mediterranean, vol 17. Geol Soc London, Sp Public. pp 1–74
Robertson AHF, Shallo M (2000) Mesozoic-Tertiary tectonic evolution of Albania in its regional Eastern Mediterranean context. Tectonophysics 316(2–4):197–254
Robertson AHF, Ustaömer T, Parlak O, Ünlügenç UC, Tasli K, İnan N (2006) The Berit transect of the Tauride thrust belt, Turkey: Late Cretaceous-Early Cenozoic accretionary/collisional processes related to closure of the Southern Neotethys. Asian J Earth Sci 27(1):108–145
Robertson AHF, Parlak O, Rizaoğlu T, Ünlügenç UC, İnan N, Tasli K, Ustaömer T (2007) Tectonic evolution of the South Tethyan Ocean: evidence from the Eastern Taurus Mountains (Elazığ region, SE Turkey). In: Ries AC, Butler RWH, Graham RH (eds) Deformation of the continental crust, vol 272. The Legacy of Mike Coward, Geological Society special publications. Geol Society, London, pp 231–270
Robertson AHF, Parlak O, Ustaomer T (2009) Melange genesis and ophiolite emplacement related to subduction of the northern margin of the Tauride–Anatolide continent, central and western Turkey. In: Van Hinsbergen DJJ, Edwards MA, Govers R (eds) Collision and collapse at the Africa–Arabia–Eurasia subduction zone, Geological Society special publications, vol 311. Geological Society, London, pp 9–66
Robertson AHF, Parlak O, Ustaömer T (2012a) Overview of the Palaeozoic–Neogene evolution of Neotethys in the Eastern Mediterranean region (southern Turkey, Cyprus, Syria). Pet Geosci 18:381–404
Robertson AHF, Parlak O, Ustaömer T (2012b) Interrelation of microcontinents and carbonate platforms in the Late Mesozoic-Early Cenozoic assembly of the Anatolian continent. In: Robertson AHF, Parlak O, Ünlügenç UC (eds) Geological development of the Anatolian continent, Geological Society special publications, vol 372. Geological Society, London
Rollinson P (2008) The geochemistry of mantle chromitites from the northern part of the Oman ophiolite: inferred parental melt compositions. Contrib Mineral Petrol 156:273–288
Rubatto D, Scambelluri M (2003) U-Pb dating of magmatic zircon and metamorphic baddeleyite in the Ligurian eclogites (Voltri Massif, Western Alps). Contrib Mineral Petrol 146:341–355
Rubatto D, Gebauer D, Fanning M (1998) Jurassic formation and Eocene subduction of the Zermatt-Saas-Fee ophiolites: implications for the geodynamic evolution of the Central and Western Alps. Contrib Mineral Petrol 132:269–287
Saccani E, Seghedi N, Nicolae İ (2004) Evidence of rift magmatism from preliminary petrological data on lower Triassic Mafic Rocks from the north Dobrogea Orogen (Romania). Ofioliti 29(2):231–241

Sarifakioğlu E, Özen H, Winchester JA (2009) Whole rock and mineral chemistry of ultramafic-mafic cumulates from the Orhaneli (Bursa) ophiolite, NW Anatolia. Turk J Earth Sci 18:55–83
Sarıfakıoğlu E, Sevin M, Dilek Y (2014) Türkiye Ofiyolit Envanteri [Ophiolite inventory of Turkey]. MTA Publ, Ankara (in Turkish)
Sarıkaya AR, Seyrek T (1976) Yeşilova – Tefenni peridotit Massifindeki krom ve nikel zenginleşmeleri prospeksiyon raporu [Report of the Cr-Ni enrichments in Yeşilova-Tefenni (Burdur) peridotite massif]. Report No: 5764. MTA (in Turkish, unpublished)
Sarp H (1976) Etude geologique et petrographique du cortege ophiolitique de la region situee au nord-quest de Yeşilova (Burdur-Turquie). These, Univ Geneve, 377p
Sayak H, Özen H, Çolakoğlu AO, Gültaşlı ÖF, Başta Ö (2009) Orhaneli (Bursa) Ofiyoliti ve Metalojenezi [Metallogeny of Orhaneli (Bursa) ophiolite]. Report No: 11121. MTA (in Turkish, unpublished)
Şenel M (1997a) 1/100.000 ölçekli Türkiye Jeoloji Haritaları, Isparta-K11 paftası [Geology of Turkey in 1:100.000 scale: Isparta K-11 sheet]. No: 11. MTA (in Turkish with English abstract)
Şenel M (1997b) 1:250.0000 Ölçekli Türkiye Jeoloji Haritaları No: 3 Antalya Paftası [Geology of Turkey in 1:250.000 scale: antalya sheet] (in Turkish with English abstract)
Şenel M (2004) Stratigraphic and structural features of Yeşilyaprak Nappe in Western Taurus Range and its comparision with the similar units in SE Anatolia and Northern Cyprus. Bull Min Res Explor 128:1–26
Şenel M (2007) 1:100.000 Ölçekli Türkiye Jeoloji Haritaları, Cizre M48 Paftası [Geology of Turkey in 1:00.000 scale: Cizre M-48 sheet]. No: 58 MTA (in Turkish with English abstract)
Şengör AMC, Yılmaz Y (1981) Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics 75:181–241
Sümer Y, Artan Ü (1983) Kışlacık mahallesi ve Alakan Köyü (Yüksekova/Hakkari) yöresinin krom etüdü [Cr-Prospection report of Kışlacık district and Alakan village (Yüksekova-Hakkari)]. Rep No: 7309. MTA (in Turkish, unpublished)
Sungurlu O (1974) VI. Region kuzey sahalarının jeolojisi [6th region: geology of North of the]. Report No: 871. TPAO. (in Turkish, unpublished)
Sungurlu O, Perinçek D, Kurt G, Tuna E, Dülger S, Çelikdemir E, Naz H (1985) Elazığ–Hazar–Palu alanının jeolojisi [Geology of Elazığ-Hazar-Palu region]. Bull Gen Direct Pet Aff 29:83–189 (in Turkish)
Tekeli O, Aksay A, Ertan İE, Işık A, Örgün BM (1981) Toros Ofiyolit Projeleri, Aladağ Projesi [Tauride ophiolite projects: Aladağ project]. Report No: 6976. MTA, (in Turkish, unpublished), Ankara
Tekeli O, Örgün BM, Işık A (1984) Geology of the Aladağ Mountains. In: Tekeli O, Göncüoğlu CM (eds) International symposium on the geology of the Taurus Belt, 1983. MTA, Ankara, pp 143–158
Ternek Z (1957) Adana Havzasının Alt Miyosen (Burdigaliyen) formasyonları; bunların diğer formasyonlarla olan münasebetleri ve petrol imkanları [Lower Miocene (Burdigalian) formations of Adana Basin and its relation with other formations and petroleum resources]. Bull Min Res Exp 49:48–66 Ankara (in Turkish)
Thayer TP (1960) Some critical differences between alpine – type and stratiform peridotite gabbro complexes. 21st International geological Congress, Copenhagen, Reports, vol 13, pp 247–259
Tilton GR, Hopson CA, Wright JE (1981) Uranium-lead isotopic ages of the Semail ophiolite Oman, with applications to Tethyan ocean ridge tectonics. J Geophys Res B 86:2763–2776
Topuz G, Göçmengil G, Rolland Y, Çelik ÖF, Zack T, Schmitt AK (2013) Jurassic accretionary complex and ophiolite from northeast Turkey: no evidence for the Cimmerian continental ribbon. Geology 41(2):255–258
Tremblay A, Meshi A, Bédard JH (2009) Oceanic core complexes and ancient oceanic lithosphere: insights from Iapetan and Tethyan ophiolites (Canada and Albania). Tectonophysics 473(1–2):36–52
Uçurum A, Koptagel O (2006) Main-component geochemistry and platinum-group element potential of Turkish chromite deposits, with emphasis on the Mugla area. Int Geol Rev 48:241–254

Uysal I, Zaccarini F, Sadıklar B, Bernhardt HJ, Bigi S, Garuti G (2009a) Occurrence of rare Ru–Fe–Os–Ir-oxide and associated platinum-group minerals (PGM) in the chromitite of Muğla ophiolite, SW-Turkey. N Jb Mineral (Abh) 185:323–333

Uysal I, Tarkian M, Sadıklar B, Zaccarini F, Meisel T, Garuti G, Heidrich S (2009b) Petrology of Al- and Cr-rich ophiolitic chromitites from the Muğla, SW Turkey: implications from composition of chromite, solid inclusions of platinum-group mineral, silicate, and base-metal mineral, and Os-isotope geochemistry. Contrib Mineral Petrol 158(5):659–674

Vergili Ö, Parlak O (2005) Geochemistry and tectonic setting of metamorphic sole rocks and mafic dikes from the Pınarbaşı (Kayseri) ophiolite, Central Anatolia (Turkey). Ofioliti 30:37–52

Warren CJ, Parrish RR, Waters DJ, Searl MP (2005) Dating the geologic history of Oman's Semail ophiolite: insights from U–Pb geochronology. Contrib Mineral Petrol 150:403–422

Yaliniz MK, Göncüoğlu MC (1998) General geological characteristics and the distribution of the Central Anatolian ophiolites. HU Earth Sci Bull 20:19–30

Yaliniz KM, Floyd P, Göncüoğlu MC (1996) Supra-subduction zone ophiolites of Central Anatolia: geochemical evidence from the Sarikaraman ophiolite, Aksaray, Turkey. Min Mag 60:697–710

Yıldız M, Balcı M, Sarıkaya A (1976) Burdur (Yeşilova-Tefenni) ve Denizli (Acıpayam) peridotit Massiflerinde krom – nikel prospeksiyonu [Cr-Ni prospecting report of Burdur (Yeşilova-Tefenni) and Denizli (Acıpayam) peridotite massifs]. Report No: 6336. MTA, (in Turkish, unpublished)

Yılmaz A (1981) Tokat ile Sivas arasındaki ofiyolitli karışığın içyapısı ve yerleşme yaşı [Inner structure of the ophiolitic melange and age of its emplacament]. Bull Geol Soc Turk 24(1):31–38 (in Turkish with English abstract)

Yılmaz Y (1984) Amanos Dağlarının Jeolojisi [Geology of Amanos Mountains]. Report No: 1920. TPAO, (in Turkish with English abstract)

Yılmaz A (1985) Yukarı Kelkit Çayı ile Munzur Dağları Arasının Temel Jeoloji Özellikleri ve Yapısal Evrimi [Basic geological characteristics and structural evolution of the region between the Upper Kelkit Creek and the Munzur Mountains]. Bull Geol Soc Turk 28(2):79–92 (in Turkish with English abstract)

Yılmaz Y, Tüysüz O (1984) Kastamonu-Boyabat-Vezirköprü-Tosya arasındaki Bölgenin jeolojisi [Geology of the Kastamonu-Boyabat-Vezirköprü-Tosya region]. Report No: 7838. MTA (in Turkish, unpublished)

Yılmaz A, Bedi Y, Uysal Ş, Aydın N (1997a) 1:100.000 ölçekli, açınsama nitelikli Türkiye Jeoloji Haritaları, Elbistan İ 23 paftası [Geology Maps of Turkey in 1:100.000 scale: İ-23 sheet] No: 50. MTA, (in Turkish with English abstract)

Yılmaz Y, Tüysüz O, Yiğitbaş E, Genç SC, Şengör AMC (1997b) Geology and tectonic evolution of the Pontides. In: Robinson AG (ed) Regional and petroleum geology of the Black sea and surrounding region, vol 68. AAPG, pp 183–226

Zaccarini F, Garuti G, Proenza JA, Campos L, Thalhammer OAR, Aiglsperger T, Lewis J (2011) Chromite and platinum-group elements mineralization in the Santa Elena ophiolitic ultramafic nappe (Costa Rica): geodynamic implications. Geol Acta 9(34):407–423

Zhou MF, Sun M, Keays RR, Kerrich RW (1998) Controls on platinum group elemental distributions of podiform chromitites: a case study of High-Cr and High-Al chromitites from Chinese orogenic belts. Geochim Cosmochim Acta 62(4):677–688