ABSTRACT: Two chromite occurrences have been found within the Meram-Çayırbağlı (Konya) Ophiolitic Complex. The occurrences are located at Helvacıbaba and Bacağınkoyak Tepe, and the complex is promising for large chromite orebodies. The chromites are formed in dunitic rocks of the Meram-Çayırbağlı Ophiolites. Chromite mineralization of >18.62 % (in weight) occurs in Helvacıbaba while the Bacağınkoyak Tepe have a minimum 35 % of Cr₂O₃. The major and trace element data of both occurrences indicate that the chemical composition of the chromite samples is mainly controlled by the Cr₂O₃ concentration.

Key words: Ophiolite, chromite, Meram-Çayırbağlı, Konya, Turkey

INTRODUCTION

The ophiolitic complexes of Turkey, cropping out in the Anatolian portion of the Alpine Orogenic Belt, cover an area of about 60,000 km². These complexes are discontinuously scattered all over the country. The ultramafic rocks as parental rocks of chromites occur mainly within the ophiolites. The emplacement of ophiolites in the Anatolian Peninsula is mostly related to Alpine Orogeny. They originated between the time intervals of Late Paleozoic and Cretaceous, but were emplaced, most likely at Late Cretaceous. Chromite grains are ubiquitously present in the ultramafic rocks of all the ophiolites of Turkey. The Meram-Çayırbağlı ophiolitic complex has long been known because it comprises one of the largest magnesite orebodies of Turkey and even Europe and Middle East. But the chromite occurrences within the complex have almost no attention by the authors despite their easily visible exposures in the field.

The Meram-Çayırbağlı ophiolitic complex is spread over 20 km x 10 km area in the central south-west of the country (south-west of Konya). The geological mapping has revealed that the thickness of the ophiolitic slides may reach up to 900 m (Zedef, 1994). The ophiolitic rocks were tectonically abduced during Maastrichtian time.
upon the Paleozoic and Mesozoic carbonates. However, there is no trace of contact metamorphism between the ophiolites and the other rocks. Tertiary conglomerates with magnesite pebbles and limestones unconformably overlie the ophiolites. Ophiolitic rocks comprise dunite, harzburgite, gabbro, troctolite and pyroxenite, but gabbro, troctolite and pyroxenite have a limited presence in the field. The dunit and harzburgite are serpentinized, carbonated and even silicified at most places. The ophiolitic rocks are strongly deformed and cataclastisized. Indication of strong deformation on ultramafic rocks can be seen at most of the ultramafic belts of Turkey (Zedef et al, 1994, Koçak et al., 2001; Döyen and Zedef, 2002).

The main aim of this paper is to report the existence of chromite occurrences (may be in economic interest) in the Meram-Çayırbağı ophiolites and present their some geological and geochemical features.

Chromite Occurrence in the Complex

Two small chromite orebodies have been observed in dunitic rocks of the Meram-Çayırbağı ophiolites. The one is at Helvacıbaba, the other is at Bacağınköy Tepe (Figure 1). For a detailed geological setting see Zedef, 1994. Reserve is unknown at both localities as the exploration programs centered on the magnesite deposits. But in the light of the field observations, a few tens of tons of chromite ores may be found in the occurrences. It is worth to stress the fact that the detailed explorations for chromite may possibly extend this tonnage up to thousands of tons of chromite since some chromite grains observed in the stream-beds of the area have similar textural features with the chromites described below.

In the Helvacıbaba, the chromite grains are distributed (as disseminated ore) in the groundmass of gangue minerals (mainly olivine). On the other hand, the Bacağınköyak

Figure 1. Location map of the Helvacıbaba (H) and Bacağınköy Tepe (B) chromite occurrences within the Meram-Çayırbağı ophiolitic complex (dashed area). The boundary of the ophiolitic complex is modified from Zedef (1994).
Tepe chromites have a massive character. With the exception of the textural differences, microscopic features of the chromitiferous samples are almost identical at both localities. Coarse to fine-grained subidiomorphic granular texture has been observed in the chromite samples under the reflected light. Extensive brecciation and granulation are well-developed in the chromite grains. Thus, highly angular or elongated fragments were produced. Both fractures and boundary of the grains were cemented either by olivine and/or by fine grains of chromite. Intense to mild fracturing without preferred orientation is a very common feature in all chromite samples.

**Geochemical Characteristics of Chromite Ores**

Four samples from Helvacıbaba and three samples from Bacağınkoyak Tepe chromite occurrences have been collected. The overall chemical composition of the disseminated ores of the Helvacıbaba and massive ores of the Bacağınkoyak Tepe is shown in Table 1. In this study, all analyses have been done in bulk samples (no treatment applied). Excepting Cr₂O₃, the major and trace element analyses have been performed on a conventionally used XRFS. For Cr₂O₃ analyses wet method was utilized. The trace element data of the Helvacıbaba chromite samples indicate that there is a considerable amount of Ni concentrations. The Ni concentrations of two samples are well over 2500 ppm while the other two have 1329 and 1434 ppm Ni respectively (Table 1). With the exception of the Ba, however, there is a negative correlation between Ni and other trace element contents of the samples (Figure 2).

<table>
<thead>
<tr>
<th>Major oxides</th>
<th>H-1</th>
<th>H-2</th>
<th>H-3</th>
<th>H-4</th>
<th>B-1</th>
<th>B-2</th>
<th>B-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr₂O₃</td>
<td>23.30</td>
<td>57.31</td>
<td>54.86</td>
<td>18.62</td>
<td>35.00</td>
<td>53.78</td>
<td>52.01</td>
</tr>
<tr>
<td>SiO₂</td>
<td>25.54</td>
<td>5.15</td>
<td>4.86</td>
<td>26.03</td>
<td>21.47</td>
<td>8.75</td>
<td>9.03</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.03</td>
<td>0.08</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>2.58</td>
<td>6.55</td>
<td>5.98</td>
<td>2.22</td>
<td>5.77</td>
<td>9.06</td>
<td>8.53</td>
</tr>
<tr>
<td>FeO*</td>
<td>7.70</td>
<td>10.28</td>
<td>10.19</td>
<td>7.48</td>
<td>10.85</td>
<td>10.36</td>
<td>11.41</td>
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<tr>
<td>MnO</td>
<td>0.14</td>
<td>0.16</td>
<td>0.15</td>
<td>0.13</td>
<td>0.16</td>
<td>0.18</td>
<td>0.19</td>
</tr>
<tr>
<td>MgO</td>
<td>40.41</td>
<td>20.05</td>
<td>23.86</td>
<td>45.11</td>
<td>26.27</td>
<td>18.36</td>
<td>17.89</td>
</tr>
<tr>
<td>CaO</td>
<td>0.12</td>
<td>0.20</td>
<td>0.11</td>
<td>0.08</td>
<td>0.02</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.82</strong></td>
<td><strong>99.78</strong></td>
<td><strong>100.4</strong></td>
<td><strong>99.7</strong></td>
<td><strong>99.58</strong></td>
<td><strong>100.61</strong></td>
<td><strong>99.2</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Trace elements</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>2688</td>
<td>1329</td>
<td>1434</td>
<td>2645</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Co</td>
<td>133</td>
<td>212</td>
<td>198</td>
<td>115</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Cu</td>
<td>11</td>
<td>24</td>
<td>30</td>
<td>6</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Zn</td>
<td>78</td>
<td>256</td>
<td>243</td>
<td>64</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Ba</td>
<td>268</td>
<td>58</td>
<td>50</td>
<td>67</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

* As total iron
n.a.- Not analysed

Note: The H indicates ‘Helvacıbaba’, B indicates ‘Bacağınkoyak Tepe’ chromite ores.
The chemical data indicates that the chromium contents of three samples are low (Between 18.62 and 35.00 %). These low values have possibly been influenced by the impurities of the samples as evidenced by the presence of high SiO$_2$ and MgO. However, there is an overall negative correlation between the chromium contents of the samples and the impurities such as SiO$_2$, Al$_2$O$_3$ and MgO. On the other hand, a positive correlation can be seen between the Cr$_2$O$_3$ and FeO. There has been no systematic changing between the Cr$_2$O$_3$ and other oxides (CaO, MnO and TiO$_2$). Ti, Mn and Ca are fairly uniformly distributed in chromites irrespective of the type of ore.

Major and trace element data of Meram-Çayırbağı chromites are comparable with many of the Alpine type chromites occurred in the Alpine Orogenic Belt (Formed prior to and during the Alpine Orogenesis). The chemical compounds of the Helvacıbaba and Bacağinkoyak Tepe chromites are even comparable to that of Early Proterozoic podiform chromites of Finland (Vuollo et al., 1995). These comparisons are subject of another paper and will be addressed elsewhere.

**DISCUSSION**

In an ultramafic terrane of the Alpine Orogenic Belt, large chromite occurrences or orebodies have generally little or no outcrops. This is also true for stratiform chromite deposits. Scoon and Teigler (1995) have proved, by tracing a little chromitiferous outcrop the existences of a large chromite reserve in the Eerste Geluk (Bushveld Complex, South Africa). The observed outcrops of chromite occurrences in the Meram-Çayırbağı Ophiolitic Complex indicate, at least, the existence of potentially economic ore reserves. Exploration programs for chromite may reveal the presence an “ore-body” in the region. Discovery of chromitiferous ore body (if any) may be very important as the Central Anatolia is relatively poor in chromite deposits with respect to other parts of the country. As mentioned previously,
the chromite occurrences in the Meram-
Çayırbaşı have a minimum 18.5 % Cr₂O₃
grade. This is economically mineable grade since
Pakistani (Ahmed, 1986) and Greek (Economou
et al. 1986) ores are being mined in around this
grade. However, our investigations show that,
in general, the Cr₂O₃ contents of the
Helvacıbaba and Baçağınköyak Tepe chromite
occurrences are well over 20 % (Table 1).

The chemistry of chromites, collected from
Helvacıbaba and Baçağınköyak Tepe
occurrences, displays that there is a keen
relationship between the Cr₂O₃ and other
major oxides such as SiO₂ and MgO. This is
also true for Cr₂O₃ and trace elements,
although the relationship between Cr₂O₃ and
minor elements is very often interpreted as
contradictory (Stowe, 1994). The chemistry of
Baçağınköyak Tepe massive ores is very similar
although little differences may occasionally be
observed. This is also the case for the
disseminated ores of Helvacıbaba. These
observations brought about the conclusion that
the chemistry of chromites depends mainly on
the concentration of Cr₂O₃ in the samples. As
the chromite ores of Meram-Çayırbaşı
ophiolites have extremely high Ni, the recovery
of Ni and other oxides could be possible from
chromite ore (Rakhasia et al. 2003; Bodas et al.
2002).

In some of the chromitiferous ultramafics,
for instance Eretria (Greece), chromite
occurrences have been found in accordance
with sulfides (Economou et al. 1986). According
to Economou and Naldrett (1984), sulfides with
chromite indicate that there is a low-level
hydrothermal system during mineralization of
both chromite and sulfides. The formation of
PGE-rich sulfides in chromitiferous layered
intrusions of the Bushweld complex is
attributed to upward migrating hydrothermal
fluids by Ballhaus and Stumpf (1986) and
Boudreau and McCallum (1992). The lack of
sulfide mineralization in the Meram-Çayırbaşı
ophiolitic complex points to the absence of any
hydrothermal activity during chromite
mineralization although there must be a low-
level extensive hydrothermal alteration (after
the chromite mineralization) during the
magnesite formation in the field (Zedef et al, 1994).

CONCLUSIONS

There are two observed chromite
occurrences in the Meram-Çayırbaşı (Konya-
Turkey) Ophiolitic Complex which is one of the
discontinuously scattered numerous ophiolitic
masses of Turkey. There has been no
exploration program for chromite in the region.
By a detailed study for chromite, large,
economically profitable chromite occurrences
and/or deposits may be found. Such a
discovery may be very important as the Central
Anatolia is relatively poor in chromite
formations.

The chromite ores of Helvacıbaba are found
as "disseminated ore type" while the
Baçağınköyak Tepe's chromites are of "massive"
character. Microscopic features of both
Helvacıbaba and Baçağınköyak Tepe chromites
are almost identical, despite their macroscopic
differences.

In the light of major and trace element
data of Helvacıbaba and Baçağınköyak Tepe
chromites, the chemistry of the ore is
mainly controlled by the content of Cr₂O₃.
The chromite ores have no trace of
hydrothermal alteration, although there has
been low-level and pervasive
hydrothermally driven magnesite
mineralization (Zedef, 1994) after the
chromite formation.

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