Investigation of Usability as Industrial Raw Material of Olivine Occurrences: A Case Study from Gelendost - Isparta, Southwestern Turkey

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Abstract. Olivine occurrences are located in the northwest of Madenli and Eğirler villages in Gelendost-Isparta, Southwestern Turkey. The aim of this study is to investigate usability as an industrial raw material of olivine formations in the peridotite. For this purpose, geological, mineralogical and geochemical properties of olivine-rich rocks outcropping in the field were examined. Allochthonous units belonging to Beyşehir-Hoyran Nappes are formed in the Upper Eocene settlement aged Şarkikaraağaç Ophiolites, the Upper Cretaceous Eğirler Formation that contains wild flysch, and the Upper Triassic Deliktas Formation that consists of recrystallized massive limestone. The Anamas-Akseki Autochthonous units are the Jurassic-Cretaceous Hacalabaz formation, which consists of dolomite and limestone, the Neogene deposits and the Quaternary alluvium. Harzburgite and dunite are observed in peridotite at the bottom of Şarkikaraağaç Ophiolite. They are dominant rocks of olivine occurrences in the field and include mainly olivine, enstatite, stockwork and vein magnesite, and locally chromite. The concentrations of major oxides for harzburgite samples vary between 41.98 and 44.59% SiO₂, between 41.32 to 45.74% MgO, and between 8.75 and 9.82% Fe₂O₃. The samples ranged from 0.1-4.50% loss on ignition of significance for their usability. Major oxide contents and loss on ignition values of olivine-rich harzburgite samples in the study area partly comply with the standard values that have been determined to be suitable for usage in industry. Consequently, olivine occurrences in the study area are used as olivine sand in industry.

1. Introduction

Olivine is a magnesium-iron silicate mineral formed in the depths of the upper mantle. It is found in the most ultrabasic and basic rocks with low silica content. Olivine minerals have a very different use because of their superior physical and chemical properties. For example; they are used in making pressure cookers from the refractory brick-making due to the high melting temperature, in the cleaning of rusty surfaces for a high hardness and resistance, as fertilizer soil with Fe and Mg, and as jeweler due to their rare green crystals.

The world olivine production is mostly in Norway, Japan, Spain, South Korea, Turkey, China, and Taiwan. Ultrabasic rocks are widely outcropped in Turkey. Olivine is produced from the Adana-Kızilyüksek, Elazığ-Kef, Bursa-Orhaneli, Antalya-Akseki, Konya-Derebucak, and Isparta-Gelendost areas. The olivine occurrences are situated in an area of about 20 km² between the Madenli and Eğirler villages of Gelendost-Isparta, Southwestern Turkey (figure 1). This study contains usability as an industrial raw material of olivine formations in the peridotite within Şarkikaraağaç Ophiolites. For this, geological, mineralogical and geochemical characteristics of olivine-rich rocks in the field were
researched. Researches associated with olivine have been conducted in previous years in the study area and in Turkey [2], [3, 4], [5], [6], [7], [8], [9].

Figure 1. Regional geological and location map of the study area [1]

2. Method of investigations
Thin sections of fifteen harzburgite samples taken from peridotite in the field were prepared in the laboratory of the Geological Engineering Department at the Süleyman Demirel University, Turkey.
Their determinations were carried out under a polarizing microscope in the Research and Application Center’s Geothermal Energy, Groundwater, and Mineral Resources of same university. To determine the usage properties of olivine in industry, the contents of major oxides were analyzed by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method in ACME Labs, Canada.

3. Results

3.1. Geology of olivine occurrences

Lithological units in the study area are observed as allochthonous and autochthonous settlements in the Anamasdağ Section. The allochthonous units are the Upper Eocene settlement aged Şarkikaraağaç Ophiolites, the Upper Cretaceous aged Eğirler formation consists of wild flysch including different originated blocks, and the Upper Triassic aged Deliktaş formation is composed of recrystallized massive limestone. The autochthonous units are the Jurassic-Cretaceous Hacalabaz formation, which consists of dolomite and limestone, Neogene aged deposits and Quaternary aged alluvium (figure 1).

Olivine occurrences in the study area are located in Şarkikaraağaç Ophiolites belonging to Beyşehir-Hoyran Nappe. The ophiolites consist of ophiolitic complex, metamorphic basement and peridotite. They are mainly composed of harzburgite and dunite, and there is diabase, pyroxenite and pegmatitic gabbro within them. The ophiolite was called as Krızldağ Ophiolite by [10] in Şarkikaraağaç, and Şarkikaraağaç Ophiolites by [5] in the Şarkikaraağaç area. These rocks show extension in an area of 20 km² and have NW-SE direction in the field (figure 1). The olivine-rich peridotites have colors of greenish-yellow and brownish-purple in the field. They became quite altered and have lost their primary features. The peridotites present regular-irregular fractured, locally brecciated structure, and often serpentinized. In the study area, they have been worked by private companies (figure 2).

3.2. Mineralogy

All the samples of thin sections were identified as harzburgite. The harzburgite contains enstatite and olivine as dominant minerals, also in places chromites. The serpentinization is partially observed in their fractures and along the edges and cleavages of olivine minerals and enstatite. Also, chromite occurrences are followed in the sections. There are extensions along certain directions in olivine minerals. The deformation curves were seen in olivine minerals within harzburgite.

3.3. Geochemistry

Fifteen samples were collected from peridotite of ophiolite series in the study area. They were carried out for major oxides and the analysis results are presented in table 1.

The samples are defined as harzburgite according to the determinations of the polarizing microscope. The major oxide contents of the harzburgite samples vary between 41.98-44.59% SiO₂, 8.75-9.82% Fe₂O₃, 41.32-45.74% MgO, 0.15-1.27% CaO, 0.10-1.11% Al₂O₃, and 0.387-0.482% Cr₂O₃. Other oxides (Na₂O, K₂O, TiO₂ and P₂O₅) could not be measured due to being below the detection limits. The loss on the ignition values (LOI) ranged from 0.10-4.50% (table 1). Al₂O₃ values are generally below 1%, and slightly over 1% in some samples. LOI values are usually between 0.1-2.8% except for the DK1-3 (4.5%) and DK2-1 (3%) samples (table 1).

3.4. Usage properties of olivine

Comparison with standard values and other olivine deposits of geochemical analysis results in the studied olivine occurrences for usage are given in table 2. The analysis results were interpreted to determine the usage properties of olivine samples in the study area. Although SiO₂, MgO and Fe₂O₃ contents vary slightly over standard values they are used as olivine sand. LOI values for usability also ranged over standard values in the DK1-3, DK2-1, DK2-3, and DK4-2 samples. Considering all the samples in the study area, olivine occurrences are suitable for use in industry because they partly comply
with the standard values for usability in industry. Consequently, the olivine occurrences are used as olivine sand in industry after crushing, screening, grading and packaging processes (table 2).

Figure 2. Field views of olivine occurrences in open pits in the study area

4. Conclusions
Olivine occurrences are located within peridotites in the Upper Eocene settlement aged Şarkikaraağaç Ophiolites depending on the Beyşehir-Hoyran Nappes. The mineralogical composition indicates that the rocks are generally composed of harzburgite and locally serpentinized. The rocks contain olivine, enstatite and chromite. It was concluded as suitable for use in industry because the major oxide contents and loss on ignition values of olivine partly comply with the standard values for usage in industry. Consequently, the olivine occurrences are used as olivine sand in industry after crushing, screening, grading and packaging processes.
Table 1. Major oxide contents (%) of harzburgite samples in the study area

| Sample Number | SiO₂ | Al₂O₃ | Fe₂O₃ | MgO | CaO | Na₂O | K₂O | TiO₂ | Sc (ppm) | LOI | TOT/C | TOT/S | Total |
|---------------|------|-------|-------|-----|-----|------|-----|------|----------|-----|-------|-------|-------|
| DL DK1-1      | 0.01 | 42.25 | 0.1   | 0.35| 0.38| <0.01| <0.01| <0.01| <0.01   | 5.1 | 1.7   |       |       |
| DK1-2         | 0.01 | 42.76 | 0.1   | 0.35| 0.18| <0.01| <0.01| <0.01| <0.01   | 7.6 | 1.2   |       |       |
| DK1-3         | 0.01 | 43.99 | 0.1   | 0.11| 0.18| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK1-4         | 0.01 | 43.99 | 0.1   | 0.93| 0.93| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK2-1         | 0.01 | 42.76 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK2-2         | 0.01 | 43.48 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK2-3         | 0.01 | 43.01 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK3-3-OC      | 0.01 | 43.69 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK4-1         | 0.01 | 43.57 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK4-2         | 0.01 | 44.17 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK4-3         | 0.01 | 43.62 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |
| DK4-4         | 0.01 | 44.07 | 0.1   | 0.99| 0.83| <0.01| <0.01| <0.01| <0.01   | 7.5 | 1.3   |       |       |

Table 2. Comparison with standard values and other olivine deposits of geochemical analysis results (%) in the studied olivine occurrences for usage modified from [9].

| Deposit Name          | MgO   | SiO₂   | Fe₂O₃ | CaO  | Al₂O₃ | LOI  |
|-----------------------|-------|--------|-------|------|-------|------|
| Aaheim (Norway)       | 49.00 | 42.60  | 6.00  | 1.80 | 1.00  | 0.60 |
| Norddal (Norway)      | 48.00 | 41.50  | 7.60  | 0.50 | 1.60  | 2.00 |
| Lefdal (Norway)       | 47.49 | 40.41  | 7.5-8.5 | 1-1.50 |       |
| Hokkaido (Japan)      | 47.00 | 42.00  | 2.00  | 0.20 | 1.00  | 0.70 |
| Carolina (USD)        | 50.50 | 40.10  | 6.70  | 0.20 | 1.00  | 0.70 |
| Washington (USD)      | 49.40 | 41.20  | 7.10  | 0.20 | 1.80  | 0.70 |
| St. Stefan (Austria)  | 48.00 | 41.00  | 10.50 |      |       |      |
| Handol (Sweden)       | 45.00 | 42.50  | 7.5-9.00 | 0.80 | 2.00  | 3.00 |
| Jamaica               | 50.05 | 41.10  | 8.60  |      |       |      |
| Kızıldağ (Akseki-Antalya, Turkey) | 50.25 | 37.50  | 8.30  | 0.40 | 1.80  |      |
| Beleğiz (Sarkikaraağaç-Isparta, Turkey) | 36.22-39.52 | 43.86-47.67 | 7.70-9.19 | 0.34-1.43 | 0.21-1.30 | 4.00-7.90 |
| Madenli (Gelendost-Isparta, Turkey) | 41.30-45.74 | 41.98-44.59 | 8.75-9.82 | 0.15-1.27 | 0.10-1.11 | 0.10-3.00 |

(The study area)

| Standard values       | > 46.00 | 38.00-42.00 | 7.00-8.00 | < 2  |

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