OLIVINE FROM NORTHERN CALIFORNIA SHOWING PERFECT CLEAVAGE*

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Abstract

Olivine showing perfect cleavages on the (010) and (100) crystal planes is described from a dunite near Dunsmuir, Siskiyou County, California. Because of its striking resemblance to pyroxene both in hand specimen and thin section, previous workers have misidentified the mineral as pyroxene, and the rock which contains it as pyroxenite or peridotite.

Introduction

Unusual olivine showing perfect cleavages parallel to the (010) and (100) crystal planes was identified in dunite from the vicinity of the Little Castle Creek chromite mine, known also as the Castle Crags or Brown mine, in the Siskiyou Mountains of northern California. Specimens for detailed study were collected on the south side of Little Castle Creek canyon about two miles southwest of Dunsmuir, near the boundary of Shasta and Siskiyou Counties, during the winter of 1940–41. The work on the olivine grew out of a geological investigation of the chromite deposits of the Little Castle Creek area by the Federal Geological Survey. A summary of the results of this investigation, with maps of the surface and underground geology, was released to the public in 1943.[1]

Previous Work

The cleavages of the olivine have confused previous workers in the area, who identified the mineral as pyroxene and the rock in which it occurs as pyroxenite or peridotite. Diller[2] states, "The country rock of the chromite ore body (Little Castle Creek mine) is in part peridotite but chiefly pyroxenite, which exhibits large cleavage surfaces often several feet in extent." J. E. Allen[3] also mentions the presence of peridotite and pyroxenite from the vicinity of the Little Castle Creek mine. No pyroxene has been identified by the author in a suite of more than 50 thin sections prepared from the ultramafic rocks of this area, so that it may be presumed that Diller and Allen were referring to rocks containing cleavable olivine. On basal sections the extinction of olivine will be parallel to the

* Published by permission of the Director of the Geological Survey, U. S. Department of the Interior.

[1] Hawkes, H. E., Chromite deposits of Little Castle Creek area, Shasta and Siskiyou Counties, Calif.: *U. S. Geological Survey*, Strategic Mineral Investigations, Preliminary maps, Press Notice released August 6, 1943.

[2] Diller, J. S., Chromite: *U. S. Geol. Survey, Min. Res.* (**1916**), pt. 1, 29.

[3] Allen, J. E., Geological investigation of the chromite deposits of California: *Calif. Jour. Mines and Geol.*, **37**, 129–132 (1941).

cleavages (010) and (100), whereas in pyroxene it will be symmetrical with respect to the cleavage (110). This simple method of distinguishing the two minerals has apparently been overlooked by the workers who misidentified the mineral.

The literature contains many references to the chromite deposits of the area.[4] The only report touching on the general geology is by C. V. Averill,[5] who includes a map showing the areal geology of the part of the Shasta quadrangle within which the area in question lies.

Olivine showing well-developed cleavages has been described in dunite from Buck Creek, North Carolina, by Pratt and Lewis.[6] They say, "The olivine is colorless in thin section and never shows crystal boundaries. It is generally cracked irregularly, particularly in the beginning of the change to serpentine. It also frequently exhibits well-developed parallel cracks representing the brachypinacoidal cleavage, and sometimes distinct basal cleavage, as well. In a basal section, cleavage parallel to the macropinacoid can often be seen also. The grains usually average from 0.5 mm. to 1 mm. in diameter, though isolated individuals of 5 mm. to 6 mm. are sometimes seen."

Geology and Petrography of the Dunite

The dunite at Little Castle Creek is part of a larger mass which extends over a considerable area south and southwest of Dunsmuir, as shown on the geologic map of the Shasta quadrangle by Averill.[7] The regional structure is complicated by intrusions of granodiorite and gabbro which are believed to be later than the dunite.

Although part of the dunite of the Little Castle Creek area is composed of olivine that shows very conspicuous cleavage, a large part is also made up of normal olivine. Time did not permit a study of the regional distribution of these two types of olivine, although such an investigation would be highly desirable. Olivine showing similar perfect cleavages was

[4] Diller, J. S., Chromite: *U. S. Geol. Survey, Mineral Res.* (**1916**), Pt. 1, 28–30.

Diller, J. S., Chromite in the Klamath Mountains, California and Oregon: *U. S. Geol. Survey, Bull.* **725,** 20–22 (1921).

Johnston, W. D., Nodular, orbicular, and banded chromite in northern California: *Econ. Geol.*, **31,** 417–427 (1936).

Bradley, W. W., *et al.*, Manganese and chromium in California: *Cal. State. Min. Bur., Bull.* **76,** 183–188; 191–193 (1918).

Allen, J. E., *op. cit.*

[5] Averill, C. V., Preliminary report on the economic geology of the Shasta quadrangle: Mining in California; *California, Dept. Nat. Res., Div. Mines,* **27,** 17–24; 27 (1931).

[6] Pratt, J. H., and Lewis, J. V., Corundum and the peridotites of North Carolina: *North Carolina Geol. Surv.*, **1,** 73 (1905).

[7] Averill, C. V., *op. cit.*

noted at the Lucky Strike chromite prospect, about four miles west-southwest of the Little Castle Creek area; it is possible, therefore, that cleavable olivine is widely distributed in the dunite.

Megascopic Appearance

On hand-specimen or outcrop surfaces the olivine cleavage, where well developed, gives the rock a very conspicuous sparkling appearance, similar to that of pyroxenite, anorthosite, or coarse-grained marble. Typical hand specimens of the rock were, in fact, frequently called anorthosite by experienced petrographers. With a hand-lens, cleavage in two directions at right angles to one another can be distinguished in many crystals. Weathered surfaces commonly are smooth and show the characteristic buff or buckskin color of dunites, which is the result of the oxidation of the iron contained in the olivine. On fresh, unweathered surfaces the rock is generally a deep green to medium gray.

Texture

In thin section, the Little Castle Creek dunite is seen to be made up of aggregates of olivine grains in subparallel orientation. The aggregates commonly range in size from 10 mm. to 40 mm., and the individual grains within the aggregates from 0.05 mm. to 4 mm. In a hand specimen the aggregates are easily mistaken for homogenous crystals. Diller was probably referring to these large aggregates when he spoke of "large cleavage surfaces often several feet in extent." The texture is allotriomorphic, and the individual olivines commonly show polygonal outlines.

The aggregate texture is tentatively believed to be the result of crushing of original large olivine crystals, accompanied by slight rotation of the fragments.

Fabric

In hand specimens of the dunite, the olivine cleavages appear as brilliantly reflecting surfaces, and hence can be used as a qualitative guide to the rock fabric. In certain localities the crystal aggregates appear to be statistically oriented, as seen by the subparallel arrangement of the major cleavage surfaces. This orientation gives the rock a planar structure and in places even a moderately well-defined cleavage or fissility. This is apparently identical to structures described by Turner.[8] Ross

[8] Turner, F. J., Preferred orientation of olivine crystals in peridotites: *Trans. Royal Soc., New Zealand*, **72**, 288–290 (1942).

and Thayer have also found a similar structure in very coarse-grained dunite southwest of the Woods mine in Lancaster County, Pennsylvania.[9] It is believed that systematic regional mapping of this foliation in the Little Castle Creek area is desirable, as it would be necessary for a complete picture of the structural petrology of the dunite mass. A regional fabric analysis of an area of equal extent in the average, non-fissile ultramafic mass would require the preparation of a prohibitive number of orientation diagrams.

Accessory Minerals

Accessory chromite in rounded grains up to 1 mm. occurs throughout the dunite, but rarely makes up more than one per cent of the rock. No pyroxenes were found in the dunite.

Secondary Minerals

Serpentine is present in a few of the thin sections examined and rarely makes up as much as 50 per cent of the total volume of the rock. Bladed chlorite is developed along crystallographic directions of many olivines, and magnetite, talc, carbonates, and fine stringers of chrysotile are locally present. In the zone of weathering, red iron oxides have been produced by breakdown of the olivine.

Mineralogy of the Olivine

Twinning and Undulatory Extinction

Twinning on the (100) composition plane is common in the dunite which carries cleavable olivine. This is identical in appearance to that figured by Rogers and Kerr.[10]

Undulatory extinction of olivine, resembling that in the quartz of strained quartzites, was observed in some of the specimens studied. In the Little Castle Creek mass it appears to be confined to dunite containing cleavable olivine, but it is not everywhere present. No correlation could be made between the prevalence of twinning and the degree to which undulatory extinction had been developed.

Cleavages

The best cleavage is normal to X, or parallel to (010); the other principal cleavage is normal to Z, parallel to (100). Cleavages parallel to (001)

[9] Ross, C. S., and Thayer, T. P., personal communications.

[10] Rogers and Kerr, *Thin-section Mineralogy*, McGraw-Hill Book Co., p. 294 (1942).

and (110) were observed in a very few grains. Several other apparent cleavages opened up during the grinding of the slides but could not be definitely correlated with simple crystal planes.

FIG. 1. Photograph of hand specimen of dunite from Little Castle Creek. White areas are caused by reflection of light from olivine cleavage surfaces. Natural size.

Optical Properties

As far as could be determined, the optical properties of cleavable olivine are identical with those of normal olivine collected from the same general area. Miss J. J. Glass determined the optical properties of one specimen of cleavable olivine with these results:

$\alpha = 1.649$ $\beta = 1.666$ $\gamma = 1.684$
2V close to 90°, dispersion noticeable.

Clarence S. Ross found the optical properties of a specimen to be as follows:

$\alpha = 1.650$ $\gamma = 1.683$
Axial angle not measured, but is near 80°.

Chemical Composition

A sample taken from the specimen by Miss Glass and analyzed in the Geological Survey laboratories was described by Michael Fleischer as follows:

"The thin section examined showed that the sample contained chlorite, introduced along crystallographic directions of the olivine, and also a little magnetite. The chlorite was removed by repeated treatments with methylene iodide, after which the magnetite was removed with the electromagnet."

		Molecular Ratio		
SiO_2	40.84	.680	or	1.00
MgO	50.27	1.247		
FeO	8.18	0.114	1.366 or	2.01
NiO	0.19	0.003		
MnO	0.17	0.002		
Fe_2O_3	0.13			
Al_2O_3	0.19		91.3 mol. % Mg_2SiO_4	
TiO_2	0.04		8.7 mol. % Fe_2SiO_4	
H_2O	0.37*			
	100.38			

* Includes a little methylene iodide.

$D_4^{25} = 3.30$

X-ray Pattern

X-ray diffraction patterns of cleavable olivine prepared by W. E. Richmond of the Survey are identical with similarly prepared photographs of ordinary olivine, and show no similarity to photos of standard ortho- and clino-pyroxene.

Significance of the Cleavage

The cleavages are believed to have been developed early in the metamorphic history of the rocks, or possibly during the crystallization of the olivine. The deformed cleavages shown in Fig. 2c indicate deformation of the olivine after the cleavage was developed. The bladed chlorite which replaces the olivine along cleavages and other crystallographic directions seems to be mainly associated with, but not restricted to dunite containing the highly cleaved olivine. The prevalence of chlorite along rectilinear lines might be attributed entirely to emplacement controlled by crystal structure, but the number of cleavages free of chlorite suggests that they developed before the chlorite came in.

No satisfactory evidence bearing on the origin of the cleavage was discovered. The development of cleavage may be related in some way to the absence of serpentine in the Little Castle Creek dunite. Serpentine-free dunite may yield to stress by an accentuation of olivine cleavages in contrast to ordinary serpentine-bearing ultramafic rocks which fail by micro-shearing of serpentine zones. Simple cataclastic or protoclastic crushing however, can not invariably produce cleavage in olivine, as intensely crushed olivine in fresh dunite from the Twin Sisters Mountains in Washington has no better cleavage than ordinary olivine.[11]

[11] Thayer, T. P., Personal communication.

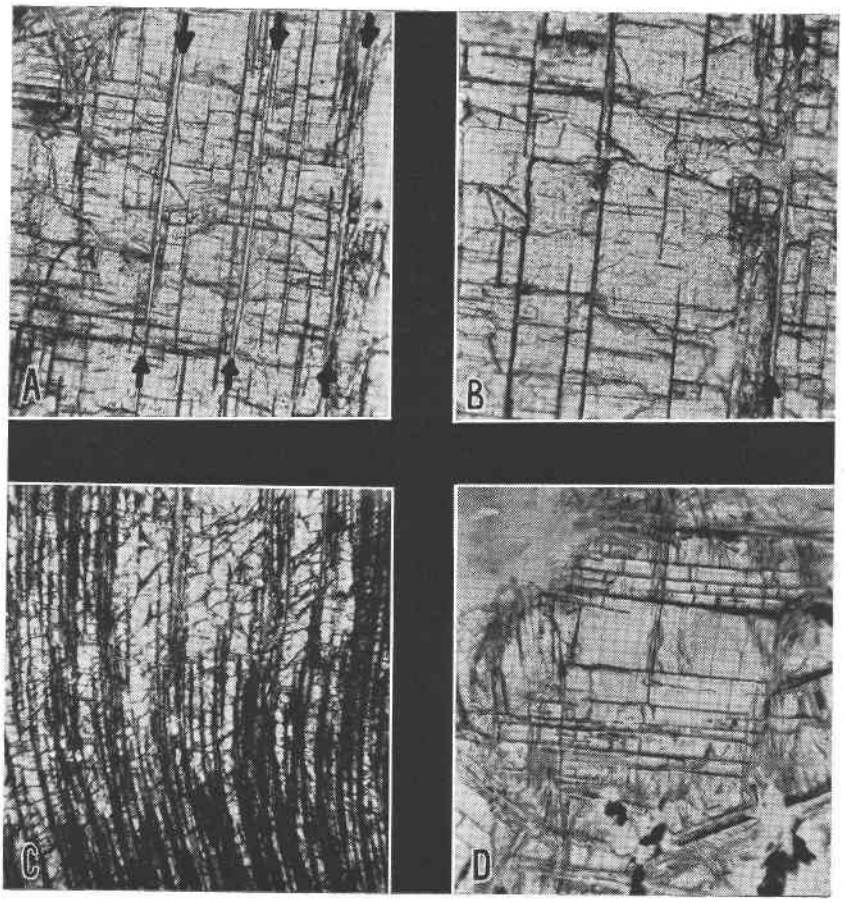

FIG. 2

A. Photomicrograph showing rectangular cleavage pattern, with chlorite (arrows) along some cleavages, Little Castle Creek area. Plain light, ×28.

B. Photomicrograph showing rectangular cleavage pattern in another grain of same slide, and greater development of chlorite (arrows) in zone along one side. Note that although chlorite occurs in all of major cleavage cracks, it does not appear to be present in finer cracks. Plain light, ×28.

C. Photomicrograph showing chlorite along bent cleavages in olivine in partly altered dunite, Little Castle Creek area. All of olivine in field is part of a single grain. Plain light, ×28.

D. Photomicrograph showing cleavage in olivine from dunite mass on Buck Creek, N. C. Note development of chlorite along wider cracks. Opaque mineral is secondary magnetite. Collected by C. S. Ross. Plain light, ×28.

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