24. Thermal Expansion of Olivine.

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Simply labeled "Egypt" as the locality of the olivine crystal used for the present experiment, its proper place and the mode of occurrence cannot be exactly known, but its chemical and optical properties are practically the same as those of the crystal from the island Gt. Johann in the Red Sea, described by J. Couyat.¹⁾

Physical properties.—The crystal is so large as to measure 5 cm. in length and 4 cm. in width, but no crystal face can be seen. The marginal part of the crystal is traversed by dark reddish striations produced by decomposition along the partings through the fresh part of a light yellowish green colour, while the inner part is free from this secondary material. Under the microscope, the material is quite fresh and contains a small quantity of minute glass globules with or without magnetite in them.

The three principal refractive indices of the crystal for sodium ray, measured by a total reflectometer, are

$$\alpha = 1.654 \quad \beta = 1.671 \quad \gamma = 1.690.$$

The specific gravity measured by a Westphal's balance is 3.33 at 4° C.

Chemical composition.—

The result of the chemical analysis made for the fresh part of the crystal is given in Table I. For comparison, the chemical composition of the olivine from St. Johann, given by Couyat, is shown in parallel in the table. From the present analysis, the following proportion can be obtained:

TABLE I.

	Weight %.		Mol. prop.	
	a	b	a	b
SiO ₂	40.06	41.3	0.6677	0.688
Al ₂ O ₃	0.69	0.0	0.0068	—
Fe ₂ O ₃	2.34	—	0.0146	—
FeO	7.69	9.0	0.1068	0.125
MnO	0.08	0.8(+ NiO)	0.0011	0.011
MgO	48.96	48.9	1.2240	1.222
CaO	0.04	—	0.0007	—
H ₂ O+	0.17	0.15	0.0139	0.0083
H ₂ O—	0.25	—	—	—
Total	100.28	100.15	—	—

1) Bull. de la Soc. Franç. de Min., 1908, 31 (341-349).

Using the cell dimensions of olivine given by Bragg and Brown, the chemical composition and the density determined by us, the number of the molecule indicated as $(\text{MgFeMn})_2\text{SiO}_4$ is 4.

Thermal expansion:—The linear thermal expansions of the olivine crystal in three mutually perpendicular directions, corresponding to the elasticity axes X, Y and Z determined optically, were measured with the same method applied for other minerals already published. The measurements were made for two specimens cut from a crystal for two different temperature ranges, one from 20°C to 600°C and the other from 20°C to 1000°C. The results are given in Table II. As is seen in the table, the two sets of the experimental results along the three principal optical directions are practically equal to each other for temperatures from 20°C to 600°C within the experimental error, while if we compare the values obtained experimentally in the temperature range 20°C—1000°C and those obtained by calculation from the formulae (1) which were obtained from the experimental results for

TABLE II.

Thermal expansion of olivine.

Temp. in °C	Linear expansion in %.									Vol. exp. in %.
	Z=a-axis			X=b-axis			Y=c-axis			
	Sp. 1	Sp. 2.		Sp. 1	Sp. 2.		Sp. 1	Sp. 2.		Sp. 2
	obs.	obs.	calc.	obs.	obs.	calc.	obs.	obs.	calc.	calc.
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.01	0.01	0.02	0.03	0.02	0.03	0.02	0.02	0.03	0.08
100	0.04	0.04	0.04	0.08	0.07	0.08	0.07	0.07	0.07	0.19
50	0.07	0.07	0.07	0.12	0.12	0.13	0.12	0.12	0.12	0.32
200	0.10	0.10	0.10	0.18	0.18	0.18	0.18	0.17	0.17	0.45
50	0.15	0.13	0.14	0.24	0.23	0.23	0.24	0.22	0.23	0.60
300	0.18	0.17	0.17	0.29	0.29	0.28	0.29	0.28	0.28	0.73
50	0.22	0.21	0.21	0.36	0.34	0.34	0.36	0.34	0.34	0.89
400	0.26	0.25	0.24	0.43	0.40	0.40	0.42	0.40	0.40	1.04
50	0.31	0.29	0.28	0.49	0.46	0.46	0.48	0.46	0.46	1.20
500	0.35	0.33	0.33	0.56	0.51	0.52	0.55	0.52	0.52	1.37
50	0.39	0.37	0.37	0.65	0.58	0.58	0.62	0.58	0.59	1.54
600	0.43	0.41	0.42	0.74	0.64	0.64	0.68	0.65	0.65	1.71
50	0.46		0.46	0.81		0.71	0.74		0.72	1.89
700	0.50		0.51	0.88		0.77	0.79		0.79	2.07
50	0.54		0.56	0.96		0.84	0.86		0.87	2.27
800	0.58		0.62	1.04		0.91	0.92		0.94	2.47
50	0.63		0.67	1.12		0.98	0.99		1.02	2.67
900	0.68		0.73	1.20		1.06	1.06		1.10	2.88
50	0.72		0.78	1.28		1.13	1.13		1.18	3.09
1000	0.76		0.84	1.36		1.20	1.20		1.27	3.31

temperatures from 20°C to 600°C, there are rather large differences between corresponding values. It is highly probable that these differences must be due to the alteration of a part of the mineral material by oxidation of ferrous component into a ferric one. Such an alteration is usually experienced in the case of thermal treatment of olivine at higher temperatures than about 600°C. Hence the thermal expansion obtained in the temperature range from 20°C to 600°C can be taken as that of the fresh olivine, whose linear expansions expressed as percentages of the length at 20°C are

$$\left. \begin{aligned} Z = \text{a-axis} &= 0.00050797 t + 0.00000036 t^2, \\ X = \text{b-axis} &= 0.00093277 t + 0.00000030 t^2, \\ Y = \text{c-axis} &= 0.00088193 t + 0.00000042 t^2, \end{aligned} \right\} \dots\dots\dots (1)$$

From Table II, we see that the expansions along b- and c-axes are practically equal to each other and are about 1.5 times of a-axis.

TABLE III.

Thermal expansion of olivine
nodule in limburgite
from Ôgusoyama.

Temp. in °C.	Lin. exp. in %.	Vol. exp. in %.
20	0.00	0.00
50	0.03	0.09
100	0.04	0.12
150	0.09	0.27
200	0.14	0.42
250	0.20	0.60
300	0.25	0.75
350	0.31	0.93
400	0.35	1.05
450	0.41	1.23
460	0.41	1.23
470	0.42	1.26
500	0.46	1.39
550	0.52	1.57
600	0.59	1.78
650	0.66	1.99
700	0.73	2.21
750	0.80	2.42
800	0.87	2.63
850	0.93	2.92
900	0.99	3.00
950	1.05	3.18
1000	1.11	3.37

Fig. 1. Thermal expansion of olivine from Egypt.

A trial of the same thermal treatment was made for an olivine nodule in limbergite from Ôgusoyama, Iwami Province. The nodule is an aggregate of fine crystals of olivine with the approximate refractive indices $\alpha=1.650$ and $\gamma=1.684$, measured by an immersion method. The nodule was cut in a cylindrical form, its length being 16 mm and the diameter 10 mm. The linear thermal expansion was measured along the direction parallel to the principal axis of the cylinder and the volume expansion was obtained by calculation. The results are shown in Table III. In this case, the measured values must be different from the actual expansion obtained from a single crystal, because the nodule is an aggregate of fine crystals arranged at random orientation. However, as the crystal grains were fine, the results obtained are not much different from those for the single crystal as seen in Table II.