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ARTIFICIAL CONVERSION OF OLIVINE INTO A SERPENTINE MINERAL

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Abstract

Hydrothermal reaction of olivine with sodium hydroxide was carried out at water vapor pressure (110 kg/cm²) and temperature (300° C). Olivine was converted easily into chrysotile and brucite under alkaline condition. By heat treatment of the synthesized serpentine at 1000° C, forsterite was formed.

Introduction

The principal occurrences of serpentine minerals are those in which they are derived from ultrabasic rocks (Francis, 1956). These processes by which serpentinization takes place in such rocks as dunites, pyroxenites and peridotites have been the subject of much discussion.

The serpentinization is a low-temperature weathering phenomenon. Many attempts have been made to effect serpentinization of natural olivines. Experimental studies on the system MgO-SiO₂-H₂O (Bowen and Tuttle, 1949) have indicated that serpentines cannot be formed at temperatures above 500° C, and that formation of serpentine by the action of water on forsterite can occur only below 400° C. Their experiments show that at 365° C and 15000 lbs/in² olivine from North Caroline with 10 per cent fayalite molecule is not serpentinized in 2 weeks, though pure forsterite is definitely affected. At 340° C and 15000 lbs/in² the North Caroline olivine is definitely serpentinized in the same period.

With water only, my results show that olivines cannot be serpentinized at 290° C and 110 kg/cm² for three hours. It was found that olivines can be serpentinized in the same period at 290° C and 110 kg/cm² under alkaline condition. The purpose of the present paper is verify that serpentinization is easier to take place under the alkaline condition than other conditions when the temperature and pressure are the same.

Starting materials and method

Olivine (90 % forsterite, 10 % fayalite) from Ichinomegate, Akita Prefecture and dunite (90 % forsterite) from Horoman, Hokkaido were prepared for starting

materials on serpentinization. Their components were determined by measuring d_{130} value (Yoder and Sahama, 1957) and by chemical analyses. The chemical analyses data for the samples are given in Table 1. The samples were ground into fine powder in an agate mortar.

Table 1. Chemical compositions of the starting materials.

	1	2
SiO ₂	40.30%	43.10%
TiO ₂	0.15	tr.
Al ₂ O ₃	0.25	1.40
Fe ₂ O ₃	none	0.53
FeO	10.26	7.09
MnO	0.09	tr.
MgO	48.60	45.63
CaO	0.07	1.30
K ₂ O	0.03	tr.
Na ₂ O	0.04	tr.
H ₂ O(+)	}0.33	0.15
H ₂ O(-)		0.35
Total	100.12	99.55

1. Olivine, nodule in basalt, Ichinomegata, Akita Prefecture, Japan (Ross, C.S., Foster, M. D. and Myers, A. T., 1954).
2. Dunite from Horoman, Hokkaido, Japan (Analyst, T Muramatsu).

Using closed autoclave (Morey type, 500 ml), water was put into the vessel and pressures were measured on heating. The powdered sample was put into an open silver crucible placed on a stainless steel stand on the bottom of the vessel to avoid mixing of sample and water. The runs were made at heating rate 2°C per minute and were maintained under confining pressure and temperature for 3 hours. This type of autoclave is unquenchable, and it takes 3 hours at 100°C to reach room pressure and temperature. The hydrothermal reactions were carried out at 290°C and 110 kg/cm². Temperature was controlled automatically, and the accuracy of measurements is believed to be within $\pm 5^\circ\text{C}$. Reacted samples were examined with an X-ray diffractometer immediately after cooling.

Results

Olivine from Ichinomegata: Experiments were carried out at 290°C and 110 kg/cm² for 3 hours. So far as no sodium hydroxide was added, the x-ray powder pattern of the treated olivine was quite the same as that of the original olivine as is shown in Fig. 1. It means that olivine cannot be altered at all under the above-mentioned condition. When 3.0 g of NaOH was added to 0.1 g of olivine, serpentine and brucite were synthesized under the condition as above. The re-

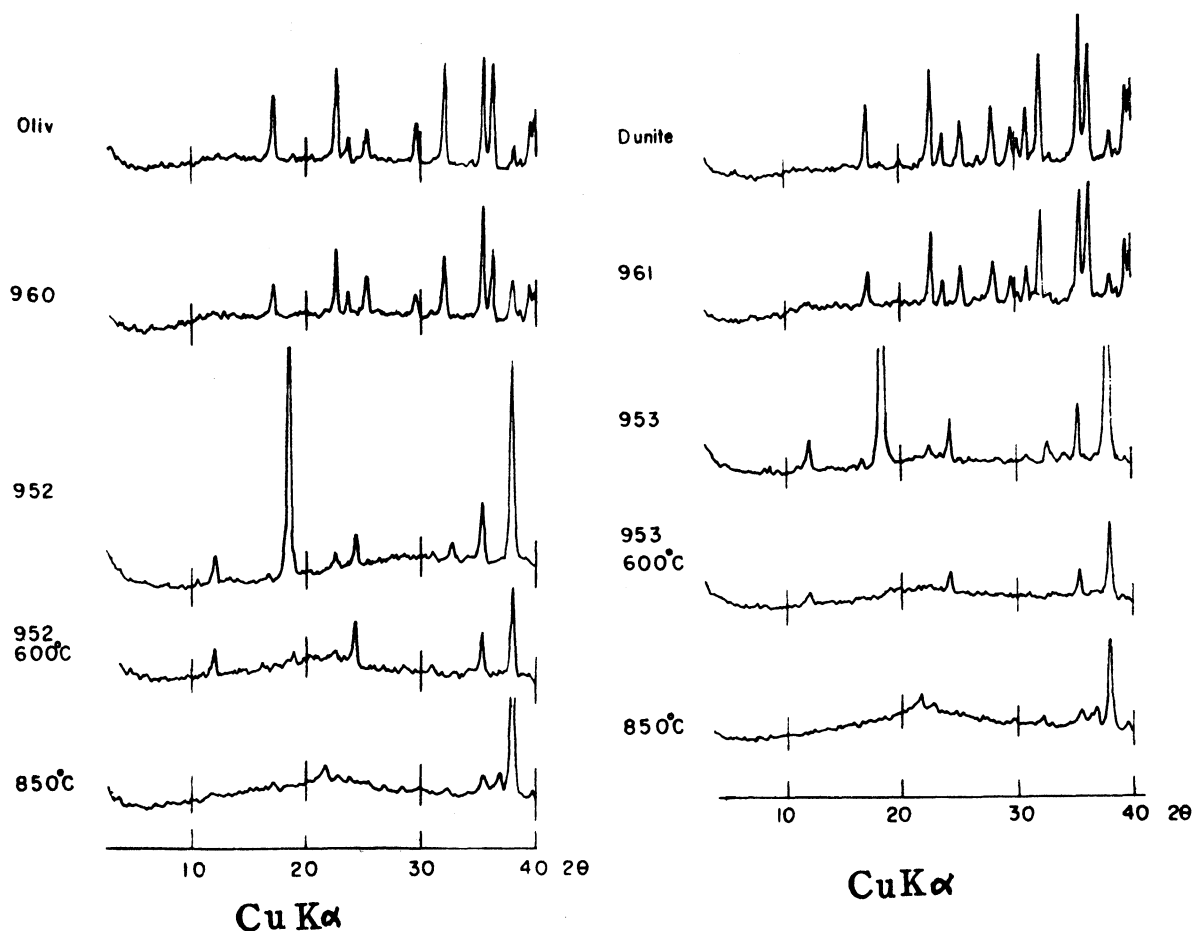


Fig. 1. X-ray diffraction patterns of the olivines and specimens synthesized at 290°C and 110 kg/cm² for 3 hours

Oliv: Olivine from Ichinomegata.

Dunite: Dunite from Horoman.

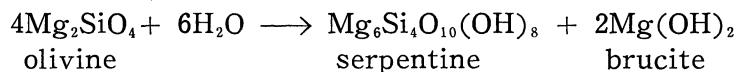
960: Treated with water pressure only.

952: Synthesized specimen after olivine (0.1 g)+NaOH (3 g).

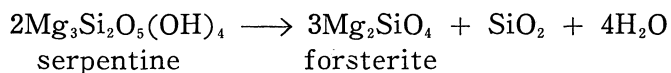
961: Treated with water pressure only.

953: Synthesized specimen after dunite (0.08 g)+NaOH (3 g).

action is considered to be as follows:



When the treated sample was heated at 600°C for one hour, periclase was formed from the sample by the decomposition of brucite, but serpentine was not destroyed. When it was heated at 850°C for one hour, the serpentine was also destroyed and forsterite was formed. This result agrees with that of previous workers (Hey and Bannister, 1948; Brindley and Zussman, 1957). The transformation probably proceeds according to the relation:



The SiO₂ is not recorded in the X-ray powder pattern and must therefore be

essentially non-crystalline when expelled from the serpentine lattice. The intensities of the peaks of periclase increased at 850°C due to the complete destruction of brucite.

Dunite from Horoman: Experiments were carried out at 290°C and 110 kg/cm² for 3 hours. When sodium hydroxide was not added, the x-ray powder pattern of the dunite did not change. Under this condition, dunite cannot be changed. But when 3.0 g of NaOH was added to 0.08 g of dunite, a serpentine mineral and brucite were easily formed from the dunite under the same hydrothermal condition (290°C, 110 kg/cm² and three hours' treatment). When the treated sample was heated at 600°C, periclase was formed from the brucite, while the serpentine remained unchanged. After heating at 850°C for one hour, however, a small amount of forsterite was formed from the serpentine. The x-ray powder patterns of the original sample and the samples treated under various conditions are shown in Fig. 1.

The photomicrograph of the sample treated hydrothermally is shown in Fig. 2. Hexagonal crystals of the brucite and needle-shaped serpentine are shown. The serpentines showing needle-shape are shown. The serpentine showing needle-shape seems to be chrysotile. As the serpentine mineral synthesized from olivine was small in amount, the kind of serpentine mineral was not identified by means of X-ray diffractometer, but judging from the photomicrograph it can be said that the serpentine formed from forsterite is always chrysotile.

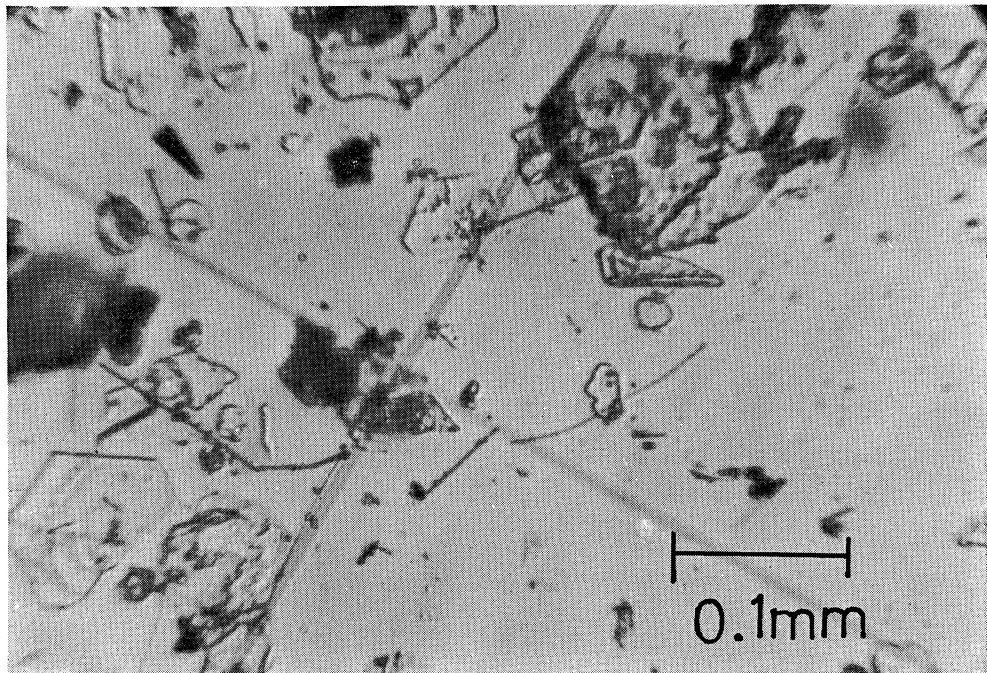


Fig. 2. The photomicrograph of synthesized specimen.

Discussion and conclusion

Olivines were serpentinized easily under the alkaline condition. This fact suggests that in the presence of alkaline solution olivine can be serpentinized at still lower temperature or in a shorter period than the case reported by Bowen and Tuttle (1949). Alkaline condition may promote the serpentinization.

Serpentine paragenesis concerning the conditions favourable for the formation of each of the structural varieties is a problem. It is possible that chemical environment has an important influence on the formation of chrysotile or antigorite, and it has been suggested that in general olivine yields chrysotile and enstatite yields antigorite (Hess et al., 1952). The result of present author agrees with that of Hess et al.. In the experimental serpentinization of talc and magnesium-rich chlorite, i. e. leuchtenbergite, lizardite was formed from the leuchtenbergite, and antigorite and lizardite were formed from talc (Tomita, 1967). These experiments suggest that serpentines formed from different rocks by weathering differ from one another in their morphology and structure.

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