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Discovery of corundum in alkali basalt at high temperature and high pressure

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Abstract

Corundum megacrysts in alkali basalts are an important source of gems. However, the genesis of corundum megacrysts is still a controversial problem. Up to now, no experimental evidence has been acquired for the crystallization of corundum from basalt under high temperature and high pressure. With alkali basalt as the starting material in this experiment, the transformation of basalt into eclogite at the pressure of 3.5 GPa and the temperature of 1400 °C was realized. In the experimental product, corundum has been discovered embraced in garnet.

1. Experimental study on the transformation of alkali basalt into eclogite

1.1. Experimental samples

Alkali basalt samples used in the experiment had been collected from near Qianyang Village, Minqing County, Fujian Province. This basalt is black in colour, compact and massive and contains spinel lherzolite xenoliths and large numbers of pyroxene megacrysts. The petrochemical composition is: SiO_2 48.86, TiO_2 2.12, Al_2O_3 13.25, Fe_2O_3 2.16, FeO 7.84, MnO 0.11, MgO 9.03, CaO 9.64, Na_2O 3.15, K_2O 1.56, H_2O^+ 1.25, H_2O^- 0.83, P_2O_5 0.62 (wt%). The fresh basalt samples, free of lherzolite xenoliths and megacrysts, were crushed and ground as fine as −200 mesh in grain size and were used as the starting material.

1.2. Experimental method

The experiment was accomplished on the wedge-type cubic anvil high-pressure apparatus in the YJ-3000-ton press at the Institute of Geochemistry, Chinese Academy of Sciences. The experiment was carried out at a designed pressure and temperature.

Table 1. Experimental conditions for the transformation of basalt into eclogite.

Sample No	35	36	37
Temperature (°C)	1400	1400	1500
Pressure (GPa)	3.00	3.50	3.50

Previous studies [1] showed that the melting temperature of this basalt at 1.0–3.5 GPa is about 1400–1500 °C. The temperature and pressure conditions for the transformation of basalt to eclogite in this experiment are presented in table 1.

1.3. Microscopic examination of the experimental product

Microscopic observation showed that present in the experimental product are, mainly, the following mineral phases: garnet, residual pyroxene, acicular clinopyroxene and glass. It is also found that the plagioclase that was ubiquitously present in the original rock has disappeared. In the experimental product, garnet is ubiquitously present; it is evenly distributed throughout the whole sample. The garnet is euhedral-gradular in form; it is distributed in the periphery of pyroxene and coexists with the residual glass and acicular minerals. The residual pyroxene in the sample is the residue of melting of phenocryst pyroxene in the original sample and the perfection of its crystal form shows a significant difference. Some of the residual pyroxene crystals still maintain their slate-primatic form as it was originally, with perfect boundaries. Some have already been greatly changed in form. The phenomenon of two kinds of pyroxene coexisting has also been observed. Acicular clinopyroxene generally coexists with garnet and glass, with one of the ends thinning out into yellowish-brown glass. So they are considered as new mineral phases crystallized from melts. According to the results of electron microprobe analysis, their composition has been confirmed to be equivalent to that of clinopyroxene.

Garnet species in the three samples are grossly similar in chemical composition. With the rise of temperature and pressure (No 35 $\rightarrow$ 36 $\rightarrow$ 37 $\rightarrow$), the FeO contents in the garnet tend to decrease with increase in the content of MgO. In the end-member components the content of pyrope tends to increase with decrease in the content of greenlandite. On the whole, pyrope is predominant, and is relatively homogeneous in chemical composition, showing the genetic character under high-pressure conditions.

2. Corundum phase in the garnet

In the three experimental samples described above, the garnet is generally less than 0.05 mm in grain size, but in sample No 36 several grains of garnet in the centre are so large as to be up to about 0.15 mm in size, in which corundum is embraced.

2.1. Occurrence and shape of the corundum

It is observed under the microscope that the corundum-bearing garnet, together with the surrounding glass and crystallized clinopyroxene, constitutes a circular area and garnet grains of different sizes constitute the circles in this area. In the centre of the circular area are present a number of coarser garnet grains, acicular clinopyroxene and glass (figure 1). Garnet A (A in figure 1) is irregular in crystal form as observed under a mono-polarized light microscope and shows incomplete extinction under a positively polarized light microscope, indicating that it contains a kind of greyish-white mineral with grade-I interference colour. As has been

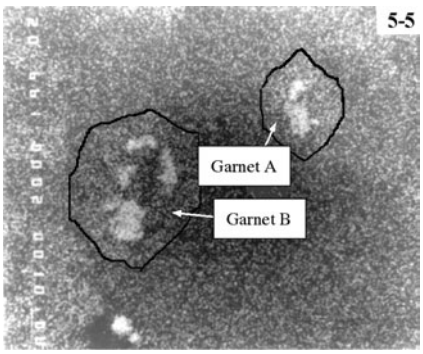

Figure 1. Corundum embraced in garnet.

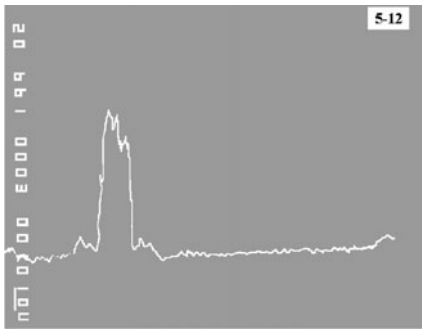

Figure 2. The x-ray concentration distribution curve of Al.

confirmed from its electron microprobe analysis, the greyish-white mineral is corundum. It has been found that coarser garnet grains generally contain corundum. Detailed analysis has been conducted on garnet A—the biggest one so far acquired and the corundum contained in it.

2.2. Chemical composition of the relevant minerals

On the basis of optically microscopic examination, the x-ray concentration distribution curves (figures 2 and 3) of Al and Si in garnet A in figure 1 are acquired by way of electron microprobe analysis. It can be seen that Al_2O_3 is largely distributed in the centre of the garnet. It is scattered in several fields of garnet A but relatively concentrated in garnet B. Almost no SiO_2 is detected in the Al_2O_3-bearing locations. From the analytical results we can see that the results for the analytical points are rather consistent with one another, indicating that the garnet is homogeneous in bulk chemical composition. No regular variation is noticed in going from the rim to the centre of the garnet.

2.3. Raman spectroscopic study of corundum in garnet A

The forgoing studies indicate compositionally that the inclusion in garnet A is corundum. In order to confirm this conclusion in terms of the structure of corundum, a micro-Raman spectroscopic examination has been conducted on the corundum in garnet A. The Raman spectra obtained are presented in figure 4. The Raman spectroscopic measurement of the corundum was effected on a Renishaw 2100-type Raman spectrometer (excitant: Ar^+ laser; wavelength: 514.5 nm; power: 800 mW; instrument resolution power: 0.1 cm^{-1}). The appearance of Raman spectral peaks at 416, 575, 644 and 749 cm^{-1} provides strong evidence of the occurrence of corundum in garnet A.

3. Discussion

From the high-temperature and high-pressure experiment described above, the basalt was converted to eclogite. The following preliminary conclusions can be drawn from the studies of the occurrence, forming environment and chemical composition of the various mineral phases in the experimental process.

First, corundum can be crystallized from magma, which was produced from partial melting. From their studies of partial melting of spinel lherzolite, Maaloe and Printzlau

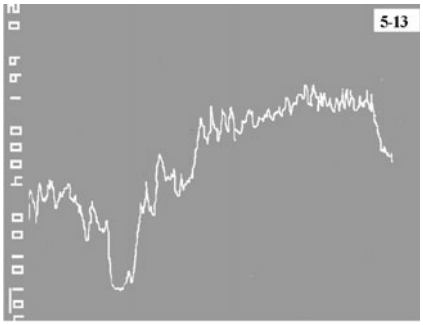

Figure 3. The x-ray concentration distribution curve of Si.

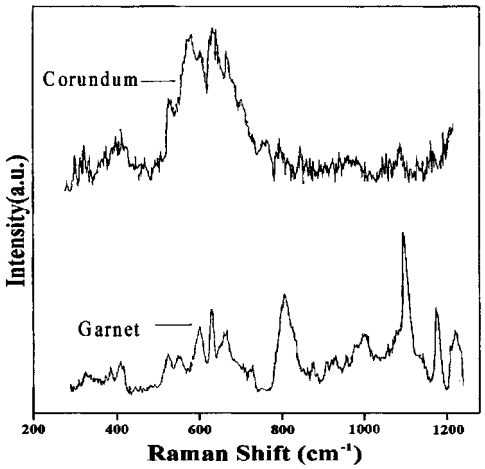

Figure 4. Raman spectra of corundum.

pointed out in 1997 that the contents of Al_2O_3 in the magma produced from partial melting of pyrolite are 10.7–20.93%. Under such circumstances the magma is saturated relative to Al_2O_3 and corundum can crystallize from it with no difficulty.

Second, Al_2O_3 can be formed in the process of the formation of grossular from the CaTs molecules in clinopyroxene. Although garnet is formed with the consumption of Al_2O_3 in the system, there is MgO-rich but CaO-poor residual pyroxene in the experimental product.

Finally, the results of this experiment lend support to the viewpoint that corundum megacrysts can be crystallized from the host basaltic magma, though the crystallization of corundum from basaltic magma is a very complex process. Its survival in the magma depends not only on reactions which are temperature and pressure dependent (the range of reaction temperature and pressure would be very narrow), but also on the dynamic process of ascending magma.

Acknowledgment

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