EXPERIMENTAL STUDY ON TWO PICRITES WITH REFERENCE TO THE GENESIS OF KIMBERLITE

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Introduction

The occurrence of eclogite xenoliths within kimberlites suggests the close genetic relationship between these two rocks. O'Hara and Yoder (1967) considered that separation of eclogite from a picritic magma at depth (25 kb or more) might produce a volatile-rich liquid similar in composition to kimberlite. According to Green and Ringwood (1967), however, a nephelinitic but not a kimberlitic magma is formed by the fractionation of a primary picritic melt. In order to find the genetic relationship between a picrite and a kimberlite, melting experiments on a nepheline-normative picritic dolerite from Nosappu Cape of the Nemuro Peninsula, Hokkaido and a hypersthene-normative picrite from Wakuike, Nagano Prefecture, Japan, have been made at various pressures and temperatures, up to 1300°C and 30 kb in presence of excess water.

Petrology of Picrites

The nepheline-normative picritic dolerite consists of plagioclase (An_{57-64}), orthoclase cryptoperthite, augite ($Ca_{41}Mg_{47}Fe_{12}$), olivine (Fo_{70}), biotite, Ti-magnetite and small amounts of ilmenite and apatite (Yagi, 1969).

The picritic basalt from Wakuike consists of plagioclase (An_{92-87}), olivine (Fo_{68-71}), augite ($Ca_{43}Mg_{42}Fe_{15}$-$Ca_{44}Mg_{39}Fe_{17}$)and magnetite phenocrysts in a groundmass of plagioclase, augite ($Ca_{41}Mg_{39}Fe_{20}$), pigeonitic augite ($Ca_{34}Mg_{42}Fe_{24}$), magnetite and slightlty devitrified mesostasis. Presence of abundant megacrysts of anorthite (An_{94}) and olivine (Fo_{81-82}) is remarkable and can be distinguished from the other crystals of this rock by the absence of zonal structure (Takeshita, 1974, 1975). Chemical compositions of these two rocks are given in Table 1.

Experimentals

Results of investigation on these two picrites are summerized in Figs. 1 and 2. The subsolidus assemblage of the Nosappu picrite consists of clinopyroxene, plagioclase, amphibole, mica, magnetite and vapor at pressures, less than 22 kb, with the solidus at around 700°C. (Fig. 1). With increasing temperature amphibole disappears first, followed successively by plagioclase, mica, magnetite and clinopyroxene. The liquidus lies around 1200°C with clinopyroxene as the primary phase. At pressures, higher than 21-22 kb and temperatures lower than 1000°C, garnet is always present and there is a fairly wide field of clinopyroxene + garnet + mica + magnetite + liquid + vapor. It is worthy of note that mica (phlogopitic) has a large stability field compared to amphibole. This fact has already been noted by Yoder and Kushiro (1969) and Modreski and Boettcher (1970), suggesting that the phlogopitic mica may indeed be the source of potassium in the upper mantle.

EPMA analyses show that the garnet, appearing in the field of

Table 1

	Picritic dolerite, Nosappu	Picritic basalt, Wakuike
SiO_2	46.07	47.47
TiO_2	1.98	0.71
Al_2O_3	11.06	17.09
Fe_2O_3	5.00	1.32
FeO	5.44	7.31
MnO	0.20	0.24
MgO	9.97	11.31
CaO	11.73	9.15
Na_2O	2.59	1.51
K_2O	2.01	0.60
H_2O+	2.22	2.56
H_2O-	1.78	0.64
P_2O_5	0.23	0.18
Total	100.28	100.09
Analyst	H.Onuki	H.Matsumoto

clinopyroxene + garnet + mica + magnetite + liquid + vapor is a solid solution of pyrope, almandine and grossularite and has a composition similar to that found in some eclogites in kimberlites. Coexisting clinopyroxenes contain up to 2.6 % Na_2O, 3.6 % Al_2O_3 and 26% CaO, similar to omphacitic pyroxenes. Therefore the separation of these garnet and clino-pyroxene will result in the depletion of CaO, Al_2O_3, and Na_2O and relative enrichment in K_2O and MgO in the residual liquid. Analysis of the glase formed immediately above the solidus at 25 kb showed it to be poor in SiO_2 (34.5 %), Al_2O_3, Na_2O_3 and CaO and rich in total iron, MgO and K_2O. These results thus substantiate the idea of derivation of a kimberlitic magma by the separation of eclogite from a picritic magma at high pressures.

The subsolidus assemblage of the Wakuike picrite is much simpler, consisting of plagioclase + amphibole + vapor with solidus around 700°C (Fig. 2). With increasing temperature, at about 800°C both clinopyroxene and magnetite appear, forming an assemblage of amphibole + plagioclase + clinopyroxene + magnetite + liquid + vapor. With further rise in temperature first amphibole and then plagioclase, magnetite and clinopyroxene disappear successively. The liquidus with clinopyroxene as the primary phase occurs at about 1250°C, slightly higher than that of the Nosappu picrite, because of higher MgO content. In this picrite garnet appears above 17-18 kb, about 5 kb below the lower stability limit of this phase in case of the Nosappu picrite which may be due to the higher concentrations of Al_2O_3 and CaO in the rock from Wakuike. Mica also does not appear in case of this rock (Fig. 2) because of vary low K_2O content.

EPMA analyses of the run products of the Wakuike picrite indicate that the garnet is a solid solution of almandine, pyrope and grossularite. The analysis of the H_2O-saturated glass, crystallized at 25 kb and 1000°C shows 42.5 % SiO_2, fairly high Al_2O_3 and CaO and very low MgO, Na_2O and K_2O contents. Therefore, although the hypersthene normative picrite produces silica undersaturated liquid at high pressures, its composition is quite different from that of kimberlite.

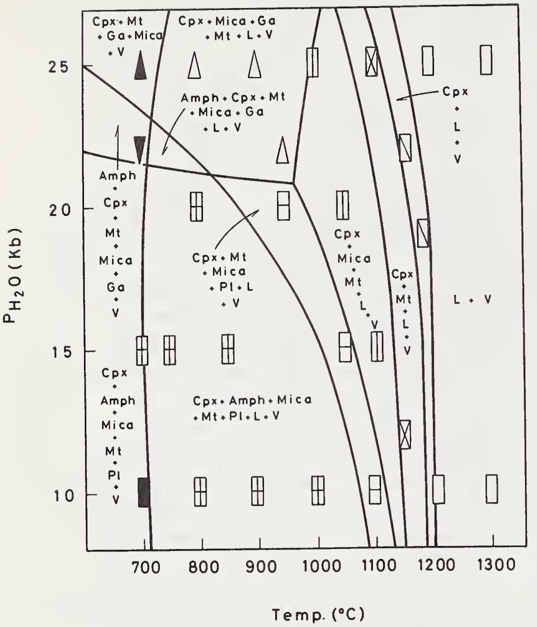

Fig. 1. P_{H2O}-T diagram of picritic dolerite from Nosappu Cape.

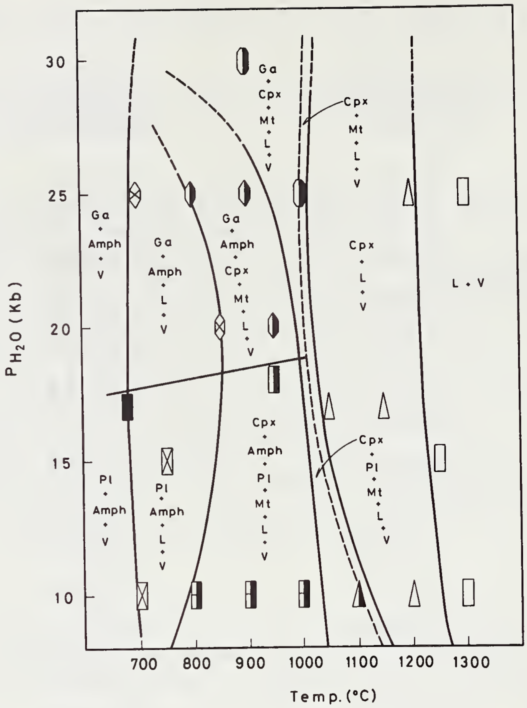

Fig.2. P_{H2O}-T diagram of picritic basalt from Wakuike

Conclusion

The present experimental study thus shows that partial melting of a nepheline-normative picrite at high pressures may produce a kimberlitic magma, by subtracting the eclogitic fractions. However, the partial melting of a hypersthene-normative picrite is not suitable for the formation of a kimberlitic magma.

The upper stability limit of amphibole in case of the Nosappu picrite indicates that the kimberlite-formation probably takes place at a depth of at least 23 kb (or 70 km) or possibly at or below 100 km under the condition of low geothermal gradient as amphiboles are usually absent in kimberlites.

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