研究報文

ALUMINIUM CONTENT OF CLINOPYROXENES
FROM BASIC IGNEOUS ROCKS

TADASHI KONDA

*Department of Geology, Faculty of Science, Yamagata
University, Yamagata*

Abstract: Superior clinopyroxene analyses show that clinopyroxenes of low Ca content have relatively low Al, while calcic clinopyroxenes are variable in Al content. The variation of Al content is related to the $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios in clinopyroxenes, as well as to the silica saturation of magmas from which they crystallize. The Si-Al replacement in clinopyroxenes is thought to be related to conditions of oxidation, and controlled by the entrance of Fe^{3+} ions into the clinopyroxene structure.

INTRODUCTION

The Al content of clinopyroxenes is an important indicator of physico-chemical condition of magmas. Kushiro (1960) has suggested that the Al content in Z positions of clinopyroxenes is proportional to the degree of undersaturation of silica in magmas from which they crystallize. Furthermore, Le Bas (1962) has found a similar tendency for the Al content of groundmass pyroxenes. Some clinopyroxenes of tholeiitic basalt, however, have a high proportion of Al_2 and those of alkalic basalt have often a low proportion of Al_2 . In this paper, the Si-Al relations in clinopyroxenes are reconsidered.

SELECTION OF PYROXENE ANALYSES

Clinopyroxene analyses quoted in this paper have been selected from the existing literature according to the following criteria:

(1) Clinopyroxenes occurring as phenocrysts in basalt and as constituents of dolerite and gabbro are taken. These clinopyroxenes represent crystals formed at early stages of magmatic fractionation, so the effect of temperature is thought to be negligible and the effect of

pressure is small. Clinopyroxenes of differentiated pegmatite veins and syenites are omitted. (2) Pigeonite are omitted, because of having different structure from diopside (Morimoto, 1959). Soda augite (containing more than 1.0 weight percent Na_2O) are also omitted. Clinopyroxenes thus selected have composition in the range of $\text{Ca}_{37-55}\text{Mg}_{30-50}\text{Fe}_{10-22}$, and the MgO/FeO ratio is usually more than 1.00. The calculation of the atomic proportions is made on the assumption that the tetrahedral position Z is completely filled by Si and Al. If Si plus Al are deficient, Ti is added to Si and Al so as to make the atomic number in Z equal to 2.00.

CA-AL RELATION

The clinopyroxenes treated in this paper are diopside, salite and augite, according to the nomenclature of Poldervaart and Hess (1951). The Ca content of the clinopyroxenes varies from 0.69 to 0.92 in atomic ratio. Figure 1 shows the relation of Ca to Si-Al replacement. Clinopyroxenes of low Ca content (less than 0.80 atomic ratio) have low Al_Z values. On the other hand, clinopyroxenes of higher Ca content vary considerably in Al_Z value.

MgSiO_3 is another major component of the clinopyroxenes, rang-

Figure 1. Ca- Al_Z relation in clinopyroxenes from different magma types. (Atomic proportions are calculated on the basis of six oxygen atoms)

ing from 30 to 50 molecular percent, but the amount of MgSiO_3 is apparently not directly related to that of Al_Z or of the total Al content in the clinopyroxenes.

$\text{Fe}_2\text{O}_3/\text{FeO}$ RATIO IN CLINOPYROXENES

The $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio in clinopyroxenes increases with an increase of the total Al content ($\text{Al}_Y + \text{Al}_Z$) as shown in Figure 2. Clinopyroxenes from peralkaline rocks have the highest $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios and also high Al_Z values as shown in Figure 2, and those from high-alumina basalt (and related gabbro) and from tholeiitic rocks mostly have low $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios and low total Al values.

Figure 2. Relation between $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio and total Al content in clinopyroxenes from different magma types. Marks are the same as those in figure 1.

Clinopyroxenes from normal alkaline rocks, from high-alumina basalt (Yoneyama; Kuno and Sawatari, 1933), from some tholeiitic basalt (Wadaki and Taga; Kuno and Sawatari, 1933) and tholeiitic gabbro (Ayabe; Sugi, 1951) have intermediate $\text{Fe}_2\text{O}_3/\text{FeO}$ and Al_Z values.

Where the $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio of clinopyroxene is high, the absolute amount of Fe_2O_3 in clinopyroxene is also high.

Figure 3 shows that the weight percentage of Fe_2O_3 in clinopyroxenes increases as Al_Z increases. The simplest formula of

Figure 3. Relation between the weight percent of Fe_2O_3 and the atomic proportion of Al_z in clinopyroxenes from different magma types. Marks are the same as those in figure 1.

clinopyroxene is $\text{CaMgSi}_2\text{O}_6$. If Al substitutes for Si in the tetrahedral position, an equivalent amount of Fe^{3+} and Al should enter into the octahedral position as is represented by the formula $\text{Ca}(\text{Mg}, \text{Fe}^{3+}, \text{Al})(\text{Si}, \text{Al})_2\text{O}_6$, provided the number of $(\text{Fe}^{3+}, \text{Al})_y$ is equal to the number of Al_z . The Ti content has been suggested as a possible control of Al_z content in clinopyroxenes (Le Bas, 1962, Figure 5). But the position of Ti in the clinopyroxene structure and the mechanism of its entrance into clinopyroxene are not yet clear (Kushiro, 1960, p. 553).

Another problem is the physical conditions controlling the $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio in magmas. According to Osborn (1959), $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio is a measure of the oxygen pressure of magmas, and the high oxygen pressure may be related to the high concentration of water.

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CITED DATA

The source of the clinopyroxene analyses in this paper are as follows.

(A) Tholeiitic rocks

Wadaki basalt (Kuno and Sawatari, 1933), picritic basalt and porphyritic gabbro from Hawaii (Muir, Tilley and Scoon, 1957), Dillsburg and Lamberville diabase (Hess, 1949), Ayabe gabbro (Sugi, 1951).

(B) Calc-alkaline rocks

Sano gabbro (Yajima, 1961).

(C) High-alumina basalts and related rocks

Yoneyama basalt (Kuno and Sawatari, 1933), Squilver dolerite (Blyth, 1948), Duluth gabbro (Hess, 1949), Skaergaard gabbro (Brown, 1957)

(D) Normal alkaline rocks

Alkaline basalt from Limerick (Ashby, 1946), Takakusayama dolerite (Sugi, 1951), Camptonite from Skaergaard (Vincent, 1953), Alkaline gabbro from Okonjeje (Simpson, 1954), Islay dolerite (Walker and Patterson, 1959), Atumi dolerite (Kushiro, 1964), alkaline basalt from Kyushu (Aoki, 1964).

(E) Peralkaline rocks

Tephrite from Vesuvius (Washington and Merwin, 1921), nepheline dolerite from Meiches and essexite from Westwald (Holzner, 1934).

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基性火成岩中の単斜輝石の Al 量

今 田 正

摘 要

久城および Le Bas によると、基性火成岩に含まれる単斜輝石で、Si-Al 置換による四配位 Al (Al_2) の量はマグマ中の Si 飽和度に左右される。然し不飽和アルカリ岩系の玄武岩中の単斜輝石で Al_2 の少ない例があるので、Si-Al 置換を生ずるもう一つの要素として Fe_2O_3/FeO 比の問題を検討した。