Jour. Fac. Sci., Hokkaido Univ., Ser. IV,
vol. 20, no. 1, March, 1981, pp. 79-86.

Ti- AND Al-RICH CLINOPYROXENES FROM THE DOLERITE DIKE IN THE MEGURO AREA OF THE HIDAKA METAMORPHIC BELT, HOKKAIDO

by

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(with 10 text-figures and 1 table)

Abstract

A Ti- and Al-rich clinopyroxene (augite-salite) is described from the dolerite dike in the southern part of the Main zone of the Hidaka metamorphic belt. Maximum contents of TiO_2 and Al_2O_3 attain up to 3.5 percent and 8.1 percent, respectively. An increase in Ti, Al, Fe/(Mg + Fe) and Ca/(Ca + Mg + Fe) and a decrease in Si from the colorless core to the pinkish margin are observed. This may suggest that SiO_2 concentration in magma crystallizing the clinopyroxene decreases successively and that the dolerite belongs to alkaline suite.

Introduction

The Hidaka metamorphic belt is composed of two distinct zones: the Western zone having oceanic type rocks, and the Main zone which have typical rocks of island arc or continental margin (Komatsu *et al.,* 1979). It has been considered that a different igneous activity occurred in each zone (Hashimoto, 1975*; Miyashita and Maeda, 1978). The Main zone is dominant in non-alkaline igneous rocks, and furthermore a minor intrusion of alkaline quartz monzonite was found (Maeda, 1979 and in preparation).

Many dikes have been reported from the Main zone (e.g. Hashimoto, 1954; Igi and Hata, 1956; Hunahashi and Igi, 1956; Akiba *et al.,* 1975; etc.). The petrographical studies of the dolerite dikes in the Meguro area was made by Tonosaki (1956), Tonosaki and Nakata (1963) and others. Tonosaki and Nakata (1963) reported "titaniferous augite" which was identified by the color under the microscope and considered that the presence of this pyroxene implies alkaline igneous activity.

In this paper the chemical compositions of the clinopyroxenes from the dolerite dike at the Meguro area are given, and the magma type of the dolerite is briefly discussed.

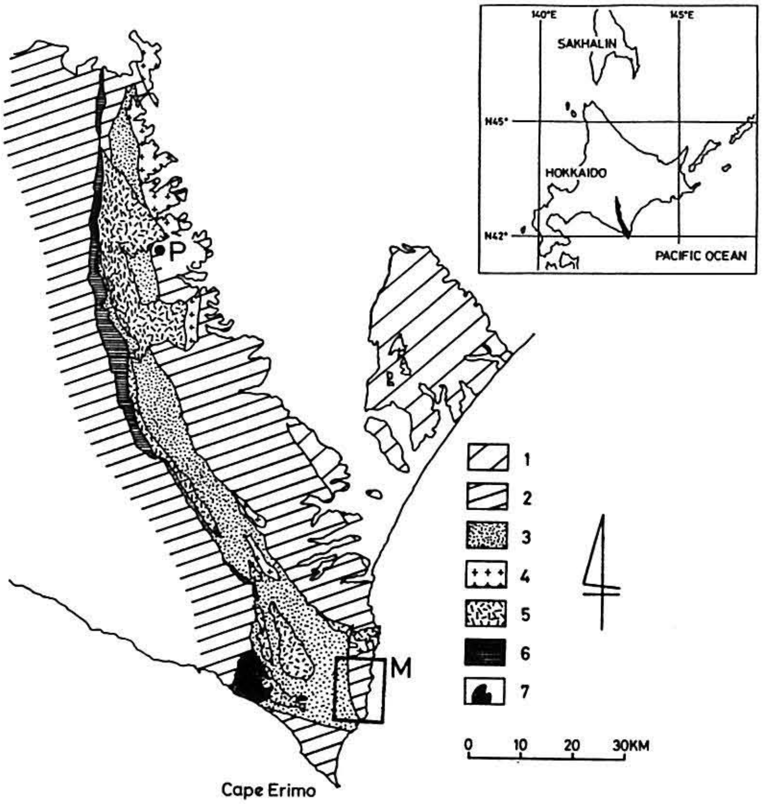
Geologic background and petrography of host rock

The Meguro area is situated at the southeastern end of the Main zone of the Hidaka metamorphic belt (Text-figure 1). Geology of in this area was investigated by Odaira (1926), Igi and Hata (1956), Tonosaki (1956 etc.) and others. According to Igi and Hata (1956), the Meguro area is divided into two parts by the Saruru sheared zone extending from north to south. The western part is occupied by migmatites, biotite gneiss and schistose biotite hornfels, and the eastern part by massive hornfels (Text-figure 2).

The dikes which are distributed in this area are classified into two types: one is dolerite,

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1705.

* The Axial-Eastern zone and the Western zone of Hashimoto (1975) correspond to the Main zone and the Western zone of Komatsu *et al.* (1979), respectively.

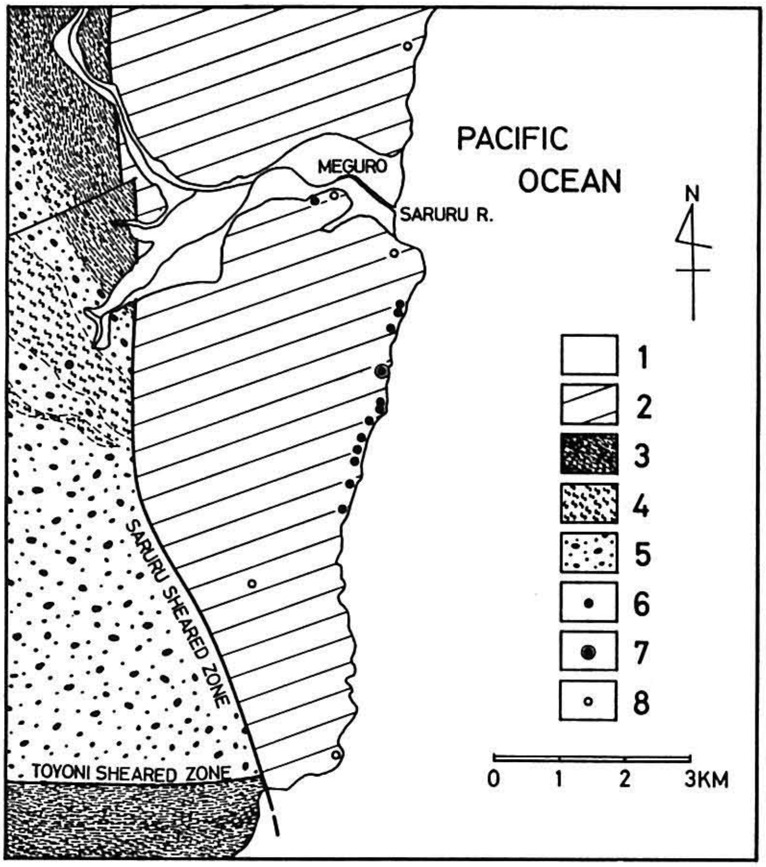


Text-fig. 1 Geologic sketch map of the Hidaka metamorphic belt and adjacent region (simplified from Yamaguchi *et al.*, 1978). Inset map shows the distribution of the Hidaka metamorphic belt (black area). 1. Tertiary rock in so-called "Green Tuff" region, 2. Hidaka Supergroup, 3. Biotite gneiss and migmatites, 4. Granitic rocks, 5. Gabbroic rocks, (3-5 belong to the Main zone) 6. Basic rocks of the Western zone, 7. Ultramafic rocks, P. Pipairo river area, where alkalic quartz monzonite was found by Maeda (1979), M. Meguro area.

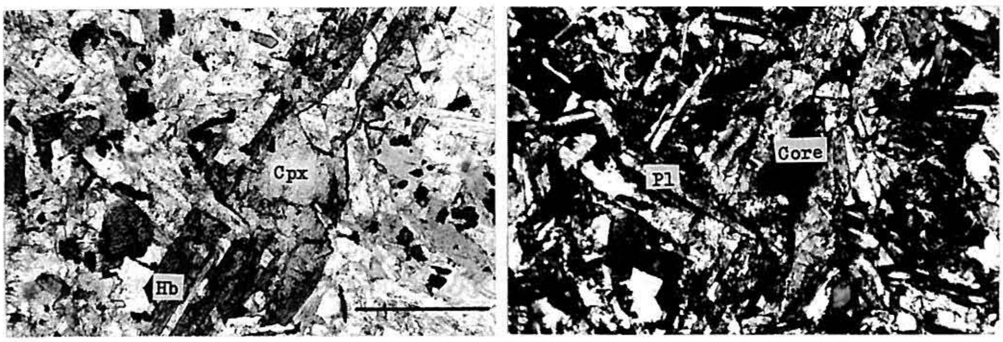
which is grayish black to dark gray and the primary minerals and texture are almost preserved, and the other is meta-dolerite, which is greenish black and mafic minerals are almost replaced by secondary minerals. Ti- and Al-rich clinopyroxene occurs in the dolerite dikes typically cropping out along the coast from Meguro to Shoya. These dolerite dikes strike N10°-20°W and dip 70°W-70°E in general.

The marginal part of the studied dike shows ophitic texture consisting of lath-shaped plagioclase (An percent* = 61-28) and subhedral to anhedral clinopyroxene and hornblende. A small amount of interstitial quartz is observed. Phenocrysts of plagioclase are observed in places. Needles of apatite and grains of opaque mineral are also present as accessory minerals. Secondary chlorite and carbonate are observed. On the other hand, in the central part, stout prismatic plagioclase and subhedral to euhedral hornblende are present, and quartz and chloritized material are filling interstices. A small amount of rounded clinopyroxene is also included. Accessory and secondary minerals are the same as those in

* An content of plagioclase was determined by the method of Yusa (1975).



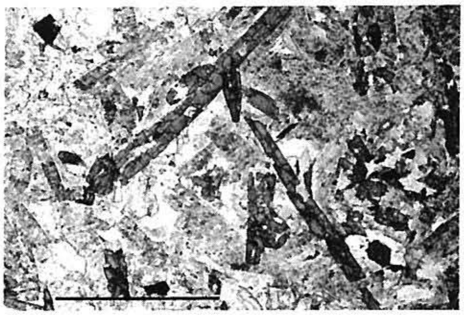
Text-fig. 2 Geologic map of the Meguro area (simplified from Igi and Hata, 1956). 1. Quaternary sediment, 2. Massive hornfels, 3. Schistose biotite hornfels, 4. Biotite gneiss, 5. Migmatites, 6. Dolerite dike, 7. Dolerite dike studied in this paper, 8. Meta-dolerite dike.



Text-fig. 3 Zoned pyroxene in the Meguro dolerite. Left: polarizer only. Right: crossed polars. Cpx: clinopyroxene. Hb; hornblende. Pl: plagioclase. Core: core of clinopyroxene at extinction position. Scale 0.3 mm.

the marginal part.

The clinopyroxene in the central and marginal part is considerably different in mode of occurrence to each other. In the central part the clinopyroxene is colorless and zoning is not distinct. Whereas the clinopyroxene in the marginal part shows the conspicuous zoning from the colorless core to the pinkish margin. The boundary between the core and the margin is fairly clear (Text-figure 3). Sometimes hour-glass structure is observed. Hornblende in the central part is brown to pale brown shows a long prismatic habit with the short axis/long axis ratio of 1/10 (Text-figure 4). Such textural evidences probably indicate the rapid crystallization by quenching. The hornblende is neither kaersutite nor hastingsitic hornblende as estimated by Tonosaki and Nakata (1963), but belongs to magnesio-hornblende (Table 1) in the classification of Leake (1968).



Text-fig. 4 Long prismatic hornblende in the Meguro dolerite. Polarizer only. Scale 1.0 mm.

Chemical composition of clinopyroxene

Analyses of constituent minerals from the marginal part of the dolerite dike were carried out at the Mining College, Akita University, using electron probe microanalyser (JEOL JXA-5). Analytical method is similar to that by Kano (1979). Table 1 shows the selected analyses of clinopyroxenes and hornblendes.

The clinopyroxene ranges from augite at the colorless core to salite at the pinkish margin (Text-figure 5, 6). The crystallization trend from augite to salite is not common in non-alkaline rocks but in alkaline rocks (e.g. Smith and Carmichael, 1969; Fodor *et al.*, 1975). The TiO_2 and Al_2O_3 contents increase from the core to the margin and the maximum contents are 3.53 percent and 8.11 percent, respectively. It is well known that Ti- and Al-rich clinopyroxene is included in alkaline rocks. Chemical compositions of clinopyroxene are plotted in Si-Al and Ti-Al diagram (Text-figure 7, 8). Most of the clinopyroxenes are plotted in the field of alkalic rocks by Kushiro (1960). Since it is problematical to apply simply the diagram of Kushiro (1960) and LeBas (1962) to the classification of rock series, as pointed out by Yagi and Onuma (1974) and others, Maruyama (1976) and Takasawa and Hirano (1977) proposed the restrictions in applying the above diagrams to clinopyroxene. Most of clinopyroxenes in this study do not satisfy the limitation of Maruyama (1976) and therefore, the compositions of the clinopyroxenes are plotted in the diagram proposed by Takasawa and Hirano (1977). The Al_2O_3 content generally increases with increasing FeO* as shown in Text-figure 9. In some grains, however, FeO* decreases from the core to the margin. In many cases, crystallization trends from

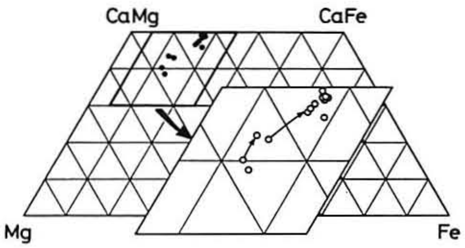
* FeO* means total Fe as FeO.

Table 1 Selected microprobe analyses of clinopyroxene (1, 2: colorless core. 3, 4: pinkish margin.) and hornblende (5, 6).

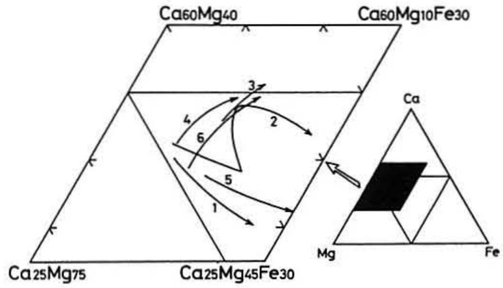
	1	2	3	4	5	6
SiO_2	49.30	47.35	46.12	44.39	44.57	44.49
TiO_2	0.74	1.91	2.34	3.52	2.07	2.15
Al_2O_3	3.10	4.87	6.67	8.11	8.04	8.36
Cr_2O_3	0.06	0.09	0.05	0.02	–	–
FeO*	7.81	7.60	9.89	10.32	18.02	18.42
MnO	0.18	0.18	0.20	0.19	0.38	0.39
MgO	17.03	15.45	11.56	10.58	11.12	10.97
CaO	20.06	21.11	21.65	21.70	10.00	10.08
Na_2O	0.47	0.46	0.50	0.50	2.51	2.56
K_2O	–	0.01	0.01	0.01	0.32	0.32
NiO	–	–	0.03	–	–	0.08
Total	98.75	99.01	99.00	99.34	97.03	97.81
Numbers of ions**						
Si	1.857	1.788	1.763	1.699	6.754	6.705
Al	0.137	0.217	0.300	0.366	1.436	1.484
Ti	0.021	0.054	0.067	0.101	0.236	0.244
Cr	0.002	0.003	0.001	0.001	–	–
Fe	0.246	0.240	0.316	0.330	2.283	2.321
Mn	0.006	0.006	0.007	0.006	0.048	0.050
Mg	0.957	0.870	0.659	0.604	2.511	2.464
Ca	0.810	0.854	0.887	0.890	1.624	1.628
Na	0.034	0.034	0.037	0.037	0.737	0.747
K	–	–	–	–	0.062	0.062
Ni	–	–	0.001	–	–	0.010
Total	4.070	4.065	4.038	4.035	15.692	15.714
M***	0.796	0.784	0.676	0.647	0.524	0.515
Ca	40.2	43.5	47.6	48.8		
Mg	47.5	44.3	35.4	33.1		
Fe	12.2	12.2	17.0	18.1		

* Total Fe as FeO ** On the basis of 6(0) for clinopyroxene and 23(0) for hornblende *** Mg/(Mg + Fe)

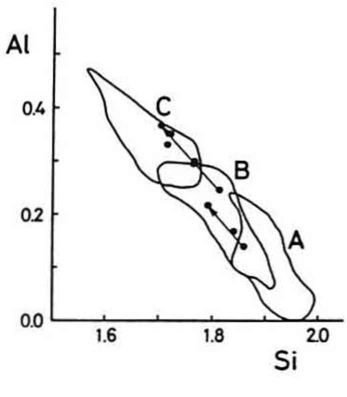
augite toward salite are observed in alkaline rocks, indicating the increase in Fe/(Mg + Fe). Therefore, Fe/(Mg + Fe) is more relevant than FeO* as an abscissa of Takasawa and Hirano's diagram to deduce the degree of crystallization. Accordingly the clinopyroxenes are plotted in Al_2O_3 – Fe/(Mg + Fe) (Text-figure 10), in which the Al_2O_3 contents increase with increasing Fe/(Mg + Fe). It is considered that groundmass clinopyroxenes in any extrusive rocks crystallized under approximately the same P-T conditions. This indicates that the difference in chemical composition of clinopyroxene from rock to rock is mainly dependent on the bulk chemistry of magma which is crystallizing the clinopyroxene. When SiO_2 in magma decreases, the reaction $CaAl_2Si_2O_8 = CaAl_2SiO_6 + SiO_2$ proceeds to the right and $CaAl_2SiO_6$ is fixed in clinopyroxene; that is the Al_2O_3 content in the clinopyroxene



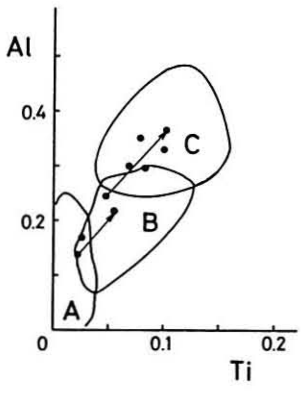
Text-fig. 5 Composition of clinopyroxenes from the Meguro dolerite. Arrows indicate direction of zoning from core to margin.



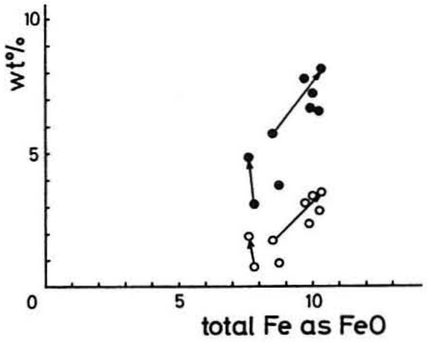
Text-fig. 6 Crystallization trends of Ca-rich clinopyroxene from the different extrusive rocks. 1. tholeiitic suite from Haleakala and West Maui volcano, Hawaii, 2. alkaline suite from Haleakala and West Maui volcano, Hawaii, 3. nephelinic suite from Haleakala and West Maui volcano, Hawaii (1-3, Fodor *et al.*, 1975), 4. trachybasalts from southern California (Smith and Carmichael, 1969, Fig. 4, No. 4), 5. tholeiitic suite from Thingmuli, Iceland (Carmichael, 1967), 6. Meguro dolerite in this study.



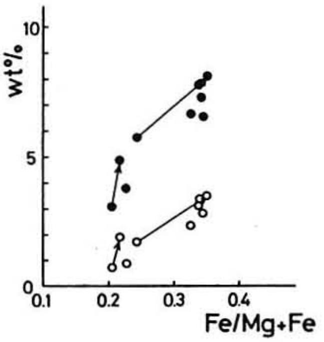
Text-fig. 7 Si-Al relation of clinopyroxene from the Meguro dolerite. Arrows indicate direction of zoning from core to margin. A, B and C are areas of clinopyroxene from the three different rock groups after Kushiro (1960). A. tholeiitic rocks, B. feldspathoid-free alkaline rocks, C. feldspathoid-bearing alkaline rocks.



Text-fig. 8 Ti-Al relation of clinopyroxene from the Meguro dolerite. Marks are the same as those in Text-figure 7.



Text-fig. 9 Al_2O_3, TiO_2 – FeO* relation of clinopyroxene from the Meguro dolerite. Solid circle: Al_2O_3. Open circle: TiO_2. Arrows indicate direction of zoning from core to margin.



Text-fig. 10 Al_2O_3, TiO_2 – Fe/(Mg + Fe) relation of clinopyroxene from the Meguro dolerite. Marks are the same as those in Text-figure 9.

increases with decreasing SiO_2 in the magma (e.g. Brown, 1967; Carmichael *et al.*, 1970; Gupta *et al.*, 1973). The behavior of Ti is also similar to Al (Text-figure 9, 10). As suggested by Verhoogen (1962), Gupta *et al.* (1973) and Campbell and Borley (1974), a decrease of SiO_2 concentration in magma results in increase of Ti as crystallization proceeds.

In general it is expected that differentiation of alkaline magma leads to a decrease in SiO_2 concentration (Carmichael *et al.*, 1970). So it appears that the Meguro dolerite including Ti- and Al-rich clinopyroxenes belongs to alkaline series. But the effect of cooloing rate on pyroxene chemistry should be also considered. Further studies are needed to clarify the magma type of the Meguro dolerite.

Acknowledgments

The author gratefully acknowledges the help received from Professor S. Hashimoto by his encouragement through the present study, and also Drs. K. Onuma, S. Miyashita and K. Niida who corrected the manuscript and made various suggestions for improving the manuscript. The members of "Research Group of Mobile Belt in Hokkaido" gave valuable suggestions. Dr. T. Maruyama of Akita University helped him in microprobe analysis, and Mr. S. Ohta and Miss C. Sato gave technical assistance for the present study. The author thanks all of these persons.

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(Manuscript received on Oct. 30, 1980)