NOTES ON PETROGRAPHY AND ROCK-FORMING MINERALOGY (4) RAPIDLY CRYSTALLIZED CLINOPYROXENES FROM TWO PALEOZOIC GREENSTONES

HITOSHI ONUKI, TAKEYOSHI YOSHIDA

*Institute of Mineralogy, Petrology and Economic Geology,
Tohoku University, Sendai*

and MUNETOMO NEDACHI

*Department of Earth Science, College of General Education,
Kagoshima University, Kagoshima*

INTRODUCTION

Dendritic titanaugites in an ultramafic picrite from the Mineoka Tectonic Belt, Boso Peninsula have been studied in detail by Tazaki (1976). Another occurrence of dendritic augite in a metabasalt has also been reported from the Mikabu Greenstone Belt of the Sanbagawa terrain by Inomata (1976). Chemical data of such clinopyroxenes formed by rapid crystallization have rarely been published in Japan.

The present authors have found metabasites containing abundant skeletal clinopyroxenes from two different Paleozoic formations (Fig. 1). The chemistry of the clinopyroxenes and their host rocks is described in this paper, along with the chemical compositions of pumpellyites in these rocks.

HOST ROCKS

One of the specimens (SNA-265) to be described below was collected from a mafic volcanic bed exposed near Fukagawa Village

in the Nishiki-cho district, Yamaguchi Prefecture. The geology and petrology of this district were studied by Nishimura and Nureki (1966) and Nishimura (1971). According to these investigations, the feebly recrystallized Paleozoic sediments which are called the Nishiki Group suffered the Sangun metamorphism and correlated to Lower to Upper Permian and are characterized by the predominance of psamite, pelite and acidic metapyroclastics, but the lower part of this Group contains mafic volcanics as lens-shaped beds accompanied with limestone and chert. The specimen studied here have come from one of the mafic volcanic beds.

The specimen is a lithic fragment in volcanic breccia with dark green color showing moderate crushed structure. Under the microscope, it is very fine-grained and contains appreciable microphenocrysts. Pumpellyite sporadically occurs as a sub-rounded monomineralic aggregate (less than 0.5 mm in diameter) of very fine crystals which is probably a pseudomorph after

Fig. 1. Photomicrographs of chain-like skeletal clinopyroxene crystals. The scale bar is common to both figures. A: SNA-265. B: MK-80802.

microphenocrystic plagioclase. Microphenocrysts of probable olivine are entirely replaced by chlorites. The matrix consists mainly of abundant clinopyroxenes (less than 0.2×0.03 mm in size) which display apparently a variety of quenched habits such as chain-like, acicular and feathery forms. The clinopyroxene at some parts within the same thin section forms a mutual intergrowth with plagioclase (presently albite) having similar size to the clinopyroxene. Interstices between the clinopyroxenes and clinopyroxene-plagioclase intergrowths are filled by very fine chlorite crystals which may represent devitrified glass. Quartz is present in veins and pools. Rarely stilpnomelane, clinozoisite and white mica are observed, together with sphene, apatite and opaque minerals. An appreciable amounts of calcite are also present as veins.

The other specimen (MK-80802) was collected from a part of massive volcanic bed in the Paleozoic formation distributed near Ootsu of Hamakita City, Shizuoka Prefecture. According to Sato (1955), the sediments called the Iinoya formation are correlated to the upper part of the Chichibu Group and consist of pelite, greenstone, limestone, chert and a little psamite. The

Table 1. Chemical analyses of greenstones containing quenched clinopyroxene

	1	2
SiO ₂	44.74	47.78
TiO ₂	1.25	1.56
Al ₂ O ₃	16.39	12.93
Cr ₂ O ₃	0.05	0.05
Fe ₂ O ₃	2.52	2.11
FeO	6.80	8.15
MnO	0.18	0.16
MgO	9.39	8.19
NiO	0.02	0.02
CaO	10.86	11.49
Na ₂ O	2.21	2.93
K ₂ O	0.19	0.08
H ₂ O ⁺	4.31	3.81
H ₂ O ⁻	0.22	0.37
P ₂ O ₅	0.11	0.07
CO ₂	0.53	n.d.
Total	99.77	99.70
01*	18.98	12.32

* The amount of normative olivine (See text).

1: SNA-265, 2: MK-80802.
(Analyst: H. Onuki)

rock is pale green in color and porphyritic. Some phenocrysts of original plagioclase are set in a groundmass mainly consisting of fine clinopyroxene, plagioclase and devitrified glass. The plagioclase phenocrysts (up to 2×1.5 mm in size) are completely replaced by rosettes of fine-needles of pumpellyite sometimes associated with anhedral albite. A few pumpellyite aggregates apparently

Table 2. EMPA analyses of quenched clinopyroxenes.

WT. %					Atomic Ratios (O = 6)				
1		2			1		2		
A	B	A	B		A	B	A	B	
SiO ₂	48.08	49.08	46.69	46.95	Si	1.795	1.843	1.757	1.787
TiO ₂	1.92	1.15	2.06	1.91	Al	0.286	0.226	0.299	0.295
Al ₂ O ₃	6.50	5.11	6.74	6.58	Ti	0.054	0.032	0.058	0.055
FeO*	8.74	9.01	9.18	11.53	Fe	0.273	0.283	0.289	0.367
MnO	0.24	0.31	0.24	0.24	Mn	0.008	0.010	0.008	0.008
MgO	12.62	12.87	13.11	10.83	Mg	0.702	0.720	0.735	0.614
CaO	21.90	22.08	21.75	21.37	Ca	0.876	0.888	0.877	0.871
Na ₂ O	0.44	0.25	0.31	0.38	Na	0.032	0.018	0.022	0.028
K ₂ O	0.00	0.00	0.01	0.01	K	0.000	0.000	0.000	0.000
Total	100.44	99.86	100.09	99.80	Total	4.026	4.020	4.045	4.025
M**	71.4	71.1	71.2	62.1	Ca	47.1	46.7	45.9	46.8
					Mg	37.8	37.9	38.5	33.0
					Fe***	15.1	15.4	15.6	20.2

* Total iron as FeO. ** Mg × 100 / (Mg + Fe + Mn). *** Fe + Mn.

1: SNA-265, 2: MK-80802.

fill amygdals. In the groundmass the clinopyroxene (usually less than 0.4×0.04 mm in size) occurs abundantly in chain, feathery and slender prismatic forms and is always associated with chlorite recrystallized from glass and/or fine plagioclase (presently albite). Sphene, apatite and opaque minerals are accessory.

Both of the specimens are affected by low-grade metamorphism characterized by the association of pumpellyite-chlorite, though the degree of recrystallization is rather low.

CHEMISTRY AND DISCUSSION

Table 1 shows the chemical analyses of the rocks. They are poor in SiO₂ (<48 wt. %), rich in MgO (>8 wt. %) and characteristically poor in K₂O (<0.2 wt. %). The ratios (FeO + 0.9Fe₂O₃)/MgO and Mg/(Mg + Fe), respectively, are 0.92 and 0.65 for SNA-265 and 1.23 and 0.59 for MK-80802. These specimens are kinds of K₂O-poor olivine tholeiite, being similar to abyssal tholeiites. The contents of their normative olivine (Table 1) are, however,

higher than those of usual abyssal tholeiites, after the recalculation to include partial reduction of Fe₂O₃ (Fe₂O₃ = 1.5 wt. %) as used by Shido and Miyashiro (1971), and adjustment of chemical analysis to 100% without H₂O and CO₂. This may be attributed, at least partially, to the depletion of SiO₂ during alteration and/or low temperature metamorphism.

The microprobe analysis has been carried out on the clinopyroxenes. The selected results possibly showing the maximum compositional range among crystals in each rock are listed in Table 2. They are all salites with considerable amounts of Al₂O₃ (5.1–6.7 wt. %) and TiO₂ (1.2–2.1 wt. %). The content of CaAl₂SiO₆, calculated after allotting Al for CaTiAl₂O₆, is constantly 8–9 molecular percent. Thus, the Al₂O₃ content is linearly dependent on the TiO₂ content.

Additionally, representative EPMA analyses of pumpellyites are given in Table 3. Boles and Coombs (1977) have stated that iron-rich pumpellyite (ranging from 10 to 23 wt. % expressed as Fe₂O₃) is a

characteristic of the zeolite and prehnite-pumpellyite facies in contrast to iron-poor pumpellyite (less than 10 wt.%) of the glaucophane schist and pumpellyite-actinolite facies. The analysed pumpellyites contain about 8-9 wt.% of total iron as Fe_2O_3 .

Table 3. EPMA analyses of pumpellyites

	WT. %			Atomic Ratios*	
	1	2		1	2
SiO_2	36.89	36.46	Si	5.982	5.878
TiO_2	0.05	0.04	Al	4.488	4.514
Al_2O_3	23.70	23.76	Ti	0.006	0.005
FeO^{**}	7.13	7.99	Fe	0.957	1.077
MnO	0.18	0.15	Mn	0.024	0.021
MgO	2.78	2.24	Mg	0.665	0.538
CaO	22.74	22.90	Ca	3.914	3.954
Na_2O	0.05	0.04	Na	0.016	0.012
K_2O	0.01	0.01	K	0.002	0.001
Total	93.53	93.59	Total	16.000	16.000

* Atomic ratios calculated on the basis of total cations = 16.

** Total iron as FeO .

1: SNA-265, 2: MK-80802.

The greenstone bed containing the rock in question is closely associated with limestone and chert in both districts. This geological association suggests submarine environment.

Because these rocks included phenocrysts or microphenocrysts of plagioclase and/or olivine, the crystal habit of clinopyroxene could have been formed by fairly quick cooling from a temperature below the liquidus, but not so rapid as to produce only palagonite glass.

Quenched clinopyroxenes are usually highly aluminous (Nesbitt, 1971; Pyke *et al.*, 1973; Fleet and MacRae, 1975; Tazaki, 1976; Inomata, 1976; Arndt *et al.*, 1977; Nisbit *et al.*, 1977) and they show a wide range of chemical composition within a single rock specimen (e.g. Fleet and MacRae, 1975; Tazaki, 1976). Rapidly

crystallized clinopyroxenes having quenched habit have to be produced by disequilibrium crystallization. Therefore, this condition has to be taken into consideration for discussions on the significance of their chemical natures (e.g. the Al_2O_3 content). The contrast of the "non-equilibrium crystallization" to the "equilibrium crystallization" of clinopyroxene in a thick lava flow was already stressed by Smith and Lindsley (1971).

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REFERENCES

- Arndt, N.T., Naldrett, A.J. and Pyke, D.R. (1977), Komatiitic and iron-rich tholeiite lavas of Munro Township, northeast Ontario. *Jour. Petrol.*, **18**, 319-369.
- Boles, J.R. and Coombs, D.S. (1977), Zeolite facies alteration of sandstones in the Southland syncline, New Zealand. *Am. Jour. Sci.*, **277**, 982-1010.
- Fleet, M.E. and MacRae, N.D. (1975), A spinifex rock from Munro Township, Ontario. *Can. J. Earth Sci.*, **12**, 928-939.
- Inomata, M. (1976), Dendritic clinopyroxene from the meta-basaltic lava of the Mikabu zone, central Japan. *Jour. Geol. Soc. Japan*, **82**, 287-289 (in Japanese).
- Nesbitt, R.W. (1971), Skeletal crystal forms in the ultramafic rocks of the Yilgarn Block, Western Australia: evidence for an Archean ultramafic liquid. *Geol. Soc. Aust. Spec. Pub.*, No. 3, 331-347.
- Nisbit, E.G., Bickle M.J. and Martin, A. (1977), The mafic and ultramafic lavas of the Belinwe Greenstone Belt, Rhodesia. *Jour. Petrol.*, **18**, 521-566.
- Nishimura, Y. (1971), Regional metamorphism of

- the Nishiki-cho district, Southwest Japan. *Jour. Sci. Hiroshima Univ., Ser. C*, **6**, 203-268.
- and Nureki, T. (1966), Geological relations of the "non-metamorphic Paleozoic formations to the Sangun metamorphic rocks in the Nishiki-cho area, Yamaguchi Prefecture. *Jour. Geol. Soc. Japan*, **72**, 385-398 (in Japanese with English abstract).
- Pyke, D.R., Naldarett, A.J. and Eckstrand, O.R. (1973), Archean ultramafic flows in the Muro Township, Ontario. *Bull. Geol. Soc. Am.*, **84**, 955-978.
- Sato, M. (1955), Geological map (scale 1:50000) of the Mikawa-Ono district and its explanatory text, pp. 47, Geol. Surv. Japan (in Japanese with English abstract).
- Shido, F. and Miyashiro, A. (1971), Crystallization of abyssal tholeiites. *Contrib. Mineral. Petrol.*, **31**, 251-266.
- Smith, D. and Lindsley, D.H. (1971) Stable and metastable augite crystallization trends in a single basalt flow. *Am. Mineral.*, **56**, 225-233.
- Tazaki, K. (1976), Dendritic titanite in ultrabasic picrite basalt from the Mineoka tectonic belt, Boso Peninsula, central Japan. *Jour. Geol. Soc. Japan*, **82** 573-580.

岩石学・造岩鉱物学ノート (4) 二つの古生界緑色岩からの急冷単斜輝石

大貫 仁・吉田 武義・根建 心具

山口県錦町地域の錦屑群下部と静岡県浜北市北部の秩父古生層上部に相当する井伊谷層から急冷単斜輝石を多量に含む緑色岩類を見出した。簡単な岩石記載のうち、岩石と急冷単斜輝石の化学組成について述べ、併せて変成パンペリー石の化学組成をも示した。