SOME RELATIONS BETWEEN CHEMICAL COMPOSITIONS AND OPTICAL PROPERTIES IN HORNBLENDE AND BIOTITE

Taneda, Sadakatu
Faculty of Sciences, Kyushu Imperial University

https://hdl.handle.net/2324/1524095

出版情報：九州帝國大學理學部紀要 : Series D, Geology. 3 (1), pp.1-12, 1947-04-20. Faculty of Science, Kyushu Imperial University
バージョン：
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Memoirs of the Faculty of Science, Kyūsyū Imperial University,
Ser. D, Vol. III, No. 1. 1947

SOME RELATIONS BETWEEN CHEMICAL COMPOSITIONS AND OPTICAL PROPERTIES IN HORNBLENDE AND BIOTITE

By

Sadakatu TANEDA

(Received Oct. 4th, 1944)

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I. Introductions.

It is well known that the course of crystallization of mafic minerals from liquid magma is not completely discussed by a triangular diagram of $CaSiO_3$-$MgSiO_3$-$FeSiO_3$ system. Especially when hornblende and biotite are concerning, it is unjust to take metasilicate components alone in consideration. Whereas, so far as the change of pyroxene components crystallized out as mafic minerals is discussed, it is not only properly desired but also convenient to use the triangular diagram for hornblende and biotite as well as for pyroxenes and olivine. Sequently for study of rocks carrying hornblende and biotite, it is also required to estimate the ratio, $CaSiO_3 : MgSiO_3 : FeSiO_3$, in these minerals by a simple method. The writer attempted to estimate it from the optical properties, and attained to a fairely successful result as reported in this paper.*

* cf. S. TANEDA: Jour. Jap. Assoc. Min. Petr. & Eco. Geol., Vol. XXIX, Nos. 3 & 5, 1943.

Professor Dr. K. SUGI read the manuscript kindly and sincere gratitude should be offered to him.

II. On hornblende

The present purpose is the estimation of the ratio, $CaSiO_3$: $MgSiO_3$: $FeSiO_3$ of the so-called the " hornblende " from the optical properties.

At the first it is desired to ascertain how far the refractive index of hornblende is an indication of its chemical composition. For this purpose the data were taken from literatures, concerning to large number of " hornblendes " and several " hastingsites."** They suggest that the refractive index is largely dependent on the ratio of Total FeO : MgO, and then to the values of Fe_2O_3, TiO_2, Al_2O_3, etc, to some extent throughout all hornblendes in the both of igneous rocks and metamorphic rocks. These relations were illustrated by plotting the values of the refractive indices, the optical angles, TiO_2, Al_2O_3, Fe_2O_3/FeO, CaO, H_2O and alkalis, against the values of FeO content (100 Total FeO/(Total FeO + MgO)). (Fig. 1). Some notable points in Fig. 1 are remarked below.

II. 1. The values of Al_2O_3, CaO, TiO_2, Fe_2O_3/FeO, H_2O and alkalis.

These values are rather variable and especially the points for some volcanic rocks and metamorphic rocks are prominent in the amount of deviation, but the general tendencies of these variation are also found as follows:

1) Al_2O_3: In the so-called the " hornblende ", Al_2O_3 is variable ranging from 3.77% to 14.98%, but the mean values is about 11% throughout ferriferous hornblende over FeO 50 in Fig. 1, and decreases with decrease of FeO content from FeO50, down to 7% at FeO25.

2) CaO: As a whole the CaO is approximately constant, that is about 13–12% throughout the range from FeO20 to FeO75, but it decreases with increase of FeO content over FeO75 down to 10% at FeO90.

3) TiO_2: Although the values of TiO_2 are variable, there is a

** The list of data is not given in this part due to the lack of space.

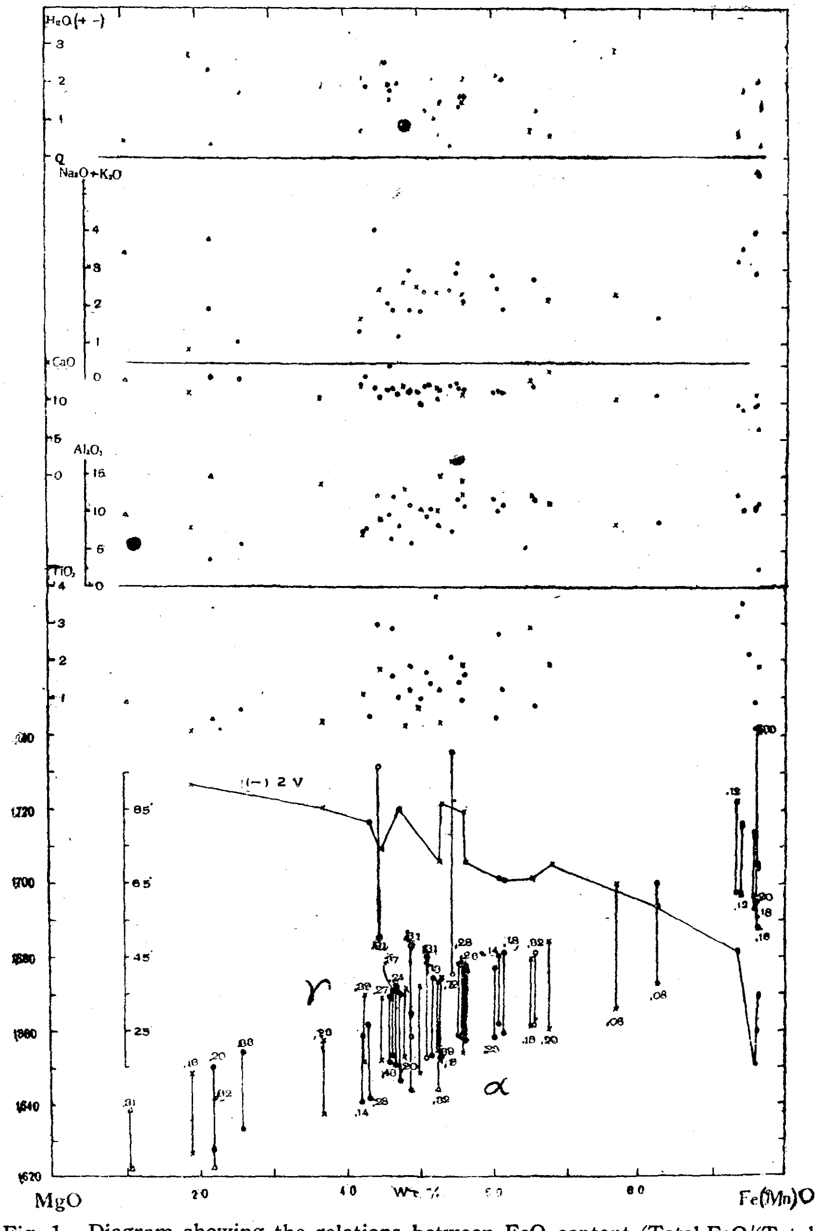

Fig. 1. Diagram showing the relations between FeO content (Total FeO/(Total FeO+MgO)) of "hornblende" and its optical properties, Al_2O_3, CaO, TiO_2, Fe_2O_3/FeO, H_2O and alkalis.

The figures (for example (, 20)) are the ratio of Fe_2O_3 expressed as FeO to total FeO.

Black circles: "Hornblende" from igneous rocks.
Blank circles: "Hornblende (and oxyhornblende)" from volcanic rocks.
Crosses: "Hornblende" from metamorphic rocks.
Squares: Hastingsite.
Triangles: Fluor-Amphibole.

tendency that it slightly increases with increase of FeO content. It is 1% for FeO45 and 2% for FeO90.

4) Fe_2O_3 (expressed as FeO)/Total FeO: The ratio is variable, and the amount of variation is large in volcanic rocks which seems to be suffered oxidation. It is, however, about 0.2 throughout the whole range of FeO content.

5) H_2O: Although the amount of H_2O is not constant, there is a tendency that it decreases with increase of FeO content. It is 2% at FeO 20 and 1.5% at FeO 90.

6) Na_2O+K_2O: The variation of Na_2O+K_2O in the amount is also prominent, but it may be possible to take 2.5% as the mean value throughout the whole range of FeO content.

II. 2. The optical angle

The optical angle decreases with increase of FeO content and the ratio Fe_2O_3/FeO, while it is considerably variable caused by the influence of other factors.

II. 3. The refractive index.

1) The refractive index increases with increase of FeO content (or the ratio Total FeO/(Total FeO+MgO)).

2) TiO_2, Fe_2O_3 and Al_2O_3 raise the refractive index to such extent as the influence must be taken into account.

3) CaO, H_2O, F and alkalis probably bring about a lowering of the refractive index.

4) Of all factors above mentioned the principal one is FeO content.

Consulting to all facts just mentioned, it may be conclusive that the refractive index of common hornblende, which is not high in Fe_2O_3 and TiO_2, increases with increase of FeO content, and can be taken as an indication of the latter.

In Fig. 2 the mean values of α, γ, $(-)2V$ and some components of hornblende against its FeO content are shown. From Fig. 1 and Fig. 2 the intensity of influnce of TiO_2, Al_2O_3, Fe_2O_3, CaO, H_2O and alkalis to the refractive index is estimated approximately.

1) TiO_2: The amount by which 0.1%* of TiO_2 raises the refra-

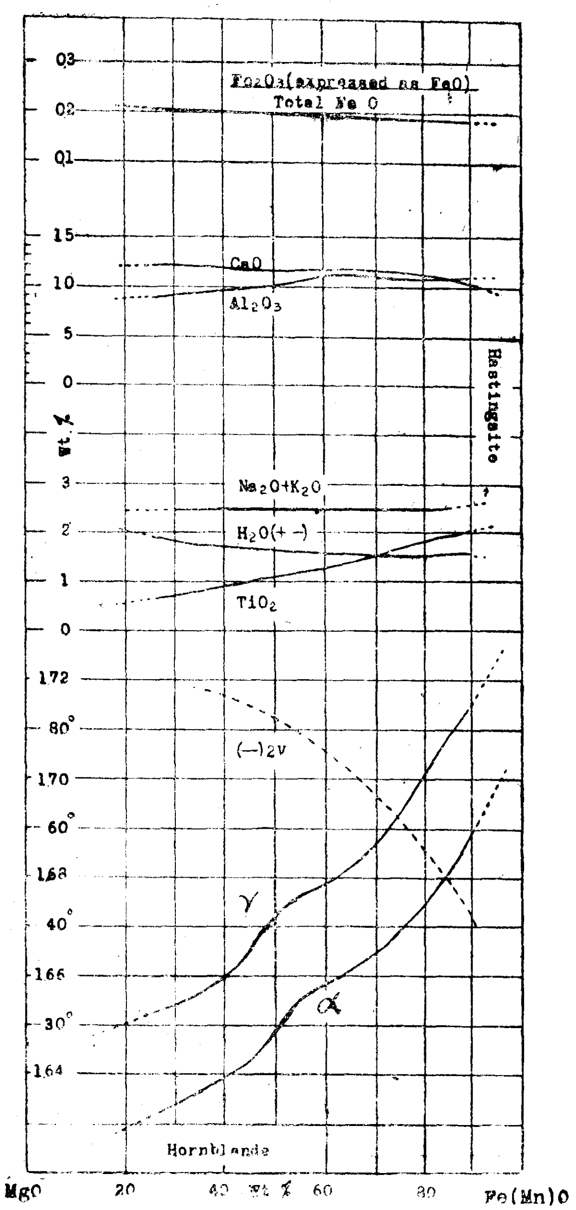

Fig. 2a. Variation between FeO content of "hornblende" and its optic properties, along with the values of TiO_2, Al_2O_3, CaO, Na_2O+N_2O, H_2O and Fe_2O_3/FeO, constructed by the mean of values plotted in Fig. 1.

ctive index is about $+0.0005$. Excess TiO_2 over 1% is hardly influential.

2) Fe_2O_3: The influence of Fe_2O_3 to the refractive index is provided by following formula: $+0.1$ (Fe_2O_3 expressed as FeO/Total FeO)*[2].

3) Al_2O_3: $+(0.001+0.00004(\text{FeO content}(>50)-50))$ per 1%*.

4) CaO: CaO appears to dilute or mask the effects of Al_2O_3. The intensity may be about $-(0.0005+0.00005(\text{FeO content}(>40)-40))$ per 1%*.

5) H_2O: -0.0005 per 1%.

6) Alkalis: -0.002 per 1%.

In this part + means the raising of the refractive index and − means the lowering of it. *The excess over the average.

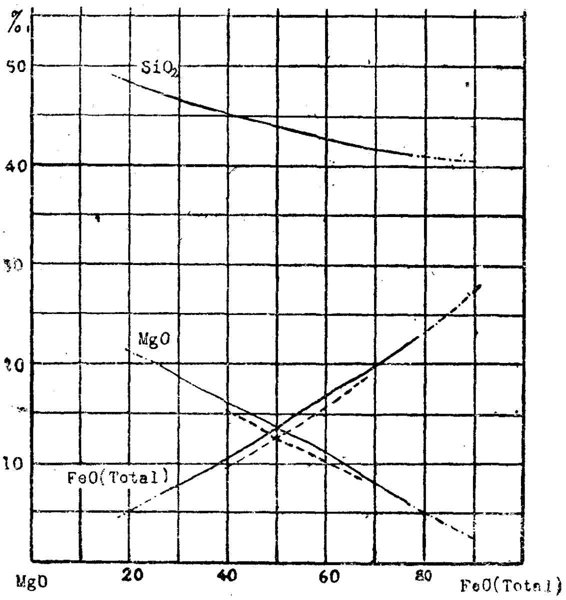

Fig. 2b. Variations between FeO content and the values of SiO_2, FeO (total) and MgO in "hornblende".
Broken line is concerned with metamophic rock alone.

From the same data the ratio $CaSiO_3 : MgSiO_3 : FeSiO_3$ was calculated and plotted in the triangular diagram, Fig. 3. In it a regularity of the change of the ratio $CaSiO_3 : MgSiO_3 : FeSiO_3$

along with γ is revealed, while the optic angle is rather variable. Sequently it is convenient to estimate the ratio of ordinary hornblende from its refractive index (γ or α) alone. For this purpose Fig. 4 was constructed. There is a notable fact that, though the data are yet few, the refractive index of hornblende (not oxyhornblende) from volcanic rocks is too high for the proportion of $CaSiO_3$, $MgSiO_3$ and $FeSiO_3$ (or $MgO:FeO$), if the relation as shown in Fig. 4 (or Fig. 2) is taken as normal. Sequently the proportions are properly estimated from corrected γ, that is 0.003 (approximate) lower than the measured value.

Appendix: **On variations between chemical compositions and optic properties in the hornblend-cummingtonite-grunerite system.**

It has been known that immiscibility gap exists between hornblende (or actinolite) and kupfferite-grunerite series. On the other hand, not so infrequently are met with light coloured hornblendes of which optic properties are intermediate between hornblende and cummingtonite. At present it is not inconceivable that the amphibole of intermediate type between hornblende and cummingtonite is produced at a certain condition, and it is not nonsense to estimate the pyroxene components of such amphibole from its optical properties.

The variation between chemical compositions and optical properties in the hornblende-cummingtonite-grunerite system is estimated from the data of hornblende, tremolite, actinolite, anthophyllite, cummingtonite and grunerite.*

From the diagram of tremolite-actinolite series and kupf-

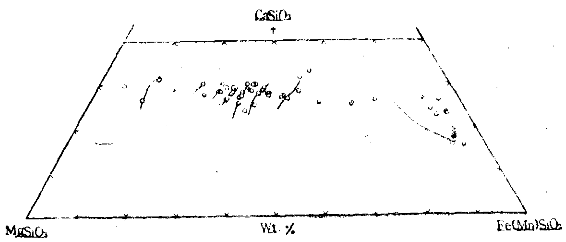

Fig. 3. Triangular diagram showing the proportions of $CaSiO_3$, $MgSiO_3$ and $FeSiO_3$ in the "hornblende". (Variation of γ is also shown).

* The data are not shown in this paper due to the lack of space.

ferite-grunerite series (Fig. 5), and that of hornblende (Fig. 4), it is conceivable that the pyroxene components of the intermediate type is estimated from its optical properties almost independing on the amount of Al_2O_3. Sequently the variations between chemical composition and optical properties in the hornblende-cummingtonite-grunerite system may be adopted to the estimation of the pyroxene components of the intermediate type (Fig. 6).

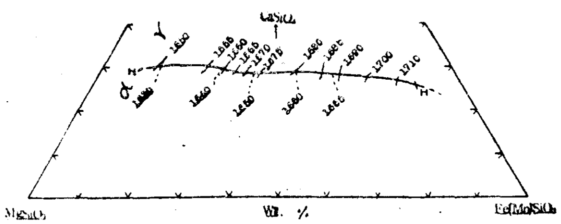

Fig. 4. Triangular diagram for the estimation of the ratio, $CaSiO_3 : MgSiO_3$ $FeSiO_3$ of "hornblende" from its refractive indices. Curve H–H shows the range of common "hornblende" in composition.

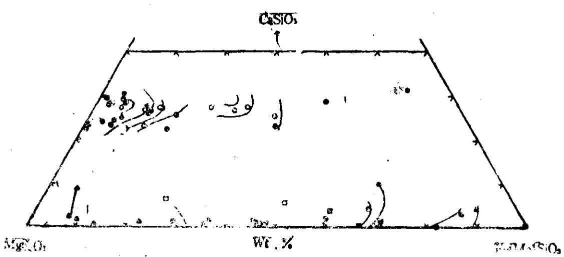

Fig. 5. Triangular diagram showing the variation between pyroxene components and the refractive index in tremolite, actinolite, anthophyllite, cummingtonite and grunerite.

III. On biotite

The similar method was adopted to the investigation of biotite as to the relation between the refractive index and chemical composition, and the writer was led to the conclusion as follows:

Although the accuracy is much inferior to the case of hornblende, the ratio $MgSiO_3 : FeSiO_3$ of the biotite in igneous rocks is also estimated from its refractive index, and the influence of

Fe_2O_3, TiO_2, Al_2O_3, CaO, and H_2O to γ is also similar to the case of hornblende. These relations are illustrated in Fig. 7 and Fig. 8.

Although it is difficult to ascertain, in the biotite the approximate amount by which 1% of TiO_2 raises the refractive index is $+0.225/FeSiO_3$*, the influence of Fe_2O_3 to the latter is $+0.13$ (Fe_2O_3 expressed as FeO/Total FeO)[2], and that of Al_2O_3 may be $+0.1/FeSiO_3$*. CaO and H_2O bring about a lowering of the refra-

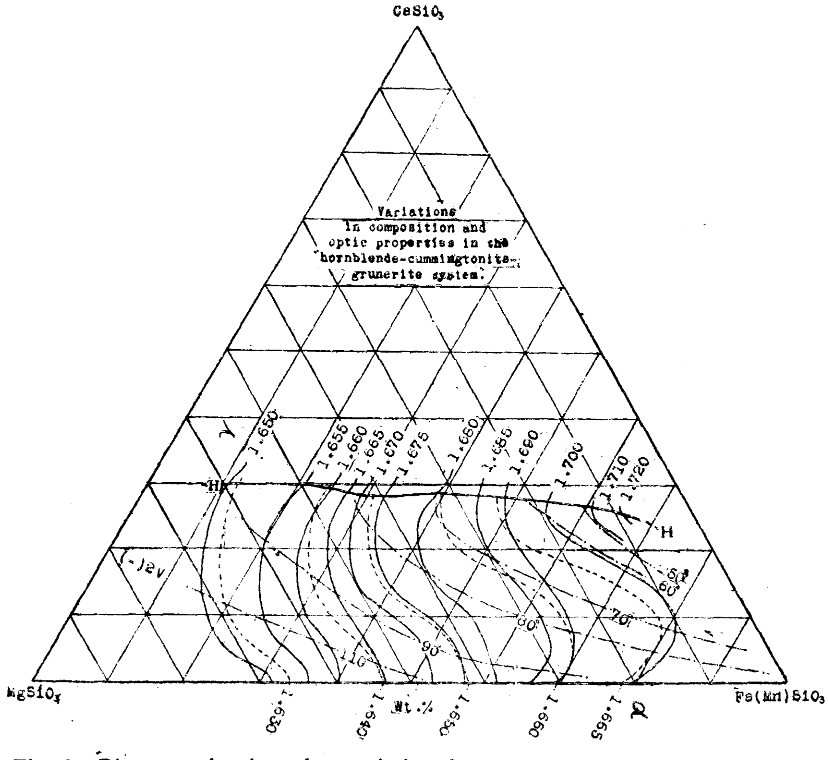

Fig. 6. Diagram showing the variation between pyroxene components and optical properties in the hornblende-cummingtonite-grunerite system. cf. Fig. 4.

ctive index. The amount of the influence of 1% of CaO is about $-0.00015 \times FeSiO_3$*, and that of 1% of H_2O is about -0.001. K_2O seems to raise the refractive index by $+0.002$ per 1%.

* $FeSiO_3 = 100\ FeSiO_3/(FeSiO_3 + MgSiO_3)$.

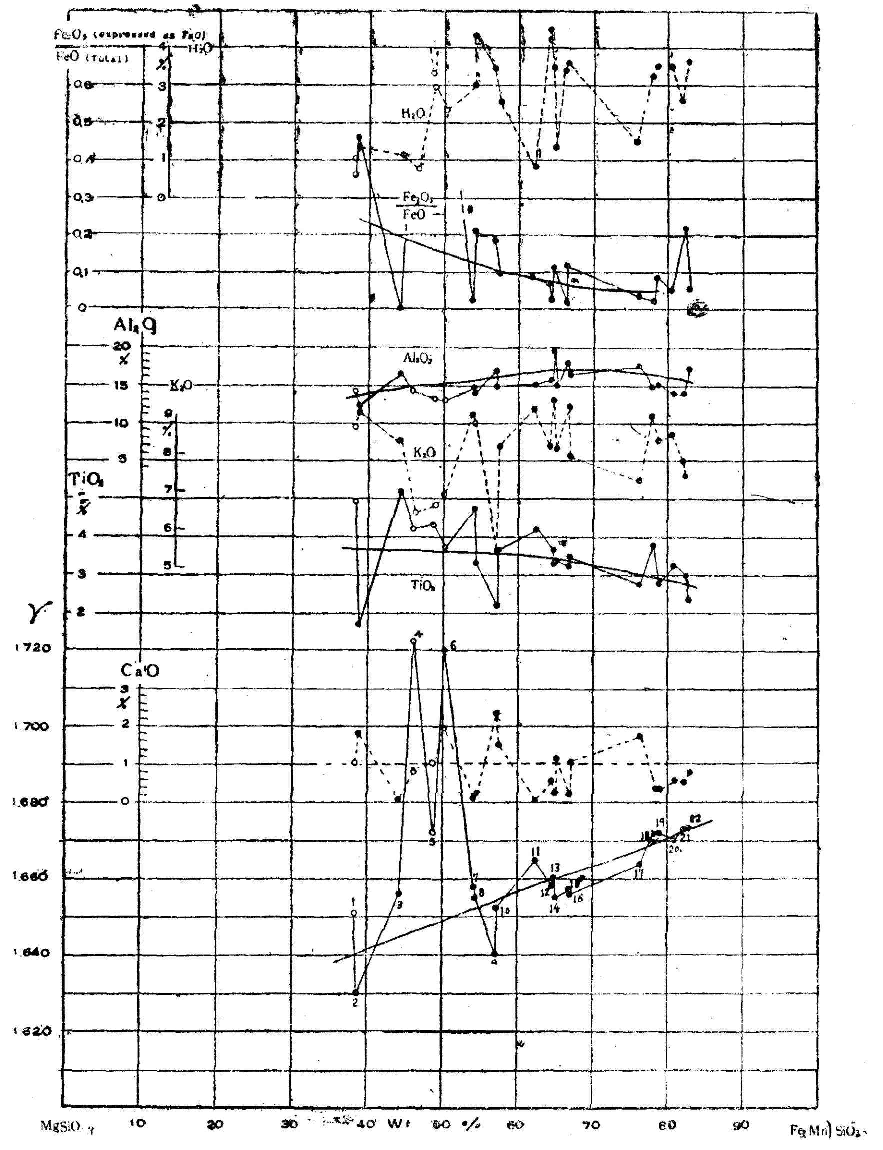

Fig. 7a. Diagram showing the change of refractive index γ, the amount of TiO_2, Al_2O_3, CaO, K_2O, H_2O and the ratio Fe_2O_3/FeO, along with the increase of Fs content in biotite.

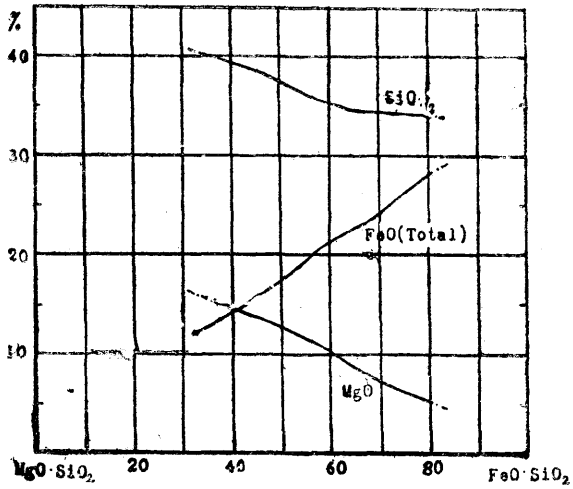

Fig. 7b. Diagram showing the change of the amount of SiO_2, FeO (Total) and MgO along with the increase of Fs content in biotite.

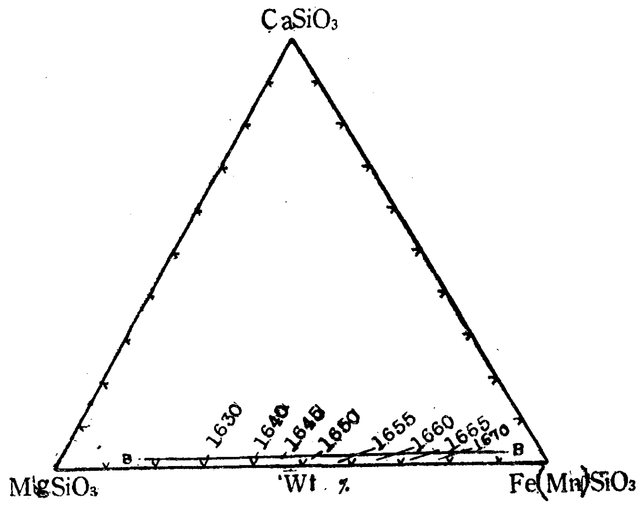

Fig. 8. Diagram showing the variation between pyroxene components and γ in biotite. Curve B-B shows the range of common biotite in composition.

IV. Summary

In the course of discussion on the crystallization of liquid magma, it is required to estimate the proportion of the pyroxene components ($CaSiO_3$: $MgSiO_3$: $FeSiOo_3$) in hornblende and biotite as well as in pyroxenes and olivine.

For this purpose a method, by which the ratio $CaSiO_3$: $MgSiO_3$: $FeSiO_3$ of hornblende and biotite could be estimated from their optical properties, was contrived. At the first it was ascertained that the refractive index of hornblende was an indication of its Total FeO/(Total FeO + MgO), and then a triangular diagram of $CaSiO_3$-$MgSiO_3$-$FeSiO_3$ system was constructed, by which the pyroxene components of hornblende could be estimated from its refractive index. On biotite also the similar method was taken. In the both minerals the amount by which Fe_2O_3, TiO_2, Al_2O_3, CaO, H_2O and alkalis give the influences to the refractive index were also estimated. Variations between chemical composition and optical properties in the hornblende-cummingtonite-grunerite system was also shown.