ON THE CUMMINGTONITE-PLAGIOCLASE ROCK OF THE KOSHIMIZU DISTRICT, TOYAMA PREFECTURE, JAPAN

(Studies on the Hida Metamorphic Rocks 3)

By

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(With 2 Plates and 5 Text-Figures)

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Introduction

In general, it is characteristic that the Hida metamorphic zone is composed of various metamorphics and intrusives such as amphibolite, amphibole gneiss, crystalline limestone, and granite. It has been said that the pelitic metamorphics are comparatively rare in this zone. A few years ago, however, some special metamorphic rocks of pelitic origin were found in the zone by the present author at Koshimizu and by Ishioka and the author at Unazuki(5). The representative rocks from the Unazuki district are staurolite-almandine schist and staurolite-cyanite almandine schist, while these from Koshimizu are as follows: cordierite-sillimanite-garnet gneiss, cordierite-sillimanite-andalusite-garnet gneiss, biotite-garnet gneiss and cummingtonite-plagioclase rock.

These rocks are locally intercalated by layers of amphibole gneiss, granitic migmatite, crystalline limestone, graphite ore bodies and occasionally invaded by gabbroic intrusives which are now partly represented by amphibolite.

Some of these pelitic rocks contain a considerable amount of graphite and they seem to belong in all respects to kinzigite, which was recently described by HIETANEN(4) in detail.

In the present paper it is intended to present a general account of the cummingtonite plagioclase rock from the petrographical and genetical points of view and the natures of the other pelitic rocks will be stated on another occasion.

Journ. Fac. Sci., Hokkaido Univ., Ser. IV., Vol. VIII., No. 4, 1954.

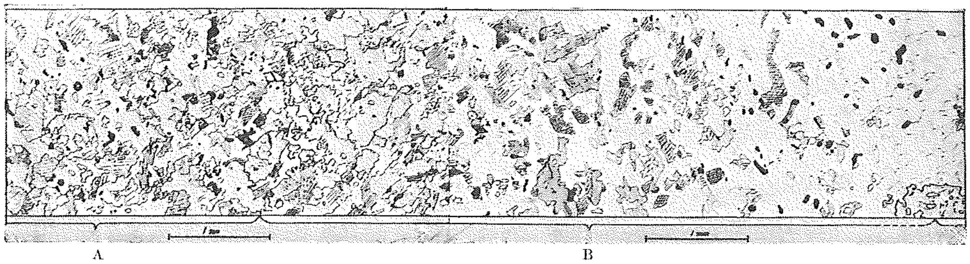


Fig. 1. Sketch showing the relation between diopside-plagioclase rock (a), amphibolite (b), cummingtonite-plagioclase rock (c), and biotite-garnet gneiss (d). (continued to the figure in the next page).

Descriptions of Rocks

The cummingtonite-plagioclase rocks of Koshimizu district generally occur as thin beds of a few mm thickness, intercalating always between the calcareous rocks and pelitic rocks. Here will be given a general account of representative typical examples of the rocks from four localities in the district.

Example 1. In the valley of the Toga river, the author found a boulder which is composed of an alternation of biotite-garnet gneiss and diopside-plagioclase rock, each layer of the rocks being 5–10 cm in thickness. The latter shows a so called boudinage[2]. (Pl. 27, (I), Fig. 1a and 1b). At the narrow part of the boudinage is found an aggregation of large crystals of garnet, which may be rich in grossularite component.

Under the microscope, the boundary zone between diopside-plagi-

TABLE 1

	Diopside-plagioclase rock	Amphibolite zone	Cummingtonite-plagioclase rock	Biotite-garnet gneiss
Thickness		5.6 mm	12.2 mm	
Quartz	6.9%	10.1%	12.2%	21.1%
Plagioclase	39.7%	31.2%	32.0%	50.0%
Biotite	—	—	7.9%	16.0%
Green amphibole	4.6%	36.7%	1.1%	0.1%
Cummingtonite	—	—	27.4%	—
Diopside	40.9%	3.0%	—	—
Garnet	5.2%	14.0%	14.2%	4.7%
Accessory minerals	2.8%	5.1%	4.5%	8.3%

oclase rock and biotite-garnet gneiss shows a peculiar zonal structure as shown in Table 1.

Diopside-plagioclase rock has equigranular structure, and its mineral paragenesis shows that it is derived from calcareous sediments. Diopside forms a short prismatic crystal, and is nearly colourless, some times pale greenish, $2V\gamma$ is 58°. In the marginal part of the diopside plagioclase rock the amount of green amphibole increases, and at first it appears as minute grain in the rim of diopside, and then gradually increases its idiomorphism. In the next amphibolite zone, green amphiboles are the only mafic component and they show regular orientation. This parallelism is conspicuously in contrast to the equigranular texture of diopside plagioclase rock.

Next to this zone, the cummingtonite-plagioclase rock is found. In the boundary part between amphibolite and cummingtonite-plagioclase rock, cummingtonite is surrounded by pale bluish green actinolitic amphibole, the quantities of which decrease gradually and at last quite disappear toward the cummingtonite-plagioclase rock. Cummingtonite has a long prismatic crystal arranged in parallel to gneissosity. The pleochroism is weak, $X=Y=$ light yellow, $Z=$ light yellowish brown, $c\Lambda Z=15°$, $2V\gamma=80°$. It may be common cummingtonite which is poor in gruenerite molecule[10]. The characteristic in this zone is the texture of plagioclase ($An=80$) which forms long spheroids elongated parallel to gneissosity, filling up the intersticials of the aggregates of cummingtonites crystals. In this plagioclase, there can be seen many vermicular quartz crystals showing a kind of myrmekitict exture. It is worthy of notice that the plagioclase in the cummingtonite-plagioclase rock has higher An content than that in the next biotite-garnet gneiss, and has myrmekitic texture, while the plagioclase of biotite-garnet gneiss always occurs as porphyroblast. The chemical composition of the cummingtonite-plagioclase rock is shown in No. 3 Table 2.

The outer zone of cummingtonite-plagioclase rock is biotite-garnet gneiss, which contains porphyroblastic plagioclase (An 40), which shows always pericline twin. The modal composition of this rock is quite similar to the biotite-garnet gneiss of example 2 explained later, and chemical composition of both rocks may also be nearly the same.

The relation among the above cited rocks is illustrated in Fig. 1.

Example 2. The outcrop of example 2 is found at about 500 m south of Koshimizu graphite mine, being composed of biotite-garnet gneiss and amphibolite. (Fig. 2). In this amphibolite there are leucocratic veins runniug parallel or obliquely to the gneissosity of the rock, partly showing ptygmatic structure. Lenticular or irregular melanocratic masses 5～10 cm in width, are often found in the amphibolite zone.

The amphibolite consists of diopside, green amphibole, plagioclase, quartz and opaque miderals. In the quartz, long needles of clear bluish green amphibole are included. Green amphibole arranges in nearly parallel, the others are in rather granular crystals. Diopside is often corroded, and An % of the plagioclase is 80 (Pl. 27, (I), Fig. 2).

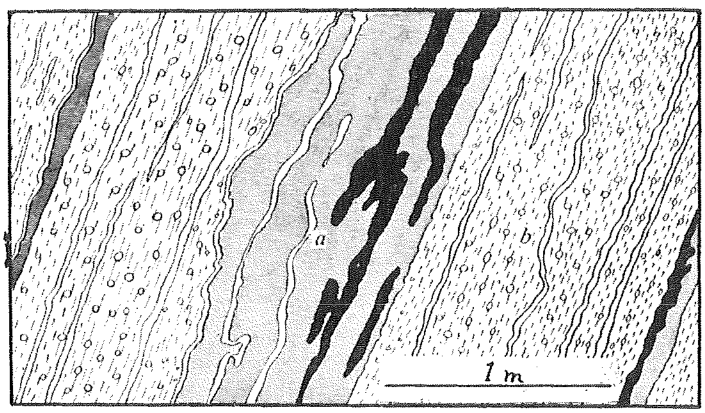


Fig. 2. Sketch showing the relationship between amphibolite and biotite-garnet gneiss. a : amphibolite, b : biotite-garnet gneiss.

The leucocratic part is built up of diopside, green amphibole, chlorite, epidote, sphene, plagioclase and quartz. Diopside contains bluish green amphibole as inclusions, showing the shieve texture. The chloritization and sericitization of plagioclase are usually conspicuous. Chemical composition of melanocratic part of amphibolite is shown in No. 1 Table 2. It is characterized by a low content of SiO_2, and by a high

TABLE 2

Chemical composition of rocks

	No. 1	No. 2	No. 3	No. 4	No. 5
SiO_2	42.81	50.17	47.15	56.24	53.5
TiO_2	0.12	0.06	1.92	0.88	
Al_2O_3	15.86	18.09	19.68	20.72	13.9
Fe_2O_3	3.97	5.00	2.46	2.06	0.8
FeO	10.17	9.99	8.38	5.79	3.2
MgO	4.98	3.15	6.80	3.07	9.2
CaO	17.96	6.94	8.36	8.85	18.3
Na_2O	3.96	5.60	2.56	1.61	0.8
K_2O	0.25	0.68	0.31	0.94	
Total	100.08	99.68	98.62	100.16	99.7

Numbers of Cations in the Standard Cells

	No. 1	No. 2	No. 3	No. 4	No. 5
Si	43.2	48.7	46.0	52.5	47.3
Ti	0.1	0.1	1.2	0.5	
Al	19.2	20.8	23.0	21.6	14.4
$Fe^{\cdot\cdot\cdot}$	3.1	3.6	1.8	1.4	0.5
$Fe^{\cdot\cdot}$	9.6	8.2	6.9	4.5	2.3
Mg	7.6	4.7	10.2	4.2	12.4
Ca	19.6	7.3	8.8	8.8	17.3
Na	7.8	10.6	4.9	2.9	1.4
K	0.3	0.9	0.5	1.2	
Total	110.5	104.9	103.3	97.6	95.6

Mineral composition

	No. 1	No. 2	No. 3	No. 4	No. 5
Quartz	2.3	10.5	12.2	22	6.9
Plagioclase	37.3	58.6	32.0	52.5	39.7
Chlorite			0.5		
Biotite		9.1	7.9	13.9	
Green Amph	27.1		1.1	1.0	4.6
Cummingt.		11.3	27.4		
Pyroxene	22.7				42.0
Garnet		0.4	14.2	3.9	5.2
Sphene	6.3				
Opaque M.	0.1	9.8	4.0	4.9	
Epidote	3.8				2.8
Caloite				7.0	
Apatite					

(No. 1) Amphibolite, at 500m south from the Koshimizu Mine. Y. YAMASITA, analyst.

(No. 2) Cummingtonite-plagioclase rock, found at the same place as No. 1, Y. YAMASHITA, analyst.

(No. 3) Cummingtonite-plagioclase rock, between diopside-plagioclase rock and biotite-garnet gneiss, at Toga river. Y. YAMASHITA, analyst.

(No. 4) Biotite-garnet gneiss, found at the same place as No. 1, Y. YAMASHITA, analyst.

(No. 5) Diopside-plagioclase rock, calculated from its modal composition.

content of CaO. These values show departure from those of any normal igneous rocks. But from the mode of occurrence, rock texture and the properties of the constituent minerals, it is suitable to consider that the material originated from igneous rock, changing chemical composition in the process of metamorphism.

Upon examining the contact part between biotite-garnet gneiss and amphibolite, the author found the cummingtonite-plagioclase rock as in the case of example 1. (Pl. 27, (I), Fig. 3). The constituent minerals of this rock are cummingtonite, green amphibole, reddish brown biotite, plagioclase, quartz and opaque minerals. Plagioclase (An 85) in this rock contains many quartz inclusions, showing poikilitic texture and its predominance in pericline twinning is characteristic. This feature is similar to that of above mentioned plagioclase (example 1).

Cummingtonite, $c \varLambda Z = 18°$, $2V\gamma = 84 \sim 86°$, has a multiple twinning, and is surrounded by a green amphibole. It may be rather rich in gruenerite molecule[10]. Chemical composition of cummingtonite-plagioclase rock (No. 2 and No. 3 in Table 2) are either high in Al_2O_3, FeO and/or MgO*. In this case the value of FeO/MgO is an important controlling factor to decide the nature of cummingtonite. As already mentioned, cummingtonite of No. 2 is rich in gruenerite molecule and that of No. 3 is poor in gruenerite molecule relatively**.

In the biotite-garnet gneiss the quartz-rich vains or lenticles are in parallel to gneissosity. The main portion of it is composed of porphyroblastic plagioclase and regularly parallel arranged biotite, though it shows something of the non-orientating, fine hornfels texture. This fact suggests that the rocks may belong to a low-grade metamorphic class rather than to the inner part of the Hida metamorphic zone. An content of porphyroblastic plagioclase is about 50, which is rather low in contrast to that of the neighbouring cummingtonite-plagioclase rock. Twinnnig of this mineral is commonly pericline. Garnets found in the contact zone are larger than those of the other part. Chemical composition of biotite-garnet gneiss is shown in No. 4 Table 2. It is rich in Al_2O_3, but is relatively poor in FeO.

Example 3. In the Momose river running beside the Koshimizu mine, the author found a boulder as shown in Fig. 3. Megascopically it is

* For reference the author cites the data for cummingtonite bytownite rock from Muuravesi, Finland: 51.27 SiO_2, 0.53 TiO_2, 17.55 Al_2O_3, 0.21 Fe_2O_3, 8.32 FeO, 0.05 MnO, 9.38 MgO, 9.18 CaO, 1.81 Na_2O, 0.50 K_2O, 0.03 P_2O_5, 0.78 $H_2O^{(+)}$, 0.08 $H_2O^{(-)}$, 0.37 S[3].

** FeO/MgO in molecular number of No. 2 and No. 3 is 1.74 and 1.21 respectively.

composed of the biotite-garnet gneiss, amphibolite, calcareous metamorphic rock, quartz veins, and dioritic rock. They are constructed into an irregular complicated structure. Under the microscope, along the contact part between biotite-garnet gneiss and amphibolite, there is found cummingtonite-plagioclase rock which shows similar properties to the above mentioned ones. The arragement of the rocks is as follows ;

a. biotite-garnet-plagioclase-quartz rock,
b. cummingtonite-plagioclase-quartz rock,
c. green amphibole-garnet-plagioclase-quartz rock,
d. diopside-green amphibole-plagioclase-quartz-sphene rock,

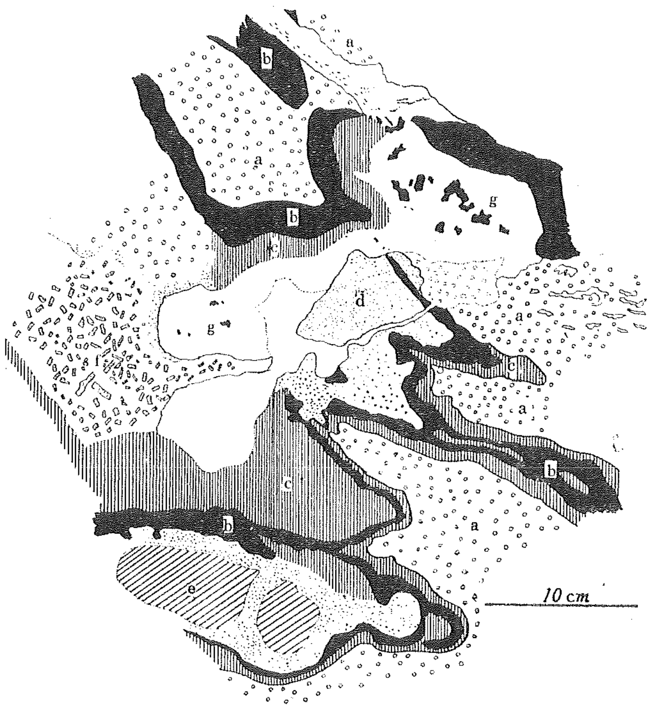


Fig. 3. Sketch showing the complicated structure which is found in the boulder at the Momose river. a : biotite garnet gneiss, b : amphibolite, c : diopside-plagioclase rock, d : fine grained amphibole gneiss, e : amphibole gneiss, f : dioritic rock, g : pyrrhotite bearing quartz vein. Cummingtonite-plagioclase rock is seen between a and c or a and b.

e. green amphibole-plagioclase-quartz rock,
f. cummingtonite-plagioclase-quartz rock,
g. biotite-garnet-plagioclase-quartz rock.

In this case also the cummingtonite-plagioclase rock occurs as a narrow zone between calcareous and pelitic rocks. This fact is similar to the case of the above mentioned two examples. But in this cummingtonite-plagioclase rock, poikilitic texture in plagioclase is not so conspicuous as in the former one. An content of plagioclase is 85. In Fig. 2, Pl. 28, (II), the contact part between cummingtonite-plagioclase rock and biotite-garnet gneiss is shown.

Example 4. In the same locality as example 3, the author found a rare type of boulder, made up of diopside-garnet-plagioclase rock (Pl. 28, (II), Fig. 2), and sillimanite-garnet-biotite-graphite gneiss, kinzigite. The former is orbicular or spherical in form, occurring just like a xenolithic mass in the igneous rocks. In the kinzigite, under the microscope, cordierite and sillimanite are found as important essential minerals of the rock (Pl. 28, (II), Fig. 4). Sillimanite occurs sometimes in long-needle form, $3\,mm \times 0.3\,mm$, and cordierite shows irregular or spheroidal forms, which usually contain small needles of sillimanite.

Cummingtonite-plagioclase rock was found between the diopside-plagioclase-garnet rock and kinzigite. Its features were very similar to the above described cummingtonite-plagioclase rocks. This rock is composed of cummingtonite, green amphibole, reddish brown biotite, quartz and opaque minerals (Pl. 28, (II), Fig. 3).

It is remarkable that cummingtonite-plagioclase rock is found between pelitic and calcareous rock without exceptions, as described above.

Origin of Cummingtonite Plagioclase Rock

Formerly, the author considered that cummingtonite-plagioclase rocks probably was derived under metamorphic conditions from sedimentary rocks which might have had originally the same special chemical composition as the present rock, and that they were produced by isochemical metamorphism.

As a result of the accumulation of much new data on the cummingtonite-plagioclase rock, however, the author proposes now to explain this phenomenon as the result of metamorphic differentiation, as SUZUKI,[8] LANEY[6] and recently TURNER[9] have stated on similar problems. It is considered that the original sedimentaries probably showed alternation of thin layers of calcareous and pelitic sediments in company with the basic lava or sheet, and afterward, cummingtonite-plagioclase rocks were made as a reaction zone between these layers in the course of metamorphism by migration of elements from both sides. In this case, the degree of migration was relatively small, for the reaction zone is usually only a few mm in width.

The author anticipated finding a description of peculiar occurrences of cummingtonite-plagioclase rock in HIETANEN's paper as in these cases, because the rocks of Kalanti district, south west Finland studied by her, are very similar in all respects to those of Koshimizu district.

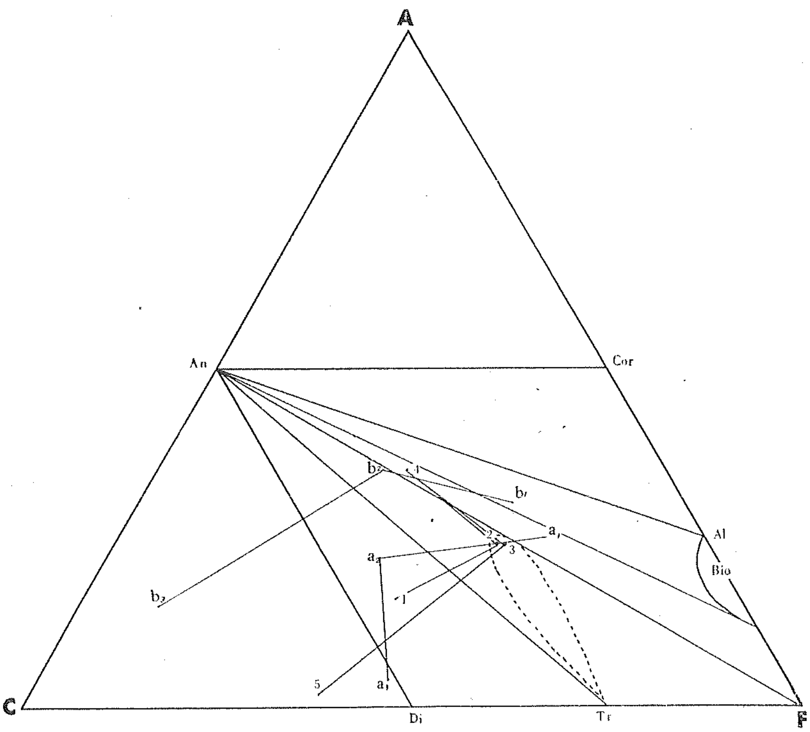


Fig. 4. ACF diagram showing variation in chemical composition, in 1-2-4, 5-3-4, b_1-b_2-b_3, and a_1-a_2-a_3. Points 1, 2, 3, 4, and 5 correspond to the Nos. in Table 2. a_3 a_2 and a_1 are points which represent calcareous concretion, reaction zone and surrounding hornfels at Oshirabetsu. b_3 b_2 and b_1 are points which represent calcareous rock, reaction zone and surrounding graywacke, at Ducktown, Tennessee.

But no detailed description on the occurrence of the rock could be found in her paper[4].

In comparison with the chemical properties of these rocks and their interrelations of each other, the author has plotted the analytical values of the amphibolite, cummingtonite-plagioclase rocks and biotite-garnet-gneiss and diopside-plagioclase rock in ACF diagram (Fig. 4). For comparison, in the same Figure, there are cited the chemical composition of calcareous concretion, its reaction zone and surrounding metamorphics of Tokati, Hokkaidô, Japan and Ducktown district, Tennessee, studied by SUZUKI and LANEY respectively.

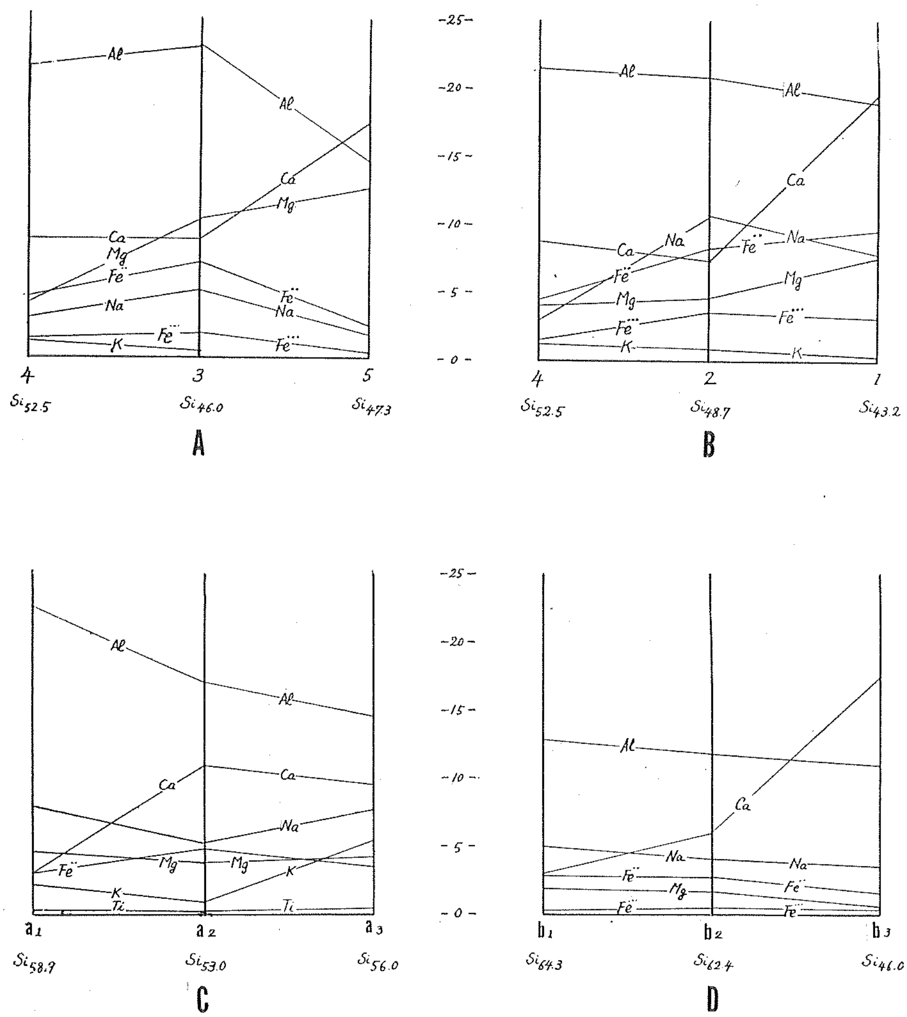
From the diagram, it is clear that there is conspicuous difference between the examples described in this paper and the reaction zones studied by Messrs SUZUKI and LANEY ; the loci representing the chemical composition of the cummingtonite-plagioclase rocks lie usually to the F side of the line which connects the points representing both the neighbouring original rocks, on the contrary the points of reaction zone which were found in Tokati and Ducktown specimens lie on the opposite side.

This disparity is considered to be derived from the difference of the amount of enriched stable elements in reaction zones. It is worthy to note that these examples all belong to amphibolite facies, from the mineral facies classification, and these reaction zones are all found between calcareous and pelitic rocks, but the reaction zones have different nature. These facts show that they have been subjected to different metamorphic conditions which are not reflected in the mineral parageneses of each rock.

The relations of each element seen in these rocks are shown in Fig. 5. In this Fig. points on ordinates represnt the number of cations in the rock when the number of oxygen ions is calculated as 160[1]. From this diagram general tendencies cannot be discerned as clearly as in Fig. 4.

It may be said, however, that Al, $Fe^{\cdot\cdot}$, $Fe^{\cdot\cdot\cdot}$ and Na tend to culminate, and to depress Ca, in both A and B of Fig, 5, and that $Fe^{\cdot\cdot}$ tends to culminate in both C and D of Fig. 5. Comparatively speaking, the amount of elements which migrated in and out is more in A and B than in C and D.

The author proposes the term *Rock Paragenesis* to denote such an inevitable relation which is shown between calcareous and pelitic



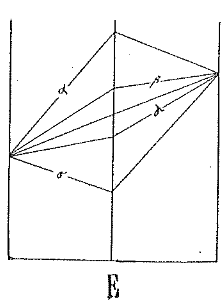


Fig. 5. The relations of each element which are seen in four cases, example 1(A), example 2 (B), Oshirabetsu (C) and Ducktown district (D). Nos. of A and B correspond to Nos. of chemical analysis in Table 2. a_3 a_2 a_1 in C are value of calcareous concretion, reaction zone and surrounding hornfels. b_3 b_2 b_1 in D are value of calcareous rock, reaction zone and surrounding graywacke.

The author regards α and β type of elements as culminated one, and γ and σ type of elements as depressed one. (See diagramm E) metamorphics and reaction zone. This term may be applicable to other phenomena, for instance, limestone-skarn-granite and country rocks-basic front-granite[7]. It may be said that the rocks of Koshimizu, Oshirabetsu and Ducktown all *belong to the same mineral facies, amphibolite facies, but show different rock parageneses.* To explain these points presicely, further studies of these kinds of metamorphic rocks must be done and more examples must be gathered.

In conclusion, the author expreses his gratitude to Professor J. SUZUKI, for his deep interest and encouragement during the work. To Assist. Prof. M. FUNAHASHI and the members of the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University and collaborators on the studies of Hida metamorphic zone, the author is indebted for helpful criticisms and advices.

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Explanation

of

Plate 27

Plate 27, (I).

Fig. 1a, b. Boudinage. G: Aggragation of garnets. 1/10 nat. size.

Fig. 2. Amphibolite. Composition: green amphibole, diopside and plagioclase. × 85.

Fig. 3. Cummingtonite-plagioclase rock. Composition: cummingtonite, poikilitic plagioclase, quartz and opaque minerals. × 85.

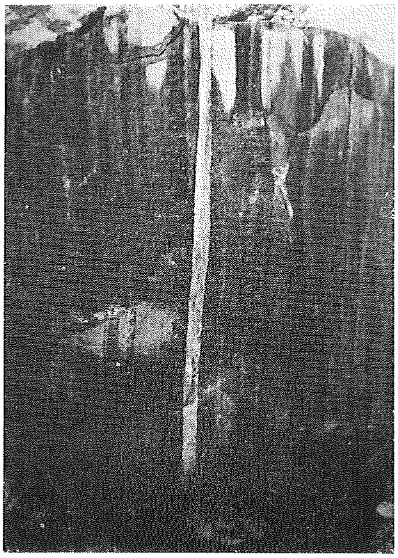

Fig. 1 a

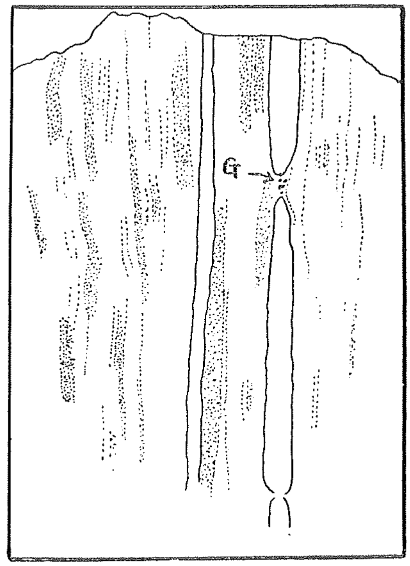

Fig. 1 b

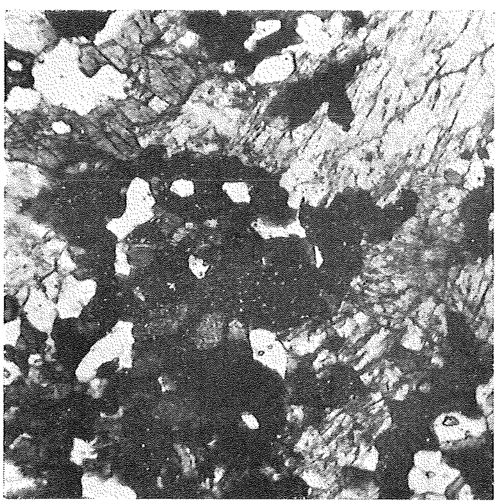

Fig. 2

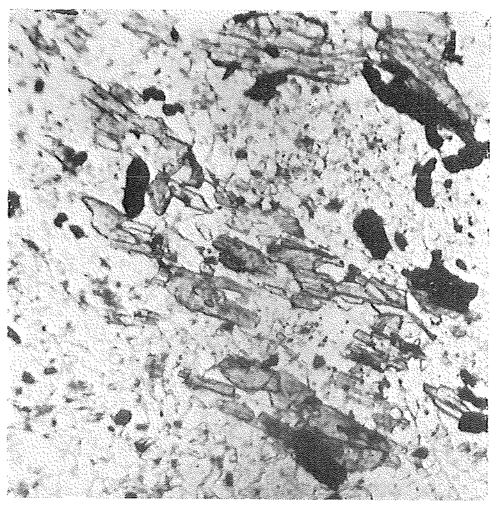

Fig. 3

H. KOBAYASHI: On the Cummigtonite-Plagioclase Rock

Explanation

of

Plate 28

Plate 28, (II).

Fig. 1. Boundary part between cummingtonite-plagioclase rock and biotite-garnet gneiss. Composition : garnet, biotite, cummingtonite, plagioclase and quartz. × 85.

Fig. 2. Diopside-garnet-plagioclase rock. × 85.

Fig. 3. Cummingtonite-plagioclase rock. Composition : cummingtonite, plagioclase, quartz and opaque. × 85.

Fig. 4. Kinzigite. Composition : sillimanite, cordierite, plagioclase, quartz and graphite. × 85.

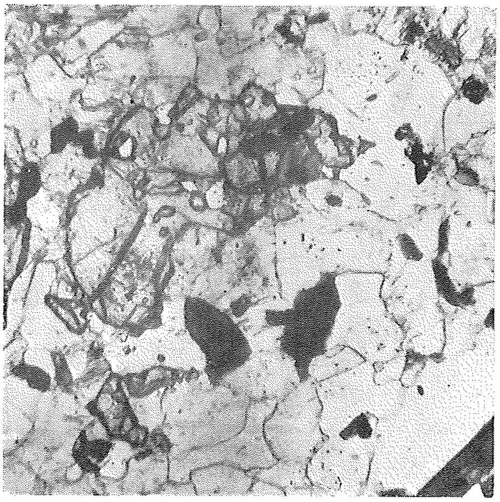

Fig. 1

Fig. 2

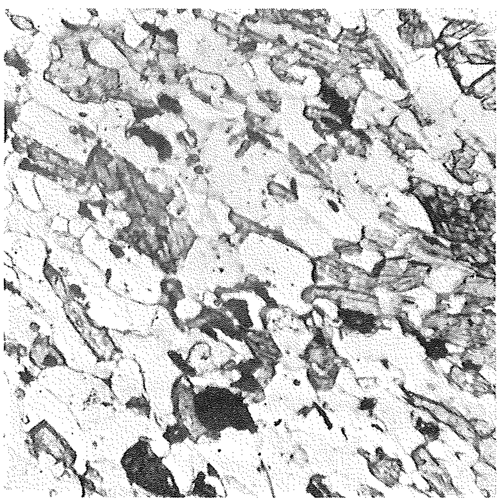

Fig. 3

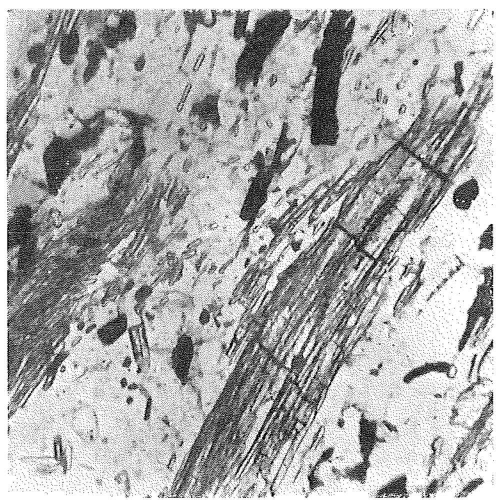

Fig. 4

H. KOBAYASHI: On the Cummingtonite-Plagioclase Rock