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On the Gabbro of the Cape of Muroto, Shikoku Island, Japan. Part I.

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Abstract

The gabbro is found as a sill in the Cretaceous? formation, and shows a fairly remarkable differentiation, and owing to this fact the mass consists of a series of gabbros from the Mg-rich gabbro to the ferrogabbro, containing, besides, the picrite-gabbro-facies. Moreover, there is the chilled diabase intraformationally intruding into the sedimentary rocks, caused by the repeated injections of the liquid partially separated from the cooling magma. The differentiation on the latest stage, however, does not crop out, though the mesostasis of this kind is observed under the microscope, nor any dioritic mass is observed. The origin of the differentiation is attributed to the strong fractionation of the magma, due to the gravitative sinking of the minerals on the earlier stage and to the rapid cooling of the magma. The olivine of the gabbro has the composition from Fa_{30} to Fa_{45}, the rhombic pyroxene from OF_{30} to OF_{43}. Generally speaking, the differentiation on the mafic components seems to be rather stronger than that on the salic ones.

The hydrous ferromagnesian silicates, such as amphiboles or micas, on the requidmagmatic stage seem to be hardly developed. The metasomatism of the magma, however, has a remarkable effect to the sedimentary rocks. The gabbro can be correlated, judging from the aspects of the crystallization in pyroxenek, to the "hypersthene rock series" of the volcanic rocks which characteristically develope in the orogen, but is clearly different from the gabbros in the kratogen.

The writer is obliged, furthermore, to give some explanations concerning the following respects: the existence of the considerable amount of olivine and pyroxenes contained in all rock-facies in the main gabbro and even in the facies on the later magmatic stage; the relation between the gradual Fe-enrichment in the mafic essential constituents during the crystallization and the Fe-oxidation; the influence of the contamination upou the magma; and the monoclinic pyroxene-gabbro itself intruding as dykes in the main gabbro. But these explanations will be detailed in Part II.

Introduction

The study on the gabbro of the Cape of Muroto, the southeast point of the Island of Shikoku, has been performed periodically during these several years by the writer. There are, also, the same kind of rocks which intrude contemporaneously at the seashores of Maruyama and Shiina, 6kms, and 9kms. respectively to the north of the cape. So the differentiation of the gabbro of the cape and its marginal metamorphisms are here reported as the representative of the three.

A. The geological characteristics

1) The geology of the environment. The geology of the environment is subject to the isoclinal and anticlinal folding of the Muroto formation*(1), and the portion taken as its axis in the black shale crops out at the west-seashore of the cape, 200 ms. apart from the gabbro; namely, the conglomerate, consisting of limestone pebbles, in the place 400 ms. to the north of Takaiwa of the west-shore, is correlated to that of Tsukimigahama in the east-shore, and between these conglomerates, black shale and the alternation of shale and sandstone are arranged symmetrically on the both sides of this axis. The shale near the conglomerate of the east side is particularly disturbed by small faults and folds. The igneous rock intrudes in the east wing of the anticlinal structure, extends towards North East until the north-shore of Bishagoiwa, 1.5kms apart from Tsukimigahama, forms a sill in the shale, bow-shaped eastwards, and dips to the west with a very high angle. The north terminal of the sill thins out in the lit-par-lit injection in the shale, where the beautiful striped structure is constructed together with the sedimentary rocks. At the south edge of Tsukimigahama, the sill develops to the utmost, and is 220 ms. wide, and elongates under the sea-water. Only its northern half, therefore, crops out. Around the part coming into contact with the igneous rock, grayish white metamorphosed sediment, which looks like a granophyre, develops, and its breadth is different at both sides of the sill; the metamorphosed zone in the east side amounts to 60 ms. in maximum, but one in the west to 90 ms. in maximum.

The gabbro of Shiina, comagmatic with the cape-gabbro, has no contact with the Shijujisan Formation**(1), which covers the Muroto Formation horizontally, perhaps unconformably, and so the relation between the two rocks can not be determined definitely. But the intrusions of these gabbros are judged to be prior to the sedimentation of the former beds, by the geological conjecture between them. By the arrangements of the various rock-facies in the gabbro of the cape, the mass is considered to have slightly tilted, into the present vertical situation after the consolidation. The above deduction will be detailed later. It seems to be reasonable that the intrusion of the gabbro has connection with the folding of the Muroto Formation***(1).

2) The arrangement of the gabbro. The gabbro is a composite sill, having

* The age of the formation is not earlier than the Cretaceous, according to J. Fukada and T. Kobayashi.

** The formation sedimented in a period not later than Miocene, according to J. Fukada and T. Kobayashi.

*** The time of the folding of the formation is regarded to be the lower Tertiary.

intruded at least twice, and classified in two groups based on the intrusive relations and the rock species. The one always contains olivine and two pyroxenes, as colored essentials, and constitutes the main part of the igneous mass; the others, which is coarse-grained, has only diopsidic pyroxene as mafic component and intrudes into the former in a state of veins.

a) Main gabbro. This mass is composed of several facies, arranged in parallel and symmetrically, from the margin to the interior, towards the elongation of the sill, though these facies vary in thickness.

The lit-par-lit injection-part in the northern terminal and the small dyke, a few meters apart from the main mass at Tsukimigahama are the fine-grained and chilled diabase (the intraformationally injected and chilled diabase). The marginal portion of the other places is the fine-grained and chilled diabase of the other kind (the chilled marginal diabase). At Bisyagoiwa the former is seen to intrude into the latter and makes a kind of branching vein from the fine-grained gabbro mentioned below*. So the former diabase is considered to be of the solution-origin connected with the fine-grained gabbro, and the latter to have derived from

Table 1. The arrangement of the various rock-facies in the main gabbro

	rock-facies \ locality	Tsukimigahama	Mikurado
east margin	chilled marginal diabase	(m) 1.5	(m)
↑	fine-grained two pyroxene-olivine-gabbro and the 1st concentration-zone	50	not cropped out
	medium-grained olivine-two pyroxene-gabbro (olivine: $\beta < 1.740$) and the 3rd concentration-zone	60	
	medium-, or coarse-grained two pyroxene-olivine-gabbro (olivine: $\beta > 1.740$)	20	12+
↓	medium-grained olivine-two pyroxene-gabbro (olivine: $\beta < 1.740$)	120	30
west margin	fine-grained two pyroxene-olivine-gabbro and the 2nd concentration-zone	7	4
	chilled marginal diabase	1.5	1.5

concentration-zone .... of mafic essential minerals (picrite-gabbro)

* The lit-par-lit injection may have been caused by the continued tectonic movement after the intrusion of the magma.

the magma on the earliest stage intruded in this position. In the interior of the chilled marginal diabase, the fine-grained pyroxene-olivine-gabbro is developed, and in thickness this rock of the east side is different from the same of the west side. The interior of the fine-grained gabbbro consists of the medium-grained olivine-two pyroxene-gabbro. In the inner part of the medium-grained facies, the concentration of the colored essentials is fairly noticed and the color-ratio of the rock somewhat increases, and this part is the ferrohypersthene-augite-hyalosiderite-gabbro containing sporadically the melanocratic lense* consisting mainly of those colored minerals. The boundaries of these rock-facies in the main gabbro show us various kinds of gradual and tranditional changes. It indicates the differentiation in situ (See Table 1).

The concentration-zones of the mafic constituents. In the main gabbro mentioned above, there are 2 or 3 horizons of the concentration-zones of the mafic essentials; namely, at Tsukimigahama, there is developed one zone on each margin of the fine-grained gabbros of the both sides adjacent to the chilled marginal diabase, and the one at the east side is named the 1st concentration-zone and the other at the west side the 2nd concentration-zone. The former shows the better development than the latter**. At the lower part of the medium-grained gabbro, namely, near the contact of the fine-grained gabbro of the east side, there is the 3rd concentration-zone, local and of smaller scale, in which irregular melanocratic masses with almost no salic minerals appear sporadically. These zones are represented by picrite-gabbros.

The mode calculated from the series of samples picked up from the sill, and arranged regularly to the traverse direction is shown on Fig. 1, from which the concentrations, and the changes of chemical composition, of the minerals are to be understood.

b) Monoclinic pyroxene gabbro (orthogabbro). This is the coarse-grained gabbro, having intruded in the comparatively inner part of the main gabbro, and developed in veins and this generally arranges in parallel with the strike of the main gabbro, but in some places the irregular veinlets branch out and cut the arrangement of the main rock-facies. In the similar position of the Maruyama-gabbro mass, there are the same dykes.

Leucocratic monoclinic pyroxene-gabbro, medium to coarse-grained, which bears the foliation due to the flow of fluid, intrudes, in veinlet, into the same kind of the non-foliated rock, mentioned above. In some cases, these two rocks, with the arrangement parallel to each other, inject into the main gabbro.

There is a great difference between these monoclinic pyroxene-gabbros and the main one on their mineral paragenesis. The periods of their intrusion, however, are continuous, and both are intimately associated, and so it seems that they have some genetical relations to each other.

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* It is coarse-grained and a kind of pegmatite.
** In the south of Bisyagoiwa, the 2nd zone is not so remarkable.

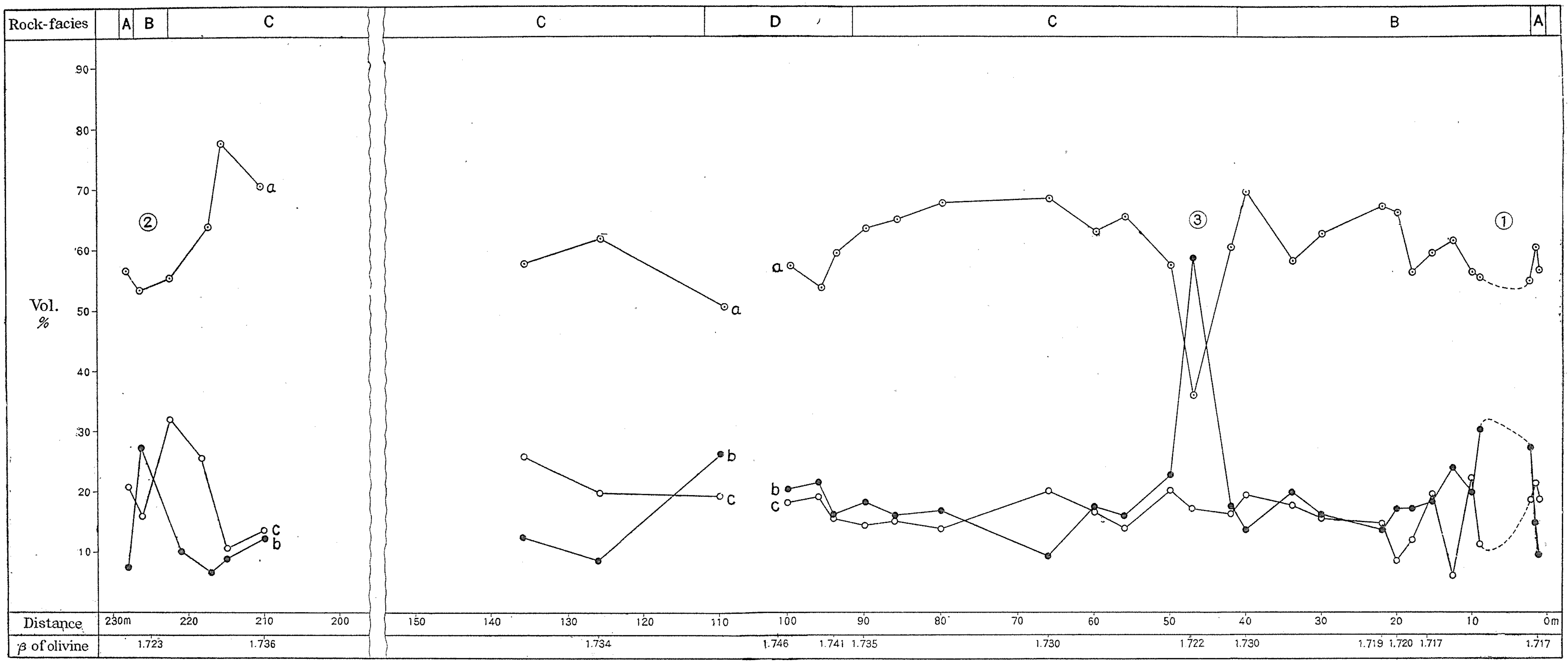

Fig. 1 The modes (vol.%) of the minerals of all the main gabbro -facies in the samples collected from the various points on the cross section of the sill (at Tsukimigahama)

A........the chilled marginal diabase
B........the fine-grained two pyroxene-olivine-gabbro
C........the medium-grained olivine-two pyroxene-gabbro
D........the medium-, or coarse-grained two pyroxene-olivine-gabbro

1........the 1st }
2........the 2nd } concentration-zone of the mafic constituents
3........the 3rd }

a........plagioclase b........olivine c........pyroxenes

The area between the points of 155m. and 195m. consists of the monoclinic pyroxene-gabbro.

B The mineralogy of the essential constituents

The optic and chemical properties of the minerals in various rock-facies are shown on Table 2 and Fig. 2. Their general characters are to be described as follows.

a) The Plagioclases. The plagioclase of the chilled marginal diabare has a zonal structure: core········An_{65-60}, periphery········An_{55}. The minerals of the fine-grained gabbro, together with picrite-gabbro, generally have a simple zonal structure: broad core········An_{75-50}; narrow outer shell········An_{50-40}. But the complicated and oscilatory zoning is rarely noticeable: $An_{70} \longrightarrow An_{80}$ (narrow and small core) $\longrightarrow An_{70-50}$ (broad) $\longrightarrow An_{50-40}$ (narrow outer-most shell). It should be noticed that the plagioclase with fairly complicated and oscilatory zonal structure exists only in these rock-facies. The plagioclases of the other inner rock-facies are zoned: core ········An_{60-55}; shell ········An_{50-40}. In the intraformationally injected and chilled diabase of the northern terminal, there are the micropheno-crysts, An_{85-75} with the same composition as the most basic zone in the zoned plagioclase in the fine-grained gabbro described above, and the lath-shaped, An_{60-55}, in the groundmass. The plagioclase of the monoclinic pyroxene-gabbro, also, has similar zoning and composition as those of the inner rock-facies in the main gabbro.

The consideration on the fractional crystallization of the plagioclase in the main mass is detailed below.

The plagioclase of An_{65-60} in the chilled marginal diabase seems to have been crystallized in the rapid cooling state*. When the An_{80} zonal structure or crystal appeared by the fractional crystallization after the consolidation of the chilled marginal diabase-facies, the partial magma** was probably squeezed out, and it made the chilled facies intraformationally injected, under rapid cooling. The mafic constituents of the groundmass in these intraformationally intruding chilled facies, crystallized in rapid cooling state, are on the later stage in the reaction series than those of the fine-grained gabbro. After the consolidation of these chilled diabases, the plagioclase gradually changed into a more sodic one, until the plagioclase of An_{40}, which was the most Na-rich on the liquidmagmatic stage, and when it was crystallized, parallelly the Fe-rich pyroxene and olivine were produced, and afterwards more Na-rich plagioclase was found around the pre-existing crystals, or replaced them; and it is now seen as mesostasis. The colored minerals produced on this crystallization stage are amphibole and mica. In the monoclinic pyroxene-gabbro, the replacement is more significant, and the plagioclase of this

* The fairly plentiful olivine phenocrysts, at least, in this rock are considered to have pre-existed in the intrusive magma, The relation between the plagioclase of An_{65-60} and of An_{80} will be detaited on Part II.

** It is judged from the composition of the chilled diabase intraformationally intruded that very small amounts of olivine and pyroxenes seem to have been contained in the partial magma.

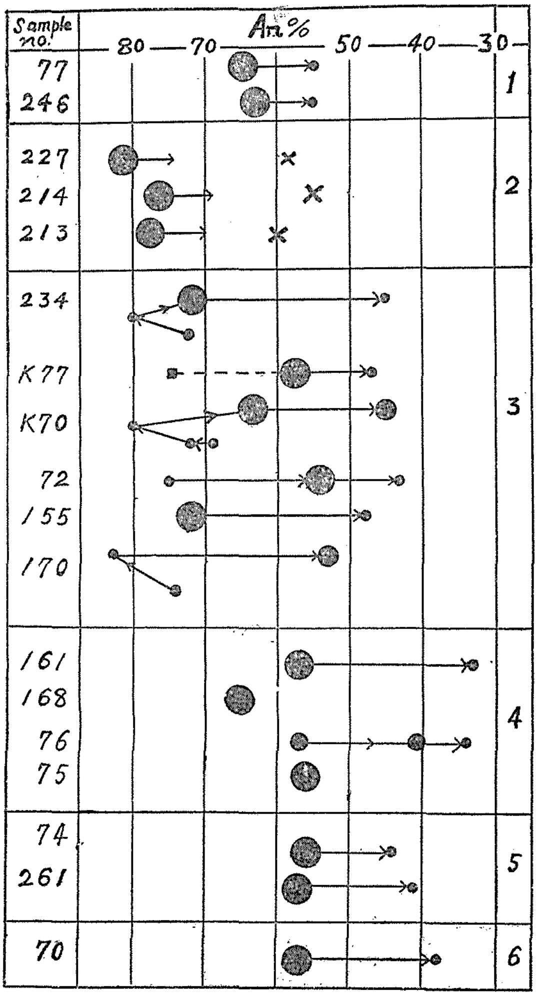

Fig. 2 The zonal structures of the plagioclases
1....in the chilled marginal diabase
2....in the chilled marginal diabase intraformationally intruding into the sedimentary rocks
3....in the fine-grained gabbro
4....in the medium-grained gabbro
5....in the medium-, or coarse-grained gabbro
6....in the monoclinic pyroxene-gabbro
arrow-head....outer cell of zonal structure
square....xenolithic core
black circle....each cell of zonal structure
(the area of the circle shows the relative dimension of each cell.)
cross ....groundmass-plagioclase

kind are An_{20-34} having contact with green amphibole bearing the periphery of dark green hastingsite. These actions may be on the deuteric stage.

b) The olivines. The olivines of the main gabbro have the chemical composition between Fa_{30} and Fa_{45}. The olivines of the earlier stage in the fine-grained gabbro, of the concentratson-zones of the colored minerals and of the chilled facies are irregularly granular, included in the plagioclase and the pyroxenes, but the shapes of those in the medium-grained gabbro are fairly subject to the outer forms of the felspers. The ferriferous olivines in the medium- and coarse-grained gabbro as well as the pyroxenes are moulded ophitically in the plagioclases, and especially those in the coarse-grained and melanocratic lense show the appearances having replaced the plagioclases of An_{40}. The ferriferous olivines, in general, have a fairly good development in cleavage. The composition of the olivine is a little more Fo-rich in the 3rd concentration-zone than in the upper horizon of the fine-grained gabbro, but, except in the former zone, its composition changes gradually and continuously from the Fo-rich to the Fa-rich, though the zonal structure in each crystal can not be cleary observed*.

c) The rhombic pyroxenes. The range of the chemical compositions from OF_{27} to OF_{43} is remarkable in the main gabbro, and the properties of the minerals have intimate resemblance to those of the olivines. The composition of the rhombic pyroxenes as well as those of the olivines in the inner rock-facies are more ferriferous than those in the outer ones, except those in the chilled margin, and in the concentration-zone of the colored minerals. The rhombic pyroxenes are homogeneous in their bodies, with no suggestion of exsolution(3): any oriented plate, graphic intergrowth, or twin is not observed under the microscope. The fact shows that these rhombic pyroxenes were crystallized out directly from the

Table 2 The optical constants and the referred chemical compositions (mol. %) of the colored constituents(4)

sample no.	olivine (β)	rhombic pyroxenc (β)	modoclinic pyroxene [n1 (110)]	rock-facies
77	1.718 (Fa_{31})	1.702 (OF_{31})	$2V=50-53°$ 1.692	1
246	undetermined		1.699	
213	undeter.	(γ) 1.709 (OF_{36})	(β) 1.703	2
214		undeter.	(β) 1.702	

* In the olivine, many grains of brown picotite are contained.

k77	1.717 (Fa_{31})	1.698 (OF_{27})	1.692	3
k70	1.718	1.700	1.691 (Wo_{36} En_{43} Fs_{21})	
170	1.720 (Fa_{32})	undeter.	1.693	
198*	1.722		1.694	4
253	1.729		1.696	
263	1.734		1.699	
262	1.736 (Fa_{40})		1.693	
261a	1.746	1.712	1.696	5
261b	1.748 (Fa_{45})	1.716 (OF_{43})	1.700 (Wo_{31} En_{45} Fs_{24})	
258	1.740	undeter.	1.698	
70	none		1.693($2V=57°$) (Wo_{35} En_{48} Fs_{17})	6
531			1.685	
246			1.697	7

1........chilled marginal diabase
2........chilled marginal diabase intraformationally intruding into the sedimentary rocks
3........fine-grained gabbro
4........medium-grained gabbro
5........medium-,or coarse-grained gabbro
6........non-foliated monoclinic pyroxene-gabbro
7........foliated monoclinic pyroxene-gabbro
*........the 3rd concentration-zone of the colored minerals

magma whose temperature is lower than that of inversion between pigeonite and rhombic pyroxene. The fact that no oriented plates are observed in these pyroxenes, means that Wo, contained in them, is too poor to exsolute, or else a little amount of it exsolutes ultra-microscopically. The writer considers that the original Wo-contents in the pyroxenes, contained as solid solution, were doubtlessly scanty, and that the crystallization-temperatures were definitely lower. It is clear from these facts that there is a definite difference between these rhombic pyroxenes and those of Karroo dolerite, Skaergaard gabbro[5], etc. having graphic intergrowth, and of Bushveld dolerite having oriented plates of great amount and the first ones, also, are a little different from those of the Ryoke gabbro and the Koyama one, in Japan, having, in general, rather smaller amount of oriented plate*.

d) The monoclic Pyroxenes**. Both the monoclinic pyroxenes of the main gabbros, and those of the monoclinic pyroxene-gabbro, have higher optical angles, and it makes clear that there is no pigeonite. The increase of Fe-amount in the pyroxenes in the main gabbro is insignificant, when their crystallizations preceed***, but the optical angle, being invariable, is 50°–53°(+).

The zonal structure of these minerals is not observable, but rarely the minerals of the ferrohyperthene-hyalosiderite-bearing facies have partially and irregularly green outer zones, though imperceptibly continuing to its inner ones, only at the parts in contact with irregular-shaped iron ore crystallized parallelly together with them. The inner and outer zones of the zonal structure have no different extinction-angle, but there have higher index and larger optical angle in the green zone than in the colorless one, and, therefore, the green zone is aegirite-augite and is probably of the alkali–Fe–rich circulating solution-origin on the later stage.

Table 3. The chemical composition of the monoclinic pyroxene in the monoclinic pyroxene-gabbro

SiO_2	50.33
TiO_2	0.48
Al_2O_3	2.82
Fe_2O_3	1.01
FeO	9.80
MnO	0.62
MgO	13.90
CaO	20.04
Na_2O	0.24
K_2O	0.01
$H_2O(+)$	0.29
$H_2O(-)$	0.34
Total	99.88

	wt.%	mol.%
Wo	36.32	34.62
Eu	43.58	48.40
Fs	20.09	16.98

The chemical composition of the monoclinic pyroxene in the coarse-grained monoclinic pyroxene-gabbro, is shown in Table 3, and the sesquioxides are not so great in amounts. As the mineral in the rock has a larger optical angle [2V = 56 — 58° (+)] and lower index than those of the main gabbro, the former was presumably crystallized in the lower temperature and is generally En-and Wo-richer than those of the latters. The monoclinic pyroxene generally appears in subophitic or ophitic, and it also appears frequently in skeletal crystal in the chilled diabase. Fig. 3 shows the chemical compositions of these two pyroxenes and the olivines inferred from optical characters, or determined from chemical analysis.

e) The amphiboles. The minerals, though in very small amount, are crystal-

* The amount of the oriented plate seems to be due to the difference of the crystallization temperature.

** The pyroxenes constitute the main part of all the pyroxenes in the main gabbros: the rhombic ones are very insignificant in amounts.

*** The fact will be reported recently.

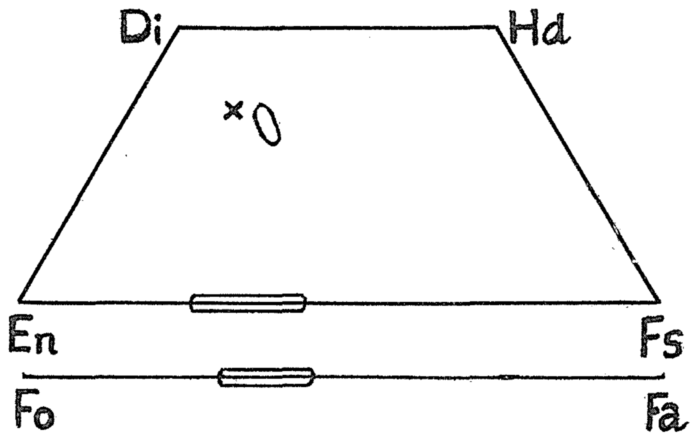

Fig. 3 The ranges of the chemical compositions of the colored essential components
enclosed area....the minerals in the main gabbro
cross............the diopsidic augite in the monoclinic pyroxene-gabbro

lized out as the rim of the olivine and the pyroxenes, or as the mesostasis between other minerals, consisting of the three varieties: the dark to light brown, the light green, and the dark green. The brown one appears as the rim of the monoclinic pyroxene, in the marginal part of which the former is scattered as patches, showing a sieve-texture. In the cases of olivines and rhombic pyroxenes, the inner rim of the colorless cummingtonite is observed. In these cases, the plane (0I0) and the c-axis are common to the host mineral and the rimmed mineral. The green variety forms the peripheral part of the brown one (Fig. 4). The following tranditional change of the amphiboles is observed: the brown ⟶ the light brown ⟶ the light green. The dark green variety appears in some portions of the margin of the light green one with distinct boundary between them, though the plane (0I0) and the c-axis of both minerals are common. The relation between the extinction angles and the optical angles of the amphiboles are shown in Fig. 5. The lighter the color of the brown variety is, the smaller the optic angle is, and the

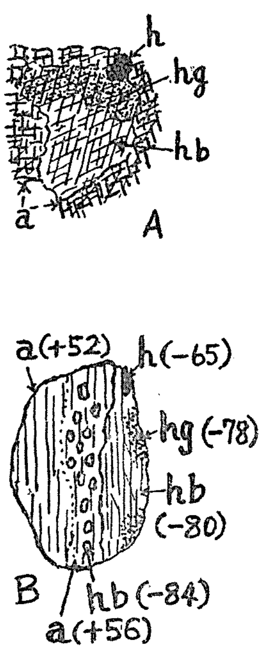

Fig. 4
Th eamphibolitization of the pyroxene

a .... augite
hb....brown hornblende
hg....green hornblende
h..... dark green hornblende
(B) .. showing the sieve-texture.
The figures in the parentheses show the optic angles.

higher the extinction angle is, Generally speaking, the brown variety becomes lighter in color, the lower in the optic angle, and the higher in the extinction angle. The light green variety, also, has the similar properties. In the dark

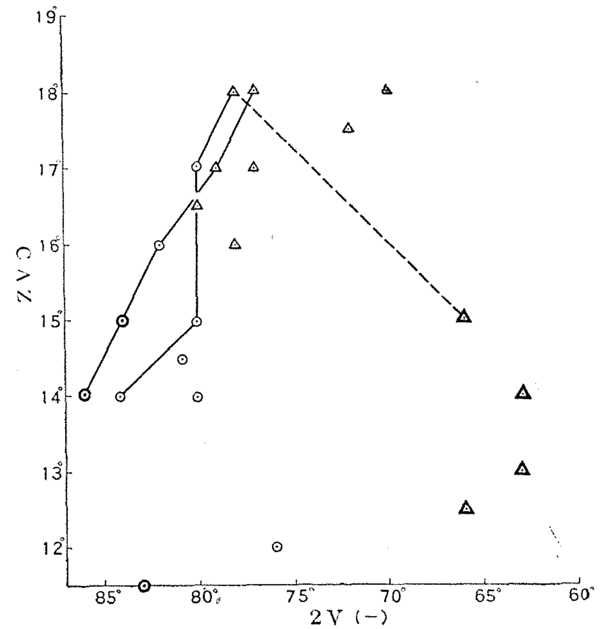

Fig. 5 The relation between the optic angle and the extinction angle in various amphiboles
large circle......brown hornblende
small circle......light brown hornblende
small triangle....green~brownish green hornblende
large triangle....dark green hornblende

green variety, the optic angle and the extinction angle are lower. The indices of refraction are low in the light green variety, and high in the two other varieties. The brown variety seems to be rich in TiO_2, and the light green to be actinolitic, and the brownish green and the dark green seem to belong to the series from common hornblende to hastingsite.

f) The biotites. There are rare occurrence of biotites as mesostasis, belonging generally to the reddish brown variety and they have low indices of refraction*.

It is one of the characteristics of this gabbro-mass that these hydrated silicates, that is, amphibole and mica, are very scanty.

g) The iron ores. There are great quantity of iron ores, magnetite, ilmenite, hematite, and pyrite, assumed as the products during the various stages of crystal-

* The dark brown varieties with higher indices, also appear rarely.

Table 4 The examples of the refractive indices of the amphiboles and the micas

sample no.	amphiboles [$n_{2(110)}$]			biotites
	brown	brownish green	dark green	
246	undeter.	1.665	1.695	1.670
170	1.685	1.667	1.679	undeter.
261a	not seen			1.654

lization: euhedral crystals in olivine, anhedral and irregular ones being crystallized contemporaneously with, or replacing, pyroxenes and so on.

The rocks on the later stage of magmatic differentiation have considerably high ratio of Fe‴ / Fe″ according to the rock analysis, due to the relatively higher increase of iron ores bearing ferric ion, in spite of the increase of ferrous ion in colored silicates on the later stage.

h) The other minerals. There are spinel, apatite, chlorite, serpentine, prehnite, and calcite, etc. as accessories, or secondary minerals in those rocks.

C. On the genesis of the Zonal arrangement of the main gabbro*

One of the main causes promoting the differentiation of a magma, concerns with the shape of the intrusive body. When the magma intruded and went into solidification, the body of Muroto Cape is considered to have dipped a little more to the west than the present vertical position. This assumption is deduced from the modes of the development, and the positions of the concentration-zones of the colored minerals, and the asymmetry of the thicknesses of various rock-facies, and of the metamorphic zones around the igneous body. From this working hypothesis, it will be able to gain the reasonable explanation of the magmatic differentiation, consistent with the field observations.

The occurrences of the concentration-zones are the powerful facter leading to the fractionation of the magma. By the intrusion of the liquid with fairly plentiful amount of olivine**, it produced the chilled marginal diabases due to

* The influence of the contamination of the sialic mass will be detaited on Part II.

** The chilled marginal facies of the mass have considerable amonnt of olivine phenocrysts, some of which may have been concentrated by the fixing due to the friction between the crystals in the flowing magma and the wall. Moreover, the magma is considered to have been enriched in olivine phenocryst in some degrees.

quenching, and then the 1st and the 2nd concentration-zones near the east and west margins. The 2nd is formed by the fixing of the olivines in the magma due to the friction between those of the magma-flow and the solidified chilled margin, and the 1st due to the gravitative sinking of the minerals on the earlier stage in addition to the fixing by the friction. The complicated zonings of the felspar of the 1st zone, and the fine-grained facies show the migration of the minerals in the magma, the settling of the crystals, and rapid cooling. Moreover, by continuous cooling of the magma, the fine-grained rock-facies is consolidated out.
By the low granularity and the reliction effect of the minerals on the earlier stage forbidden from the reaction with the liquid, the consolidation of this rock, also, may be considered to be performed rapidly, and the extent of the diffusion during the crystallization on this stage be restricted*. Moreover, even on this stage, the gravitative sinking of the minerals continued so that the comparatively earlier minerals concentrated fairly in this rock of the east margin**.

After the intrusive body was covered by the thicker shell of the fine-grained gabbro, the residual solution was, thenceforth, cooled a little more slowly, and the diffusion in it became a little more remarkable, but even then, reliction effect of the minerals are inferred to be fairly perceived***. As the diffusion came to be a little more remarkable, the colored minerals more Mg-rich than those on the later stage of the fine-grained rock-facies, were locally crystallized out in a small amount during the earlier and short period of the consolidation of the medium-grained gabbro, and sank down on the upper border of the fine-grained one, constructing the small, infrequently observed, masses concentrated in the mafic minerals, namely, the 3rd concentration-zone of these minerals****. Then medium-grained gabbro gradually consolidated out. The reliction effect of the minerals is strongly continued due to rather rapid cooling even on this stage, so the colored minerals, crystallized in the later period, became gradually rich in Fa and OF***** and the plagioclase rich in Ab, due to the imperfection of the reaction between the crystals and the liquid, and therefore, there appeared the ferrohypersthene-augite-hyalosiderite-gabbro at the innermost part of the sill, and in it occured the concentrated portions of the mafic minerals as the melanocratic lense.

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* The restriction is partly due to the escapment of the volatile substances from the magma. The phenomena of this escapement cause the production of the broad metamorphic zones of metasomatic characters around the igneous body.

** The lst concentration-zone as well as the fine-grained gabbro of the east side is thicker and more remarkable than the equivalents of the west side.

*** The weak concentration of the residual volatile substances of the small amount after the escapement of the main portion on the fine-grained gabbro stage, is concerned with this.

The escapement, or poverty of the volatile substance in the crystallization-period is, the writer eonsiders, one of the characteristics of this gabbro.

**** Near the part where the fine grained-gabbro and the medium-grained one of the west side contact with each other, there is no concentration-zone equivalent to the 3rd zone.

***** The chemical change of the monoclinic pyroxene during the differentiation is being studied at present.

After the consolidation of the ferrogabbro, the residual solution migrates in the rock mass, making the acid mesostasis to be crystallized. The influence of the contamination of the sialic mass upon the magma, the discontinuity of the chemical compositions of the minerals between the chilled diabases and the other facies, the consideration of the orthogabbro, the chemical compositions of the various rock-facies, and the metamorphism of the sedimentary rocks, etc. will be detailed on Part II.

The gabbros in Japan are often influenced by the granites, namely, granitizations, and, even without the influence by the granitization, the olivines and the pyroxenes themselves, contained in these rocks, have the small ranges of the chemical composition, in general, owing to the crystallization of the amphiboles and other hydrous essential components on the earlier stage. The gabbro of the cape, however, has the characters different from the calc-alkaline rock proper at the following respects: the crystallization of the fairly ferriferous colored minerals which concentrated in the rock-facies on the later strge of the main gabbro; the inexistence of the amphiboles and the micas of the liquid-magmatic stage; and the other mineralogical assemblages and the chemical properties. This gabbro is to be correlated to "the hypersthene rock series" of volcanic rocks, advocated by H. Kuno[4], judging from their pyroxene-crystallization. On the other hand, the gabbro has very distinct difference from the gabbros of the Kratogen, e. g., Karroo[5], Skaergaard[5], etc..

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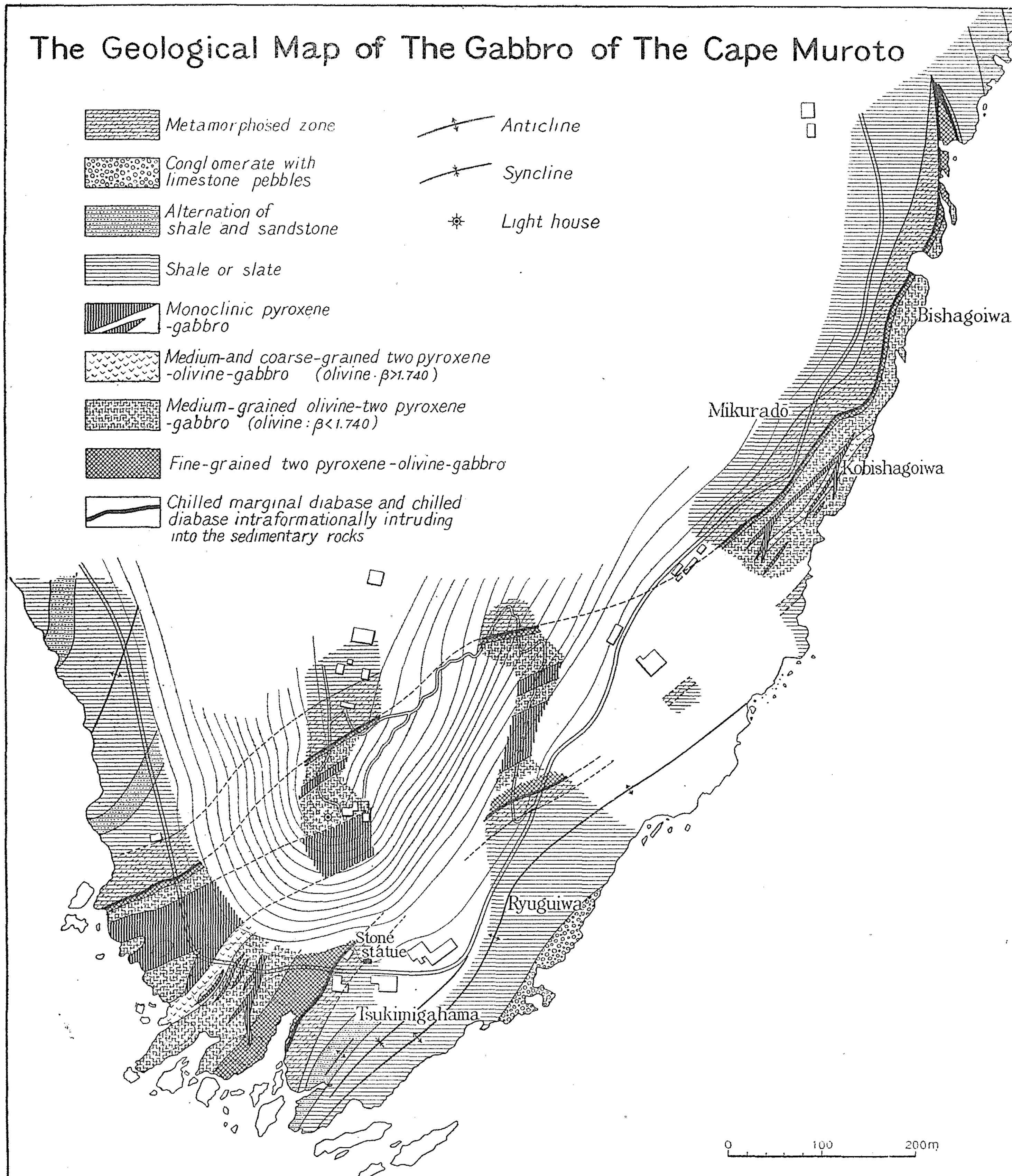

The Geological Map of The Gabbro of The Cape Muroto
Metamorphosed zone
Conglomerate with limestone pebbles
Alternation of shale and sandstone
Shale or slate
Monoclinic pyroxene -gabbro
Medium-and coarse-grained two pyroxene -olivine-gabbro (olivine · β>1.740)
Medium-grained olivine-two pyroxene -gabbro (olivine : β<1.740)
Fine-grained two pyroxene-olivine-gabbro
Chilled marginal diabase and chilled diabase intraformationally intruding into the sedimentary rocks
Anticline
Syncline
Light house
Bishagoiwa
Mikurado
Kobishagoiwa
Ryuguiwa
Stone statue
Tsukimigahama
0
100
200m