On Metamorphic Dikes in the Hiroshima Granitic Complex

By

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with 2 Tables, 5 Text-figure, and 4 Plates

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ABSTRACT: A dike swarm, extending about 50 km E-W and 5~10 km wide, is found near Hiroshima City in the Hiroshima granitic complex. The dike swarm consists of various rock types ranging in composition from andesitic to rhyolitic, especially biotite-bearing hornblende-quartz-porphyrite and diorite-porphyrite being abundant. Although porphyrite and diorite-porphyrite have been intruded into the granitic rocks, some of them show metamorphic texture, that is, crystals of hornblende have been replaced wholly or partly by biotite, iron ore, quartz, apatite, and plagioclase.

The intrusives in the Niho and Mukainada areas, situated to the east of Hiroshima City, are divided into three groups, that is, the Ôkô metamorphic porphyrite group, the Fuchizaki porphyrite group and the Tanna porphyrite group, based on their sequence of intrusion and petrographic features. Among these dike rocks, all of the Ôkô group and the early intrusives of the Fuchizaki group have metamorphic texture. The early porphyrite groups, that is the Ôkô group and the early Fuchizaki group, are presumed having intruded not long after the intrusion of the granitic rocks, which maintained high temperature and mobile conditions. Therefore, the granitic rocks are supposed still to have had some abilities to affect metamorphism at the time of the intrusion of the early porphyrite groups. The metamorphic texture is interpreted as the result of replacement of hornblende in the early porphyrite groups under the supply of potassium from the cooling granitic rocks.

CONTENTS

I. INTRODUCTION

Granites distributed widely in Chûgoku district have been regarded as Upper Cretaceous or Early Tertiary of age except the gneissose granite in the Oki Island, that of Rengeji, Shimane Prefecture, the Ryôke granitic rocks in the southern parts of Hiroshima and Yamaguchi Prefectures. These Cretaceous or Early Tertiary granitic rocks, which have been called the "Chûgoku Batholith" in general, can be divided into three groups according to their geological situations as well as petrological characters by the writer.

TABLE 1 CRETACEOUS AND EARLY TERTIARY IGNEOUS ROCKS IN CENTRAL CHUGOKU

	Volcanic Rocks	HIROSHIMA Granitic Complex	Central Plutonic Group	SANIN Granitic Complex
Palaeogene	Tertiary Volcanics	↑	KUCHIWA ↑ Plutonic Rocks	↑
Upper Cretaceous	SAKUGI Volcanics	↓	↓ ; ↑ IBARAICHI Plutonic Rocks	↓ ; ↑
Lower Cretaceous	TAKADA Rhyolitic Rocks KISA Andesitic Rocks		↓	↓

The Hiroshima granitic complex consists of granodiorites, biotite-granites, granite-porphyries, aplites, and syenitic rocks etc. This body extends from the eastern part of Yamaguchi Prefecture through Hiroshima Prefecture to Okayama Prefecture along the Inland Sea of Seto. In the Hiroshima granitic complex near Hiroshima City, there are many intrusive rocks, mainly dikes, which have various compositions ranging from basic to acidic. Especially, biotite-bearing hornblende-quartz-porphyrites are abundant. Phenocrysts of hornblende in some of these dike rocks occur wholly replaced with tiny biotite flakes, but in other dikes such phenomena are not observable, and between these two extreme cases there are many dike rocks showing various metamorphic characters. Based on this fact, the author at first supposed that these metamorphic textures have been brought about by the intrusion of the granite, and that the diversity of the metamorphic characters should have been caused by the successive intrusion of the granites and porphyrites. If this assumption could be accepted, analysing the sequence of the plutonic history of the Hiroshima granitic complex are possible by seeking the relation between granites and porphyrites. With the progress of the field survey, however, it has been revealed that the granites near Hiroshima City are older than the porphyrites and that there are no intrusive rocks possibly exerted metamorphic effects upon the porphyrites. Therefore, the former assumption of the author has become to be abandoned, and he sought new evidences bearing upon the origin of the metamorphic features of the dike rocks.

The author selected as the type localities the Niho and Mukainada areas, on the south-eastern part of Hiroshima City to solve this problem. In these areas there occur many porphyrites dikes showing various metamorphic textures and the succession of emplacement of the dikes can be clearly determined within narrow areas.

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II. Outline of Geology

The Hiroshima granitic complex near Hiroshima City was intruded into Palaeozoic rocks and the Takada rhyolite complex, which represent the roof-pendant. The granite occurring along the contact is generally fine-grained, forming a zone of two or three hundreds meters in thickness, and this marginal facies passes gradualy to the main body of coaser-grained granite possessing basic inclusions. As the quantity of inclusions increase, hornblende appears in the granite.

Cutting the granitic complex many intrusive bodies, mainly dikes, are developed in a belt extending from Tsuda through Hiroshima City to Kumano. The direction of the belt is nearly E–W, the width being 5～10 km and the length about 50 km. The width of the dikes is variable, commonly 5～30 m and rarely attaining to 200 m. Among these intrusives biotite-bearing hornblende-quartz-porphyrites or diorite-porphyrites are the most abundant. Some of these intrusives show metamorphic textures, that is, hornblende in the rocks has become an aggregate of biotite flakes. The occurrence of the metamorphic porphyrites seem to be restricted within the hornblende-bearing granodiorite.

At the Niho and Mukainada areas various kinds of porphyrites are developed. The former area is situated on the southeast of Hiroshima City and its highest point is Mt. Niho (212.2 m). The latter lies to the east of Niho across the Ôta River and is occupied by low hills. Both areas represent land-tied islands. The porphyrites of the Niho and Mukainada areas can be divided into three groups, that is, the Ôkô metamorphic porphyrite group, the Fuchizaki porphyrite group and the Tanna porphyrite group.

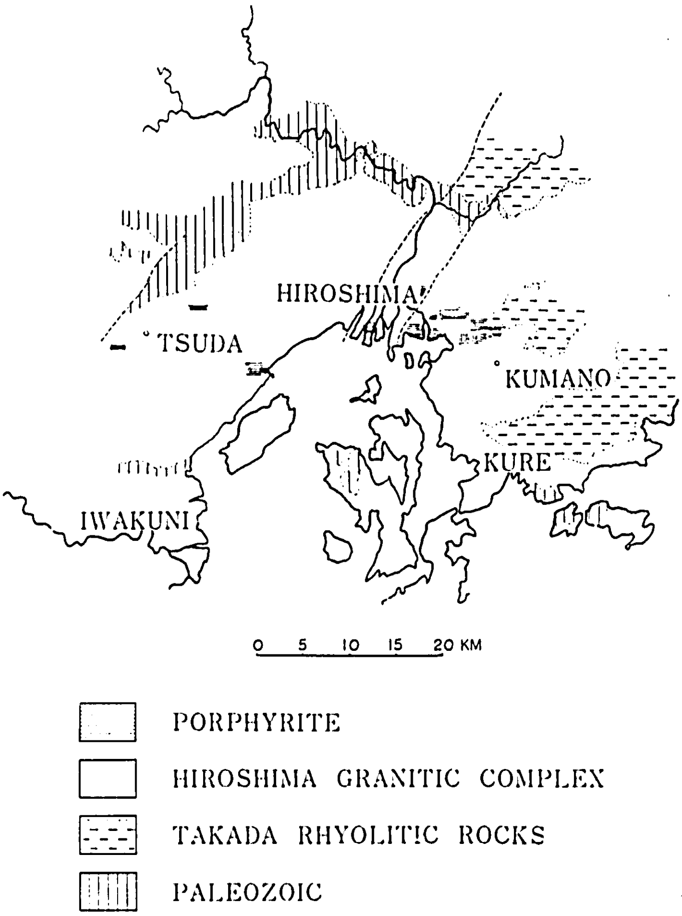

Fig. 1 Geological outline map near Hiroshima City.

III. Rock Types

A. Granites

1. Biotite-granite

The granite distributed in the Mukainada area is fine or medium-grained homogenous rock composed of oligoclase, quartz, K-feldspar, and biotite. The fine-grained granite occurring mainly on the northern part of the Mukainada area passes gradually into the medium-grained granite without any clear boundary. On the southern part of the Mukainada area, facing the sea, inclusions are found only within the granite. As the inclusion begins to appear, the grain-size becomes larger, the colour becomes darker, and hornblende begins to appear.

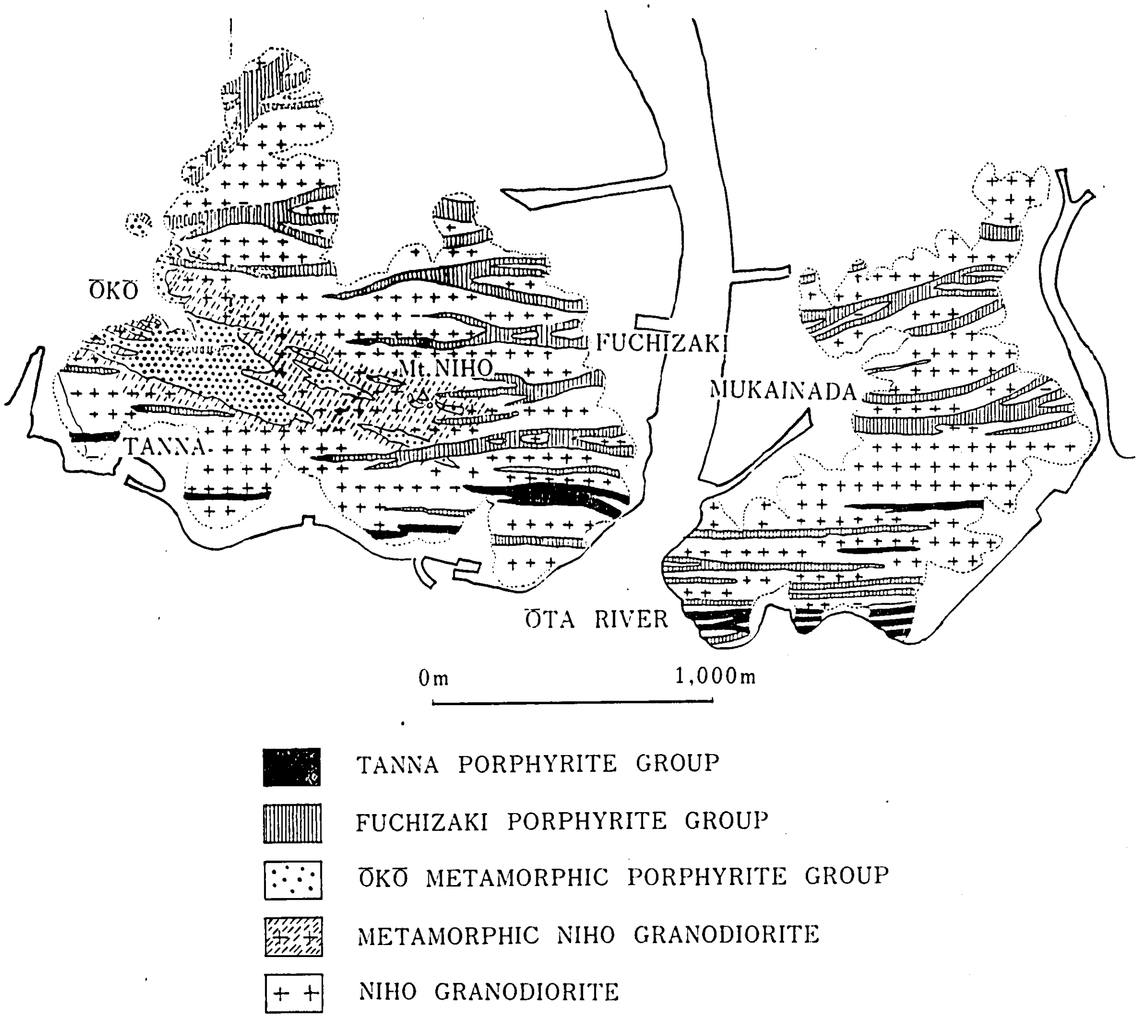

Fig. 2 Geological map of Niho and Mukainada areas.

2. Hornblende-bearing biotite-granodiorite

The granite exposed in Ôkô and Fuchizaki is a considerably heterogeneous, consisting of plagioclase, K-feldspars, quartz, biotite, and hornblende, accompanied by allanite and ironore as accessory ingredients. The granite is coarser than the biotite-granite of the Mukainada area, possessing numerous inclusions, especially abundant near the Ôkô metamorphic porphyrite (see below), and porphyroblasts of K-feldspar. With the decrease of the inclusions the colour becomes lighter and finally the granodiorite resembles the biotite-granite on the northern part of the Mukainada area in appearance.

3. Hornblende-bearing biotite-porphyritic granodiorite

In the central part of the Niho area porphyritic granodiorite is exposed. It has stripe-like distrubition with N–S trend and comes in contact with the hornblende-bearing biotite-granodiorite on the east side as well as on the west side. The porphyritic granodiorite consists of megacrysts of plagioclase, of which the cores are andesine and the rims oligoclase, attaining sometimes to ca. 2 cm in length, large quartz crystals with irregular cracks, biotite, and clear yellowish-green hornblende, and the matrix is composed of sodic plagioclase, quartz, K-feldspar, and biotite. The porphyritic granodiorite, as seen in the granodiorite, has subangular large inclusions. The boundary between the porphyritic and the non-porphyritic granodiorites is not clear, probably being gradual.

4. Syenite

Syenite consisting of sodic plagioclase, K-feldspars, hornblend, and a small amount of quartz and biotite is found commonly in the medium-grained biotite-granite and granodiorite, while it can not be found in the fine-grained biotite-granite and porphyritic granodiorite. The syenite occurs as small irregular or dike-like masses, being often accompanied by pegmatite, mainly quartz-pegmatite, and aplite.

5. Inclusion

As observed commonly in the granite region there are many inclusions composed of plagioclase, hornblende, biotite, and quartz, which might be called microdiorite, in the area under consideration. The inclusions are subangular and various in size; ordinarily 5~10 cm, some attaining to 2~3 cm in long diameter. They are distributed from Ôkô to the southern part of the Mukainada area with E–W trend in all the types of granites except the fine-grained biotite-granite.

6. Thermally metamorphosed granite

The granodiorite and the porphyritic granodiorite above mentioned showing effects of thermal metamorphism are distributed in keeping with the distribution of the metamorphic diorite-porphyrite. The crystals of hornblende in them have become aggregates of biotite flakes and the crystals of biotite have been partly or wholly replaced with smaller biotite flakes (Plate 28, Fig. 1~4).

B. PORPHYRITES

1. The Ôkô metamorphic porphyrite group.

In an area extending from Ôkô to the summit of Mt. Niho there are distributed irregular-shaped intrusive rocks, their trends being as a rule WNW–ESE. Although the texture of these intrusives differs from place to place, some being porphyritic, others dioritic or intermediate in grain-size, all of the rocks composing these intrusives are characterized by the metamorphic texture, such as the aggregates of biotite flakes after hornblende. In the porphyritic one the groundmass is purplish in colour. Therefore, we can easily distingish them from other types of porphyrites. These metamorphic porphyrites are grouped as the Ôkô metamorphic porphyrite group after the locality name.

In the Ôkô metamorphic porphyrite group the porphyrites intruded at earlier stages have generally coaser textures, rarely showing chilled marginal facies compared with the later ones. The Ôkô group consists of rocks ranging from diorite or diorite-porphyrite to fine-textured porphyrite. The fine-textured metamorphic porphyrites occur as marginal facies of diorite-porphyrites or as independent intrusives.

The fine-grained porphyrites carry phenocrysts of normal-zoned plagioclase, of which the core is labradorite and the rim oligoclase, quartz, sometimes corroded, well shaped hornblende replaced with biotite flakes, and a small amount of idiomorphic biotite. The groundmass consists of felspars, quartz, and biotite (Plate 29, Fig. 4; Plate 30, Fig. 1~4). The proportion of constituent minerals determined by micrometric analysis on the thin sections of the rock from the Ôkô quarry is as follows.

Phenocryst	42%	Groundmass	58%
Plagioclase	77%		
Quartz	13%		
Hornblende Biotite	10%		

The coarse-textured metamorphosic diorite-porphyrites are found at Ôkô, the summit of Mt. Niho and the southern peak of Mt. Niho. They carry phenocrysts of normal-zoned plagioclase, of which the core is labradorite and the rim oligoclase, showing rather ragged outline, quartz, well shaped hornblende which has become aggregates of tiny biotite flakes, iron ore, quartz, plagioclase, and idiomorphic biotite. The groundmass is holocrystalline, consisting of plagioclase, quartz, biotite, and a few quantity of orthoclase. In some diorite-porphyrites, however, the distinction between phenocryst and groundmass is not so easy (Plate 29, Fig. 1~3). The result of micrometric analyses from the Ôkô quarry is shown below.

Plagioclase ...... 49% Quartz 39%
Hornblende+Biotite ......10% Orthoclase 1%
Iron ore 1%

2. The Fuchizaki porphyrite group.

Through the Niho and Mukainada areas, porphyrites belonging to this group are the most abundant. Some of them are irregular in shape when viewed on the exposure. They suddenly pinch out or change their direction around the joint surface of the granite, and sometimes neighbouring dykes are conbined together into a single dyke, while a dyke often branches into a number of dykes. Their general trends are nearly E–W.

Porphyrites belonging to this group do not show metamorphic textures normally, and even when metamorphic textures are seen, they are not so distinct as in the Ôkô metamorphic group (Plate 31, Fig. 1). The non-metamorphic porphyrites assume a greyish-green colour on the fresh surface and yellowish-brown when weathered. They carry phenocrysts of normal-zoned plagioclase, of which the core is labradorite and the rim oligoclase, quartz occasionally showing corroded forms, hornblende, and clear biotite. In some dikes hornblende is clear, in others it has been altered to chlorite or a part of it has been changed to an aggregate of biotite flakes. The groundmass consists chifly of felspars, quartz, and biotite.

The result of micrometric analyses on the thin sections of non-metamorphic porphyrites is shown below.

Phenocryst	50%	Groundmass	50%
Plagioclase	67%	Felspars	46%
Quartz	22%	Quartz	28%
Hornblende	10%		
Biotite	1%	Biotite	26%

3. The Tanna porphyrite group.

The Tanna porphyrite group is distributed in the southern part of the Niho and Mukainada area. It is distinguished from the above-mentioned groups in the field by its greyish-blue colour.

The porphyrite of this group carries phenocrysts of normal-zoned plagioclase, partly altered to calcite, quartz often showing corroded froms, hornblende which have been replaced with chlorite, calcite, iron ore, and epidote, and biotite. The groundmass consists of felspars, quartz, and altered biotite. Calcite is often observed throughout the groundmase.

C. THE CHEMICAL CHARACTERS.

The chemical composition and molecular norms, calculated after Barth (1951), of typical rocks in the Niho and Mukainada areas are shown in Table 2.

The chemical composition of above rocks and Late Mesozoic or Early Tertiary intrusive rocks developed in Hiroshima Prefecture, including above rocks, are plotted in Fig. 3

IV. MUTURAL RELATIONS OF ROCK TYPES.

1. Mutural relations of the rock types of the Ôkô metamorphic porphyrite group.

The Ôkô metamorphic porphyrite group is composed of intrusives ranging from diorite or diorite-porphyrite to fine-grained porphyrites which ordinarilly occur as chilled marginal facies of the intrusive body against the granodiorite, but, in some cases, as observed at the Ôkô quarry, the fine-grained porphyrite has been

TABLE 2 (A) CHEMICAL COMPOSITION AND MOLECULAR NORM

	Granodiorite (1)	Metamorphic diorite-porphyrite (2)	Metamorphic porphyrite (3)	Non-metamorphic porphyrite (4)	Tanna porphyrite (5)
SiO_2	70.64	69.92	64.16	66.06	63.60
TiO_2	0.16	0.12	0.14	0.19	0.28
Al_2O_3	15.90	16.25	16.80	16.45	16.00
Fe_2O_3	0.46	0.33	1.74	0.81	0.56
FeO	2.32	2.78	4.20	3.11	3.91
MnO	0.00	tr	0.02	Tr	0.00
MgO	0.50	1.67	2.40	2.20	2.80
CaO	2.31	2.40	3.73	3.50	5.20
Na_2O	3.75	3.30	3.30	4.15	4.10
K_2O	3.20	1.60	1.30	1.60	1.00
H_2O^+	0.68	0.81	1.32	1.12	1.41
H_2O^-	0.12	0.31	0.49	0.22	0.60
P_2O_5	0.06	0.03	0.21	0.18	0.14
Total	100.10	99.52	99.81	99.59	

Analyst H. SHIBATA

TABLE 2 (B) THE MOLECULAR NORM

Or	19.0	9.5	8.0	9.5	6.0
Ab	34.0	30.0	30.5	38.0	37.5
An	11.5	12.5	17.5	16.5	23.0
Q	27.8	33.3	25.3	22.1	17.8
Co	2.4	5.3	4.2	2.2	
Σ Salic	94.7	90.6	85.5	88.3	84.3
Hy	4.4	8.8	11.8	10.2	14.4
Mt	0.5	0.3	2.0	0.9	0.6
Il	0.2	0.2	0.2	0.2	0.4
Ap			0.5	0.5	0.3
Σ Femic	5.1	9.3	14.5	11.8	15.7

1) Hornblende-bearing biotite granodiorite (The Tanna quorry).
2) Metamorphic biotite-bearing hornblende quartz diorite-porphyrite (The Ôkô metamorphic porphyrite group. The Ôkô quorry).
3) Metamorphic biotite-bearing hornblende quartz porphyrite (The Ôkô metamorphic porphyrite group. The Ôkô quorry).
4) Non-metamorphic biotite-bearing hornblende quartz porphyrite (The Fuchizaki porphyrite group. North-east of the Ôkô quorry).
5) Alterd biotite-bearing hornblende quartz porphyrite (The Tanna porphyrite group. The Tanna quorry).

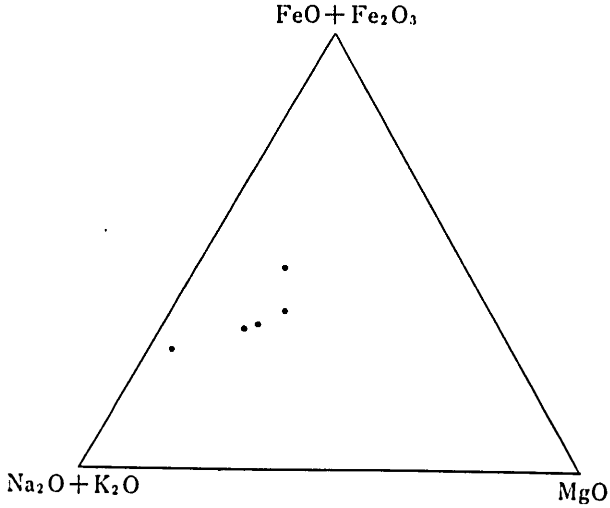

Fig. 3a. Fe_2O_3+Fe O—Na_2 O+K_2O—Mg O diagram, showing the positions of typical rocks of the Ôkô and Mukainada areas.

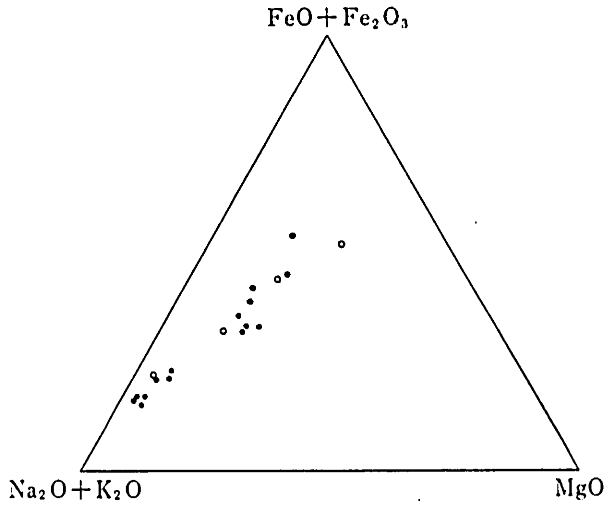

Fig. 3b. Fe O+Fe_2O_3—Na_2O+K_2O—Mg O diagram, showing the positions of Cretaceous or Early Tertiary igneous rocks in Chûgoku district.

intruded into the coarse-grained diorite-porphyrite. At this locality numerous inclusions of the diorite-porphyrite together with the granodiorite are found in the fine-grained porphyrite (Fig. 5). Although the detail of successive intrusion of these rock types has not been clarified in the field, the Ôkô group can be taken as a composite intrusive body.

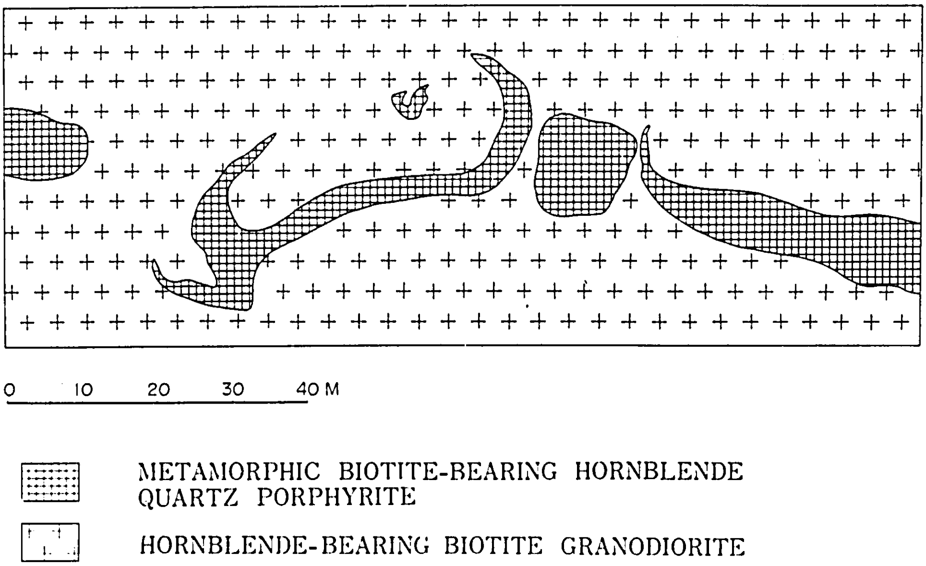

Fig. 4 Occurrence of metamorphic porphyrite at the summit of Mt. Niho.

2. Relations between the hornblende-bearing biotite granodiorite and the Ôkô metamorphic porphyrite group.

The Ôkô group, generally, shows marginal facies against the hornblende-bearing biotite-granodiorite, and the granodiorite around the Ôkô group has a metamorphic texture. The metamorphic aureole is narrow, near the Ôkô quarry about 50 m in width, and gradually, the width diminishes towards the east.

The coarse-grained porphyrite commonly occurs in the central part of the Ôkô intrusive body, but, in some cases, they come into contact directly with the granodiorite, the contact being observed about 50 m east of the Ôkô quarry. Because of its equigranular nature of the diorite-porphyrite, it appears like diorite or granodiorite. This diorite-porphyrite does not become finer towards the contact between the diorite-porphyrite and the granodiorite, and in addition the granodiorite does not change its graine size towards the contact. No slip planes can be found at the contact. Therefore, it is rather difficult to draw the boundary between the diorite-porphyrite and the granodiorite.

At the summit of the Mt. Niho, metamorphic diorite-porphyrites are found in the granodiorite. They are not so coarse-grained as the diorite-porphyrite of the Ôkô quarry. Although each porphyrite body shows irregular shape, the general strike is E–W. The boundaries between the diorite-porphyrites and the granodiorite are slip planes except one of the eastern end (Fig. 4).

In the fine-grained metamorphic porphyrite of the Ôkô quarry, described above, there are many inclusions of angular or subangular shape of the metamorphic granodiorites and the diorite-porphyrites, the largest one attaining 30cm in long diameter (Fig. 5, Plate 31, Fig. 5).

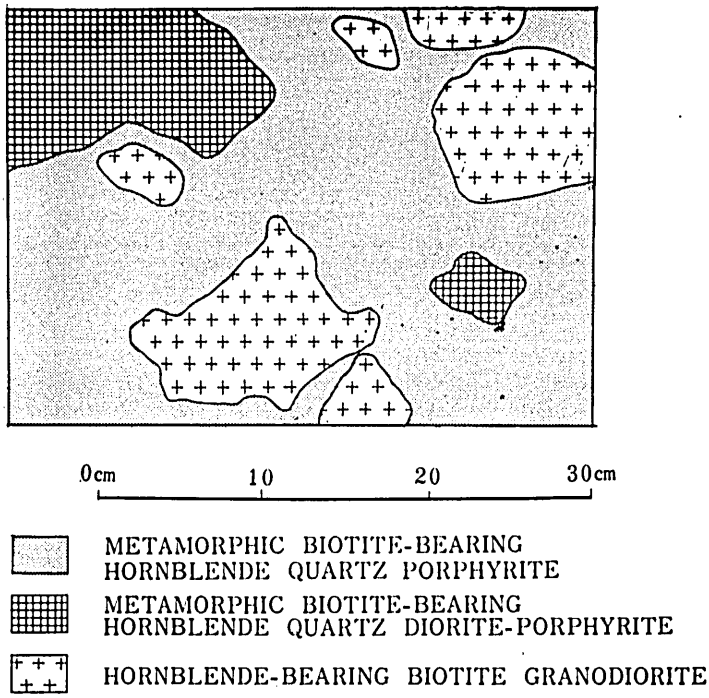

Fig. 5 Xenolithes in fine grained metamorphic porphyrite belonging to the Ôkô group.

Considered from the features observed at the former exposure, mentioned above, the granodiorite may be presumed to have maintained the condition of relatively higher temperature at the time of intrusion of the diorite-porphyrite.

From the occurrence of the diorite-porphyrites at the summit of the Mt. Niho following interpretations will be allowed. The diorite-porphyrites first came into contact with the granodiorite as a dike, and then, owing to the mobility that the granodiorite maintained at the time of the intrusion of the diorite-porphyrite, the dike was splitted into small isolated masses of irregular shapes.

The occurrece of the fine-grained porphyrite at the Ôkô quarry, which is a later member of the Ôkô group, may be interpreted to indicate that the granodiorite had lost its mobility almost wholly when the fine-grained porphyrite came into contact with the granodiorite.

Summarizing above interpretations the Ôkô group should represent the intrusion occurred at different stages of the cooling history of the granodiorite.

3. Relations between the Ôkô metamorphic porphyrite group and the Fuchizaki porphyrite group.

Contact relations between the Ôkô group and the Fuchizaki group are observed 200 m south-west and 150 m south-east of the Ôkô quarry. At the localities, non-metamorphic porphyrite, belonging to the Fuchizaki group, cut the

Ôkô group cleanly and in the former breccias of the diorite-porphyrite of the Ôkô group are included. The contact between the Ôkô group and the Fuchizaki group having metamorphic texture has not been found.

4. Relations between the Fuchiazki porphyrite group and the Tanna porphyrite group.

In the southern part of the Mukainada area, yellowish-green porphyrites belonging to the Fuchizaki group are cut by a darkgray dike belonging to the Tanna group.

V. Interpretation of Metamorphic Textrue.

As the distribution of the metamorphic granodiorite is restricted in the circumference of the Ôkô metamorphic porphyrite group, the metamorphic texture of the granodiorite can be related to the intrusion of the Ôkô group.

Porphyrites found in the Ôkô and Mukainada areas, which are divided into the Ôkô metamorphic porphyrite group, the Fuchizaki porphyrite group and the Tanna porphyrite group, have been intruded later than the granodiorite. Whereas, the earlier intrusives in these porphyrites, all of the Ôkô group and early intrusives of the Fuchizaki group, have metamorphic textures. The origin of the metamorphic texture will be interpreted as follows.

The porphyrite groups, as above discussed, might be taken as representing intrusives intruded into the granodiorite not long after the intrusion of the latter, and at the time of the intrusion of the early Ôkô group the granodiorite yet maintained high temperature and mobile conditions. From the latter interpretation it follows that the granodiorite had some abilities to effect metamorphism at the time of the intrusion of the early Ôkô group. The metamorphic ability of the granodiorite has been lost gradually as time passes, because the earlier intrusives show more effect of metamorphism by the granodiorite than the later ones.

When the Ôkô group came into contact with the granodiorite crystals of plagioclase, quartz, hornblende, and biotite coxisted in the intrusives. However, the hornblende became unstable by the suply of potassium from the granodiorite and finally it has been replaced wholly by biotite, a small amount of iron ore, quartz, apatite and plagioclase. As the Fuchizaki group is a member of the dike swarm, together with the Ôkô group and the Tanna group, which is considered to be a product of successive intrusions, the granodiorite might still maintained metamorphic ability at least at the earlier stage of the intrusion of the Fuchizaki group. In fact, the early dikes of the Fuchizaki group show recognizable metamorphic texture, but the later dikes of the Fuchizaki group and the Tanna groups show no metamorphic texture.

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Explanation of Plate XXVIII

Fig. 1 Metamorphic hornblende-bearing biotite granodiorite east of the Ôkô quarry. 15×.

Fig. 2 Hornblende in metamorphic hornblende-bearing biotite granodiorite east of the Ôkô quarry. It has become an aggregate of biotite flakes. 20×.

Fig. 3 Biotite in metamorphic hornblende-bearing biotite granodiorite east of the Ôkô quarry. 22×.

Fig. 4 Biotite in metamorphic hornblende-bearing biotite granodiorite east of the Ôkô quarry. 22×.

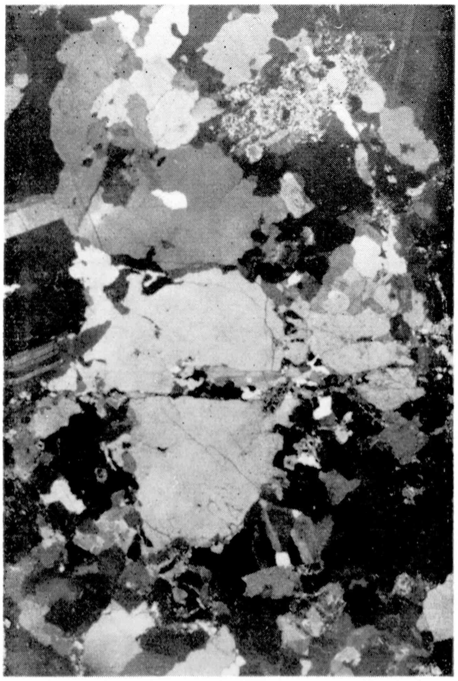

Fig. 1

Fig. 2

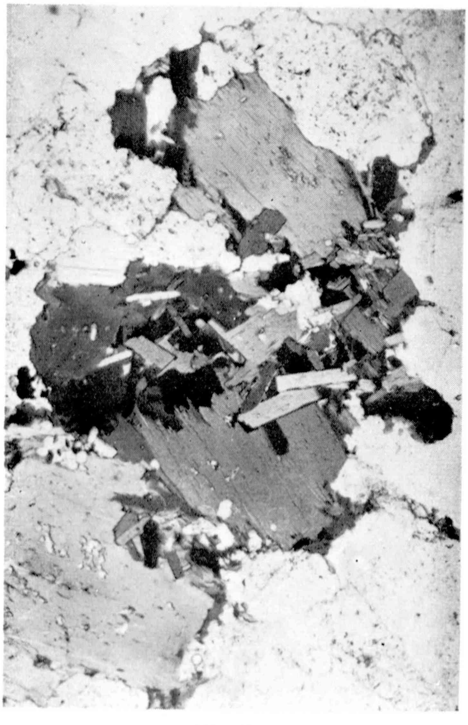

Fig. 3

Fig. 4

Explanation of Plate XXIX

Fig. 1 Metamorphic biotite-bearing hornblende quartz diorite-porphyrite belonging to the Ôkô metamorphic porphyrite group at the Ôkô quarry. In holocrystalline ground-mass there are porphyritic zoned plagioclase, quartz and hornblende which has been replaced an aggregate of biotite flakes. 5×.

Fig. 2 Biotite-bearing hornblende quartz diorite-porphyrite, Ôkô quarry: showing well zoned plagioclase and replaced hornblende. 17×.

Fig. 3 Replaced hornblende in diorite-porphyrite belonging to the Ôkô metamorphic porphyrite group, Ôkô quarry: A hornblende crystal has been replaced by biotites, iron ore, quartz, plagioclase and apatite. 70×.

Fig. 4 Metamorphic fine textured porphyrite belonging to the Ôkô metamorphic porphyrite group, west of the Ôkô quarry: the phenocrysts are of strongly zoned plagioclase, quartz, hornblende which has become an aggregate of tiny biotite flakes. The groundmass is composed of felspers, quartz and biotite. 15×.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Explanation of Plate XXX

Fig. 1 Metamorphic fine-grained porphyrite belonging to the Ôkô metamorphic porphyrite group, north of the Ôkô quarry. 20×.

Fig. 2 Metamorphic fine-grained porphyrite belonging to the Ôkô metamorphic porphyrite group. The felspar is strongly zoned, a crystal of clear biotite is seen at the upper part of a hornblende which has been changed to biotite flakes. 25×.

Fig. 3 A hornblende crystal in metamorphic porphyrite belonging to the Ôkô metamorphic porphyrite group, south of Ôkô quarry. 53×.

Fig. 4 The same hornblende (cross nicole). 60×.

Fig. 1

Fig. 2

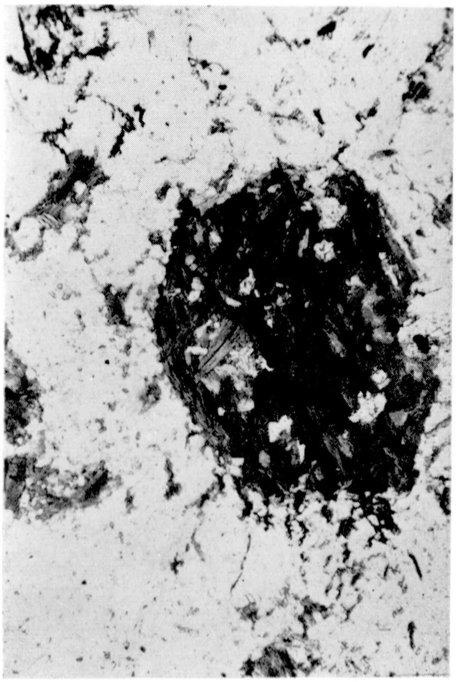

Fig. 3

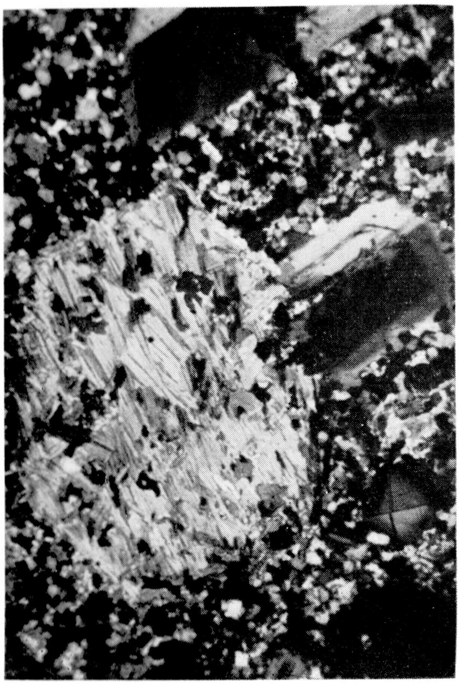

Fig. 4

Explanation of Plate XXXI

Fig. 1 Hornblende in the early Fuchizaki porphyrite group. The crystal has been replaced partly by biotite, north of the Ôkô quarry. 90×.

Fig. 2 Non-metamorphic biotite-bearing hornblende quartz porphyrite belonging to the Fuchizaki porphyrite group. 5×.

Fig. 3 Non-metamorphic porphyrite belonging to the Fuchizaki porphyrite group, 300 m north of the Ôkô quarry: Phenocrysts are of strongly zoned plagioclase and non-alterd hornblende. 17×.

Fig. 4 A contact between the metamorphic granodiorite and the Ôkô metamorphic fine-grained porphyrite at the Ôkô quarry. 8×.

Fig. 5 Xenoliths in the metamorphic porphyrite at the Ôkô quarry. They are metamorphic granodiorites and diorite-porphyrite. 1/3.5×.

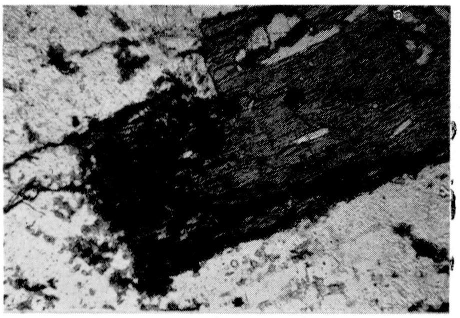

Fig. 1

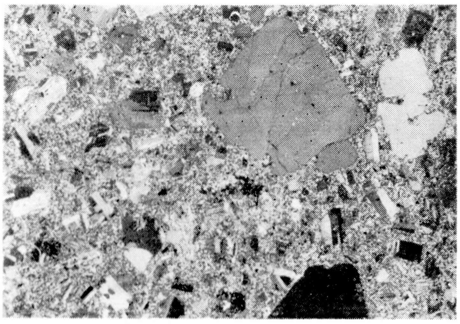

Fig. 2

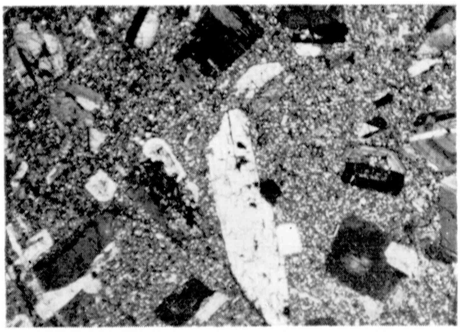

Fig. 3

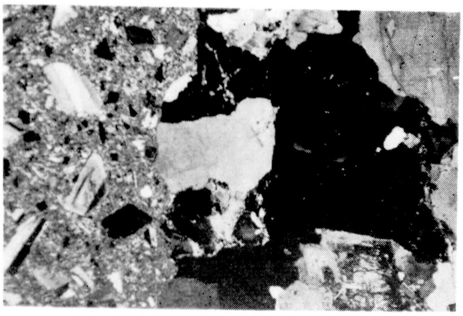

Fig. 4

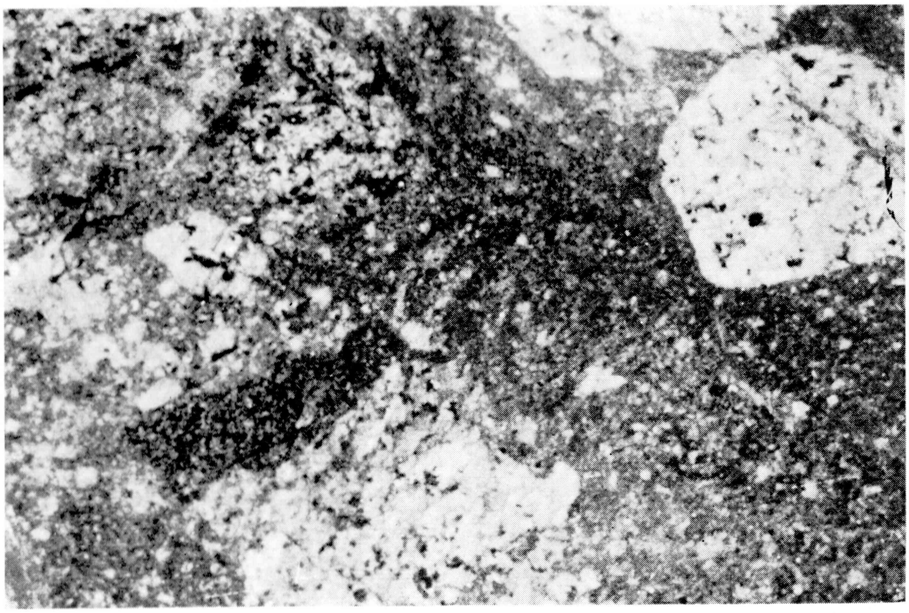

Fig. 5