STUDIES OF VARIATION IN MINERAL COMPOSITIONS OF SOME GRANODIORITIC MASSES IN JAPAN AND KOREA

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(With 5 Tables and 5 Figures)

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Introduction

Although an intrusive rock which has been geologically treated as one mass, is often considered to be uniform or homogeneous in composition, it is not impossible to find some partial fractuation in mineral compositions in the mass. This point may be a very significant foundation for understanding the structure and the genesis of intrusive masses. With reference to the mineral composition, from the standpoint of homogeneity of rock masses, F. CHAYES lately has reported on many examples of some granitic masses, and his description seems to be appliciable to those phenomena.

The present writer has had opportunities to study acid plutonics since 1949; this paper embodies the results of field observation and laboratory work especially only on the volumetric relations of the chief mineral constituents of the intrusive masses. CHAYES has asserted the effectuality of the method of measuring volume proportion of mineral constituents by thin section analyses made by point counter, but all the results reported here by the writer are by the "Integrationstisch" of LEITZ. For considering how composition variation exists over the whole igneous mass, the writer took two examples in Japan and Korea. Details on the geology and the interesting metamorphic rocks around the igneous masses of these two localities will be described on some future occasion.

Inzan granodiorite mass in Korea(1)

The granodiorite mass in the Inzan district of northern Korea takes the form of small rounded stock about 15 km^2 in area intruding amongst the adjacent sedimentaries of the lower Palaeozoic and Pre-Cambrian formations. Various kinds of hypabyssal rocks associated with the plutonics are found in and near the mass. Though the evidence is inconclusive as to the age of the intrusion in the district, it is considered, from indirect geological data in other districts, to be closely connected in time with late Cretaceous. The surrounding sedimentaries are partly or wholly metamorphosed into various hornfelses and skarn-minerals bearing dolomitic limestones and are considered to have been rendered crystalline by the action of the igneous mass.

The rocks composing the intrusive mass are fine- to medium-grained biotite granodiorites accompanying or without hornblende. From the intrusive mass, 49 samples of plutonics and 14 samples of dike rocks were collected by T. Ishikawa and random thin sections were prepared from every sample. The writer measured the modal mineral proportion on each thin section with the results shown in Tables 1 and 3. To ascertain the mineral composition variation in a limited small area, the writer made arbitarily five thin sections cut from each of five hand specimens which were collected from different localities (points 53, 1, 48, 55, 33 in Figure 1) in the intrusive mass. Microscopic analyses on each thin section are reported in Table 2, in which composition differences among hand specimens can be detected.

A careful examination of the volumetric relations of the essential constituent minerals and of the composition of plagioclase of whole samples leds one to an interesting conclusion on the mass. An analysis of the results indicates that the total salic content and especially quartz-potash felspar content have very significant meaning in the rock composition. Under the microscope, quartz and potash felspar fill up the space among idiomorphic or hypidiomorphic plagioclase, therefore it may be considered that the crystallization stage of the former two is

(1) Suzuki, Y. (1952) On the structure of the granodiorite mass in the Inzan district in northern Korea. (in Japanese). Jour. Geol. Soc. Japan, Vol. 58, No. 683, pp. 365-372.

TABLE 1 Modal analyses of granodiorite in the Inzan district.

No.	Quartz	Potash felspar	Plagio-clase	Horn-blende	Biotite	Other minerals	Quartz potash felspar content	Total salic content
1	31.6	22.2	39.2	0.0	0.5	0.5	53.8	93.0
2	20.8	21.4	46.0	3.5	8.2	0.1	42.2	88.2
3	22.6	18.4	45.8	2.4	10.3	0.5	41.0	86.8
6	21.4	16.4	45.0	5.4	11.7	0.1	37.8	82.8
7	22.4	19.9	35.9	8.0	13.8	0.0	42.3	78.2
8	27.7	23.2	39.4	0.5	9.0	1.2	50.9	90.3
9	25.7	18.8	39.2	1.1	0.6	14.6	44.5	83.7
10	27.7	16.8	44.8	1.9	8.6	0.2	44.5	89.3
11	26.2	17.7	45.0	0.7	8.2	2.2	43.9	88.9
14	27.0	16.7	42.7	4.9	8.7	0.0	43.7	86.4
15	22.2	16.9	44.9	3.2	12.7	0.1	39.1	84.0
16	25.2	20.8	40.3	0.6	10.3	2.8	46.0	86.3
17	28.6	13.7	41.4	0.0	15.6	0.7	42.3	83.7
19	25.9	26.0	39.8	0.9	7.0	0.4	51.9	91.7
20	20.2	15.5	39.9	7.7	16.3	0.4	35.7	75.6
21	25.4	26.5	37.1	2.8	7.9	0.3	51.9	89.0
22	22.7	20.1	45.2	0.4	11.1	0.5	42.8	88.0
23	18.1	24.7	43.2	3.0	10.6	0.4	42.8	86.0
25	16.6	35.1	34.7	10.8	1.7	1.1	51.7	86.4
26	17.1	26.6	39 6	10.3	5.2	1.2	43.7	83.3
27	23.9	26.1	38.5	1.7	9.5	0.3	50.0	88.5
28	26.8	23.6	38.3	2.1	8.5	0.7	50.4	88.7
30	24.5	19.0	42.5	3.5	9.8	0.7	43.5	86.0
33	22.9	17.7	44.8	3.5	10.7	0.4	40.6	85.4
34	21.2	9.7	49.5	7.5	12.0	0.1	30.9	80.4
35	21.1	21.1	48.9	1.7	7.1	0.1	42.2	91.1
36	20.2	21.0	44 4	0.0	12.3	2.1	41.2	85.6
37	26.6	26.4	35.0	1.6	10.1	0.3	53·0	88.0
38	23.7	15.2	49.0	2.6	9.3	0.2	38.9	87.9
39	23.7	24.9	39.3	1.4	10.3	0.4	48.6	87.9
40	23.5	16.8	42.9	1.0	5.9	9.9	40.3	83.2
42	24.7	18.7	44.8	1.8	9.9	0.1	43.4	88.2
44	29.5	24.4	36.1	1.7	6.9	1.4	53.9	90.0
45	28.0	30.0	30.0	0.8	6.7	4.5	58.0	88.0
46	24.0	26.1	40.7	0.8	8.4	0.0	50.1	90.8
47	28.2	20.6	39.4	0.0	5.2	6.6	48.8	88.2
48	26.9	17.7	42.8	1.4	10.5	0.7	44.6	87.4
49	24.6	23.6	39.5	2.8	9.1	0.4	48.2	87.7
50	25.4	33.2	32.7	0.4	7.3	1.0	58.6	91.3
52	15.1	16.5	49.0	6.7	11.6	1.1	31.6	80.6
53	23.9	18.1	44.1	4.9	8.7	0.3	42.0	86.1
54	23.7	16.6	42.6	4.7	11.5	0.9	40.3	82.9
55	25.2	30.1	37.9	0.1	5.0	1.7	55.3	93.2
56	23.5	20.3	42.9	2.2	10.6	0.5	43.8	86.7
57	25.5	16.7	42.4	5.1	9.6	0.7	42.2	84.6
59	24.3	20.3	42.9	1.9	9.8	0.8	44.6	87.5
60	27.6	23.2	34.9	3.9	10.9	0.1	50.2	85.1
61	22.7	15.0	48.6	4.1	9.4	0.2	37.7	86.3
63	29.0	18.1	41.5	3.0	8.0	0.4	47.1	88.6

1) Numerical values are shown by volume percentage.
2) Quartz-potash felspar content = quartz + potash felspar.
3) Total salic content = quartz + potash felspar + plagioclase.
4) Quartz + potash felspar + plagioclase + hornblende + biotite + other minerals = 100.
5) In all tables in this report, above relations hold.

TABLE 2 Composition variations within handspecimens of the Inzan granodiorite mass.

No.	Quartz	Potash felspar	Plagio-clase	Horn-blende	Biotite	Other minerals	Quartz potash felspar content	Total salic content
53-1	23.9	18.1	44.1	4.9	8.7	0.3	42.0	86.1
53-2	24.7	22.9	44.5	1.8	6.1	0.0	47.6	92.1
53-3	22.7	21.8	45.2	0.7	9.3	0.3	44.5	89.7
53-4	24.8	16.7	49.1	1.6	7.7	0.1	41.5	90.6
53-5	24.8	15.0	48.5	2.3	9.3	0.1	39.8	88.3
1-1	31.6	22.2	39.2	0.0	6.5	0.5	53.8	92.0
1-2	24.2	23.1	40.8	0.3	11.4	0.2	47.3	88.1
1-3	29.5	18.4	41.3	0.8	9.6	0.4	47.9	89.2
1-4	26.8	16.4	44.9	1.0	10.5	0.4	43.2	88.1
1-5	29.3	18.8	39.1	1.3	11.4	0.1	48.1	87.2
48-1	26.9	17.7	42.8	1.4	10.5	0.7	44.6	87.4
48-2	25.3	18.6	47.5	1.1	7.4	0.1	43.9	91.4
48-3	32.6	13.4	45.5	0.6	7.8	0.1	46.0	91.5
48-4	27.4	18.4	43.3	1.7	9.0	0.2	45.8	89.1
48-5	26.3	19.9	42.3	1.6	9.2	0.7	46.2	88.5
55-1	25.2	30.1	37.9	0.1	5.0	1.7	55.3	93.2
55-2	30.9	24.9	35.5	0.4	6.0	1.3	55.8	91.3
55-3	31.6	20.8	40.7	0.1	6.5	0.3	52.4	93.1
55-4	30.9	24.3	36.8	0.4	7.4	0.2	55.2	92.0
55-5	26.6	24.1	39.5	0.2	9.3	0.3	50.7	90.2
33-1	22.9	17.7	44.8	3.5	10.7	0.4	40.6	85.4
33-2	27.1	12.6	47.2	4.1	8.8	0.2	39.7	86.9
33-3	21.0	15.0	48.9	7.3	7.8	0.0	36.0	84.9
33-4	23.6	14.4	47.4	5.7	8.7	0.2	38.0	85.4
33-5	22.6	14.5	50.9	3.6	8.0	0.4	37.1	88.0

TABLE 3 Dike rocks in and near the Inzan granodiorite mass.

	No.	Quartz	Potash felspar	Plagio-clase	Horn-blende	Biotite	Other minerals	Quartz potash felspar content	Total salic content
A	4	27.5	62.0	8.8	0.3	1.2	0.2	89.5	98.3
	5	30.3	55.9	2.8	0.4	10.6	0.0	86.2	89.0
	18	33.3	56.3	8.2	0.3	1.5	0.4	89.6	97.8
	24	34.2	37.7	25.5	1.1	1.2	0.3	71.9	97.4
	29	42.6	42.6	13.5	0.0	0.0	1.3	85.2	98.7
	31	39.0	42.4	12.2	4.4	0.8	1.2	81.4	93.6
	41	32.8	52.4	10.6	0.6	2.9	0.7	85.2	95.8
	62	28.1	55.2	14.1	0.0	2.3	0.3	83.3	97.4
B	43	22.2	12.8	45.2	6.2	13.6	0.0	35.0	80.2
	58	14.3	35.9	36.3	12.3*	1.2	0.0	50.2	86.5
C	12	12.4	2.4	58.4	9.5	16.7	0.6	14.8	73.2
	13	13.7	2.0	58.7	9.7	15.6	0.3	15.7	74.4
	51	8.9	10.9	49.1	18.2	12.5	0.4	19.8	68.9
D	32	3.0	64.3	10.4	9.3	0.9	12.1*	67.3	77.7

A: Leucocratic dike rocks in the mass.
B: Intermediate dike rocks in the mass.
C: Melanocratic dike rocks in the mass.
D: A dike rock near the mass, which seems somewhat different from above dike rocks.
* includes little pyroxene.

younger than that of the latter. For this reason, quartz-potash felspar content is a significant unit in the rock composition and must be treated apart from plagioclase in the total salic content.

In order to compare the partial compositions of the whole plutonic mass, total salic content and quartz-potash felspar content of every sample are all plotted on their own original localities in the map (Figure 1). It seems that the values of the numerous points resemble each other through the rock mass. In this figure, the area of comparatively high salic content is limited by a real line showing nearly good agreement with the central part of the mass, and on the other hand the melanocratic minerals predominate in the marginal parts of the mass.

Also quartz-potash felspar content limited by the dotted line in the same figure, is high at the central part and low at the marginal; such tendency seems more remarkable than that of the total salic content.

The nature of the plagioclases shows also that rocks of the marginal zone of the mass are a somewhat basic compared with those of the central part.

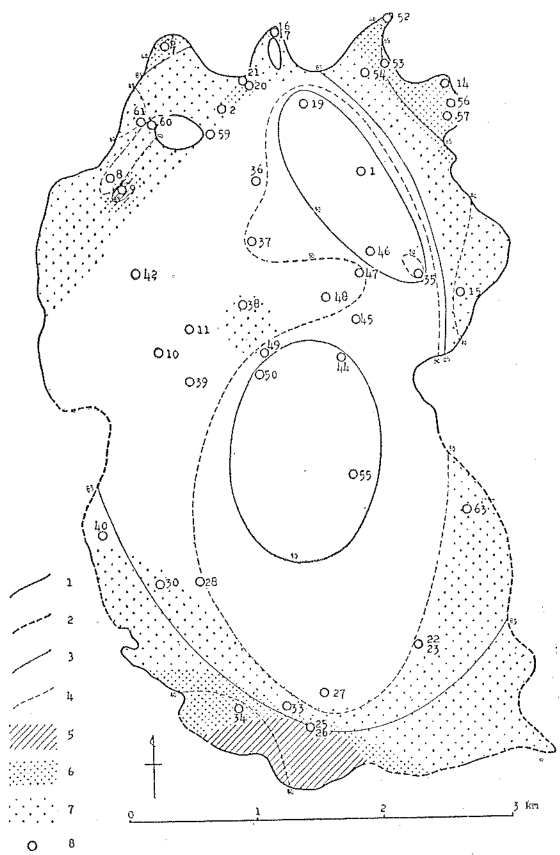

Figure 1. Structural map of granodiorite mass in the Inzan district.

1) Granodiorite sedimentaries contact.
2) Granodiorite sedimentaries uncertain contact.
3) Contour line of total salic content (quartz + potash felspar + plagioclase)
4) Contour line of quartz-potash felspar content.
5) Area where hornblende exceeds biotite.
6) Area where hornblende : biotite = 5 : 5 ~ 4 : 6.
7) Area where hornblende : biotite = 4 : 6 ~ 2 : 8.
8) Locality of samples: the numbers correspond to those of Table I. In this figure dike rocks omitted.

Those facts would indicate that the mass was made from nearly homogeneous material alone. Because of the homogeneity of this composition, it is a very reasonable consideration that this mass was not formed by granitization, but was derived from the material which was once in the melted condition. A similar consideration, although different somewhat from the above case, was stated already by CHAYES[(2)] respecting the granites of New England.

In short, even though a partial fractuation exists in the mineral compositions, it can be recognized that the central part of this mass is more leucocratic than the marginal part.

The melanocratic minerals in the rocks are mostly biotite and less abundant hornblende. The relation diagram between the above two minerals in every sample is shown in Figure 2. On the whole, when melanocratic minerals are few, the rocks contain only biotite, but if melanocratic mineral contents increase over about 8 percent of the whole constituents by volume, hornblende begins to appear and beyond that percentage both minerals tend to increase linearly. However, in general, the ratios of biotite to hornblende are generally similar to each other through the whole mass, as is shown in Figure 1. The rock facies in the marginal part of the granodiorite mass, contains a little more hornblende than that in most of the central part of it. It is noticeable that some special rock facies contain an extremely high content of hornblende. Excellent examples of these features are to be seen in the southern parts of the mass. It might be considered that those special parts had been effected by some action such as assimilation.

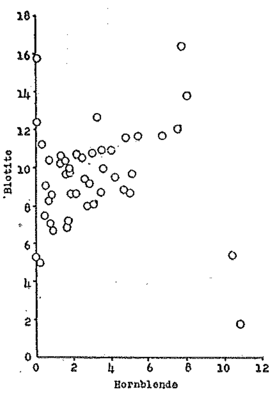

Figure 2.

Diagram of relation between biotite and hornblende. Numerical values are shown by volume percentage.

Numerous dike rocks of leucocratic or melanocratic natures traverse or are found near the granodiorite mass in the Inzan district. Though they show variations in composition and texture, most of them may have been differentiated from the same magma related to the granodiorite mass. The microscopic analyses of these dike rocks are tabulated in Table 3, in-

(2) CHAYES, F. (1950) Composition of the granites of Westerly and Bradford, Rhode Island. Amer. Jour. Sci. Vol. 248, pp. 378–407; (1950) Composition of some New England granites. Trans. New York Acad. Sci. Ser. 2, Vol. 12, No. 5,; (1952) The fine-grained calcalkaline granites of New England. Jour. Geol. Vol. 60, pp. 207–254.

dicating significant difference in mineral composition compared with the granodioritic rocks composing the country mass.

Kesengawa granodiorite mass in Takata district in Japan(3)

Similar measurements were made by the writer, on a granodiorite mass in the Takata district in the Kitakami-mountainland of the northeastern part of Japan proper. The granodioritic rocks in that district are divided into two main types according to their modes of occurrence and petrological features. The two types are the Kesengawa and the Hikamiyama. This paper deals with the properties of the granodioritic rocks of the Kesengawa type. The mass occurs in the shape of an elongated thick zone, extending over 17 km in nearly NS direction with a maximum width of about 3 km.

The mass is now considered to be an intrusive in younger Cretaceous age, and the adjacent sedimentaries, considered to be chiefly Palaeozoic, have been metamorphosed into hornfelses which often contain chiastolite, cordierite, anthophyllite, sillimanite, ottrelite, garnet, corundum, spinel, vesuvianite, wollastonite, etc.

The petrographical character of the rocks of this mass is medium-grained hornblende biotite granodiorite. It is macroscopically not very different from the above described granodiorite in Inzan mass.

In the Takata district granodioritic mass, 26 points were selected. Data were assembled on the mineral composition of the rock samples which were collected from the above localities in Table 4.

As shown in the Table, in this case, quartz and potash felspar vary generally parallel in volume, and the two have reverse trend to plagioclase. Then also it may be reasonable to treat the total volume of quartz and potash felspar, separate from that of plagioclase. If quartz and potash felspar are considered together the total content has a more clear tendency than in the case of a single one of them, in the volume relation with plagioclase or other minerals.

Hereupon, total salic content and quartz-potash felspar content are regarded as the most important units; their variations through the rock mass are shown in Figure 3.

Studies of the variation in composition in the small area are based

(3) Suzuki, Y. (1952) On the structure of the granodioritic rocks in the Takata district of the Kitakami-mountainland, northeastern Japan. (in Japanese). Jour. Geol. Soc. Japan, Vol. 58, No. 676, pp. 1-16.

TABLE 4 Modal analyses of granodiorites of the Kesengawa type in the Takata district.

No.	Quartz	Potash felspar	Plagio-clase	Horn-blende	Biotite	Other minerals	Quartz potash felspar content	Total salic content
1	28.2	12.8	48.1	2.9	7.7	0.3	41.0	89.1
2	27.7	9.1	46.8	6.8	8.1	1.5	36.8	83.6
3	29.1	12.5	39.8	6.8	10.9	0.9	41.6	81.4
4	18.3	12.8	53.8	9.7	4.7	0.7	31.1	84.9
5	28.7	13.7	45.2	11.4	0.7	0.3	42.4	87.6
6	21.6	12.6	53.1	5.6	7.0	0.1	34.2	87.3
7	32.1	14.9	38.5	6.5	7.8	0.2	47.0	85.5
8	17.7	5.3	52.9	12.4	11.7	0.0	23.0	75.9
9	29.5	7.1	44.0	9.8	9.7	0.0	36.5	80.5
10	25.6	14.6	43.9	5.9	9.4	0.6	40.2	84.1
11	28.9	8.7	44.8	9.5	7.7	0.4	37.6	82.4
12	16.9	7.0	46.2	20.8	9.1	0.0	23.9	70.1
13	14.1	7.1	55.7	5.4	17.2	0.4	21.2	77.0
14	16.2	3.4	52.7	11.6	15.3	0.8	19.6	72.3
15	12.3	7.7	69.5	4.7	5.8	0.0	20.0	89.5
16	23.5	6.9	48.5	10.2	10.7	0.2	30.4	78.9
17	18.2	2.5	51.6	13.1	14.3	0.3	20.7	72.3
18	18.7	11.5	53.5	6.6	9.3	0.4	30.2	83.7
19	26.2	1.4	53.7	8.6	9.8	0.3	27.6	81.3
20	22.6	8.4	47.6	10.4	10.8	0.2	31.0	78.6
21	17.3	2.8	46.5	19.8	13.4	0.2	20.1	66.6
22	11.6	0.0	53.6	20.9	13.9	0.0	11.6	65.2
23	23.2	9.5	55.0	6.3	5.7	0.3	32.7	87.7
24	27.9	14.7	43.1	8.0	6.3	0.0	42.6	85.7
25	26.3	11.4	43.7	10.1	7.8	0.7	37.7	81.4
26	16.8	6.8	46.0	15.8	14.5	0.1	23.6	69.6
41	19.7	12.0	51.4	10.7	5.1	1.1	31.7	83.1
42	15.5	18.9	51.2	10.6	3.7	0.1	34.4	85.6
43	19.1	18.3	43.4	11.7	7.4	0.1	37.4	80.8
44	17.6	18.7	46.8	10.6	6.3	0.0	36.3	83.1

Localities of Nos. 41–44 are not indicated on the Figure 3, because they are far apart from the main field.

TABLE 5 Composition variation within handspecimen of the Kesengawa granodiorite mass.

No.	Quartz	Potash felspar	Plagio-clase	Horn-blende	Biotite	Other minerals	Quartz potash felspar content	Total salic content
10–1	25.6	14.6	43.9	5.9	9.4	0.6	40.2	84.1
10–2	22.1	18.7	43.8	6.8	7.9	0.7	40.8	84.6
10–3	22.4	18.3	44.5	5.8	8.6	0.4	40.7	85.2
10–4	22.8	13.1	49.6	6.2	8.1	0.2	35.9	85.5
10–5	22.1	15.2	41.0	11.9	9.5	0.7	37.3	78.3
10–6	20.0	18.7	46.3	7.2	7.8	0.1	38.7	85.0

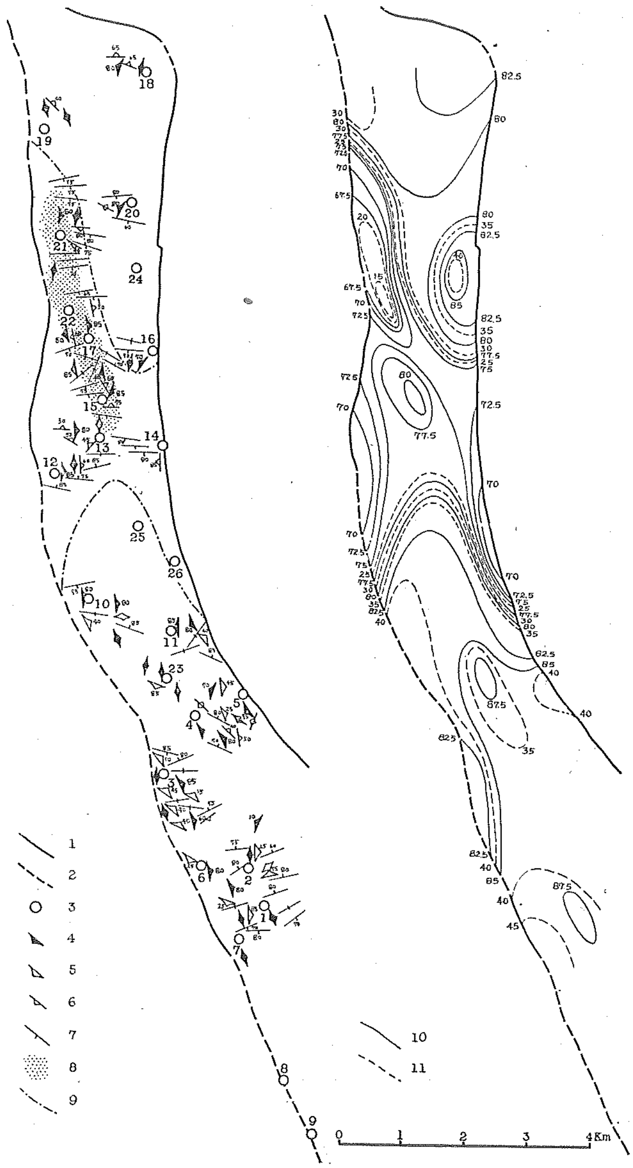

Figure 3.

Structural map of granodiorite mass in the Takata district.

1) Granodiorite sedimentaries contact.
2) Granodiorite sedimentaries uncertain contact.
3) Locality of samples; the numbers correspond to those of Table 4.
4) Orientation of mineral arrangement in the mass.
5) Aplite vein group.
6) Aplite vein.
7) Cross joint.
8) Schlieren-rich zone.
9) Rock facies boundary.
10) Contour line of total salic content.
11) Contour line of quartz-potash felspar content. Numerical values are shown by volume percentage.

on micrometric analyses of six thin sections which have been cut from a single hand specimen collected from the locality No. 10 (Fig. 3), as shown in Table 5.

From these results, computed critical region (5% significance level) of total salic content is not over ±1.64%, and that of quartz-potash felspar content is within ±5.59%. Then contour lines relating to volume percentage in Figure 3, are drawn every 2.5% in total salic content and 5% in quartz-potash felspar content, according to the above computed values. Contour lines are parallel to orientation of mineral arrangement of rocks, which have been determined by field observation and petrofabric analyses under the microscope.

From this figure, it is noticeable that the rocks in the southern part of the mass are high in total salic content, while those in the middle part show the lowest value. In general the composition values vary gradually to each other between neighbouring points. There exist, however, two conspicuous zones where contour lines are very close. Also by using contour line of quartz-potash felspar content, the similar results are obtained, though in this case, a more intensive difference is observed in the mass. These facts may indicate the existence of some discontinuities among these rock facies in the above rock mass.

These features can be found, though not so distinctly, in the fields by macroscopical observation. It is remarkable that numerous aplitic veins traverse the field of the southern rock facies of the intrusive, while in the northern rock facies few aplite veins exist. On the just southern part of the northern contour-concentrated-zone (conspicuous zone), a schlieren-rich zone distributes remarkably.

In short, these results indicate that the intrusives are locally heterogeneous in composition and structure, so that the granodioritic rock of the Kesengawa type may be again divided into three sub-types, from north to south, namely the Setamai, Yokota and Takekoma types which show comparatively sharp boundaries even in the field. Now such a boundary is named by the writer "Rock facies boundary".

Homogeneity relating to the genesis of this mass differs somewhat from that of the Inzan mass. Especially quartz-potash felspar content seems to play a more significant role in the formation of the mass.

It seems more reasonable to consider that the intrusive body had been partially affected by liquid material of quartz and potash felspar rich composition in the last stage, rather than to consider that quartz and potash felspar had crystallized out by fractional differentiation from the original mass-forming material as magma.

From the above statement, it seems that the Kesengawa mass might not have been formed, as a whole, directly from a magma of approximately the same composition. Each of the sub-types of the intrusives, however, might have been formed simultaneously as a hybrid product due to the partial mixture of semi-consolidated more melanocratic material and introduced liquid of aplitic composition. Those sub-divided partial masses were formed by different ratios of mixed materials.

Comparison between these two masses

The essential rocks which comprise the masses both of Inzan and Kesengawa, are to be called petrographically, hornblende biotite granodiorite. However, between them some remarkable differences as a whole in the volume percentage of their constituent minerals can be seen.

The volumetric analyses of the rocks themselves in both districts show respectively an apparently small variation; however, a closer inspection of the values obtained indicates that there are in fact certain distinct differences between them, especially in the volumetric relation, as are shown in Figures 4 and 5.

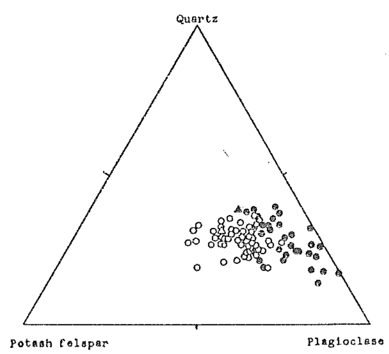

Figure 4.

Salic minerals diagram for Kesengawa and Inzan Masses. (Data are recalculated from Tables 1 and 4).

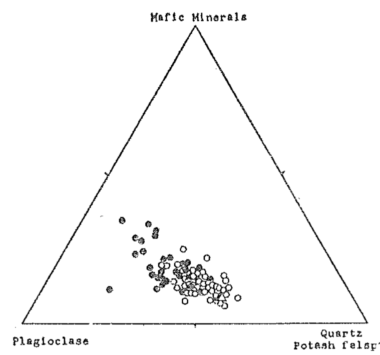

Figure 5.

Volume percentage of constituent minerals of Kesengawa and Inzan granodiorite masses. (Data from Tables 1 and 4).

Black circles :	Kesengawa granodiorite.
White circles :	Inzan granodiorite.
Black triangle :	General average (Norm) of granitic rocks of Japan.
White triangle:	General average (Norm) of granitic rocks of Europe, America, etc.

For reference, in Figure 4, normative values calculated from average chemical compositions of granitic rocks fo Japan,[4] and of Europe, America, etc.,[5] are plotted on the same diagram. The rocks from the Inzan district of Korea significantly differ from those of the Kesengawa type and the average normative value of Japanese granites and that bear rather an approximation to that of European and American type, after DALY.[5] It is an interesting fact that a provincial tendency is indicated in norm and also mineral compositions.

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(5) DALY, R. A. (1914) Igneous rocks and their origin, p. 19.