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Author(s)	Suzuki, Jun
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ON THE RODINGITIC ROCKS WITHIN THE SERPENTINITE MASSES OF HOKKAIDO

By

Jun SUZUKI

(With 2 Tables and 2 Figures)

Contribution from the Department of Geology and Mineralogy,
Faculty of Science, Hokkaido University, Sapporo No. 527

Introduction

The ultra-basic rocks, which are now mostly represented by serpentinite, are widely developed in and along the areas of the so-called Kamuikotan metamorphic complex in the form of comparatively large lenses and belts extending from the north to the south in linear direction along tectonic zones in central Hokkaido.

It is not seldom possible to find numerous small dikes and blocks of various kinds of leucocratic rocks associating with some melanocrates, invaded in the serpentinite masses. Most of these dike rocks appear to be the end phase derivatives of the ultra-basic rocks and are believed to be genetically related to each other indicating that they might have been differentiated from the same magma and may belong to a single intrusive series.

The representative kinds of leucocratic rock found in Hokkaido, to the best of the writer's knowledge are albitite, quartz albitite, quartz albitophyre, albite aplite, anorthosite, trondhjemite, pegmatite, micro-diorite, diorite-aplite, diorite-gabbro-aplite, gabbro-aplite, etc.

In addition to these various above-mentioned leucocrates, there can be found, in places, many blocks or dikes of some characteristic rocks in the serpentinite masses. On account of their petrological nature and mode of occurrence, these characteristic rocks suit the definitions of so-called *rodingite*, given by MARSHALL (1911) for the original rock from the Roding River in the district of the Dun Mountains in New Zealand.

In a recent paper the writer offered a preliminary account of the

petrological natures and origin of the rodingite in serpentinite, based upon observations carried out in Hokkaido.

Petrological Natures

The rodingites occur always in company with serpentinite masses in localities too numerous for description throughout the whole serpentinite area in Hokkaido. Their individual occurrences are usually small and the total volume of them is also not so much as the other leucocrates (Suzuki, 1940, 1952, 1953).

They show generally the form of irregularly rounded masses, 0.3~10 m. in maximum diameters or widths and in some rare places they form narrow dikes, or veins, invading the serpentinite mass. The boundaries of these blocks and dikes are in general fairly well marked being in sharp contact with the surrounding serpentinite. There can, however, be occasionally seen some rodingites which merge quite gradually outward into surrounding serpentinites such an occurrence being characterised by the absence of any sharp bounding line between them.

The rodingites are fine- to medium-grained compact rock, showing milky white to greyish white in colour, with grains of essential constituents in them invisible exactly to the unaided eye. Where the rock contains much dark pyroxene or vesuvianite crystal, it shows blotched light greenish or brownish appearance.

Among rodingite blocks, a notable marginal zone, one to several cm. in width and dark greyish green in colour, is often observed. In this case the zone commonly shows a transition from light coloured part outward to a darker zone.

Under the microscope, the rocks are found to be holocrystalline and to be chiefly composed of grossularite, diopside and zoisite, and also a small amount of scattered minute grains of magnetite and flakes of chlorite. Sometimes they contain vesuvianite as an essential constituent.

A most noticeable feature of the rodingite is the petrological characters as compared with the leucocratic rocks. There is marked difference in mineral composition between the general leucocratic rocks and the rodingites; the former always contain feldspar as an essential constituent, the latter are wanting in or show scanty, if any, signs of feldspar.

The crystals of grossularite and diopside in the rodingite are fine

or medium and usually equal in size, and are closely packed together without definite arrangement. Owing to the mutual interference of crystal grains, only a minority of them have developed their ideal shape.

In comparison with the central part where grossularite is the most important constituent, the marginal zone of the rodingite mass contains rather abundant chlorite and antigorite flakes. In the extreme dark-coloured border zone grossularite and diopside always have undergone partial or complete replacement by chlorite and antigorite and in places the zone appears like serpentinite.

Grossularite—In general the rodingite is chiefly composed of a fine-grained mosaic of grossularite grains, while diopside and zoisite, though constantly present, are much less plentiful. Grossularite may in some cases reach much as 80 per cent of the total composition of the rocks.

In section, allotriomorphic and often very highly irregular grains of grossularite, ranging between 0.1 mm. and 1.0 mm. in diameter but sometimes reaching 1.5 mm., are usually colourless and transparent though frequently rimmed with cloudy white materials.

The mineral shows optical anomaly with accompanying very weak birefringence with shagreen surface and slight zonal structure though minute grain is almost isotropic. Occasionally the comparatively large crystal is divided into three or more segments. The index of refraction of the mineral is about $1.735 < n < 1.740$. The aggregation of grossularite often fills up the cracks in pyroxene relics, on the other hand the aggregation is partly penetrated by fine veinlets of calcite.

Diopside—This mineral occasionally occurs prominently constituent usually in association with grossularite and zoisite, though the amount of diopside crystal is usually less than that of grossularite. Microscopically, diopside crystal occurs in subidiomorphic form being 0.2–1.5 mm. in length, and it is partly intermingled with a small quantity of tremolite and chlorite which are probably the secondary alteration products. In all cases it shows a short prismatic habit and is almost colourless, in which the cleavage (110) is nearly perfect. The double refraction is rather low and the maximum extinction angle $c:Z$ on 010 is about 45° .

Approaching the serpentinite the colourless diopside crystals of rodingite are seen to acquire a pale green coloured border zone of more ferrous diopside and they are sometimes rimmed with minute flakes of chlorite.

In the fine-grained aggregation of grossularites, there can be often seen crystals of pyroxene of another kind, which seem to possess the nature of common augite and are considered to be residual crystals of the original rock. They are light yellowish in colour, and the marginal part of the crystal has been frequently replaced by chlorite, with which grains of magnetite and prisms of actinolite may be associated. They show usually undulate extinction and are partly penetrated or metasomatized by grossularite or diopside aggregation.

Ziosite—This is of frequent occurrence in association with the other minerals, but it is not so widely distributed as grossularite and diopside, being always in small amount. Zoisite which in the section occurs as shapeless grains 0.1~0.2 mm. in diameter, is a nearly colourless and poorly birefringent type, rich in the clinozoisite molecule.

Vesuvianite—Vesuvianite bearing rodingites were found in a few localities, viz., in the vicinity of Niseu in Hidaka Province and of Kana-yama and Yamabe in Ishikari Province, where they mostly occur as outcrops in wide vein form. Microscopic examination shows vesuvianite to be composed of minute short prismatic crystals, 0.2~0.5 mm. in length. Usually it occurs in the form of a veinlet of irregular aggregation in the grossularite- and diopside-bases. It is almost colourless or very slight brownish in colour. It shows straight extinction and the characters of the mineral and zone are negative. In the coloured crystal, sometimes very slight pleochroism can be observed. Double refraction is low showing a unique light indigo-violet.

Chlorite—The mineral is present especially in marginal zone of rodingite mass though it is constantly scattered in very small amount in the central part associating with the margins and cracks of grossularite and diopside themselves. It occurs in minute ragged flakes faintly pleochroic in pale green tints, and it is characterized by a very low birefringence.

Prehnite is observed in some sections in small amounts, filling up the interstices of the essential constituents.

Feldspar, if present in small amounts, is much too altered for its composition to be determined.

Magnetite and *epidote* occur in relatively small amounts and are universal accessories, while *calcite* and *tremolite* are occasionally noted.

As has already been stated by HARADA (1943) it is very interesting to note that the most of the magnetite grains in the rodingite found in the Yamabe district, Ishikari Province, occur as perfectly

formed cubic crystals. The mineral grains occur as a mosaic aggregation, each crystal of which is generally less than 1 mm. in diameter and shows fine crystal with face of a(100), though minute development of o(111) cutting the corners of cube, can be very occasionally observed in them. Penetrate twinning of cubes is often found.

The occurrence of *antigorite* is limited to extremely marginal facies of rodingite blocks, in association with chlorite. It shows irregular form with fibrous habit and low double refraction.

Quartz is usually absent but occasionally minute grains or veinlets of the mineral occur interstitially among the essential constituents.

TABLE I. Chemical analyses of rodingites

	A	B	C	D	E	F	G	H
SiO ₂	38.43	40.58	35.34	33.95	33.42	37.87	43.29	47.32
TiO ₂	tr.	tr.	1.54	0.42	0.30	—	0.18	0.22
Al ₂ O ₃	22.06	15.03	13.36	19.91	14.34	20.07	20.98	20.10
Fe ₃ O ₂	1.70	3.56	6.24	1.28	10.32	5.42	1.28	0.48
FeO	1.95	3.90	5.18	6.98	2.44	n.d.	2.26	3.55
MnO	—	—	—	0.28	0.75	—	0.25	0.25
MgO	2.41	4.45	6.61	5.23	4.66	1.01	9.05	7.14
CaO	28.56	26.62	27.34	26.95	29.40	31.80	17.05	13.80
Na ₂ O	1.35	1.51	—	0.15	0.14	1.35	1.13	2.84
K ₂ O	0.34	0.26	none	—		1.17	0.61	0.68
H ₂ O ⁽⁺⁾	2.50	3.56	4.03	4.85	3.63	0.56	4.23	3.80
H ₂ O ⁽⁻⁾	0.10	0.50	—	—	—	co ₂ 0.75	—	—
Cr ₂ O ₃	—	—	none	none	none	—	0.09	none
NiO	—	—	0.02	—	—	—	—	—
CuO	—	—	0.05	—	—	—	—	—
Total	99.40	99.97	99.71	100.00	99.40	100.00	100.40	100.18

(A) Rodingite (Light-colored core). Kanayama, Minamihurano-mura, Sorachi-gun, Ishikari Province. (M. SAMBONSUGI, Anal.).

(B) Rodingite (Marginal zone). Locality ditto (ditto, Anal.).

(C) Rodingite. Roding River, Dun Mountains, Nelson, New Zealand. (J. S. MACLAURIN, Anal.).

(D) Rodingite. Locality ditto (ditto, Anal.).

(E) Rodingite. Lee Valley, Dun Mountains, Nelson, N. Z. (ditto, Anal.).

(F) Rodingite. Codes Point, Dun Mountains, Nelson, N. Z. (ditto, Anal.).

(G) Prehnite rodingite. Serpentine Valley, Dun Mountains, Nelson, N. Z. (ditto, Anal.).

(H) Prehnite rodingite. Long Gulley, Dun Mountains, Nelson, N. Z. (ditto, Anal.).

In some rocks small veinlets of clear granular *calcite* cut irregularly across the sections in all directions.

Scapolite crystal has never been recognised in any of the rodingitic rock of Hokkaido, but judging from its chemical properties, it may be expected in future to be found in some rock.

As has been indicated above, the rodingites are characterised by their mineral composition; it is noticeable that the rock does not clearly fall into any of the classification of the common igneous rocks, in view of their somewhat similarity respecting mineral assemblage to skarn. There is no evidence anywhere of violent diastrophism, though weak shearing stress must have had a slight influence upon the alteration process, and it is believed that metasomatism has produced marked changes in the rocks. The significance of this will be discussed later in dealing with the metasomatism of these rocks.

The chemical compositions of the central part and marginal zone of the typical rodingite dike at Kanayama, Ishikari Province (SAMBON-SUGI, 1937), are shown in Table 1.

In the sections, the round volumetric per cent of the constituent minerals in the central and marginal parts of the rodingite from Kanayama, which were chemically analysed respectively is as follows; Grossularite 70~75%, diopside 12~23%, vesuvinite 0.5~1%, chlorite and antigorite 1~3%, calcite 1~10%.

The remaining parts of this paper will be devoted to a discussion of the chemical aspects of the rodingite under investigation. For comparison a tabulation has been made of the chemical analyses of typical rodingites from the original locality in the Dun Mountains, New Zealand (MARSHALL, 1911).

Origin of the Rocks

From the peculiarities in the composition and occurrence of the rock, question arises whether the rodingite mass is a cognate product with serpentinite or whether it originated accidentally as xenolithic block in serpentinite or whether it is due to metasomatic action on leucocratic rocks by lime-rich solutions liberated in the process of serpentinitisation.

In spite of the fact that the mineral constitution of the rodingite is similar in all respects to that of skarn mass which is due to contact metamorphism of limestone by igneous rock, it is not suitable from the geological viewpoint to treat the rocks as skarn which were produced

from limestone xenolith by metasomatism. There are, so far as known at present, very few or scarce limestone layers in the pre-existing basement rocks in all parts of serpentinite area in Hokkaido. When all the factors of occurrence, petrology and type of associated mineralisation are considered it appears most probable that the rodingite occurrences are genetically related to the leucocrates rather than to the limestone xenolith.

On account of the igneous cycle in the serpentinite regions, it is considered that the ultra-basic rocks were the earliest intrusives, followed closely by the leucocratic rocks and, after an interval, by aqueous solution rich in lime which appears to be an end derivative rising from the cooling ultra-basic mass. Under these circumstances, it is most probable that the rodingites were produced from pre-existing leucocrates affected by later lime-metasomatism. It is obvious that in this case water also due to the influence of concentrated lime-rich magmatic water, played an important part during the reaction to make much hydrous silicates in the rodingite.

Most of the rock has, however, been so thoroughly metasomatised that all original structure and constituents have been lost excepting the presence of a small amount of relict pyroxene crystal in some rock; the distinctive characteristics of the original rocks may have been largely obscured and there is no clue to the direct identify of them.

Rodingitic rocks have attracted the attention of many petrologists (GRANGE, 1927; TURNER, 1930, 1933; SUZUKI, 1940; etc) since they were primarily studied by MURGOCI (1900) on the rocks from Roumania, and by MARSHALL (1911), BELL (1911), and BENSON (1914) on those from New Zealand respectively.

Though many studies have been made in connection with the natures and many opinions offered on the genesis of rodingite ever since, it appears to be the general opinion of many petrologists that the rock might have been produced from mediate or basic rocks by lime-metasomatism.

On account of the natures of lime connected with the origination of rodingite, TURNER (1951) stated as follows: "The added lime here is probably magmatic. Some writers regard it as having been concentrated in residual solutions left after crystallization of the ultra-basic 'magma' while others envisage it as having been set free during serpentinization of diopsidic pyroxene in the peridotite".

As a rodingite has been labeled by many authors "altered gabbro or eucrite" (BENSON, 1926; GRANGE, 1927; ARSHINOV and MERENKOV 1930; TURNER, 1933), it is also suitable to consider that the rodingitic rocks in Hokkaido have originated in a similar way and are a metasomatic product of differentiated dike rocks with the dioritic or gabbroic natures which invade serpentinitised peridotites. As the mineral compositions of basic rocks and rodingite are so complicated, it is not possible sche-

TABLE 2. Chemical analyses of leucocrates and serpentinite

	1	2	3	4	5	6	7	8
SiO ₂	67.17	72.92	70.24	60.21	51.11	68.54	70.45	37.29
TiO ₂	0.30	0.16	0.07	0.52	0.25	—	0.10	—
Al ₂ O ₃	18.22	16.69	16.86	16.70	14.14	17.09	16.43	8.38
Fe ₂ O ₃	0.46	0.25	0.14	0.28	0.38	2.74	0.37	7.23
FeO	0.65	0.50	0.86	1.40	8.91	0.45	0.71	2.23
MnO	0.06	tr.	tr.	0.22	0.28	—	0.03	—
MgO	1.08	0.43	0.73	5.27	7.78	1.39	1.53	28.20
CaO	0.92	0.42	0.92	7.23	12.49	2.16	3.11	0.43
Na ₂ O	9.46	7.43	6.85	6.76	1.74	2.00	4.43	—
K ₂ O	0.33	0.29	1.94	0.36	0.24	1.84	1.07	—
P ₂ O ₅	—	—	—	tr.	tr.	—	0.58	—
H ₂ O(+)	0.92	0.48	0.86	1.31	—	—	1.54	12.37
H ₂ O(-)	0.31	0.20	0.48	0.19	—	—	—	3.32
Ign. loss	—	—	—	—	2.59	3.14	—	—
Total	99.88	99.77	99.95	100.45	99.91	99.35	100.35	99.45

- (1) Albitite. Shinnito Mine, Saru-gun, Hidaka Province Hokkaido. (S. KOMATSU, Anal.).
- (2) Quartz albitite. Bankei, Nukahira Mine, Saru-gun, Hidaka Province. (S. KOMATSU, Anal.).
- (3) Quartz albitite. Tanukiiwa, Hatta Mine, Saru-gun, Hidaka Province. (S. KOMATSU, Anal.).
- (4) Prehnite-bearing hornblende albitite. Utonai River, Nakagawa-gun, Teshio Province. (S. KOMATSU, Anal.).
- (5) Diorite-gabbro-aplite. Penke, Takadomari, Uryu-gun, Ishikari Province. (A. KANNARI, Anal.).
- (6) Trondhjemite. Yamabe, Sorachi-gun, Ishikari Province. (H. KONISHI, Anal.).
- (7) Trondhjemite. Horonari, Tadoshi-mura, Uryu-gun, Ishikari Province. (T. NEMOTO, Anal.).
- (8) Serpentinite accompanying with vesuvianite-bearing rodingite. Kanayama, Minami-hurano-mura, Sorachi-gun, Ishikari Province. (M. SAMBONSUGI, Anal.).

matically to express the change between them, the changes accompanying metasomatism, in the case of Hokkaido, may roughly summed up as follows;

Basic leucocrate + Lime
+ Water $\rightarrow$ Rodingite.

If such a relation does exist, it seems probable that most of the essential mineral of rodingite may be the recrystallized product *in situ* of the original members, plagioclase, pyroxene, etc. in the basic rock, in the course of lime-metasomatism.

For comparison with the chemical composition of rodingites and related rocks, chemical analyses of some typical leucocratic rocks in serpentinite masses and serpentinite itself in Hokkaido, will be shown

in Table 2 for reference. The chemical characteristics of these rocks are shown in the A-C-F diagram (Fig. 1), and the variation diagram (Fig. 2) which gives good illustration of their relation.

In Figure 1 there are plotted the calculated molecular values of the chemical data of Tables 1 and 2 together with those of a number of the average composition of diorite and gabbro as given by DALY and JOHANSEN respectively.

Rodingites are always characterized by the relatively low values of silica, alumina and alkalis and contrariwise by high values of lime, indicating that involved addition and subtraction of considerable amounts of chief components had taken effect during metasomatic process.

Obviously the chemical composition of the rodingites themselves shows a small variation and the loci of the rodingites mostly fall into

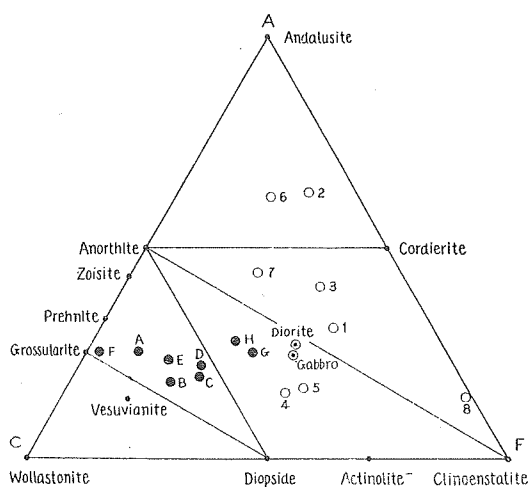


Fig. 1. A-C-F diagram illustrating variation in composition in the rodingites of Table 1 and in the leucocrates and serpentinite of Table 2.

Black circles (A~H) are rodingite.

White circles are leucocrates (1~7) and serpentinite (8).

Average values of gabbro and diorite are added in the diagram for reference.

A, C and F are calculated so that

$$A + C + F = 100: A = \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 - (\text{Na}_2\text{O} + \text{K}_2\text{O});$$

$$C = \text{CaO}; F = \text{MgO} + \text{FeO} + \text{MnO}.$$

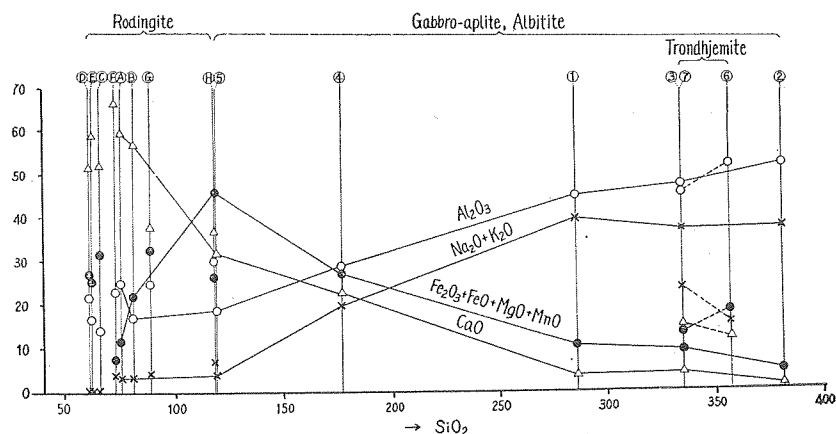


Fig. 2. Variation diagram for the rodingite (A and B) and leucocratic rocks (1~7) in the serpentinite masses of Hokkaido. Six analyses (C~H) of the rodingites of the Dun Mountains are added in the diagram for reference.

In the diagram, the chemical data of Tables 1 and 2 are represented graphically, with lettered points corresponding to similarly lettered columns of the Tables.

the metamorphic field being surrounded with grossularite, diopside, zoisite, prehnite and vesuvianite, etc. showing the close relationship between their chemical composition and mineral constituents.

Rodingite is considered to be derived from leucocratic rocks by lime-metasomatism, but in this case, it may safely be inferred that the rodingite shows a rather close relationship especially to the gabbroic or dioritic leucocrate. This is reasonable because the relatively high values of silica, alumina and alkalis and comparatively low figures for lime clearly differentiate the albititic and trondhjemitic rocks from rodingitic rock, though the ferrous oxide and magnesia show no marked difference in these two series. These points are well illustrated in the A-C-F diagram (Fig. 1) and variation diagram (Fig. 2).

As mentioned above, most of the rodingites from Hokkaido are considered to be the result of metasomatism of earlier basic leucocrates, the original structures of which have been completely obscured by metasomatism. But according to ASAI (1950) and BAMBA (1950) who have studies respectively on the rodingitic rocks from the ultra-basic mass which rises over three prefectures of Hiroshima, Okayama and Tottori, and from Mt. Ubu, Aichi Prefecture, there are gabbroic rocks

parts of which have been converted into grossularite-fels by lime-metasomatism. ASAI and BAMBA have themselves traced every gradation from gabbroic rock to pure grossularite-fels and they state also that the origins of such special parts are often clearly indicated by the presence of original gabbroic structure which is retained even in completely metasomatized parts. These facts endorse the idea of the intimate relation between rodingites and basic rocks in the serpentinite, from the genetical point of view.

It is noticeable that the marginal zone of rodingite mass shows special dark appearance in comparison with the central part and in the vicinity of such basic borders the rock is often hybridised yielding more chlorite and antigorite. The zone is made up of a mineral assemblage of further metamorphic origin and it seems probable that in the course of metasomatic process, dark minerals have arisen as a result of the action of lime-rich residual fluids at a late stage in crystallisation as well as from the diffusion with transfer of magnesia, ferrous and ferric oxides across the original boundary from surrounding serpentinite.

In recent years some rodingitic rocks have been reported from the other serpentinite masses in Japan (KINOSHITA, 1936, BAMBA, 1950, ASAI, 1950), though they are not yet described in a detailed discussion. As it is expected that more rocks will be found in each of the serpentinite areas, more particular attention will be given later to the characters of the rock.

The writer wishes to express his hearty appreciation to Prof. SAMBONSUGI who has performed the chemical analyses of the rodingites from Hokkaido published in this paper, and the writer is indebted as well to Messrs. ASAI and BAMBA for much helpful discussion with reference especially to the origin of the rodingitic rocks.

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