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PRELIMINARY PETROLOGICAL STUDIES OF THE GRANITIC ROCKS IN THE SØR RONDANE MOUNTAINS, EAST ANTARCTICA

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Abstract: The Sør Rondane Mountains mainly consist of Proterozoic metamorphic rocks and various kinds of Late Proterozoic to Early Paleozoic granitic rocks. The Early Paleozoic granitic rocks can be divided into two types, concordant granites and discordant granites. Chemical analyses of major and trace elements for the Early Paleozoic granitic rocks are presented. The discordant granites are characterized by high Ba, Sr and alkalies. In contrast, the concordant granites are high in Y and Nb and slightly low in CaO, Cr and Sr compared with the discordant granites. Most of the concordant granites are classified as within plate granites and the discordant granites as volcanic arc granites, based on trace elements. Mineral compositions in the granitic rocks are also related to the two granite types. Mg/(Mg+Fe) ratios of ferromagnesian minerals of the concordant granites are very low, while those of the discordant granites have intermediate Mg/(Mg+Fe) ratios. Anorthite contents of plagioclases in the concordant granites are low, while those of the discordant granites have slightly high anorthite content compared with those of the concordant granites. These chemical features and the Sr initial ratios may suggest that these two granite types were formed under different conditions.

1. Introduction

It is characteristic of the Sør Rondane Mountains that various kinds of granitic rocks are widely distributed among high-and medium-grade metamorphic rocks. Plutonic rocks in the Sør Rondane Mountains can be divided into Early Paleozoic granitic rocks and Late Proterozoic tonalite based on Rb-Sr whole rock isochron ages (TAINOSHO *et al.*, 1992a).

This paper presents chemical compositions of the Early Paleozoic and Late Proterozoic plutonic rocks and their minerals, and reveals the chemical characteristics of the plutonic rocks.

2. Geological Outline

The central part of the Sør Rondane Mountains consists mainly of Proterozoic granulite- and amphibolite-facies metamorphic rocks, and various kind of granitic rocks (Fig. 1). Previous studies have showed evidence of 1000 Ma granulite-facies metamorphism, in the northern part of the Sør Rondane Mountains, and 500 Ma plutonism (KOJIMA and SHIRAISHI, 1986; ISHIZUKA and KOJIMA, 1987; SHIRAISHI and KOJIMA, 1987; SAKIYAMA *et al*., 1988; SHIRAISHI *et al*., 1991; ASAMI *et al*., 1992). Strong deformation and thrust-up movement took place and mylonite zones were formed in this area. The metamorphic rocks were formed by a collision event before 1000 Ma and were rearranged by thrust faults at about 540 Ma, followed by the Early Paleozoic granitic activities which took place in the tectonic environments of the active plate margin (OSANAI *et al*., 1992).

The Early Paleozoic granitic rocks in the Sør Rondane Mountains can be divided into two types on the basis of their field relations with the surrounding rocks. One type is granitic rocks with concordant boundaries (concordant granite), and the

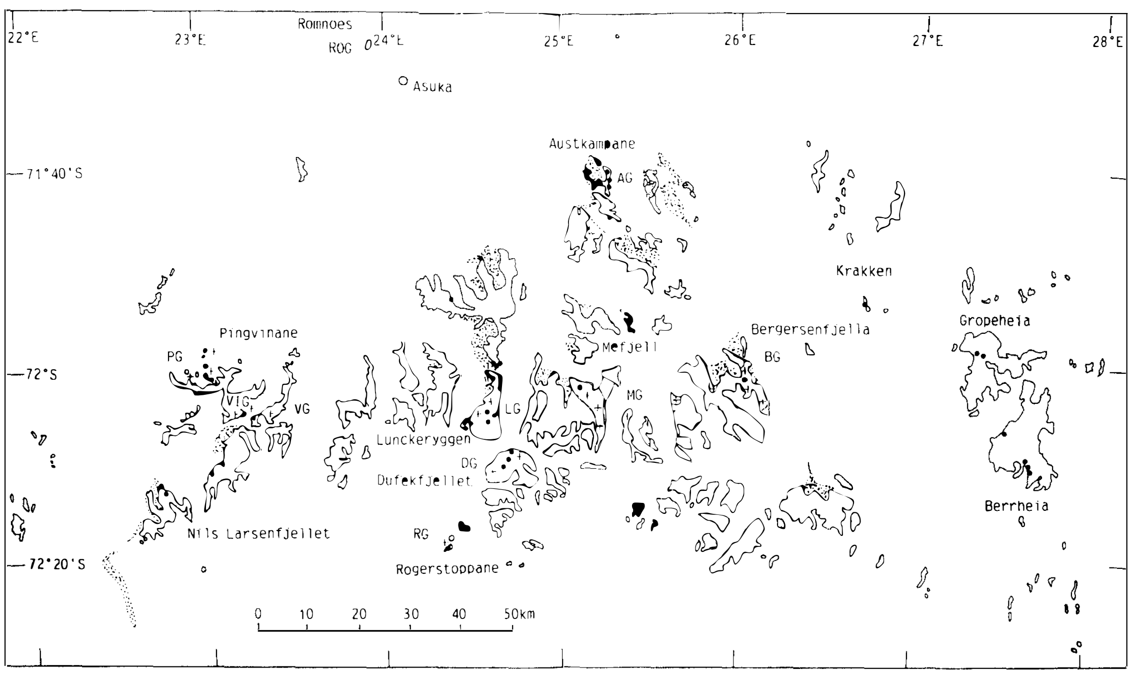

Fig. 1. Map showing distribution of the granitic rocks and sampling locations. Simplified from the unpublished geologic map by National Institute of Polar Research. Dotted symbols represent moraine, crossed symbols represent granitic rocks, and the other parts surrounded by solid lines show outcrop areas of metamorphic rocks. Solid circles represent sample locality points. AG (Austkampane Granite), DG (Dufek Granite), LG (Lunckeryggen Granite), MG (Mefjell Quartz monzonite), PG (Pingvinane Granite), RG (Rogerstoppane Granite), VG (Vengen Granite), VIG (Vikinghøgda Granite), ROG (Romnoes Granite).

other is granitic rocks with discordant boundaries (discordant granite) (TAKAHASHI *et al.*, 1990). Rb-Sr and K-Ar whole rock ages of the above two granitic rocks are around 500-550 Ma (TAKAHASHI *et al.*, 1990; TAINOSHO *et al.*, 1992a). The concordant boundary is parallel to the gneissosity of the surrounding rocks, whether it is diffuse or sharp. On the other hand, the discordant boundary is sharp and cuts across the gneissosity of the gneiss.

Among the granitic bodies studied (Fig. 1), Austkampane Granite (AG), Vikinghøgda Granite (VIG), Mefjell Quartz monzonite (MG), Vengen Granite (VG), Rogerstoppane Granite (RG), Bergersen Granite (BG) and Pingvinane Granite (PG) are concordant granites, whereas Dufek Granite (DG), Romnoes Granite (ROG) and Lunckeryggen Granite (LG) are discordant granites (SAKIYAMA *et al*, 1988; TAKAHASHI *et al.*, 1990). The granitic rocks generally occur as isolated masses. Therefore, it is difficult to formulate intrusive relationships among the granitic rocks.

The Nils Larsen tonalite is the only Late Proterozoic intrusive rock. This tonalite occurs in the southern part of the Sør Rondane Mountains. The tonalite has been subjected to mylonitization under the conditions of the greenschist to epidote amphibolite facies (KOJIMA and SHIRAISHI, 1986).

3. Description of the Granitic Rocks

Outline of geology and petrography for the granitic rocks is described below. The modal analyses are plotted on a quartz-K-feldspar-plagioclase diagram (Fig. 2).

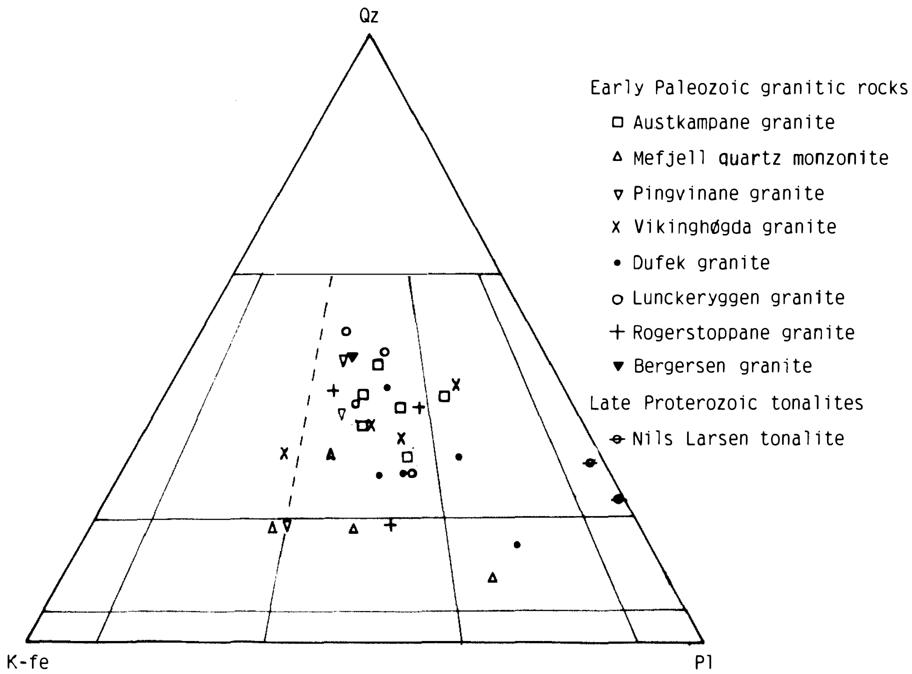

Fig. 2. Modal distribution of quartz (Qz), K-feldspar (K-fe) and plagioclase (Pl) of the granitic rocks from the Sør Rondane Mountains, based on the IUGS SUBCOMMISSION (1973) system.

3.1. Early Paleozoic granitic rocks

(1) Concordant granites

The Mefjell Quartz monzonite intrudes into the gneiss parallel to its gneissosity with a clear boundary, and is sometimes intruded by fine-grained biotite granite and locally by dioritic dykes. It is foliated by mafic mineral orientation and rarely has mafic layering. The quartz monzonite is medium-grained and contains much hornblende (7-15%), and is composed mainly of K-feldspar, plagioclase, quartz, hornblende, biotite and clinopyroxene.

The Austkampane Granite is a small intrusion and is coarse-grained gneissose hornblende biotite granodiorite to granite. Mafic minerals of the granite show a parallel arrangement giving the gneissosity. The granite is composed mainly of quartz, plagioclase, K-feldspar and biotite.

The Bergersen Granite is a small intrusion and intrudes into the gneiss parallel to its gneissosity with an unclear boundary. The granite is a fine-grained gneissose biotite granite, and is composed of K-feldspar, quartz, plagioclase and biotite.

The Vikinghøgda Granite intrudes into the gneiss with a boundary parallel to the gneissosity of the gneiss. This granite includes many gneissose rocks whose margins are often diffused. The granite is equigranular fine-grained gneissose biotite granite, and is composed of quartz, plagioclase K-feldspar, biotite and muscovite.

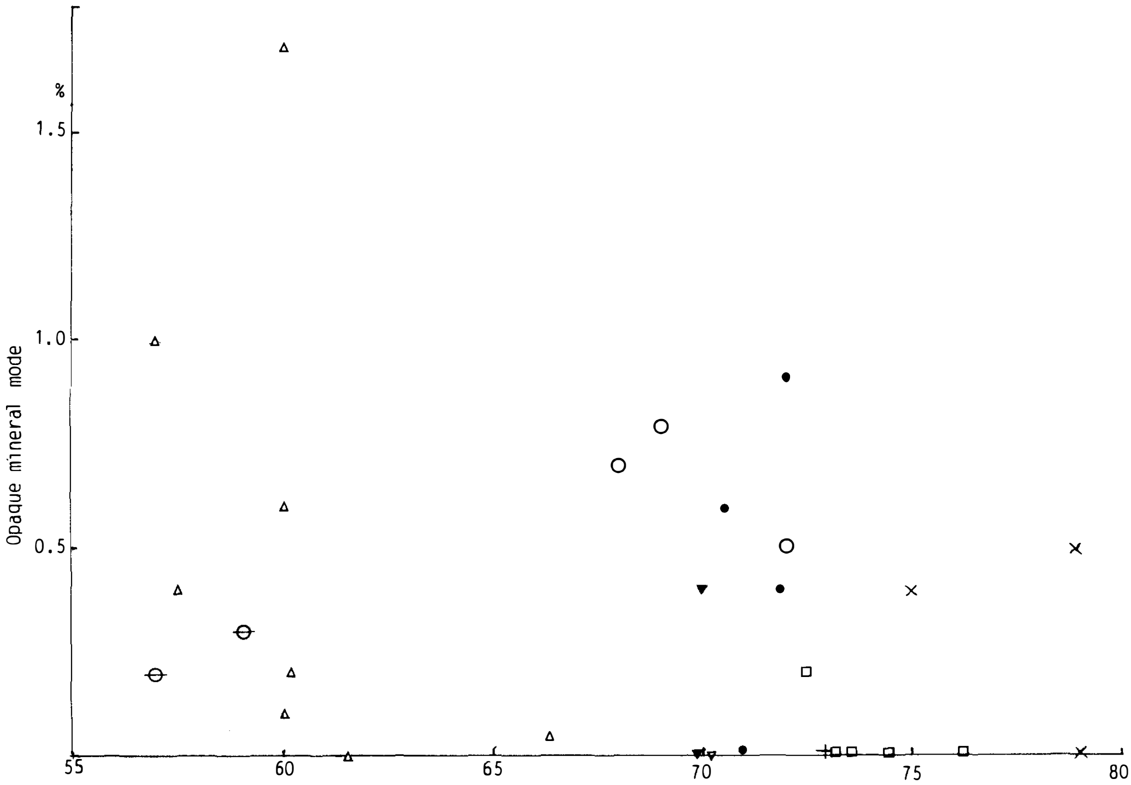

Fig. 3. Relations between modal content of opaque mineral and SiO_2 wt% of the host rock. Same symbols as Fig. 2.

The Vengen Granite is in fault contact with gneisses and strongly mylonitized, and may be more appropriately named a porphyroclastic mylonite. Lithology before mylonitization may be not deduced in detail. It is composed mainly of plagioclase, quartz and K-feldspar with accessory chrorite (secondary).

The Pingvinane Granite intrudes into the gneisses and includes xenoliths of gneisses whose contacts are often diffused in a 10 m width near margin. The margin of this granite lies in a parallel arrangement to the gneissosity of the gneiss. Most of the granite except for the marginal facies is massive and equigranular, coarse-grained biotite hornblende granite, composed of K-feldspar, quartz, plagioclase, hornblende and biotite.

The Rogerstoppane Granite is medium-grained hornblende biotite gneissose granite, and is composed mainly of plagiocase, quartz, K-feldspar biotite and hornblende.

(2) Discordant granites

The Lunckeryggen Granite forms a stock composed of coarse-grained biotite granite to hornblende biotite granite with fine-grained biotite granite. The coarse-grained granite is generally homogeneous and massive, but it has weak foliation which may be the primary flow structure along the northern margin. This granite intrudes into the Nils Larsen Tonalite with a leucocratic margin, and sporadically

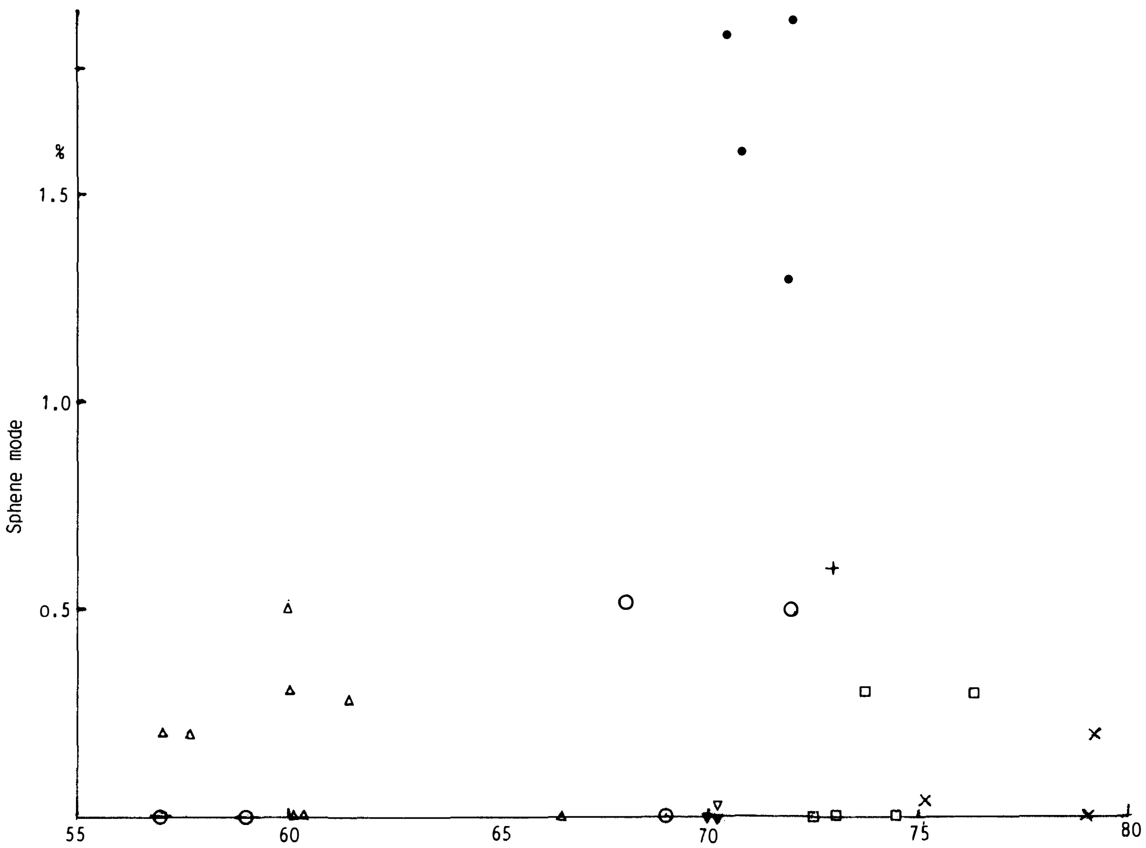

Fig. 4. Relations between modal content of sphene and SiO_2 wt% of the host rock. Same symbols as Fig. 2.

contains dark inclusions. This granite has relatively high opaque mineral contents (Fig. 3). Main constituents of the coarse-grained granite are quartz, K-feldspar, plagioclase and biotite with or without hornblende.

The Dufek Granite is massive medium-grained biotite granite with fine-grained biotite granite, and is partly mylonitized by late faulting. This granite is fairly abundant in sphene (Fig. 4).

3.2. Late Proterozoic tonalite

The Nils Larsen Tonalite is a medium-to coarse-grained biotite hornblende tonalite (Fig. 2), characterized by high hornblende content (24–30%), and has many lenticular dark inclusions. This tonalite is more or less mylonitized by regional mylonitization. Principal constituents are plagioclase, quartz, hornblende and biotite.

4. Whole Rock Chemistry

Chemical analyses of the granitic rocks have been performed by means of XRF and ICP by Chemex Labs Ltd. in Canada.

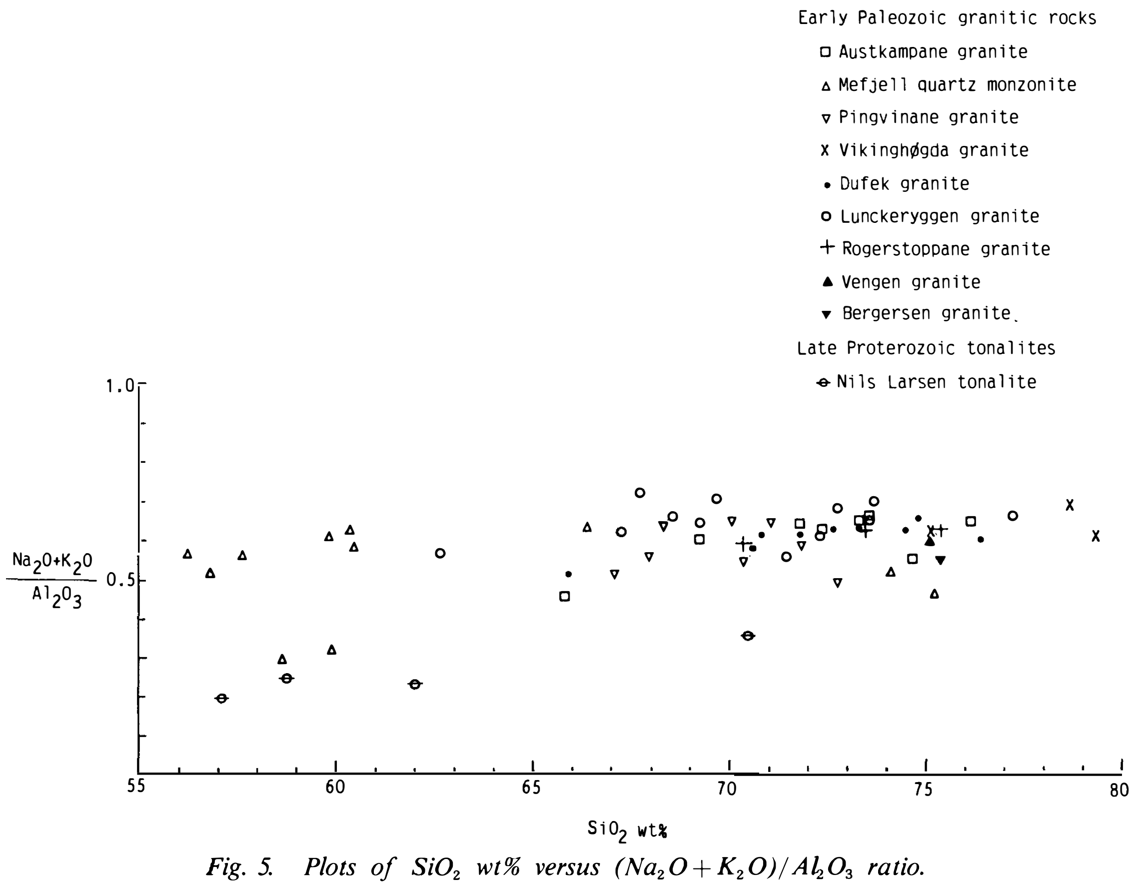

Fig. 5. Plots of SiO_2 wt% versus $(Na_2O+K_2O)/Al_2O_3$ ratio.

4.1. Early Paleozoic granitic rocks

(1) Concordant granites

The Mefjell Quartz monzonite shows characteristics of high $(Na_2O+K_2O)/Al_2O_3$ ratio and Ba (Figs. 5 and 6). The Austkampane Granite is relatively higher in Rb and lower in Sr than those of the other granitic rocks (Figs. 6 and 7). The Vikinghøgda Granite shows the characteristics of relative high $(Na_2O+K_2O)/Al_2O_3$ ratio and low Sr and Cr (Figs. 5 and 7). The Vengen Granite is low in Cr and Ba (Figs. 6 and 7). The Pingvinane Granite is characterized by high Ba (Fig. 6). The Rogerstoppane Granite is relatively low in Sr and Cr and high in Nb (Figs. 7 and 8). On a Y-Nb diagram (Fig. 8), the concordant granites fall in the field within plate granites except for the Mefjell Quartz monzonite and the Vengen Granite which are plotted in the volcanic arc granite field.

(2) Discordant granites

The Lunckeryggen Granite is high in $(Na_2O+K_2O)/Al_2O_3$ ratio and Rb (Figs. 5 and 6). The Dufek Granite is high in Sr and relatively low in Cr and $(Na_2O+K_2O)/Al_2O_3$ ratio (Figs. 5 and 7). The discordant granites are classfied as volcanic arc granites (Fig. 8).

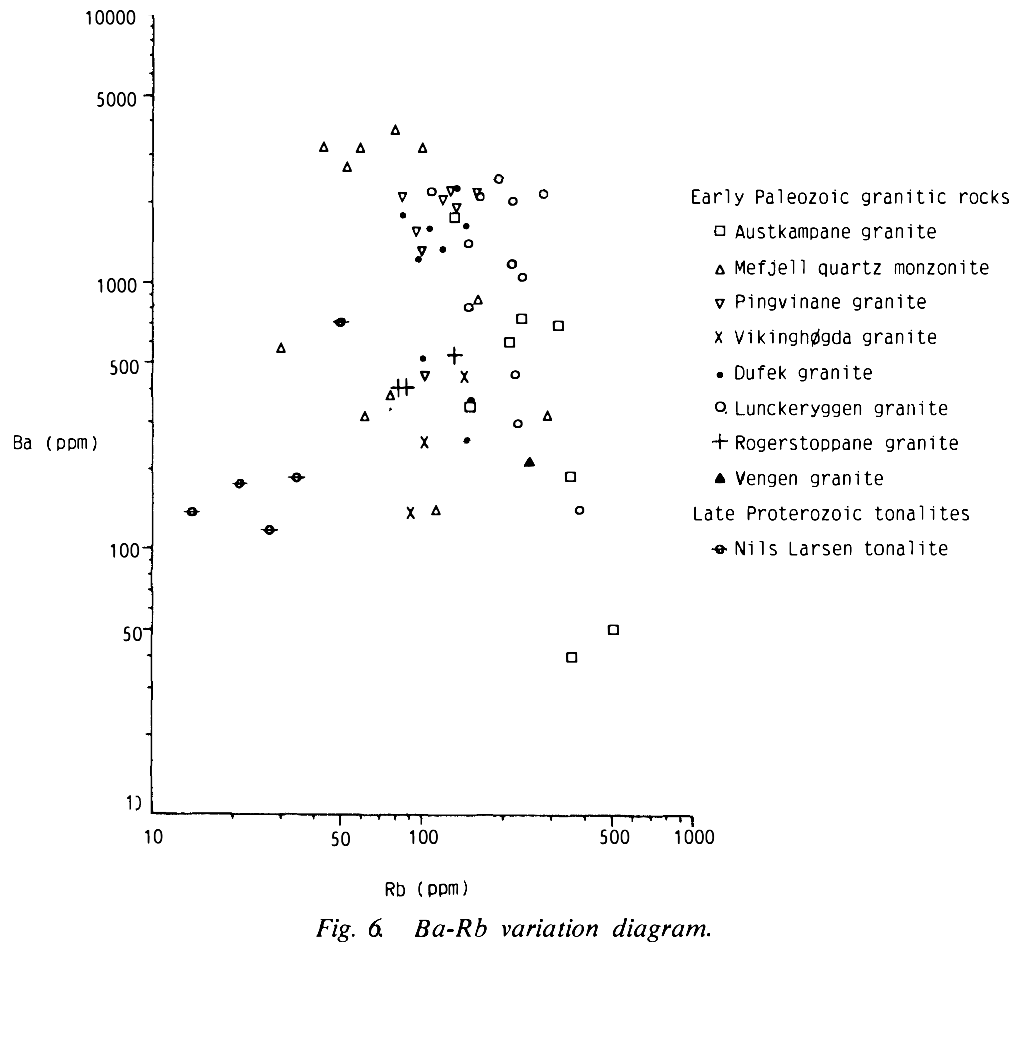

Fig. 6. Ba-Rb variation diagram.

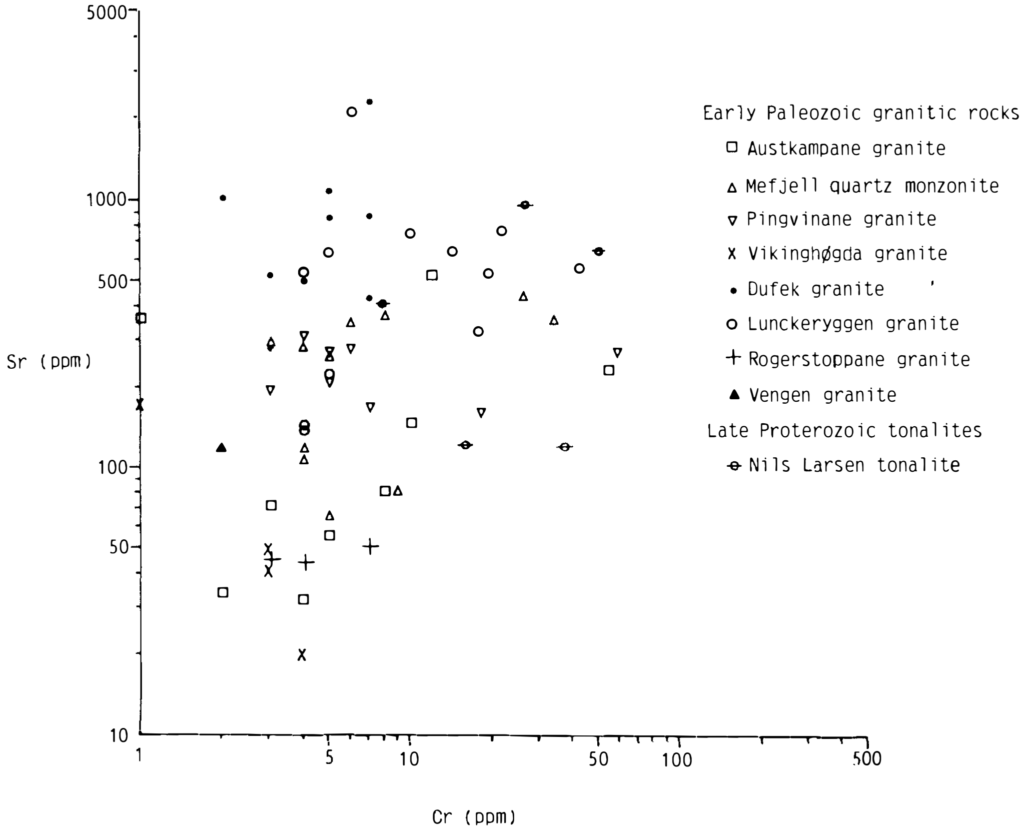

Fig. 7. Sr-Cr variation diagram.

4.2. *Late Proterozoic tonalites*

The Nils Larsen Tonalite is low in $(Na_2O+K_2O)/Al_2O_3$ ratio, Ba and Rb and high in Cr (Figs. 5, 6 and 7).

5. Mineral Chemistry

Mineral analyses were done with the EDS at the Faculty of Science of Kobe University using the Bence-Albee correction procedure. Selected individual analyses are listed in Tables 1-6 and plotted in Figs. 9-13.

Plagioclases are commonly weakly zoned and variable in composition (Table 1, Fig. 9). Plagioclases in the concordant granites are considerably sodic (An 5-19), especially, plagioclase in the Pingvinane Granite is strongly sodic (An 5). However, plagioclases in the Romnoes Granite (discordant granite) are somewhat calcic (around An 30) compared with those in the other granitic rocks (Fig. 9). Thus, plagioclases in the discordant granites have a tendency to be slightly rich in anorthite content compared with those of the concordant granites.

Most of the analyzed K-feldspars are characterized by considerably high orthoclase content (Or 92-97), but K-feldspar in the Romnoes Granite has slightly low orthoclase content (Or 84) (Fig. 9).

Chemical compositions of biotites in the concordant granites are characterized

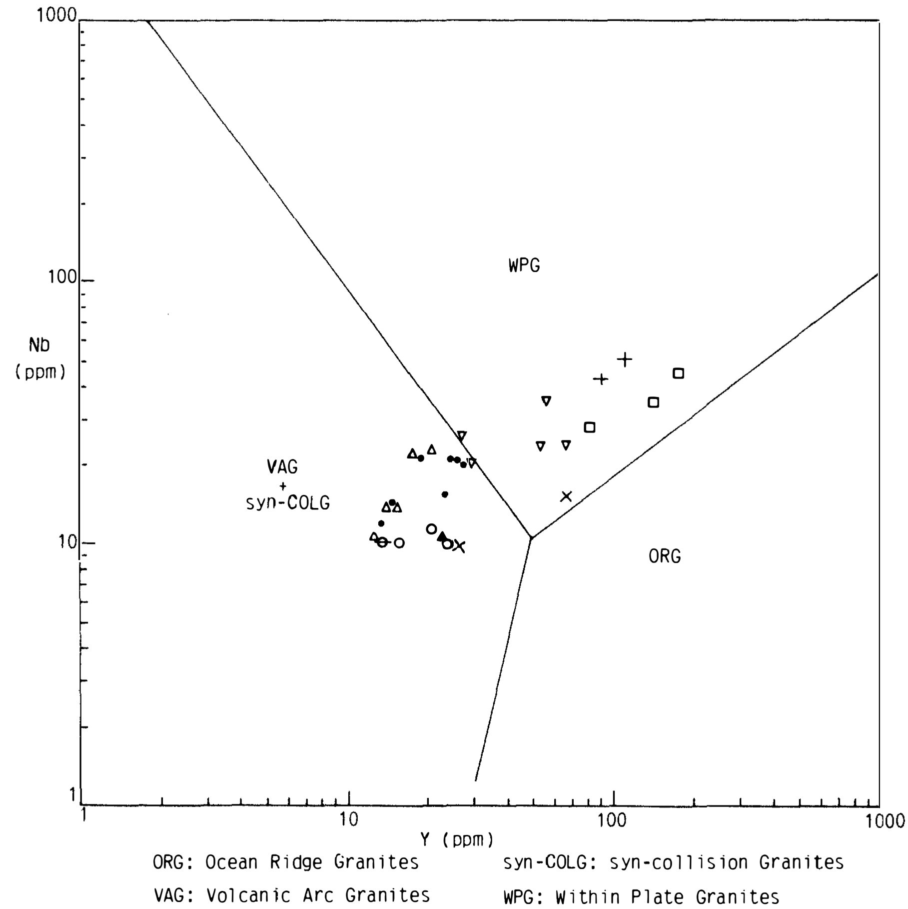

Fig. 8. Y-Nb diagram of Pearce *et al. (1984) (after* Tainosho *et al., 1992a). Same symbols as Fig. 7.*

by low Mg/(Mg+Fe) ratios, ranging from 0.01 to 0.13. Biotites from the Mefjell Quartz monzonite and Pingvinane Granite have particularly Fe-rich components compared with those from the discordant granites, although the host rocks of the Mefjell Quartz monzonite and Pingvinane Granite have low SiO_2 wt% compared with those of the other granitic rocks. Biotites in the discordant granites have intermediate Mg/(Mg+Fe) ratios, ranging from 0.25 to 0.53 (Fig. 10). Biotites from the Pingvinane, Bergersen and Rogerstoppane Granites are slightly poor in Si (Fig. 10).

Analyzed calcic amphiboles are plotted in fields of ferro-hornblende and ferro-tchermakitic hornblende (Fig. 11). Hornblendes as well as biotites from the Mefjell Quartz monzonite and Pingvinane Granite are rich in Fe, but the Romnoes granite (discordant granite) has slightly higher Mg/(Mg+Fe) ratios than those of the other granitic rocks.

Most analyzed ilmenites occurring as independent grains are close to $FeTiO_3$ with minor Fe_2O_3 (Fig. 12, Table 5). In the Bergersen Granite, the ilmenite is enriched in $MnTiO_3$. Analyzed magnetites are near end-member magnetite (Fig. 12).

Garnet from the Rogerstoppane Granite is rich in spessartine and almandine

Table 1. Chemical compositions of plagioclases.

	Romnoes	Mefjell	Dufek	Luncke-ryggen	Rogers-toppane	Ping-vinane	Berger-sen	Nills Larsen
SiO_2	60.86	65.36	64.36	66.27	64.79	65.22	64.13	58.75
TiO_2	0.02	0.00	0.02	0.07	0.11	0.10	0.08	0.10
Al_2O_3	24.86	21.34	23.08	21.97	22.18	20.57	22.49	25.87
Cr_2O_3	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.19	0.01	0.07	0.15	0.32	0.17	0.18	0.28
MnO	0.00	0.00	0.01	0.11	0.16	0.24	0.19	0.21
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	6.26	2.25	4.09	2.19	2.51	1.09	2.98	7.10
Na_2O	8.18	10.43	9.81	10.45	10.09	10.49	9.71	7.49
K_2O	0.34	0.10	0.13	0.11	0.18	0.12	0.00	0.00
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.77	99.49	101.57	101.32	100.34	98.00	99.76	99.80
Si	2.69	2.89	2.80	2.88	2.85	2.92	2.83	2.63
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	1.30	1.11	1.18	1.12	1.15	1.09	1.17	1.37
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Mn	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.30	0.11	0.19	0.10	0.12	0.05	0.14	0.34
Na	0.70	0.89	0.83	0.88	0.86	0.91	0.83	0.65
K	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00
P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cations per 8 oxygens.

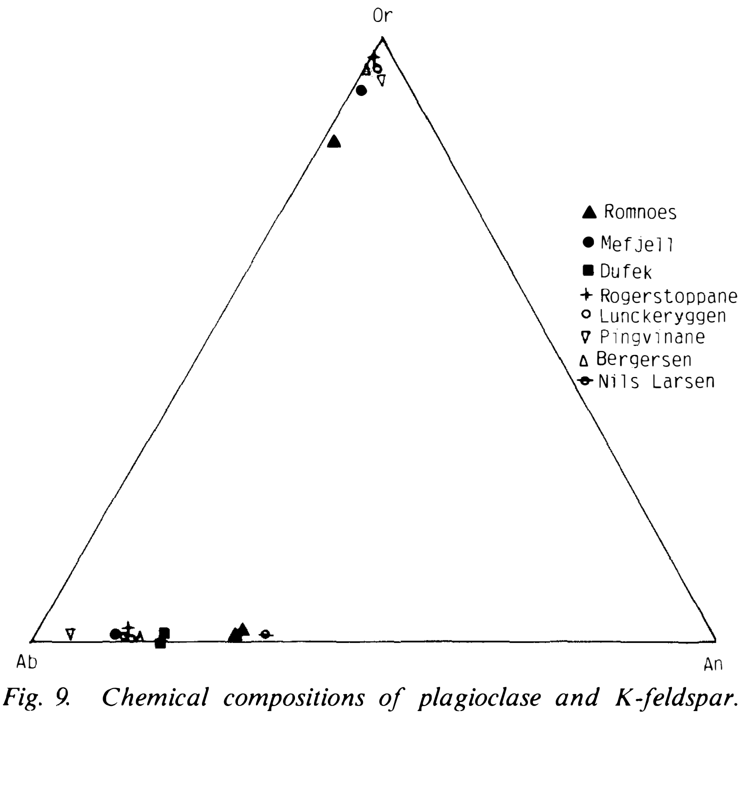

Fig. 9. Chemical compositions of plagioclase and K-feldspar.

Table 2. Chemical compositions of K-feldspars.

	Romnoes	Mefjell	Luncke-ryggen	Rogers-toppane	Pingvinane	Bergersen
SiO_2	64.44	64.38	63.30	62.61	63.60	61.97
TiO_2	0.04	0.00	0.34	0.33	0.34	0.13
Al_2O_3	18.92	18.43	19.11	18.98	19.11	18.47
Cr_2O_3	0.02	0.01	0.00	0.00	0.00	0.00
FeO	0.02	0.01	0.26	0.32	0.26	0.17
MnO	0.00	0.00	0.22	0.18	0.22	0.13
NiO	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.02	0.00	0.00
CaO	0.07	0.02	0.13	0.07	0.13	0.13
Na_2O	1.70	0.88	0.56	0.34	0.56	0.30
K_2O	13.93	14.98	15.03	15.06	15.03	15.09
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.14	98.71	98.95	97.91	99.25	96.39
Si	2.98	3.00	2.95	2.95	2.95	2.97
Ti	0.00	0.00	0.01	0.01	0.01	0.01
Al	1.03	1.01	1.05	1.06	1.05	1.04
Cr	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.00	0.00	0.01	0.01	0.01	0.01
Mn	0.00	0.00	0.01	0.01	0.01	0.01
Ni	0.00	0.00	0.00	0.00	0.00	0.00
Mg	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.00	0.00	0.01	0.01	0.01	0.01
Na	0.15	0.08	0.05	0.03	0.05	0.03
K	0.82	0.89	0.89	0.91	0.89	0.92
P	0.00	0.00	0.00	0.00	0.00	0.00

Cations per 8 oxygens.

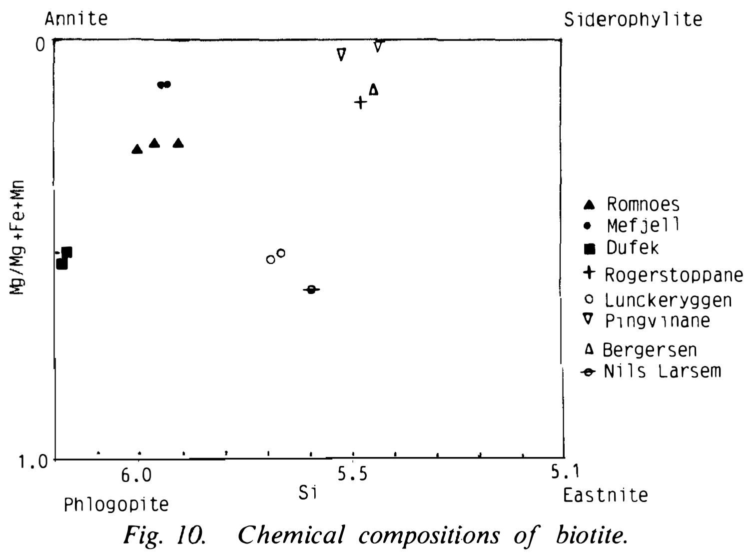

Fig. 10. Chemical compositions of biotite.

Table 3. Chemical compositions of biotites.

	Romnoes	Mefjell	Dufek	Luncke-ryggen	Rogers-toppane	Ping-vinane	Nils Larsen	Berger-sen
SiO_2	35.29	33.73	37.89	37.55	33.67	32.66	37.14	33.85
TiO_2	4.50	4.36	1.69	2.09	1.88	1.70	2.42	3.90
Al_2O_3	13.43	13.18	14.91	15.31	17.63	15.85	15.69	15.46
Cr_2O_3	0.00	0.01	0.00	0.17	0.00	0.15	0.20	0.14
FeO	28.24	33.15	18.38	18.46	29.61	36.36	16.83	30.32
MnO	0.11	0.22	0.49	0.80	0.50	0.46	0.27	0.57
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	5.35	2.04	11.40	11.67	2.45	0.08	13.41	2.43
CaO	0.03	0.09	0.00	0.13	0.10	0.12	0.01	0.16
Na_2O	0.07	0.00	0.00	0.00	0.00	6.00	0.00	0.00
K_2O	9.16	8.64	9.77	9.42	8.82	7.96	9.25	8.58
P_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	96.18	95.41	94.53	95.59	94.75	95.34	96.09	95.40
Si	5.60	5.55	5.80	5.69	5.45	5.44	5.59	5.47
Ti	0.54	0.54	0.19	0.24	0.01	0.21	0.27	0.47
Al	2.51	2.55	2.70	2.74	3.36	3.11	2.78	2.94
Cr	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.02
Fe	3.75	4.56	2.36	2.34	4.01	5.06	2.12	4.10
Mn	0.02	0.03	0.06	0.10	0.07	0.06	0.04	0.08
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	1.27	0.50	2.60	2.64	0.59	0.02	3.01	0.59
Ca	0.01	0.02	0.00	0.02	0.02	0.02	0.00	0.03
Na	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	1.85	1.82	1.91	1.82	1.82	1.69	1.78	1.77
P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cations per 22 oxygens.

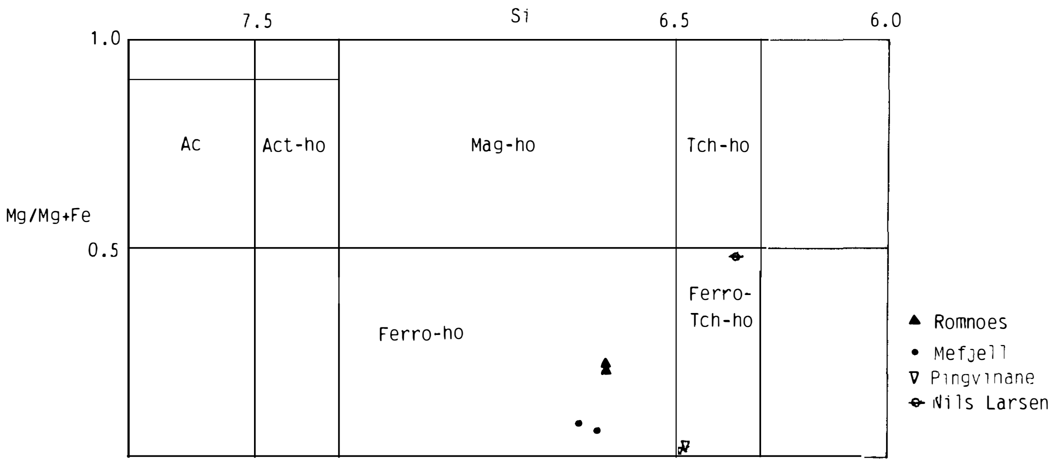

Fig. 11. Chemical compositions of hornblende.

Table 4. Chemical compositions of hornblendes.

	Romnoes	Mefjell	Pingvinane	Nils Larsen
SiO_2	40.46	39.95	38.34	41.24
TiO_2	1.62	0.39	1.37	0.66
Al_2O_3	10.50	10.56	9.19	11.88
Cr_2O_3	0.00	0.00	0.00	0.00
FeO	27.63	31.27	33.27	18.46
MnO	0.30	0.59	0.85	0.57
NiO	0.00	0.00	0.00	0.00
MgO	4.03	1.71	0.04	9.56
CaO	10.68	10.68	10.23	12.15
Na_2O	1.87	1.90	0.58	1.18
K_2O	1.44	1.35	1.36	0.38
P_2O_5	0.00	0.00	0.00	0.00
Total	98.53	98.40	95.23	96.08
Si	6.68	6.73	6.49	6.94
Ti	0.20	0.05	0.18	0.09
Al	2.04	2.10	1.83	2.36
Cr	0.00	0.00	0.00	0.00
Fe	3.81	4.40	4.71	2.60
Mn	0.04	0.08	0.12	0.09
Ni	0.00	0.00	0.00	0.00
Mg	0.99	0.43	0.01	2.40
Ca	1.89	1.93	1.85	2.19
Na	0.60	0.62	0.19	0.38
K	0.30	0.29	0.29	0.08
P	0.00	0.00	0.00	0.00

Cations per 23 oxygens.

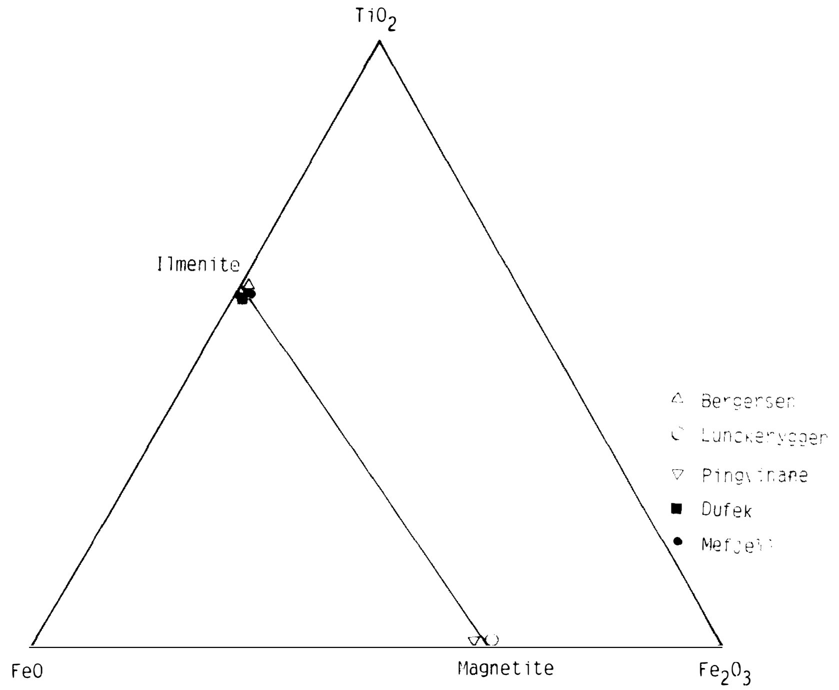

Fig. 12. Chemical compositions of opaque minerals.

Table 5. Chemical compositions of opaque minerals.

	Mefjell	Dufek	Luncke-ryggen	Pingvinane	Bergersen
SiO_2	0.00	0.00	0.04	0.05	0.04
TiO_2	52.66	53.20	0.23	0.24	53.38
Al_2O_3	0.01	0.02	0.00	0.00	0.01
Cr_2O_3	0.01	0.00	0.00	0.00	0.00
FeO	46.75	46.22	95.83	94.89	41.91
MnO	2.01	2.37	0.32	0.37	7.17
NiO	0.00	0.00	0.00	0.00	0.00
MgO	0.02	0.00	0.00	0.00	0.02
CaO	0.03	0.01	0.17	0.10	0.12
Na_2O	0.04	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.05	0.05	0.07
P_2O_5	0.00	0.00	0.00	0.00	0.00
Total	101.53	101.82	96.64	95.70	102.72
Si	0.00	0.00	0.00	0.01	0.01
Ti	7.91	7.95	0.02	0.02	7.92
Al	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00
Fe	7.81	7.68	7.91	7.91	6.91
Mn	0.34	0.40	0.03	0.03	0.20
Ni	0.00	0.00	0.00	0.00	0.00
Mg	0.01	0.00	0.00	0.00	0.00
Ca	0.01	0.00	0.02	0.01	0.01
Na	0.01	0.00	0.00	0.00	0.00
K	0.00	0.00	0.01	0.01	0.00
P	0.00	0.00	0.00	0.00	0.00

Cations per 24 oxygens for ilmenite and 8 oxygens for magnetite.

components and poor in pyrope component (Table 6). This garnet is not markedly zoned.

Clinopyroxene as well as the other ferromagnesian minerals in the Mefjell Quartz monzonite is rich in FeO and poor in MgO and Al_2O_3 (Table 6). The clinopyroxenes are salite in classification.

Sphene in the Dufek Granite is low in FeO (Table 6).

6. Chemical Differences Between the Late Proterozoic Tonalite and the Early Paleozoic Granitic Rocks

The Early Paleozoic granitic rocks are characterized by high alkalis, Ba, Rb and Y and low MgO and Ni. In contrast, the Late Proterozoic tonalite has distinctively high Ni and CaO and low Rb, NH_4, alkalis (Table 7, Figs. 5-8) and Sr-isotope initial ratio of 0.70237 (TAKAHASHI *et al.*, 1990; TAINOSHO *et al.*, 1992a). On the basis of trace elements, the Late Proterozoic tonalite can be regarded as an M-type granite, and many of the Early Paleozoic granitic rocks belong to A-type granite (TAINOSHO *et al.*, 1992a). The Late Proterozoic tonalite has high hornblende modal content,

Table 6. Chemical compositions of sphene (O = 24), clinopyroxene (O = 6) and garnet (O = 12).

	Dufek (Sphene)	Mefjell (Cpx)	Rogerstoppane (Gamet)
SiO_2	30.53	49.58	36.72
TiO_2	35.85	0.05	0.13
Al_2O_3	2.90	0.43	21.49
Cr_2O_3	0.00	0.00	0.00
FeO	1.88	24.57	23.06
MnO	0.08	1.11	10.34
NiO	0.00	0.00	0.00
MgO	0.04	3.31	9.32
CaO	28.11	20.76	0.00
Na_2O	0.00	0.33	0.00
K_2O	0.00	0.04	0.05
P_2O_5	0.00	0.00	0.00
Total	99.39	100.18	101.11
Si	4.83	2.00	2.94
Ti	4.26	0.00	0.01
Al	0.54	0.02	2.31
Cr	0.00	0.00	0.00
Fe	0.25	0.83	1.55
Mn	0.01	0.04	0.70
Ni	0.00	0.00	0.00
Mg	0.01	0.20	0.80
Ca	4.75	0.90	0.00
Na	0.00	0.03	0.00
K	0.00	0.00	0.01
P	0.00	0.00	0.00

and Mg/(Mg+Fe) ratios of mafic minerals are higher than those of the Early Paleozoic granitic rocks. Chemical composition of the Late Proterozoic tonalite is clearly different from those of the Early Paleozoic granitic rocks. These chemical features and isotopic data suggest that the Late Proterozoic tonalite and Early Paleozoic granitic rocks are different parent magmas which represent the different $^{87}Sr/^{86}Sr$ ratio.

7. Chemical Differences Between the Concordant Granites and the Discordant Granites in the Early Paleozoic Granitic Rocks

The discordant granites in the Early Paleozoic granitic rocks are chemically characterized by having high Sr and Ba contents and low Y (Figs. 6, 7 and 8). The concordant granites are high in Y and Nb and low in Cr (Figs. 7 and 8). Thus, chemical compositions of the discordant granites are different from those of the concordant granites. The concordant granites are classified as within plate granite except for the Mefjell Quartz monzonite, while the discordant granites belong to volcanic arc granite. This result suggests that the tectonic settings are different for the two types of granite.

Table 7. Selective chemical compositions of the granitic rocks and NH_4

Locality No.	Nils Larsen B900 11902C	Nils Larsen B900 11903A	Aust-kampane B900 11107D	Aust-kampane B900 11206A	Ping-vinane B900 11305D	Ping-vinane B900 11405B	Viking-høgda B900 11702
SiO_2	59.33	56.98	72.48	68.23	68.23	67.00	79.38
TiO_2	0.53	0.64	0.14	0.27	0.58	0.37	0.09
AL_2O_3	18.04	18.26	13.28	13.64	14.24	14.75	11.18
Fe_2O_3	2.63	3.24	0.61	0.57	1.25	1.56	0.75
FeO	3.03	3.40	1.09	2.02	3.50	3.45	0.52
MnO	0.10	0.09	0.03	0.04	0.05	0.09	0.01
MgO	2.99	3.40	0.06	1.15	0.28	2.12	0.15
CaO	6.97	7.89	1.25	5.06	1.88	2.49	0.73
Na_2O	4.70	4.19	3.52	2.36	3.41	3.74	3.60
K_2O	1.23	0.34	5.05	5.77	5.91	4.16	3.21
P_2O_5	0.21	0.15	0.01	0.06	0.12	0.12	<0.01
BaO	0.01	0.01	0.02	0.08	0.23	0.17	0.02
LOI	1.32	0.77	0.89	1.35	0.57	1.08	0.49
Total	101.09	99.36	98.43	100.60	100.25	101.10	100.14
ppm							
Ag	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ba	190	130	190	730	2100	1616	260
Be	<0.5	<0.5	3.0	1.5	<0.5	<0.5	1.0
Bi	<2	<2	<2	<2	<2	<2	<2
Cd	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co	20	24	1	20	1	18	21
Cr	27	49	3	12	5	58	3
Cu	14	16	2	20	3	7	12
Mo	<1	<1	<1	<1	2	<1	<1
Ni	20	23	<1	6	<1	10	<1
Pb	18	<2	76	24	32	28	16
Sr	973	649	73	531	273	272	49
V	88	127	<1	22	2	36	<1
W	160	160	<10	250	<10	180	260
Zn	78	64	64	34	150	154	26
F	1490	360	4380	190	890	1320	160
Rb	34	3	350	230	120	96	101
Ga	18	18	24	14	24	19	18
Hf	10	2	6	<2	4	6	6
Nb	10	not/ss	3216	13	24	21	15
Y	14	not/ss	140	54	55	30	68
Zr	100	not/ss	155	52	540	250	110
Al	7.46	9.57	6.68	7.37	7.26	7.60	5.52
1000Ga/Al	1.9	1.9	3.6	1.9	3.3	2.5	3.0
Y/Nb	1.4	—	4.4	4.2	2.3	1.4	4.5
NH_4	30	10	80	71	81	22	12

LOI : ignition loss, not/ss : the value is less than the lower limit of detection.

content of biotites in the Sør Rondane Mountains (TAINOSHO *et al., 1992b*).

Viking-høgda B900 11703A	Luncke-ryggen B900 11902A	Luncke-ryggen B900-11902B	Dufek B900 12305A	Dufek B900 12305B	Rogers-toppane B900 12310A	Rogers-toppane B900 12310C	Mefjell B900 12502	Mefjell B900 12503
77.15	71.63	62.70	71.93	71.90	70.43	73.31	57.63	56.16
0.06	0.44	0.43	0.23	0.42	0.16	0.09	0.82	1.05
13.17	14.04	19.48	14.98	14.30	13.79	13.87	18.24	17.14
1.01	1.11	1.71	1.06	1.58	0.84	0.75	1.87	2.19
0.51	1.37	0.80	0.78	0.86	1.47	0.99	4.61	5.91
0.01	0.03	0.02	0.02	0.03	0.04	0.03	0.12	0.15
0.12	0.92	0.35	0.38	0.66	0.26	0.18	0.41	0.54
0.91	2.20	2.16	1.82	1.88	1.26	1.13	3.51	3.78
4.91	4.05	5.20	4.78	4.12	4.54	4.68	4.71	4.29
2.88	3.85	6.22	4.01	4.31	3.58	3.59	5.69	5.62
<0.01	0.31	0.02	0.12	0.17	0.03	0.01	0.23	0.31
0.01	0.08	0.25	0 13	0.15	0.05	0.04	0.36	0.34
0.59	0.73	0.65	0.39	0.62	1.77	1.44	1.09	0.54
101.34	100.76	99.99	100.69	101.00	98.22	100.11	99.29	98.02

<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
140	820	2140	1210	1390	540	410	3210	3130
2.5	7.0	4.0	3.0	2.0	3.0	2.5	<0.5	<0.5
<2	<2	<2	<2	<2	<2	<2	<2	<2
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
27	11	10	13	2	12	15	1	1
3	14	6	2	7	5	3	3	2
7	1	2	1	4	2	1	6	7
<1	<1	<1	<1	<1	<1	<1	<1	<1
1	8	2	1	3	1	<1	<1	<1
28	36	60	32	32	16	14	4	4
41	640	2130	1020	884	62	44	289	168
<1	20	34	10	15	4	<1	<1	<1
400	130	100	150	>10	170	180	<10	10
20	56	38	30	48	90	98	74	98
430	1900	850	410	880	1530	900	250	300
90	150	165	97	120	130	86	44	58
22	19	21	19	18	23	25	20	20
16	10	2	4	10	8	10	8	8
not/ss	13	15	12	20	43	52	11	14
not/ss	21	31	13	27	90	110	13	17
not/ss	265	465	125	285	150	125	395	825
6.86	7.20	10.10	7.58	7.38	7.20	7.04	9.15	8.78
3.2	2.6	7.08	2.5	2.4	3.2	3.6	2.2	2.3
—	1.6	2.1	1.1	1.4	2.09	2.10	1.2	1.8
23	41		66	49	107	76	36	45

The Dufek and Lunckeryggen Granites, which are classified as discordant granite, have low initial $^{87}Sr/^{86}Sr$ ratios (Dufek Granite, 0.70372; Lunckeryggen Granite, 0.70504) (TAKAHASHI *et al.*, 1990; TAINOSHO *et al.*, 1992a). On the contrary, the Mefjell Quartz monzonite, which is a concordant granite with a clear boundary with the gneiss, shows higher values in initial $^{87}Sr/^{86}Sr$ ratios (0.70563) than those of the discordant granites (TAINOSHO *et al.*, 1992a). The Pingvinane Granite is a concordant granite with an unclear boundary and has two groups of initial $^{87}Sr/^{86}Sr$ ratio, one shows 0.70345-0.70354 and the other shows 0.70658-0.70680 (TAKAHASHI *et al.*, 1990). As mentioned above, the difference in initial $^{87}Sr/^{86}Sr$ ratios of the granitic rocks seems to correlate with field occurrence, that is, the concordant granites have slightly high initial $^{87}Sr/^{86}Sr$ ratios compared with those of the discordant granites.

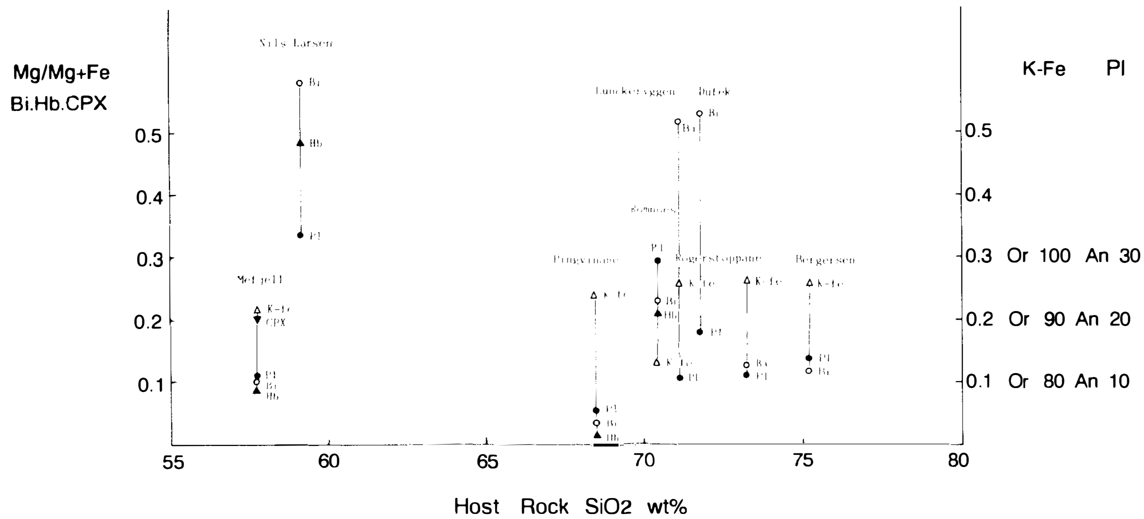

Fig. 13. Plot of SiO_2 wt% of the host rocks versus Mg/(Mg+Fe) ratios, anorthite content and orthoclase content of the minerals. Pl : plagioclase, K-fe : K-feldspar, Bi : biotite, Hb : hornblende, CPX : clinopyroxene

The chemical compositions of the minerals in the Early Paleozoic granitic rocks are variable. On a plot of SiO_2 wt% of the host rocks *versus* Mg/(Mg+Fe) ratios, anorthite and orthoclase contents of minerals (Fig. 13), no consistent variation trend is found. Ferromagnesian minerals of the concordant granites are rich in Fe and have Mg/(Mg+Fe) values similar to those of the host rocks. This chemical character is a feature recognized commonly in A-type granite (WHALEN *et al.*, 1987). Ferromagnesian minerals of the discordant granites have intermediate Mg/(Mg+Fe) values. K-feldspars from the granitic rocks except for the Romnoes Granite have similar orthoclase contents. Plagioclases in the concordant granites are low in anorthite content, but those in the discordant granites except for the Lunckeryggen Granite have slightly higher anorthite content than those of the concordant granites (Fig. 13). Thus, the granitic rocks have their own characteristics in mineral chemistry. However, there are chemical differences, comparing minerals in granitic rocks from two granite types. The difference in mineral chemistry seems to correlate with their whole rock chemistry. These differences of chemical features suggest that physico-chemical conditions of the above two granite types are clearly different.

These relationships between the whole rock and mineral chemistry, isotopic data and the field occurrences may suggest that these two granite types are derived from different parent magma or the concordant granites were formed by mixing between the granitic magma and the surrounding metamorphic rocks.

8. Concluding Remarks

The Early Paleozoic granitic rocks, which are classified on the basis of the field occurrence and petrography, are chemically examined.

1) The concordant granites have generally similar compositions. For example, the concordant granites are chemically characterized by high Nb and Y and low Cr. On the contrary, the discordant granites are high in Sr and Ba and low in Y.

2) Mineral compositions in the granitic rocks are also related to the two granite types. Ferromagnesian minerals in the concordant granites are poor in Mg/(Mg+Fe), while ferromagnesian minerals of the discordant granites have intermediate composition in Mg/(Mg+Fe). Plagioclases in the concordant granites are rich in albite components, while those in the discordant granites have slightly higher anorthite contents than those of the concordant granites.

3) Chemical compositions of the concordant granites are clearly different from those of the discordant granites. These chemical features may suggest that these granitic rocks derived from different parent magmas or the concordant granites were formed by mixing between the granitic magma and the surrounding metamorphic rocks.

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