NATIONAL INSTITUTE OF POLAR RESEARCH

ANTARCTIC GEOLOGICAL MAP SERIES
SHEET 32 WIDERØEFJELLET

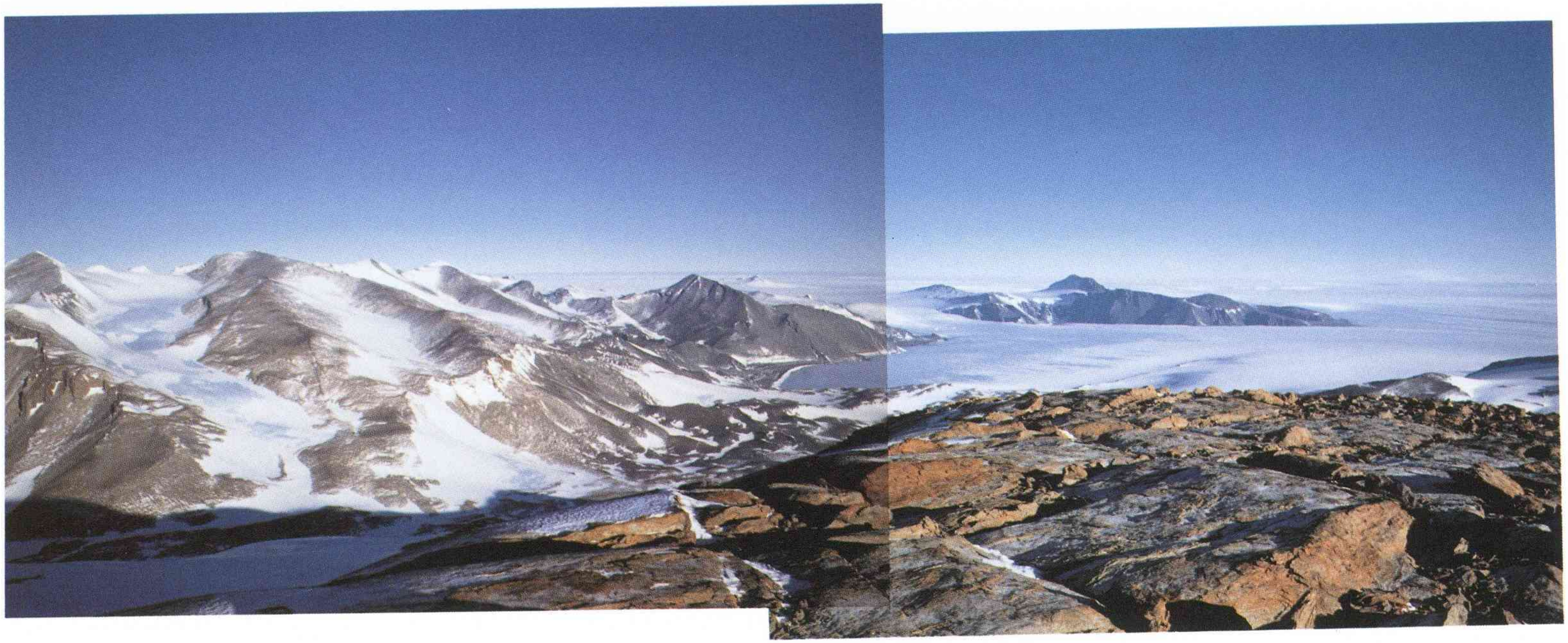
Explanatory Text of Geological Map of Widerøefjellet, Sør Rondane Mountains, Antarctica

Kazuyuki SHIRAISHI, Yasuhito OSANAI, Yoshiaki TAINOSHO,
Yuhei TAKAHASHI, Noriyoshi TSUCHIYA, Satoru KOJIMA,
Keizo YANAI and Kiichi MORIWAKI

NATIONAL INSTITUTE OF POLAR RESEARCH
TOKYO, MARCH 1992

National Institute of Polar Research
9-10, Kaga 1-chome, Itabashi-ku
Tokyo 173, Japan

Plate 1



Main massif of Widerøefjellet and Nils Larsenfjellet (far right back), viewed from the summit of Vikinghøgda (2751 m). The peak in the left-end is the highest peak (2996 m) in the Sør Rondane Mountains (photograph taken on September 15, 1990).

Explanatory Text of Geological Map of Widerøefjellet, Sør Rondane Mountains, Antarctica

Kazuyuki SHIRAISHI[1)], Yasuhito OSANAI[2)], Yoshiaki TAINOSHO[3)], Yuhei TAKAHASHI[4)], Noriyoshi TSUCHIYA[5)], Satoru KOJIMA[6)], Keizo YANAI[1)] and Kiichi MORIWAKI[1)]

1. Introduction

The Sør Rondane Mountains, located between 22°E to 28°E and 71.5°S to 72.5°S, form one of the largest mountains in East Antarctica. Geological and glaciological surveys of these mountains had been performed by Belgian parties during 1958 to 1970. Based on the result of these investigations a geological map (1:500000 in scale) was published (VAN AUTENBOER, 1969). The Widerøefjellet region, the western part of the Sør Rondane Mountains, was partly surveyed by Belgian geologists in 1958-1960. Following the reconnaissance survey by the 25th Japanese Antarctic Research Expedition (JARE-25, 1983-1984), the JARE-26 (1984-1985), 29 (1987-1989), 30 (1988-1989) and 31 (1989-1991) groups conducted field surveys of the Widerøefjellet region (MEMBERS OF THE SØR RONDANE RECONNAISSANCE PARTY, 1985; MORIWAKI *et al.*, 1986, 1989; OSANAI *et al.*, 1990; SHIRAISHI, 1992). Among them the JARE-26 group widely surveyed the northern lowland of the region on basement geology, geodesy and geomorphology, whereas the JARE-31 group carried out geological survey mainly in the southern highland and isolated nunataks with helicopters. The JARE-30 group mainly conducted geomorphological and paleomagnetic works in the same region as JARE-26. The wintering parties at Asuka Station in JARE-29 and 31 performed supplementary geological survey in the Widerøefjellet region.

The mapped area is situated in the western part of the Sør Rondane Mountains and

---

1) National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173.
2) Department of Earth Sciences and Astronomy, Fukuoka University of Education, 729, Akama, Munakata, Fukuoka 811-41.
3) Department of Geology, Faculty of Education, Kobe University, Nada-ku, Kobe 657.
4) Geological Survey of Japan, 1-3, Higashi 1-chome, Tsukuba 305.
5) Department of Resources Engineering, Faculty of Engineering, Tohoku University, Aramaki, Aoba-ku, Sendai 980.
6) Department of Earth Sciences, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-01.

bounded by Gillockbreen* on the east, and by the eastern part of Bamsefjell on the west. The elevation at the northern foot of the mountains is about 1000 m above sea level, whereas that of the plateau to the south is almost 3000 m (Plate 1).

2. General Geology

2.1. Geomorphology

The Sør Rondane Mountains form barriers (up to almost 3000 m above sea level) damming the flow of inland ice. In the mapped area, outlet glaciers (H.E. Hansenbreen, Gunnestadbreen and Gillockbreen) have been deeply excavated the mountains, and the deepest bottoms of them are inferred to reach almost present sea level (VAN AUTENBOER and BLAIKLOCK, 1967). A large part of the mountains was once covered by an expanded ice sheet (VAN AUTENBOER, 1964; IWATA, 1987; HIRAKAWA *et al.*, 1988; HAYASHI and MIURA, 1989; ANIYA, 1989; HIRAKAWA and MORIWAKI, 1990). The mountains are in many places covered with tills showing various degree of weathering. Relative ages of these tills were classified into five stages of weathering, and they were correlated from the mid-Pliocene to the latest Pleistocene based on cosmogenic-radiometric ages of exposed bedrocks (NISHIIZUMI *et al.*, 1991; MORIWAKI *et al.*, 1991).

The old tills exposed since the Pliocene are located on flat-topped mountains, with a maximum height above the present ice surface of 600 m, and on the floors of ice-free valleys. Some of the tills attain several tens of metres in thickness (maximum thickness is over 100 m at Nils Larsenfjellet). These thick tills were probably produced and transported by temperate ice prior to or during the Pliocene, as suggested for thick tills in the Beardmore Glacier region by MERCER (1972). Most of these old tills form basal till moraine fields, but some constitute lateral moraines suggesting either stagnation or re-advance of the ice sheet. The surfaces of the oldest tills form reddish desert pavements in most places.

Although the top surfaces of the thick tills are flat, they terminate abruptly in steep scarps on the top of glacial valley walls within the mountains. Such a situation suggests these tills were deposited on an extensive and gently sloping surface into which later glaciation has incised glacial valleys, so producing several separate mountain blocks. On the other hand, the old tills in an ice-free valley between Widerøefjellet and Vikinghøgda (Plate 1) suggest that the valley has been ice-free since perhaps the latest Pliocene, in spite of its low elevation.

---

* Place names used in this paper are after the topographic map "Sør-Rondane"(1:250000) published by Norsk Polarinstitutt (1957). In this usage, suffixes "fjell, fjella or fjellet" and "breen" mean "mountain" and "glacier" in Norwegian, respectively.

Young tills aged from middle to the latest Pleistocene form lateral moraines of small volume on some mountain flanks and formerly glaciated valley walls at up to 100 m above the present ice surface, and rather vast but thin supraglacial moraine fields around the mountain blocks. The former records either stagnation or even a re-advance of the ice sheet. Their small volume suggests they reflect a change to colder ice in the middle or early Pleistocene. The latter suggests that relatively stable ice sheet since the latest Pleistocene.

The distribution and characteristics of tills, cosmogenic age data, and glacial landforms lead following glacial history of the western part of the Sør Rondane Mountains (MORIWAKI and HIRAKAWA, 1992; MORIWAKI *et al.*, in press):

Miocene to Early Pliocene: The former gentle-sloped Sør Rondane Mountains were covered by a temperate ice sheet. The ice sheet produced, transported and deposited a large quantity of the old tills.

Middle to late Pliocene: Deglaciation took place and the old tills were exposed. The lower ice surface caused several temperate outlet glaciers to be channelled between the higher parts of the mountains, and eroded deeply the valley systems, dividing the mountains into separate blocks. The ice surface fell to lower than that of the present time, judging from the altitude of the Viking Valley till.

Pleistocene to Holocene: The ice sheet re-advanced after the beginning of Pleistocene, was probably a cold polar one, as it poorly glaciated the mountains and formed only small lateral moraines of the young tills on valley walls at about 100 m higher than the present ice surface. After this re-advance the surface of the ice sheet has been steadily falling with only minor fluctuations, leaving small lateral moraines and thin moraine fields surrounding the mountains at heights of less than 10 m above the present ice surface.

2.2. *Basement geology*

The Sør Rondane Mountains consists mainly of Proterozoic high- and medium-grade metamorphic rocks and various plutonic rocks (KOJIMA and SHIRAISHI, 1986; ISHIZUKA and KOJIMA, 1987; SAKIYAMA *et al.*, 1988; SHIRAISHI *et al.*, 1991, TAINOSHO *et al.*, 1991). The metamorphic rocks show evidence of 1000 - 1100 Ma granulite facies metamorphism (SHIRAISHI and KAGAMI, 1991; GREW *et al.*, 1992) in the northern and eastern parts and were intruded by 950 Ma and *ca.* 500 Ma plutonic rocks (TAKAHASHI *et al.*, 1990, 1991). Outcrops in the Widerøefjellet region are represented by various kinds of metamorphic and plutonic rocks, and minor dykes. Intermediate gneiss which possibly represents mixtures of metasedimentary and metavolcanic rocks, and pelitic to psammitic gneisses are dominant among the metamorphic rocks; thin layers and lenses of calcareous and basic rocks also occur in many places.

Plutonic rocks which range from granite to diorite are sporadically distributed as masses and stocks of km size. Slightly metamorphosed dolerite dykes which strike NNW-SSE are found in many places throughout the area.

Foliation of the gneisses generally strikes E-W and dips monoclinally to the south. The most remarkable major structural feature in the mapped area is a pronounced E-W trending shear zone which was referred to as the Main Shear Zone (MSZ) (Plates 2c, 4b; KOJIMA and SHIRAISHI, 1986). Another E-W trending narrow shear zone which traverses the mapped area is inferred at the southern highland. Between the two shear zones, where metatonalite predominantly distributes, shear fracture and mylonitization extensively develop. Thus, as a whole, the area forms a wide shear "belt" more than 15 km in width. Its eastern end is cut by syenite and granite plutons in the central part of the mountains, and its western end is obscured by ice.

VAN AUTENBOER (1969) and VAN AUTENBOER and LOY (1972) made distinction between the gneisses forming the northern ridges and those forming the southern massifs into two units: the Teltet-Vengen group in the north, which consists of gneisses of various compositions and the Nils Larsenfjellet group in the south, which comprises "tonalitic to dioritic biotite-hornblende-(chlorite-epidote) gneisses" associated with basic schist and minor amount of psammitic and calcareous schists. Their boundary is close to the MSZ, but the definition of both "groups" has not been clear; *viz.* structural division or lithological contrasts between both groups. The metasedimentary rocks in the Nils Larsenfjellet group have similar rock associations with those of the Teltet-Vengen group. Recent work at the eastern extension of the MSZ at Jenningsbreen in the central part of the mountains (T. TOYOSHIMA, M. OWADA and K. SHIRAISHI, unpublished data) revealed that MSZ does not cause a significant lithostratigraphic break but just a northern limit of the wide mylonitized belt. Lithological boundary between metasedimentary rocks and metatonalite trend slightly oblique to the trend of the mylonite belt.

Because of the ambiguity, we abandon the terms of the Teltet-Vengen and Nils Larsenfjellet groups, instead, we divided the region into two units in the present geological map with respect to the metamorphic grade; the granulite facies Northeastern Terrane and the amphibolite-facies and lower grade Southwestern Terrane. The boundary between the two terranes is inferred to be a large shear zone on the basis of the observation in the central part of the Sør Rondane Mountains. It is called the Sør Rondane Suture (SRS) by OSANAI *et al.* (1991).

3. Metamorphic Rocks

Metamorphic rocks are classified into the following rock types for mapping units, based on the mode of occurrence and lithologic facies:

1) garnet-orthopyroxene-hornblende-plagioclase-quartz,
2) orthopyroxene-clinopyroxene-biotite-hornblende-plagioclase-quartz.
In the Southwestern Terrane:
3) garnet-hornblende-biotite-plagioclase-quartz,
4) hornblende-biotite-K-feldspar-plagioclase-quartz,
5) hornblende-epidote-plagioclase(An_{18-30})-quartz.

Orthopyroxene-bearing hornblende gneiss is found from a xenolith in a granite mass in Tanngarden. Secondary epidote and chlorite are commonly found. In some cases, it is ambiguous under the microscope whether epidote is of primary or of secondary origin.

Detailed petrography and electron microprobe studies of the biotite-hornblende gneisses and amphibolites are given by SHIRAISHI and KOJIMA (1987).

3.3. Amphibolites

Pyroxene amphibolite with or without orthopyroxene is recognized as a dark coloured band of 0.1 to 1.0 m wide, interbedded within garnet-biotite gneiss and biotite-hornblende gneiss at Perlebandet, Vesthaugen and Tanngarden. Typical mineral assemblages are as follows:

1) orthopyroxene-clinopyroxene-hornblende-biotite-plagioclase-quartz,
2) orthopyroxene-clinopyroxene-cummingtonite-hornblende-plagioclase-quartz,
3) clinopyroxene-biotite-hornblende-plagioclase.

Biotite amphibolite is common in the Southwestern Terrane (Plate 7c). Typical mineral assemblages are:

4) garnet-biotite-hornblende-plagioclase-quartz,
5) epidote-biotite-hornblende-plagioclase-quartz.

Dark coloured bands a few tens to a hundred metres wide, in which amphibolite alternates with biotite-hornblende gneiss, are present throughout the two terranes.

3.4. Marble and skarn

The term skarn is used in this explanatory text for several kinds of rock associations, such as hornblende pyroxenite, garnet-hornblende pyroxenite, pyroxene-biotite amphibolite and calc-silicate rocks.

All these rocks are closely associated with marble. The marble and skarn beds form zones up to a hundred metres wide in Perlebandet and Vengen ridge. They generally occur as thin beds up to 5 m wide and as small lenses a few tens of cm long in biotite gneisses and hornblende gneisses (Plate 2a). In Bamsefjell and Røysane, thin elongated blocks and lenses of 0.3-1.0 m wide are common. Constituent minerals of the skarns from Perlebandet in the Northeastern Terrane are (Plate 6):

1) olivine-spinel-humite-phlogopite-pargasite-dolomite--rutile,

Table 1. Chemical analyses of metamorphic rocks from the Widerøefjellet region.

Sp. No.	1	2	3	4	5	6	7	8	9	10
wt%										
SiO2	40.53	47.97	44.63	51.94	51.46	8.89	43.36	59.71	43.68	65.72
TiO2	3.95	0.72	0.69	0.43	0.84	0.1	1.86	1.08	0.48	0.37
Al2O3	16.76	19.45	15.22	9.54	15.38	1.57	17.68	15.87	21.28	14.44
Fe2O3	3.16	5.58	6.2	1.43	6.78	0.23	7.46	3.49	6.5	1.8
FeO	12.87	9.30	11.81	2.47	13.26	1.33	1.74	4.15	7.04	5.11
MnO	0.28	0.28	0.7	0.1	0.41	0.05	0.23	0.15	0.2	0.12
MgO	5.84	4.31	6.29	13.55	6.95	16.26	1.89	2.7	6.24	2.54
CaO	5.92	11.54	10.25	17.45	1.13	37.01	21.32	5.66	13.58	6.78
Na2O	2.49	0.04	1.06	0.37	0.15	0.07	3.75	---	0.21	2.45
K2O	6.22	0.06	1.95	3.28	0.05	0.4	3.17	---	0.06	0.6
P2O5	1.98	0.24	0.04	0.08	0.14	0.02	0.75	0.27	0.03	0.07
CO2	----	<0.5	4.07	----	<0.2	34.34	3.24	<0.2	0.7	<0.2
Total*	100	100	100	100	100	100	100	100	100	100
Trace element in ppm										
Ba	----	<0.5	20	580	760	70	120	740	60	140
Co	----	88	----	12	----	----	----	----	----	----
Cr	----	30	20	82	32	21	22	20	12	28
Cu	----	130	----	1	----	----	----	----	----	----
Ni	----	<2	13	29	14	6	9	8	4	8
Pb	----	3	----	12	----	----	----	----	----	----
Sr	----	----	110	148	10	540	610	270	166	128
V	----	50	730	36	360	20	310	150	430	170
Zn	----	25	133	172	144	73	145	94	75	66
F	----	16	90	1280	1100	2050	770	740	80	150
Rb	----	201	1	105	19	3	15	130	3	18
Hf	----	<1	<1	4	<2	<1	3	4	<1	----
Nb	----	28	----	13	----	----	----	----	----	<5
Y	----	136	6	30	81	9	150	61	<5	9
Zr	----	----	12	91	36	43	110	225	16	37

*Total normalized to 100 Analyst: Chemex Lab.

Sp. No.		
1	85020954B	Biotite amphibolite (Vesthaugen)
2	A90011607D2	Garnet amphibolite (Caussinknappen)
3	85012203T	Epidote-chlorite schist (metatonalite) (Walnumfjella)
4	A90011301A	Biotite-bearing hornblende metatonalite (Verheyefjellet)
5	85012152B	Garnet-biotite gneiss (Teltet)
6	85012164B	Calcite-phlogopite-humite-dolomite marble (Vengen)
7	85012252B	Epidote-dolomite-calcite calc-silicate rock (Vikinghøgda)
8	85012555B	Mylonitic biotite gneiss (Vikinghøgda)
9	85020456B	Epidote-chlorite schist (Greenschist) (Widerøefjellet)
10	85020454A	Hornblende gneiss (Widerøefjellet)

Table 1. (continued)

Sp. No.	11	12	13	14	15	16	17	18	19
wt%									
SiO2	63.88	52.9	63.97	58.58	69.50	68.10	64.99	66.45	65.24
TiO2	0.45	0.83	1.31	0.5	1.00	0.49	0.73	0.54	0.47
Al2O3	15.69	16.39	14.15	17.1	15.30	15.33	12.23	14.38	14.02
Fe2O3	2.46	4.27	1.95	3.31	1.58	2.93	1.94	1.19	1.83
FeO	4.89	6.18	5.45	6.46	4.43	3.20	10.78	3.93	4.59
MnO	0.13	0.29	0.11	0.18	0.09	0.08	0.23	0.14	0.15
MgO	2.13	6.39	1.08	2.85	2.26	2.36	3.82	3.77	3.43
CaO	6.58	9.06	3.93	8.89	1.10	2.11	1.84	4.11	6.8
Na2O	3.23	3.39	3.39	1.72	1.42	2.54	1.35	1.73	3.19
K2O	0.46	0.18	4.24	0.3	3.25	2.72	1.88	3.63	0.17
P2O5	0.1	0.12	0.42	0.11	0.07	0.13	0.20	0.13	0.11
CO2	<0.2	<0.2	<0.2	----	----	----	----	----	----
Total*	100	100	100	100	100	100	100	100	100
Trace element in ppm									
Ba	180	40	1000	50	500	360	250	130	40
Co	----	----	----	17	12	8	16	10	15
Cr	16	46	10	6	84	125	164	24	132
Cu	----	----	----	73	48	42	1	7	5
Ni	3	22	1	2	33	53	72	14	36
Pb	----	----	----	<2	16	18	2	6	4
Sr	122	260	180	237	117	138	96	85	286
V	140	330	60	119	86	61	94	48	126
Zn	72	194	150	100	104	74	154	172	66
F	240	600	1300	140	430	400	450	800	360
Rb	22	4	140	5	148	118	88	127	4
Hf	----	<1	11	<2	8	2	6	6	2
Nb	<5	----	----	6	17	13	16	14	8
Y	26	15	105	5	49	31	43	53	11
Zr	89	64	370	26	230	95	155	165	63

*Total normalized to 100 Analyst: Chemex Lab.

Sp. No.		
11	85020455A	Tonalitic gneiss (Wideøefjellet)
12	85012959B	Biotite-bearing hornblende amphibolite(Tanngarden)
13	85013151	Biotite-bearing hornblende amphibolite (Tanngarden)
14	A90011607D1	Garnet-bearing hornblende metatonalite(Caussinknappen)
15	A90011406A	Biotite-hornblende gneiss(Dungane)
16	A90011406D	Biotite-hornblende gneiss(Dungane)
17	A90011406E	Biotite-hornblende gneiss(Dungane)
18	A90011607C	Hornblende metatonalite(Caussinknappen)
19	A90011602A	Metatonalite (Røysane)

Table 1. (continued)

Sp. No.	20	21	22	23	24	25	26	27	28
wt%									
SiO2	70.1	51.1	71.35	54.03	58.74	65.62	74.16	51.71	61.54
TiO2	0.38	0.26	0.3	0.63	0.42	0.39	1.1	0.65	0.9
Al2O3	14.27	14.05	15.51	19.48	15.82	14.33	12.21	14.48	16.44
Fe2O3	1.64	2.71	0.62	3.05	2.42	1.43	1.34	2.72	3.21
FeO	3.56	8.12	1.94	6.51	6.69	4.62	4.76	5.98	4.22
MnO	0.12	0.25	0.04	0.16	0.17	0.1	0.04	0.18	0.11
MgO	1.13	9.67	0.87	3.17	3.84	4.3	1.46	9.87	4.12
CaO	5.18	11.23	3.59	9.13	8.59	3.79	0.29	9.19	6.59
Na2O	3.18	2.44	4.18	3.25	2.2	3.05	0.52	3.14	2.34
K2O	0.34	0.16	1.51	0.43	1.02	2.31	4.06	1.9	0.36
P2O5	0.1	0.01	0.09	0.16	0.09	0.06	0.06	0.18	0.17
CO2	----	<0.2	<0.2	<0.2	----	<0.2	<0.2	<0.2	----
Total*	100	100	100	100	100	100	100	100	100
Trace element in ppm									
Ba	80	30	720	120	140	510	400	940	180
Co	6	32	----	----	----	15	----	----	----
Cr	58	410	8	14	38	107	72	370	116
Cu	11	26	----	----	----	16	----	----	----
Ni	19	67	1	2	12	17	105	97	31
Pb	4	2	----	----	----	<2	----	----	----
Sr	203	106	410	160	122	72	12	850	146
V	47	271	40	240	260	112	150	150	160
Zn	62	114	64	85	81	72	151	137	89
F	120	140	200	200	190	290	260	1350	230
Rb	8	2	50	27	14	32	120	49	4
Hf	<2	<2	----	55	42	4	12	4	5
Nb	7	8	5	<5	<5	8	----	----	----
Y	5	11	16	----	----	24	77	42	24
Zr	20	23	145	23	21	76	320	170	135

*Total normalized to 100 — Analyst: Chemex Lab.

Sp. No.			
	20	A90011603A	Garnet-bearing hornblende metatonalite (Røysane)
	21	A90011605A	Hornblende metatonalite (Røysane)
	22	85020202	Biotite metatonalite (Nils Larsen)
	23	85020201C	Gneissose hornblende biotite metatonalite (Nils Larsenfjellet)
	24	85020451	Mylonitic metatonalite (Nils Larsenfjellet)
	25	A90010708	Muscovite-chlorite-biotite schist (Bamsefjell)
	26	85020608B	Garnet-sillimanite-biotite gneiss (Perlebandet)
	27	85020703	Two-pyroxene cummingtonite amphibolite (Perlebandet)
	28	85021004F	Orthopyroxene-clinopyroxene-biotite gneiss (Vesthaugen)

1) garnet-biotite gneisses (Ggb),
2) biotite-hornblende gneisses (Gbh),
3) amphibolites (Amp and Amb),
4) marble and skarn (M),
5) metatonalite associated with greenschist (To and Sch).

1) to 4) compose the Northeastern Terrane, and 1)-5) is included in the Southwestern Terrane. Chemical compositions of these rock types are shown in Table 1.

3.1. Garnet-biotite gneisses and pyroxene granulite

Garnet-biotite gneisses are typical pelitic to semi-pelitic gneisses in the present area. Thinly (mm order) to thickly (m order) banded biotite gneisses are widely distributed. Typical mineral assemblages are:

1) garnet-biotite-plagioclase-K-feldspar-quartz,
2) garnet-sillimanite-biotite-plagioclase-K-feldspar-quartz,
3) garnet-cordierite-biotite-plagioclase-K-feldspar-quartz.

Assemblage 2) and 3) are found only in the northern nunataks: Vesthaugen and Perlebandet (Plate 7a). Feldspathic and quartzofeldspathic gneisses (pyroxene granulite) which accompany the garnet-biotite gneisses in Vesthaugen have the following mineral assemblages:

4) cordierite-spinel-orthopyroxene-biotite-plagioclase,
5) cordierite-sillimanite-garnet-biotite-K-feldspar-plagioclase-quartz,
6) orthopyroxene-garnet-biotite-K-feldspar-plagioclase-quartz.

Retrograde green biotite, muscovite and chlorite are common (Plate 7b). Representative electron microprobe analyses of the constituent minerals from the garnet-biotite gneisses from Vesthaugen are shown in Appendix.

On the other hand, garnet-biotite gneisses which occur in the southern massifs (Plates 3a, 7b) and the highland (Walnumfjella, Teltet and Caussinknappen) include:

7) garnet-biotite-muscovite-plagioclase-quartz,
8) muscovite-biotite-plagioclase-K-feldspar-quartz.

Such a variety of metamorphic mineral assemblages implies the contrast of P-T conditions between the Northeastern and the Southwestern Terranes.

3.2. Biotite-hornblende gneisses

Biotite-hornblende gneisses form the greatest proportion of the metamorphic rocks except for metatonalite. The biotite-hornblende gneisses generally show banded structure in mm to cm orders. Alternated bands of biotite gneiss and hornblende gneiss 0.2 to 1.0 m wide are common (Plate 3a). Epidote veins 2 to 5 cm wide are found in biotite-hornblende gneisses in places. Typical mineral assemblages in the Northeastern Terrane are:

2) olivine-spinel-humite-phlogopite-pargasite-dolomite-plagioclase,
3) clinopyroxene-phlogopite-scapolite-plagiocalse,
On the other hand, those from the Southwestern Terrane are:
4) clinopyroxene-garnet-hornblende-epidote-scapolite-plagioclase-quartz,
5) clinopyroxene-garnet-epidote-calcite-quartz-sphene,
6) olivine-spinel-pargasite-calcite-dolomite-phlogopite-tremolite.

3.5. Metatonalite and greenschist

These rocks are main constituents of the southern part of Southwestern Terrane. The metatonalite is a medium- to coarse-grained gneissose rock containing various proportions of dark greenschist (epidote-chlorite and/or chlorite-epidote-biotite schist). The greenschist forms thin layers up to 1 m wide and lens-shaped blocks, ribbons, and schlieren-like dark inclusions up to 1 m long, with their long axes oriented parallel to the foliation (Plate 5). Bandles of greenschist layers and lenses tend to make narrow zones of a few to tens metres wide in the metatonalite (Plate 2b). On the other hand, bands of the dark greenschist alternating with the biotite gneiss some 100 m to 500 m wide are also observed in the northern escarpment of Walnumfjella and Widerøefjellet. These modes of occurrence suggest that the greenschist originated from mafic intrusive body and dykes into the tonalite and sediments.

The most conspicuous features in these rocks are various degree of mylonitic and cataclastic textures (Plate 8). Typical gneissose metatonalite is composed of bluish green hornblende, biotite, epidote, plagioclase and quartz. It rarely contains garnet and K-feldspar with accessory apatite, zircon ilmenite and rare magnetite. Chlorite and saussuritized plagioclase are common. It shows pronounced mylonitic texture, with plagioclase and K-feldspar porphyroclasts having asymmetric pressure shadow tails, but rarely remaining idiomorphic features in plagioclase. As mylonitization increases, the proportions of epidote and chlorite increase and plagioclase is more saussuritized, whereas the proportions of hornblende and biotite decrease. Therefore, epidote, zoisite and chlorite as well as saussuritized plagioclase are secondary products, probably under the greenschist facies condition related to the mylonitization. The mineral assemblage of the greenschist is identical with that of the tonalite.

It is not uncommon that the greenschist consists entirely of secondary minerals; in such schistose rocks, chlorite displays crenulation cleavage which was formed probably during retrograde metamorphism.

4. Plutonic Rocks

Plutonic rocks occupying in the Widerøefjellet region are composed of granite and diorite and are divided into two types based on the field occurrences: Pingvinane and Vengen granites after nearby place names (KOJIMA and SHIRAISHI, 1986; TAKAHASHI *et al.*, 1990, 1991). These granitic rocks are characterized by having high absolute alkali abundances and low CaO, high Zr, Ga, F and Nb. Many of the granites belong to A-type granites judging from these chemical features (Table 2) (TAINOSHO *et al.*, 1991).

4.1. Vengen granite

The main portion of the Vengen granite forms the "Kanino-tume Peak (a tentative name)"

Table 2. Chemical analyses of granitic rocks and metadolerites from the Widerøefjellet region.

Sp. No.	1	2	3	4	5	6	7	8	9	10
wt%										
SiO2	47.45	70.04	71.98	74.07	75.33	77.15	51.83	50.86	54.12	67.95
TiO2	4.06	0.34	1.02	0.04	0.09	0.06	3.50	3.22	2.52	0.45
Al2O3	13.88	14.37	12.70	13.85	13.98	13.17	13.94	13.71	14.14	14.66
Fe2O3	3.00	1.46	1.54	0.30	0.32	1.01	3.80	2.57	2.24	0.82
FeO	7.65	2.22	2.97	0.45	0.49	0.51	7.12	8.95	6.67	3.05
MnO	0.15	0.04	0.03	0.06	0.02	0.01	0.15	0.15	0.13	0.05
MgO	4.93	0.10	0.05	0.08	0.08	0.12	4.12	5.24	5.12	0.27
CaO	7.65	1.50	1.40	1.02	1.03	0.91	6.43	6.92	6.20	2.13
Na2O	2.76	3.54	3.38	4.31	4.10	4.91	2.90	3.02	3.43	3.75
K2O	2.73	6.17	4.44	4.79	4.59	2.88	2.47	2.00	2.46	4.63
P2O5	1.90	0.07	0.13	0.04	0.03	<0.01	1.32	1.15	0.92	0.06
BaO	0.16	0.24	0.15	<0.01	0.05	0.01	---	---	---	0.33
LOI	0.23	0.95	0.86	0.16	0.39	0.59	---	---	---	0.25
H2O(+)	---	---	---	---	---	---	0.96	0.77	1.21	---
H2O(-)	---	---	---	---	---	---	0.12	0.17	0.17	---
Total	96.55	101.04	100.65	99.18	100.50	101.34	98.66	98.76	99.33	98.40
Analyst	C	C	C	C	C	C	K	K	J	C

Analyst: C. Chemex Laboratory Inc.; K. Kanisawa & Ishikawa; J. Japan Chemical Analysis Center

Sp.No.			
	1	85020955A	Quartz-diorite (Vesthaugen)
	2	B90011405A	Coarse-grained hornblende-biotite granite (Tanngarden)
	3	B90011305A	Coarse-grained biotite granite (Tanngarden)
	4	85012254A	Fine-grained biotite granite (Vikinghøgda)
	5	B90011704B	Fine- to medium-grained granite (Vikinghøgda)
	6	B90011703A	Fine-grained biotite gneissose granite (Vikinghøgda)
	7	84021207	Metadolerite (hornblende-biotite schist) (Vesthaugen)
	8	84022003	Metadolerite (Utnibba)
	9	85012604C	Metadolerite (Walnumfjella)
	10	85013052	Biotite-hornblende granite (Tanngarden)

Table 2. (continued)

Sp. No.	1	2	3	4	5	6	7	8	9	10
Trace element in ppm										
Ag	---	<0.5	<0.5	---	<0.5	<0.5	0.5	0.5	0.5	---
Ba	1240	2270	1330	80	450	140	2100	1620	1260	---
Be	---	0.5	<0.5	---	1.0	2.5	1.5	0.5	1.0	---
Bi	---	<2	<2	---	<2	<2	<2	<2	<2	---
Cd	---	<0.5	<0.5	---	<0.5	<0.5	2.5	1.5	2.0	---
Co	---	<1	<1	---	1	27	29	33	29	---
Cr	44	5	7	4	1	3	55	155	119	---
Cu	---	3	8	---	1	7	<1	12	10	---
Mo	---	<1	11	---	<1	<1	<1	<1	<1	---
Ni	20	1	<1	3	<1	1	30	69	73	---
Pb	---	32	24	---	38	28	12	8	14	---
Sr	780	211	171	20	169	41	1235	1045	891	---
V	230	<1	2	10	<1	<1	135	145	125	---
W	---	<10	<10	---	<10	400	<10	<10	<10	---
Zn	188	136	170	23	38	20	174	150	132	---
F	2500	620	430	150	280	430	---	---	---	---
Rb	78	128	100	200	145	90	70	25	61	---
Hf	380	16	24	84	<2	16	---	---	---	---
Nb	24	36	26	8*	10	not/ss	28	21	20	---
Y	---	58	26	---	26	not/ss	59	44	49	---
Zr	57	445	600	75*	68	not/ss	350	315	290	---
CO_2	<0.20	---	---	<0.20	---	---	---	---	---	---
S	0.124	---	---	<0.001	---	---	---	---	---	---
Th	---	---	---	---	---	---	3	2	9	---
U	---	---	---	---	---	---	4	1	4	---
La	---	---	---	---	---	---	65	55	53	---
Ce	---	---	---	---	---	---	149	125	122	---
Pr	---	---	---	---	---	---	<5	<5	<5	---
Nd	---	---	---	---	---	---	91	76	80	---
Sm	---	---	---	---	---	---	15.0	12.0	12.0	---
Eu	---	---	---	---	---	---	4.6	3.9	3.2	---
Gd	---	---	---	---	---	---	<50	<50	<50	---
Tb	---	---	---	---	---	---	1.6	1.1	0.9	---
Dy	---	---	---	---	---	---	10	9	7	---
Ho	---	---	---	---	---	---	<1	<2	<2	---
Er	---	---	---	---	---	---	<20	<20	<20	---
Tm	---	---	---	---	---	---	<1	<1	<1	---
Yb	---	---	---	---	---	---	2.3	1.9	2.0	---
Lu	---	---	---	---	---	---	0.5	0.4	0.4	---
1000Ga/Al	-	3.4	3.6	---	2.5	3.2	---	---	---	---
Y/Nb	-	1.6	1	---	2.6	---	---	---	---	---

Not/SS: less than detection limit Analyst: Chemex Lab.

the southern end of the Vengen ridge (Plate 4). The apophyses extend to the eastern part of the Vikinghøgda and the central part of the Vengen ridge. This is a fine- to medium-grained gneissose biotite granite with an unclear boundary concordant to the foliation of the host rocks. This granite includes many xenoliths of gneisses whose margins are often diffused. It is composed mainly of quartz, plagioclase, K-feldspar, biotite and muscovite with

Table 3. Modal analyses of selected granites from the Wiederøefjellet region.

Sp.No.	1	2	3	4	5
vol%					
Plagioclase	38.4	27.2	22.8	27.0	22.9
K-feldspar	26.0	23.8	44.0	51.5	26.8
Quartz	31.5	46.6	31.3	18.3	43.9
Biotite	8.6	0.5	0.8	-	6.4
Hornblende	-	-	-	3.0	-
Actinolitic amphibole	-	-	-	0.3	-
Opaque mineral	0.4	0.5	-	-	-
Muscovite	2.2	1.2	1.1	-	-
Sphene	-	0.2	-	-	-

Sp. No.1	B90010603	Mylonitic granite (Kanino-tume Peak, Vengen)
2	B90011702	Gneissose fine-grained biotite granite(Vikinghøgda)
3	B90011701B	Lecocratic granite (Vikinghøgda)
4	B90011405A	Coarse-grained hornblende granite (Pingvinane)
5	B90011403	Porphylitic biotite granite (Pingvinane)

accessory sphene, apatite, zircon and opaque oxides (Table 3). It has high magnetic value (200 to 300 $\times 10^{-4}$ SIU) corresponding to value of the magnetite-series granites (ISHIHARA, 1977; SATO and ISHIHARA, 1983).

The Vengen Granite is strongly mylonitized to protomylonite and cataclasite in the area of MSZ (Plates 4, 9a; KOJIMA and SHIRAISHI, 1986).

4.2. Pingvinane granite

The granite forms chains of nunataks extending from north of Tanngarden, through Pingvinane to Utsteinen and covers an area of about 120 km^2. It intruded the gneiss of the Southwestern Terrane with migmatitic marginal zone of about 10 m width. This granite has low magnetic values (3 to 8 $\times 10^{-4}$ SIU) corresponding to the ilmenite-series. The granite has massive and coarse-grained equigranular texture. It shows schlieren structure in some outcrops. It is composed mainly of K-feldspar, quartz, plagioclase, hornblende and biotite with accessory opaque minerals, sphene, apatite and zircon. The medium-grained granite at Utsteinen shows reddish and contains more hornblende than biotite.

The granite in Bamseungen is correlated to the Pingvinane granite judging from the petrographical feature and magnetic susceptibility.

4.3. Vesthaugen diorite and quartz diorite

The dioritic rocks outcrop in Vesthaugen (KOJIMA and SHIRAISHI, 1986). It is a dark greyish coarse-grained rocks consisting mainly of orthopyroxene, clinopyroxene, hornblende, biotite, plagioclase and quartz (Plate 9b). It is characteristic that hornblende shows a poikilitic texture.

5. Dyke Rocks

5.1. Granite sheet and dyke

Many small sheet-like intrusive bodies of granite and granodiorite of a few tens metres thick at most are found all over the mapped area (KOJIMA and SHIRAISHI, 1986). Most of bodies are too small to be represented on the geological map. Fine- to medium-grained dyke rocks composed of biotite granite, two-mica granite and garnet two-mica granite are found all over the area. There are numerous sheet-like bodies of granite, granodiorite and trondhjemite which concordantly intrude the metamorphic rocks. Their contacts with the metamorphic rocks are commonly obscure and they give a migmatitic appearance in many places. The youngest granitic pegmatite represents dyke swarms in some places. It is not clear whether this pegmatite was derived from the above granite masses.

5.2. Metadolerite

Slightly metamorphosed dolerites (metadolerites) are characteristic in the western part of the Sør Rondane Mountains (Plate 3c). The metadolerite dykes uniformly strike NNW-SSE with nearly vertical or moderate westerly dips. They can generally be traced for a few hundred metres, because of the limited size of outcrops. However, several dykes over a few kilometres long are observed in air photographs of Walnumfjella and Widerøefjellet. It is a few tens of centimetres to several metres wide and shows the clean-cut contacts with the host rocks. Distinct chilled margins are commonly observed indicating that the gneiss terrain had been considerably uplifted before the granite emplacement.

The dykes also intrude Palaeozoic granite, but are cut in places by the youngest veins of Palaeozoic granite and pegmatite and by gently dipping faults although scarcely. Some basic schists in contact with granite from Vesthaugen is considered to be thoroughly recrystallized dolerite.

The slightly metamorphosed dolerite is composed essentially of relicts of igneous pyroxenes and plagioclase laths in a typical subophitic texture, together with ilmenite needles (Plate 9c). Fine biotite with or without hornblende scatters randomly throughout a thin section. Quartz occurs in many rocks as minute interstitial grains and ocelli surrounded by biotite and carbonate. In one dyke, orthopyroxene is overgrown by clinopyroxene that show sector zoning. In other rocks, either clino- or orthopyroxene is present. Clinopyroxene ($Mg_{47}Fe_{13}Ca_{40}$) is characteristically rich in TiO_2 (up to 2.6 wt%) and Al_2O_3 (up to 3.9 wt%). Besides ilmenite, accessory minerals are apatite, magnetite and sulfide minerals.

Geochemistry of the metadolerite has been briefly reported by SHIRAISHI *et al.* (1988) together with similar dyke rocks from widely separated exposures throughout the eastern Queen Maud Land (Table 2). The metadolerites are typical sub-alkaline basalts on the Zr/TiO_2 *vs.* Nb/Y diagram and plot in the continental basalt field on the FeO-MgO-Al_2O_3

diagram and within-plate basalt field on a Ti-Zr-Y diagram. They are characterised by high TiO_2 (up to 3.50 wt%), high P_2O_5 (up to 1.32 wt%), low MgO (4.12-5.24 wt%) and enrichment of the light rare earth elements relative to heavy rare earth elements. Such petrochemical characteristics are analogous to the Late Proterozoic metabasites reported from eastern North America which have been explained as small degree of partial melting during early stages of continental rifting (COISH *et al.*, 1985).

6. Metamorphism

Because the general structural trend is approximately E-W, we are able to use the result from the central part of the mountains (ASAMI and SHIRAISHI, 1987; SHIRAISHI and KOJIMA, 1987; SHIRAISHI *et al.*, 1991). The Northeastern Terrane is characterised by orthopyroxene-bearing assemblages, diagnostic of the granulite facies. SHIRAISHI and KOJIMA (1987) examined the regional gradation of the metamorphic grade through the Northeastern and the Southwestern Terranes. Judging from the variations of chemical compositions of calcic amphiboles as well as mineral assemblages of the basic to intermediate gneisses, the gradual change of peak metamorphic grade across the Sør Rondane Suture has not been detected. *P-T* conditions of the granulite facies regional metamorphism were estimated to be 750-830°C based on garnet-biotite, garnet-pyroxenes and pyroxenes compositions and 7-8.5 kbar based on GRAIL and garnet-pyroxene-plagioclase compositions. On the other hand, retrograde textures are widespread in the metamorphic rocks .

In the Southwestern Terrane, an epidote-hornblende-plagioclase(An_{18-30}) assemblage indicating the epidote-amphibolite facies condition is observed both in metatonalite and in basic to intermediate gneisses and schists. However, retrograde epidote and chrolite which are hydration products of Ca-amphibole are common throughout the region. Thus it is difficult to distinguish the two events. KOJIMA and SHIRAISHI (1986) explained that the retrograde metamorphism was associated with the intense mylonitization. It is significant that no relict mineral assemblage indicating upper amphibolite- to granulite facies conditions and associated psammitic to pelitic schists in the southern part of the Southwestern Terrane.

A boulder of gneiss containing garnet-sillimanite-biotite-K-feldspar-quartz, which represents the upper amphibolite-facies condition or a higher temperature condition, was obtained at the moraine field stretching northwards from Nils Larsenfjellet, where metatonalite and dark greenschist are developed.

7. Geologic Structure

On a macroscopic scale, foliation of the metamorphic rocks generally strikes E-W, and gently dips 20°S to 50°S. The main foliation is parallel to the compositional banding of the constituent rocks. Mesoscopic tight to isoclinal folds, some of which are of an intrafolial type are commonly observed throughout the mapped area (Plate 3b). These formed during the earliest deformation, probably under the peak metamorphic conditions. In the south of the MSZ in the Southwestern Terrane, the secondary mylonitic foliation with steep dips (60°S to 90°S) are predominant. The foliation in the metatonalite is concordant with the elongation of the greenschist fragments and is subparallel to pyrite-impregnated quartz veins up to 1 m wide intrude along the shear planes.

8. Geochronology

In the pioneer work by Belgian group, most radiometric dates on both the metamorphic and plutonic rocks indicate early Palaeozoic and some show late Proterozoic ages (PICCIOTTO *et al.*, 1964). The oldest age, 2700 Ma determined by U-Pb on detrital zircon from gneisses, was reported by PASTEELS and MICHOT (1970). The age of the peak metamorphism has been estimated *ca.* 1000 Ma with Sm-Nd and Rb-Sr whole-rock isochron on the granulite facies rock in the Northeastern Terrane from Brattnipene, northeastern extension of the present region (SHIRAISHI and KAGAMI, 1991). TAKAHASHI *et al.* (1990) reported a Rb-Sr whole-rock isochron age of 956 ± 39 Ma with initial ratio 0.70237 for the metatonalite from Nils Larsenfjelle and the westernmost part of Widerøefjellet. This age is similar to that of granulite facies metamorphic rocks from the Northeastern Terrane.

A whole-rock K-Ar age of a metadolerite collected from the southern end of Smålegga yields 536 ± 27 Ma (KOJIMA and SHIRAISHI, 1986) and that from Utnibba at 30 km north of Smålegga yields 451 ± 12 Ma and 488 ± 18 Ma (TAKIGAMI *et al.*, 1987). The discrepancy may be caused either by the difference of cooling rate between the metadolerites from the two areas or by the difference of the intrusion ages of granites which might reset the isotopic systems of the dolerites.

^{40}Ar-^{39}Ar ages of biotite of Pingvinane granite are 498.5 ± 8.8 Ma as plateau age and 487.1 ± 8.8 Ma as total age (TAKIGAMI *et al.*, 1991). These ages are consistent with previously reported radiometric ages of the granite taking the closure temperature ages into consideration (PICCIOTTO *et al.*, 1964; PASTEELS and MICHOT, 1970).

References

ANIYA, M. (1989): Landforms of the Balchenfjella area, the Sør Rondane, East Antarctica. Nankyoku Shiryô (Antarct. Rec.), **33**, 353-375.

ASAMI, M. and SHIRAISHI, K. (1987): Kyanite from the western part of the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 150-168.

COISH, R.A., FLEMING, F.S., LARSEN, M., POYNER, R. and SEIBERT, J. (1985): Early rift history of the proto-Atlantic Ocean: Geochemical evidence from metavolcanic rocks in Vermont. Am. J. Sci., **285**, 351-378.

HAYASHI, M. and MIURA, K. (1989): Glacial landforms and weathering processes in the Balchenfjella region, eastern part of the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **3**, 65-80.

HIRAKAWA, K., MATSUOKA, N. and MORIWAKI, K. (1988): Reconstruction of maximum glacial extent in the central Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **2**, 146-161.

HIRAKAWA, K. and MORIWAKI, K. (1990): Former ice sheet based on the newly observed glacial landforms and erratics in the central Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **4**, 41-54.

ISHIHARA, S.(1977): The magnetite-series and ilmenite-series granitic rocks. Mining Geol., **27**, 293-305.

ISHIZUKA, H. and KOJIMA, H.(1987): A preliminary report on the geology of the central part of the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 113-128.

IWATA, S. (1987): Debris-mantled rectilinear slopes in the western Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 178-192.

KOJIMA, S. and SHIRAISHI, K. (1986): Note on the geology of the western part of the Sør Rondane Mountains, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **43**, 116-132.

MEMBERS OF THE SØR-RONDANE RECONNAISSANCE PARTY (1985): Report on the reconnaissance survey of the Sør-Rondane Mountains, 1984. Nankyoku Shiryô (Antarct. Rec.), **82**, 46-70 (in Japanese with English abstract).

MERCER, J.H. (1972): Some observations on the glacial geology of the Beardmore Glacier area. Antarctic Geology and Geophysics, ed. by R. J. Adie. Oslo, Universitetsforlaget, 427-433.

MORIWAKI, K. and HIRAKAWA, K. (1992): Glacial landforms and late Cenozoic history of the western Sør-Rondane Mountains. Nankyoku Shiryô (Antarct. Rec.), **36**, 15-48 (in Japanese with English abstract).

MORIWAKI, K., SHIRAISHI, K., IWATA, S., KOJIMA, S., SUZUKI, A., TERAI, K., YAMADA, K. and SANO, M. (1986): Report on the geological, geomorphological and geodetic survey of the Sør-Rondane Mountains, 1985 (JARE-26). Nankyoku Shiryô (Antarct.Rec.), **86**, 36-107 (in Japanese with English abstract).

MORIWAKI, K., FUNAKI, M., HIRAKAWA, K., TOKIEDA, K., ABE, H., HIGASHI, S. and MIYAWAKI, H. (1989): Report on the geomorphological, paleomagnetic, geodetic, zoological and botanical field work in the Sør-Rondane Mountains, 1988-89 summer season (JARE-30). Nankyoku Shiryô (Antarct. Rec.), **33**, 293-319 (in Japanese with English abstract).

MORIWAKI, K., HIRAKAWA, K. and MATSUOKA, N. (1991): Weathering stage of till and glacial history of the central Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **5**, 99-111.

MORIWAKI, K., HIRAKAWA, K. HAYASHI, M. and IWATA, S. (in press): Late Cenozoic glacial history in the Sør-Rondane Mountains, East Antarctica. Recent Progress in Antarctic Earth Science, ed. by Y. YOSHIDA. Tokyo, Terra Scientific Publishing.

NISHIIZUMI, K., KOHL, C.P., ARNOLD, J.R., KLEIN, J., FINK, D. and MIDDLETON, R. (1991): Cosmic ray produced ^{10}Be and ^{26}Al in Antarctic rocks: Exposure and erosion history. Earth Planet. Sci. Lett., **104**, 440-454.

OSANAI, Y., TAKAHASHI, Y., TAINOSHO, Y., TSUCHIYA, N., HAYASHI, T. and HIRUTA, S. (1990): Report of geological, geodetic and biological fieldwork in the Sør-Rondane Mountains, 1989-1990 (JARE-31). Nankyoku Shiryô (Antarct. Rec.), **34**, 445-481 (in Japanese with English abstract).

OSANAI, Y., TAKAHASHI, Y., SHIRAISHI, K., SAKIYAMA, T., TAINOSHO, Y. and TSUCHIYA, N. (1991): Chemical features of metamorphic rocks from the central Sør Rondane Mountains, East Antarctica. Abstracts, Sixth International Symposium on Antarctic Earth Sciences. Tokyo, Natl. Inst. Polar Res., 468-473.

PASTEELS, P. and MICHOT, J. (1970): Uranium-lead radioactive dating and lead isotope study on sphene and K-feldspar in the Sør-Rondane Mountains, Dronning Maud Land, Antarctica. Eclogae Geol. Helv., **63**, 239-254.

PICCIOTTO, E., DEUTSCH, S. and PASTEELS, P. (1964): Isotopic ages from the Sør Rondane Mountains, Dronning Maud Land. Antarctic Geology, ed. by R.J. ADIE. Amsterdam, North-Holland, 570-578.

SAKIYAMA, T., TAKAHASHI, Y. and OSANAI, Y.(1988): Geological and petrological characters of the plutonic rocks in the Lunckeryggen-Brattnipene region, Sør-Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **2**, 80-95.

SATO, K. and ISHIHARA, S.(1983): Chemical composition and magnetic susceptibility of the Kofu complex. Bull. Geol. Surv. Jpn., **34**, 413.

SHIRAISHI, K. (1992): Activities of the forth wintering party at Asuka Station by the 31st Japanese Antarctic Research expedition in 1990. Nankyoku Shiryô (Antarct. Rec.), **36**, 83-108.

SHIRAISHI, K. and KOJIMA, S.(1987): Basic and intermediate gneisses from the western part of the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 129-149.

SHIRAISHI, K. and KAGAMI, H. (1991): Sm-Nd and Rb-Sr ages of metamorphic rocks from the Sør Rondane Mountains, East Antarctica. Abstracts, Sixth International Symposium on Antarctic Earth Sciences. Tokyo, Natl Inst. Polar Res., 528-533.

SHIRAISHI, K., KANISAWA, S. and ISHIKAWA, K. (1988): Geochemistry of post-orogenic mafic rocks from the eastern Queen Maud Land, East Antarctica. Proc. NIPR Symp. Antact. Geosci., **2**, 117-132.

SHIRAISHI, K., ASAMI, M., ISHIZUKA, H., KOJIMA, H., KOJIMA, S., OSANAI, Y., SAKIYAMA, T., TAKAHASHI, Y., YAMAZAKI, M. and YOSHIKURA, S. (1991): Geology and metamorphism of the Sør Rondane Mountains, East Antarctica. Geological Evolution of Antarctica, ed. by M.R.A. THOMSON *et al.* Cambridge, Cambridge Univ. Press, 77-82.

TAINOSHO, Y., TAKAHASHI, Y., OSANAI, Y., TSUCHIYA, N., SAKIYAMA, T. and OWADA, M. (1991): Petrochemical character of the granites from the Sør Rondane Mountains, East Antarctica. Abstracts, Sixth International Symposium on Antarctic Earth Sciences. Tokyo, Natl Inst. Polar Res., 558-563.

TAKAHASHI, Y., ARAKAWA, Y., SAKIYAMA, T., OSANAI, Y. and MAKIMOTO, H. (1990): Rb-Sr and K-Ar whole rock ages of the plutonic bodies from the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **4**, 1-8.

TAKAHASHI, Y., TAINOSHO, Y., ARAKAWA, Y., SAKIYAMA, T. and OWADA, M. (1991): Geology and geochemistry of the granitoids in the Sør Rondane Mountains, East Antarctica. Abstracts, Sixth International Symposium on Antarctic Earth Sciences. Tokyo, Natl Inst. Polar Res., 564-569.

TAKIGAMI, Y., KANEOKA, I. and FUNAKI, M. (1987): Age and paleomagnetic studies for intrusive and metamorphic rocks from the Sør Rondane Mountains, Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 169-177.

TAKIGAMI, Y., FUNAKI, M. and TOKIEDA, K. (1991): ^{40}Ar-^{39}Ar ages and paleomagnetic studies of igneous and metamorphic rocks from the Sør Rondane Mountains, East Antarctica. Abstracts, Sixth International Symposium on Antarctic Earth Sciences. Tokyo, Natl. Inst. Polar Res., 570-575.

VAN AUTENBOER, T. (1964): The geomorphology and glacial geology of the Sør-Rondane, Dronning Maud Land. Antarctic Geology, ed. by R.J. ADIE. Amsterdam, North-Holland, 81-103.

VAN AUTENBOER, T. (1969): Geology of the Sør-Rondane Mountains. Geologic Maps of Antarctica, ed. by C. CRADDOCK *et al.* New York, Am. Geogr. Soc., Sheet 8, Pl. VIII (Antarctic Map Folio Ser., Folio 12).

VAN AUTENBOER, T. and BLAIKLOCK, K.V. (1967): Ice-flow and thickness measurements in the Sør-Rondane, Dronning Maud Land, Antarctica. J. Glaciol., **6**, 69-81.

VAN AUTENBOER, T. and LOY, W. (1972): Recent geological investigations in the Sør-Rondane Mountains, Belgicafjella and Sverdrupfjella, Dronning Maud Land. Antarctic Geology and Geophysics, ed. by R.J. ADIE. Oslo, Universitetsforlaget, 563-571.

Appendix. Representative microprobe analyses of metamorphic rocks from Vesthaugen.

Sp. No. 84021214 Spinel-cordierite-sillimanite-garnet-biotite gneiss

	Gt(c)	Gt(r)	Bi	Crd(r)	Crd(c)	Sil	Sp
wt %							
SiO2	36.94	36.73	34.70	47.88	48.16	36.54	0.16
TiO2	0	0.05	3.74	0.04	0.03	0.03	0
Al2O3	20.63	20.35	17.98	32.74	32.52	62.00	54.13
Cr2O3	0	0.01	0	0.02	0	0	0
FeO	37.23	38.08	23.70	9.48	9.91	0.69	38.73
MnO	0.93	0.70	0.07	0.13	0	0.04	0.06
MgO	2.82	2.50	5.99	7.60	7.76	0.01	1.57
CaO	0.79	0.76	0.06	0.02	0	0.02	0.05
Na2O	0	0.04	0.06	0.09	0.09	0	0.05
K2O	0	0	8.82	0	0	0	0.06
ZnO	0	0.13	0	0	0.07	0.09	1.92
Total	99.33	99.36	95.12	98.02	98.54	99.42	96.73
O=	12	12	22	18	18	10	8
Si	3.009	3.006	5.400	4.976	4.986	1.991	0.010
Ti	0	0.003	0.438	0.003	0.002	0.001	0
Al	1.980	1.963	3.298	4.009	3.968	3.984	3.856
Cr	0	0.001	0	0.002	0	0	0
Fe	2.536	2.606	3.084	0.824	0.858	0.031	1.958
Mn	0.064	0.049	0.009	0.012	0	0.001	0.003
Mg	0.342	0.305	1.391	1.117	1.198	0.001	0.142
Ca	0.069	0.067	0.010	0.002	0	0.001	0.003
Na	0	0	0.018	0.018	0.017	0	0.006
K	0	0	1.750	0	0	0	0.005
Zr	0	0.008	0	0.002	0.005	0.004	0.086
Mg/Mg+Fe	0.119	0.105	0.311	0.588	0.583	-	0.068

Sp. No. 84021216 Garnet-orthopyroxene-biotite gneiss

	Gt(c)	Gt(r)	Op(f)	Op(in)	Bi(c)	Bi(r)
wt %						
SiO2	37.07	36.87	48.89	48.48	35.75	35.63
TiO2	0.05	0.03	0.14	0.44	4.70	4.63
Al2O3	20.54	20.59	2.00	2.48	13.86	14.56
Cr2O3	0.02	0	0.01	0.01	0.04	0.08
FeO	33.71	35.16	32.88	32.12	18.85	19.37
MnO	0.74	0.91	0.19	0.24	0.04	0.02
MgO	4.61	3.34	13.94	14.24	11.38	11.32
CaO	1.66	1.02	0.03	0.17	0.02	0.11
Na2O	0	0	0.02	0	0.10	0.06
K2O	0	0.04	0.01	0	9.18	8.44
ZnO	0	0.06	0.06	0.14	0	0.02
Total	98.40	98.02	98.17	98.32	93.92	94.24
O=	12	12	6	6	22	22
Si	3.005	3.020	1.955	1.932	5.545	5.493
Ti	0	0.002	0.004	0.013	0.548	0.537
Al	1.963	1.987	0.094	0.116	2.533	2.645
Cr	0	0	0	0	0.005	0.009
Fe	2.286	2.409	1.099	1.070	2.445	2.497
Mn	0.051	0.063	0.006	0.008	0.005	0.003
Mg	0.557	0.408	0.831	0.846	2.630	2.602
Ca	0.114	0.089	0.001	0.007	0.004	0.018
Na	0	0	0.001	0	0.029	0.019
K	0	0.004	0	0	1.817	1.660
Zn	0	0.003	0.002	0.004	0	0.002
Mg/Fe+Mg	0.196	0.145	0.430	0.441	0.518	0.510

(c): core, (r): rim, (f): fine grain, (in): inclusion in garnet

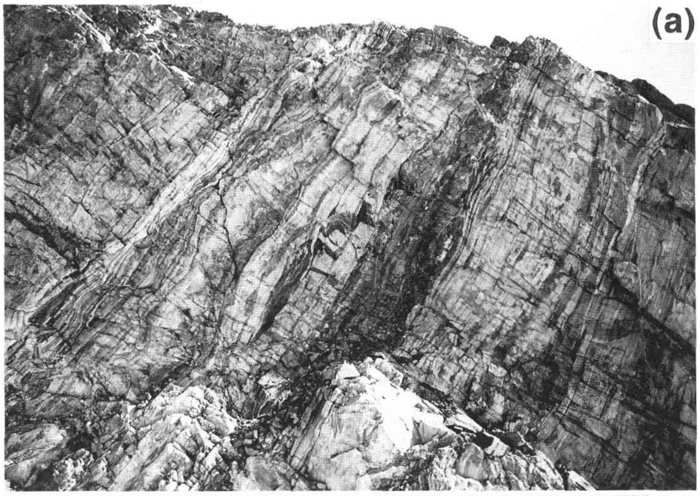
Plate 2

(a) Marble and skarn layer. Note pinch-and-swell structure of skarn. Loc. Perlebandet.

(b) Metatonalite associated with dark greenschist. Note the steep dip of the mylonitic foliation.
Loc. Nils Larsenfjellet.

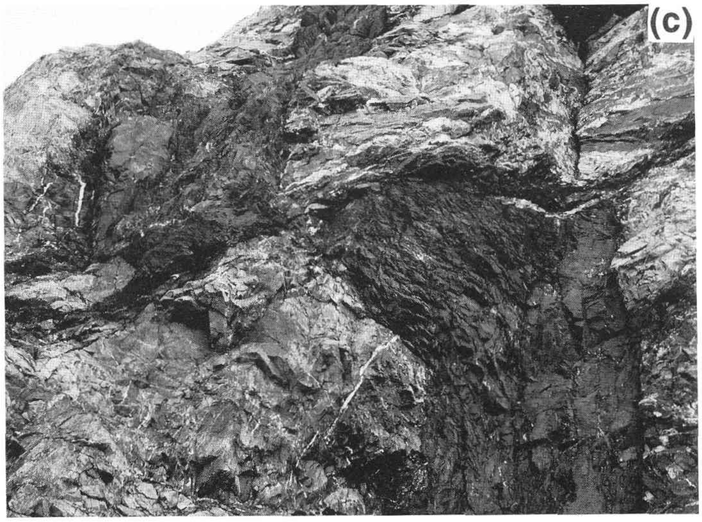
(c) Dark greenschist on the Main Shear Zone. White veins are mylonitic aplite. Loc. Takano-tume Peak, Walnumfjella.

Plate 3



(a) Layered sequence of banded biotite gneisses. Loc. Smålegga.

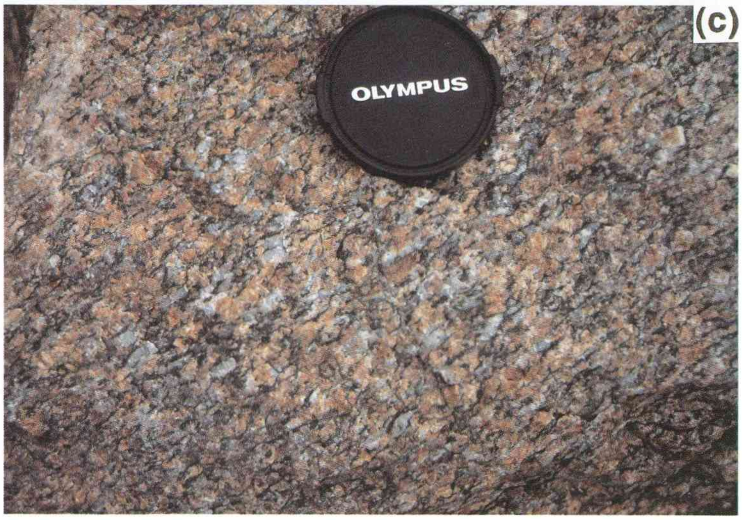
(b) Tightly folded banded biotite gneiss. Note axial plane foliation produced by secondary deformation. Near a local shear zone. Loc. Smålegga.



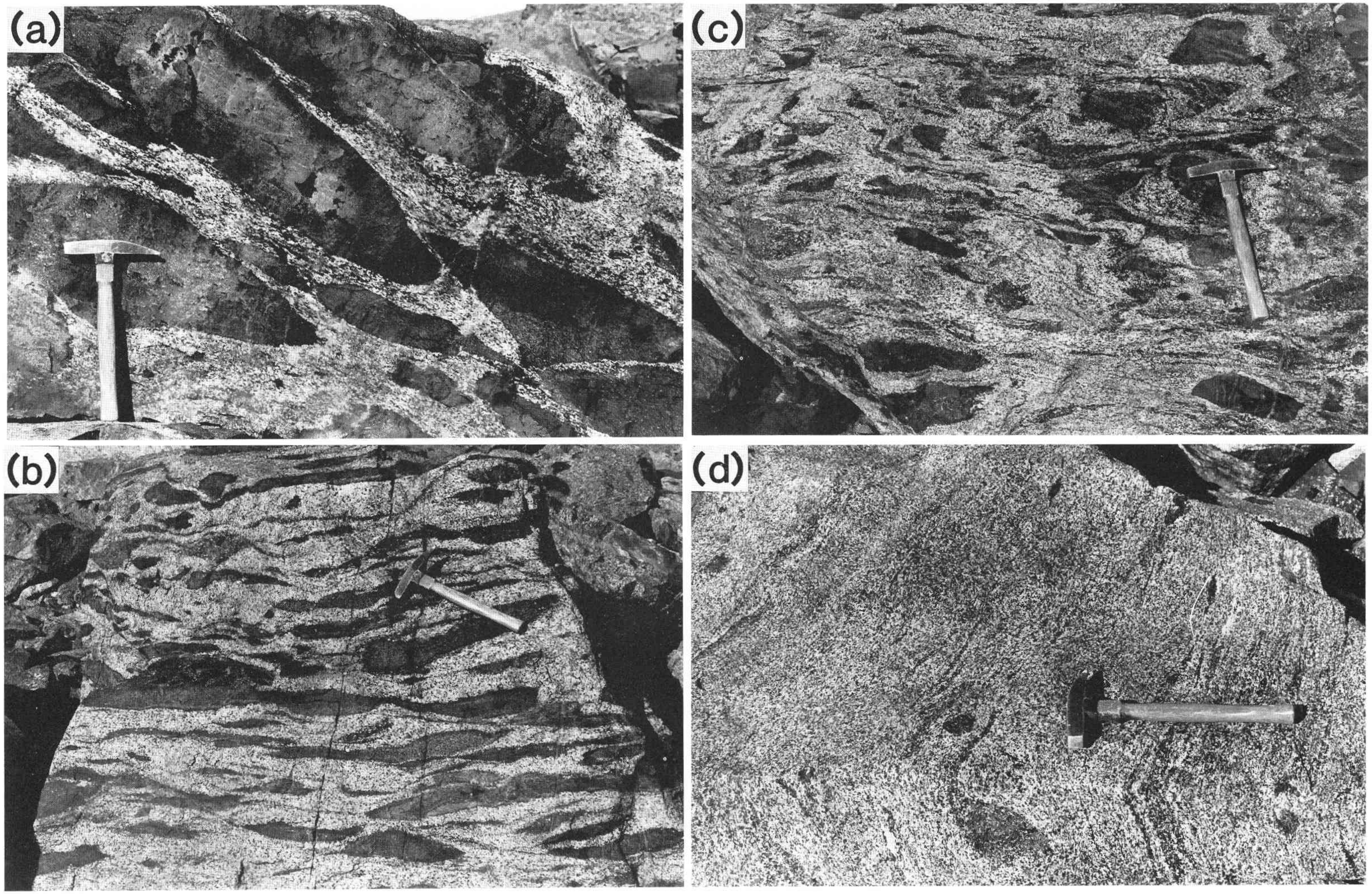
(c) Metadolerite dyke cut by the later fault. Note the chilled margin of the dyke. The width of the dyke is approximately 6 m. Loc. Smålegga.

(a) Vengen granite.
Loc. Kanino-tume Peak,
Vengen.

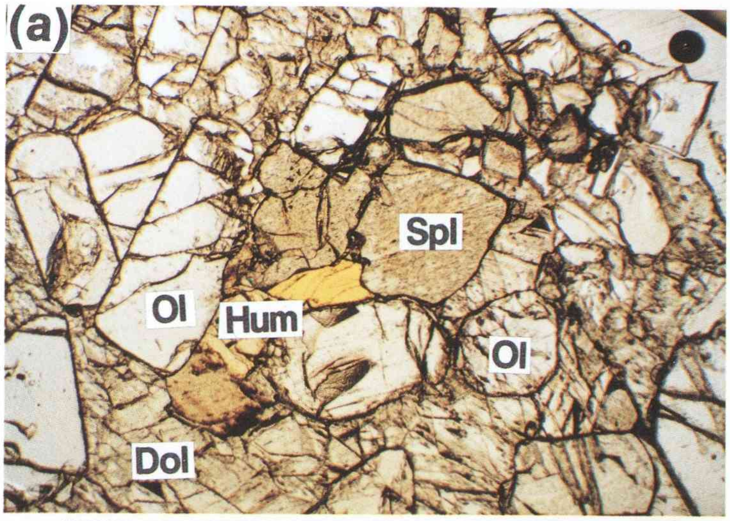
(b) A foot of the above granite peak crossed by MSZ. Dark layers are mylonitised amphibolite layers.



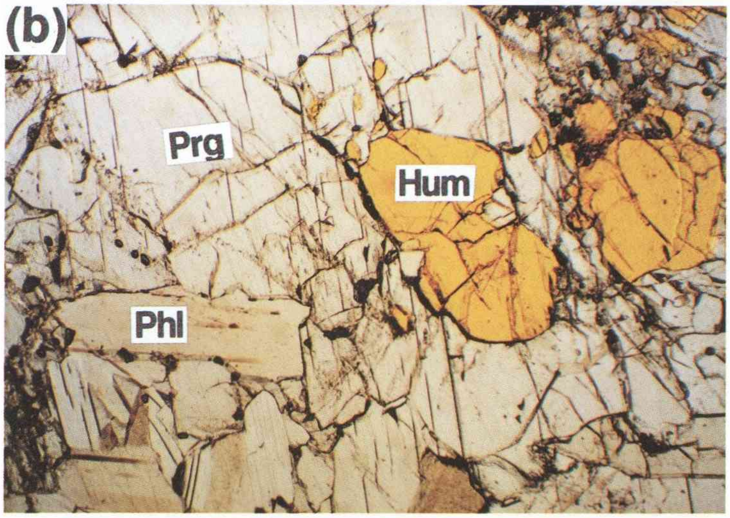
(c) Close up of the weakly mylonitised facies of Vengen granite.



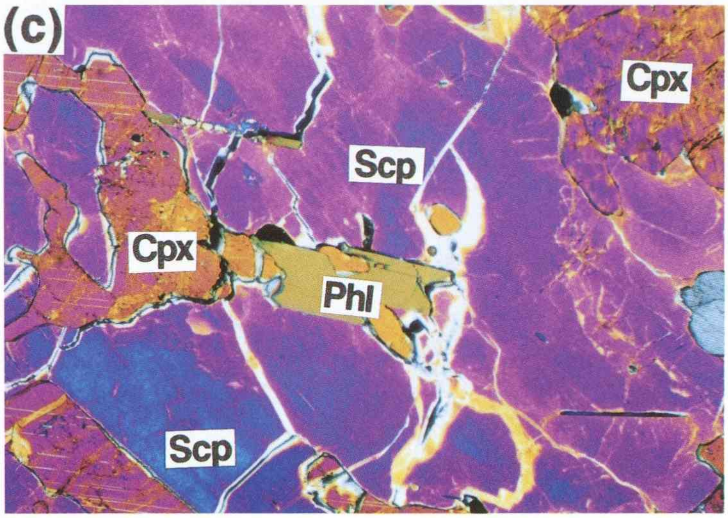
Various modes of occurrence of metatonalite associated with fragments of dark greenschist. (a) to (d) showing the successive sequence of the assimilation of the greenschist with the metatonalite. Loc. Nils Larsenfjellet.



(a) Photomicrograph of skarn (85020701A). Loc. Perlebandet. Dol: dolomite, Hum: humite, Ol: olivine, Spl: spinel. Open nicol. Width of photograph is 3.2 mm. Mineral abbreviations are common in all photographs.

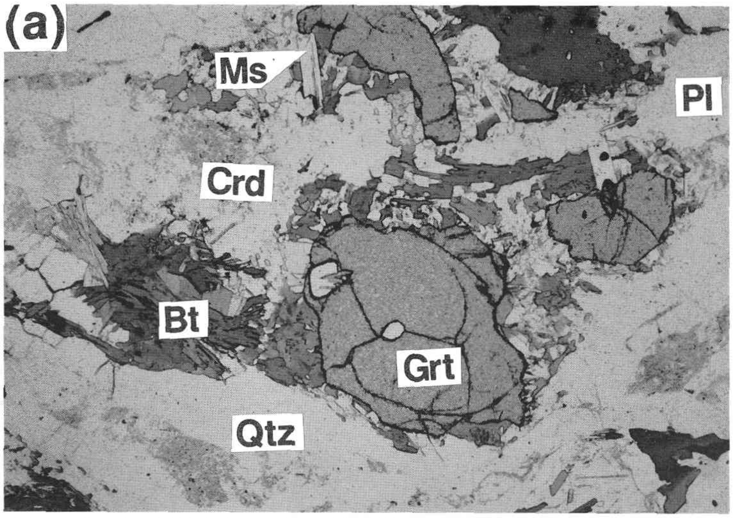


(b) Photomicrograph of skarn (85020701A). Loc. Perlebandet. Prg: pergasite, Phl: phlogopite. Open nicol. Width of photograph is 3.2 mm.

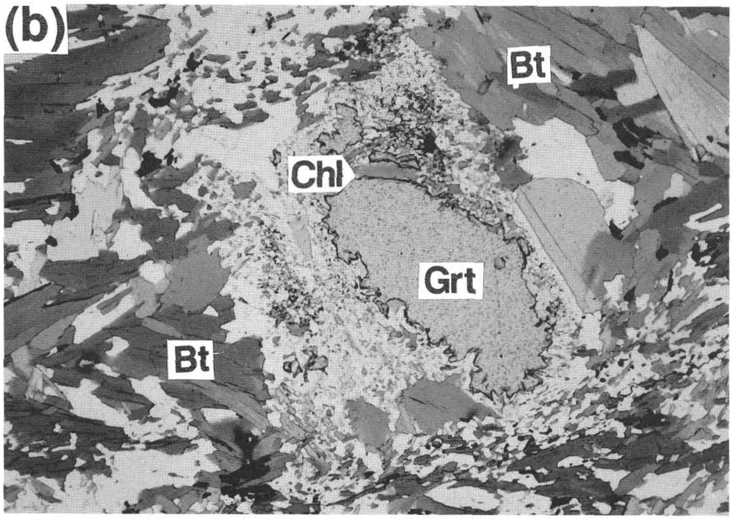


(c) Photomicrograph of skarn (85020702B). Loc. Perlebandet. Cpx: clinopyroxene, Scp: scapolite. Cross nicol. Width of photograph is 3.2 mm.

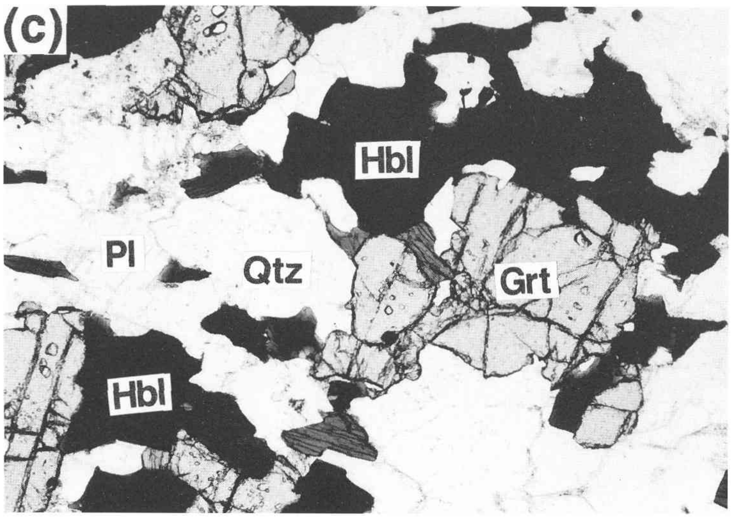
Plate 7



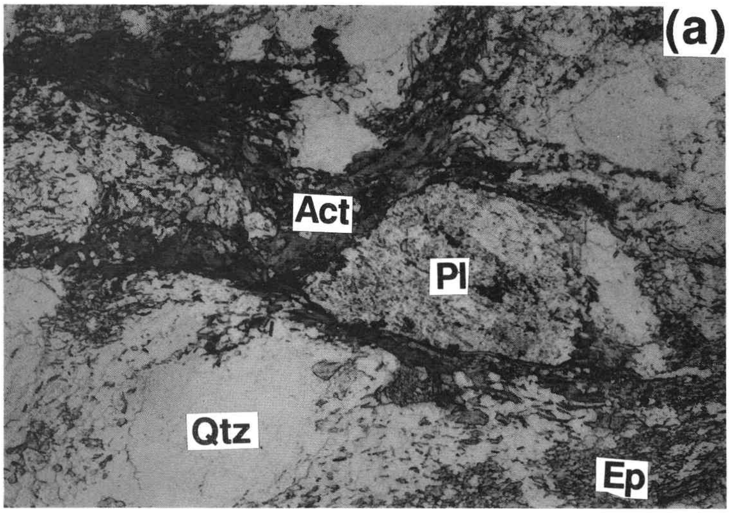
(a) Photomicrograph of garnet (Grt)-cordierite (Crd) gneiss (85020608B). Loc. Perlebandet. Bt: biotite, Pl: plagioclase, Ms: muscovite, Qtz: quartz. Open nicol. Width of photograph is 3.2 mm.



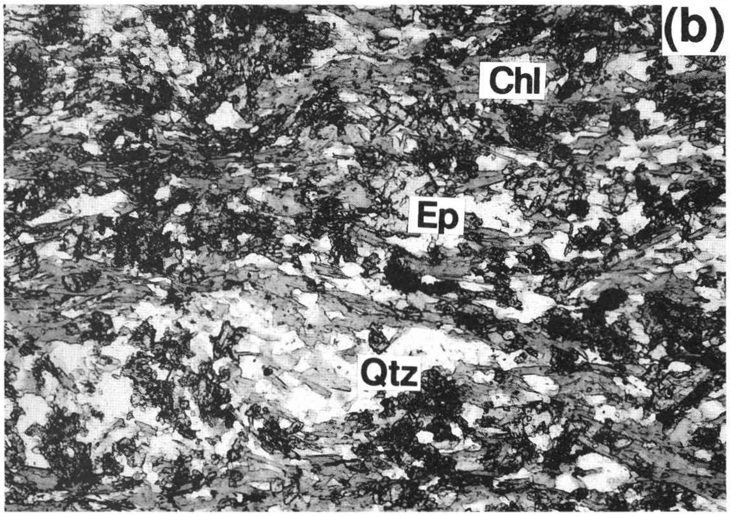
(b) Photomicrograph of garnet-biotite gneiss (85020105). Loc. Tanngarden. Note garnet breakdown to chlorite (Chl). Open nicol. Width of photograph is 3.2 mm.



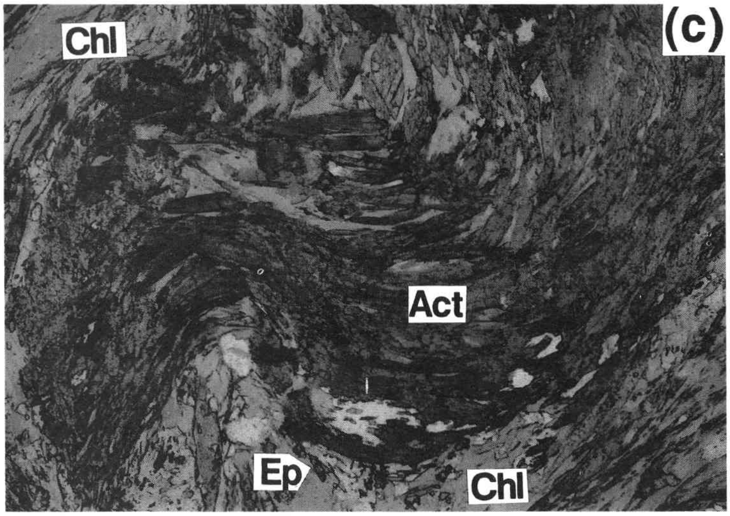
(c) Photomicrograph of garnet amphibolite (850202T1). Loc. Otto Borchgrevinkfjellet. Hbl: hornblende. Open nicol. Width of photograph is 3.2 mm.



(a) Photomicrograph of metatonalite (O90010708). Loc. Bamsefjell. Act: actinolite, Ep: epidote. Open nicol. Width of photograph is 3.2 mm.

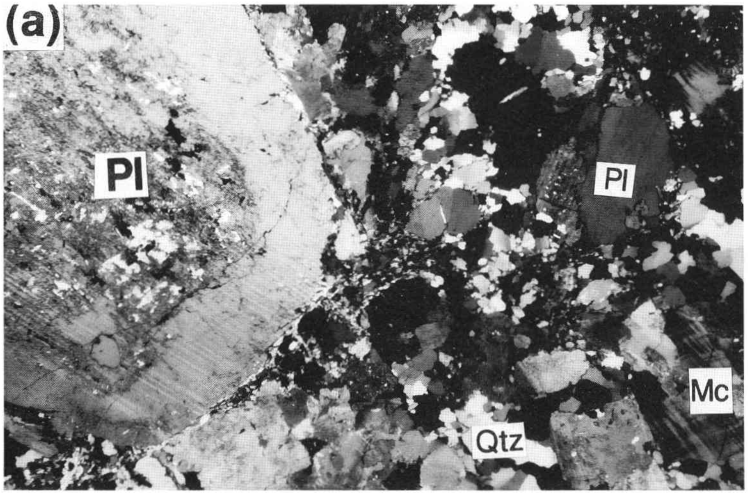


(b) Photomicrograph of chlorite (Chl)-epidote schist (85012302B). Loc. Smålegga. Open nicol. Width of photograph is 3.2 mm.

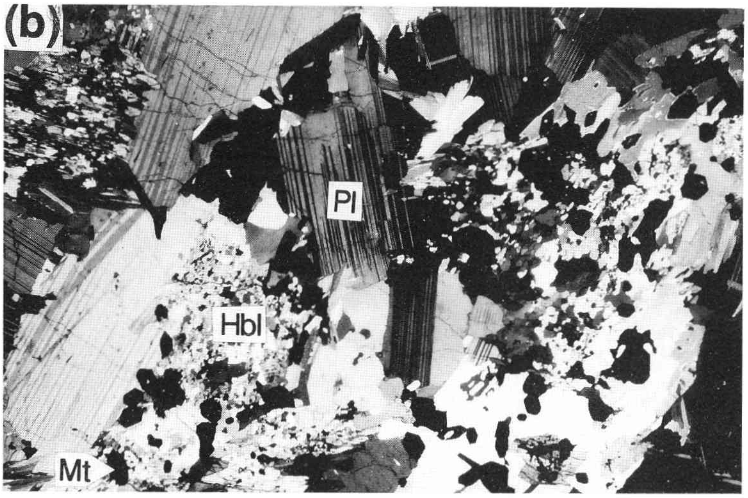


(c) Photomicrograph of folded actinolite-chlorite schist (85012513). Loc. Walnumfjella. Open nicol. Width of photograph is 3.2 mm.

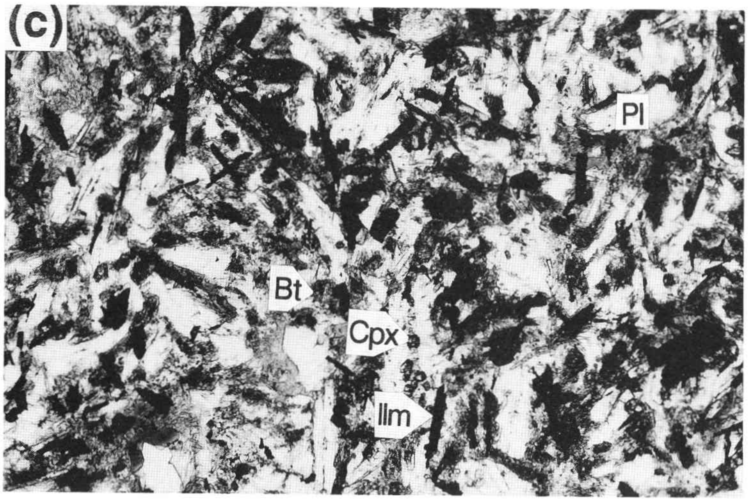
Plate 9



(a) Photomicrograph of slightly mylonitised Vengen granite (9091407). Loc. Kanino-tume Peak, Vengen. Mc: Microcline. Cross nicol. Width of photograph is 6.5 mm.



(b) Photomicrograph of Vesthovde diorite (84021205). Cross nicol. Width of photograph is 6.5 mm.

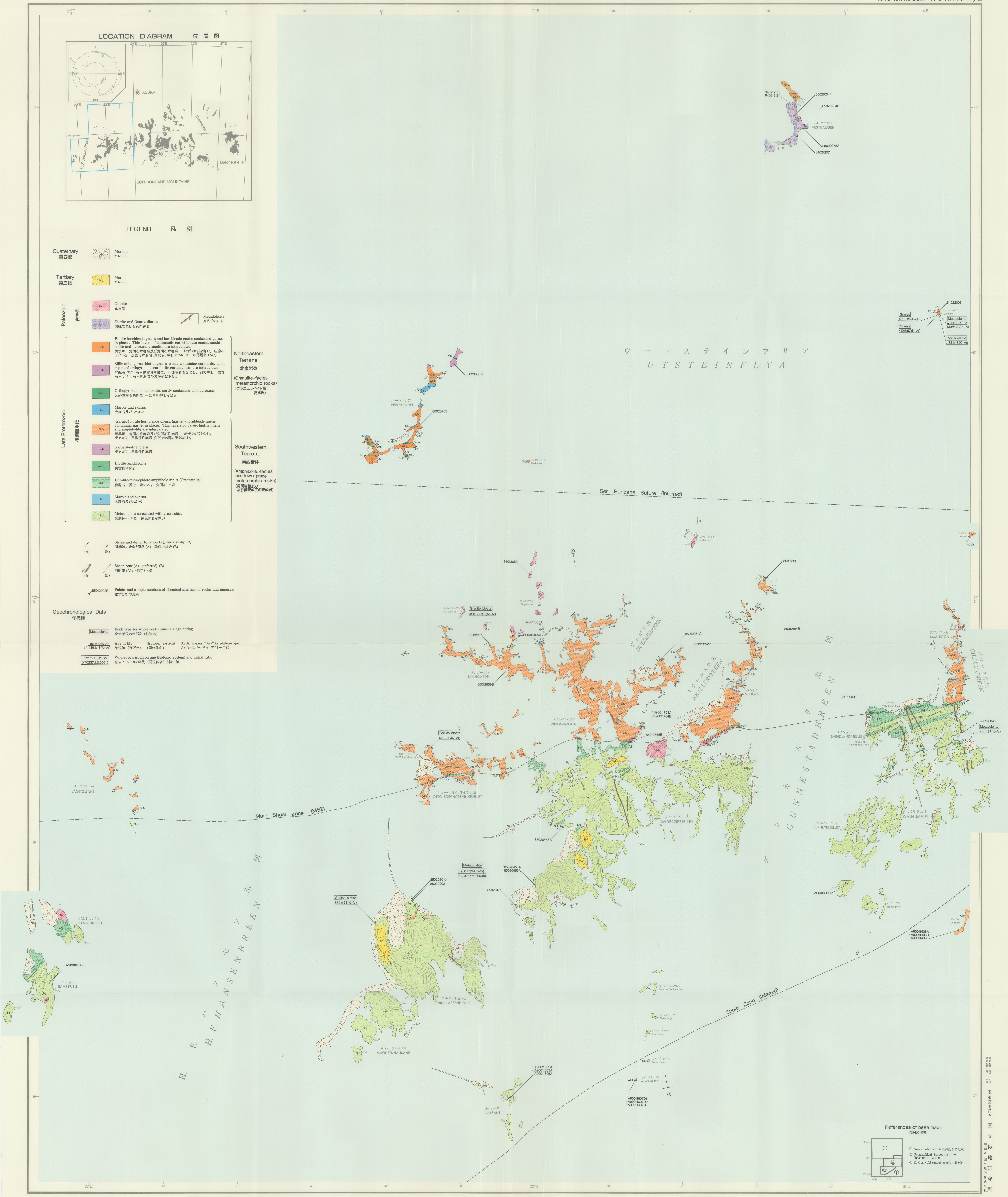


(c) Photomicrograph of metadolerite (85020355). Loc. Otto Borchgrevinkfjellet. Ilm: ilmenite. Open nicol. Width of photograph is 1.3 mm.

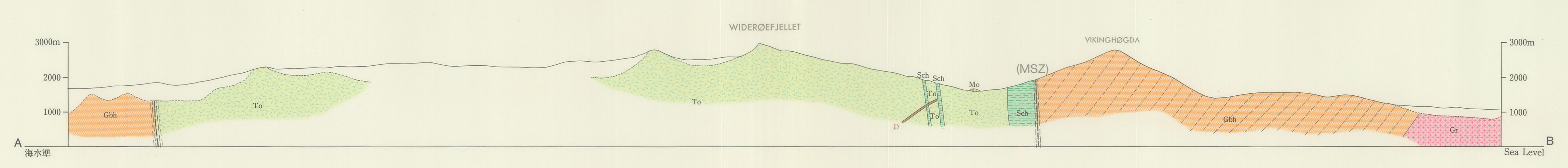
Antarctic Geological Map Series

Sheet 1	East Ongul Island 1:5,000	March 1974
Sheet 2	West Ongul Island 1:5,000	March 1974
Sheet 3	Teöya 1:5,000	March 1975
Sheet 4	Ongulkalven Island 1:5,000	March 1975
Sheet 5	Langhovde 1:25,000	March 1976
Sheet 6 & 7	Skarvsnes 1:25,000	March 1977
Sheet 8	Kjuka and Telen 1:25,000	March 1979
Sheet 9	Skallen 1:25,000	March 1976
Sheet 10	Padda Island 1:25,000	March 1977
Sheet 11	Cape Hinode 1:25,000	March 1978
Sheet 12	Lützow-Holm Bay 1:250,000	March 1989
Sheet 13	Prince Olav Coast 1:250,000	March 1989
Sheet 14	Sinnan Rocks 1:25,000	March 1983
Sheet 15	Cape Ryûgû 1:25,000	March 1980
Sheet 16	Akebono Rock 1:25,000	March 1986
Sheet 17	Niban Rock 1:25,000	March 1983
Sheet 18	Kasumi Rock 1:25,000	March 1984
Sheet 19	Tenmondai Rock 1:25,000	March 1985
Sheet 20	Akarui Point and Naga-iwa Rock 1:25,000	March 1984
Sheet 21	Cape Omega 1:25,000	March 1979
Sheet 22	Oku-iwa Rock 1:25,000	March 1981
Sheet 23	Honnör Oku-iwa Rock 1:25,000	March 1987
Sheet 24	Rundvågskollane and Rundvågshetta 1:25,000	March 1986
Sheet 25	Botnneset 1:25,000	March 1987
Sheet 26	Strandnibba 1:25,000	March 1985
Sheet 27(1)	Mt. Fukushima, Northern Yamato Mountains 1:25,000	March 1978
Sheet 28	Central Yamato Mountains, Massif B and Massif C 1:25,000	March 1982
Sheet 29	Belgica Mountains 1:25,000	March 1981
Sheet 30	Southern Yamato Mountains (Massif A and JARE-IV Nunataks) 1:25,000	March 1988
Sheet 31	Balchenfjella 1:100,000	March 1991
Sheet 32	Widerøefjellet 1:100,000	March 1992

GEOLOGICAL MAP OF WIDERØEFJELLET
ビーデレー山地質図



発行責任者：国立極地研究所
地質調査：白石和行 (1984)
白石和行・小嶋 智・森脇喜一 (1985)
矢内桂三 (1988)
森脇喜一・平川一臣 (1989)
小山内康人・田結庄良昭・高橋裕平・土屋範芳・白石和行 (1990)
編集者：白石和行・森脇喜一



縮尺 1 : 100,000 SCALE

NATIONAL INSTITUTE OF POLAR RESEARCH, TOKYO, JAPAN

Geological survey by Kazuyuki SHIRAISHI in 1984
Kazuyuki SHIRAISHI, Satoru KOJIMA and Kiichi MORIWAKI in 1985
Keizo YANAI in 1988
Kiichi MORIWAKI and Kazuomi HIRAKAWA in 1989
Yasuhito OSANAI, Yoshiaki TAINOSHO, Yuhei TAKAHASHI, Noriyoshi TSUCHIYA and Kazuyuki SHIRAISHI in 1990
Compiled by Kazuyuki SHIRAISHI and Kiichi MORIWAKI

1992
WIDERØEFJELLET
ビーデレー山地質図
1 : 100,000