JAPANESE ANTARCTIC RESEARCH EXPEDITION

ANTARCTIC GEOLOGICAL MAP SERIES
SHEET 27 NORTHERN YAMATO MOUNTAINS
(2) MT. TORIMAI

Explanatory Text of Geological Map
of
the Northern Yamato Mountains, Antarctica
(2) Mt. Torimai

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TOKYO, MARCH 1995

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1. The Yamato Mountains

The Yamato Mountains are situated at 71°15'-72°05'S latitude and 34°45'-36°55'E longitude in Queen Maud Land, East Antarctica. The mountains extend for about 60 km north-south, and are made up of Massifs A to G from the south to the north and several nunataks. They rise 100-800 m above the ice sheet surface of 1500-2200 m above sea level, including the highest peak, Mt. Fukushima (2494 m), in Massif D.

After the first finding of the mountains from the air in 1937 by the Norwegian party led by L. CHRISTENSEN, and the subsequent confirmations of the existence from the air in 1960 by the Belgian party, ground parties of the Japanese Antarctic Research Expedition (JARE) visited the mountains for scientific studies. Geological investigation of the Yamato Mountains was first carried out by K. KIZAKI of JARE-4 in 1960. He made a geological map of the area (1:100,000 in scale) and described the outline of the geology and petrography (KIZAKI, 1965; TATSUMI and KIZAKI, 1969; OHTA and KIZAKI, 1966). In 1969, M. YOSHIDA and H. ANDO of JARE-10 surveyed the JARE-IV Nunataks in the southeastern part and some other areas of the mountains (YOSHIDA and ANDO, 1971). A more detailed geological survey of Massifs D, E, F and G was made in 1973 by K. SHIRAISHI of JARE-14 (SHIRAISHI, 1977; SHIRAISHI *et al.*, 1978). K. YANAI of JARE-15 and Y. MATSUMOTO of JARE-16 traced unsurveyed areas in 1974 and 1975, respectively. K. YANAI, T. NISHIDA and H. KOJIMA of JARE-20 resurveyed Massif C and JARE-IV Nunataks in the 1979-80 season (YANAI *et al.*, 1982). K. SHIRAISHI, M. ASAMI and Y. OHTA of JARE-21 surveyed Massifs A and B in detail and reexamined Massifs D, E, F and G in the same season and K. SHIRAISHI did additional field work on Massif A in the next season (SHIRAISHI *et al.*, 1982, 1983b; ASAMI and SHIRAISHI, 1983, 1985). T. KATSUSHIMA of JARE-23 surveyed Massif A and the Southern Yamato Nunataks in 1982-1983. Y. MOTOYOSHI of JARE-33 surveyed Massifs D, E, F and G for additional mapping in 1992.

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2. Geology of Mt. Torimai and the Northern Areas

2.1. General geology

Mt. Torimai and the northern areas include Massifs E, F and G from south to north and small nunataks. The Yamato Mountains, as a whole, are composed of high-grade metamorphic rocks, syenitic rocks and granitic rocks. In particular, widespread igneous activity is characteristic. Because orthopyroxene is a common mineral in two-pyroxene biotite gneiss, the metamorphic grade has attained granulite-facies conditions, whereas mineral parageneses in the granitic gneiss and biotite amphibolite suggest the amphibolite-facies conditions (SHIRAISHI *et al.*, 1982; ASAMI and SHIRAISHI, 1983).

The Yamato Mountains belong to the Yamato-Belgica Complex of HIROI *et al.* (1991) which is characterized by low-pressure type metamorphism, *c.* 750°C and less than 6 kbar (ASAMI and SHIRAISHI, 1985; SHIRAISHI *et al.*, 1987) and widespread igneous activity (KIZAKI, 1965; SHIRAISHI *et al.*, 1983a, b; ZHAO *et al.*, 1995) relative to the neighboring Lützow-Holm Complex (HIROI *et al.*, 1991).

The isotopic data, including the recent ion microprobe (SHRIMP) U-Pb zircon dating, have been obtained from throughout the Yamato Mountains (Table 1) and the present region (Table 2).

2.2. Geology and petrography of the Mt. Torimai and the northern areas

The rocks of Mt. Torimai and the northern areas can be classified into the following rock types on the basis of the mode of occurrence, lithologic facies and mineral assemblages. Abbreviations in parentheses correspond to the legend of the geological map.

1) Clinopyroxene syenite (Sc)

2) K-feldspar porphyritic two-pyroxene syenite (Sp)

3) Orthopyroxene- and garnet-bearing aplitic granite (Gr)

4) Orthopyroxene-biotite gneiss (Gn)

5) Mafic granulite (Gm)

6) Marble (M)

7) Pegmatite (P)

The syenites were once described as syenite gneisses (SHIRAISHI, 1977; SHIRAISHI *et al.*, 1978). However later field investigations in the whole mountains revealed that most syenites are free from deformation and recrystallization (YANAI *et al.*, 1982; SHIRAISHI *et al.*, 1982, 1983b). Thus they are believed to have been emplaced during the waning stages of the regional metamorphism. Bulk chemical analyses of the representative rocks are listed in Table 3. Mineral abbreviations in the Plates are after KRETZ (1983).

2.2.1. Clinopyroxene syenite (Sc)

Clinopyroxene syenite is a major rock type in the region, and is very heterogeneous in terms of mineral assemblages, modal composition and texture. The main constituent minerals are clinopyroxene, Ca-amphibole, biotite, K-feldspar, and sodic plagioclase (An 4-15) with or without quartz (Plate 4A). The accessory minerals are zircon, allanite, ilmenite, magnetite, hematite and pyrite. Clinopyroxene is diopsidic with high Na_2O of up to 1.5wt%. Ca-amphibole is edenitic to edenitic hornblende, and it generally replaces clinopyroxene and rarely biotite. K-feldspar generally occurs as vein-type perthite. Sodic plagioclase usually occurs as patches or veins in perthite or as small blebs along the grain boundaries of K-feldspar.

Table 1. Rb-Sr, K-Ar and U-Pb ages from the Yamato Mountains.

Method	Age(Ma)	Rock and Mineral	Locality	Specimen No.	Ref.
Rb-Sr	718.4±33.7	gneisses	Massif A	A107, A108	1
	(I* = 0.70899±0.00026)			A529, A530	
Rb-Sr	696±165	gneisses	Massif A	A100, A119, A120C	1
	(I* = 0.70725±0.00078)			A512, A548A	
Rb-Sr	493.3±4.5	biotite, K-feldspar, plagioclase (gneiss)	Massif A	Y80A529	4
	(I* = 0.71548±0.00008)				
Rb-Sr	466±3	biotite, hornblende, K-feldspar (syenite)	Massif E	73120405	**
	(I* = 0.70624±0.00032)				
	457	biotite (granitic gneiss)	Massif D	YD218	2
	383	K-feldspar (gneiss)		A08	3
K-Ar	483±15	biotite (two pyroxene-biotite gneiss)	Massif A	Y80A120C	4
	469±14	biotite (orthopyroxene-biotite gneiss)	Massif A	Y80A529	4
	442±22	pyroxene	Massif A	A79121411	5
	411±21	syenite	Massif A	K79122607	5
	401±20	hornblende-biotite gneiss	Massif A	A79121504	5
	400±20	syenite	Massif C	K79112910	6
	363±18	augen gneiss	Massif C	74121709	6
	363±18	syenite	Massif C	N79120112	6
	359±18	syenite	Massif C	A79120102	6
U-Pb	~2470	zircon (core)	Massif A	Y80A530	7
(SHRIMP)	~500-600	zircon (rim)	Massif A	Y80A530	7

*initial ratio. **see Table 2.
Ref.: 1, SHIBATA *et al.* (1986); 2, PICCIOTTO and COPPEZ (1964); 3, MAEGOYA *et al.* (1968); 4, SHIBATA *et al.* (1985); 5, KOJIMA *et al.* (1982); 6, YANAI *et al.* (1982); 7, SHIRAISHI *et al.* (1994).

The Rb-Sr mineral isotope analyses for a clinopyroxene syenite (sp. 73120405) yields 466 ± 3 Ma with an initial ratio of 0.70624 ± 0.00032 (Table 2). This can probably be looked upon as a two point isochron since three of the samples formed a cluster and the biotite defined the isochron. However, this age is in good agreement with the Rb-Sr mineral isochron age of orthopyroxene-biotite gneiss from Massif A (Table 1, SHIBATA *et al.*, 1985).

Table 2. Rb-Sr analytical data for a clinopyroxene syenite (sp. 73120405) from the northern Yamato Mountains.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	±
Whole rock	142	1827	0.225	0.70721	0.0001
Biotite	798	142	16.44	0.81535	0.00025
Hornblende	16	593	0.077	0.70671	0.0001
K-feldspar	130	5445	0.0691	0.70726	0.00015

Analyst: Teledyne Isotopes.

2.2.2. K-feldspar porphyritic two-pyroxene syenite (Sp)

K-feldspar porphyritic two-pyroxene syenite characterized by dark gray feldspar and quartz occurs as layers within the clinopyroxene syenite (Plate 2B). Schlieren-like contact of the clinopyroxene syenite and the K-feldspar porphyritic two-pyroxene syenite is characteristically seen in Massif E (Plate 3A). The main constituent minerals are biotite, clinopyroxene, orthopyroxene, plagioclase and abundant K-feldspar with or without quartz (Plate 4B and 4C). The biotite has up to 5wt% TiO_2. The K-feldspar characteristically contains aligned globules and needles of ilmenite and hematite. Ca-amphibole occurs only as small patches in clinopyroxene. Accessory minerals are apatite, zircon, ilmenite, with rare magnetite and pyrite. Petrography of this syenite was described in detail by OHTA and KIZAKI (1966).

2.2.3. Orthopyroxene- and garnet-bearing aplitic granite (Gr)

Orthopyroxene- and garnet-bearing aplitic granite shows diffuse contacts against the syenites and occasionally displays a nebulitic structure, or lit-par-lit injection in the syenites (Plate 3B). The constituent minerals are garnet, orthopyroxene, biotite, plagioclase, K-feldspar and quartz, and minor opaque mineral and zircon. Orthopyroxene and garnet occur as separate crystals (Plate 5A). Biotite is probably of secondary origin, partly replacing orthopyroxene and garnet. K-feldspar is perthite and plagioclase is characterized by albite twinning and partly with myrmekitic texture. The texture of orthopyroxene- and garnet-bearing aplitic granite is totally subhedral equigranular, suggesting plutonic origin.

2.2.4. Orthopyroxene-biotite gneiss (Gn)

Table 3. Chemical compositions of rocks from the northern Yamato Mountains.

Sp. No.	73120203	73120204	73120208	73120402	73120405	73120510	73120601	73120606	Y80G8
Rock type#	A	A	A	B	B	B	A	A	C
Major element(%)									
SiO_2	57.09	59.41	62.03	58.71	49.41	59.02	58.03	55.97	73.91
TiO_2	0.99	1.05	1.09	0.88	1.59	0.99	0.99	0.96	0.13
Al_2O_3	13.73	13.36	14.52	14.32	7.49	14.51	14.33	13.72	13.67
Fe_2O_3	1.42 *	1.04	0.99	1.56	3.35	1.34 *	1.38 *	1.43	0.41 *
FeO	3.82	4.19	3.46	3.77	5.60	3.62	3.73	4.26	1.11
MnO	0.08	0.09	0.10	0.08	0.14	0.08	0.09	0.09	0.03
MgO	3.95	3.65	2.42	3.56	9.06	2.79	3.25	5.51	0.14
CaO	4.29	3.68	3.03	3.98	9.34	3.56	4.21	5.36	1.82
Na_2O	3.23	2.58	3.84	3.38	2.84	3.96	3.60	3.33	3.29
K_2O	7.19	6.93	6.44	6.63	3.18	7.22	7.13	5.92	4.36
P_2O_5	0.70	1.08	0.50	0.66	3.40	0.54	0.67	0.85	0.02
LOI	n.d.	1.89	0.91	1.76	3.30	n.d.	n.d.	1.88	n.d.
Rest	n.d.	1.17	0.63	0.66	1.17	n.d.	n.d.	0.69	n.d.
Total	96.49	100.02	99.96	99.95	99.87	97.63	97.41	99.97	98.89
C.I.P.W. norms									
Q	-	7.20	6.48	2.18	0.02	-	-	-	33.33
C	-	-	-	-	-	-	-	-	0.28
Or	42.49	41.63	38.67	40.17	19.70	42.67	42.14	35.92	25.77
Ab	27.33	22.52	33.02	29.33	21.83	33.51	30.46	28.93	27.84
An	1.73	4.85	3.42	4.43	-	0.49	1.88	5.14	8.9
Ne	-	-	-	-	-	-	-	-	-
Di	7.56	5.46	6.97	9.22	20.18	11.09	11.86	13.24	-
Hy	4.51	12.16	6.71	9.07	20.29	2.64	3.14	4.73	1.89
Ol	2.79	-	-	-	-	2.16	2.50	6.03	-
Mt	2.06	1.56	1.46	2.32	3.61	1.94	2.00	2.13	0.59
Il	1.88	2.06	2.10	1.71	3.17	1.88	1.88	1.87	0.25
Ap	1.62	2.64	1.20	1.60	8.44	1.25	1.55	2.07	0.05
Trace element(ppm)									
Sc		10	7	11	20			13	
Cr	188	142	116	171	666	67	111	281	<1
V	112	86	60	80	135	118	109	123	13
Ni	30	57	17	19	222	19	20	30	4
Cu	6	10	6	14	9	7	4	14	<1
Zn	77	127	62	92	172	66	67	84	44
Ga		21	26	24	15			21	
Ba	2994	5077	2245	2470	2095	3168	2842	3087	1151
Rb	266	244	252	381	90	268	220	281	119
Sr	1548	2083	1176	1124	2341	1618	1498	1027	174
Pb		34	33	50	23			35	
Th		19	50	39	50			5	
U		4	5	6	8			2	
Hf		26	16	16	46			6	
Zr	641	810	572	481	1583	808	512	177	126
Nb	20	22	45	33	58	39	32	10	7
Y	43	40	42	40	109	39	39	31	21
La		111	88	67	452			41	
Ce		230	191	134	901			91	
Nd		104	81	66	309			49	
Source	M	Z	Z	Z	Z	M	M	Z	M

#Rock type: A, K-feldspar porphyritic two-pyroxene syenite; B, Clinopyroxene syenite; C, Aplitic granite.
*Estimated value assuming Fe_2O_3 = (Total Fe_2O_3)/4.
Source: M, MOTOYOSHI (unpublished); Z, ZHAO *et al.* (1995).

Orthopyroxene-biotite gneiss occurs in Massif G. The foliation of orthopyroxene-biotite gneiss is generally weak, and occasionally it occurs as discordant layers in quartzofeldspathic rocks. The constituent minerals are orthopyroxene, biotite, amphibole, plagioclase, K-feldspar (perthitic) and quartz, with minor zircon and opaque minerals (Plate 5B). Plagioclase is characterized by albite twinning without distinctive zonal structure. The texture is typical subhedral equigranular. On the basis of the mineral assemblage, this rock is referred to be "charnockite" in a strict sense.

2.2.5. Mafic granulite (Gm)

Mafic granulite occurs as isolated lenses in quartzofeldspathic biotite gneisses at the northern part of the region. It consists of clinopyroxene, orthopyroxene, green hornblende, plagioclase, biotite and opaque mineral (Plate 6A). Orthopyroxene occurs as irregular-shaped crystal being interlocked with plagioclase. Green hornblende and biotite are probably of secondary origin, because they occur intersticially between orthopyroxenes. Unidentified opaque minerals occur as rounded grains in orthopyroxene.

2.2.6. Marble (M)

Marble occurs as concordant layers at the northern part of the region. The constituent minerals are calcite with less scapolite, phlogopite, clinopyroxene, graphite and zircon as other constituents. Scapolite and clinopyroxene are rounded grains completely surrounded by calcite. Abundant graphite is one of the characteristics of the marble (Plate 6B).

Calc-silicate rock is associated with marble, and is composed of wollastonite, scapolite, clinopyroxene, anorthitic plagioclase, calcite, quartz, graphite, sphene and zircon (Plate 6C). Scapolite shows zonal structure with the retardation decreasing from core to rim. Calcite and quartz are associated next to wollastonite. Judging from the mode of occurrence, this association is a breakdown product after wollastonite.

2.2.7. Pegmatite (P)

Pegmatite occurs on a small scale in the region. It intruded the basement gneisses, but sometimes the contact with the basement gneisses is unclear. The constituent minerals are essentially K-feldspar, plagioclase and quartz, with secondary calcite and biotite occasionally.

3. Geologic Structure

Foliation is defined as a small scale layered structure in handspecimen. The foliation of syenites in Massifs E and F generally trends in a NE-SW direction and dips to the east. The foliation shows a half basin structure open to the north at the southern part of Massif E, suggesting an original igneous structure. In Massif G, the foliation which is parallel to the layered structure of up to several tens meters wide trends ENE-WSW and monoclinally dips to the north. These trends in foliation are closely correlated with the morphological arrangement of the massifs in the northern Yamato Mountains.

4. Conditions of Metamorphism and Plutonism

With respect to the *P-T* conditions of metamorphism, SHIRAISHI *et al.* (1983b), ASAMI and SHIRAISHI (1985) and SHIRAISHI *et al.* (1987) pointed out that the Yamato Mountains have undergone low-pressure conditions as evidenced by the wollastonite-anorthite association in calc-silicate rocks from the southern part of the Mountains. From the northern Yamato Mountains, wollastonite-anorthite association, which is almost equivalent to that reported by ASAMI and SHIRAISHI (1985), is also reported from a calc-silicate rock. Moreover, experimental studies on amphiboles in syenites (OBA and SHIRAISHI, 1993, 1994) revealed that the amphiboles crystallized at pressures lower than 3 kbar. On the basis of the geochemical investigations, ZHAO *et al.* (1995) proposed that the syenites in the Yamato Mountains were generated by fractionation and magma mixing of a silica-undersaturated alkali basaltic magma with a crustal melt in a lower-crust magma chamber, followed by further crystal fractionation/cumulate-melt unmixing at middle to upper crustal levels (< 5 kbar). These lines of evidence probably confirm that the northern Yamato Mountains have also been subjected to low-pressure conditions, and the syenites are believed to have been emplaced during the waning stages of the regional metamorphism.

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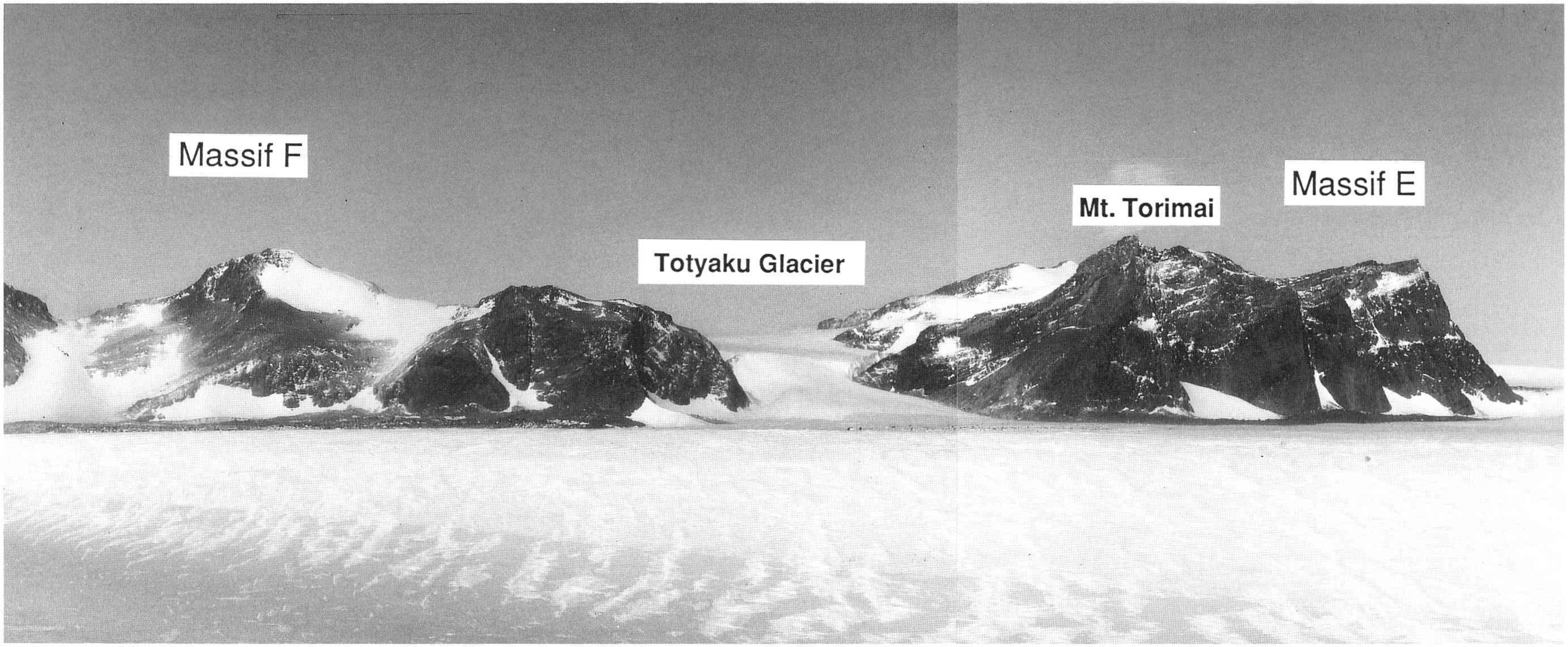
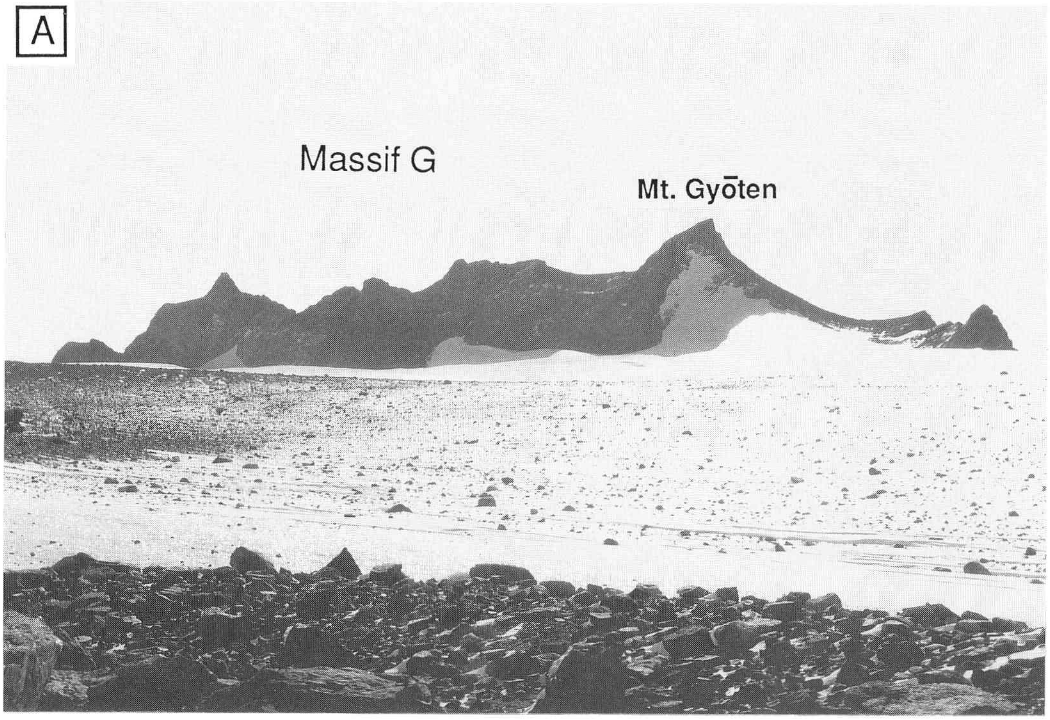


Massifs E and F viewed from west.

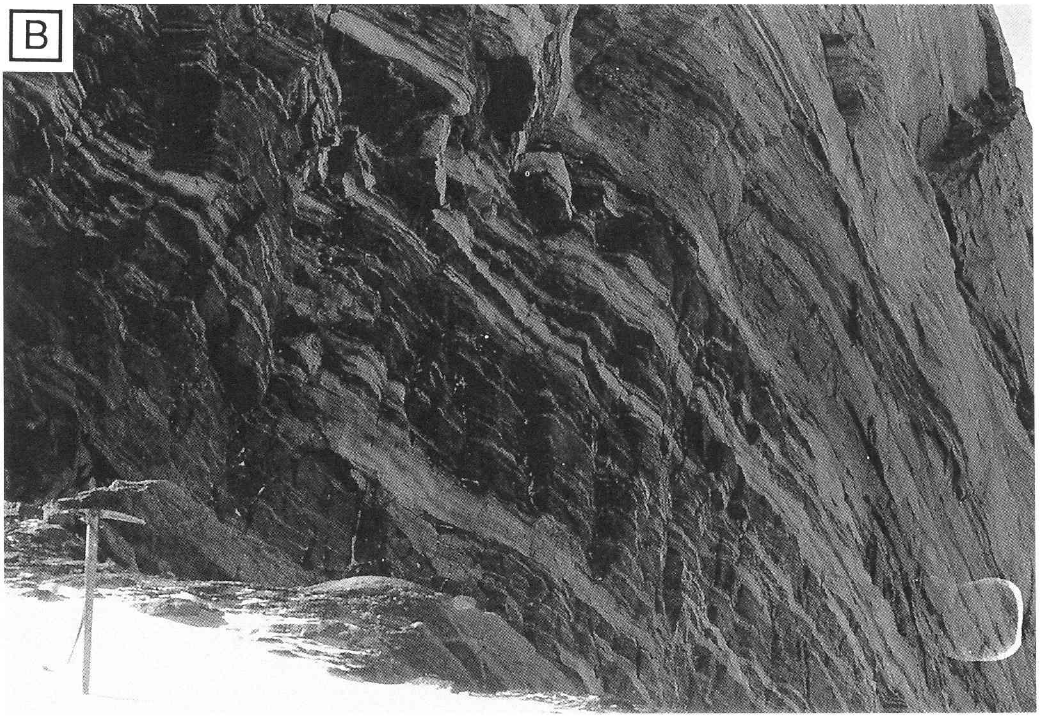
Plate 2



A. Massif G viewed from south.

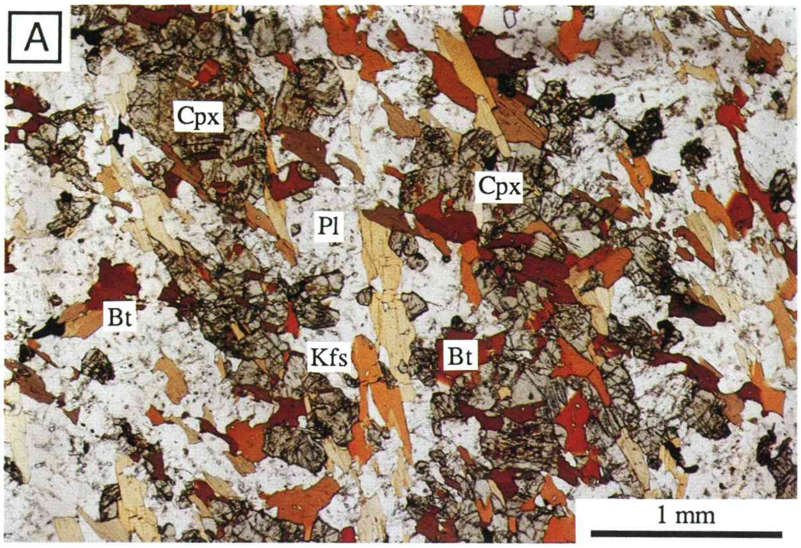
B. Weathered surface of K-feldspar porphyritic two-pyroxene syenite. Large dark-colored K-feldspar porphyroblasts are shown (Massif G).

A. Schlieren-like contact of K-feldspar porphyritic two-pyroxene syenite and clinopyroxene syenite (Massif E).

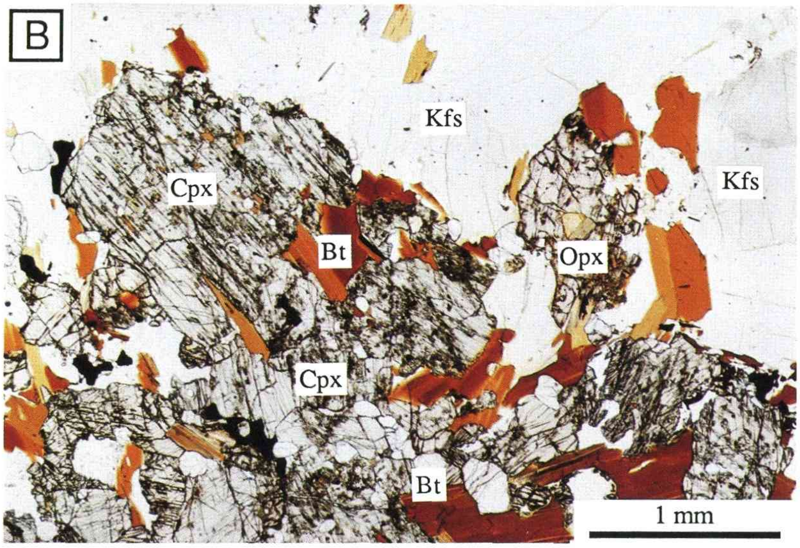


B. Lit-par-lit injection of aplitic granite in syenite (Massif G).

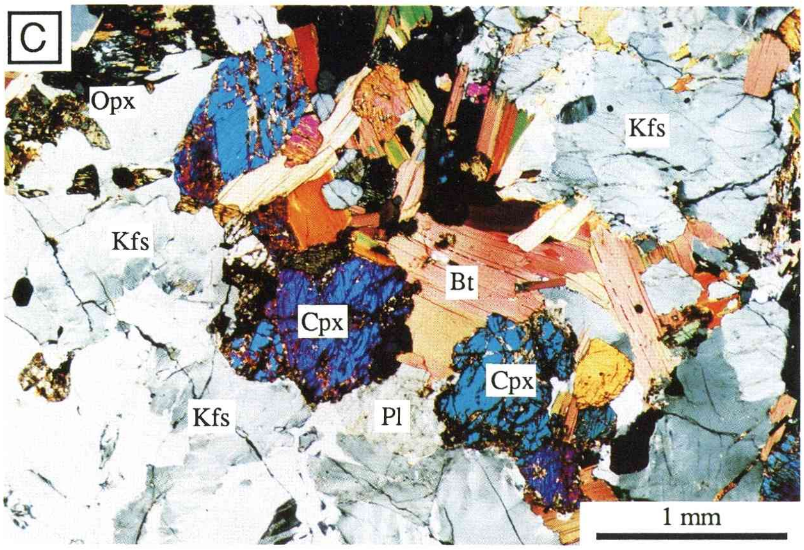
Plate 4



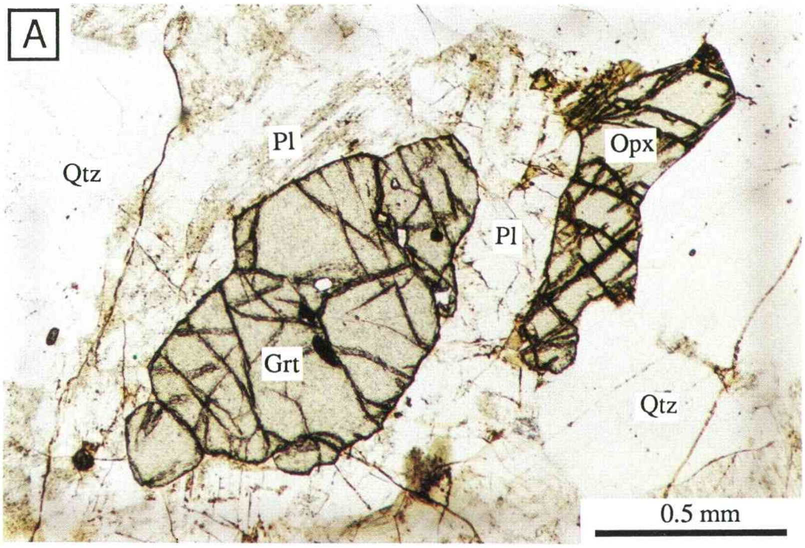
A. Clinopyroxene syenite composed of Cpx, Bt, Pl and Kfs as main constituents (Sp. 92110802C).



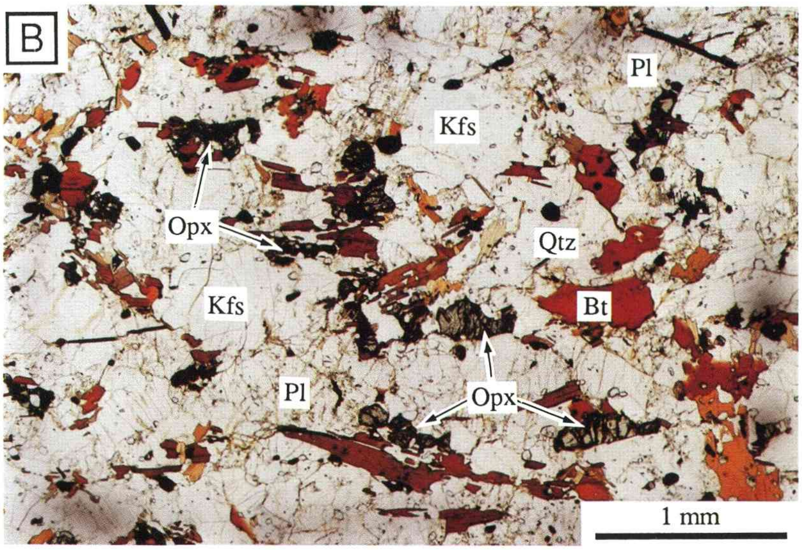
B. K-feldspar porphyritic two-pyroxene syenite composed of Cpx, Opx, Bt and Kfs as main constituents (Sp. 73120606).



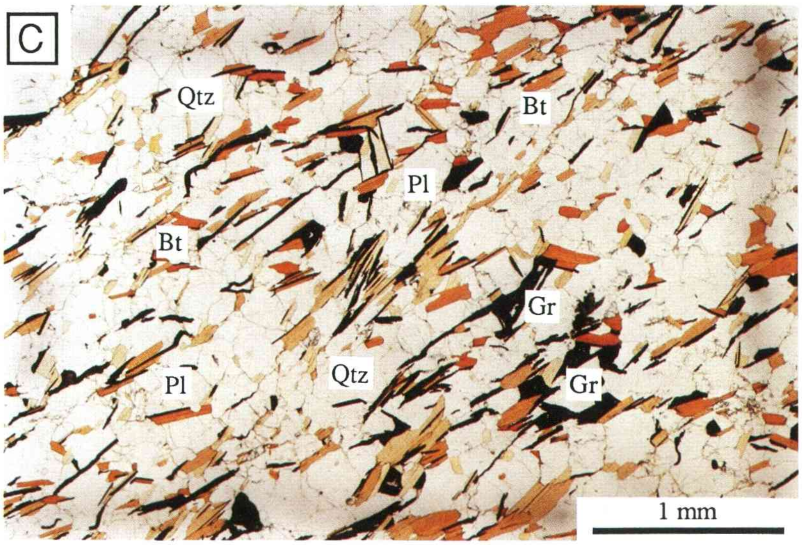
C. K-feldspar porphyritic two-pyroxene syenite composed of Cpx, Opx, Bt and Kfs as main constituents (Sp. 73120203).



A. Orthopyroxene- and garnet-bearing aplitic granite composed of Grt, Opx, Bt, Pl and Qtz as main constituents (Sp. 73120504).

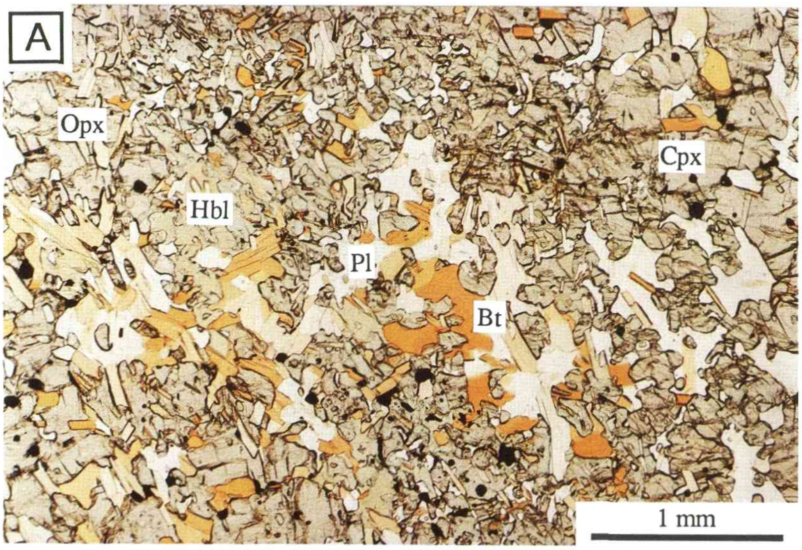


B. Orthopyroxene-biotite gneiss composed of Opx, Bt, Kfs, Pl and Qtz as main constituents (Sp. 92110905).

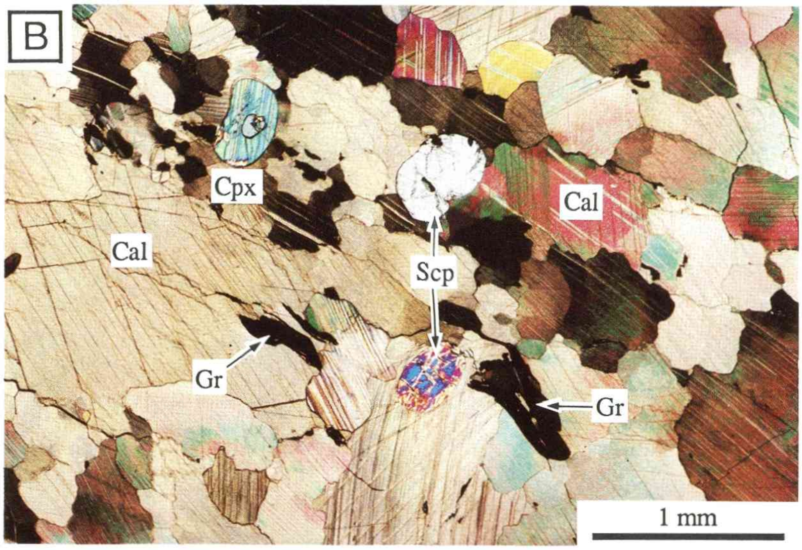


C. Biotite gneiss composed of Bt, Gr, Pl and Qtz as main constituents (Sp. 92110904).

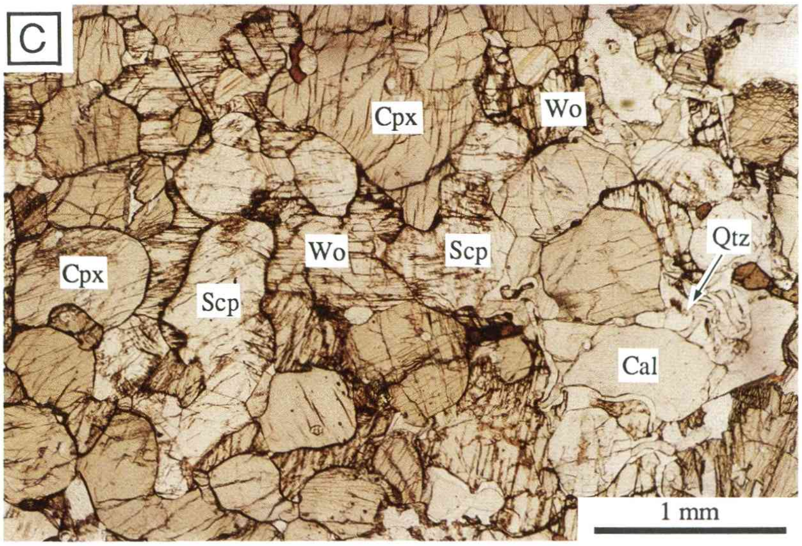
Plate 6



A. Mafic granulite composed of Cpx, Opx, Hbl, Bt and Pl as main constituents (Sp. 92110901A).



B. Marble composed of Cal, Cpx, Scp and Gr as main constituents (Sp. 92110802A).



C. Calc-silicate rock composed of Cpx, Wo, Scp, Cal and Qtz as main constituents (Sp. 92110801C).

Antarctic Geological Map Series

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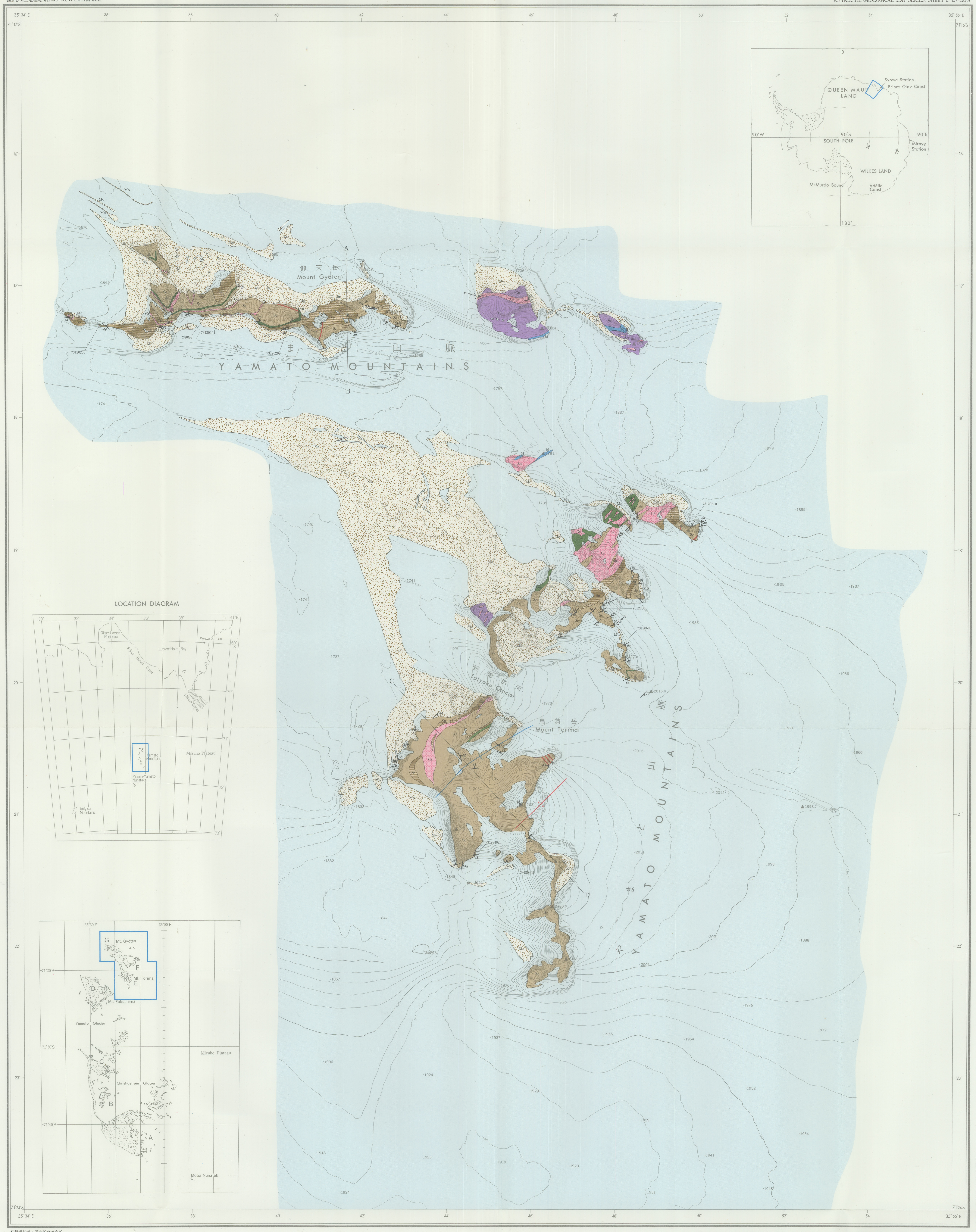
GEOLOGICAL MAP OF THE NORTHERN YAMATO MOUNTAINS
(2) MT. TORIMAI
やまと山脈北部地質図
(2) 鳥舞岳

地形は国土地理院刊行25,000分の1地形図による。

ANTARCTIC GEOLOGICAL MAP SERIES, SHEET 37 (2) (1995)



LEGEND
凡例

- Mo — Morain モレーン
- P — Pegmatite ペグマタイト
- Gr — Orthopyroxene- and garnet-bearing aplitic granite 斜方輝石ザクロ石含有アプライト質花崗岩
- Sc — Clinopyroxene syenite 単斜輝石閃長岩
- Sp — K-feldspar porphyritic two-pyroxene syenite カリ長石斑状変晶両輝石閃長岩
- Gn — Orthopyroxene-biotite gneiss 斜方輝石黒雲母片麻岩
- Gm — Mafic granulite 苦鉄質グラニュライト
- M — Marble (locally with calc-silicate rock) 大理石（所々に珪灰質岩を伴う）
- Banding, foliation, or schistosity planes 縞状構造、葉理構造、または片状構造
- Mineral lineation 鉱物線構造
- Axial trace, antiform or synform 軸褶曲
- 73120203 Point of sample and number analyzed chemically 化学分析値の地点および試料番号
- ▲ 2056 Triangular point 三角点
- · 2031 Spot height 標準点

平成七年三月二十五日印刷
平成七年三月三十一日発行

著作権所有兼発行者 国立極地研究所
印刷所 国土地図株式会社

NATIONAL INSTITUTE OF POLAR RESEARCH, TOKYO, JAPAN

1 : 25,000

発行責任者：国立極地研究所
地質調査：木崎甲子郎 1960
安藤久男 1970
吉田 勝 1970
白石和行 1973、1980
松本徑夫 1975
矢内桂三 1979
西田民雄 1979
小島秀康 1979
浅見正雄 1980
太田昌秀 1980
本吉洋一 1992
編集者：本吉洋一、白石和行

Geological Survey by Koshiro KIZAKI in 1960
Hisao ANDO in 1970
Masaru YOSHIDA in 1970
Kazuyuki SHIRAISHI in 1973 and 1980
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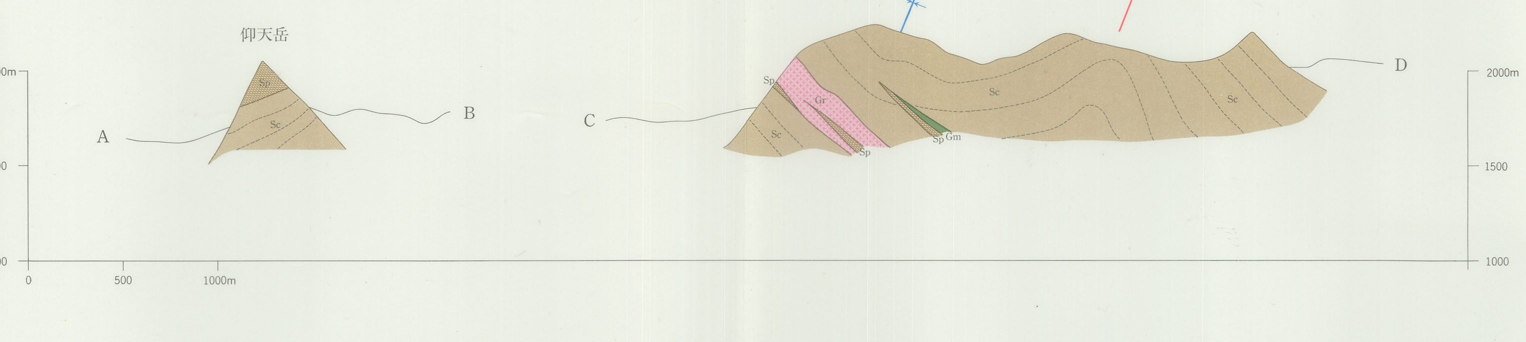
Compiled by Yoichi MOTOYOSHI and Kazuyuki SHIRAISHI



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