NATIONAL INSTITUTE OF POLAR RESEARCH

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SHEET 15 CAPE RYÛGÛ

Explanatory Text of Geological Map of Cape Ryûgû, Antarctica

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1. Introduction

The Cape Ryûgû region lies on the Prince Olav Coast, East Antarctica. It is located at 67°58′S in latitude and 43°55′E–44°10′E in longitude, about 220 km northeast of Syowa Station, has an ice-free area of 10 km in the east-west length with a width of 2 km.

Geological survey by Japanese Antarctic Research Expedition (JARE) in Cape Ryûgû was carried out for the first time by the authors, members of JARE-19, from December 31, 1977 to January 9, 1978 (NAKAI *et al.*, 1979a, b). Other scientific observations carried out in this region at the same time were as follows: a biological survey by H. KANDA, a geophysical survey by K. KAMINUMA and a geodesic survey by T. KUNIMI (KAMINUMA *et al.*, 1978).

The field scientists used for survey the aerial photographs which were produced at the scale of approximately 1 : 25500 by the JARE-6 in January 1962.

2. Geology of Cape Ryûgû

The Cape Ryûgû region is bounded by the Antarctic Sea on the north, and is covered with continental ice on the southern margin. The highest point of bare rocks is about 170 m above the sea level. Along the U-shaped valleys running in the east-west direction, glacial morainic deposits and numerous ponds are distributed.

The basement rocks exposed in this area are classified into the following types on the basis of their petrographical features:

1. Garnet-biotite gneiss (Ggb)
   1.1. Garnet-biotite gneiss (Ggb)
   1.2. Staurolite-bearing sillimanite-garnet-biotite gneiss (Gss)
2. Leucocratic muscovite-bearing biotite gneiss (Glm)
3. Hornblende-bearing biotite gneiss (Ghb)

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3.1. Hornblende-biotite gneiss (Ghb)
3.2. Biotite gneiss (Gb)
4. Leucocratic hornblende-biotite gneiss (Glh)
5. Amphibolite and fine-grained biotite-hornblende gneiss (Amp, Gfh)
5.1. Amphibolite (Amp)
5.2. Fine-grained biotite-hornblende gneiss (Gfh)
6. Coarse-grained hornblende gneiss (Gch)
7. Epidote-clinopyroxene-hornblende gneiss (Gep)
8. Clinopyroxene gneiss (Gp)
8.1. Fine-grained clinopyroxene gneiss (Gfp)
8.2. Diopside-bearing pegmatoid (Pd)
8.3. Coarse-grained clinopyroxene gneiss (Gcp)
9. Garnet-clinopyroxene rock (Rgp)
10. Crystalline limestone (Ls)
11. Augen gneiss (Gau)
12. Pegmatite (Pg)
13. Aplite (Ap)

The stratum consisting of these metamorphic rocks is named Ryûgû group in this paper. Ryûgû group is stratigraphically divided into the following four formations: the Lowermost formation, Lower formation, Middle formation and Upper formation, arranged after the order of zonal distribution from north to south. They are successively conformable and grade into one another.

Lowermost formation: It is composed mainly of hornblende-bearing biotite gneiss characteristically containing magnetite and ilmenite. The rock occurs as the lowermost horizon in the northern part of the east area, and is associated with thin layers of fine-grained biotite-hornblende gneiss, amphibolite, clinopyroxene gneiss, epidote-clinopyroxene-hornblende gneiss and garnet-clinopyroxene rock. Pegmatite and aplite dykes and/or sheets are found to cut the hornblende-bearing biotite gneiss.

Lower formation: It is exposed in the southern part of the east area and is composed mainly of amphibolite, fine-grained biotite-hornblende gneiss, clinopyroxene gneiss, garnet-biotite gneiss and hornblende-bearing biotite gneiss. The garnet-biotite gneiss stratigraphically overlies amphibolite and fine-grained biotite gneiss horizon, alternating with hornblende-bearing biotite gneiss.

Middle formation: It is exposed in the northern part of the west area, and is composed of amphibolite, fine-grained biotite-hornblende gneiss, coarse-grained hornblende gneiss, clinopyroxene gneiss, hornblende-bearing biotite gneiss, staurolite-bearing sillimanite-garnet-biotite gneiss, leucocratic hornblende-biotite gneiss and leucocratic muscovite-bearing biotite gneiss. At the extreme east of the west area, the lower part of this formation which is composed of hornblende-bearing biotite gneiss, amphibolite and fine-grained biotite-hornblende gneiss exhibits remarkable folding structure. Interfingering relationships between hornblende-

bearing biotite gneiss and leucocratic muscovite-bearing biotite gneiss are observable at the eastern part of the west area. Crystalline limestone and augen gneiss occur as lenses or thin layers within the hornblende-bearing biotite gneiss in a limited area of the extreme west.

Upper formation: It is exposed in the southern part of the west area and is composed of leucocratic hornblende-biotite gneiss, coarse-grained hornblende gneiss, epidote-clinopyroxene-hornblende gneiss, leucocratic muscovite-bearing biotite gneiss and hornblende-bearing biotite gneiss.

The foliation plane of gneissosity or banded structure of the metamorphic rocks in the Cape Ryûgû region generally runs in the east-west direction and dips to the south monoclinally from 30° to 50° as a whole. In some places syncline and anticline are observed.

Judged from the mode of occurrence, the mineral associations and mineralogical

Table 1. Chemical compositions of rocks from Cape Ryûgû.

No.	1	2	3	4	5	6	7	8	9	10	11
SiO_2	68.47	54.26	74.85	68.21	64.72	49.80	64.58	50.66	49.15	64.59	47.97
TiO_2	0.65	1.03	0.13	0.75	0.40	0.77	0.63	1.40	0.80	0.43	0.90
Al_2O_3	15.08	20.65	15.23	14.81	17.86	11.23	12.96	19.15	16.73	10.82	7.90
Fe_2O_3	3.71	7.28	0.88	3.18	2.49	7.21	2.96	8.01	6.05	2.15	8.63
FeO	2.52	4.01	0.30	1.87	1.93	4.37	3.26	2.98	4.76	2.42	5.78
MnO	0.36	0.17	0.05	0.18	0.11	0.22	0.15	0.11	0.19	0.12	1.79
MgO	2.60	4.92	0.38	0.90	1.29	12.31	3.86	3.11	6.56	5.38	8.08
CaO	3.24	1.02	2.24	2.59	5.36	10.70	6.24	8.91	13.22	9.42	17.91
Na_2O	1.85	3.37	3.64	3.19	3.50	1.75	1.86	3.46	0.58	1.45	0.61
K_2O	2.21	1.80	1.37	2.92	1.16	0.59	2.17	0.75	0.72	2.06	0.00
P_2O_5	0.09	0.22	0.09	0.19	0.19	0.35	0.10	0.33	0.21	0.11	0.64
H_2O (−)	0.07	0.09	0.01	0.05	0.02	0.04	0.17	0.07	0.02	0.04	0.05
H_2O (+)	0.09	0.44	0.01	0.26	0.01	0.05	0.20	0.13	0.33	0.19	0.22
Total	100.94	99.26	99.18	99.10	99.04	99.39	99.14	99.07	99.32	99.18	100.48

Analyst: Ryuichi SUGISAKI.

1. 601A Garnet-biotite gneiss.
2. 704A Staurolite-bearing sillimanite-garnet-biotite gneiss.
3. 801 Leucocratic muscovite-bearing biotite gneiss.
4. Ry5 Hornblende-biotite gneiss.
5. 509 Leucocratic hornblende-biotite gneiss.
6. 502 Amphibolite.
7. Ryl Fine-grained biotite-hornblende gneiss.
8. 502C Coarse-grained hornblende gneiss.
9. 508 Epidote-clinopyroxene-hornblende gneiss.
10. Ry3 Fine-grained clinopyroxene gneiss.
11. SY301 Garnet-clinopyroxene rock.

characters of metamorphic rocks, the metamorphic grade in the region is as high as the amphibolite facies (YOSHIKURA, 1979; YOSHIKURA *et al.*, 1979).

Some representatives of the chemical compositions of metamorphic rocks are given in Table 1.

The petrographical characters of the constituent rocks will be described below.

3. Petrography

3.1. Garnet-biotite gneiss (Ggb)

3.1.1. Garnet-biotite gneiss (Ggb)

This is a melanocratic and fine- to medium-grained rock with granoblastic to lepidoblastic texture. Red garnets are scattered in this rock. This rock is composed mainly of quartz, plagioclase, K-feldspar, biotite and garnet, with subordinate amounts of allanite, apatite, zircon and opaque mineral. White-mica and chlorite are seen as alteration products. Plagioclase occurs as xenoblastic grains which exhibit well-developed polysynthetic twinning and zoning. Biotite is reddish-brown to dark-brown in color and shows tabular habit. The biotite rarely includes allanite, and shows pleochroic haloes. K-feldspar with microcline grid twinning is present in half of the investigated rock specimens.

3.1.2. Staurolite-bearing sillimanite-garnet-biotite gneiss (Gss)

This is a melanocratic medium- to coarse-grained rock and shows the compositional banding composed of ferromagnesian and quartz-feldspathic bands. Under the microscope, this rock exhibits granoblastic texture. It consists mainly of quartz, plagioclase, biotite, sillimanite, garnet and staurolite, with accessory apatite and opaque mineral. Plagioclase is medium- to coarse-grained crystal and fine-grained one has a calcic rim. Biotite is brown in color. Sillimanite is crowded in quartz-feldspathic band, and exhibits radiating fibrolitic texture. Minor amounts of prismatic and well-cleavaged sillimanite crystals are seen in the fibrolite. Poikiloblastic garnets with pinkish tint are present in the melanocratic band. Rotated quartz inclusion trains are observed in the garnet. Staurolite is golden yellow in color, and is replaced by fine-grained plagioclase with calcic rim.

3.2. Leucocratic muscovite-bearing biotite gneiss (Glm)

This is a leucocratic and siliceous medium- to coarse-grained rock. The rock is composed mainly of quartz, plagioclase, K-feldspar, biotite, muscovite and garnet, with accessory allanite, apatite, zircon and opaque mineral. In altered samples, biotite is substantially replaced by epidote or chlorite. Plagioclase shows antiperthitic texture with microcline grid twinned lamellae. K-feldspar is interstitial crystal. Biotite is pleochroic with X = pale brown, Z = dark brown, and some of them show vermicular forms. Muscovite is commonly associated with biotite along its cleavage. The muscovite is presumably of secondary origin judging from their textural relationship.

Obviously secondary origin white-mica flake which replaced plagioclase is observed in altered rock. Small rounded garnet is ubiquitous in this rock. Allanite occurs occasionally surrounded by epidote and shows pleochroic halo in biotite.

3.3. Hornblende-bearing biotite gneiss (Ghb)

This rock is the most predominant rock type in this region. The relative amounts of hornblende and biotite in this rock show some local variation and the rock grades into biotite-hornblende gneiss, hornblende-biotite gneiss, biotite gneiss and garnet-bearing biotite gneiss. These rocks are closely associated in the field and also similar in lithological characters. Hornblende-biotite gneiss and biotite gneiss are briefly described as follows.

3.3.1. Hornblende-biotite gneiss (Ghb)

The rock is fine- to medium-grained and shows granoblastic or lepidoblastic texture. Main constituents are quartz, plagioclase, K-feldspar, biotite, green-hornblende and minor amounts of apatite, allanite, sphene and opaque mineral with or without garnet. Plagioclase has antiperthitic texture and shows the microcline grid twinning in potassium rich phase. K-feldspar exhibits microcline grid twinning. Biotite occurs as subidioblastic plates of variable size whose planar preferred orientation results in a well-developed lepidoblastic fabric. It is reddish brown to brown in color. Biotite is unaltered in most specimens, but sometimes it is clearly replaced by chlorite, epidote, muscovite or prehnite. Small amounts of garnet occur as fine-grained rounded crystals with pinkish tint. Muscovite, being present in considerable amounts, is of secondary origin after feldspar or biotite.

3.3.2. Biotite gneiss (Gb)

This is a medium- to coarse-grained rock and is characterized by generally conformable compositional banding of ferromagnesian and quartz-feldspathic bands. K-feldspar rich quartz-feldspathic band is pinkish tint to the naked eye. This rock sometimes contains coarse-grained magnetite-ilmenite crystal ranging in diameter up to 5 mm. Microscopically this rock is characterized by a lepidoblastic or granoblastic texture. The principal constituents are quartz, plagioclase, K-feldspar and biotite, with hornblende, garnet, apatite, allanite, zircon, sphene and opaque mineral as accessories. In altered rock, chlorite, white-mica, calcite, epidote or prehnite are present as a secondary product. Plagioclase occurs as xenoblastic to subidioblastic grains showing well-developed polysynthetic twinning and sometimes zoning. Some of them exhibit antiperthitic texture. Secondary alteration accounts for replacement of plagioclase by white-mica flakes. Xenoblastic K-feldspar with microcline grid twinning occurs in about half of the examined rock samples. Biotite is reddish-brown to dark-brown in color, and associated with allanite, apatite, chlorite, white-mica, epidote and prehnite.

3.4. Leucocratic hornblende-biotite gneiss (Glh)

This rock is leucocratic medium- to coarse-grained in appearance. Under the

microscope, it shows a granoblastic or lepidoblastic texture. It consists mainly of plagioclase, quartz, K-feldspar, biotite and green-hornblende, with accessory apatite, allanite, zircon and opaque mineral. Secondary epidote, sphene, chlorite, prehnite, white-mica and calcite are present. Most plagioclase shows antiperthitic texture with microcline grid twinned lamellae. Many fine white-mica flakes occur as alteration product in some plagioclase. Small amounts of xenoblastic K-feldspar with microcline grid twinning occupy interspaces between plagioclase and quartz. Biotite is brown in color and sometimes shows vermicular texture.

3.5. Amphibolite and fine-grained biotite-hornblende gneiss (Amp, Gfh)

3.5.1. Amphibolite (Amp)

This is a fine- to medium-grained melanocratic to hypermelanic rock, and massive to weakly foliated in appearance. The rock alternates with comparatively leucocratic biotite-hornblende gneiss and shows banded structure of 5–20 cm in thickness. Under the microscope, the rock shows approximately equigranular granoblastic to lepidoblastic texture. It is composed mainly of hornblende, plagioclase, and minor amounts of biotite, opaque mineral, apatite and with or without quartz, garnet, epidote, clinozoisite and sphene. Hornblende is pleochroic with X' = yellow, yellowish green, Z' = brownish green, green, deep green. Biotite is pleochroic with X = pale yellow and $Y \fallingdotseq Z$ = dark brown, brown. Some crystals of plagioclase have distinct zonal structure of core and albitic margin. A part of amphibolite contains considerable amounts of garnet 0.5–1 cm in diameter, which is poikiloblastic crystal including small granular quartz, plagioclase and hornblende. Epidote and clinozoisite are included in more or less altered rock, and biotite is replaced by chlorite in the rock.

3.5.2. Fine-grained biotite-hornblende gneiss (Gfh)

This is a fine-grained intermediate to melanocratic and weakly foliated rock, alternating with amphibolite. Under the microscope, it exhibits approximately equigranular granoblastic to weakly lepidoblastic texture. Some of the rock have a preferred orientation of biotite and hornblende. The rock is composed mainly of plagioclase, hornblende, quartz, biotite and small amounts of opaque minerals, apatite, sphene, with or without K-feldspar or garnet. Hornblende is pleochroic with X' = yellow, greenish yellow, Z' = deep green, green. Biotite is pleochroic with X = yellow, pale brownish yellow, $Y \fallingdotseq Z$ = brown, dark brown. Some part of hornblende is converted into colorless amphibole. K-feldspar occurs as interstitial grains among plagioclase and sometimes shows undulatory microcline texture. Occasionally, the rock contains porphyroblastic garnet.

3.6. Coarse-grained hornblende gneiss (Gch)

This is a coarse-grained and foliated rock, exposed with amphibolite, fine-grained biotite-hornblende gneiss and epidote-clinopyroxene-hornblende gneiss in the west area. Under the microscope, it shows granoblastic to lepidoblastic texture

and is composed mainly of plagioclase, hornblende, biotite, quartz and small amounts of opaque mineral, sphene and with or without K-feldspar, epidote, calcite or chlorite. Hornblende shows deep green, green to yellow in axial color. Biotite is pleochroic with X=pale yellow, Y≒Z=brown, greenish brown, and part of crystal converted to chlorite and prehnite. K-feldspar shows distinct microcline texture.

3.7. Epidote-clinopyroxene-hornblende gneiss (Gep)

This is a coarse-grained melanocratic rock. The rock consists chiefly of large crystals of greenish yellow epidote, deep green hedenbergite and black hornblende and usually has a pegmatitic appearance. Under the microscope, it exhibits granoblastic to lepidoblastic texture and is composed of hedenbergite, hornblende, epidote and small amounts of quartz, plagioclase, calcite, scapolite, sphene, apatite and opaque mineral. Hedenbergite is pale green to pale yellowish green in axial color. Hornblende is pleochroic with deep green to yellowish green.

The rock of a "spinifex"-like appearance which is shown by arrangement of long prismatic hornblende occurs closely associated with epidote-clinopyroxene-hornblende gneiss. It is composed of hornblende, plagioclase, quartz, epidote, opaque mineral, sphene, apatite and with or without K-feldspar, biotite, calcite and scapolite. Under the microscope, hornblende and biotite show distinct poikiloblastic texture, but the matrix exhibits rather small-grained equigranular granoblastic texture. Hornblende is deep green, green to yellow in axial color and makes usually sponge-form aggregate. K-feldspar shows microcline texture.

3.8. Clinopyroxene gneiss (Gp)

3.8.1. Fine-grained clinopyroxene gneiss (Gfp)

This is a fine-grained intermediate to melanocratic rock of green to deep green. The foliation is rather weak and the rock has a massive appearance. The rock occurs as concordant layers of 10–30 cm in thickness, intercalated with the amphibolite and fine-grained biotite-hornblende gneiss. Under the microscope, it exhibits equigranular granoblastic texture and is composed of plagioclase, clinopyroxene, K-feldspar, quartz, hornblende, sphene, apatite and opaque mineral, with or without biotite and calcite. Clinopyroxene is colorless or weakly pleochroic with pale green to pale yellow and is partly replaced by pale green hornblende. Biotite is brown, dark brown to yellow in axial color. K-feldspar shows microcline texture. Some of the clinopyroxene gneiss contains considerable amounts of biotite and colorless amphibole (cummingtonite).

3.8.2. Diopside-bearing pegmatoid (Pd)

This rock is coarse-grained massive in appearance and is closely associated with clinopyroxene gneiss. The rock occurs as irregular veinlets or pools intruding into the clinopyroxene gneiss. The rock is composed mainly of clinopyroxene, plagioclase, quartz and small amounts of pale green hornblende, K-feldspar, calcite, sphene, apatite and clinozoisite.

3.8.3. Coarse-grained clinopyroxene gneiss (Gcp)

This is a coarse- to medium-grained and leucocratic to intermediate rock and has foliated structure. The rock occurs as concordant layers within the hornblende-bearing biotite gneiss. Under the microscope, it exhibits equigranular granoblastic texture and is composed mainly of K-feldspar, clinopyroxene, quartz, hornblende, epidote and small amounts of plagioclase, sphene and opaque mineral. Clinopyroxene shows poikiloblastic texture and weak pleochroism of colorless to pale green, pale yellow. Hornblende is green to pale green, pale yellow in axial color. K-feldspar shows perthitic and microcline texture.

3.9. Garnet-clinopyroxene rock (Rgp)

This is a medium-grained massive rock and occurs as small lens or concordant layers in the hornblende-bearing biotite gneiss of the extreme east. It is composed mainly of garnet, clinopyroxene, quartz, calcite and small amounts of actinolitic amphibole, apatite and opaque mineral. Clinopyroxene shows pleochroism of pale green to pale yellowish green and a part of the crystal is converted into actinolitic amphibole. Garnet exists as poikiloblastic crystal.

3.10. Crystalline limestone (Ls)

This rock is pure crystalline limestone and is white in color, coarse-grained, being composed mostly of equigranular calcite. Under the microscope, only calcite is observed as constituent mineral of this rock.

3.11. Augen gneiss (Gau)

This is a red to reddish pink colored coarse-grained foliated rock, and has a lot of augen-form porphyroblasts of K-feldspar including magnetite crystal as an eyeball. Under the microscope, it exhibits granoblastic to lepidoblastic texture and is composed mainly of plagioclase, quartz, K-feldspar and minor amounts of biotite, hornblende, sphene, apatite and opaque mineral. K-feldspar shows microcline texture and partly perthitic texture. Biotite is pleochroic with X = yellow, $Y \fallingdotseq Z$ = dark brown. Hornblende is pleochroic with X' = yellowish green, Z' = deep green, green.

3.12. Pegmatite (Pg)

Pegmatite distributed in this region is subdivided into two types, namely white pegmatite and pink pegmatite, according to their color. Both types of pegmatite occur as clear-cut network dyke ranging in width from a few tens of centimeters to several meters. Some of them are interlayered as thin lens-shaped band with gneiss. The white pegmatite occurs mainly in the east area of this region, and sometimes contains large biotite, garnet or magnetite crystal. The pink pegmatite is found in the extreme east, especially in the vicinity of Otohime-iwa, and is characterized by the existence of large salmon pink colored K-feldspar. Main constituents of both pegmatites are quartz, K-feldspar, plagioclase, biotite, hornblende and muscovite with minor amounts of clinopyroxene, garnet, allanite, apatite and opaque mineral.

3.13. Aplite (Ap)

This rock occurs as concordant seam in the hornblende-bearing biotite gneiss. It is a fine- to medium-grained leucocratic rock. Under the microscope, this rock shows equigranular texture, and is composed mainly of K-feldspar, quartz, plagioclase, biotite and muscovite with subordinate amounts of garnet and apatite. K-feldspar exhibits typical microcline texture.

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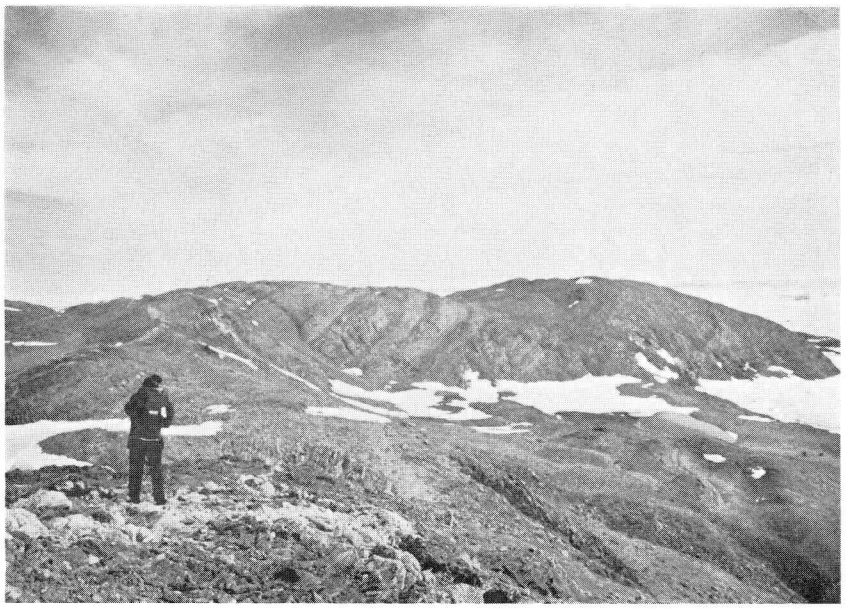
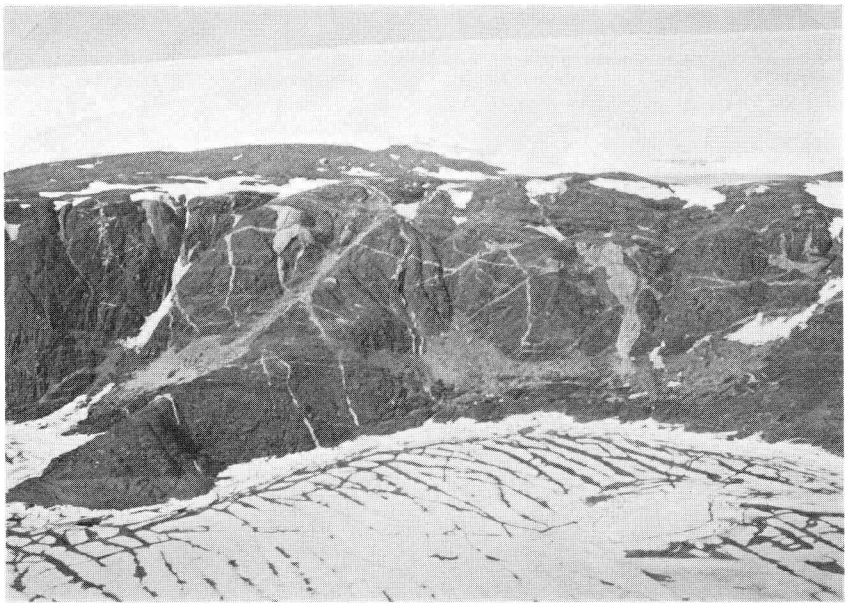
a. Aerial view of the east area of Cape Ryûgû. The right side of bare rocks is the Antarctic Sea and opposite side is the continental area.

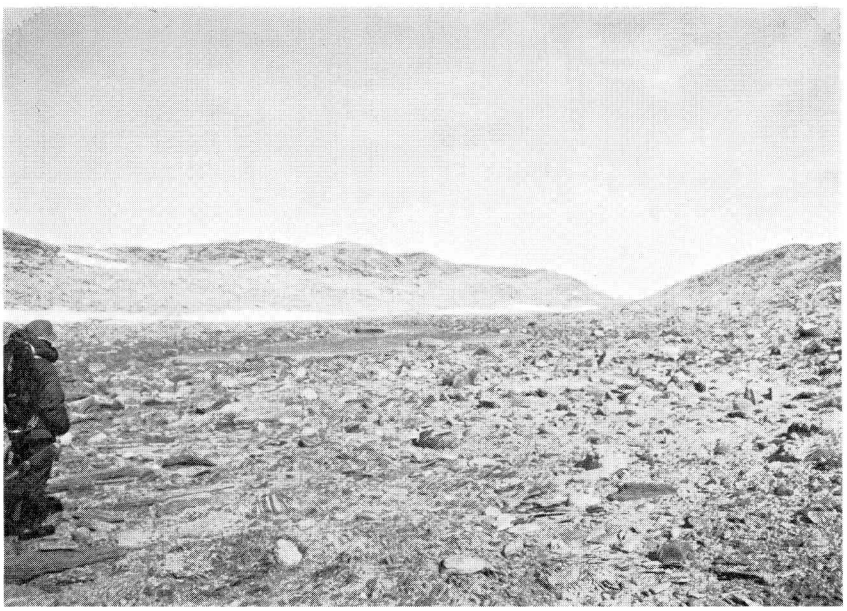


b. Monoclinal structure in the northern part of the east area of Cape Ryûgû.

Plate 2



a. Network pegmatite dykes in the hornblende-bearing biotite gneiss in the northern part of the east area of Cape Ryûgû.



b. U-shaped valley in the southern part of the east area of Cape Ryûgû.

Antarctic Geological Map Series

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