GEOLOGY AND GEOLOGIC STRUCTURE OF THE LANGHOVDE AND SKARVSNES REGIONS, EAST ANTARCTICA

Yukio MATSUMOTO,*

Department of Geology, Faculty of Liberal Arts, Nagasaki University, 1–14, Bunkyo-machi, Nagasaki 852

Masaru YOSHIDA

Department of Geoscience, Faculty of Science, Osaka City University, 459, Sugimoto-cho, Sumiyoshi-ku, Osaka 558

and

Keizo YANAI

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

Abstract: The Langhovde and Skarvsnes regions lie on the east coast of Lützow-Holm Bay, East Antarctica. These regions are bounded by latitude 69°10′S–69°32′S and longitude 39°27′E–39°53′E.

In the Langhovde and Skarvsnes regions is distributed the Ongul group named by YOSHIDA *et al.* (Third Symp. Antarct. Geol. Geophys., Madison, Univ. Wisconsin, 1977 b). The Ongul group is characterized by alternating layers of gneissic rocks of the late Precambrian time. The gneissic rocks exposed in these regions are classified as follows: (1) Metabasites, (2) Charnockitic rocks, (3) Hornblend gneiss, (4) Marble, (5) Garnet-biotite gneiss, (6) Porphyroblastic gneiss, (7) Garnet gneiss, (8) Migmatitic gneiss, (9) Garnet-bearing granitic gneiss, (10) Microcline granite and gneissose microcline granite and (11) Pegmatite.

Many types of folds and fractures in the Langhovde and Skarvsnes regions are divided into four stages; the first stage (D_1): recumbent folds followed by isoclinal folds with the axis running in the north-south direction, the second stage (D_2): closed to open folds with the east-west trend, the third stage (D_3): gentle folds with northery trend, and the fourth stage (D_4): diagonal sets of fractures trending N65°W and N60°E.

1. Introduction

The Langhovde and Skarvsnes regions lie on the east coast of Lützow-Holm Bay, East Antarctica, and situated about 20 km to 40 km south of Syowa Station,

* Present address: Department of Mineralogical Science and Geology, Faculty of Science, Yamaguchi University, 1677–1, Yoshida, Yamaguchi 753.

East Ongul Island. The Langhovde region including the Hamnenabben and Revsnes areas is bounded by latitudes 69°10′S–69°19′S and longitudes 39°34′E–39°52′E. The Skarvsnes region includes the Breidvågnipa and Byvågåsane areas, and is located at 69°19′S–69°32′S latitude and 39°27′E–39°53′E longitude.

The ground survey of these regions was conducted first by Japanese geologists in 1957 and since then some members of the Japanese Antarctic Research Expedition visited these regions with various scientific objects. The geology of these regions was surveyed by T. TATSUMI and T. KIKUCHI in 1957–1958 and K. KIZAKI in 1962–1964, and was outlined by TATSUMI and KIKUCHI (1959a, 1959b) and the brief petrography was presented by TATSUMI *et al.* (1964). From 1967 to 1977, some scientists surveyed these regions and surroundings areas where geological surveyed was carried out by H. ANDO, M. YOSHIDA in 1968–1970, T. ISHIKAWA in 1971–1973, S. KOZIMA and K. SHIRAISHI in 1973, and K. YANAI in 1973–1975, and Y. MATSUMOTO in 1974–1976. The superimposed folding system and geologic outline of these regions and surrounding areas were reported by ISHIKAWA (1974, 1976), YOSHIDA *et al.* (1977), and YOSHIDA (1978). The geological map (1 : 25000) of the Langhovde region was compiled by T. ISHIKAWA (ISHIKAWA *et al.*, 1976), and the geological map of the Skarvsnes region (1 : 25000) was compiled by Y. MATSUMOTO, supplemented by the geologic data mainly after T. TATSUMI, K. KIZAKI, S. KOZIMA, T. ISHIKAWA, K. YANAI and Y. MATSUMOTO, and by discussions on geologic structures with K. YANAI, M. YOSHIDA and Y. MATSUMOTO (ISHIKAWA *et al.*, 1977). The tectonics and geology of charnockites around Lützow-Holmbukta which includes the Langhovde and Skarvsnes regions, were summarized by M. YOSHIDA (1978) and YOSHIDA *et al.* (1976, 1977a, b).

Among the ice-free areas of the east coast of Lützow-Holm Bay, the Skarvsnes region is the largest in dimension and the Langhovde region is the second. In these regions, gneissic rocks are well exposed.

M. YOSHIDA reported that among the geologic structures of the Skallen and Skallevikhalsen regions, the first major fold is characterized by recumbent type (YOSHIDA, 1977, 1978). On the other hand, Y. MATSUMOTO and K. YANAI discovered a fault of overthrust type at the western part of the Skarvsnes region in 1975. The present authors, after discussing the geologic structure of the Skarvsnes and Langhovde regions in 1976–1977, have reached a conclusion that the first and second major folds in the two regions are characterized by recumbent and isoclinal types similar to the Skallen and Skallevikhalsen regions. The geologic structure of these regions was reported also by ISHIKAWA *et al.* (1977), YANAI *et al.* (1977), YOSHIDA *et al.* (1977a, b), YOSHIDA (1978) and MATSUMOTO (1978), but their conclusions differ to some extent from that of ISHIKAWA (1976) and ISHIKAWA *et al.* (1976).

In this paper the recent study on the outline of geology and geologic structure in the Langhovde and Skarvsnes regions is reported.

2. General Geology of the Langhovde and Skarvsnes Regions

In the Langhovde and Skarvsnes regions is distributed the Ongul group. The name Ongul group was first given by YOSHIDA *et al.* (1977b). The Ongul group is characterized by alternated layers mainly of charnockitic rocks and paragneisses such as garnet-biotite gneiss or porphyroblastic gneiss. Each of the layers is more than a hundred meters thick. Hornblende gneiss and granitic gneiss are also found in lesser amount. Intercalations of thin layers of metabasite are often characteristic of the charnockitic rocks.

Table 1. Radiometric ages of rock from the Langhovde and Skarvsnes regions.

Specimen No.	Locality	Lithology	Mineral	Method	Age (m.y.)	Ref.
JARE 57112001	Langhovde 69°13′S, 39°38′E	Granitic pegmatite in granitic gneiss	Biotite	Rb-Sr	525±40	1
A-09	Langhovde	Gneissic rock	Biotite	Rb-Sr	526	2
A-01 68013113	Langhovde 69°13′S, 39°45′E	Biotite pyroxene, amphibolite	Biotite	K-Ar	463	3
A-24	Breidvågnipa 69°22′S, 39°46′E	Gneissose rock	K-feldspar	Rb-Sr	1116	2
JARE 5711070	Skarvsnes 69°26′S, 39°34′E	Granitic pegmatite in dioritic gneiss	Biotite	Rb-Sr	510+30	1
AS	Skarvsnes 69°29′S, 39°34′E	Garnet biotite gneiss	Whole rock	K-Ar	363	4
A-04	Skarvsnes 69°27′S, 39°37′E	Gneissose rock	K-feldspar	Rb-Sr	745	3

1. NICOLAYSEN *et al.*, 1961, 2. MAEGOYA *et al.*, 1968, 3. YANAI and UEDA, 1974, 4. KANEOKA *et al.*, 1968.

Previously the metamorphic rocks of the Ongul group in these regions were correlated with the basement complex of East Antarctica purely on petrographical grounds, and were assigned to the Precambrian age. However, the recent dating of biotite, euxenite, potassium feldspar and phlogopite by Rb–Sr, U–Pb and K–Ar methods suggests that the latest metamorphism in these regions occurred in the late Cambrian or early Paleozoic time (NICOLAYSEN *et al.*, 1961; SAITO *et al.*, 1961; MAEGOYA *et al.*, 1968; KANEOKA *et al*, 1968; YANAI and UEDA, 1974), and the earlier events, such as the one 1116 million years old in radiometric age by MAEGOYA *et al.* (1968), are only poorly recognized. Age determinations so far made on the basement rocks of the Langhovde and Skarvsnes regions are listed in Table 1.

3. Distribution and Petrography of Gneissose Rocks in the Langhovde and Skarvsnes Regions

Figs. 1 to 4 show the geological maps and geological cross sections of the Langhovde and Skarvsnes regions.

The rocks exposed in these regions are classified on the basis of their modes of ocurrense and petrographic features as follows; (1) Metabasites, (2) Charnockitic rocks, (3) Hornblende gneiss, (4) Marble, (5) Garnet-biotite gneiss, (6) Porphyroblastic gneiss, (7) Garnet gneiss, (8) Migmatitic gneiss, (9) Garnet-bearing granitic gneiss, (10) Microcline granite and gneissose microcline granite, (11) Pegmatite, (12) Beach sand and gravel, (13) Terrestrial deposits including moraines, fluvioglacial deposits, talus and aeolian sand.

Metabasites: Within the gneissic rocks (charnockitic rocks, hornblende gneiss, garnet-biotite gneiss and porphyroblastic gneiss) there are many layers, lenses and irregular-shaped bodies of basic metamorphic rocks (Fig. 5). They are medium- to coarse-grained and usually black to dark greenish black in color. In the northern

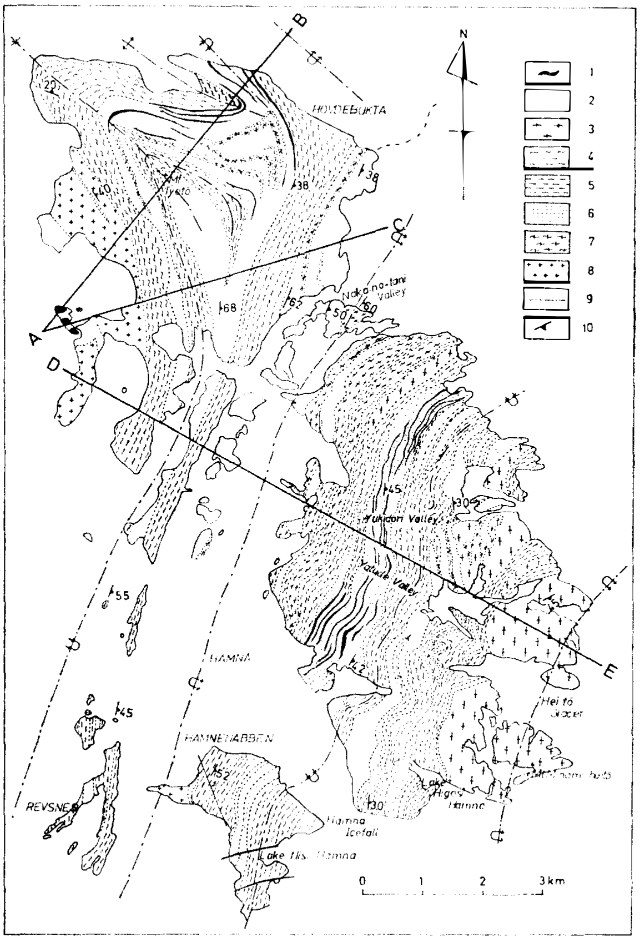

Fig. 1. Geological map of Langhovde. 1: Metabasite. 2: Charnockitic rocks. 3: Hornblende gneiss. 4: Garnet-biotite gneiss. 5: Porphyroblastic gneiss. 6: Garnet gneiss. 7: Garnet-bearing granitic gneiss. 8: Microcline granite. 9: Axial trace of folds. 10: S-plane.

part of Mt. Tyôtô and in the Yukidori and Naka-no-tani Valleys of the Langhovde region, and in the northern parts of Mt. Suribati and Mt. Hiroe of the Skarvsnes region, and in the southern and central parts of the Byvågåsane area, they continue in the strike direction for a considerable distance. In the vicinity of the axis of fold structure, minor folds of similar trend are observed in the metabasites. Especially the metabasites in garnet gneiss show a continuity as a thin bed, often with boudinage. Metabasites occur also at Osen as many ovoid-shaped bodies within charnockitic rocks and garnet-biotite gneiss.

Charnockitic rocks: Charnockitic rocks are the most widespread in the Skarvsnes region especially in the medial part. They occur extensively throughout the Langhovde region, especially in Mt. Tyôtô, Naka-no-tani Valley and Yukidori Valley. The typical rock is uniformly fine- to medium-grained, granoblastic in texture, and usually dark brown and grey due to the coloring of feldspar and quartz crystals. It contains hypersthene, clinopyroxene, quartz, potassium feldspar, plagioclase, hornblende and biotite, and sometimes garnet. A weak foliation made of the parallel arrangement of mafic minerals and the elongated dark inclusions, is

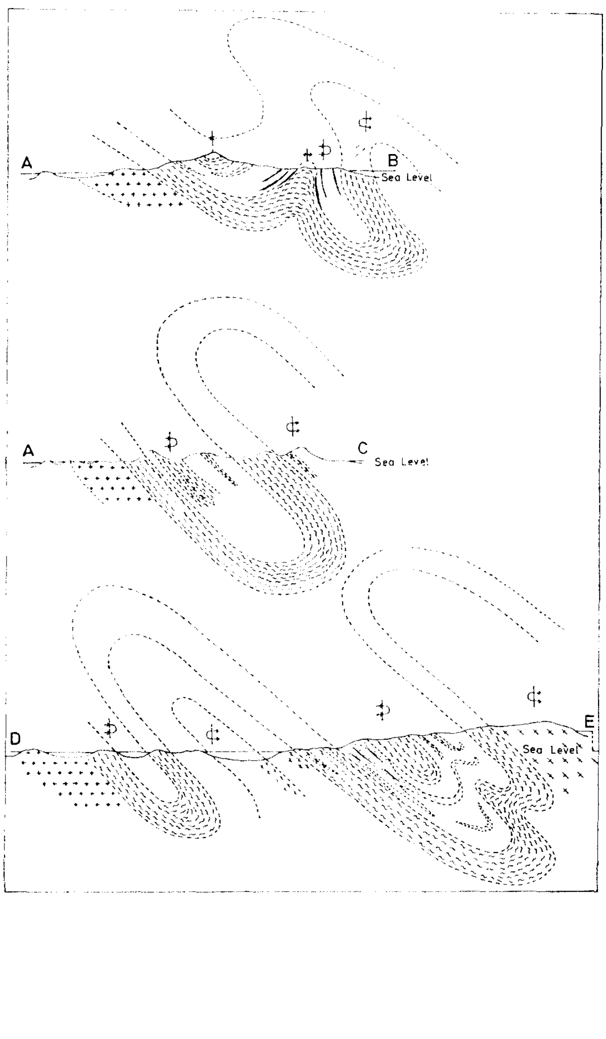

Fig. 2. Geological cross section of Langhovde. The marks are the same as in Fig. 1.

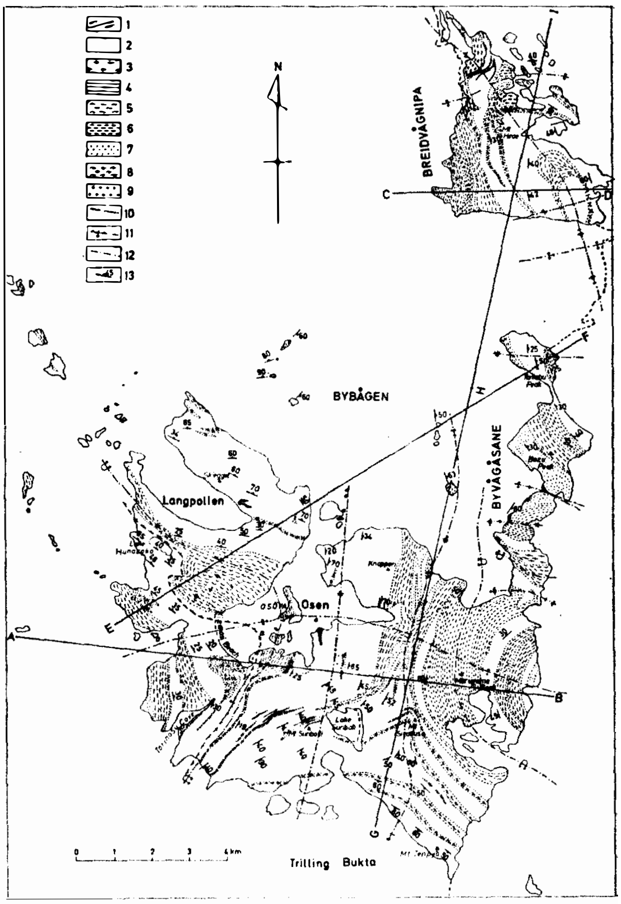

Fig. 3. Geological map of Skarvsnes.
1: Metabasite. 2: Charnockitic rocks. 3: Hornblende gneiss. 4: Marble. 5: Garnet-biotite gneiss. 6: Porphyroblastic gneiss. 7: Garnet gneiss. 8: Garnet-bearing granitic gneiss. 9: Migmatitic gneiss and gneissose microcline granite. 10: Fault. 11: Thrust fault. 12: Axial trace of folds. 13: S-plane.

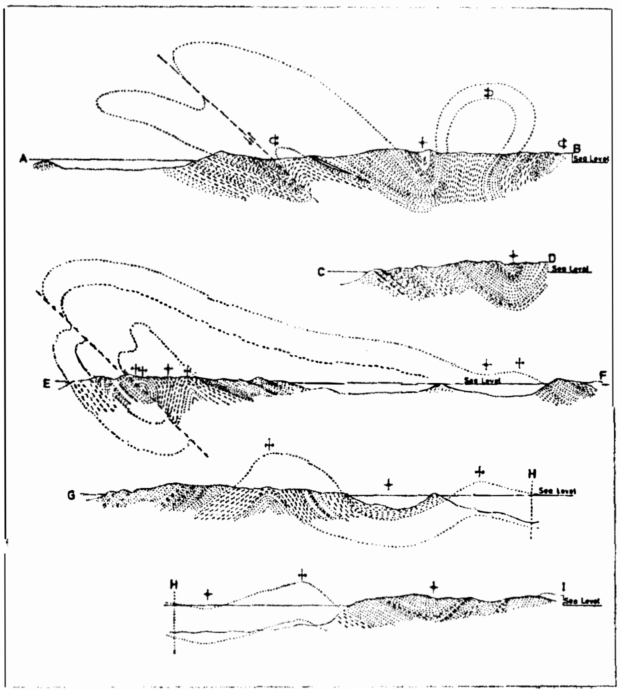

Fig. 4. Geological cross section of Skarvsnes. The marks are the same as in Fig. 3.

developed in the rock.

Hornblende gneiss: Hornblende gneiss occurs at Mt. Heitô and Mt. Minami-heitô of the Langhovde region, and in the northern part of Mt. Suribati of the Skarvsnes region and in the southern part of the Byvågåsane area. It is characterized by the presence of hornblende and the absence of pyroxenes and garnet. The rock is medium- to coarse-grained. Colored minerals are small in quantity but plagioclase and quartz are found in large quantities. The grey color of the rock is due to the large quantity of plagioclase. Basic xenoliths, lenticular in form, are often found in the rock.

Marble: Marble is distributed in the northern part of the Breidvågnipa area. It occurs as three or four layers, one meter to several tens of meters thick. The layers are generally associated with the skarn and allied rocks. An intrusive appearance of the marble in other plutonic and metamorphic rocks was observed in many places. A migmatitic appearance with xenolithic blocks of surrounding rocks, the blocks having a reaction rim, is not unusual. The marble comprises two types, one is pure marble and the other with scattered colored minerals, both being variable in mineral assemblages. The marble is very white, coarse- to very coarse-grained, and equigranular, being composed mostly of equant calcite. Very small amounts of small-grained phlogopite, apatite and ilmenite occur usually.

Garnet-biotite gneiss: Garnet-biotite gneiss is widely distributed in the Langhovde and Skarvsnes regions and is characterized by the large quantity of garnet and biotite and the absence of hornblende. The rock is reddish brown in color because of the abundance of garnet. Potassium feldspar often occurs as phenocrystic crystals, giving a porphyroblastic appearance to the rock in places. Foliation of this rock is due to the parallel arrangement of garnet and biotite. Alternation of melanocratic layers consisting of biotite and leucocratic layers consisting of quartz and feldspars accounts for the distinct foliation. The rock possesses a well-defined large-scale banding due to concentration of biotite and garnet, since the layers varied in resistance to erosion.

Porphyroblastic gneiss: This rock occurs in the Hamnenabben and Byvågåsane areas, in the western part of the Breidvågnipa area, and in the vicinity of Maruyama Peak of the Skarvsnes region. The rock is characterized by relatively large crystals of potassium feldspar, approximately 3 to 4 cm in diameter. It is fine- to medium-grained and has a distinct gneissose structure displayed by concentration of biotite flakes. The matrix is composed of minute crystals of garnet, biotite, quartz, potassium feldspar and plagioclase. This rock is generally bedded with garnet-biotite gneiss. These two rocks are very similar in appearance, and probably closely related in their genetical process.

Garnet gneiss: Garnet gneiss is distributed in the central part of the Langhovde region, in the part of the Skarvsnes region, and in the central part of the Byvågåsane

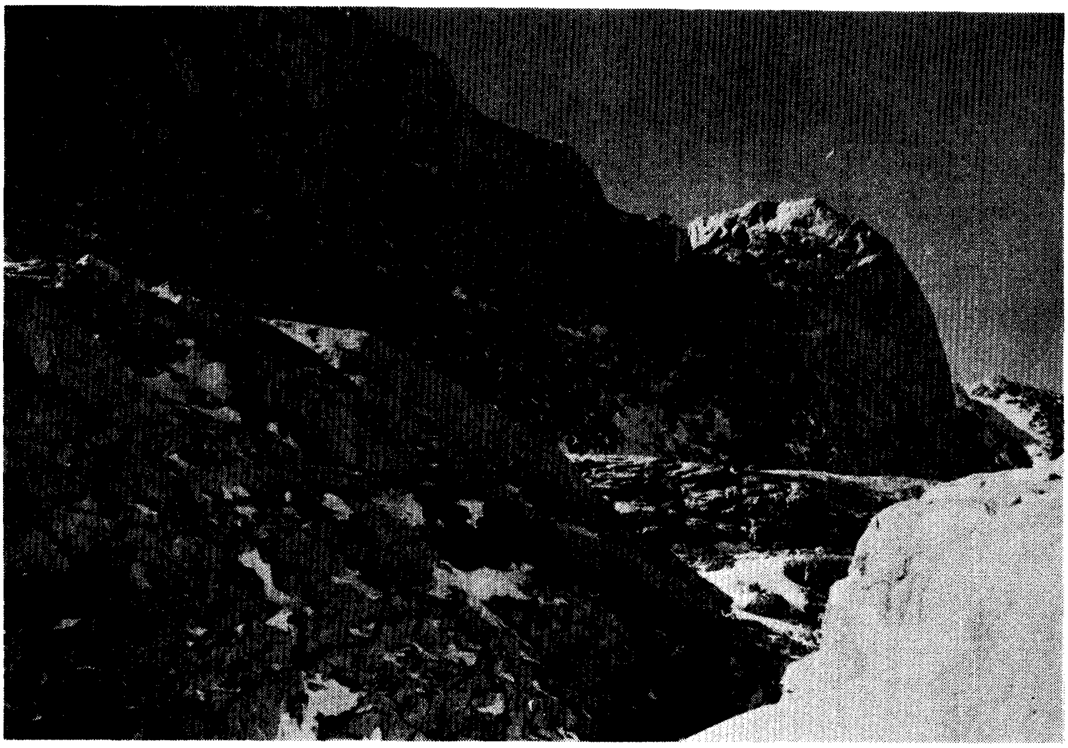

Fig. 5. Thin lenticular beds of metabasite in garnet gneiss in the Yukidori Valley of the Langhovde region.

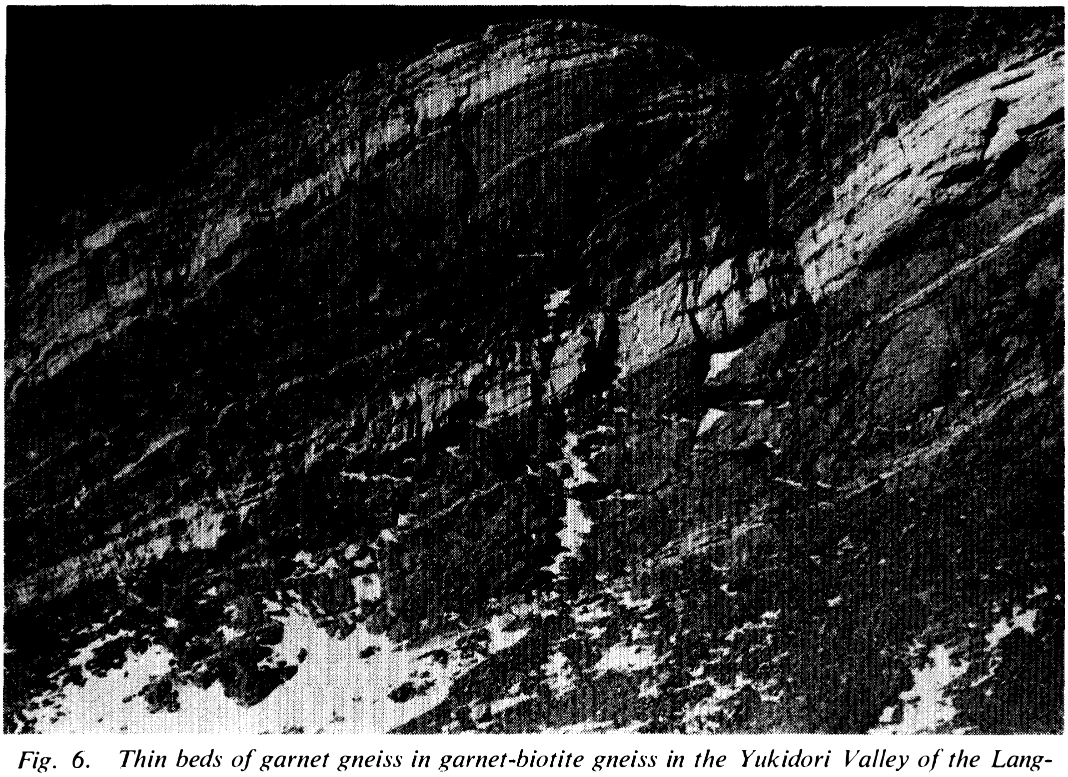

Fig. 6. Thin beds of garnet gneiss in garnet-biotite gneiss in the Yukidori Valley of the Langhovde region.

Fig. 7. Pegmatite intrusion in charnockitic rocks in Torinosu Cove of the Skarvsnes region.

Fig. 8. The Hunazoko thrust in the Ongul group, east of Torinosu Cove of the Skarvsnes region.

area. This rock forms thick beds in the Yukidori Valley of the Langhovde region and in the Byvågåsane area. The garnet gneiss alternates with garnet-biotite gneiss and charnockitic rocks (Fig. 6). The rock is generally leucocratic and massive, includes spot-like garnet, and shows a weak foliation. It is useful as a key bed because of its continuity. In this rock, a gneissose structure is not distinct.

Migmatitic gneiss: Migmatitic gneiss is distributed in the northwestern part of the Breidvågnipa area. This rock is generally fine- to medium-grained and composed mainly of biotite, plagioclase, potassium feldspar, quartz and garnet. A gneissose structure is usually distinct and is developed parallel to the boundary plane of other rocks, but in some localities the rock is quite massive.

Garnet-bearing granitic gneiss: This rock occurs in the vicinity of Mt. Tyôtô, in the south of the Nakano-tani Valley, in the south of the Lake Higashi-yukidori of the Langhovde region, in the southern part of the Skarvsnes region, and in the Breidvågnipa area. The garnet-bearing granitic gneiss is generally medium-grained, roughly equigranular, and consists essentially of pink or white feldspars, quartz and biotite, with garnet in minor amounts. The rock is bedded, and shows a foliation which is due to linear arrangement of minute crystals of biotite. A gneissose structure of this rock is usually distinct but in some localities the rock is quite massive. The rock occurs as a thin layer and is employed as a key bed in the vicinity of Mt. Tyôtô, Langhovde region, and in the vicinity of Torinosu Cove and Mt. Sirasuso.

Microcline granite and gneissose microcline granite: Microcline granite is widely distributed in the western part of the Langhovde region, and gneissose microcline granite is distributed in the northeastern part of the Breidvågnipa area. These rocks always have pink-colored pottassium feldspar as the most characteristic contituent. These two rocks are fine- to rather coarse-grained and composed mainly of biotite, plagioclase, perthite, quartz and garnet, with or without a little antiperthite. The gneissose structure of these rocks is usually weak and is developed parallel to the contact plane. These rocks and the pegmatite correspond to the pink granites of YOSHIDA (1978).

Pegmatite: This rock occurs as lenticular bodies, clear-cut veins and dikes in the vicinity of Mt. Tyôtô of the Langhovde region, and in the northern part of Hiroe Point of the Breidvågnipa area, and in the vicinity of Torinosu Cove of the Skarvsnes region. Straight dikes of pegmatite are about 30 cm wide and 1.5 km long, and trend N–S and E–W across the geological structure. The rock stands out in relief 40 cm high from the country rock all around (Fig. 7). Irregular-shaped pegmatite occurs in the garnet-biotite gneiss. It is observed that the garnet content increases in the country rock near the pegmatite.

Beach sand and gravel: Near the present shoreline and in the lowlands of Kominato Inlet, Yatude Valley, Yukidori Valley and Lake Oyayubi of the Langhovde region, and Torinosu Cove, Kizahasi Beach, Lake Suribati and Lake Hunazoko of the Skarvsnes region, some fossil-bearing sand and gravel deposits are found.

These deposits are composed mainly of fragments of rocks exposed in the region, although there are also some erratic boulders. The sorting of the deposits is notably poor. The distribution of the deposits is restricted to the low areas, their highest locality being 20 m above sea level in the central part of the Langhovde region, and in the vicinity of the Lake Suribati. The deposits at about 1.5–2 to 6 m above sea level contain such fossils as *Adamussium colbecki* and *Laternula elliptica* (MORIWAKI, 1974; ISHIKAWA, 1974). Main localities of the fossils are Ko-minato Inlet, Lake Oyayubi, Shimo-kama cove, Lake Suribati and Torinosu Cove. Age determinations by the ^{14}C method were done, as shown in Table 2.

Table 2. ^{14}C ages of fossils from raised beach deposits in the Langhovde region.

Locality	Elevation above sea level (m)	Sample	Age B.P. (years before 1950)	Ref.
Ko-minato Inlet				
Langhovde 03	5–6	*Laternula elliptica*	23830±910	1
Langhovde 04	1.5	*Adamussium colbecki*	4290± 90	
Langhovde 07	6	*Adamussium colbecki*	10250±210	
Langhovde 08	6	*Laternula elliptica*	over 33400	
Oyayubi Island	2		2000±220	1
Simo-kama	1.5	*Laternula elliptica*	3840± 90	2

1. MORIWAKI, 1974, 2. ISHIKAWA, 1974.

Terrestrial deposits: Terrestrial deposits are distributed throughout the ice-free area and along the margin of the ice sheet. Glacial deposits are accumulated in a large quantity around the continental glacier and form moraine. They are a poorly sorted mixture of gravel, sand and silt. Glacial deposits are distributed in the Naka-no-tani Valley of the Langhovde region, in the eastern part of the Breidvågnipa area, in the eastern part of the Tankobu Peak of the Byvågåsane area, and in the eastern part of Mt. Tenpyô and in the southern part of Knappen of the Skarvsnes region.

4. Geologic Structure of the Langhovde and Skarvsnes Regions

Various types of folds and fractures were found in the Langhovde and Skarvsnes regions by many geologists, and a thrust was discovered in the Skarvsnes region by Y. MATSUMOTO and K. YANAI in 1975. General geologic structure and their succession and tectonic interpretation were given by ISHIKAWA (1976), YANAI *et al.* (1977), YOSHIDA *et al.* (1977a, b), YOSHIDA (1978) and MATSUMOTO (1978), and the outline of geologic structures in the Langhovde and Skarvsnes regions was reported by the present authors and others (ISHIKAWA *et al.*, 1976, 1977).

A thrust was observed in the northeast part of Torinosu Cove, with its plane striking N50°E and dipping 60° to the east (Fig. 8). This thrust passes through the east of Torinosu Cove, the offing of Kizahasi Beach and the north of the Lake Hunazoko, and show a convex form in the east. This thrust, designated as "Hunazoko Thrust", might have occurred in relation to the D_1 Osöya antiform.

Various types of folds and fractures in these regions are divided into four stages. The principal geologic structure of these regions is intense polyclinal folding D_1 trending N–S with an almost horizontal enveloping surface. Some other open and gentle folds were found superposing on the polyclinal folds. The axial traces of folds are approximately parallel to the coastal line of Lützow-Holm Bay including the present regions (YOSHIDA, 1978). All the folds in the present regions are classed as N–S trending polyclinal fold of isoclinal, mushroom, and asymmetric forms with wavelength over a few kilometers (D_1), E–W trending open to close fold with wavelength over some kilometers (D_2), and again N–S trending gentle fold with wavelength over ten or more kilometers (D_3). Diagonal set fractures took place after these foldings (D_4). D_1 folds are the Langhovde synform, Naka-no-tani antiform, Yukidori synform and Heito antiform of the Langhovde region, and the Osöya antiform, Sirasuso synform, Maruyama antiform and Hiroe synform of the Skarvsnes region. D_2 folds are the Kizahasi antiform and other folds with the folding axis of an E–W trend, and D_3 fold is the Osen synform.

4.1. Stage 1 (D_1)

In stage 1, recumbent and isoclinal folds represent the axial trace trending N–S in these regions.

The Langhovde synform is found from the closed distribution of the garnet-biotite gneiss occurring near Mt. Tyôtô. Axial trace of the Langhovde synform passes through the south of Mt. Tyôtô, east of the Lake Nurume, south of Oyayubi Island, to the south of Revsnes in the western part of the Langhovde region. This synform is an isoclinal type with the axial plane moderately dipping east.

The Naka-no-tani antiform is estimated form the distribution of the charnockitic rocks widely occurring near the Naka-no-tani Valley. Axial trace of this synform passes through the central part of the Langhovde region. The Naka-no-tani synform is an isoclinal type, its axial plane moderately dipping east.

The Yukidori synform is estimated from the distribution of the garnet-biotite gneiss widely occurring near the Lake Yukidori. Axial trace of this synform passes through the Lake Yukidori, Simo-kama, the west of Hamna Icefall, to the Lake Nisi-Hamna. This synform is an isoclinal type, its axial plane moderately dipping east.

The Heitô antiform is estimated from the distribution of the hornblende gneiss widely occurring near the Heitô Glacier. Axial trace of the Heitô antiform passes through the southeastern part of the Langhovde region. This synform is an isoclinal type, its axial plane moderately dipping east.

The Hiroe synform is distinctly shown on the geological map of the Breidvågnipa area (ISHIKAWA *et al.*, 1977), where zonally arranged charnockitic rocks and garnet-biotite gneiss show a horseshoe shape distribution convex to the north. Axial trace of the Hiroe synform passes through the central part of this horseshoe shape. This Hiroe synform is an asymmetric close fold, its vertical axial plane gently plunging south.

The Osöya antiform is found from the closed distribution of the garnet-biotite gneiss widely occurring near Osöya. The ridge of this antiform lies in the northeast of the Hunazoko thrust, running parallel to it, in the south and the northwest of Osöya. The Osöya antiform is an isoclinal type, its axial plane moderately dipping east to northeast and the axis plunging south to southwest.

The Sirasuso synform is found east of Knappen, through Mt. Sirasuso, to the east of Trillingöyane. This synform is an asymmetric close fold with a nearly vertical axial plane. The profile of this synform appears to change from close to gentle towards south, *i. e.*, towards the upper horizon, indicating a disharmonic nature of this fold. The axis of this antiformal plunges gently and northerly in the north of the Kizahasi antiform, and plunges southerly in the south of the Kizahasi antiform.

The Maruyama antiform is estimated form the distribution of porphyroblastic gneiss near Maruyama Peak. Axial trace of this antiform passes through the Maruyama Peak, and shows a semicircle convex to the west. Porphyroblastic gneiss is distributed parallel to the axial trace. This Maruyama antiform is a tight or mushroom fold with a nearly vertical axial plane trending N–S.

In addition to the above mentioned, isoclinal minorfolds with the N–S trend developed near Knappen are considered to belong to the D_1 folds. There is a possibility that the Maruyama antiform took place synchronously with the formation of the porphyroblastic gneiss, and therefore, belongs to the D_3.

4.2. *Stage 2* (D_2)

The folding axes of D_2 folds curve in various styles. These D_2 folds are represented by the axial trace trending E–W in these regions.

In the northern part of the Langhovde region, the ESE–WNW or SE–NW trending antiforms or synforms with the most characteristic features of D_2 stage are found in the geological map. The antiform located in the east of Ko-minato Inlet has an E–W axis plunging to the east. The northern wing of this antiform is steep, but the southern wing is gentle. In the northern part of this antiform, the existence of a synform is inferred from the distribution of charnockitic rocks, the axis of the estimated synform trending NW–SE to N–S, plunging to the southeast or south, and showing an isoclinal folding type. Another antiform is found from the distribution of garnet-biotite gneiss and charnockitic rocks near Mt. Tyôtô, through Langhovde-Kita Point, to the south of Mt. Tyôtô. This antiform is an asymmetric type with its axial plane moderately dipping northeast and the axis plunging southeast.

In the Breidvågnipa area and the northern and southern parts of Byvågåsane, the E–W trending antiforms or synforms of D_2 stage are found in the geological map.

These folds have steep axial planes. The wavelength of D_2 major folds is several kilometers but that of the minor folds is several hundreds of meters.

Gneissic rocks occurring around Maruyama Peak show a semicircle distribution concave to the east, and those of the Kizahasi Beach and Osöya concave to the west. A continuing line of the axes of these semicircles is the axial trace of the Kizahasi antiform, its axis plunging west in the eastern part and plunging east in the western part. The axial trace of the Kizahasi antiform passes through the Kizahasi Beach, Osöya, Osen, and the north of Maruyama Peak, thus curved convex to the north.

4.3. Stage 3 (D_3)

Some of the axes D_2 folds appear to be gently bent north or south. The change in the plunge and trend of the D_2 folds indicates the superposition of D_3 folds.

The Osen synform runs N–S near Osen in the central part of the Skarvsnes region. The change in the trend and plunge of the Kizahasi antiform distinctly displays the effect of this Osen fold. The axial plane of this fold appears vertical and planer trending N–S, although the plunge of the axis is uncertain.

4.4. Stage 4 (D_4)

Diagonal sets of fracture trending N65°W and N60°E are well developed throughout the region. The fractures are easily traced as lineation on aerial photographs. These fractures are considered to be conjugate sets of shear fractures caused by the E–W compressional stress field (Ishikawa, 1976; Yoshida, 1978).

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