# GEOLOGY AND GEOLOGIC STRUCTURE OF THE NORTHERN ONGUL ISLANDS AND SURROUNDINGS, EAST ANTARCTICA

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***Abstract:*** The outline of geology and geologic structure of the northern Ongul Islands and surroundings of Lützow-Holm Bay, East Antarctica is herein described. In this region is distributed the Ongul Group of the Lützow-Holm Bay System. The Ongul Group is characterized by alternating layers of gneissic rocks of late Precambrian age. The crystalline rocks exposed in this region are classified as follows: (1) metabasite, (2) charnockitic rock, (3) hornblende gneiss, (4) garnet-biotite gneiss, (5) potassium feldspar porphyroblastic gneiss, (6) garnet gneiss, (7) garnet-bearing granitic gneiss and (8) pegmatite.

Tectonically two principal deformational stages are discriminated in this region; the first deformational stage: inclined isoclinal folds with the axial trace trending north-south, the second deformational stage: close to open folds with the axial trace of an east-west trend. The third deformational stage which is distinguished in the Langhovde and Skarvsnes regions adjacent to this region is not so clearly recognized, but the conjugate sets of fractures which occurred during a later deformational stage are well developed throughout this region.

## 1. Introduction

The Ongul Islands are situated in the northeast of Lützow-Holm Bay and separated from the Sôya Coast of the Antarctic Continent by Ongulsundet (Ongul Strait) about 5 km wide. The islands are bounded by latitudes 68°55.5′S–

69°05.5′S and longitudes 39°25′E–39°40′E and consist of over ten islands.

In the southern Ongul Islands the geological map on a scale of 1:5000 was already published on four larger islands, East Ongul Island, West Ongul Island, Teöya and Ongulkalven, by YANAI *et al.* (1974a, b, 1975a, b). While in the northern Ongul Islands, several rather small islands lie sporadically, and a few reports on their geology have been presented. A few kilometers east of the Ongul Islands across Ongulsundet, some small outcrops of the crystalline rocks, which have not been sufficiently studied, form a discontinuous row along the Sôya Coast.

This paper reports the recently obtained outline of geology and geologic structure of the basement rocks in the northern Ongul Islands and surroundings.

Since the large-scale topographical map of this region has not been available, field data are plotted on the conventional map compiled from various aerial photographs taken by the Japanese Antarctic Research Expedition, and a brief tectonic sketch of the region is drawn on the working map edited by K. MORIWAKI in 1979.

## 2. Geology

### *2.1. Geology of each island and outcrop*

Figures 1 to 14 show geologic sketch of basement rocks of each island and outcrop in this region. The nomenclature of metamorphic and pultonic rocks in the region is generally based on the usage in the geological maps of East Ongul Island, West Ongul Island, Teöya and Ongulkalven. The term foliation used in this paper is referred to all planar structures develop in the metamorphic rocks but in most instances it corresponds to s-plane.

2.1.1. Mendori Island and its neighboring islands (Fig. 1)

There are some small islands contiguous to the northern part of West Ongul Island. Wakadori Island, Mendori Island and Ondori Island are drawn up respectively south to north. These islands are composed mainly of charnockitic rock (Fig. 16). Three thin layers of garnet-bearing granitic gneiss and small bodies of metabasite and pegmatite are associated with charnockitic rock. On Wakadori Island and Mendori Island small bodies or lenticular bodies of garnet amphibolite are developed within charnockitic rock (Fig. 23) and the rock extends to West Ongul Island.

Hiyoko Island lies just east of Mendori Island and consists mainly of hornblende gneiss. Thin beds of charnockitic rock and garnet gneiss are associated with hornblende gneiss, and metabasite is found to occur partly. The foliation of gneissic rocks in these islands strikes N5°E to N32°W and dips 30° to 70° to the east.

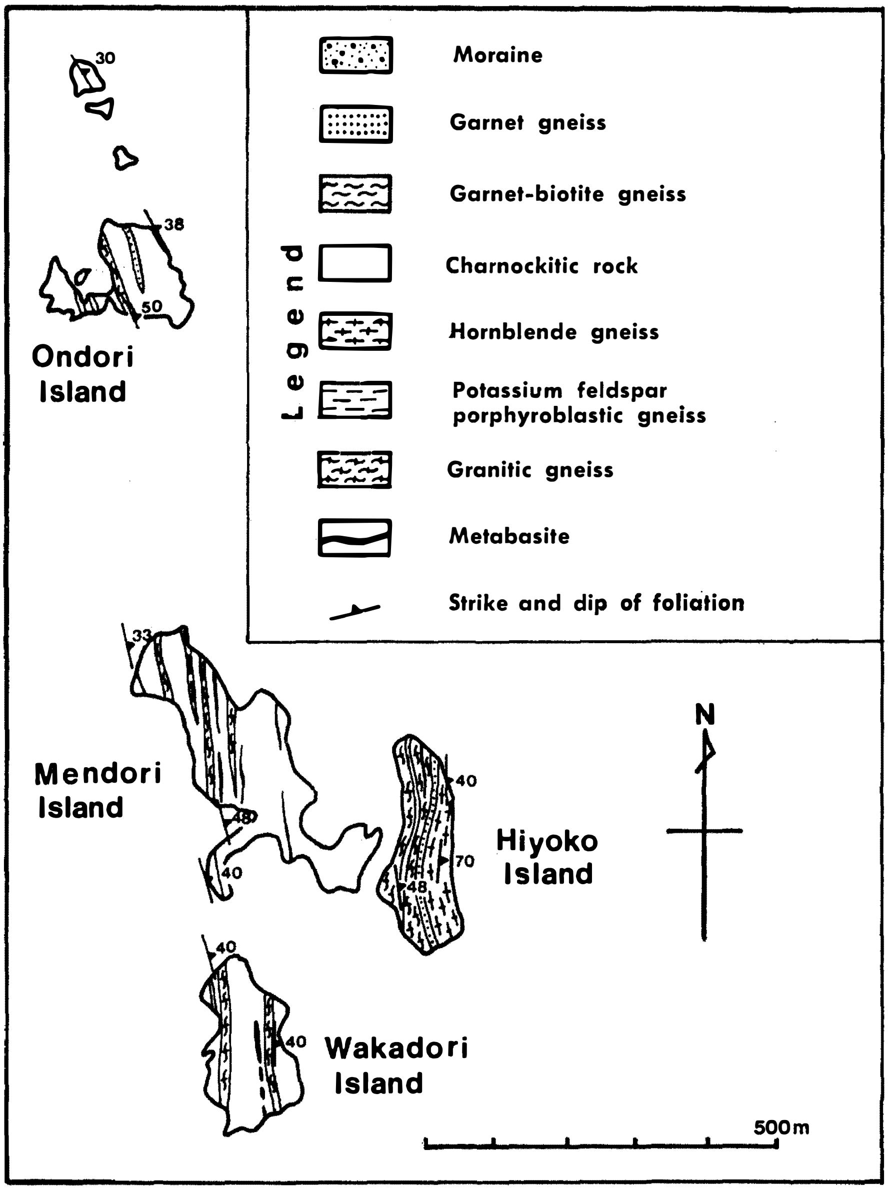


*Fig. 1. Geologic sketch of Mendori Island and its neighboring islands.*

2.1.2. Meholmen (Fig. 2)

Meholmen is a rather large island situated about 5 km northwest of Syowa Station of East Ongul Island, and is very slender in shape and about 1200 m in length north to south. It is composed mainly of charnockitic rock, and three layers of hornblende gneiss are found within it. Small lenticular or irregular bodies of metabasite and pegmatite are associated with charnockitic rock (Fig. 17). The foliation strikes N10° to 45°W and dips 46° to 80°E or 80°W. At the northern end of the island an antiform trending north-south is recognized and it seems to extend southward through the central part of the island.

2.1.3. Utholmen (Fig. 3)

Utholmen is situated about 9 km north-northwest of Syowa Station and consists of two small islets each about 100 m in diameter. Both islets are composed of charnockitic rock (Fig. 18). In the southwestern islet the foliation strikes N45°E and dips 40° to 70°NW. In the northeastern islet it strikes N55°W and dips 45°NE.

2.1.4. Unnamed islets between Utholmen and Kita-zima Island (Fig. 4)

There are two small islets between Utholmen and Kita-zima Island. They are slightly closer to Kita-zima Island and situated about 9 km north of Syowa Station. Both islets are composed of hornblende gneiss. Pegmatite 30 cm in width is found in both islets. The foliation of hornblende gneiss strikes N65°E and dips 35°S. Pegmatite runs N15°W and dips 70°W.

2.1.5. Kita-zima Island (Fig. 5)

Kata-zima Island lies about 10 km north-northeast of Syowa Station and is about 100 m in diameter. It is composed entirely of charnockitic rock. The foliation strikes N50°W and dips 50°S at the east end of the island and strikes N70°E and dips 50°S at the west end. So a synform passes through the central part of the island. It may correspond to the West Ongul Synform as will be mentioned later.

2.1.6. Naka-zima Island (Fig. 6)

Naka-zima Island situated about 7.5 km northeast of Syowa Station consists of four islets, and is about 700 m in total length east to west. The islets are composed of charnockitic rock and hornblende gneiss (Fig. 20). In the eastern part of the largest islet are developed many small bodies of pegmatite which are nearly parallel with one another and run N15° to 35°W and dips 60°W as shown in Fig. 21.

2.1.7. Unnamed islets north of Hatusima Island (Fig. 7)

There is an unnamed islet about 2 km north of Hatusima Island and also are three islets about 1 km further north of it. These four islets are all composed of hornblende gneiss, partly intruded by pegmatite. The foliation of hornblende gneiss strikes NS to N50°W and dips 30° to 80°E.

2.1.8. Hatusima Island (Fig. 8)

Hatusima Island is located just north of Nesöya and about 700 m in length east to west. The island is composed of charnockitic rock and hornblende gneiss with subordinate amounts of garnet gneiss, garnet-bearing granitic gneiss and metabasite. Molybdenite occurs sporadically in charnockitic rock as is observed at Nesöya and East Ongul Island. Strike of the foliation crosses nearly at a right angle to the direction of extension of the island and varies from N45°E to N25°W and dip of it varies from 30° to 50°E.

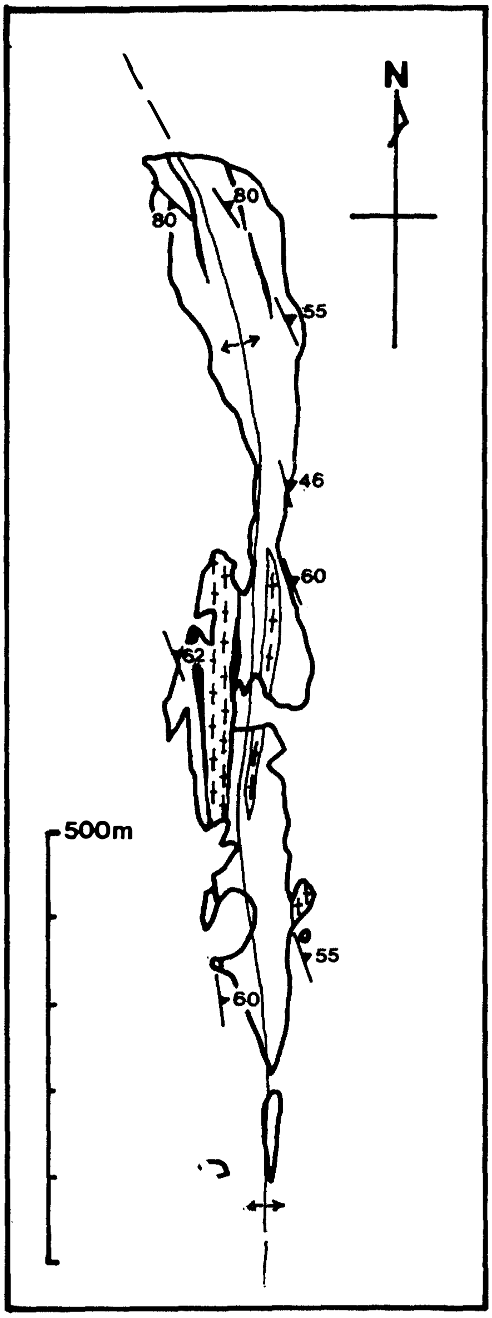


Fig. 2. Geologic sketch of Meholmen. For legend see Fig. 1.

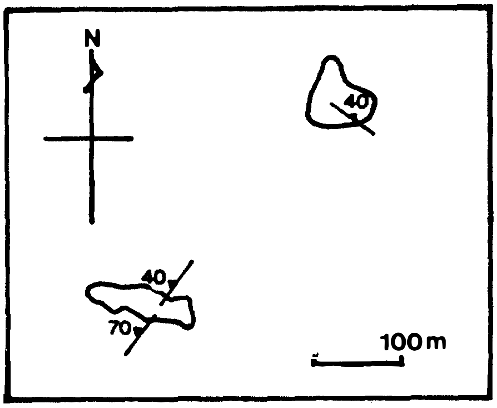


Fig. 3. Geologic sketch of Utholmen. For legend see Fig. 1.

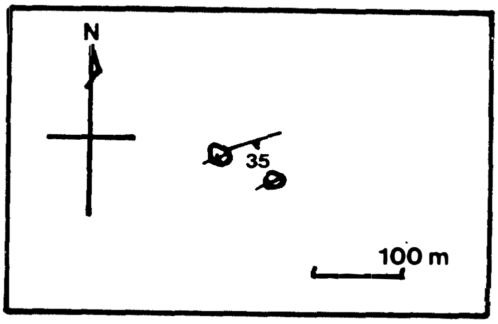


Fig. 4. Geologic sketch of unnamed islets between Utholmen and Kita-zima Island. For legend see Fig. 1.

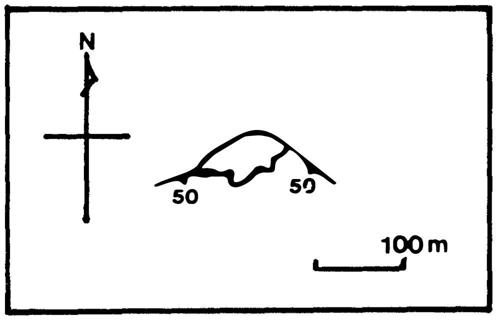


Fig. 5. Geologic sketch of Kita-zima Island. For legend see Fig. 1.

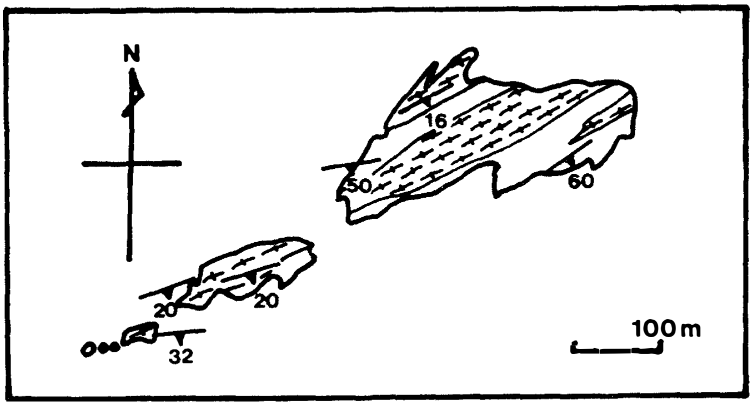


*Fig. 6. Geologic sketch of Naka-zima Island. For legend see Fig. 1.*

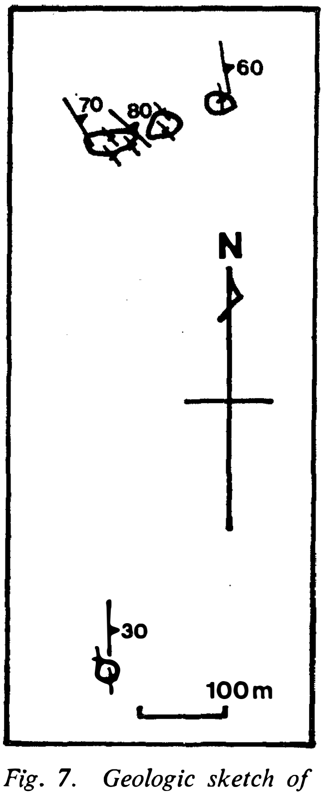


*Fig. 7. Geologic sketch of unnamed islets north of Hatusima Island. For legend see Fig. 1.*

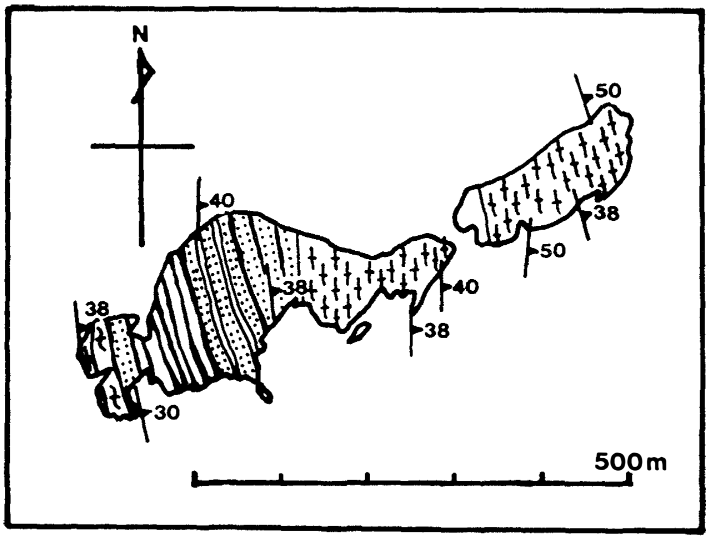


*Fig. 8. Geologic sketch of Hatusima Island. For legend see Fig. 1.*

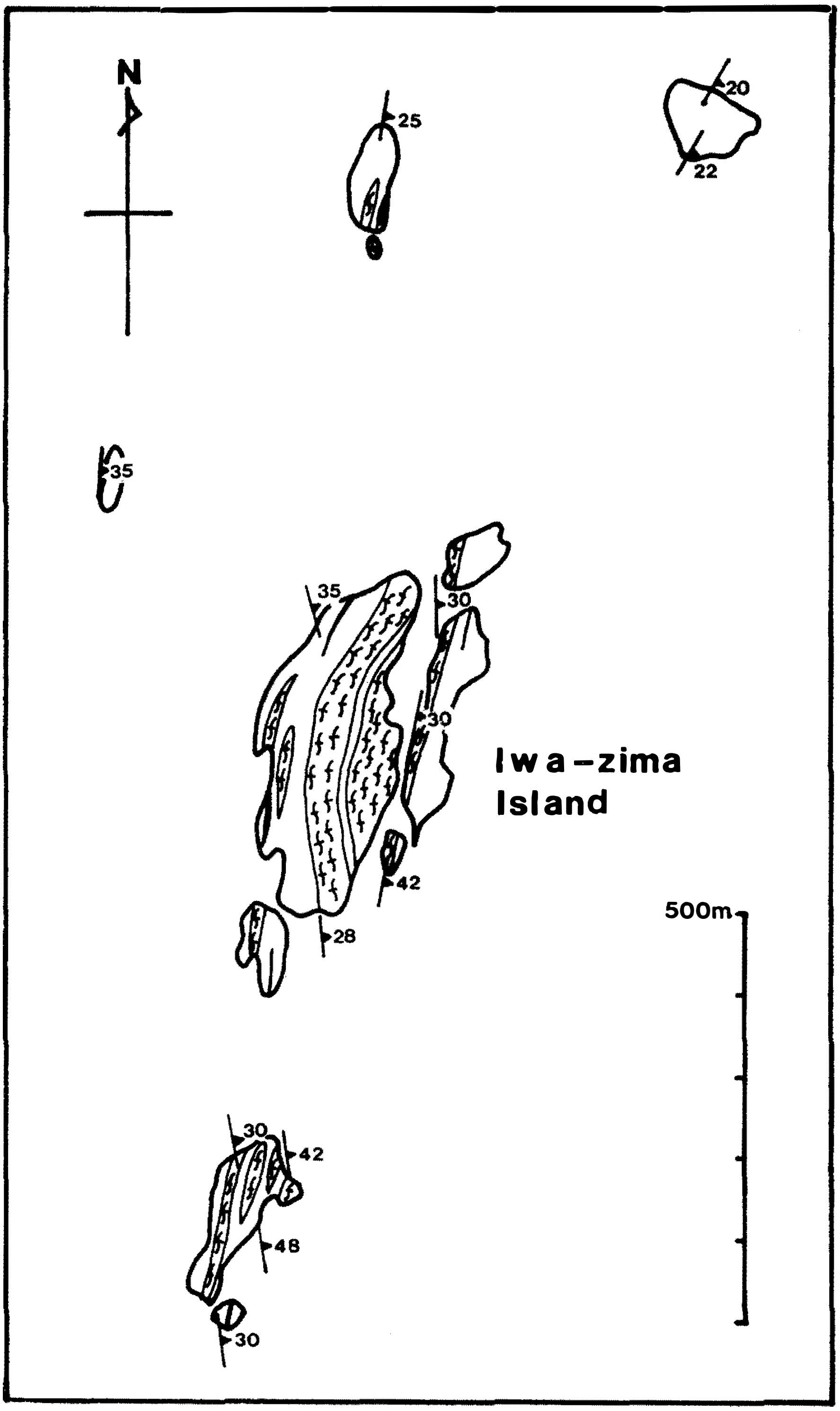


*Fig. 9. Geologic sketch of Iwa-zima Island and its neighboring islets. For legend see Fig. 1.*

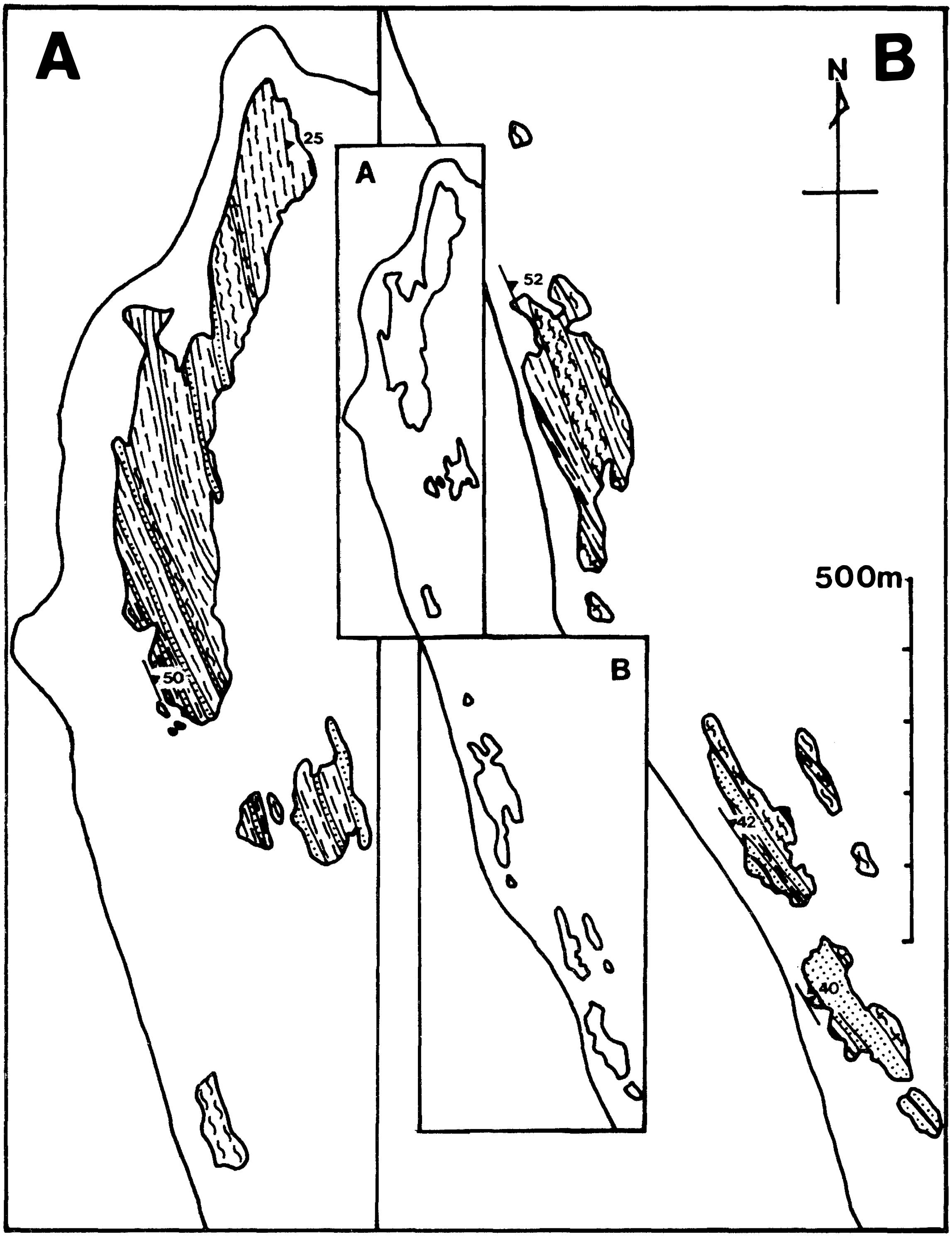


*Fig. 10. Geological sketch of Mukai Rocks. For legend see Fig. 1.*

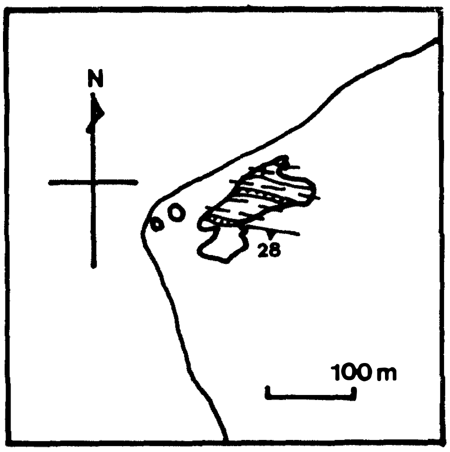


*Fig. 11. Geological sketch of unnamed rocks between Matukawa-iwa Rock and Mukai Rocks. For legend see Fig. 1.*

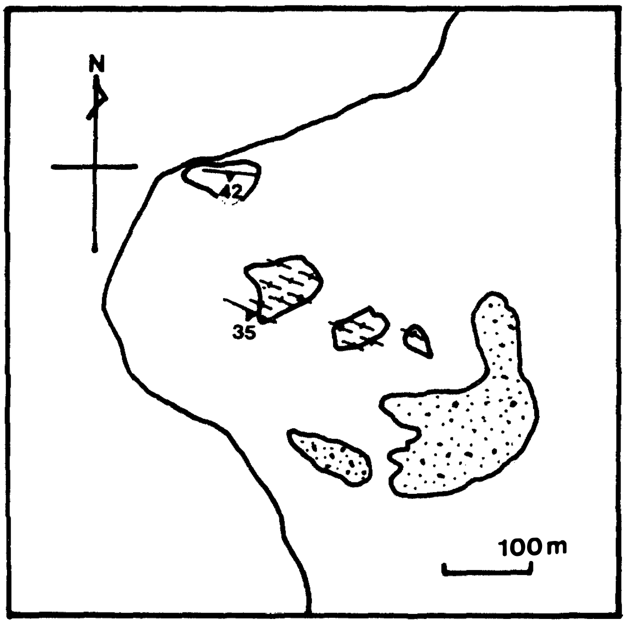


*Fig. 12. Geologic sketch of Matukawa-iwa Rock. For legend see Fig. 1.*

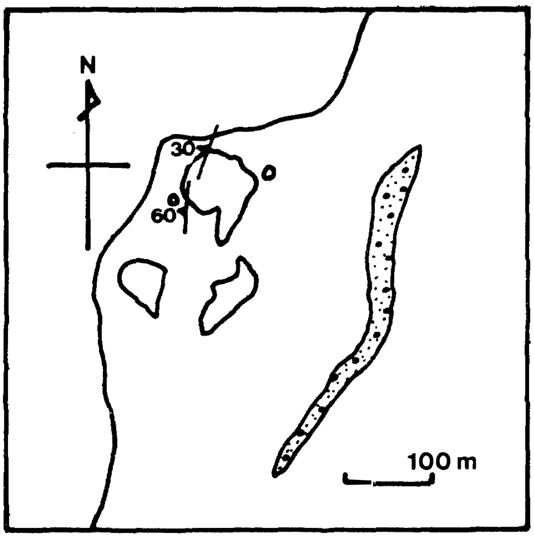


*Fig. 13. Geologic sketch of Mitu-iwa Rock. For legend see Fig. 1.*

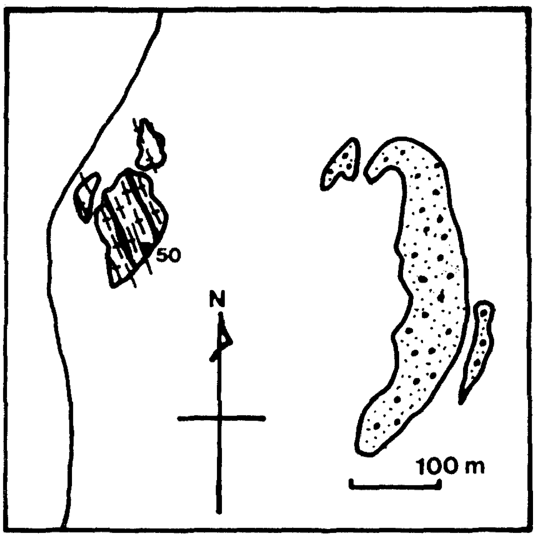


*Fig. 14. Geologic sketch of Tottuki Point. For legend see Fig. 1.*

2.1.9. Iwa-zima Island and its neighboring islets (Fig. 9)

Iwa-zima Island is situated 2 km northeast of Syowa Station and about 400 m in length north to south. There are some islets around it. The islands are composed mainly of charnockitic rock and garnet-bearing granitic gneiss (Fig. 22). Some lenticular bodies of metabasite occur within these rocks. The foliation strikes parallel to the direction of extension of the island, being N15°W, and dips 22° to 48°E. The structure is seemingly homoclinal.

2.1.10. Mukai Rocks (Fig. 10)

Mukai Rocks crop out along coast line about 10 km east of Teöya and of a very elongate shape, about 3300 m in length north to south. They are composed mainly of potassium feldspar porphyroblastic gneiss and a subordinate amount of garnet-biotite gneiss. In the northern part of them some thin beds of garnet gneiss and a thin bed of charnockitic rock and hornblende gneiss are associated with the main constituent rocks. In the southern part are found garnet-bearing granitic gneiss, garnet gneiss, hornblende gneiss and metabasite within the main constituent rocks. As a whole the foliation strikes nearly parallel to the coast line, being N25° to 35°W, and dips 45° to 50°E.

2.1.11. Unnamed rocks between Matukawa-iwa Rock (tentative name) and Mukai Rocks (Fig. 11)

The unnamed rocks crop out near the coast 5 km east of East Ongul Island. They lie about 2500 m north of the northern end of Mukai Rocks. They are composed mainly of potassium feldspar porphyroblastic gneiss and charnockitic rock, with subordinate amounts of garnet gneiss, hornblende gneiss and metabasite. The foliation strikes N85°W and dips 28°S.

2.1.12. Matukawa-iwa Rock (tentative name) (Fig. 12)

Matukawa-iwa Rock crops out near the coast about 4 km east of Iwa-zima Island. It is composed of charnockitic rock and hornblende gneiss. The foliation strikes N65° to 85°W and dips 35° to 42°S.

2.1.13. Mitu-iwa Rock (Fig. 13)

Mitu-iwa Rock lies 3 km north-northeast of Matukawa-iwa Rock and 7 km south-southwest of Tottuki Point, and consists of three small rocks which are entirely charnockitic rock (Fig. 19). The foliation strikes N5° to 20°E and dips 30° to 60°W. Some thin layers of pegmatite are found to intrude the charnockitic rock.

2.1.14. Tottuki Point (Fig. 14)

Three small rocks crop out near Tottuki Point which has been familiar to the member of the Japanese Antarctic Research Expedition as the landing place on the way from Syowa Station to inland area in recent years. They are composed mainly of hornblende gneiss, and small lenticular or stretched bodies of metabasite are often found within it. The foliation strikes N25°W and dips 50°E.

### 2.2. *Distribution and petrography of gneissic rocks*

The basement rocks exposed in this region are classified on the basis of their modes of occurrence and petrographic features as follows: (1) metabasite, (2) charnockitic rock, (3) hornblende gneiss, (4) garnet-biotite gneiss, (5) potassium feldspar porphyroblastic gneiss, (6) garnet gneiss, (7) garnet-bearing granitic gneiss and (8) pegmatite. The metamorphic rocks belong to the Ongul Group, named by YOSHIDA *et al.* (1977) and defined by YOSHIDA (1978), of the Lützow-Holm Bay System of TATSUMI *et al.* (1964).

***Metabasite:*** Within the gneissic rocks (charnockitic rock, hornblende gneiss, garnet-biotite gneiss, garnet gneiss and potassium feldspar porphyroblastic gneiss) there are nearly concordant thin beds, lenses and irregular-shaped bodies of basic metamorphosed rocks. They are medium- to coarse-grained and usually black to dark greenish black in color, and crop out in the western part of Naka-zima Island, Tottuki Point, central and southern parts of Mukai Rocks, Hatusima Island and Meholmen. The rock has various facies such as hornblende eclogite (composed of garnet, hornblende, clinopyroxene, orthopyroxene, phlogopite and/or plagioclase) as shown in Fig. 28, hornblendite (hornblende, ± garnet, ± phlogopite, ± orthopyroxene, ± clinopyroxene) and pyroxenite (orthopyroxene, clinopyroxene, biotite, plagioclase, ± garnet, ± hornblende).

Amphibolite lenses occur within charnockitic rock in Mendori Island and Wakadori Island. The lenses are concordant with the gneissose structure of the charnockitic rock. Amphibolite is characterized by banded streaks of coarse-grained garnet crystals in grayish white matrix as shown in Fig. 23, so that the foliation is more distinct than other gneisses. Its mineral assemblage is represented by garnet, hornblende, biotite, plagioclase, magnetite and sometimes green spinel (Fig. 29).

***Charnockitic rock:*** Charnockitic rock is most widely distributed in this region. The typical rock is uniformly fine- to medium-grained, granoblastic in texture and usually dark brown to bluish gray due to the presence of abundant colored feldspar and quartz crystals. Pyroxene is always present. The rock is composed of orthopyroxene (hypersthene), clinopyroxene, plagioclase, potassium feldspar, quartz and magnetite, with minor amounts of garnet, biotite, muscovite, apatite and zircon. Pyroxene is often converted into hornblende in this rock as shown in Fig. 24. The foliation is not so distinct, although the banded structure resulting from concentration of mafic minerals and/or elongated dark inclusions is partially observed.

***Hornblende gneiss:*** Hornblende gneiss is distributed in Hiyoko Island, Meholmen, unnamed islets between Utholmen and Kita-zima Island, unnamed islets north of Hatusima Island, eastern part of Hatusima Island, Naka-zima Island and Matukawa-iwa Rock. In other places it occurs as thin beds within gneissic rock. The rock is characterized by the presence of hornblende and the absence of pyroxene. It is generally medium- to coarse-grained and bluish gray, brownish gray or reddish gray in color. The foliation is distinct but partly observed in the massive portion. The rock is composed of green hornblende, biotite, plagioclase, potassium feldspar, quartz and magnetite and sometimes a small amount of garnet, with apatite and zircon as accessory minerals (Fig. 25).

***Garnet-biotite gneiss:*** Thin beds of garnet-biotite gneiss are found within gneissic rocks (potassium feldspar porphyroblastic gneiss, garnet gneiss and garnet-bearing granitic gneiss) in Mukai Rocks. The rock is fine- to medium-grained, with similar mineral assemblage as that of potassium feldspar porphyroblastic gneiss but is characteristically reddish brown in color due to the presence of abundant garnet and biotite. Potassium feldspar often occurs as large crystals, giving a porphyroblastic appearance to the rock in places. The foliation of this rock is due to parallel arrangement of garnet and biotite. Alternation of melanocratic layer consisting of biotite and garnet and leucocratic layer consisting of quartz and feldspar accounts for the distinct foliation. The constituent minerals are garnet, biotite, quartz, potassium feldspar and plagioclase, with such accessory minerals as magnetite, apatite and zircon.

***Potassium feldspar porphyroblastic gneiss:*** Potassium feldspar porphyroblastic gneiss is distributed most widely in Mukai Rocks. The rock is characterized by relatively large grains of potassium feldspar, approximately 3 to 4 cm in diameter. Except for these large crystals of potassium feldspar, the rock is fine- to medium-grained and has a distinct gneissose structure displayed by concentration of biotite flakes. The matrix is composed of garnet, biotite, quartz and plagioclase, with accessory minerals such as magnetite, apatite and zircon.

***Garnet gneiss:*** Thin beds or lenses of garnet gneiss are found within gneissic rocks (charnockitic rock, hornblende gneiss, potassium feldspar porphyroblastic gneiss, garnet-biotite gneiss and garnet-bearing granitic gneiss) in Hatusima Island, Mukai Rocks, unnamed rocks between Matukawa-iwa Rock and Mukai Rocks and Hiyoko Island. The rock is fine- to medium-grained, showing spotted garnet crystals of reddish brown color in leucocratic matrix. Foliation is not conspicuous. The constituent minerals are garnet, quartz, with minor amount of potassium feldspar and plagioclase (Fig. 26). Magnetite, apatite and rare clinopyroxene are found as accessories.

***Garnet-bearing granitic gneiss:*** Garnet-bearing granitic gneiss is rather widely distributed in Hatusima Island, Iwa-zima Island and its neighboring islets and Mukai Rocks, where it occurs as concordant sheets within gneissic rocks. It is generally medium-grained and equigranular. The rock often grades into various rock-facies such as white aplitic gneiss, reddish potassium feldspar porphyroblastic gneiss as shown in Fig. 22, and pinkish-colored gneissose granite. The foliation of the rock is generally due to planar arrangement of minute crystals of biotite. In some localities the rock is almost massive. It is composed of garnet, biotite, plagioclase, potassium feldspar and quartz, with magnetite and apatite as accessory minerls (Fig. 27).

***Pegmatite:*** This occurs as lenticular bodies, clear-cut veins and dykes throughout this region. There are two kinds of pegmatite in this region: one is pink microcline pegmatite which occurs as dykes and contains much pink microcline perthite, quartz, biotite and partially abundant magnetite, and the other occurs as irregular patches of white color and is composed of microcline perthite and quartz, associated with a minor amount of biotite.

## 3. Geologic Structure

### *3.1. Previous works*

Various types of folds and fractures developed throughout the region around Lützow-Holm Bay were genetically settled and divided into four deformational stages by YOSHIDA (1978) on the basis of the results of many valuable investigations that had been presented by some Japanese geologists (KIZAKI, 1964; YOSHIDA, 1970; YOSHIDA and ANDO, 1971; YOSHIDA, 1975a, b, 1977; YOSHIDA *et al.*, 1976, 1977b; ISHIKAWA, 1976; ISHIKAWA *et al.*, 1976, 1977).

The nomenclature of folds in the present paper follows that of FLEUTY (1964) as was done by YOSHIDA (1978).

The oldest tectonic stage of the region is represented by recumbent and isoclinal folds, their axial traces trending approximately parallel to the coast line of the continent, and some thrust faults which occurred in relation with the folding ($D_1$). The second deformational stage is represented by open to close folds, their axial traces running nearly perpendicular to the $D_1$ folds ($D_2$). The third deformational stage is represented by gentle folds of which axial traces are nearly parallel to the $D_1$ folds, and by which the $D_1$ and $D_2$ folds were refolded ($D_3$). The conjugate sets of fractures occurred during the fourth deformational stage ($D_4$).

This scheme of polyphase deformations was recently verified in the Langhovde and Skarvsnes regions by MATSUMOTO *et al.* (1979) and MATSUMOTO (1979).

### *3.2. Present work*

The brief geological sketch and outline of geologic structure of almost the whole area of the Ongul Islands and surroundings are given in Fig. 15.

The interpretation of the geologic structure in the main Ongul Islands including East Ongul Island, West Ongul Island, Ongulkalven and Teöya given by YOSHIDA (1978) on the basis of KIZAKI (1964), YOSHIDA *et al.* (1977) and many other studies, is modified a little by the result of re-examination of geology of East Ongul Island and some adjacent islands carried out during the wintering in 1979–1980 by the junior authors of the present paper (T. NISHIDA, K. YANAI and H. KOJIMA). They discriminated one set of folds in the eastern part of East Ongul Island, of Nesöya and of Hatusima Island; an inclined isoclinal synform in the

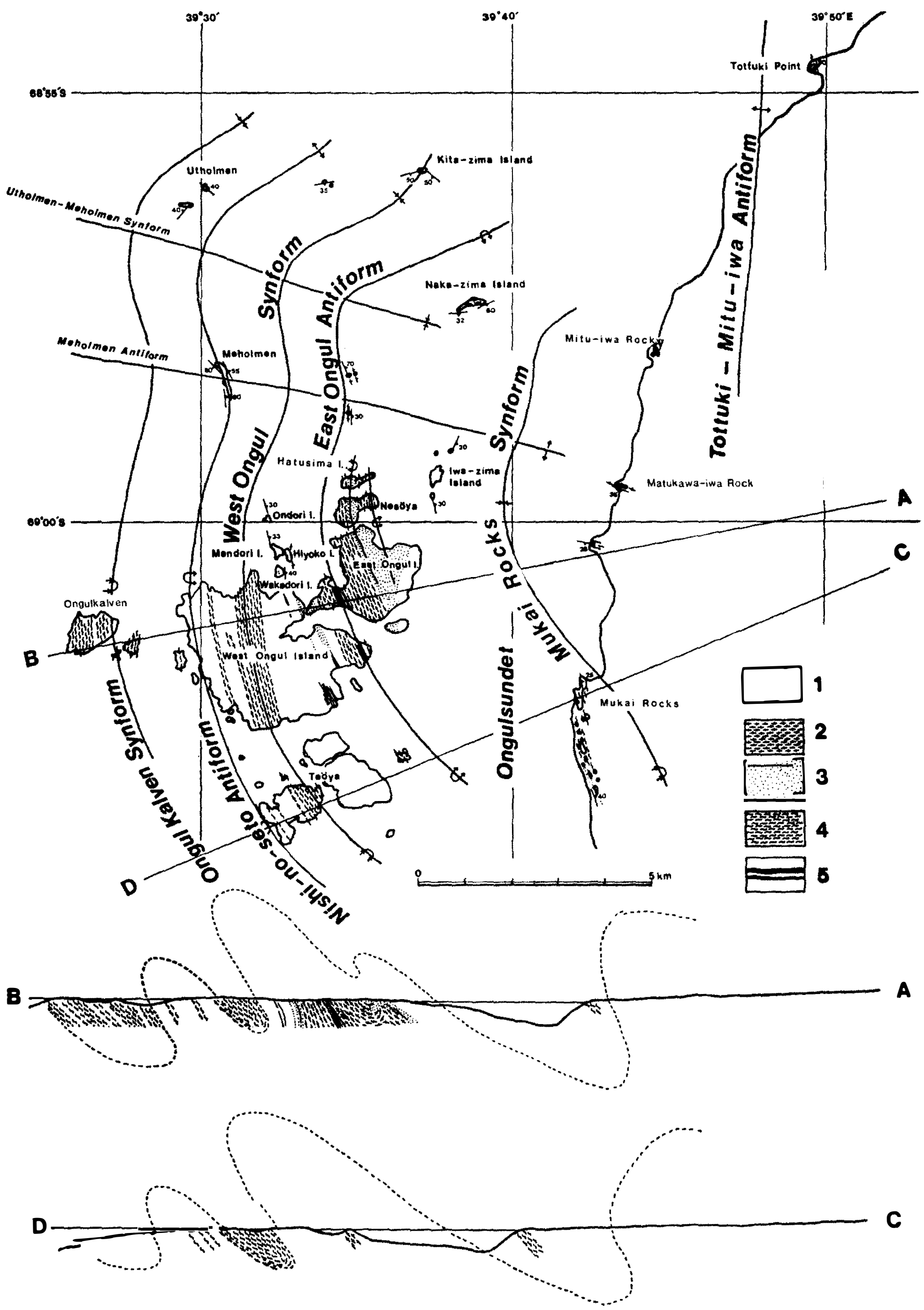


*Fig. 15. Geologic structure of the Ongul Islands and adjacent areas. 1. charnockitic rock, 2. hornblende gneiss, 3. garnet gneiss, 4. garnet-biotite gneiss and potassium feldspar porphyroblastic gneiss, 5. metabasite.*

western side and an isoclinal to gentle antiform in the eastern side of the area. Further, they correlated a successive metamorphic sequence composed mainly of garnet gneiss in the area with that distributed near the Naka-no-seto Strait which lies between East Ongul Island and West Ongul Island, and presumed a larger gently or moderately eastward-inclined isoclinal antiform named East Ongul Antiform between these successions. The axial trace of this antiform seems to extend northerly from the Kai-no-hama Beach through Nishi-no-ura Cove to the west off Nesöya and Hatusima Island.

The rock association of the central part of West Ongul Island (YANAI *et al.*, 1974b) and the central part of Teöya (YANAI *et al.*, 1975a) closely resembles that of Ongulkalven (YANAI *et al.*, 1975b) and that of Mukai Rocks as described in the present paper and shown in Fig. 10. These metamorphic sequences composed mainly of garnet-biotite gneiss and potassium feldspar porphyroblastic gneiss are probably correlared with each other. In this case, an interpretation of the structure as for the western part of East Ongul Antiform can be in favor of YOSHIDA (1978). Three estimated major folds are named west to east Ongulkalven Synform, Nishi-no-seto Antiform and West Ongul Synform, and the prolongations of their axial traces to the north are shown in Fig. 15. Among them the axial trace of the Nishi-no-seto Antiform extends most probably to Meholmen. These folds are apparently of an inclined isoclinal type in the main Ongul Islands, but to the north they tend to become steeply inclined or nearly upright in the dip of axial plane and tight, close to even open in the degree of acuteness.

Similarly, the newly named Mukai Rocks Synform is estimated to run northerly along the eastern margin of Mukai Rocks and Ongulsundet to halfway between Naka-zima Island and Mitu-iwa Rock. The fold seems to be inclined isoclinal in the south and upright open in the north. The newly named Tottuki–Mitu-iwa Antiform is presumed to run north-south between Tottuki Point and Mitu-iwa Rock on the basis of the attitude of the gneissic rocks on both outcrops, and may be open to close, upright there.

These estimated six major folds and one set of folds discriminated on the eastern limb of the East Ongul Antiform may have occurred in the oldest deformational stage. Some thrust faults reported from East Ongul Island by KIZAKI (1964) and YANAI *et al.* (1974a) run nearly in parallel with the axes of the folds and they may have been caused by this folding. This deformational stage is correlated with $D_1$ stage of YOSHIDA (1978).

From the attitude and distribution of gneissic rocks in the northern part of the studied area, one set of major folds is determined to exist, with their axial traces crossing those of the folds of the first deformational stage at near right angles; Utholmen–Meholmen Synform and Meholmen Antiform. They are close to open folds of wave-length up to 2 km and their axial traces run ESE to WNW and the hinges plunge towards the ESE. The folds appear to disturb the fold system of the first deformational stage and postdate it. They are correlated with the folds of $D_2$ stage of YOSHIDA (1978).

Because of the scarcity of detailed field observations and the discontinuous and scattered outcrops in the region, the third deformational stage which was distinguished elsewhere around Lützow-Holm Bay by YOSHIDA (1978), MATSUMOTO *et al.* (1979) and MATSUMOTO (1979) is not so clearly recognized, but the conjugate sets of fractures which occurred during a later deformational stage are well developed throughout this region.

## 4. Conclusions

As the result of geological study of the northern Ongul Islands and surroundings, the authors have come to the following conclusions:

(1) The metamorphic rocks of this region belong to the Ongul Group defined by YOSHIDA (1978).

(2) Two principal deformational stages are discriminated in the region. Although the third deformational stage is not so clearly recognized, the sequence of deformation is considered similar to that of YOSHIDA (1978). The relationship between this tectonic sequence and metamorphism and plutonism remains to be clarified.

(3) In the Ongul Islands and their surroundings, the area west of Ongulkalven (only Benten Island) and the vast area between Teöya and Langhovde (some islands such as Ongulgalten, Migi-zima Island, Hidari-zima Island and Rumpa) are left for future geological survey.

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*Fig. 16. Charnockitic rock at Wakadori Island.*

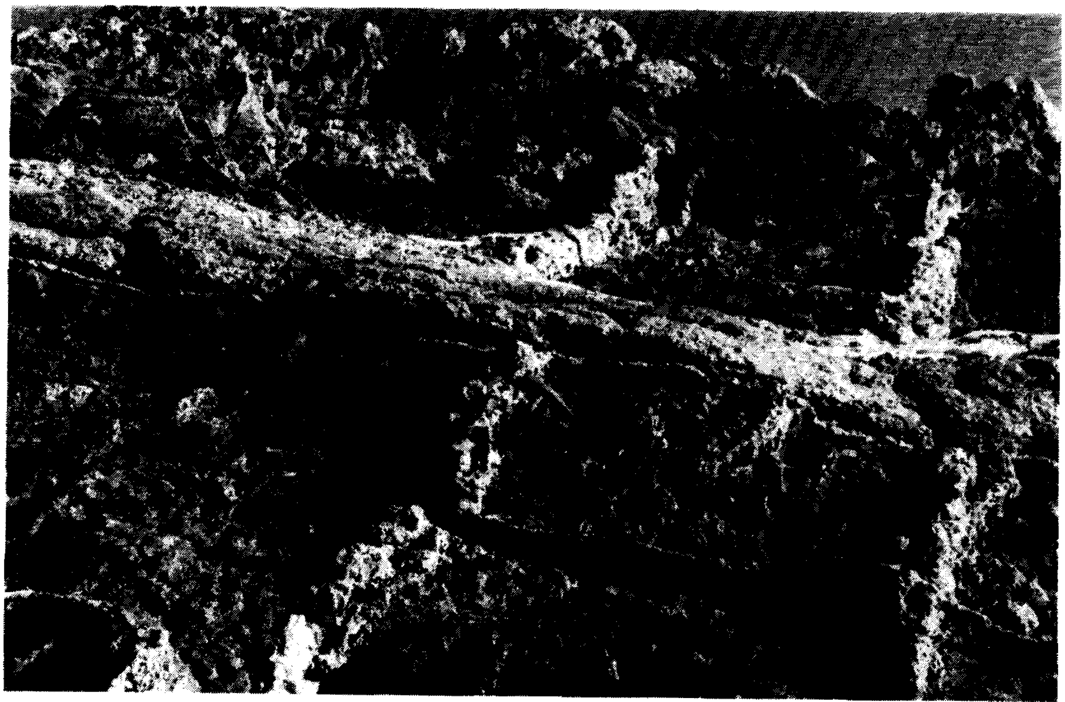

*Fig. 17. Charnockitic rock and pegmatite dykes at Meholmen.*

*Fig. 18. Minor folds in charnockitic rock at Utholmen.*

*Fig. 19. Charnockitic rock at Mitu-iwa Rock.*

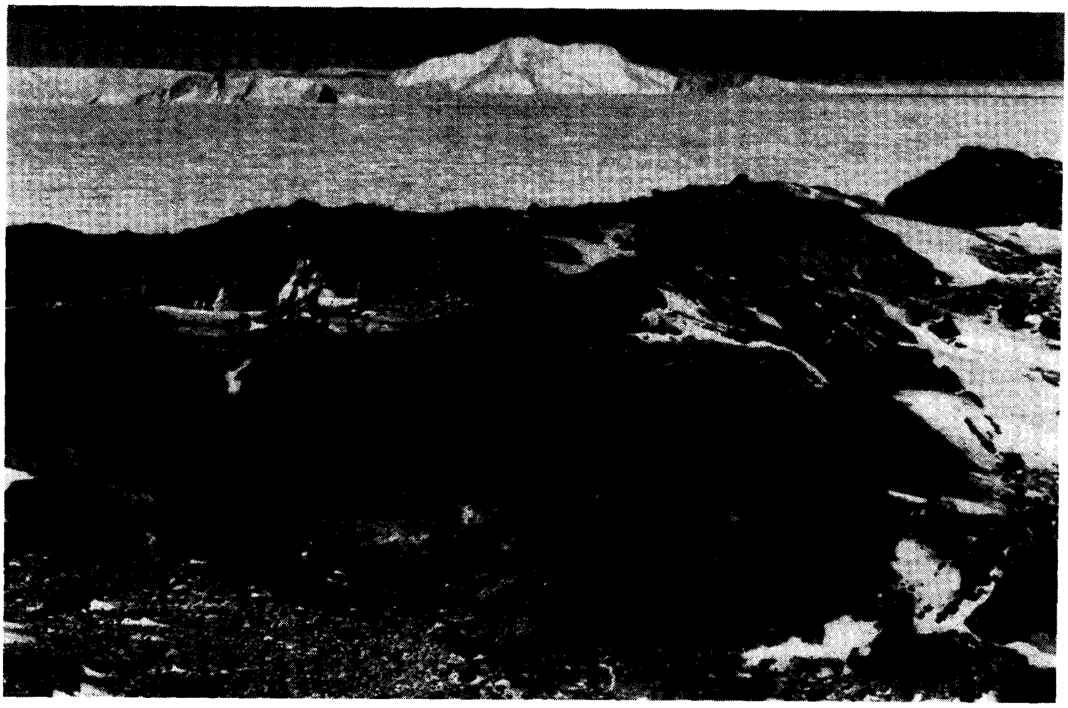

*Fig. 20. Folded hornblende gneiss at Naka-zima Island.*

*Fig. 21. Parallel dykes of pegmatite in hornblende gneiss at Naka-zima Island.*

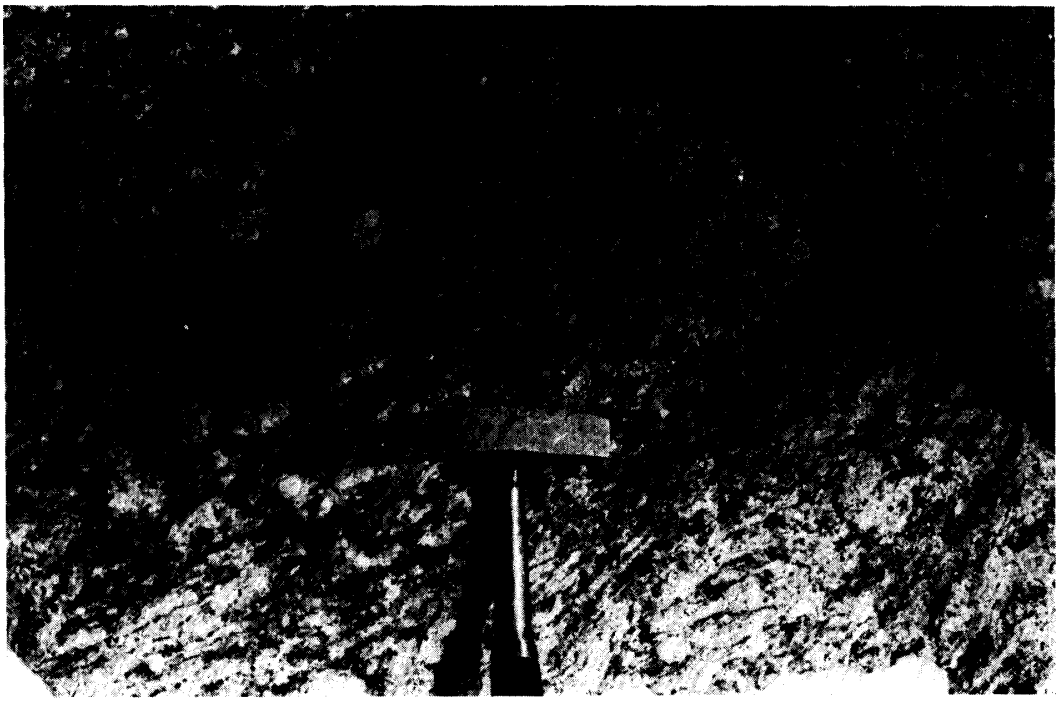

Fig. 22. *Granitic gneiss at Iwa-zima Island.*

Fig. 23. *Amphibolite at Wakadori Island.*

*Fig. 24. Hornblende-bearing charnockitic rock at Utholmen. Specimen No. 75093008. Plane polarized light, long dimension of photograph is about 1.5 mm.*

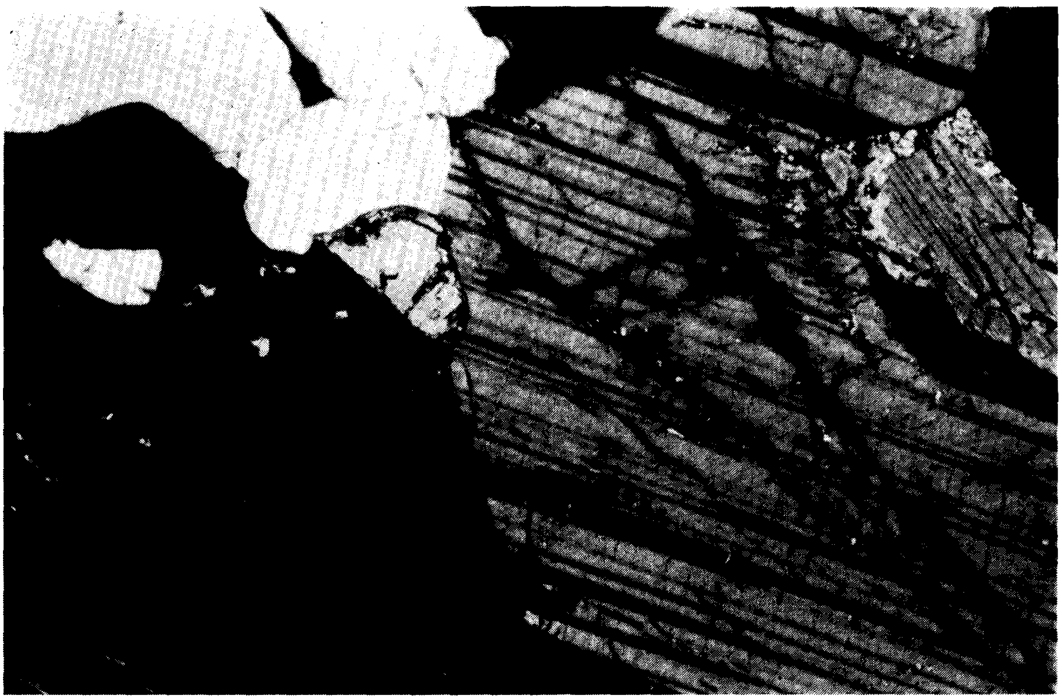

*Fig. 25. Hornblende gneiss at Hatusima Island. Specimen No. 75100201. Crossed polarized light, long dimension of photograph is about 1.5 mm.*

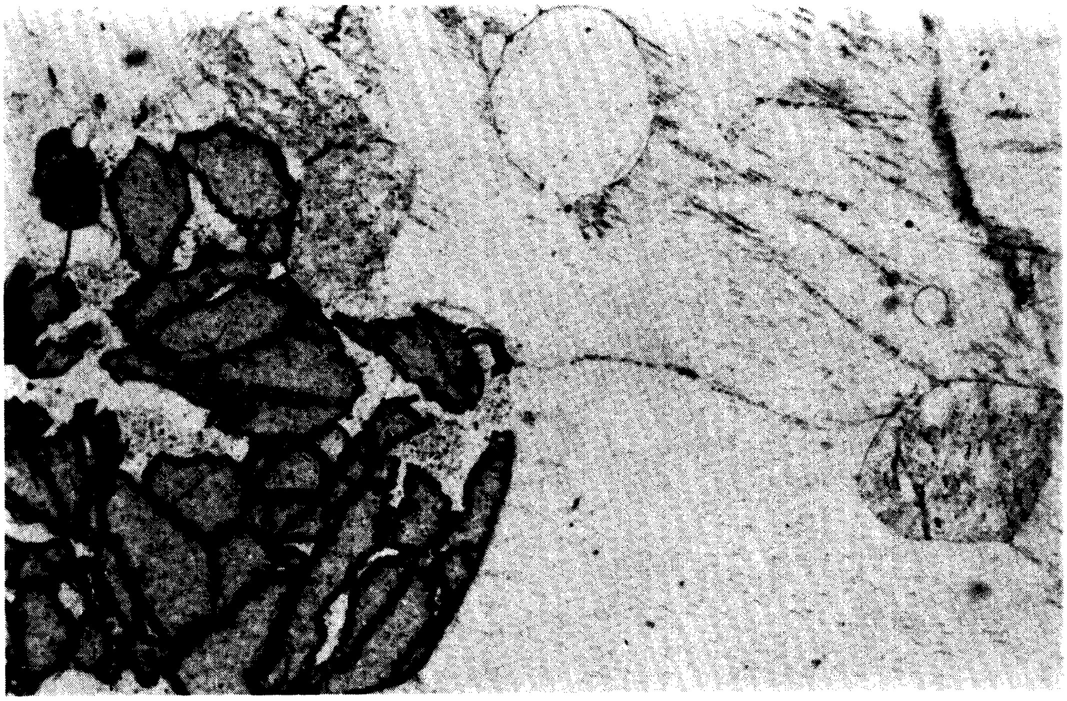

*Fig. 26. Garnet gneiss at the largest outcrop of unnamed rocks between Matukawa-iwa Rock and Mukai Rocks. Specimen No. 75092708. Plane polarized light, long dimension of photograph is about 1.5 mm.*

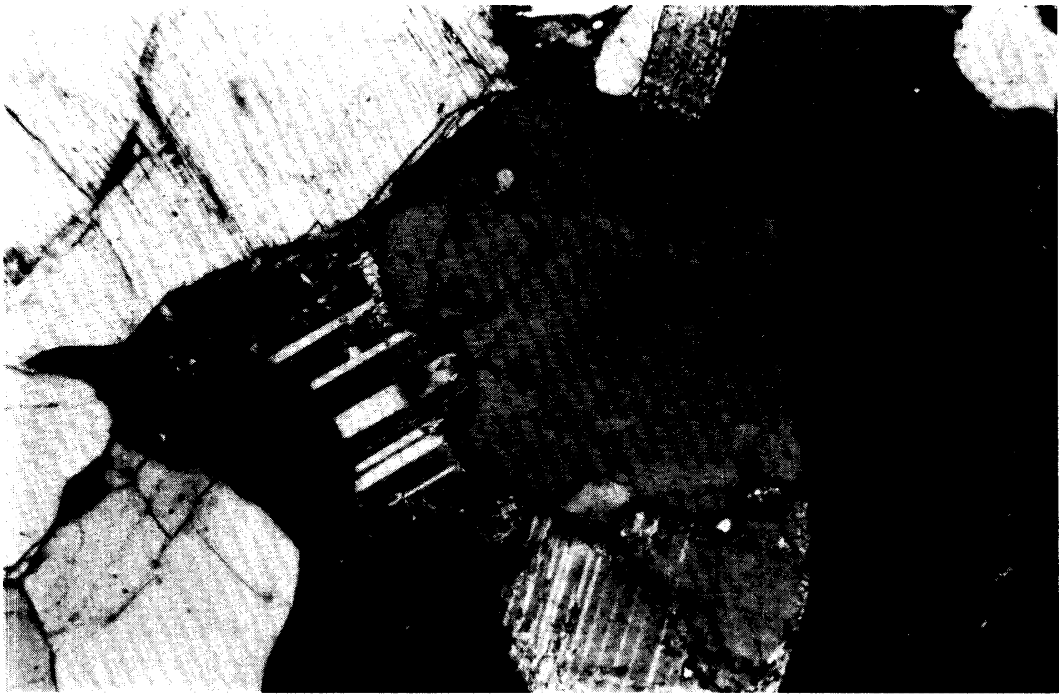

*Fig. 27. Garnet-bearing granitic gneiss at Iwa-zima Island. Specimen No. 75092901. Crossed polarized light, long dimension of photograph is about 1.5 mm.*

*Fig. 28. Metabasite at Meholmen. Specimen No. 75093003. Plane polarized light, long dimension of photograph is about 1.5 mm.*

*Fig. 29. Amphibolite at Mendori Island. Specimen No. 75100305. Plane polarized light, long dimension of photograph is about 1.5 mm.*