Structural Geology and Petrology of East Ongul Island, East Antarctica

Part I. Structural Geology

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南極東オングル島の構造地質および岩石

第1部 構造地質

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要 旨

東オングル島は，南北 2.5 km，東西 2 km の小島で，まわりはいくつかの小さな島をめぐらしている．地形図は，地理調査所（現国土地理院）作製による 1:5,000 地形図を使用することができた．

この島は，各種の片麻岩から構成されている．チャーノカイト質片麻岩（立見，菊池により閃緑岩質片麻岩とされたもの）・角閃石片麻岩・柘榴石片麻岩（同上花崗閃緑岩質片麻岩）・花崗岩シートおよび花崗岩質，含角閃石二種のペグマタイトである．

この地域の構造の特徴は，ひとつの大きな西側に倒れた等斜褶曲構造である．その前面には，小褶曲の重なりあった前縁帯が，主褶曲に沿って南北に分布する．これら褶曲の内核に柘榴石片麻岩が分布している．

褶曲の外郭は，チャーノカイト質片麻岩でとりかこまれているが，小褶曲帯の西側（前面）は，角閃石片麻岩帯となっている．この帯は，花崗岩シートの迸入帯であり，その交代作用によって，チャーノカイト質片麻岩が角閃石片麻岩に変ったものである（Fig. 5）．

線構造は，片理のうねりである．その方向と落しは，褶曲軸のそれと一致する（b-線構造）．ところが，島の西部では，同じ性格の線構造が，褶曲軸に直角な a-線構造となっている（Fig. 1, Plate 1）．このことは，線構造形成が，主運動と直接関係のない，第2次の部分運動によることを示している．

ペグマタイトと節理とは，運動後半の断裂ではあるが，そのパターンは一致しない．これは，その形成時期にずれがあるからである．ペグマタイトは褶曲の主運動期，節理はそれにやや遅れた曲隆運動期のものであろう．

褶曲から断裂形成・衝上にいたる運動と，片麻岩の交代作用や花崗岩・ペグマタイトの迸入とには，深い関係が認められる．

1. Introduction

During the wintering at Syowa Station (69°00′ S, 39°35′ E) located on the East Ongul Island in Lützow-Holm Bay of East Antarctica, the author had the opportunity to investigate an interesting structural unit and the petrology of the island. The extensive rock exposures on the Prince Harald Coast including the Ongul Islands

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have been preliminarily surveyed and reported by TATSUMI and KIKUCHI (1959), members of the wintering team of the first Japanese Antarctic Research Expedition, 1956-58.

The East Ongul Island, located near the northeastern coast of Lützow-Holm Bay, is 2.5 km from north to south and 2 km from east to west, and is surrounded by a few small islands. The islands are morphologically rather flat and smooth so that geological investigations are quite easy. The hills of the East Ongul Island are generally 30 m or so in elevation and may represent remnants of an old erosion surface formed by glaciation. The surface is now dissected by shallow valleys which are filled with névé even in summer. There are also many scattered ponds.

The topographical map prepared by the Geographical Survey Institute of Japan to a scale of 1 : 5,000 was available as a basis for geological mapping.

The present report deals only with the geologic structure of the East Ongul Island, petrographical descriptions are included only when necessary for the understanding of the structure. The island is composed of various gneisses, viz., charnockitic hypersthene gneiss, garnet gneiss and hornblende gneiss, usually associated with amphibolite bands which are useful for structural analysis. Small granitic sheets concordant with the gneisses occur in the western part of the island. The gneisses are intruded by numerous pegmatite dikes which comprise two kinds, granitic pegmatite and hornblende pegmatite.

The charnockitic gneiss had been believed to be Precambrian in age owing only to its petrographical characteristics. However, the absolute ages of the rocks from the Lützow-Holm Bay area were determined as about 4.7×10^8 years (U-Pb method) by SAITO et al. (1961) and as about 5×10^8 years (Rb-Sr method) by NICOLAYSON et al. (1961). Thus, the age of the charnockitic gneiss of this area is considered Palaeozoic.

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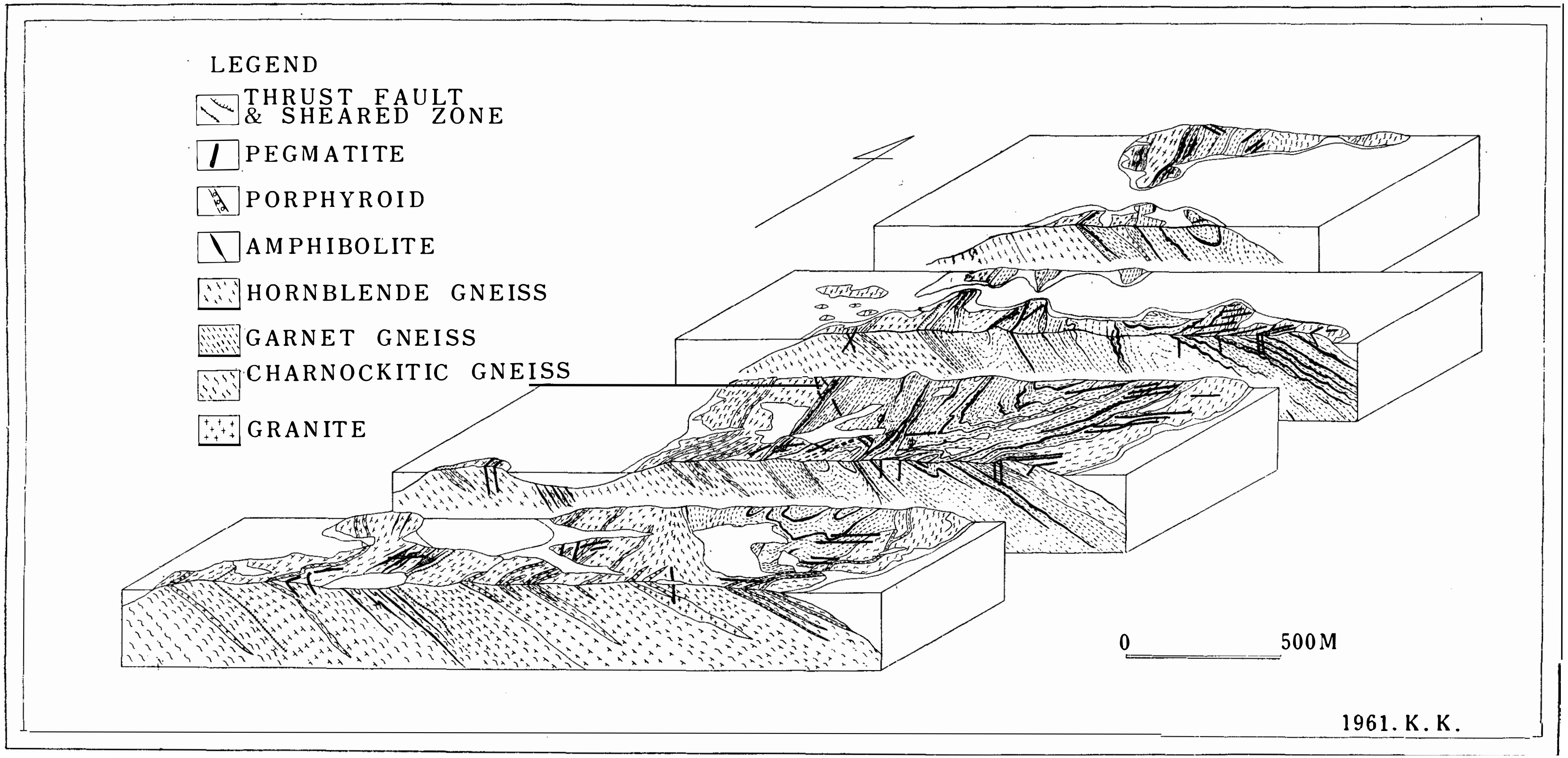
2. Structure (Plates 1 and 2)

The unique structural feature of the islands is represented by the isoclinal folding of the eastern half with a width of 1 km and a length of 6 km, although the northern part of the fold becomes obscure due to the sea.

The general strike of foliation and the direction of the folding axes are approximately N 20° W, and the dip of the foliation ranges from 10° E in the eastern limb of the fold to 40° E in the western limb.

The core of the anticline is generally composed of garnet gneiss with rare occurrence of charnockitic gneiss as relict. In the eastern part and the westernmost part of the island, charnockitic gneiss is found constituting the outer mantle of the fold where the dip is very gentle. In the western limb of the fold occurs the zone of

Plate 1. BLOCK DIAGRAM OF EAST ONGUL ISLAND



anticlines and synclines of small scale being composed of garnet gneiss associated with amphibolite bands. This zone, having a width of 500 m, extends from north to south through the median zone of the island.

A small thrust fault is observed near the western limit of the anticline. The fault dips 50° E with a brecciated zone although displacement is not so clear.

The western half of the island is occupied by hornblende gneiss, charnockitic gneiss and their alternations, with rather gentle easterly dipping.

Foliation The rocks of the area are more or less characterized by a kind of megascopic s-plane. This will be referred to as foliation. It is rather pronounced, as in the hornblende gneiss, especially in the amphibolite and its alternants, but may be weak or absent in some of the charnockitic gneiss, garnet gneiss and granitic gneiss. The foliation is defined by the dominant orientation of a platy mineral such as mica and prismatic amphibole, and also by alternating layers of verying compositions, such as mafic component and quartzofeldsparthic part. Narrow bands of the amphibolite showing conspicuous foliation serve as a key for the structural analysis, although the foliation itself is contorted asymmetrically in some cases, because basic rocks such as amphibolite are more viscous than acidic rocks under the condition of high pressure.

The general strike of the foliation is N 20° W, except in the eastern limb of the anticline where it is N 20° E, and the dip is about 10-20° E, in the eastern limb and about 30-40°, attaining to 60° in maximum, in the western limb.

Lineation A conspicuous feature of the megascopic fabrics is the strong lineation which can be recognized in almost all rocks, but it is most marked in the garnet gneiss constituting the anticlinal core.

The visible lineation is characterized by the following features.

1. The lineation marks the axis of undulations on the foliation plane with 10 cm to 1 m wave length which may be accompanied by anticlinal folds of a larger scale.

2. Preferred orientation of mineral grains also difines the lineation, although the location preserving the lineation may be limited. Only in some of the garnet gneiss this grain orientation is preserved. The strike and dip of the lineation are the same as those of the axis of undulations.

Plate 1 shows the orientation of two kinds of lineations known in the area, Fig. 1. being an equi-areal projection of the poles of 98 lineations. From Plate 1, it can be seen that the strike of the lineation is rather uniform in the area restricted within the anticline, regardless of the variations of strike of foliation or rock type.

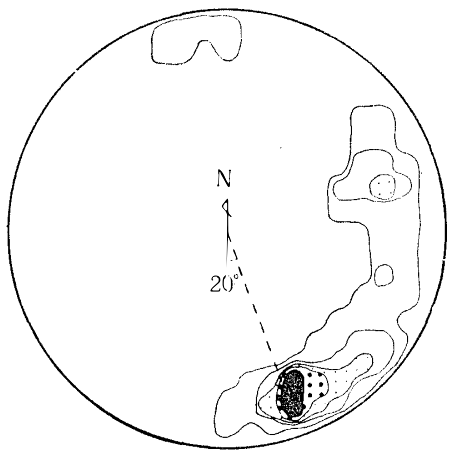


Fig. 1. 98 lineations measured in the whole area, the maximum coincide with the one of the fold and the submaximum normal to the fold axis; contours 5-10-15-20, max. 22 per cent per 1 per cent area.

The strike is N 20° W and the dip is 20° SE as the maximum in Fig. 1. The lineation is parallel to the fabric axis and is defined as a B(=*b*) lineation because the maxima of the poles of the lineation in Fig. 1 coincide with those of the axes of the folds in Fig. 2.

However, in the western area where the frontal part of the recumbent anticline is located, the strike of the lineation changes to the east as represented as a submaximum in Fig. 1, and is oriented at right angles to the *b*-axis. The lineation may represent not only a *b*-lineation perpendicular to the direction of tectonic transport but also an *a*-lineation parallel to the movement, and both lineations present characteristic uniform undulations.

For a long time the lineation related to the tectonic transport was a subject of discussions among many investigators (B. Sander, 1930, E. Cloos, 1946, A. Kvale, 1947, etc.).

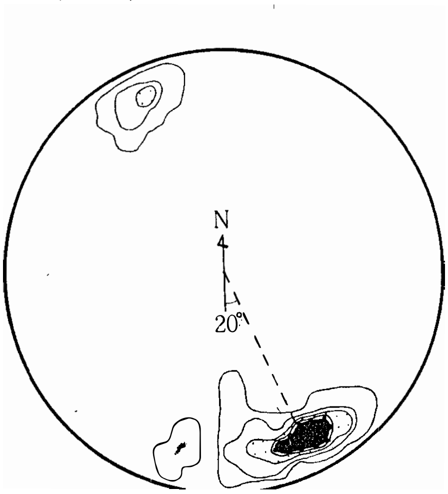


Fig. 2. 39 fold axes measured in the whole area; contours 5-10-15-20, max. 28 per cent per 1 per cent area.

In the present case, the lineation seems to have resulted from partial movement differentiated from the tectonic transport, although it shows no direct relation to the direction of the tectonic transport. Hence, the lineation may be a result of a differential movement of the second order which affected the foliation.

Folding An isoclinal folding, occupying the main part of the island, is a unique structural feature. The main fold associated with smaller ones plunges to the south, and the northern limb may plunge to the north on the Nesoya Island although the northern half of the fold submerges beneath the sea. This fold seems to be a structural unit having a lenticular shape, and may suggest the existence of a

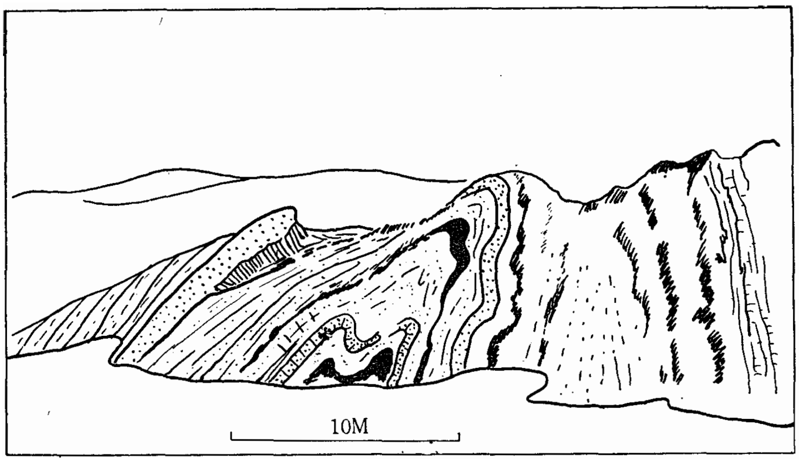


Fig. 3. Sketch showing a example of small fold of garnet gneiss (stippled) with amphibolite bands (solid black).

migmatized dome.

Many small anticlinal and synclinal folds have been identified. They are distributed in the frontal zone, 500 m wide, of the isoclinal recumbent fold. Fig. 2 is an equi-areal projection of 39 axes of fold. It shows that the main direction of the fold axes is N 20° W and that the most of the axes plunge to the south, as the available data have been collected chiefly from the southern half of the main fold.

Conspicuous drag folds have been identified in the inner core of the main fold. They are manifested especially by the amphibolite bands in the garnet gneiss. It is clear that the drag folds were formed by shearing involved in the folding.

The western limb of the fold structure is truncated by a thrust fault which becomes indistinct toward the southern limb probably due to a smaller scale.

Joints Joints in the area are divided into two systems, one being of the inner core of the fold and the other of the outer mantle.

Fig. 4a is a strike frequency diagram of 120 joints measured within the inner core of the fold. The majority of joint planes are parallel or subparallel to a structural axis *c*, thus showing a pair of (*hk 0*) joints in the inner core of the fold. Moreover, the strike of the joint acutely intersects the fold axis toward the southern limb. Most of (*hk 0*) joints have been diagnosed as shear joints. It seems evident that the joints under consideration were produced by shearing subsequent to the folding involved in the main stress normal to the fold axis.

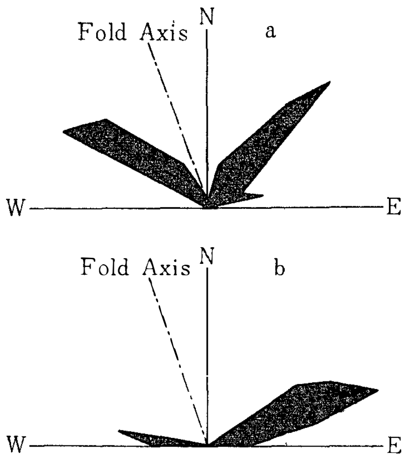


Fig. 4. Strike frequency of joints; a, inner core of the main fold showing shear joint, b, outer mantle of the fold showing tension joint.

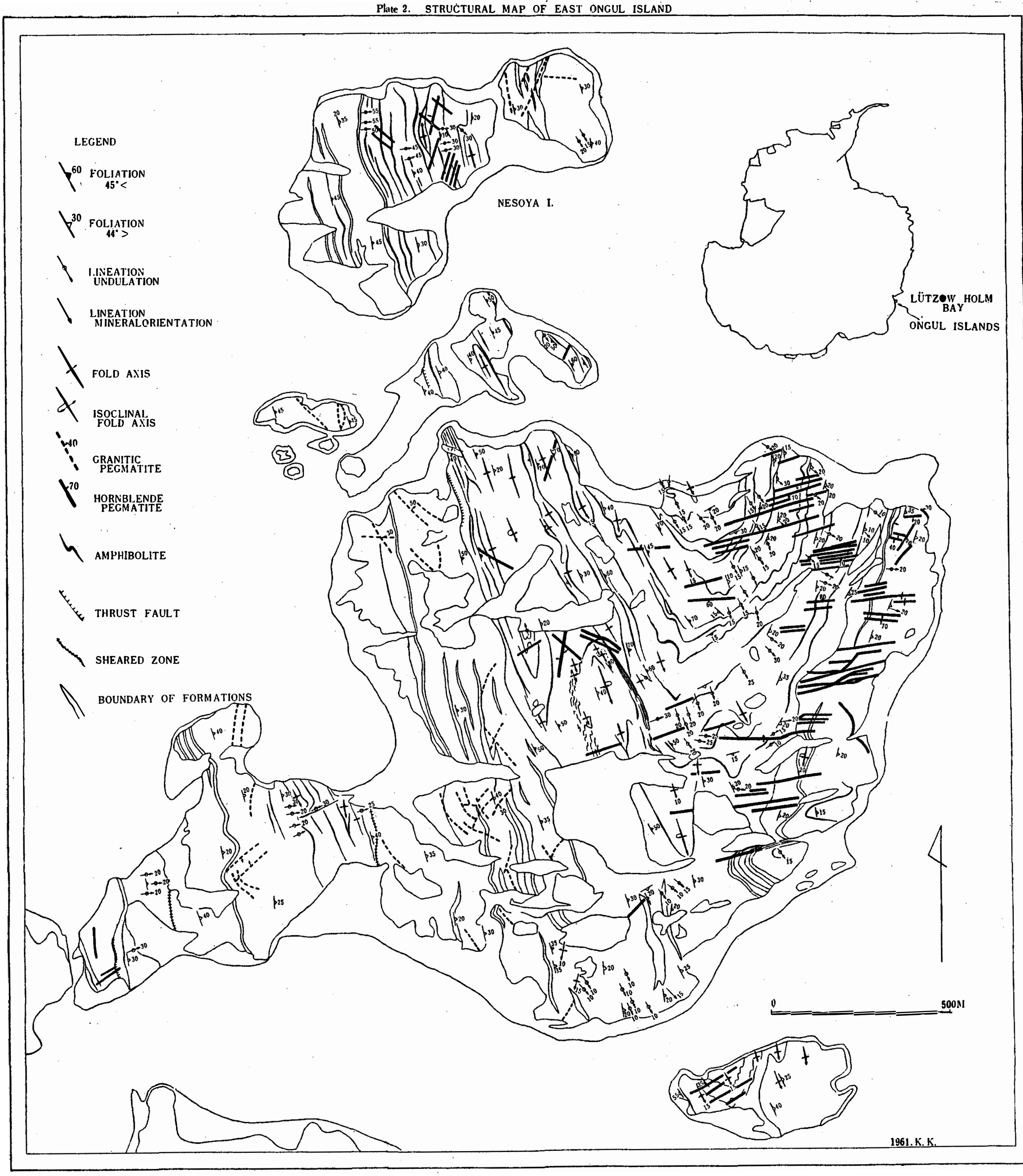
The *ac* joint perpendicular or subperpendicular to the fold axis is the commonest joint in the outer mantle area, as Fig. 4b shows. In the hornblende gneiss, the joints are markedly developed in every exposure. They are comparatively plane and open, and show all characteristics of tension fracture, though their length is shorter than others. Their apparent length ranges from 50 cm to 100 cm.

The *ac* joint is usually developed not only in the hornblende gneiss but also in the charnockitic gneiss constituting the outer mantle, unlike the garnet gneiss in which the (*hk 0*) joint is developed in the inner core of the fold. It is noticeable that the tensional stretching through the outer mantle has produced the *ac* joint during the later stage of the folding.

Pegmatite Pegmatites are distributed all over the area; especially in the eastern part pegmatite swarms are found. Pegmatites of this area comprise two kinds, hornblende pegmatite and granitic pegmatite, and their mineral facies are controlled by the facies of the country rocks (RAMBERG, 1949).

As in the case of the joints, pegmatites can be divided into two systems. Axial

Plate 2. STRUCTURAL MAP OF EAST ONGUL ISLAND



stretching through the folding axis produced the pergmatite patten parallel or subparallel to *ac* joint in the eastern wing. On the contrary, the western part of the island, including the small folding zone, is distinctly a compressional area. Therefore, the shear pattern will form many pairs of granitic pegmatites over the area (Plate 1).

There are conspicuous overlaps of the distributions of shear and tension patterns indicated by the joint systems and the pegmatite systems. The *ac* pegmatites are developed even in the inner core of the fold where only shear joints occur, and the shear pegmatites occur in the western part of the island where *ac* joints predominate.

For explanation of this overlapping of the different kinds of strain in the same area, a dating of the sequence will be required. According to field observations, the pegmatites are traversed by subsequent joints. The difference between the pegmatite pattern and the joint pattern may be ascribed to the different types of the tectonic style which exerted successively.

Pegmatites have intruded when the tectonic transport proceeded from east to west normal to the fold axis, and the movement has culminated in an earlier stage. They have been controlled by the axial tension in the eastern wing of the fold, independently of the compressional shearing in the western part of the frontal zone and the adjacent area. Subsequent upheaval of the migmatized inner core of the fold has produced the joint pattern as described above.

3. Structural development and metasomatism

The East Ongul island is composed of a unique structural unit, a lenticular recumbent fold associated with small folds in the frontal zone. The folding must have occurred as a result of the tectonic transport which proceeded from east to west. The underlying garnet gneiss, i.e., the migmatized charnockitic gneiss, which was warped up, must be regarded as the inner core of the fold. The hornblende gneiss is distributed in the adjacent area of the frontal zone of the fold and is difined by the intrusion

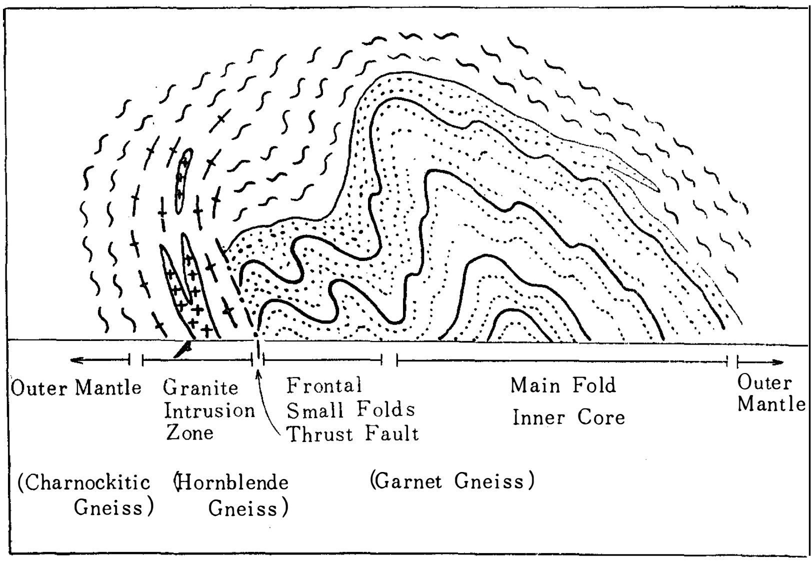


Fig. 5. Schematic profile of the East Ongul Island.

area of granitic sheets and pegmatite. The strong metasomatism which converted the charnockitic gneiss into the hornblende gneiss was presumably accelerated by a compressional stress as suggested by the pegmatite pattern and granite intrusion. The folding area has been intruded by the hornblende pegmatite at the same time.

The subsequent upwarping of the fold with less pronounced horizontal stress seems to have formed the joint systems and the thrust fault on a small scale.

During the folding movement, the metasomatic processes must have been the most important factor not only in the formation of the hornblende gneiss but also the garnet gneiss of the inner core.

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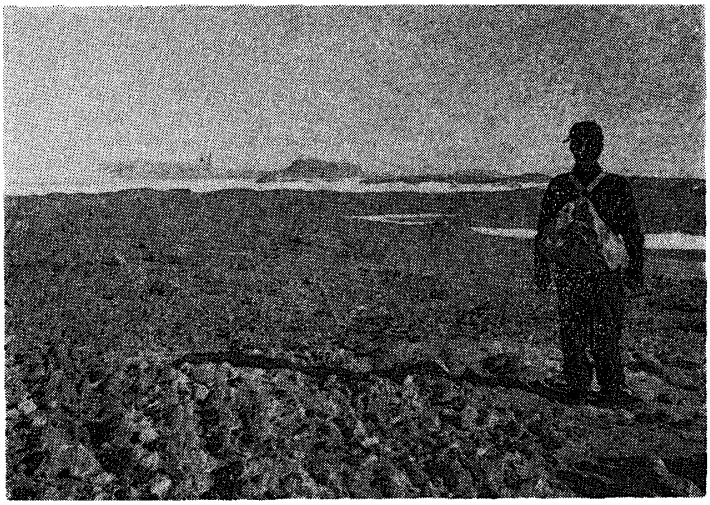

Plate 3. Surface feature of the East Ongul Island, showing hornblende gneiss. Looking south from the highest point. Langhovde and Skjegget in the background.

Plate 4. Small anticline of garnet gneiss with amphibolite bands.

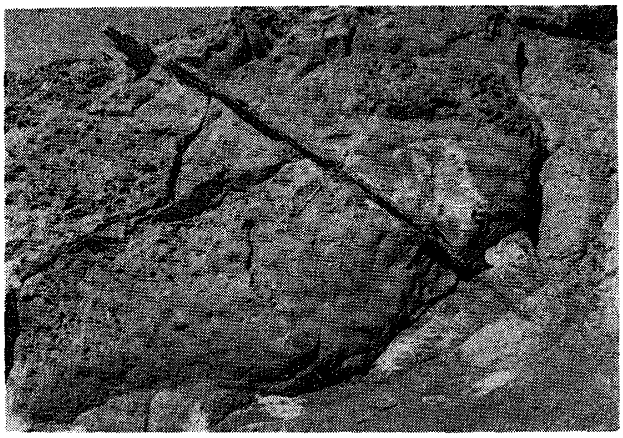

Plate 5. Hornblende pegmatite cutting across the charnockitic gneiss.

Plate 6. Hornblende gneiss cut by *ac* joints.