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NOTE ON THE GEOLOGY OF THE WESTERN PART OF THE SØR RONDANE MOUNTAINS, EAST ANTARCTICA

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Abstract: Results of the geological investigation by the 26th Japanese Antarctic Research Expedition in the western part of the Sør Rondane Mountains are outlined. The area is underlain by various kinds of metamorphic and plutonic rocks. Foliation of gneisses trends E-W, dipping monoclinally southward. The metamorphic rocks are divided into two groups: the northern group which consists of pelitic, psammitic and intermediate gneisses and subordinate amounts of basic and calcareous rocks, and the southern group which comprises gneissose tonalite with basic fragments and minor amounts of pelitic and calcareous gneisses. A pronounced shear zone separates the two groups. Although metamorphic grade of the regional metamorphism reaches up to the granulite facies in the northern group, mineral assemblages showing the epidote-amphibolite facies are commonly observed in the southern part of the northern group and in the southern group. It is characteristic that intense mylonitization associated with retrograde metamorphism under the greenschist facies condition is widespread, especially in the southern group. Plutonic rocks are granite, syenite and diorite which form sporadic stocks and small masses throughout the region. Slightly metamorphosed dolerite dikes which show distinct chilled margins intrude the metamorphic rocks. Newly obtained whole-rock K-Ar age on the dolerite indicates 536±27 Ma.

1. Introduction

The Sør Rondane Mountains, located between 22° to 28°E and 71.5° to 72.5°S, form one of the largest mountains in East Antarctica. Geological and glaciological surveys of these mountains had been performed by Belgian parties during 1958 to 1970. Based on the result of these investigations a geological map (1:500000 in scale) was published (VAN AUTENBOER, 1969). According to VAN AUTENBOER and LOY (1972), the Sør Rondane Mountains are composed of various kinds of metamorphic and plutonic rocks. They divided the metamorphic rocks into two units; the Teltet-Vengen group in the north, which consists of gneisses of various compositions and the Nils Larsenfjellet group in the south, which comprises "tonalitic to dioritic biotite-hornblende-(chlorite-epidote) gneisses" associated with basic fragments. Most radiometric dates on both the metamorphic and plutonic rocks indicate early Paleozoic and some show late Proterozoic ages. The oldest age, 2700 Ma determined by U-Pb on detrital zircon from gneisses, was reported by PASTEELS and MICHOT (1970).

Following the reconnaissance survey by the 25th Japanese Antarctic Research Expediton (JARE-25, 1983-1984), the JARE-26 group (1984-1985) performed a geological survey of the western part of the Sør Rondane Mountains from January 6 to

February 13, 1985 (MEMBERS OF THE SØR RONDANE RECONNAISSANCE PARTY, 1985). This paper presents a geologic outline and a brief description of the metamorphic and plutonic rocks in the study area. It is hoped that the framework presented here may provide a basis for more rigorous interpretation by detailed petrologic and geochronologic studies.

2. General Geology

The investigated area is bounded by Gjelbreen on the east, and by the eastern part of Nils Larsenfjellet on the west (Fig 1). The elevation at the northern foot of the mountains is about 1000 m above sea level, whereas that of the plateau to the south is almost 3000m. Jagged mountains, steep slopes and large ice falls with many crevasses prevent surface access to the center of the mountain range and to the southern plateau.

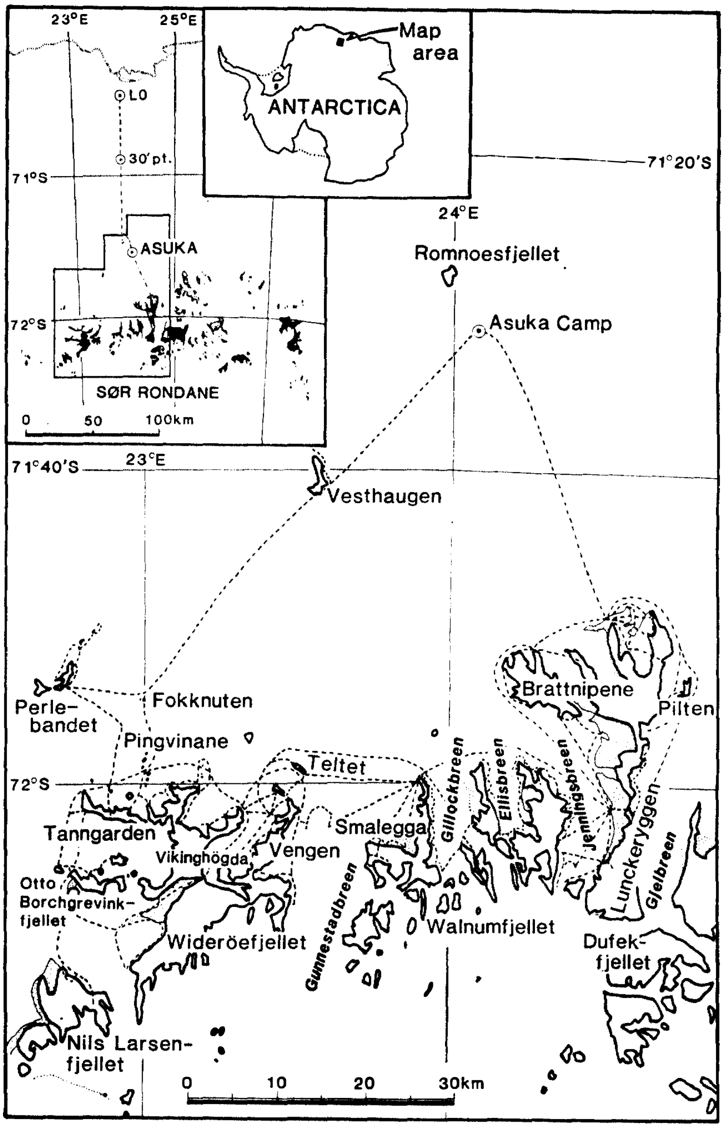

Fig. 1. Map showing location of the investigated area and place names.

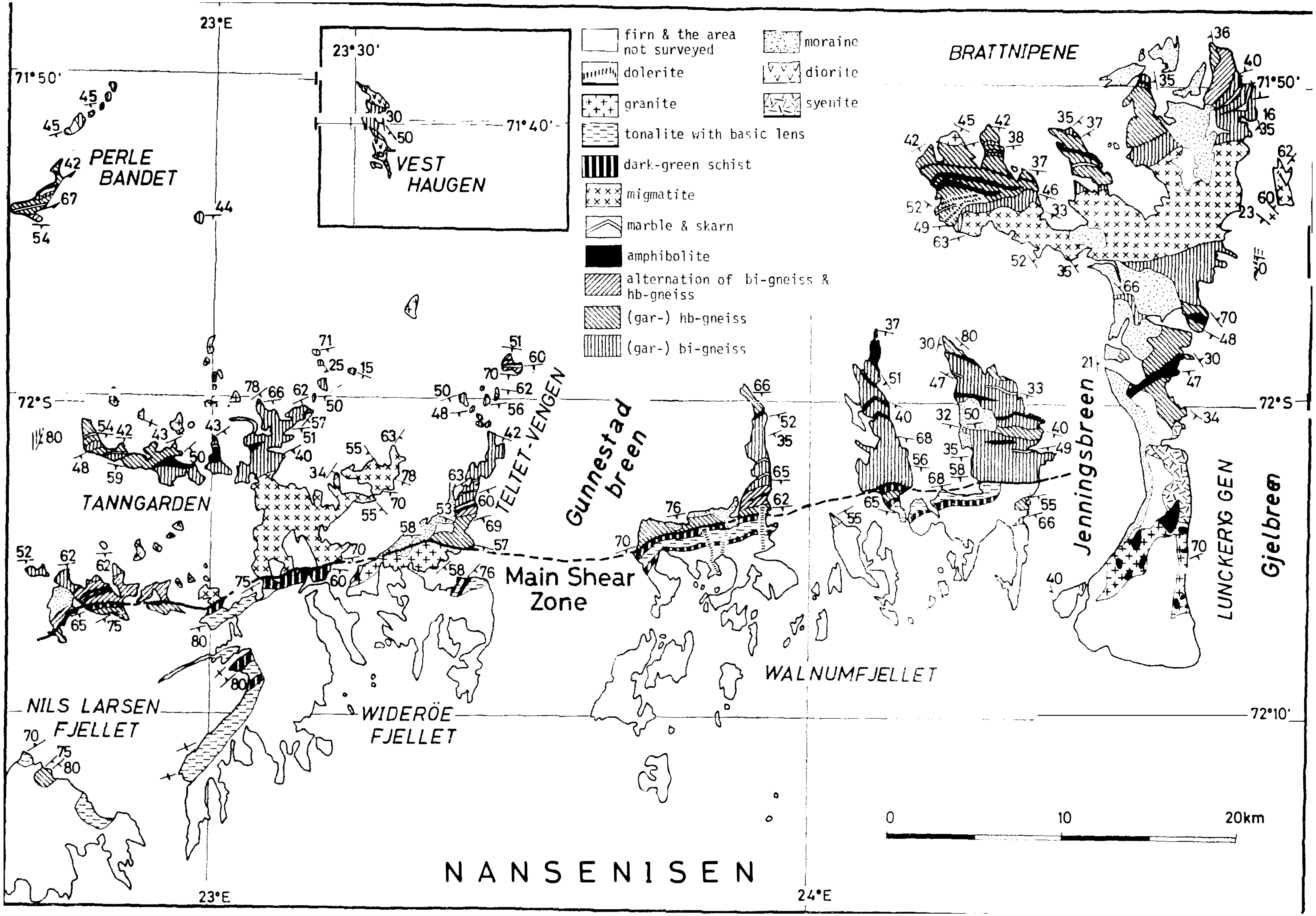

Fig. 2. Generalized geological map of the western part of the Sør Rondane Mountains.

Outcrops in this area are represented by various kinds of metamorphic and plutonic rocks. Pelitic, psammitic and intermediate gneisses are dominant among the metamorphic rocks, but calcareous and basic rocks occur also in many places. Foliation of the gneisses strikes generally E-W and dips monoclinally to the south. A pronounced shear zone trending E-W traverses the center of the area (Main Shear Zone: MSZ) (Fig. 2; Plate 4b, c). Metamorphic rocks in the south of this zone are altered to mylonite and cataclasite to varying degrees in many places. VAN AUTENBOER and LOY (1972) define the boundary between the Teltet-Vengen group and the Nils Larsenfjellet group on the northern limit of MSZ, but the definition of both groups is so ambiguous that in this paper the rock group distributed to the north of MSZ is tentatively called the northern group and that to this south is called the southern group. It must be noted that this division is no more than an indication of the areal distribution of the metamorphic rocks. Gneissose tonalite and basic schist occur as main constituents in the southern group, with minor amounts of biotite gneisses, marble and skarn. Local shear zones which are probably related to MSZ exist throughout the area even within the northern group (Plate 2b).

Plutonic rocks which include granite, syenite and diorite are sporadically distributed as masses or stocks of km size in both groups. Slightly metamorphosed dolerite dikes which are rarely cut by faults are found in many places throughout the area. Minor lamprophyre dikes are found, though rarely.

The generalized geological map of the investigated area is shown in Fig. 2.

3. Metamorphic Rocks

Metamorphic rocks are classified into the following rock types for mapping units, based on the mode of occurrence and lithologic facies;

1) biotite gneiss,
2) hornblende gneiss,
3) amphibolite,
4) marble and skarn,
5) migmatite,
6) gneissose tonalite and dark green schist.

1) to 5) compose the Teltet-Vengen group, and 6) is included in the Nils Larsenfjellet group, of VAN AUTENBOER and LOY (1972).

3.1. Biotite gneisses

Biotite gneisses are typical pelitic to semi-pelitic gneisses in the study area. Thinly (mm order) to thickly (m order) banded biotite gneisses are widely distributed in the northern group (Plate 2a); however, biotite gneiss layers up to several tens of meters wide rarely occur in the southern group.

Typical mineral assemblages are:

1) garnet-biotite-plagioclase-K-feldspar-quartz,
2) garnet-orthopyroxene-biotite-plagioclase-K-feldspar-quartz,
3) garnet-sillimanite-biotite-plagioclase-K-feldspar-quartz.

Assemblage 2) is found at the northwestern corner of Brattnipene. It is a medium-grained, dark colored and dense rock with a charnockitic appearance. Assemblage 3) is so far found only in the northern part of the northern group; Vesthaugen, Brattnipene and Perlebandet.

Feldspathic and quartzo-feldspathic gneisses which accompany the biotite gneisses in Vesthaugen have the following mineral assemblages:

4) cordierite-spinel-orthopyroxene-biotite-plagioclase,
5) cordierite-sillimanite-garnet-biotite-K-feldspar-plagioclase-quartz,
6) orthopyroxene-garnet-biotite-K-feldspar-plagioclase-quartz.

On the other hand, biotite gneisses which occur in the southern parts of Lunckeryggen and Walnumfjellet include:

7) garnet-biotite-muscovite-plagioclase-quartz,
8) muscovite-biotite-plagioclase-K-feldspar-quartz assemblages.

Such a variety of mineral assemblages implies wide ranges of P-T condition; seemingly the metamorphic grade decreases toward the south.

3.2. Hornblende gneisses

Together with the biotite gneisses, hornblende gneisses form the greatest proportion of the metamorphic rocks throughout the northern group. The hornblende gneisses show a banded structure of mm to cm orders. Alternating bands of biotite gneiss and hornblende gneiss 0.2 to 1.0 m wide are common. Epidote veins 2 to 5 cm wide are found in hornblende gneisses in places. Typical mineral assemblages are:

1) garnet-orthopyroxene-hornblende-plagioclase-quartz,
2) orthopyroxene-clinopyroxene-biotite-hornblende-plagioclase-quartz,
3) garnet-hornblende-biotite-plagioclase-quartz,
4) hornblende-biotite-K-feldspar-plagioclase-quartz,
5) hornblende-epidote-plagioclase (An_{18-30})-quartz.

Orthopyroxene-bearing hornblende gneisses are found in Brattnipene and Tanngarden. At the latter locality, orthopyroxene was obtained from a xenolithic fragment in a granite mass. Secondary epidote and chlorite are commonly found. In some cases, it is ambiguous under the microscope whether epidote is of primary or of secondary origin.

3.3. Amphibolite

Amphibolite is recognized as a dark-colored band of 0.1 to 1.0 m wide, interbedded within biotite gneiss and hornblende gneiss. Dark-colored bands a few tens to a hundred meters wide, in which amphibolite alternates with hornblende gneiss, are present in many places. Typical mineral assemblages are;

1) orthopyroxene-clinopyroxene-hornblende-biotite-plagioclase-quartz,
2) clinopyroxene-biotite-hornblende-plagioclase,
3) garnet-biotite-hornblende-plagioclase-quartz,
4) epidote-biotite-hornblende-plagioclase-quartz.

In the southern part of Lunckeryggen, biotite amphibolite occurs as large xenolithic blocks several tens meters wide in granite.

3.4. *Marble and skarn*

The term skarn is used in this paper for several kinds of rock associations, such as hornblende pyroxenite, garnet-hornblende pyroxenite, pyroxene-biotite amphibolite and calc-silicate rocks. All these rocks are closely associated with marble. The marble and skarn complex, intercalated in biotite gneisses and hornblende gneisses, is found mainly in the northern group. However, a marble bed 15 m wide is found in the southern group in the uppermost reaches of Jenningsbreen. Although the marble and skarn beds form zones up to several hundred meters wide in some places such as Perlebandet and Vengen ridge, they usually occur as thin beds up to 5 m wide and as small lenses a few tens of cm long. Constituent minerals of the skarn include clinopyroxene, grossular, forsterite, pargasite, phlogopite, scapolite, humite, anorthite and quartz.

3.5. *Migmatite*

Large masses of homogeneous and nebulitic migmatite of granitic to granodioritic compositions form the massifs of Brattnipene and Vikinghögda. Migmatitic gneisses showing agmatite, diktyonite, schollen and other structures are locally found in the northern group as well as in the margin of the above masses (Plate 1).

3.6. *Gneissose tonalite and dark green schist*

These rocks are the main constituents of the southern group. The gneissose tonalite is a medium- to coarse-grained rock containing various proportions of dark green schist. The dark green schist forms thin layers up to 1 m wide and lens-shaped blocks, ribbons, and schlieren-like dark inclusions up to 1 m long, with their long axes oriented parallel to the foliation (Plate 3). Modes of occurrence suggest that the tonalite intrusion migmatized the original rock of dark green schist. On the other hand, bands of the dark green schist alternating with the biotite gneiss some 100 to 500 m wide are also observed in the northern escarpment of Walnumfjellet and Wideröefjellet. Probably these rocks behaved as host rocks intruded by the tonalite.

The most conspicuous feature in these rocks is the varied degree of mylonitic and cataclastic textures. Typical gneissose tonalite is composed of bluish green bornblende, biotite, epidote, plagioclase and quartz. It rarely contains garnet. Chlorite and saussuritized plagioclase are common. It shows pronounced mylonitic texture, with plagioclase and K-feldspar porphyroclasts having asymmetric pressure shadow tails. As mylonitization increases, the proportions of epidote and chlorite increase and plagioclase is more saussuritized, whereas the proportions of hornblende and biotite decrease. Therefore, epidote and chlorite as well as saussuritized plagioclase may be secondary products, probably under the greenschist facies condition related to the mylonitization. The mineral assemblage of the dark green schist is identical with that of the tonalite. It is not uncommon that dark green schist consists entirely of secondary minerals; in such schistose rocks, chlorite displays crenulation cleavage which was formed probably during retrograde metamorphism.

4. Plutonic Rocks

4.1. Granite

Three masses of granite are found. These are named Lunckeryggen granite, Vengen granite and Pingvinane granite after nearby localities. Smaller granite bodies and dikes occur sporadically throughout the area. They are coarse- to medium-grained leucocratic granite containing biotite, hornblende, microcline, plagioclase and quartz as main constituents. Accessory minerals are apatite, fluorite, zircon and magnetite. The Lunckeryggen granite contains mafic enclaves a few tens of centimeters in places, and is intruded by younger granitic pegmatite a few meters wide. The Vengen granite shows a weak cataclastic texture, and is mylonitized to the degree of protomylonite. The Pingvinane granite is massive and homogeneous in appearance. The granitic dikes intruded into the southern group are commonly mylonitized.

4.2. Syenite

A large syenite mass occurs in the central part of Lunckeryggen. Although the syenite is emplaced at the eastern extension of MSZ, no distinct shear zone is found in the syenite mass. It is a coarse-grained rock, and the leucocratic part is reddish brown to deep violet in color, showing remarkable schillerization probably due to K-feldspar megacrysts with tiny inclusions of hematite. The syenite has a heterogeneous appearance in a mesoscopic scale. It is characteristic that dark mafic bands a few tens of centimeters to a several meters wide show rhythmic layering (Plate 5a). Moreover, rounded blocks of mafic part are embedded in more leucocratic matrix of the syenite. Constituent minerals are K-feldspar, bluish green hornblende, bluish green clinopyroxene, biotite, quartz and plagioclase. The order of emplacement between the syenite and the Lunckeryggen granite is not clear. The syenite itself is intruded by a younger amazonite-bearing leucocratic syenite dike which is characterized by bluish green microclines (amazonite) (Plate 5b).

4.3. Diorite

A dark dioritic to granodioritic intrusive rock occurs at Vesthaugen, an isolated nunatak in the northwestern part of the investigated area. It is a dark grayish coarse-grained rock consisting chiefly of orthopyroxene, clinopyroxene, hornblende, biotite, plagioclase and quartz.

5. Dike Rocks

5.1. Metadolerite

Slightly metamorphosed dolerite (metadolerite) is found throughout the present area. It is a few tens of centimeters to several meters wide and shows the clean-cut contacts with the host rocks. Distinct chilled margins are commonly observed. It is noteworthy that it is cut by gently dipping faults although scarcely.

The dolerite is composed of relicts of pyroxenes and plagioclase laths in a typical subophitic texture. together with ilmenite needles. Fine biotite scatters randomly throughout a thin section.

Table 1. Whole-rock K-Ar age for slightly metamorphosed dolerite from Smalegga in the Sør Rondane Mountains.

Sample No.	$^{40}Ar^*$ ($scc/g \times 10^{-5}$)	$^{40}Ar^*$ (%)	K (%)	Age (Ma)
85012604D	4.55	97.8	1.88	536±27

Decay constants are after STEIGER and JÄGER (1977).
Analyst: Teledyne Isotope Co.

A whole-rock K-Ar age (536±27 Ma) on a specimen of the dolerite collected from the southern end of Smalegga was newly obtained (Table 1). It should be noted that the age is coeval to the U-Pb ages on zircon from the granite reported by PASTEELS and MICHOT (1970). The age therefore probably indicates the time of reheating by the granite. If this is true, the dolerite dikes intruded into the "cold" gneisses prior to the emplacement of the granite.

5.2. *Lamprophyre*

Lamprophyres 50 cm wide are found at the southwestern corner of Lunckeryggen. They intrude both granite masses and the metamorphic rocks, and are cut by pinkish leucogranite and epidote veins. The lamprophyre is composed mainly of K-feldspar, bluish-green hornblende and biotite. Epidote, apatite, fluorite and opaque minerals are also present as accessories.

5.3. *Granitic pegmatite*

Granitic pegmatite is found in the northern group and, in restricted areas, this rock occurs as dike swarms (Plate 5c). It is not clear whether this pegmatite was dirived from the above-mentioned granite masses. On the other hand, there is granite pegmatite intruding into the Lunckeryggen granite. Detailed examinations dealing with the succession of the granitoids are planned for the future.

6. Geologic Structure

On a macroscopic scale, foliation of the metamorphic rocks strikes generally E-W and the strike of MSZ is roughly parallel to the foliation. Simplified lithostratigraphic columnar sections are shown in Fig. 3. The thicknesses of the northern group and the southern group are estimated to be several thousand meters and about 5000 m, respectively. However, mesoscopic tight to isoclinal folds are commonly found in the northern group (Plate 2b, 4a). Moreover, VAN AUTENBOER and LOY (1972) described a large scale recumbent fold at Vestjelmen, the eastern extension of the northern group. Therefore, more complicated structure is inferred in the northern group, as is typically shown in Brattnipene where the foliation generally strikes NW-SE and dips variably.

Dips in the southern group (60°S to 90°S) are generally steeper than those in the northern group (20°S to 50°S). The foliation in the southern group is subparallel to local shear planes, and pyrite-impregnated quartz veins up to 1 m wide intrude along the shear planes.

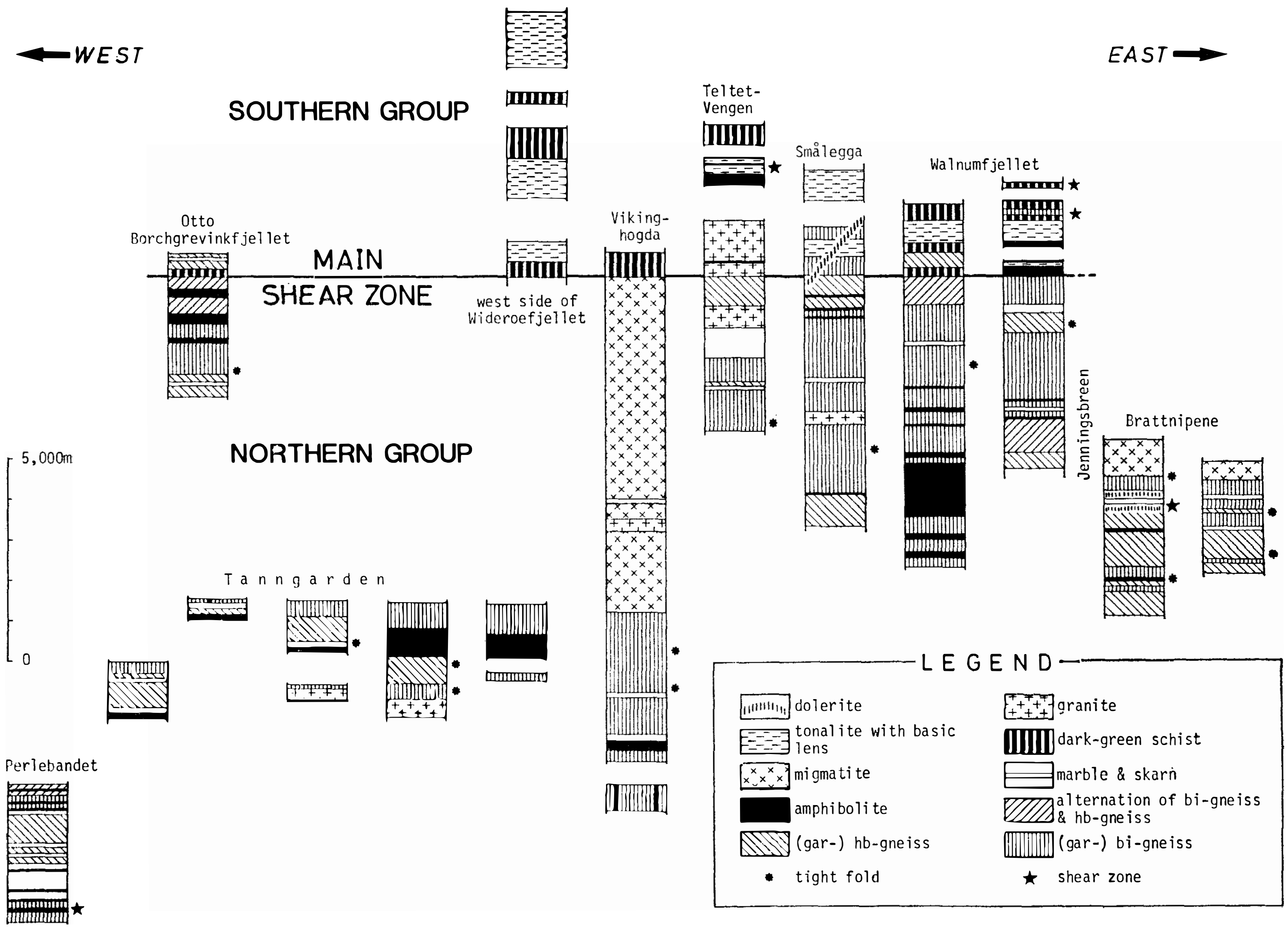

Fig. 3. Generalized columnar sections in the investigated area.

7. Discussion

7.1. Relationship between the northern group and the southern group

The relationship between the northern group and the southern group is not well understood. Careful observation around the boundary between both groups brought a tentative conclusion on this question. At the pass between Vikinghögda and Widröefjellet, alternating dark green schist and biotite schist occur in fault contact with the migmatite to the north. The fault has a cataclastic zone several meters wide, and extends westward to Otto Borchgrevinkfjellet. On the other hand, continuous changes from the northern group to the southern group are observed along the left bank of the Jenningsbreen. The northern part of the bank is formed of hornblende gneiss, biotite gneiss and marble. Following to the south, the gneisses alternate increasingly with dark green schist until finally the gneisses disappear. In this area no distinct fault is found, but mylonitization is widespread. Based on these observations, it is considered that both groups had been a continuous succession before the formation of MSZ.

7.2. Genetic relations of the rocks

There are two criteria used to estimate the succession of the emplacement of the rocks. One is the distribution of the mylonitic rocks. The southern group is characterized by intense mylonitization and retrograde metamorphism under the greenschist facies condition, whereas the northern group is affected by retrograde metamorphism to less degree. It is not uncommon in the southern group that leucocratic granitic dikes which are mylonitized as well as the host rocks, are found. However, the granite masses in Lunckeryggen and Pingvinane shows no distinct mylonitic textures. Therefore, there may have been multiple stages of the granite intrusions before and after the mylonitization accompanied by retrograde metamorphism. Although the metadolerite dikes are cut by gently dipping faults, they show no mylonitic texture even in MSZ.

On the other hand, the newly obtained whole-rock K-Ar age on the metadolerite dikes, which have been so far considered to be Jurassic (VAN AUTENBOER, 1969), shows early Cambrian. It is reasonably concluded that the dolerite dikes have been thermally metamorphosed by the granite of contemporaneous age. The time relationship between the granite intrusions and the faulting in the metadolerites is not clear.

The relationship between the widespread early Paleozoic granite plutonism and the regional metamorphism in eastern Queen Maud Land has been controversial (*e.g.* HIROI and SHIRAISHI, 1986). The fact that the metadolerite dikes show distinct chilled margins indicates that the gneiss terrain had been considerably uplifted before the granite emplacement. On the basis of the field observations, and taking the above discussion into consideration, the tentative tectonic history of the region is as follows:

1) Sedimentation and basic igneous activity,
2) Regional metamorphism up to the granulite facies and tonalite intrusion,
   —Uplifting?—
3) Older granite intrusion into the tonalite,
4) Mylonitization and retrogressive metamorphism (formation of MSZ),
5) Dolerite intrusion (older than 536 ± 27 Ma),
6) Younger granite and syenite intrusion (accompanied by faulting?),

7) Granitic pegmatite and amazonite leucocratic syenite intrusions.

7.3. *Metamorphic grade*

Metamorphic grade is also an interesting subject in this region. Orthopyroxene-bearing assemblages, diagnostic of the granulite facies, are restricted in the northern part of the northern group. In the southern part of the northern group and in the southern group, an epidote-hornblende-plagioclase (An_{18-30}) assemblage indicating the epidote-amphibolite facies condition is observed. However, effects due to retrogressive metamorphism are common throughout the region, especially in the southern group. In addition, in the moraine field stretching northward from Nils Larsenfjellet, where the gneissose tonalite and dark green schist are developed, a boulder of gneiss containing garnet-sillimanite-biotite-K-feldspar-quartz, which represents the upper amphibolite facies condition or an even higher temperature condition, was obtained. Therefore, the metamorphic grade in the Sør Rondane Mountains may not simply decrease toward the south. More rigorous examination of mineral chemistry should be performed.

Acknowledgments

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Plate 1

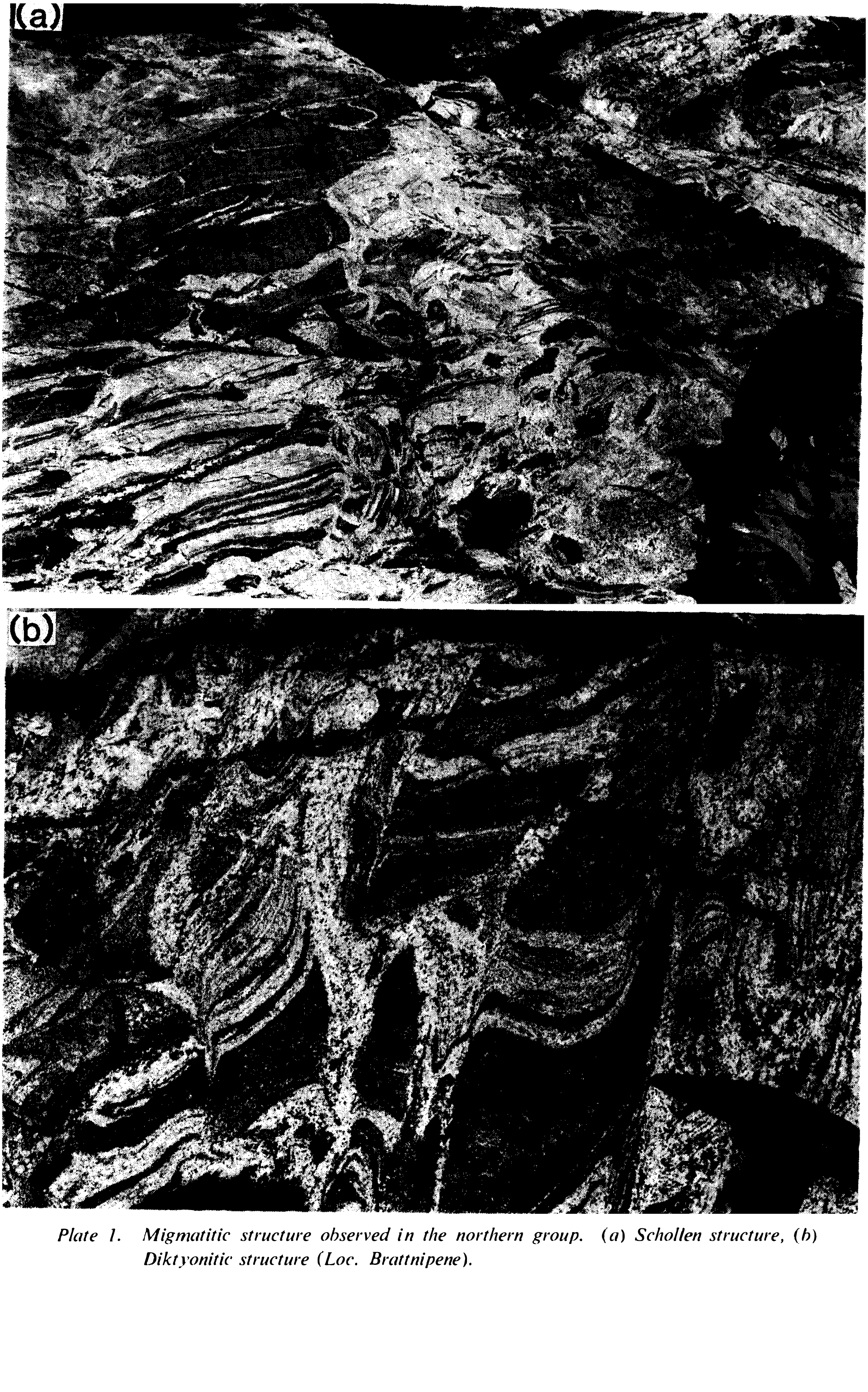

Plate 1. Migmatitic structure observed in the northern group. (a) Schollen structure, (b) Diktyonitic structure (Loc. Brattnipene).

Plate 2

Plate 2. (*a*) *Layered sequence of banded biotite gneisses* (*Loc. Smalegga*). (*b*) *Tightly folded banded biotite gneiss. Note axial plane foliation produced by secondary deformation. Near a local shear zone* (*Loc. Smalegga*).

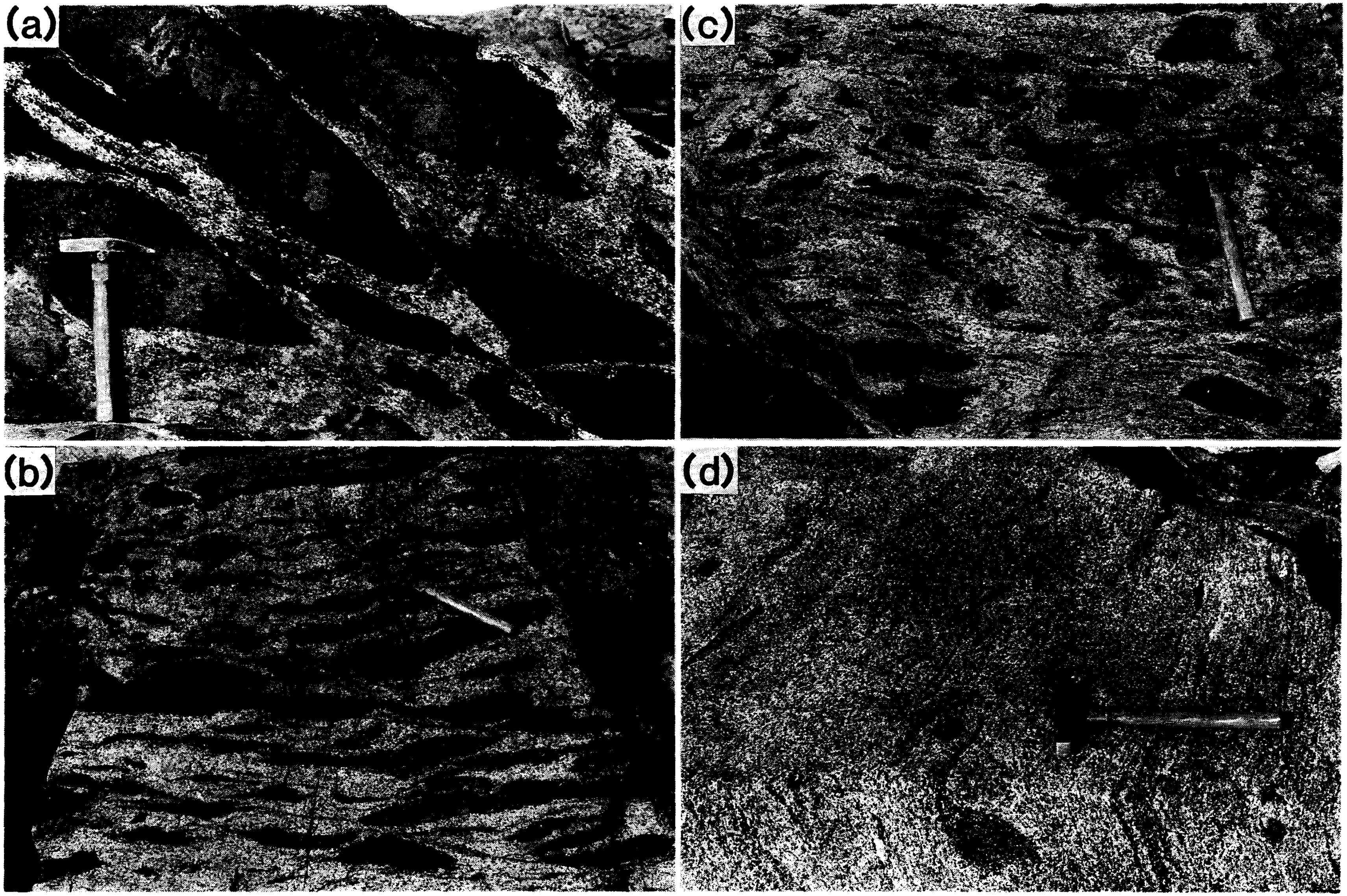

Plate 3. Various modes of occurrence of gneissose tonalite associated with fragments of dark green schist (Loc. Nils Larsenfjellet).

Plate 4

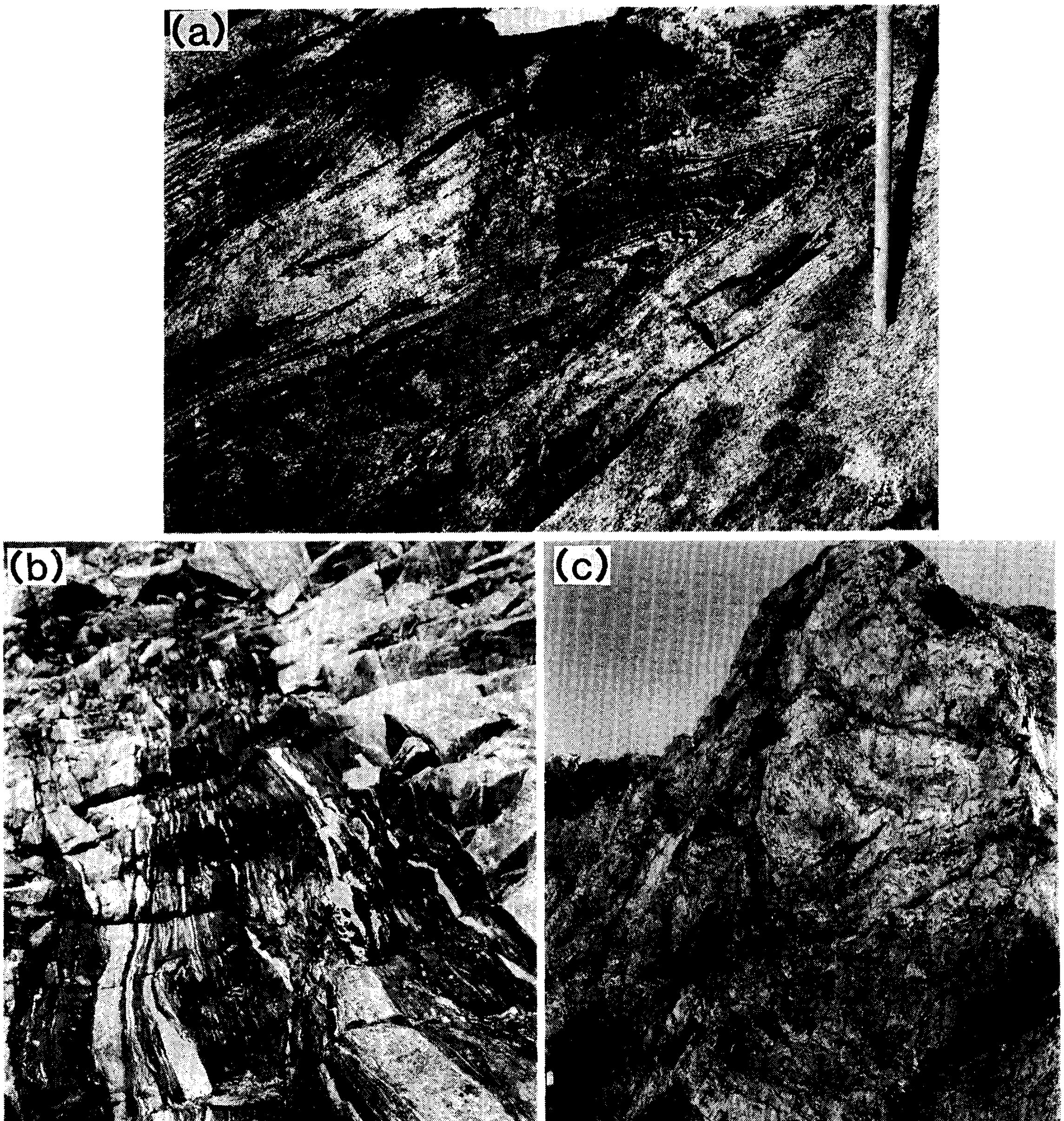

Plate 4. (*a*) *Tight fold in biotite gneiss in the northern group* (*Loc. Brattnipene*). (*b*) *Intensely mylonitized biotite gneiss. Dark layers consist mainly of chlorite and green biotite, and light layers are quartzofeldspathic ultramylonite* (*Loc. eastern bank of the Gunnestad-breen*). (*c*) *The Main Shear Zone. The cliff is about 100 m high* (*Loc. southern part of Smalegga*).

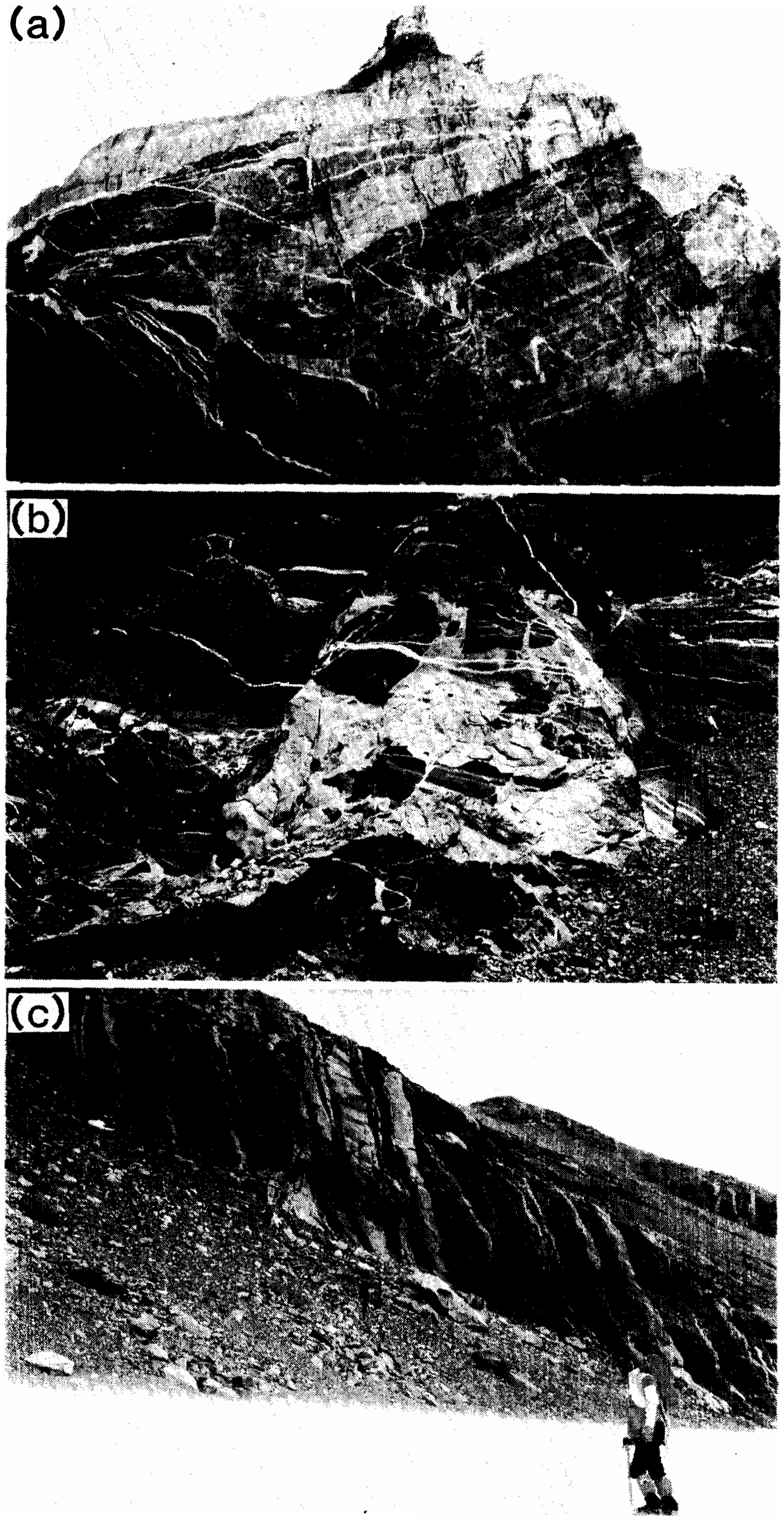

Plate 5. (*a*) *Syenite showing reverse grading bands. Height of the cliff is about 500m* (*Loc. Lunckeryggen*). (*b*) *Amazonite-bearing leucocratic syenite intruding the above syenite. Height of the cliff is about 50m.* (*c*) *Granitic pegmatite swarm intruding hornblende gneiss* (*Loc. Brattnipene*).