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GEOLOGY OF THE MT. RIISER-LARSEN AREA OF THE NAPIER COMPLEX, ENDERBY LAND, EAST ANTARCTICA

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Abstract: The summer party of the 38th Japanese Antarctic Research Expedition (1996-97) performed field work in the Mt. Riiser-Larsen area of the Archaean Napier Complex, Enderby Land, East Antarctica. The area is underlain by various kinds of metamorphic rocks and unmetamorphosed intrusive rocks. Of these, the metamorphic rocks are tentatively divided into the layered gneiss series, massive gneiss series, and transitional gneiss series. The layered gneiss series, occurring in the central to northwestern part of the area, is characterized by layering structure composed of several types of garnet felsic gneiss with subordinate amounts of orthopyroxene felsic gneiss, pelitic and mafic gneisses, impure quartzite, and metamorphosed banded iron formation. The massive gneiss series is predominant in the southern to southeastern part and consists mainly of massive orthopyroxene felsic gneiss, in which the layering structure is not conspicuous and the lithology is rather monotonous. The transitional gneiss series is developed between the layered and massive gneiss series, in which metamorphosed anorthosite and ultramafic rocks occur characteristically as thin layers or blocks or pods. Metamorphic foliation, which is almost always parallel to the layering structure, strikes NE-SW to E-W and dips at moderate to gentle angles (20–40°) to the south or southeast. The mineral associations indicate that the majority of the metamorphic rocks could belong to the high temperature granulite facies at metamorphic temperature higher than 1000°C. Unmetamorphosed doleritic intrusive rocks, so-called Amundsen Dikes, intrude throughout the area, striking N-S and NE-SW. Furthermore, there are many shear zones, following preexisting structures such as dike margins, in which the gneisses and dikes have been sheared to mylonites or pseudotachylite-like rocks.

key words: East Antarctica, Enderby Land, geology, Mt. Riiser-Larsen, Napier Complex

1. Introduction

In northern Enderby Land of East Antarctica occurs the Napier Complex (Figs. 1 and 2A) that consists mainly of metamorphic rocks with minor unmetamorphosed intrusive rocks. The metamorphic rocks are characterized by the presence of such diagnostic minerals and assemblages as sapphirine+quartz, osumilite, inverted

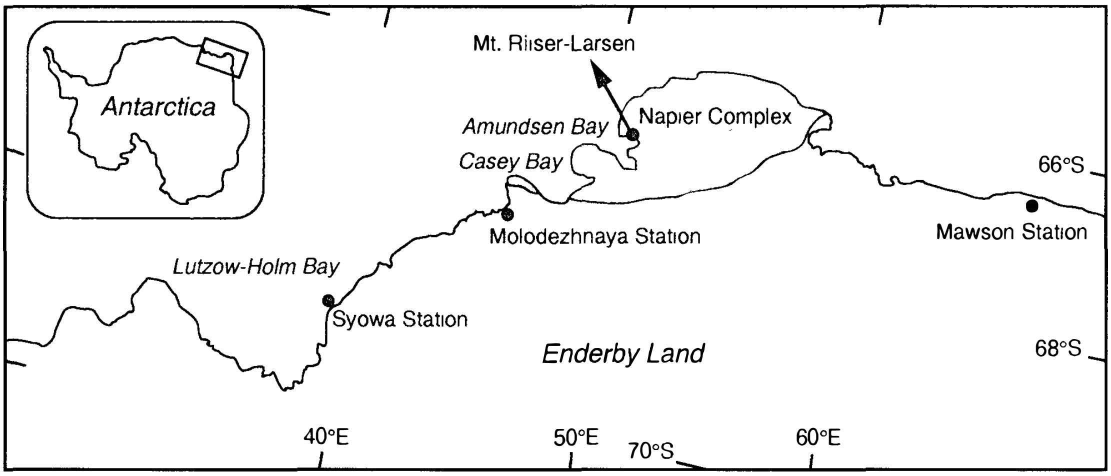

Fig. 1. Locality map of the Mt. Riiser-Larsen area, Enderby Land, East Antarctica.

pigeonite, and sillimanite + orthopyroxene + garnet, indicating metamorphic temperature as high as 1000°C (*e.g.*, SHERATON *et al.*, 1987). Furthermore, the ion microprobe U-Pb dating of zircon has revealed very old age (3930 ± 10 Ma ago) for the tonalitic precursor of orthogneiss (BLACK *et al.*, 1986). The Napier Complex thus provides an excellent opportunity for understanding the nature and origin of ultra-high temperature metamorphism as well as the formative process of Archaean continental crust.

Several parties of the Japanese Antarctic Research Expedition (JARE) performed reconnaissance field work in the Napier Complex; *e.g.*, JARE-23, -29, -31, -34, -36 and -37. Of these, JARE-23, -29, -36 and -37 worked in the Mt. Riiser-Larsen area, JARE-31 in the Mt. Pardoe and Tonagh Island areas, and JARE-34 in the Casey Bay area (Fig. 1). Scientific results based on these JARE works have been published: *i.e.*, geomorphology (YOSHIDA and MORIWAKI, 1983; HAYASHI, 1990), geology and structure (MAKIMOTO *et al.*, 1989; ISHIKAWA *et al.*, 1994), metamorphic petrology (MOTOYOSHI and MATSUEDA, 1984, 1987; MOTOYOSHI and HENSEN, 1989; MOTOYOSHI *et al.*, 1990, 1994, 1995; MOTOYOSHI, 1996), and petrochemistry and geochronology (TAINOSHO *et al.*, 1994, 1997; OWADA *et al.*, 1994). Following these JARE works, we did the field work in the Mt. Riiser-Larsen area for 65 days from December 16, 1996 to February 18, 1997 (ISHIZUKA *et al.*, 1997). In this paper, we report on the geology of the area along with a brief description of the metamorphic and intrusive rocks.

2. Outline of Geology

The Mt. Riiser-Larsen area is located in the northern coast range along Amundsen Bay, northwestern Enderby Land, East Antarctica, and belongs to the central Napier Complex (Fig. 1). The area, measuring approximately 13 × 7 km, is bounded on the south by Adams Fjord, and on the west, north and east by continental ice sheets (Fig. 3). Mt. Riiser-Larsen (66°47′S, 50°42′E) is the highest peak (868 m) in the area (Fig. 2B), and there are several mountain ridges extending west-east or north-south, which have often been dissected by glacial erosion to form arêtes or knife ridges with steep slopes. Also, there are several frozen lakes in the area, of which the largest is named

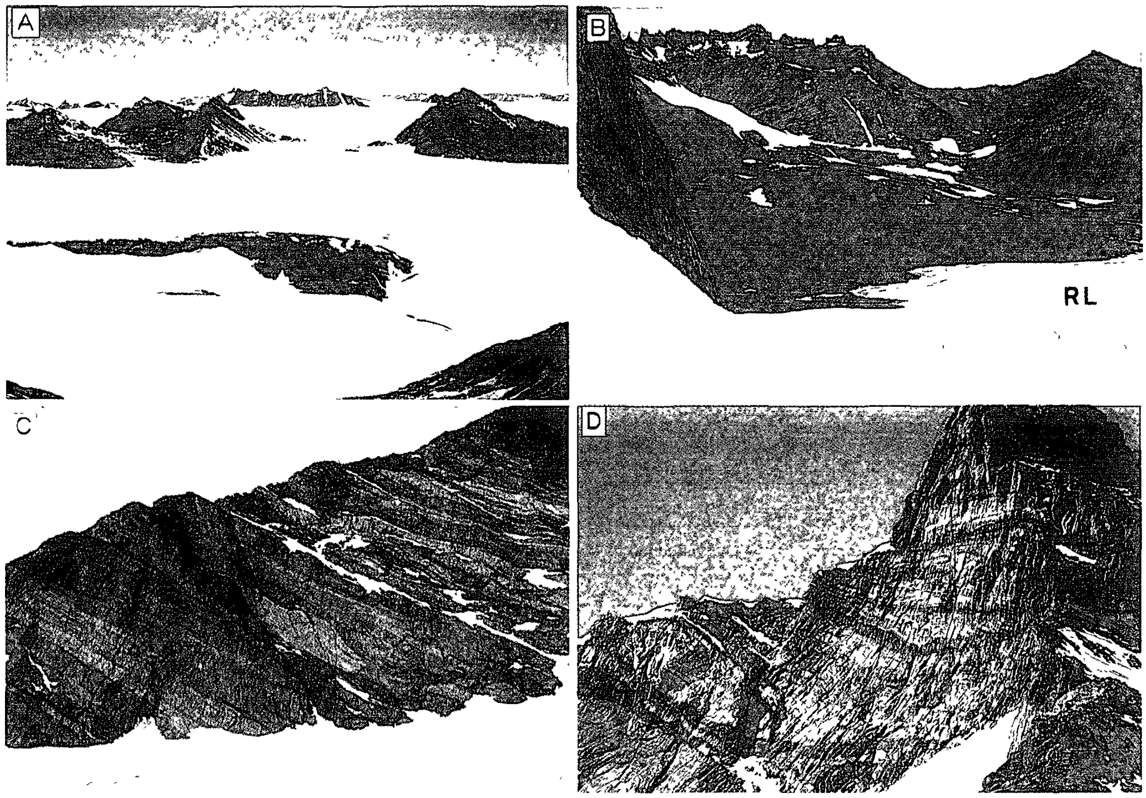

Fig. 2. A: Far-distance view of the Napier Complex distributed along the coast range of Amundsen Bay, Enderby Land, East Antarctica, viewed from the north. B: Mt. Riiser-Larsen (the highest peak) and Richardson Lake (RL) in the central part of the surveyed area, viewed from the northeast. C: Well developed layering structure consisting mainly of garnet felsic gneiss with minor mafic and pelitic gneisses, impure quartzite, and meta-BIF. The black-colored rocks intruding the gneisses are the Amundsen Dikes. The width of the field of view is approximately 600 m. D: Well developed layering structure composed mainly of the garnet felsic gneiss with minor mafic and osumilite-bearing pelitic gneisses. Note that the black-colored layer of the mafic gneiss observed in the center of the outcrop seems to be oblique against the neighboring layers of the garnet felsic gneiss. The width of the photograph is approximately 300 m.

Richardson Lake (Fig. 2B).

Moraine deposits are well developed throughout the area, especially in the central to southwestern part. On the basis of their topographic situations, morphology, and degree of weathering, they have been classified into four groups (Moraine-1, -1', -2 and -3) by Yoshida and Moriwaki (1983) or three groups (Tula Moraine, Mt. Riiser-Larsen Moraines I and II) by Hayashi (1990); the Tula Moraine nearly corresponds to Moraine-1 and -1', and Mt. Riiser-Larsen Moraines I and II to Moraine-2 and -3, respectively. These moraine deposits usually cover basement rocks, and thus outcrops of the basement rocks are restricted to the mountain ridges as well as steep slopes, but in the southwestern part the basement rocks are exposed to form relatively flat hills.

A generalized geologic map of the surveyed area is illustrated in Fig. 4. As may be seen in Fig. 4, the area is underlain by various kinds of metamorphic rocks with subordinate amounts of unmetamorphosed intrusive rocks (Figs. 2C and 2D). Of

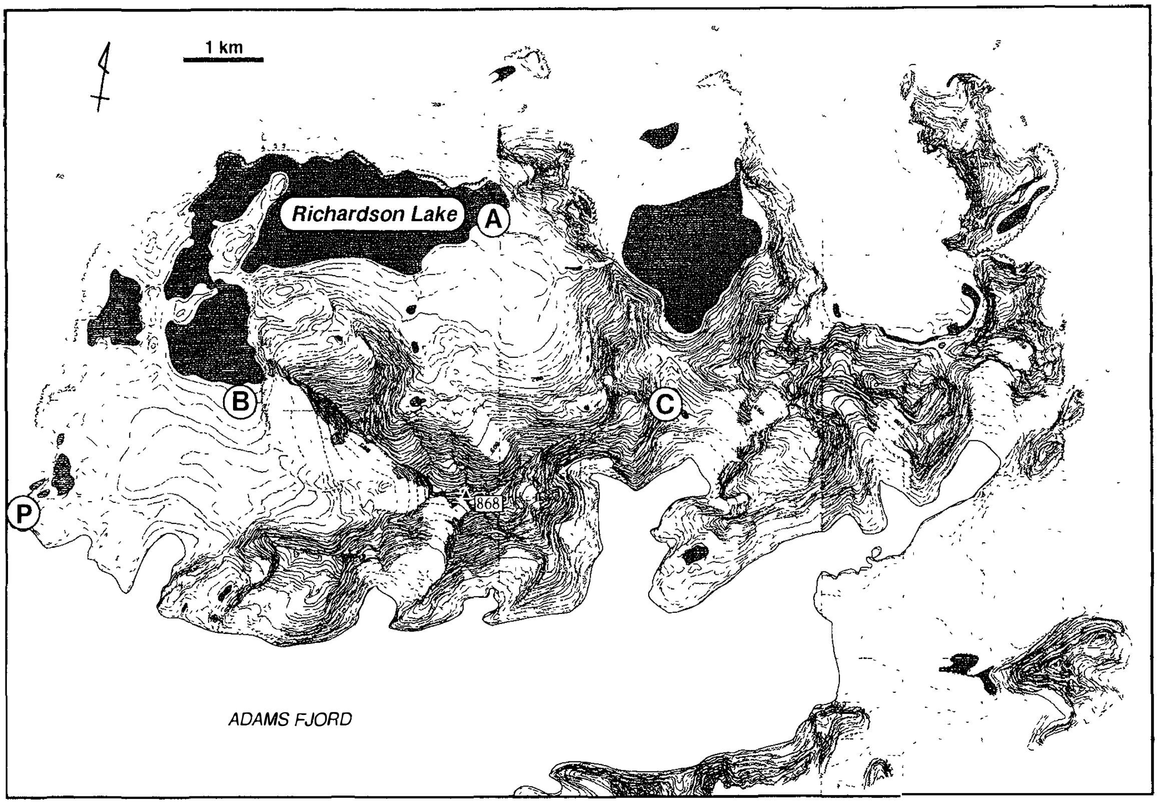

Fig. 3. Topographic map of the Mt. Riiser-Larsen area. A, B and C represent the main camp, advance-B and -C camps, respectively. P indicates the locality of the penguin colony.

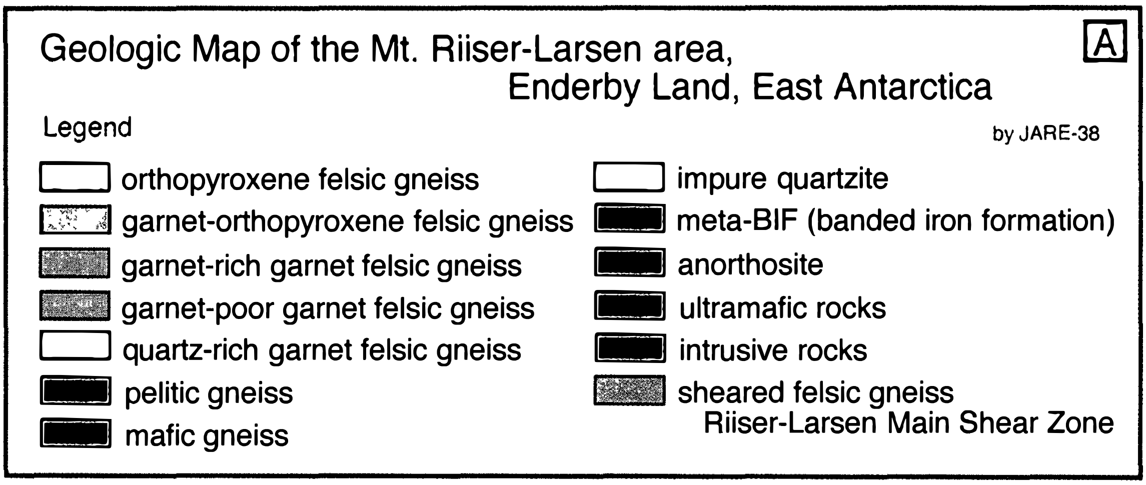

Fig. 4. Generalized geologic map of the Mt. Riiser-Larsen area. A: Legend. B: The western part. C: The central part. D: The eastern part.

these, the intrusive rocks are provisionally named Amundsen Dikes (*e.g.*, SHERATON *et al.*, 1987). Metamorphic foliation strikes NE-SW to E-W, and dips at moderate to gentle angles (20–40°) to the south or southeast. There are a few synforms and antiforms inferred in the area, giving rise to the variations of the strikes and dips of metamorphic foliation. The development of preferred orientation of metamorphic

Fig. 4B.

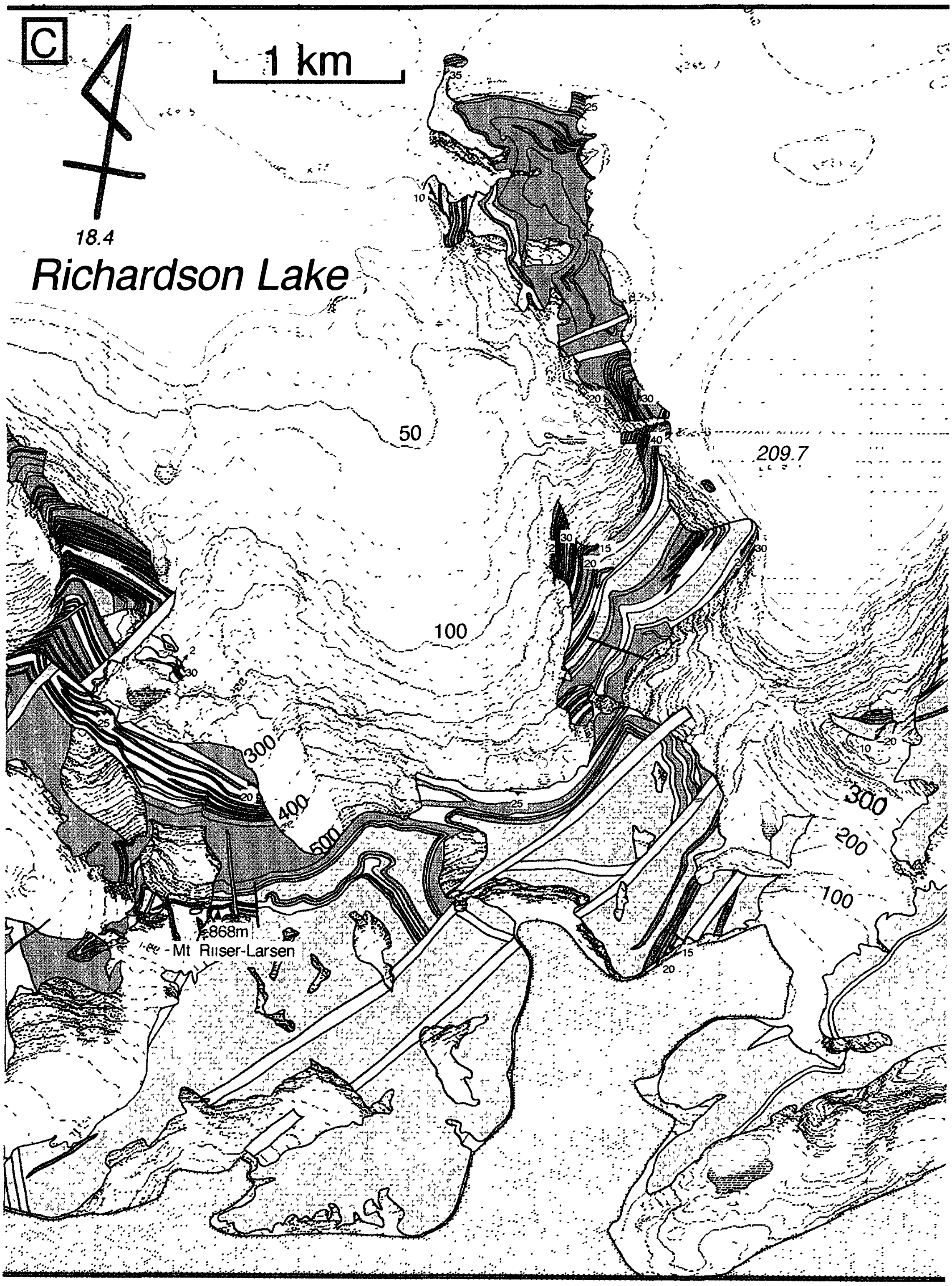
C
1 km
18.4
Richardson Lake
50
209.7
100
300
400
500
300
200
100
868m
Mt Riiser-Larsen

Fig. 4C.

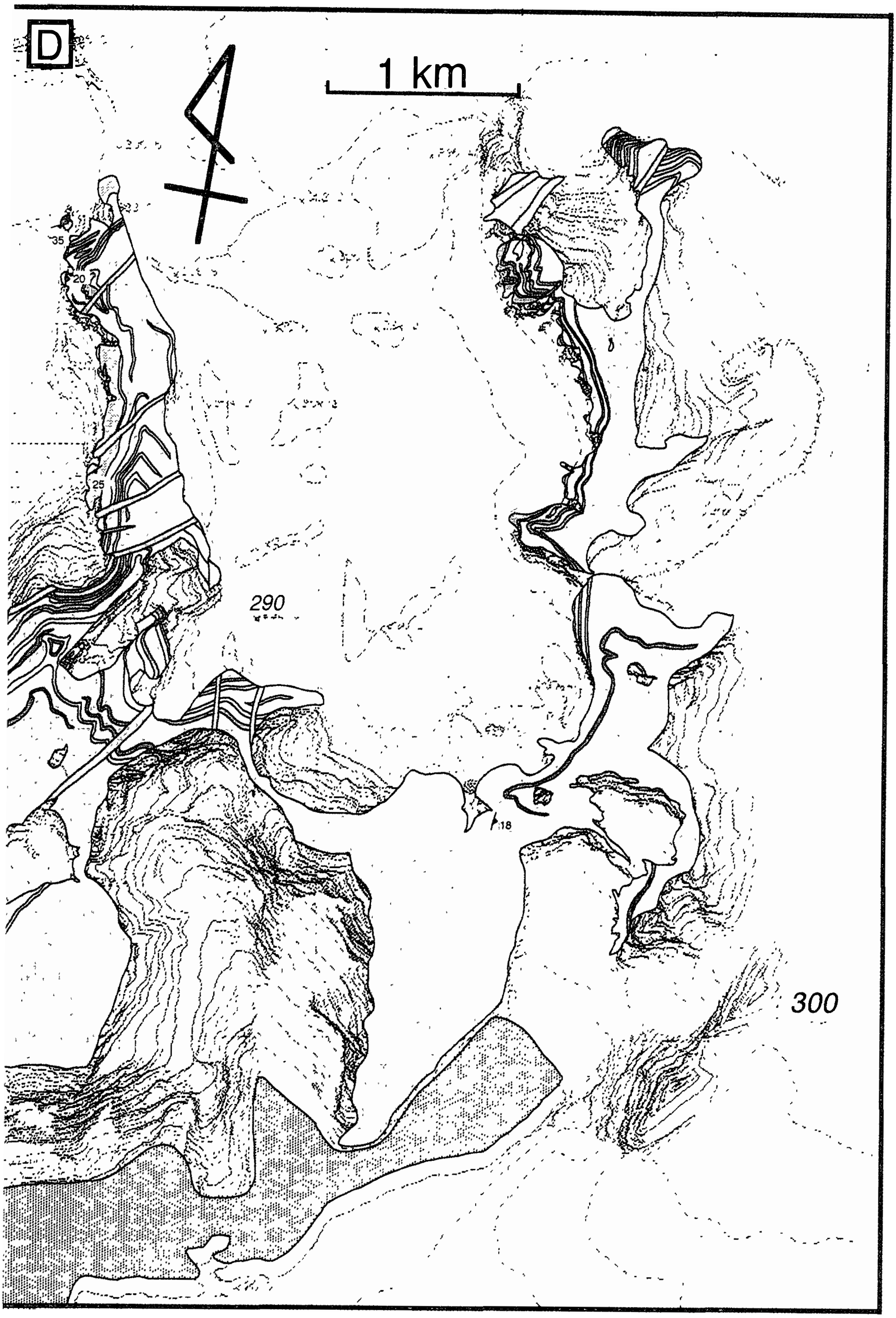

Fig. 4D.

minerals is generally very weak, although elongated quartz and, where present, sillimanite, define a lineation.

Shear zones are the most prominent structures in the area, in which the metamorphic rocks have been sheared to mylonites or sometimes pseudotachylite-like rocks (Fig. 5A). These shear zones are mostly near-vertical and tend to follow preexisting structures such as dike margins. The widths of shear zones range from several centimeters to a few meters, but in the western part a shear zone with the width of about 1 km develops, striking north to south; we call this shear zone Riiser-Larsen Main Shear Zone (R-LMSZ) (Fig. 4B). The lithology and structure of metamorphic rocks are discontinuous from the western to the eastern parts of the R-LMSZ.

3. Metamorphic Rocks

We classify metamorphic rocks into the following rock types: 1) orthopyroxene felsic gneiss; 2) garnet felsic gneiss, which is further subdivided into four types by difference of modal proportion of minerals such as garnet, orthopyroxene and quartz; 3) pelitic gneiss; 4) mafic gneiss; 5) impure quartzite; 6) metamorphosed banded iron formation (meta-BIF); 7) anorthosite; and 8) ultramafic rocks. The distribution of each rock type is shown in Fig. 4. Calc-silicate rocks, which have been reported from other areas of the Napier Complex (*e.g.*, SHERATON *et al.*, 1987), were not observed in the surveyed area.

3.1. Orthopyroxene felsic gneiss

Orthopyroxene felsic gneiss is widespread in the area (Fig. 5B). In the central to northwestern part it is commonly interlayered with the garnet felsic gneiss and sometimes pelitic and mafic gneisses, and rarely impure quartzite and meta-BIF. The layers of the orthopyroxene felsic gneiss range from several tens of centimeters to several meters in thickness. In the southern to southeastern part, the orthopyroxene felsic gneiss is also predominant, but the layering structure is not conspicuous and the lithology is rather monotonous. Weak compositional layerings sometimes develop in the orthopyroxene felsic gneiss (Fig. 5C).

The orthopyroxene felsic gneiss is pale purple to gray in color and medium to coarse in grain size, and commonly exhibits granoblastic texture. Most commonly, it is massive but locally foliated. Pleochroic orthopyroxene, quartz and feldspar minerals are the main constituents; the first two minerals display euhedral to subhedral crystal form. In particular, quartz is often elongated as defining a mineral lineation (Fig. 5D). Orthopyroxene is sometimes altered to biotite along cleavages and margins. Feldspar minerals include plagioclase and K-feldspar, commonly forming perthite to mesoperthite. The quartz + feldspar association without orthopyroxene also develops as forming thin layers several centimeters to a few meters thick. Accessory minerals include zircon, apatite, ilmenite, magnetite, and rarely rutile, titanite and allanite.

3.2. Garnet felsic gneiss and garnet-orthopyroxene felsic gneiss

Garnet felsic gneiss occurs mainly in the central to northwestern part, commonly accompanied by orthopyroxene felsic gneiss, pelitic and mafic gneisses, impure quartzite and meta-BIF (Figs. 2C and 2D), but in the southern to southwestern part several layers of the garnet felsic gneiss are only present within the orthopyroxene felsic gneiss. The modal proportion of garnet and quartz is highly variable to give rise to the variation of rock-color in the field, and at least three color-types of the garnet felsic gneiss are recognized, that is, orange-, gray- and white-colored types. On the geologic map (Fig. 4), the orange-colored type is shown as garnet-rich, gray-colored type as garnet-poor, and white-colored type as quartz-rich garnet felsic gneiss, respectively. Even within one rock type, there is a difference in modal proportion of garnet, which results in the development of a heterogeneous garnet-free portion with visible scale. Also, another type of garnet felsic gneiss occurs: it is gray in color and characteristically includes orthopyroxene; on the geologic map (Fig. 4), it is shown as the garnet-orthopyroxene felsic gneiss.

The garnet felsic gneiss commonly exhibits granoblastic texture, and ranges from medium to coarse in grain size. Major constituent minerals include garnet, quartz and feldspar minerals, of which garnet is commonly subhedral to anhedral in crystal form. Sillimanite, sapphirine, orthopyroxene and osumilite are also included, but less common. The following mineral associations are observed in the garnet felsic gneiss and garnet-orthopyroxene felsic gneiss.

1) garnet + quartz + perthite to mesoperthite,

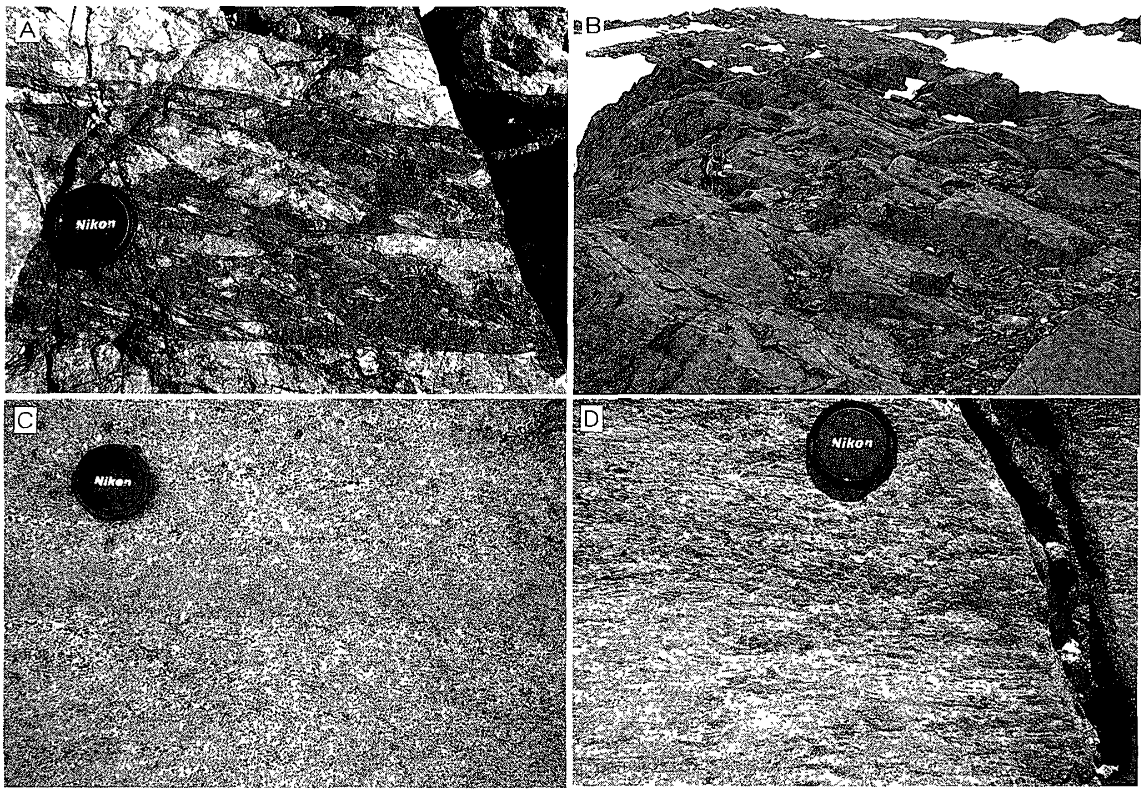

Fig. 5. A: Sheared gneiss to mylonite or pseudotachylite-like rock observed in the Riiser-Larsen Main Shear Zone. B: Orthopyroxene felsic gneiss of the massive gneiss series. C: Weakly developed compositional layering observed in the orthopyroxene felsic gneiss. D: Lineation defined by preferred orientation of elongated quartz in the orthopyroxene felsic gneiss.

2) garnet + orthopyroxenite + quartz + perthite to mesoperthite,
3) garnet + sillimanite + quartz + perthite to mesoperthite,
4) garnet + plagioclase + perthite to mesoperthite,
5) garnet + sapphirine + sillimanite + quartz + K-feldspar,
6) garnet + sillimanite + osumilite + quartz + K-feldspar,
7) sapphirine + orthopyroxene + sillimanite + osumilite + quartz,
8) sapphirine + orthopyroxene + sillimanite + osumilite + quartz + plagioclase.

The garnet-free assemblages of 7) and 8) are restricted to the garnet-free portion of the heterogeneous quartz-rich garnet felsic gneiss. Osumilite is commonly armored by symplectite composed of cordierite + orthopyroxene + quartz + K-feldspar. Sapphirine is sometimes replaced by cordierite or orthopyroxene + sillimanite, but it is also observed to be in direct contact with quartz. Zircon, apatite, rutile and opaque minerals are accessories.

3.3. Pelitic gneiss

Pelitic gneiss is less common in the area, and occurs interlayered with the garnet felsic gneiss and rarely orthopyroxene felsic gneiss. Small blocks or pods of pelitic gneiss are rarely embedded in the garnet felsic gneiss. Gray to dark gray color is

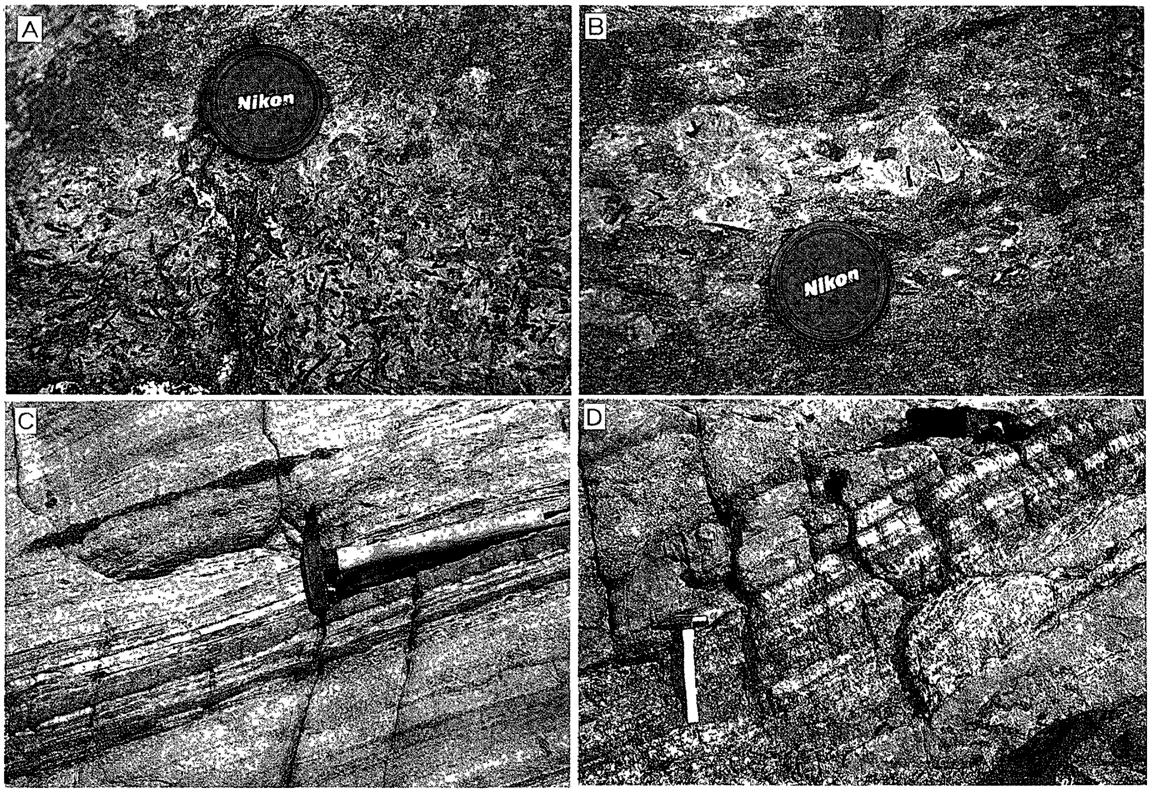

Fig. 6. A: Coarse-grained and euhedral crystals of sapphirine in the pelitic gneiss. B: Coarse-grained and euhedral to subhedral crystals of sapphirine in the pelitic gneiss. Note that several sapphirine crystals are embedded within garnets. C: Thin layers observed in the pelitic gneiss, which are composed of sapphirine, quartz and feldspar with or without orthopyroxene and phlogopite. D: Pale blue-colored impure quartzite interlayered with the orthopyroxene felsic gneiss.

typical of the pelitic gneiss in hand specimens. The preferred orientation of sillimanite is the most conspicuous feature.

The pelitic gneiss comprises mainly garnet, sillimanite, quartz and feldspar minerals, of which garnet is commonly coarse-grained, being up to 10 cm in diameter. Other minerals such as orthopyroxene, sapphirine, osumilite, biotite or phlogopite and spinel are also present, but less common (Figs. 6A, 6B and 6C). The following are the observed mineral associations in the pelitic gneiss.

1) garnet + sillimanite + quartz,
2) garnet + sillimanite + quartz + plagioclas,
3) garnet + sillimanite + quartz + perthite to mesoperthite,
4) garnet + sillimanite + orthopyroxene + sapphirine + quartz,
5) garnet + sillimanite + orthopyroxene + sapphirine + osumilite + quartz,
6) garnet + orthopyroxene + sapphirine + quartz + perthite to mesoperthite,
7) garnet + orthopyroxene + sapphirine + osumilite + quartz + perthite to mesoperthite,
8) sapphirine + orthopyroxene + biotite or phlogopite + plagioclase,
9) sapphirine + orthopyroxene + biotite or phlogopite + K-feldspar + spinel,
10) sapphirine + orthopyroxene + osumilite + sillimanite + quartz + plagioclase + K-feldspar.

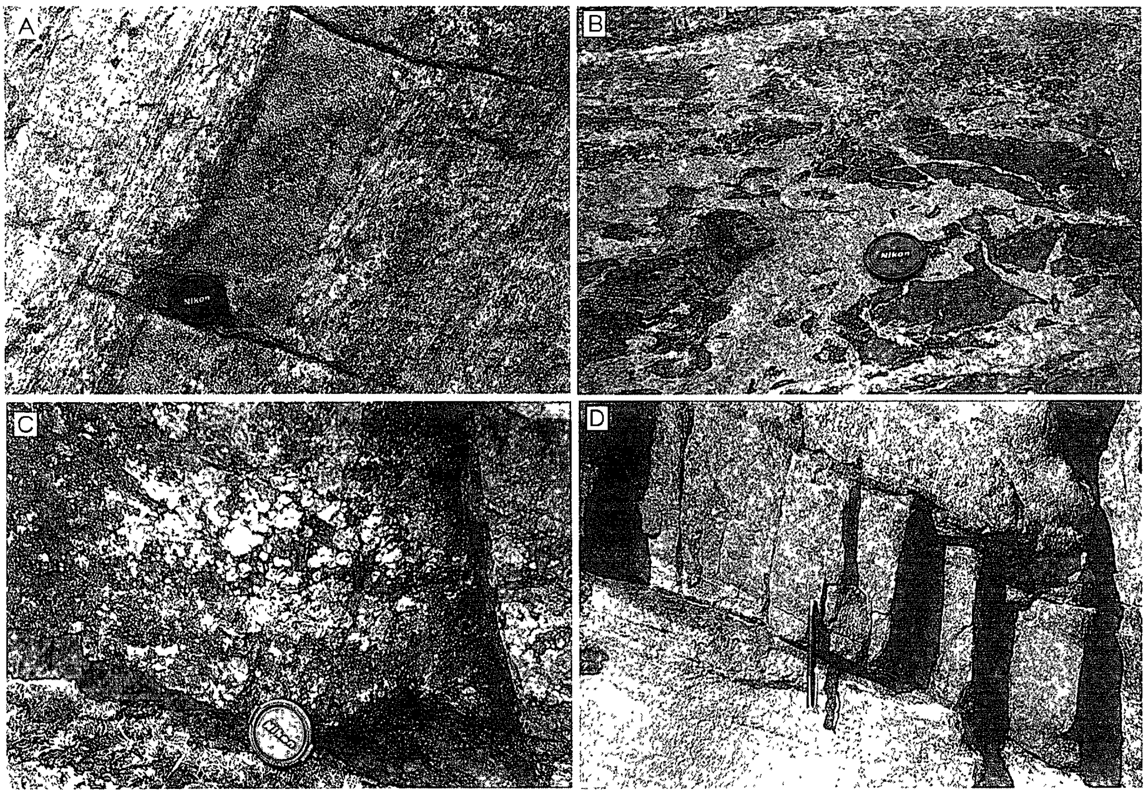

Fig. 7. A: Quartz-bearing mafic gneiss interlayered with the orthopyroxene felsic gneiss. B: Irregular-shaped patches or veins of the felsic rocks developed in the quartz-free mafic gneiss. C: Very coarse-grained magnetite and quartz in the meta-BIF. D: Thin layer of the meta-BIF interlayered with the garnet felsic gneiss. The magnet pen is 10 cm in length.

Garnet commonly exhibits an anhedral crystal form, while sillimanite is euhedral to subhedral. Also, sillimanite is sometimes included in garnet. Spinel is often embedded within garnet or sillimanite. In the sapphirine-bearing associations, the retrograde cordierite with or without orthopyroxene and K-feldspar usually occurs as a reaction product between sapphirine and quartz. The garnet-free associations of 8), 9) and 10) are observed only in the pelitic gneiss occurring as blocks or pods. Rutile and opaque minerals are predominant accessories, but zircon and monazite are not common.

3.4. Mafic gneiss

Mafic gneiss occurs interlayered with the garnet felsic gneiss and sometimes with the orthopyroxene felsic gneiss, ranging in thickness from a few centimeters to a few meters (Fig. 7A) In the western part the mafic gneiss occurs forming a relatively large mass of 700×200 m. Most important, the layers of the mafic gneiss are sometimes oblique against the layers or foliation of the neighboring garnet felsic gneiss (Figs. 2D and 8), and the grain size of the mafic gneiss is rarely observed to be gradually changed from the fine-grained near the contact with the garnet felsic gneiss to the coarse-grained in the center of the layer (Fig. 8) This may indicate intrusive rock which is a precursor of some mafic gneisses In the southern part, irregular-shaped patches or pods or veins of felsic rocks occur in the mafic gneiss (Fig. 7B).

Most mafic gneisses are medium-grained and granoblastic-polygonal in texture. There are at least two types of the mafic gneiss: one includes quartz and the other does not. The quartz-bearing mafic gneiss is light-gray, but the quartz-free one is dark-gray in color Also, the grain size tends to be finer in the quartz-bearing mafic gneiss than the quartz-free one. The observed mineral associations in the mafic gneiss are as follows.

1) clinopyroxene + plagioclase,
2) clinopyroxene + plagioclase + quartz,
3) clinopyroxene + orthopyroxene + plagioclase,
4) orthopyroxene + quartz + plagioclase,
5) clinopyroxene + orthopyroxene + quartz + plagioclase.

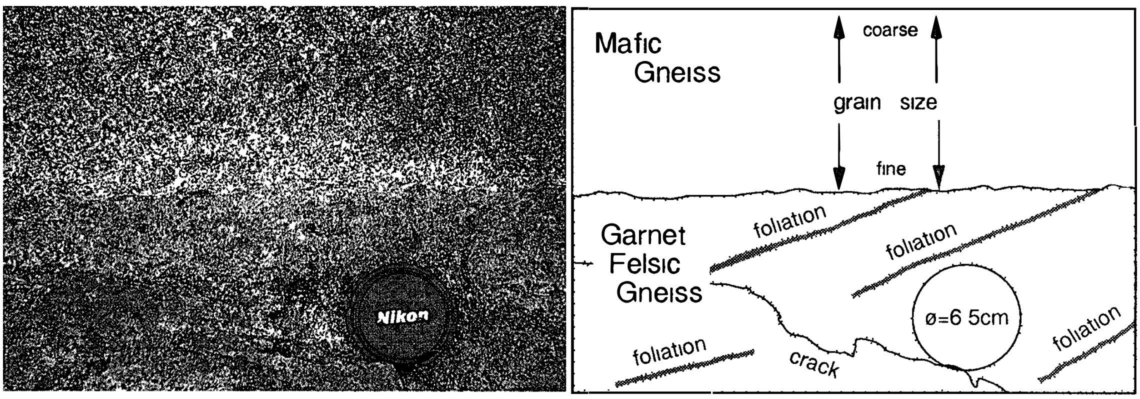

Fig. 8 Close-up view of the contact between mafic gneiss and garnet felsic gneiss. Note that the grain size of the mafic gneiss tends to gradually become fine toward the contact, and the foliation of the garnet felsic gneiss is oblique against the contact

Apatite and Fe-Ti oxide mineral are accessories. Small amounts of hornblende and/or biotite are rarely included as primary (?) phases. Partial replacement of pyroxenes to actinolite or hornblende is apparently present.

3.5. *Impure quartzite*

Medium- to coarse-grained impure quartzite occurs throughout the area, interlayered mainly with the garnet felsic gneiss and rarely orthopyroxene felsic gneiss (Fig. 6D). The layers range in thickness from several centimeters to a few meters, but in the coast region of the southwestern part the mappable-scaled impure quartzite occupies the relatively flat hill. Small amounts of impure quartzite are also present as thin layers or lenticular blocks within the pelitic gneiss. Metamorphic foliation develops weakly.

Most conspicuous, the color of quartz from the impure quartzite is pale to dark blue in hand specimens, similar quartzites have been reported from the charnockites of Southern India and other areas by JAYARAMAN (1939) who interpreted them as reflecting the presence of Ti in quartz. Sapphirine and, less commonly, garnet and orthopyroxene are present but are minor constituents. Retrograde cordierite with or without K-feldspar and orthopyroxene develops between quartz and sapphirine. Accessory miner-

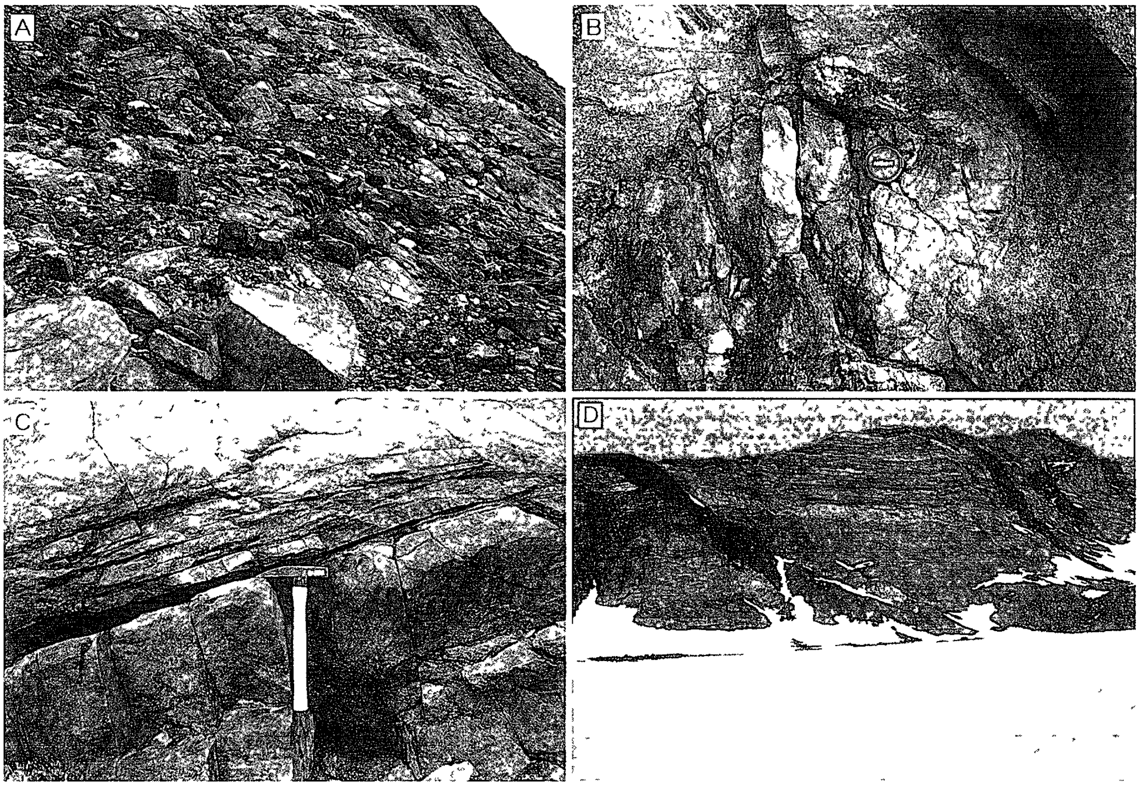

Fig. 9. A: Blocks of peridotites (yellow-colored) included in the orthopyroxene felsic gneiss. B: Orthopyroxenite pod embedded within the orthopyroxene felsic gneiss. Note that the pod is characteristically armored by pale blue quartz. C: Layered peridotites within the orthopyroxene felsic gneiss. Note that a thin layer of strongly foliated peridotites develops at the contact between the massive peridotites and orthopyroxene felsic gneiss. D: The Amundsen Dikes (black-colored) intruding the metamorphic rocks.

als include spinel, rutile, zircon and biotite. In the spinel-bearing quartzite from Mt. Riiser-Larsen, MOTOYOSHI and MATSUEDA (1987) and MOTOYOSHI *et al.* (1990) have described the corundum + quartz association and interpreted it as a metastable product formed in an overstepping reaction during cooling.

3.6. *Meta-BIF*

Metamorphosed banded iron formation (meta-BIF), having black to dark-green color, is widespread in the area, occurring as layers and sometimes blocks within the garnet felsic gneiss and rarely orthopyroxene felsic gneiss (Figs. 7C and 7D). The thickness of the meta-BIF layer ranges from several centimeters to several tens of centimeters, but it is rarely more than a few meters. Also, the meta-BIF occurs as thin layers between the pelitic gneiss layers, indicating that the meta-BIF may have been sedimentary in origin. Medium- to sometimes coarse-grained magnetite and quartz are the main constituents with or without clinopyroxene, orthopyroxene and amphibole, to which garnet is rarely added.

3.7. *Anorthosite*

Anorthosite, having gray-black color in the field, is restricted to the southwestern part and associated with the mafic gneiss, but the contact relationship between these rocks is obscure in the field. The anorthosite is massive and generally displays granular texture defined by coarse-grained calcic plagioclase with or without orthopyroxene, clinopyroxene and Fe-Ti oxide.

3.8. *Ultramafic rocks*

Ultramafic rocks exist sporadically in the area, and several rock types such as clinopyroxenite, orthopyroxenite, peridotites and serpentinite are recognized They commonly occur as lenticular or rounded blocks with a diameter of a few ten centimeters to several meters (Fig. 9A). The blocks of clinopyroxenite and peridotites are in clear contact with the host gneiss, while the blocks of orthopyroxenite are commonly surrounded by the pale blue quartz rind (Fig. 9B) In the southern part the peridotites occur as layers of several tens of centimeters thickness within the orthopyroxene felsic gneiss, where the strongly foliated peridotites develop at the contact between the peridotites and orthopyroxene felsic gneiss (Fig. 9C).

The clinopyroxenite is black and massive, while the orthopyroxenite is yellow to pale brown and also massive Clinopyroxene and orthopyroxene are the main constituent minerals in the clinopyroxenite and orthopyroxenite, respectively The peridotites, which comprise mainly olivine, clinopyroxene and orthopyroxene, are also yellow to pale brown in color, and commonly massive but rarely foliated as defined by elongated orthopyroxene. These main constituent minerals are generally coarse-grained and equigranular. Accessory minerals include hornblende, biotite or phlogopite, spinel, magnetite, and rarely plagioclase.

4. Intrusive Rocks

Abundant intrusive rocks, Amundsen Dikes, occur throughout the area, striking

N-S and NE-SW (Figs. 2C and 9D) The width of intrusive rocks varies from several tens of centimeters to a few meters, but rarely reaches 20 m A chilled margin (several centimeters in thickness) is well developed, but thin intrusive rocks lack a distinct chilled margin No thermal effect is observed in the host gneiss. Near the shear zones, the dike rocks are also sheared to mylonites or sometimes pseudotachylite-like rocks The Rb-Sr whole rock data show 1190±200 Ma for the intrusion age of the Amundsen Dikes (Sheraton and Black, 1981) These suggest that the shearing postdated the intrusion of the Amundsen Dikes (1190±200 Ma).

Most intrusive rocks are black- to dark-gray-colored and massive, and fairly fresh, and display subophitic to intergranular textures Light-gray-colored intrusive rocks also occur, they are commonly porphyritic in texture Relatively thick intrusive rocks, being more than a few tens of meters thick, have coarse-grained and equigranular

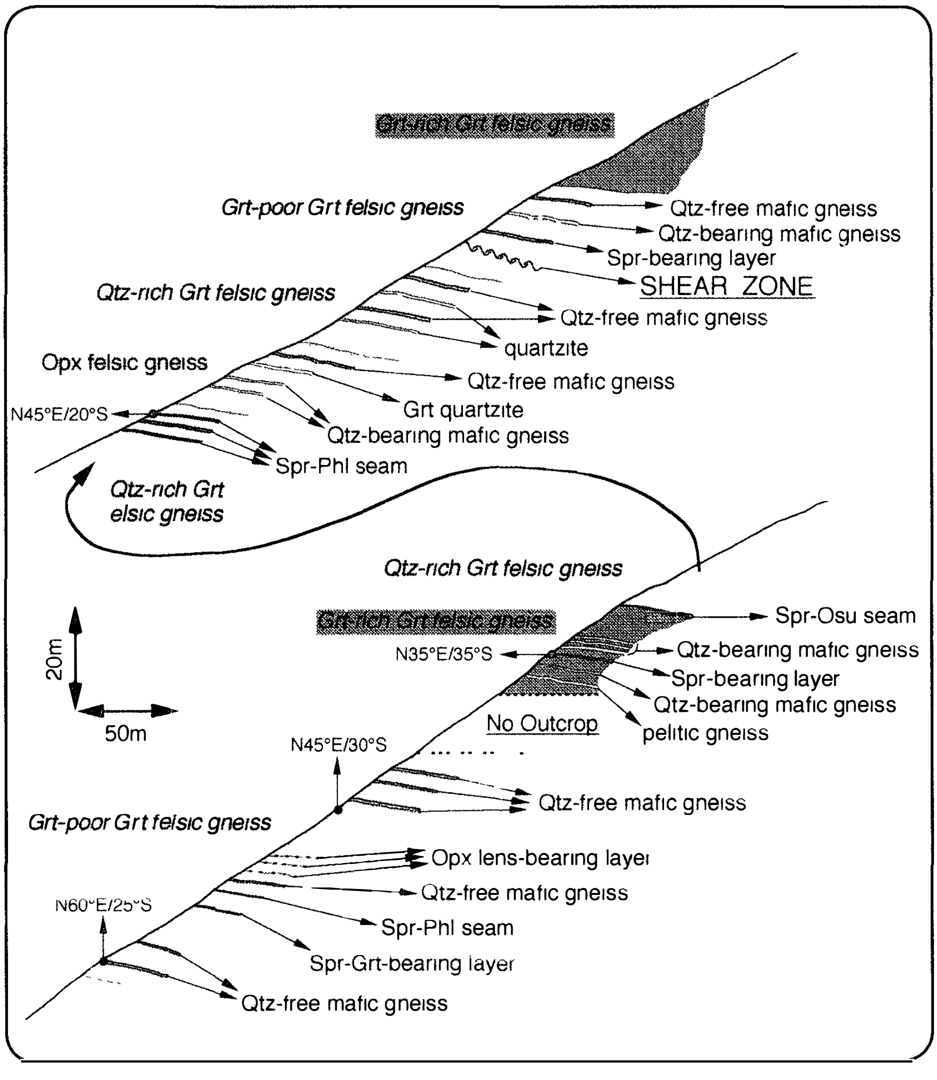

Fig 10 A detailed geologic section of the area, about 1 2 km southeast from the main (A) camp Note that the layering structure is essentially composed of garnet felsic gneisses, and other rock types are interlayered with or within garnet felsic gneisses

(gabbroic) texture in the central portion. Constituent minerals of the intrusive rocks include plagioclase and clinopyroxene with or without small amounts of orthopyroxene, hornblende and biotite. When the rocks are porphyritic, the phenocrysts comprise plagioclase and clinopyroxene. Most commonly, plagioclase is chemically zoned. Accessory minerals are quartz, ilmenite, magnetite, apatite and pyrite. Alteration to fine-grained green hornblende sometimes develops along the margin and/or cleavage of clinopyroxene.

5. Concluding Remarks

As shown in Fig. 4, the layering structure is well developed in the central to northwestern part of the area The detailed geologic section illustrated in Fig 10 shows that this layering structure, which is almost always parallel to metamorphic foliation, is essentially formed by alternation of layers of various types of garnet felsic gneiss such as garnet-rich, garnet-poor and quartz-rich garnet felsic gneisses; other rock types such as orthopyroxene felsic gneiss, pelitic and mafic gneisses and impure quartzite are interlayered with or within the layers of certain varieties of garnet felsic gneiss Also, meta-BIF, which does not crop out in the area of Fig. 10, commonly develops as thin layers within the garnet felsic gneiss.

In the southern to southeastern part such a layering structure is not conspicuous, and the lithology is rather massive and monotonous. In this area, the orthopyroxene felsic gneiss predominates, with small amounts of layers composed of the garnet felsic

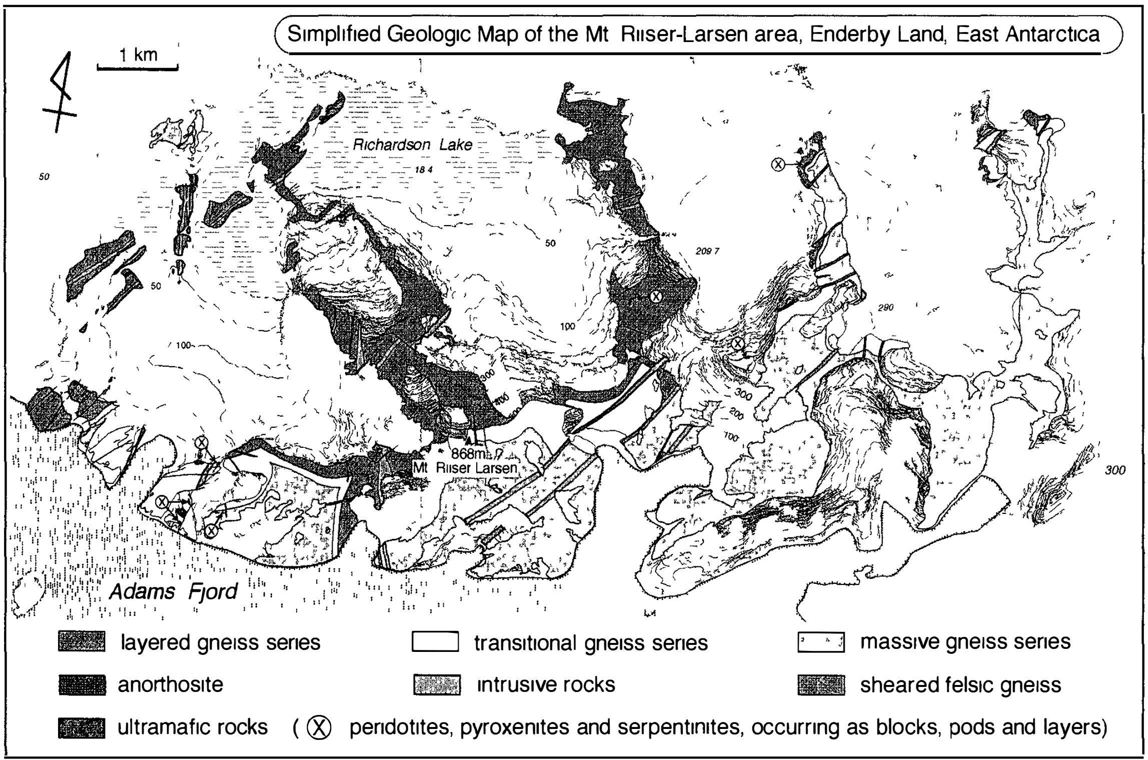

Fig 11 Simplified geologic map of the Mt Riiser-Larsen area

gneiss, pelitic gneiss, mafic gneiss, impure quartzite and meta-BIF

Thus, we propose that the metamorphic rocks in the central to northwestern part of the area be referred to simply as the layered gneiss series, and those in the southern to southeastern part as the massive gneiss series As noted by SHERATON *et al.* (1987), this essentially follows Soviet geologists' subdivision of the Napier Complex into two major gneiss groups. massive pyroxene-quartz-feldspar gneiss with minor mafic granulite, and layered garnet-quartz-feldspar gneiss with subordinate pelitic, psammitic, and ferruginous metasediments (KAMENEV, 1975) However, these two gneiss series are not mutually exclusive, and, indeed, transitional varieties occur between the two gneiss series, referred to here as the transitional gneiss series, in which blocks or pods of anorthosite and ultramafic rocks are characteristically included It is, therefore, possible that such a subdivision means to represent the predominant rock type on the simplified geologic map as shown in Fig. 11

Many peoples have suggested that the layering structure is sedimentary in origin with minor intrusives (now represented by the mafic gneiss) (MOTOYOSHI and MATSUEDA, 1984, SHERATON *et al.,* 1987, MAKIMOTO *et al.,* 1989) Although the field occurrence of the layering structure is strongly reminiscent of the sedimentary origin for the precursors of the layered gneiss series, more data such as geochemical and geochronological data are apparently needed to discuss this problem as well as the origin of the massive gneiss series On the other hand, the mineral associations observed in the present study are consistent with the previously estimated metamorphic conditions at temperatures of more than 1000°C (*e.g.*, SHERATON *et al.,* 1987) In this report, only a brief petrographic description is presented, detailed observations and analyses of mineral textures and chemistries are needed to evaluate more precisely the *P-T* evolution of the Napier Complex

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