REEXAMINATION OF METAPELITES IN THE CAPE OMEGA AREA, WESTERNMOST PART OF PRINCE OLAV COAST, EAST ANTARCTICA

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Abstract: Through the reexamination of metamorphic rocks in the Cape Omega area, the associations of orthopyroxene-garnet-biotite and cordierite (mg= 0.95)-sillimanite-biotite (mg=0.92) are found in some kinds of metapelites. Based upon the petrographical and mineralogical investigations of the rocks, it is clarified that metamorphic conditions of the area were around 680°C and 5 kb.

1. Introduction

The metamorphism around Lützow-Holm Bay and the Prince Olav Coast has recently been clarified in detail by Japanese geologists. The metamorphic conditions in the Lützow-Holm Bay region have been summarized as 725±25°C and 6.3± 1.3 kb (SUZUKI, 1983). The characteristics of the metamorphism in the Prince Olav Coast have been clarified on the basis of the regional distribution and textural features of aluminium silicates (HIROI *et al.*, 1983). According to them, the area has undergone medium-pressure type metamorphism and the metamorphic grade gradually increased

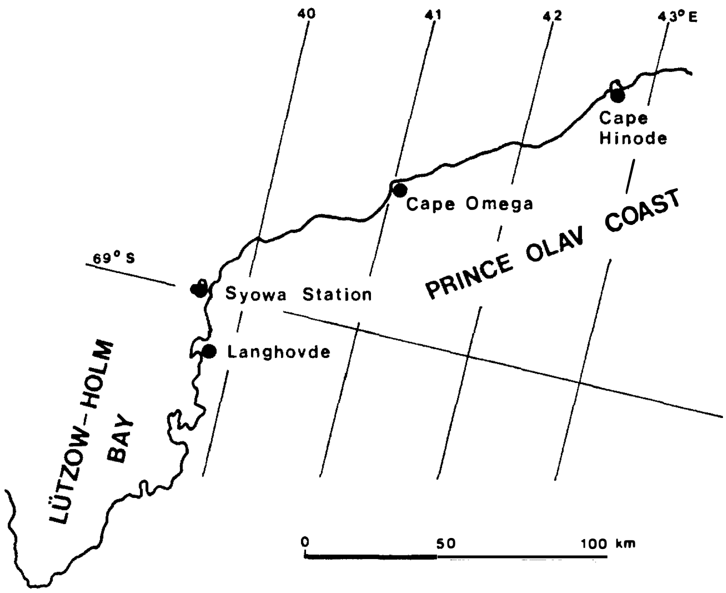

Fig. 1. Location map of the discussed areas in the region from Lützow-Holm Bay to the Prince Olav Coast, East Antarctica.

westwards from the amphibolite facies to the granulite-amphibolite transition.

One of the most controversial points is how the metamorphic grade changed from the Prince Olav Coast to the Lützow-Holm Bay region. The metamorphic rocks in the Cape Omega area, which is situated in the westernmost part of the Prince Olav Coast (Fig. 1), will give a clue to solve the problem mentioned above. The preliminary note on the petrographical characteristics of the metamorphic rocks in the area was formerly given by the present author (1979). After that, through the reexamination, some peculiar kinds of metamorphic rocks have been found to occur sporadically in this area. This paper presents the petrography and petrological significance of these rocks.

2. General Geology

In the Cape Omega area, which is situated about 80 km northeast of Syowa Station, East Ongul Island, are widely distributed such metamorphic rocks as the ones derived from pelitic to psammitic, basic to intermediate, and calcareous sedimentary equivalents (Fig. 2). So-called metabasites are also found in concordance

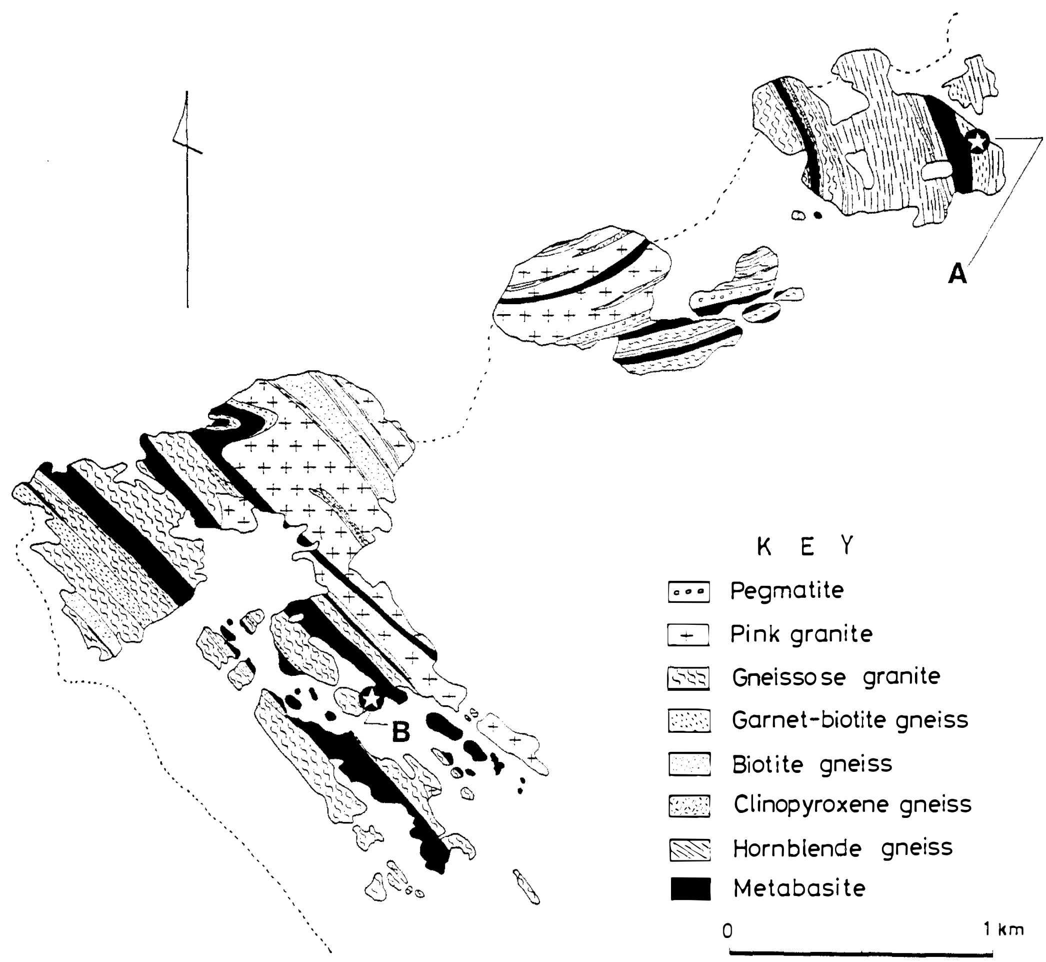

Fig. 2. Geological map of the Cape Omega area. Points A and B show the localities of specimens Nos. 77010630 and 77010708, respectively.

with the surrounding rocks as the characteristic members among the metamorphites. They show variable lithofacies as will be described below. Plutonic rocks are mainly gneissose granite with concordant appearance and pink granite closely associated with pegmatite showing discordant occurrence.

Pelitic and psammitic metamorphic equivalents are characterized by the association of biotite+plagioclase+K feldspar+quartz±garnet. Muscovite is sometimes found as an essential metamorphic mineral. Garnet, when exists, is almandinous with the MgO content around 2 to 5 wt%. Both CaO and MnO contents are smaller than 7%. The mg value (Mg/Mg+Fe) of biotite is in the range of 0.4 to 0.5. An% in plagioclase is usually 20 to 37.

Hornblende gneiss, derived from basic to intermediate rocks, is characterized by the association of hornblende+biotite+plagioclase+K feldspar+quartz. Clinopyroxene is sometimes found.

Clinopyroxene gneiss, originated from some kind of lime-silicate rocks, takes the typical association of clinopyroxene+hornblende+plagioclase+K feldspar+quartz± scapolite±garnet.

Metabasite shows such variable lithofacies as eclogitic rock, clinopyroxene amphibolite, biotite amphibolite, clinopyroxenite and so on. Among them, is also found the rock with the association of fassite (with 5.65 to 10.43 wt% of Al_2O_3)+ garnet ($Gros_{66.0-66.3}Alm_{31.4-31.6}Pyr_{0.9-1.0}Spes_{1.2-1.6}$) + scapolite (meionite$_{83}$) + hornblende. The occurrence of fassite has already been reported from Cape Hinode by KANISAWA and YANAI (1982). The petrological significance of the rock in the Cape Omega area will be given in a separate paper.

The general metamorphic grade in the area seems to be of the amphibolite facies, but the possibility of the existence of metamorphic rocks suggesting the formation under higher condition, probably of the granulite facies was deduced (SUZUKI, 1979).

3. Petrography

Among the pelitic metamorphic rocks in the Cape Omega area, it is interesting that there occur two kinds of rocks with the stable association of orthopyroxene+ garnet+biotite (specimen No. 77010630) and with that of sillimanite+cordierite+ biotite (specimen No. 77010708). The petrographical characteristics of them are given below.

3.1. Specimen No. 77010630

The rock is found in the easternmost part of the area (Locality A in Fig. 2). It occurs in a part of garnet-biotite gneiss intercalated with metabasite and hornblende gneiss. It shows a marked foliated structure characterized by the alternation of leucocratic feldspathic and melanocratic biotite-rich layers.

Under the microscope, the medium-grained granoblastic texture is characteristic (Fig. 3). The essential mineral assemblage of the rock is orthopyroxene+garnet+ biotite+plagioclase+K feldspar+quartz. Accessory minerals are apatite, zircon and ore. Secondary muscovite is sometimes found. Chemical compositions of such major constituent minerals as orthopyroxene, garnet and biotite are shown in

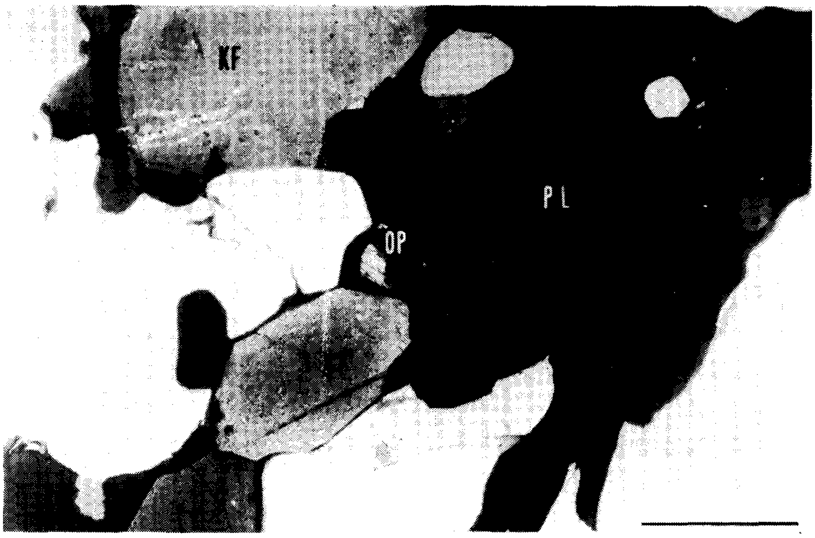

Fig. 3. Photomicrograph of specimen No. 77010630. Scale bars=0.25 mm. Crossed nicols. OP: orthopyroxene, BI: biotite, PL: plagioclase, KF: K feldspar.

Table 1. Chemical compositions of main constituent minerals in metapelites from Cape Omega area.

	1 Opx	2 Gar-r	3 Gar-c	4 Biot	5 Cord	6 Biot
SiO_2	51.47	37.58	37.91	36.30	48.34	37.73
TiO_2	0.19	0.09	0.05	3.20	0.05	2.57
Al_2O_3	0.65	21.05	21.09	14.46	33.83	18.33
FeO*	30.38	28.98	26.11	18.20	1.29	3.04
MnO	0.86	4.25	3.07	0.24	0.14	0.10
MgO	15.94	3.02	4.13	12.40	12.63	20.86
CaO	0.70	5.16	7.26	0.04	tr.	tr.
Na_2O	0.05	0.04	0.07	0.07	0.23	0.16
K_2O	0.04	0.03	0.02	9.53	0.01	10.36
Total	100.26	100.20	99.70	94.45	96.52	93.16
			Numbers of ions			
O	6.000	24.000	24.000	22.000	18.000	22.000
Si	1.991	5.995	6.000	5.582	4.921	5.452
Ti	0.005	0.011	0.006	0.370	0.004	0.280
Al	0.029	3.959	3.934	2.620	4.060	3.124
Fe	0.983	3.867	3.456	2.341	0.110	0.367
Mn	0.028	0.575	0.411	0.031	0.012	0.012
Mg	0.919	0.718	0.975	2.841	1.916	4.493
Ca	0.029	0.883	1.231	0.007	—	—
Na	0.003	0.013	0.020	0.022	0.046	0.044
K	0.002	0.005	0.004	1.870	0.001	1.911

* Total Fe as FeO. 1 to 4: Specimen No. 77010630. 5 and 6: Specimen No. 77010708.

Table 1.

In the specimen only one grain of orthopyroxene is found. It is very fine-grained (less than 0.1 mm), but is not xenocrystic. The composition is $Ca_{1.5}Mg_{46.9}Fe{+}Mn_{51.6}$, plotted in the ferrohypersthene region. The composition seems to be similar to that in the specimen from the Langhovde area (SUZUKI, 1982), although the Al_2O_3 content is somewhat lower.

Garnet usually has irregular shapes. It shows a distinct zoned structure with a rather Mg-rich core, namely, the rim has the composition of $Gros_{14.6}Alm_{64.0}Pyr_{11.9}Spes_{9.5}$ and the core $Gros_{20.3}Alm_{56.9}Pyr_{16.0}Spes_{6.8}$.

Deep brownish biotite is developed in parallel arrangement. The mg value is around 0.55.

Plagioclase is unzoned and sometimes antiperthitic. The composition of host crystal is An 43 to 46, having a rather higher Ca content compared with plagioclase (An 20 to 37) in the common garnet-biotite gneiss in the area.

3.2. Specimen No. 77010708

The rock is found in the central part of Omega-nisi Rock (Locality B in Fig. 2). It occurs as a concordant layer of 2 m thick, intercalated between metabasite and gneissose granite (Fig. 4). The foliation characterized by the compositional banding develops in parallel with that of the surrounding rocks.

Under the microscope, the medium-grained granoblastic texture is characteristically developed (Fig. 5). The essential mineral assemblage is cordierite+sillimanite+biotite+mesoperthite+quartz with no graphite. Accessory minerals are apatite, zircon and ore. Secondary muscovite is sometimes found. The alternation of cordierite+sillimanite rich aluminous layer with leucocratic quartzo-feldspathic one is distinctly developed. Representative chemical compositions of the main constituent minerals are shown in Table 1.

Cordierite occurs as euhedral crystals, partly altered to pinite. It is worthy of note that the mg value is fairly high, reaching 0.95.

Sillimanite is aluminium silicate polymorphs newly found in the Cape Omega area. It usually occurs as long prisms, showing a distinct parallel arrangement.

Fig. 4. Photograph showing the mode of occurrence of specimen No. 77010708. It (center) is intercalated between metabasite (MB) and gneissose granite (GR).

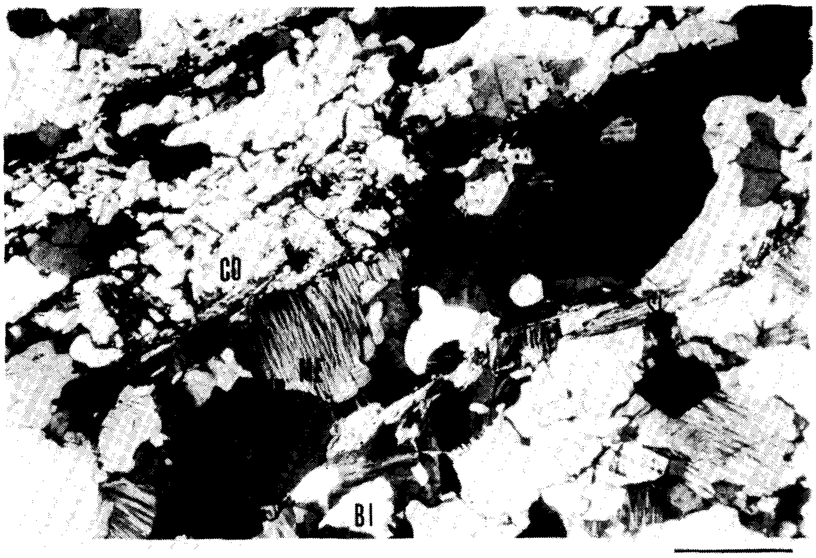

Fig. 5. Photomicrograph of specimen No. 77010708. Scale bars=0.5 mm. Crossed nicols. CO: cordierire, SI: sillimante, BI: biotite, ME: mesoperthite.

Brownish biotite takes part in the foliated structure. It is characterized by a high Mg content (mg=0.92), as in the case of associated cordierite. The value shows a distinct contrast to the values of biotite in ordinary pelitic metamorphics, in which the mg value ranges from 0.4 to 0.5. The petrological significance of the association of Mg-rich cordierite and biotite accompanied by sillimanite and K feldspar will be given later.

4. Discussions

Based upon the petrological characteristics mentioned above, and described previously (SUZUKI, 1979), the metamorphic conditions of the Cape Omega area will be reexamined below.

At first, temperature condition will be estimated using Mg-Fe distribution coefficient between coexisting garnet and biotite in pelitic rocks. Figure 6 shows the distribution of Mg and Fe between these two phases. In the figure, the line of $K_D=0.31$ shows the relation in the Lützow-Holm Bay region (SUZUKI, 1983), suggesting the formation temperature around 730°C. KANISAWA and YANAI (1982) clarified the relationship of the pair from the Cape Hinode area, about 80 km northeast of the area concerned. According to them, pairs of biotite inclusions in garnet and immediately adjacent garnet, plotted on the line of $K_D=0.16$, cannot suggest the equilibrium relationship, due to the compositional homogenization of garnet during the progressive metamorphism. Meanwhile, the pairs of matrix biotite and rim part of garnet are plotted on the lines of $K_D=0.26$ and 0.29, showing the temperature around 650°C in the Cape Hinode area.

The plots of the pairs from the Cape Omega area, though scattered, cluster in the region under the line of $K_D=0.31$ (Fig. 6). By the use of THOMPSON's method (1976), biotite-garnet core pairs indicate comparatively higher temperatures than those

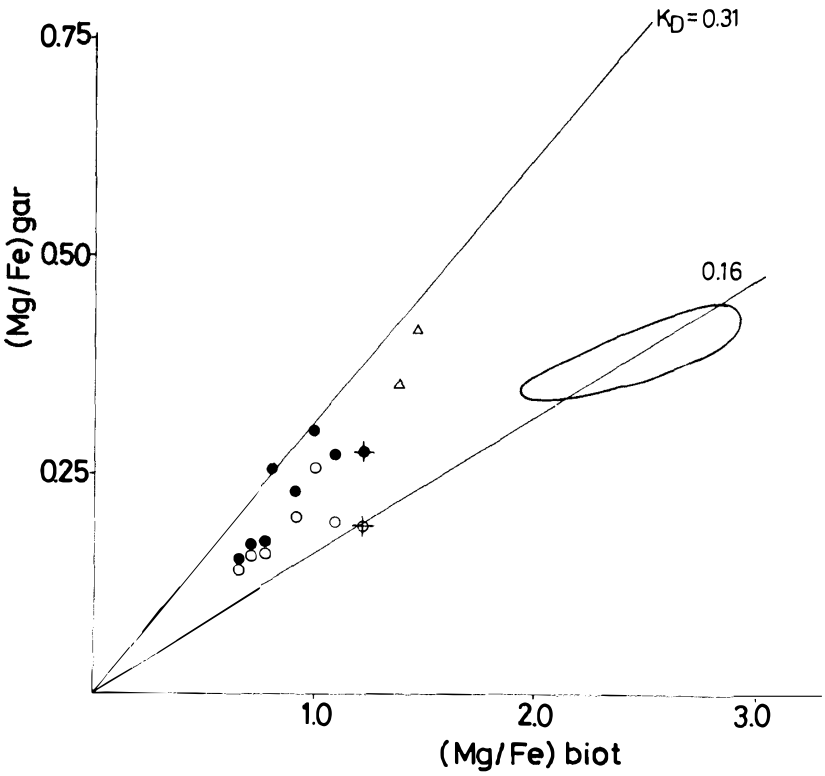

Fig. 6. The distribution of Mg and Fe between coexisting biotite and garnet (see text). Circle: pairs in pelitic rocks of the Cape Omega area, Cirlce with cross: pairs in the specimen No. 77010630. Triangle: pairs from Cape Hinode (KANISAWA and YANAI, 1982). Open symbol shows the pair of biotite and garnet rim, while closed one that of biotite and garnet core. Full line encloses the pairs of biotite inclusions in garnet and immediately adjacent garnet from Cape Hinode (KANISAWA and YANAI, 1982).

of the rim pairs, in the range of 636–735°C, averaging 683°C. The temperature previously given by SUZUKI (1979) was estimated by another method (FERRY and SPEAR, 1978) and the value was too high. The pair of biotite-garnet core in specimen No. 77010630 described above, which is unique by taking orthopyroxene among metapelites in the area, gives the rather low temperature value. It may be due to the abundance of CaO and MnO in the garnets and to the secondary alteration by the igneous activity, for example, of pink granite, but a strict reason cannot be revealed here.

All things considered, it is not unreasonable to assume that the temperature condition deduced from the pairs of biotite-garnet core in the Cape Omega area is as high as 680°C, which may suggest that the condition is of intermediate grade between the Lützow-Holm Bay and Cape Hinode regions.

Next, the association of cordierite and biotite with sillimanite is worthy of note. HOLDAWAY and LEE (1977) experimentally clarified the stability relationship of the Mg-Fe cordierite and K feldspar and determined the univariant reaction curves of the following reaction:

Mg-Fe biotite+sillimanite+quartz=Mg-Fe cordierite+K feldspar+Vapor.

According to them, the curves shift towards the higher pressure side as the mg value

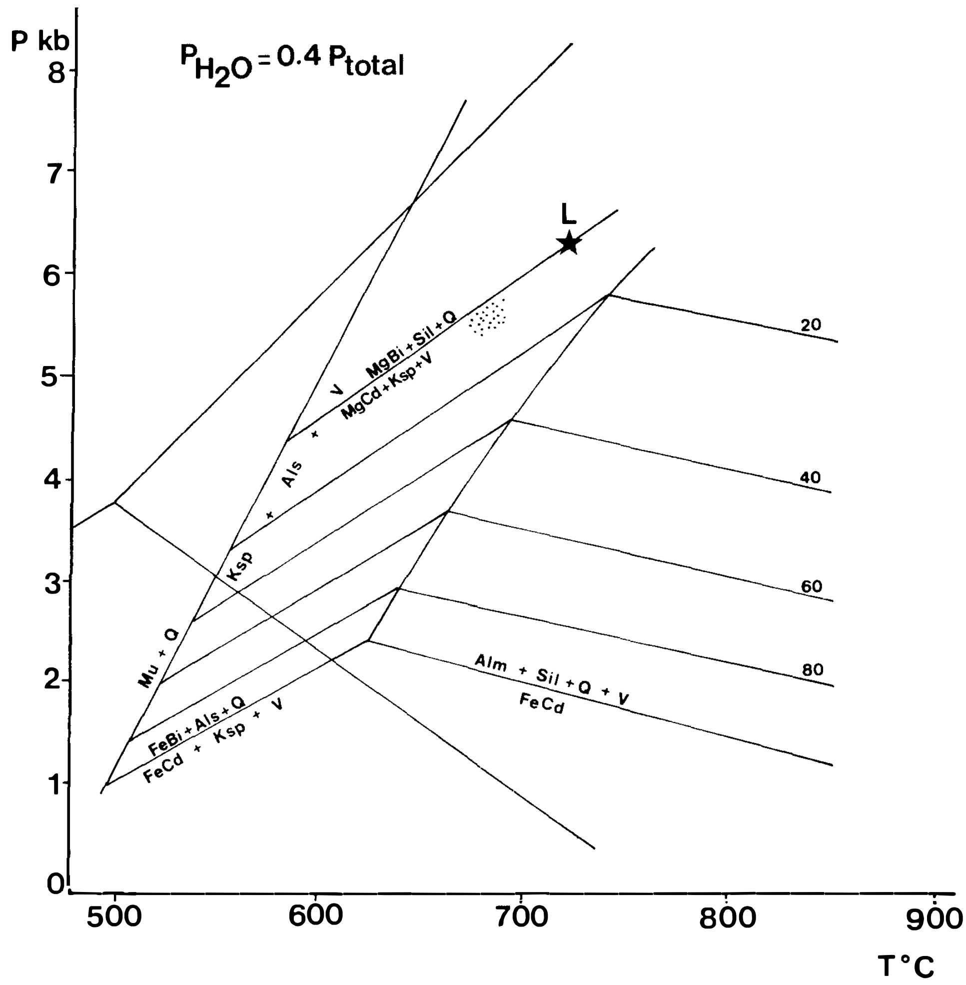

Fig. 7. Pressure and temperature of the Cape Omega area (stippled). Source of data: Al_2SiO_5 stability field (HOLDAWAY, 1971), cordierite stability (HOLDAWAY and LEE, 1977), muscovite breakdown curves (KERRICK, 1972). L shows the metamorphic conditions of Lützow-Holm Bay (SUZUKI, 1983). Numbers refer to the Fe content of cordierite.

in cordierite increases (Fig. 7). Moreover, decreasing P_{H_2O} moves the curves to lower temperature.

As mentioned before, the mg value of cordierite is 0.95. An accurate estimation of temperature concerning the rock has not been made, but if it could be assumed that the rock has experienced the similar temperature condition estimated before under which the surrounding gneisses in the Cape Omega area have been metamorphosed, the pressure condition suggested by the rock in question is as high as 5 kb based upon the stability of Mg-Fe cordierite (Fig. 7). The figure shows the case of $P_{H_2O}=0.4P_{total}$. The specimen concerned contains no graphite, thus the maximum P_{H_2O} may be higher than this case. Therefore, the actual pressure may be somewhat different from that estimated here, though the difference may not be very large.

The stippled area in Fig. 7 gives the inferred field of pressure and temperature during the peak of the main phase of metamorphism in the Cape Omega area. In the figure, are also shown the metamorphic conditions of the granulite facies metamorphism in the Lützow-Holm Bay region (SUZUKI, 1983). As can be seen from the figure, the metamorphic grade in the Cape Omega area is slightly lower than that of the Lützow-Holm Bay region.

The problem is the relationship of metamorphism in the regions of Lützow-Holm Bay and the Prince Olav Coast. In the former region, the association of orthopyroxene-clinopyroxene is usually found in basic metamorphites. Meanwhile, the occurrence of the association is only known in some areas in the western part of the latter region suggesting the westward increase of metamorphic grade (HIROI *et al.*, 1983). Judging from the feature described above and the estimated pressure and temperature conditions, it is not unreasonable to consider that the metamorphic grade may increase westwards from the Prince Olav Coast to Lützow-Holm Bay.

All things considered, the western part of the Prince Olav Coast is characterized by the sporadic appearance of particular metamorphic rocks with the mineral associations which apparently suggest the higher metamorphic conditions than those induced from the associations in the surrounding ordinary rocks. The sporadic occurrence of these associations may chiefly be depending on the bulk rock chemistry, and be characteristic of the transitional area between the amphibolite facies and the granulite one.

The author (1979) considered that the Cape Omega area was the polymetamorphic terrane. It is true some associations and the compositions of garnet core suggest the higher graded formation condition than that inferred, for example, from the association of matrtix biotite and garnet rim. However, the possibility that the feature may be interpreted from the viewpoint of retrogressive change of metamorphic conditions must be reexamined further by taking into consideration the above-mentioned significance of sporadic occurrence of the assemblages suggesting the apparently higher grade of metamorphism.

To establish the thermal structure and metamorphic history of the area from the Prince Olav Coast to Lützow-Holm Bay, it seems necessary to estimate the *P–T* paths followed by the constituting rocks in each region through detailed investigations of textural features and phase relations.

5. Conclusions

On the basis of the reexaminations of metamorphic rocks, the metamorphic conditions of the Cape Omega area, westernmost part of the Prince Olav Coast, have been discussed with the following conclusions.

1) Two kinds of metapelites are newly found. One is characterized by the association of orthopyroxene+garnet+biotite and another of cordierite (mg=0.95)+sillimanite+biotite (mg=0.92).

2) Based upon the Mg-Fe distribution compared between garnet and biotite in metapelites of the area, metamorphic temperature is estimated to be around 680°C.

3) The appearance of Mg-rich cordierite and biotite associated with sillimanite and K feldspar may suggest the equilibrium condition around 5 kb under the temperature condition mentioned above.

Acknowledgments

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