METAMORPHIC AND PLUTONIC ROCKS IN THE CAPE OMEGA AREA, EAST ANTARCTICA

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Abstract: The Cape Omega area is situated at about 80 km northeast of Syowa Station, East Ongul Island. The area is composed of various kinds of metamorphic and plutonic rocks. Total thickness of constituent rocks can be estimated to be 2000 m at least. Metamorphites are derived from basic, pelitic, psammitic and calcareous sedimentary equivalents. So-called metabasites are also the characteristic member among the metamorphites in the area. Plutonic rocks are mainly gneissose granite, pink granite and pegmatite. The area is characterized by the existence of macroscopic folds, their axes trending approximately E-W. The axes coincide with the trend of lineations and that of β-maximum for the gneissosity. Judging from the mineral association and mineralogical characters of metamorphites, general metamorphic grade is as high as the amphibolite facies. The granulite facies rocks, however, have been preserved among the ubiquitously distributed amphibolite facies ones. Time and spatial relationship between the two metamorphisms of different grade has been clarified in terms of polymetamorphism.

1. Introduction

Cape Omega with an area of 6.8 km^2 is located at 68°34′S –68°36′S latitude and 41°00′E–41°08′E longitude on the northern Sôya Coast, East Antarctica. It is about 80 km northeast of Syowa Station, East Ongul Island. The name of the area was given by the Japanese Promotive Headquarters of Antarctic Research Expedition in 1962. Brief geological survey was carried out before the present report. The preliminary investigation was conducted in 1969 by M. YOSHIDA, member of the 10th Japanese Antarctic Research Expedition (JARE–10).

During the period from 5th to 10th of January 1977, the geological survey in detail was carried out as a part of the summer operation by JARE–18. The participants were K. MORIWAKI (geographer), S. OTAKI (geodesist), F. FUKUI (geochemist) and the author.

Unfortunately, no reconnaissance toposheets except for the 1: 250000 series Prince Olav Coast, had been prepared before the investigation by JARE–18. The ground survey was carried out by the use of aerophotographs which had been taken by JARE–3 at the scale of approximately 1: 25500.

The outline of geology and petrography of metamorphic and plutonic rocks of the Cape Omega area has already been presented by the author (SUZUKI and MORIWAKI, 1979). In the present paper, more detailed discussions on the petrological characters of the constituent rocks and on the metamorphic condition in the area concerned are given.

2. Geology

2.1. General geology

The area in question is composed of various kinds of metamorphic and plutonic rocks (Fig. 1). The metamorphic rocks derived from basic, pelitic, psammitic and calcareous rocks are widely developed. So-called metabasite, in addition, is one of the characteristic members among the metamorphites. Generally speaking, the foliation in the metamorphic rocks has the trend of NW–SE dipping to the southwest.

Plutonic rocks in the area can be classified into the following three groups; that is, gneissose granite, pink granite and pegmatite.

2.2. Geological structure

Judging from the lithological continuity in the field, the existence of macroscopic

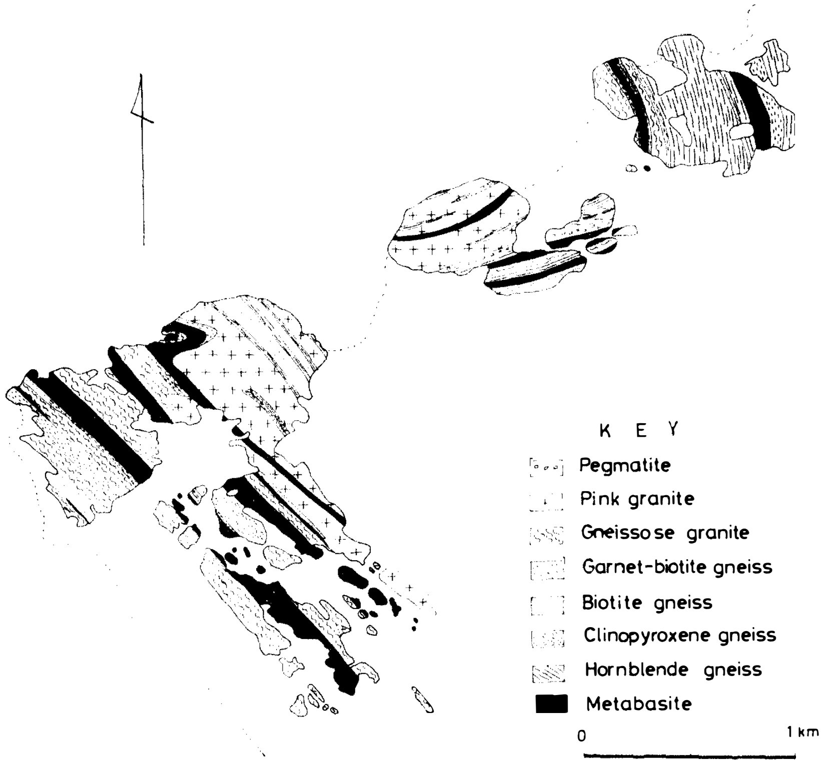

Fig. 1. Geological map of the Cape Omega area.

folds with the axes of E–W trend is expected.

In the mesoscopic scale, the structural elements are observed as follows using the different subscript numerals:

S_1; the distinct gneissosity parallel to the lithologic layering, which may be parallel to the original bedding surface.

S_2; the axial plane of minor fold, which has the wave length in the order of 10 to 50 cm.

L_1; the lineation represented by the intersection of S_1 and S_2.

L_m; the lineation represented by the preferred orientation of such prismatic minerals as hornblende and biotite. In most cases, it is parallel to L_1.

The π-diagram for S_1 is shown in Fig. 2. The azimuth and plunge of the β-maximum, read from the figure, are N75°W and 35°, respectively. The lineations L_1 and L_m have been plotted in Fig. 3 to show a distinct maximum, whose azimuth and plunge are N80°W and 40°, respectively. Therefore, the trend of lineations coincides parallelly with that of the β-maximum. The axes of the aforementioned macroscopic folds also coincide with this trend.

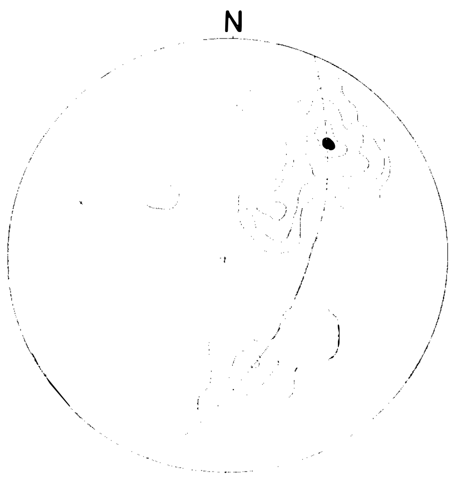

Fig. 2. π-diagram for S_1 in the Cape Omega area. 50 points. Contours: 20–16–8–4–2%.

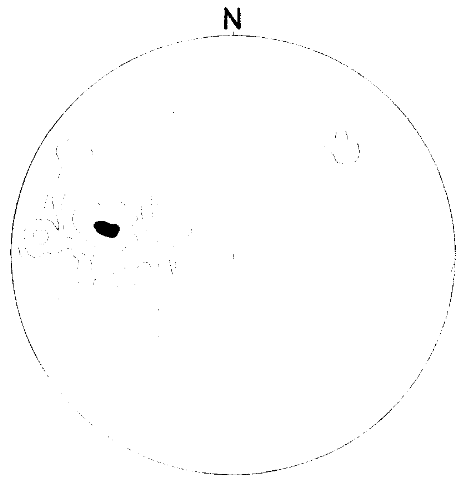

Fig. 3. Lineation diagram in the Cape Omega area. 52 points. Contours: 30–15–8–4–2%.

2.3. Stratigraphy

Judging from the geological structure, the lower horizons are exposed generally in the more northeastern part of the mapped area. Therefore, the apparent stratigraphy in the area can be summarised as follows;

The lower horizon Hornblende gneiss

↓

Gneissose granite

↓

Hornblende gneiss, biotite gneiss, clinopyroxene gneiss associated with pink granite

↓

Pink granite

↓

Metabasite associated with gneissose granite

↓

The upper horizon Garnet-biotite gneiss associated with gneissose granite

The summarizing schematic columnar sections are presented in Fig. 4. The total thickness of the constituents, read from the figure, can be estimated to be 2000 m at least.

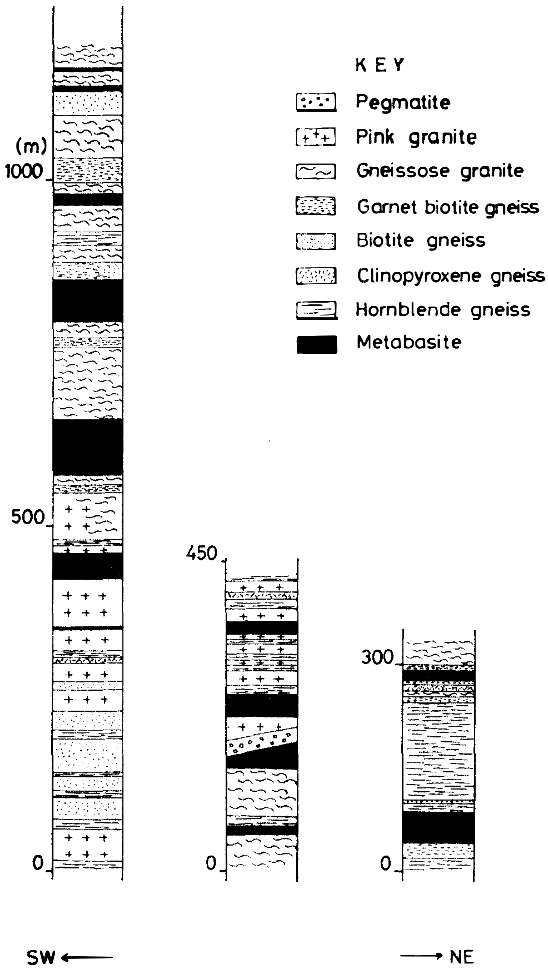

Fig. 4. Columnar sections in the Cape Omega area.

3. Petrography

In this section, the metamorphic and plutonic rocks are discussed with reference to their distribution, characters on the scale of handspecimen, mineral assemblages, chemical characteristics of the main constituent minerals and the conditions of their genesis.

3.1. Metamorphic rocks

3.1.1. Hornblende gneiss

The rock is widely developed in the northeastern part, that is stratigraphically lower, of the area. It is characterized by the alternation of melanocratic layers rich in hornblende and biotite, and quartzo-feldspathic leucocratic layers. The rock is generally medium-grained. Greenish hornblende, biotite, plagioclase, microcline and quartz are the main constituents. Clinopyroxene is sometimes found.

The mineral association suggests that the rock originated from some kind of basic rock.

3.1.2. Clinopyroxene gneiss

As well as the biotite gneiss to be mentioned later, this rock is the main constituent of the middle horizon in the stratigraphic succession of the area. It is medium-grained, and being easily weathered the rock has lower relief than the surrounding rocks. The main constituent minerals are clinopyroxene, greenish hornblende, plagioclase, calcite and sphene. Ca-rich garnet is occasionally associated. According to the mineralogy, the rock might have been derived from rocks corresponding to some kind of calcareous ones. It may be placed under the category of lime-silicate gneiss.

3.1.3. Biotite gneiss

It is distributed mainly in the western part of the area. It is medium-grained and rather massive in appearance, being often associated with pink granite. The gneiss is characterized by the association of biotite, muscovite, microcline, plagioclase and quartz.

The mineral assemblage and texture of the rock suggest the original rock to be psammitic one.

3.1.4. Garnet-biotite gneiss

It is generally developed in the upper horizon, that is in the western part, of the area. The rock is dark in color, being often associated with the sporadic occurrence of porphyroblastic garnet. Biotite, garnet, muscovite, microcline, plagioclase and quartz are the main constituents, their chemical compositions being given in Table 1. No aluminosilicate minerals have been found yet from the area.

The mineral association suggests that the rock could have been derived from the pelitic equivalent.

3.1.5. Metabasite

It is characteristic of the area concerned that so-called metabasites are often and universally developed. They occur as beds or irregularly shaped bodies in the surrounding gneisses and granites. Metabasites show such wide variations in mineral association as eclogitic rock (clinopyroxene-garnet-plagioclase-hornblende-quartz-

Table 1. Chemical compositions of the main constituent minerals in garnet-biotite gneiss (specimen No. 77010501) from the Cape Omega area.

	1	2	3	4	5	6	7
SiO_2	62.5	64.1	46.0	37.2	37.4	35.2	35.5
TiO_2	0.02	0.04	0.41	0.10	0.07	3.38	3.68
Al_2O_3	23.1	18.3	33.7	20.9	21.2	17.2	17.9
FeO*	0.21	0.20	2.07	35.6	33.5	19.1	20.2
MnO	0.06	0.06	0.04	1.80	1.57	0.16	0.12
MgO	0.01	0.01	0.76	3.41	4.78	9.88	9.19
CaO	4.99	0.13	0.03	1.50	1.86	0.05	0.05
Na_2O	8.51	1.19	0.30	0.03	0.01	0.08	0.08
K_2O	0.36	15.08	15.08	0.06	0.04	9.89	9.91
Total	99.8	99.1	94.3	100.6	100.4	94.9	96.6
				Numbers of ions			
O	32.000	32.000	22.000	24.000	24.000	22.000	22.000
Si	11.118	11.934	6.229	5.972	5.950	5.407	5.370
Al	4.840	4.028	5.381	3.951	3.975	3.119	3.200
Ti	0.002	0.006	0.042	0.012	0.008	0.391	0.419
Mg	0.002	0.003	0.154	0.815	1.134	2.264	2.074
Fe″	0.031	0.031	0.234	4.777	4.454	2.452	2.554
Mn	0.009	0.010	0.005	0.245	0.212	0.020	0.015
Ca	0.951	0.026	0.005	0.259	0.317	0.008	0.008
Na	2.933	0.431	0.007	0.008	0.002	0.024	0.024
K	0.081	3.584	1.900	0.012	0.008	1.939	1.915

1: Plagioclase, 2: Microcline, 3: Muscovite, 4: Garnet-1, 5: Garnet-2, 6: Biotite-1, 7: Biotite-2

* Total Fe as FeO

scapolite), clinopyroxene amphibolite (clinopyroxene-hornblende-biotite-microcline-plagioclase-quartz), biotite amphibolite (biotite-hornblende-plagioclase-quartz), clinopyroxenite (clinopyroxene-plagioclase-scapolite-garnet) and so on.

Generally speaking, they are characterized by the dark greenish color and massive appearance. Table 2 shows the chemical compositions of the main constituents of the rocks. High contents of Al_2O_3 in clinopyroxene and of K_2O in hornblende are remarkable.

3.2. *Plutonic rocks*

3.2.1. Gneissose granite

It is distributed in the middle to upper horizons, being concordant with the surrounding gneisses. The rock is rather coarse-grained and is characterized by distinct foliation. The trend of the foliation is concordant to that of the surrounding gneis-

Table 2. Chemical compositions of the main constituent minerals in metabasites from the Cape Omega area.

	1	2	3	4	5	6
SiO_2	44.3	45.1	42.4	35.7	37.0	38.1
TiO_2	0.03	0.03	1.09	1.56	3.76	0.52
Al_2O_3	26.7	33.9	10.4	15.7	13.2	14.0
FeO*	0.22	0.18	13.9	20.2	17.1	14.5
MnO	tr.	0.03	0.33	0.36	0.31	1.58
MgO	0.05	0.02	7.38	7.46	14.6	0.53
CaO	20.2	18.5	24.1	12.2	0.02	30.1
Na_2O	2.52	1.21	0.23	0.36	0.13	0.02
K_2O	0.12	0.03	0.02	4.38	9.45	0.04
Total	94.1	99.0	99.9	97.9	95.6	99.4
			Numbers of ions			
O		32.000	6.000	23.000	22.000	24.000
Si+Al	12.000					
Si	7.011	8.414	1.653	5.622	5.599	6.165
Al	4.989	7.471	0.480	2.915	2.348	2.672
Ti	0.003	0.005	0.032	0.184	0.427	0.063
Mg	0.013	0.006	0.429	1.751	3.286	0.128
Fe''	0.030	0.028	0.455	2.660	2.167	1.964
Mn	—	0.004	0.011	0.047	0.039	0.216
Ca	3.427	3.696	1.007	2.062	0.003	5.221
Na	0.773	0.437	0.017	0.109	0.037	0.006
K	0.023	0.008	0.001	0.879	1.823	0.009

1: Scapolite in eclogitic rock (specimen No. 77010907A)
2: Plagioclase in eclogitic rock (specimen No. 77010907A)
3: Clinopyroxene in eclogitic rock (specimen No. 77010721)
4: Hornblende in eclogitic rock (specimen No. 77010721)
5: Biotite in biotite amphibolite (specimen No. 77010615)
6: Garnet in eclogitic rock (specimen No. 77010804)
* Total Fe as FeO

ses. The main constituents are biotite, plagioclase, microcline and quartz. Biotite shows always parallel arrangement.

3.2.2. Pink granite

The rock is widely developed throughout the area. It is fine- to medium-grained and is rather massive. It is generally saccharoidal in appearance and characterized by the presence of pinkish microcline. It occurs often with an agmatitic appearance (Fig. 5). The main constituent minerals are biotite, plagioclase, microcline and quartz. The development of gneissosity in the granite is rarely observed.

Fig. 5. Agmatitic appearance of pink granite.

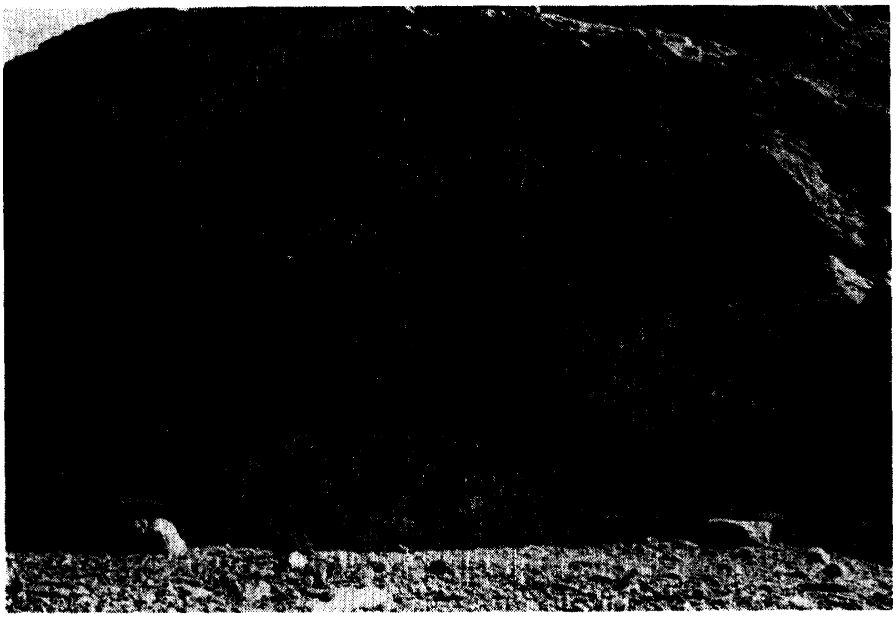

Fig. 6. Ptygmatic folds of pegmatite.

3.2.3. Pegmatite

Some pegmatite veins or dikes are found penetrating the surrounding rocks at oblique angles to their general trend.

The width of the veins or dikes ranges from a few cm to 60 m. The rock is characterized by biotite, pinkish microcline, plagioclase and quartz. It sometimes shows ptygmatic folds (Fig. 6).

4. Metamorphism

On the basis of the preceding descriptions of the geological and petrographical properties of the metamorphic rocks, as well as of the mineralogical characters complemented below, the metamorphic conditions and history in the area concerned will be discussed in the following.

4.1. Division of two metamorphic facies

Summarizing up the results of the microscopic observations, the metamorphic assemblages in metamorphites are shown in Table 3. From the table, the following should be notable.

Table 3. Mineral associations in the metamorphic rocks from the Cape Omega area.

Hornblende gneiss
Hornblende ± clinopyroxene + biotite + microcline + plagioclase + quartz
Clinopyroxene gneiss
Clinopyroxene + hornblende ± biotite ± garnet + calcite + sphene ± microcline + plagioclase + quartz
Biotite gneiss
Biotite + muscovite + microcline + plagioclase + quartz
Garnet-biotite gneiss
Garnet + biotite + muscovite + microcline + plagioclase + quartz
Metabasite
Clinopyroxene + hornblende + biotite ± microcline + plagioclase + quartz
Biotite + hornblende + plagioclase + quartz
Clinopyroxene + garnet + scapolite + microcline + plagioclase + quartz
Clinopyroxene + garnet + scapolite + plagioclase

In metamorphites derived from basic rocks, the association of orthopyroxene-clinopyroxene, which is the critical one in the granulite facies metamorphic rocks, has not generally been found yet from the area. Besides that, hornblende in the basic metamorphites is generally greenish in color.

In the pelitic and psammitic metamorphites, muscovite is stably existing, no aluminosilicate minerals having been found yet. In most gneisses, potassium feldspar is now represented by microcline with a clear appearance.

Based on these associations, the general metamorphic grade in the area is that of the amphibolite facies.

Besides the mineral assemblages summarized above, the chemical characteristics of each metamorphic mineral give the key to clarify the genetical conditions of the rocks. As shown by MIYASHIRO (1973), the chemical composition of muscovite in metapelites is changed in the process of increasing metamorphic grade. An example of the chemical composition of muscovite from garnet-biotite gneiss is shown in Table 1. The result is plotted on the MIYASHIRO's diagram (Fig. 7). The composition corresponds to those in metapelites of the amphibolite facies.

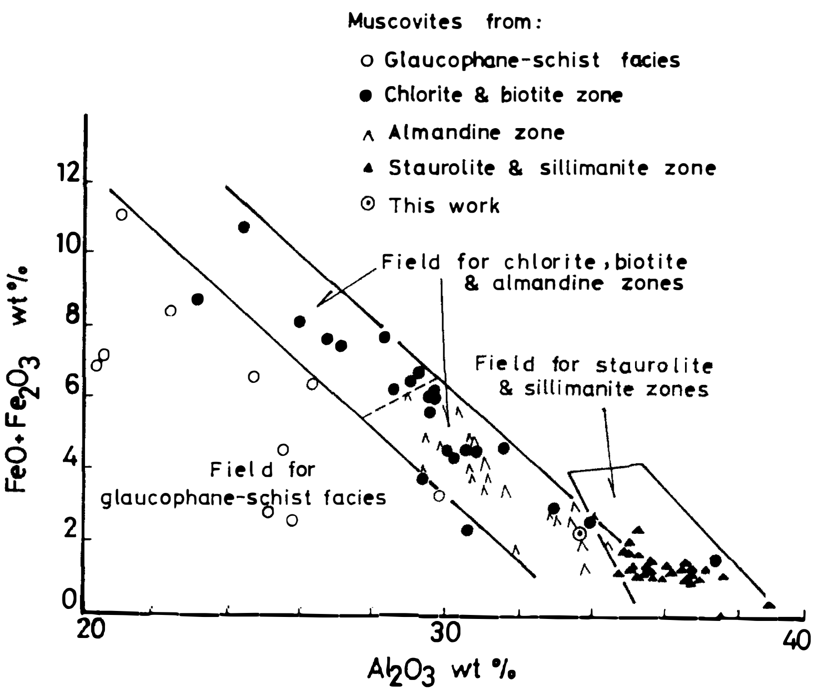

Fig. 7. Composition of muscovites from metapelites as related to the metamorphic grade (after MIYASHIRO, *1973).*

Meanwhile, in metapelites, partitioning of Fe and Mg among coexisting ferromagnesian minerals often gives the estimation of metamorphic temperature. Many authors, such as THOMPSON (1975), GOLDMAN and ALBEE (1977) and FERRY and SPEAR (1978) exhibit the figures or equations to estimate the temperature. Following the equation presented by FERRY and SPEAR (1978), the metamorphic temperatures are calculated using biotite-garnet pairs from the area (Table 4). The precision of determinations is within 50°C. The chemical compositions of the minerals used here are shown in Table 1. The condition estimated from the pair of garnet 1 and biotite 1 is consistent with that of the amphibolite facies. While, another pair from the same specimen gives a higher temperature, perhaps consistent with that of the granulite facies. The grain of garnet in the former pair shows the euhedral appearance, while that in the latter pair the irregular shape, being penetrated by such

Table 4. Metamorphic temperature estimated from garnet and biotite compositions.

	Garnet-1—biotite-1	Garnet-2—biotite-2
2 kb	581° C	814° C
3	585	819
4	589	823
5	593	828

minerals as biotite and muscovite along the fractures. It may well be said that the latter pair may be the preserved relict of the older metamorphic products. On the basis of the morphology of garnet grains and the calculated metamorphic temperatures, it is assumed that the granulite facies metamorphism could have occurred in the area, where amphibolite facies metamorphites are ubiquitously distributed.

In this connection, the occurrence and mineralogical characters of metabasites are notable. As described in the former section, metabasites are often exposed in the area as irregularly shaped enclaves in the surrounding gneisses and pink granite. Judging from the Ca distribution relation between scapolite and plagioclase, the metamorphic grade suggested by metabasites is that of granulite facies (SUZUKI, 1979).

With these facts in mind, the metamorphic grade estimated in the area can be divided into at least two, the one of the granulite facies and the other of the amphibolite facies. The essential problem is the time and space relationships between the two metamorphic grades.

4.2. Time and spatial relationship between the granulite facies rocks and the amphibolite facies ones

Summarizing the above descriptions, in the area concerned, the metamorphic assemblages suggesting the granulite facies occur as decomposing grains or as enclaves in the surrounding amphibolite facies gneisses and pink granite.

About the time and spatial relationship between the granulite facies metamorphics and the amphibolite facies ones, at least two cases can be discriminated. The one is the progressive change from the lower to the higher grade (such as in Adirondacks and Broken Hill). In these areas, marked isograds can be drawn. Another is the overlapping of two phases of metamorphism, namely polymetamorphism (such as in Ceylon and Hida, Japan). In these areas, granulite facies rocks are found only as preserved rocks in the amphibolite facies surroundings.

In the case of the discussed area, the possibility of progressive metamorphism from the amphibolite facies to the granulite facies would be denied, because no isograds can be drawn and there seems to exist no such a simple thermal structure that the amphibolite facies rocks progressively grade into the granulite facies ones. Therefore, it should be assumed that the earlier metamorphic assemblages of the granulite facies have been locally preserved among the ubiquitously distributed amphibolite facies rocks of the later metamorphic episode. Most of the granulite facies assemblages have undergone intense retrogradic metamorphism to result in the association containing hydrous phases at the expense of anhydrous ones.

5. Conclusions

On the basis of the geological and petrological studies on the metamorphic and plutonic rocks of the Cape Omega area, the author has come to the following conclusions.

1) The metamorphic rocks were derived from such sedimentary rocks as basic, pelitic, psammitic and calcareous ones.

2) Metamorphic mineral parageneses and mineralogical characteristics suggest the general metamorphic grade to be the amphibolite facies.

3) Based on the calculated temperature using the biotite-garnet geothermometer and on the Ca distribution relation between scapolite and plagioclase, it may well be said that the metamorphic assemblages suggesting the granulite facies condition can also exist.

4) Judging from the mode of occurrence and microscopic features, the granulite facies rocks seem to show the relict parageneses preserved among the ubiquitously distributed amphibolite facies metamorphites.

5) Time and space relationship between the granulite facies and amphibolite facies metamorphisms are clarified in terms of polymetamorphism.

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