

# Mg-Al SKARN OF THE SKALLEVIKHALSEN ON THE EAST COAST OF LÜTZOW-HOLM BAY, EAST ANTARCTICA

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**Abstract:** The genesis of skarns that accompany crystalline marbles in the Skallevikhalsen region on the east coast of Lützow-Holm Bay, East Antarctica, is discussed on the basis of the mode of occurrence and mineral paragenesis. The marbles in question are usually accompanied by distinctly zoned nodules that are thought to have been formed during the granulite facies metamorphism by the interaction of dolomitic limestones and exotic rock fragments incorporated in them. Examination in the CaO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> system leads to the conclusion that the mineral parageneses observed in these skarns have been largely controlled by the chemical potentials of Mg, Al and Si.

In addition, the significance of the occurrence of some semi-precious minerals, such as sapphire and spinel, is also briefly discussed in relation to similar minerals from Sri Lanka and southern India and the reconstruction of Gondwanaland.

## 1. Introduction

Metamorphosed limestones are generally scarce throughout East Antarctica, and there are few reports of skarn type deposits associated with crystalline marbles in high-grade metamorphic terrains.

The marbles and skarns which occur in the Skallevikhalsen region on the east coast of Lützow-Holm Bay, East Antarctica (Fig. 1), are composed of various kinds of skarn minerals, such as calcite, dolomite, forsterite, diopside, phlogopite, and spinel, with scapolite and corundum as accessories. These minerals are found not only in the marble itself but also in the nodule-like blocks which sporadically exist in the marble.

This paper is a preliminary report to discuss the genesis of the skarns based on the mode of occurrence and mineral paragenesis. The specimens examined in this study were collected during geological surveys in Antarctica by the Japanese Antarctic Research Expedition (JARE).

## 2. Geology of the Skallevikhalsen

Following the initial mapping by HANSEN (1946), TATSUMI and KIKUCHI (1959) out-

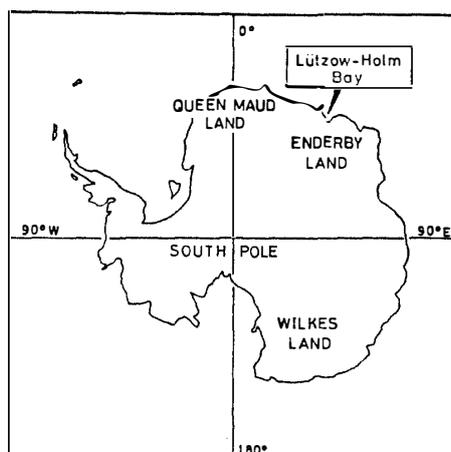


Fig. 1. Location map of Lützow-Holm Bay.

lined the geology of the Skallevikhalsen region, and later gave a brief petrographic description (TATSUMI *et al.*, 1964). After that many Japanese geologists visited the region; their results were compiled by YOSHIDA *et al.* (1976) and YOSHIDA (1977, 1978).

The region is composed of various granulite facies metamorphic rocks, including paragneisses (garnet gneiss, hornblende gneiss, garnet-biotite gneiss), metabasites, garnet gneissose granite, brown gneissose granodiorite, and marbles with skarn and allied rocks (*e.g.* BANNO *et al.*, 1964a, b; SUWA, 1968). Distribution of rocks is illustrated in Fig. 2. The general trend of the basement rocks is ENE-WSW and very distinct stratification is characteristic. From detailed geological and petrographical observa-

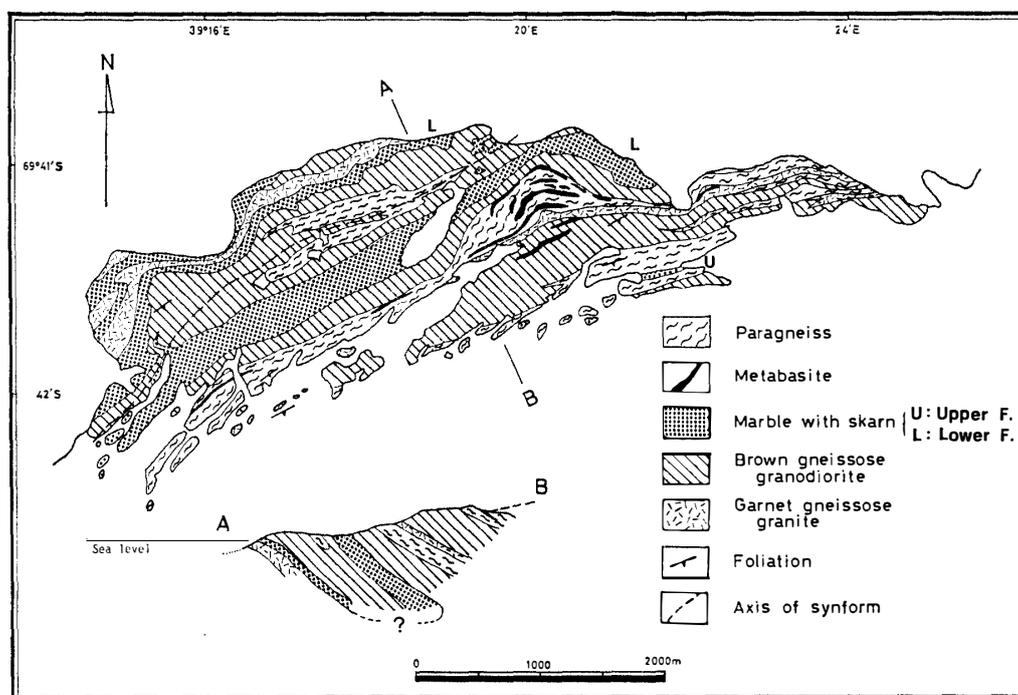


Fig. 2. Geological sketch map of the Skallevikhalsen with cross section along A-B. Simplified after YOSHIDA *et al.* (1976).

tions, YOSHIDA *et al.* (1976) and YOSHIDA (1977, 1978) postulate the existence of a large scale synform. Radioisotopic ages have been determined for two minerals from the adjacent Skallen regions; they are 530 Ma Rb-Sr age for biotite (NICOLAYSEN *et al.*, 1961) and 375–485 Ma U-Pb age for euxenite (SAITO *et al.*, 1961) in pink pegmatite.

Marbles interbedded with the surrounding metamorphic rocks are classified into two major formations, the Skallen Upper Formation and the Skallen Lower Formation (YOSHIDA *et al.*, 1976), and the latter is widely distributed in the region. They are variable in thickness and have a tendency to grade into gneisses as shown in Plate 1c. Small lenses of marble are also intercalated in the gneissose rocks. The layers or lenses of crystalline marbles are usually accompanied by skarns and allied rocks.

Table 1. Chemical compositions of co-existing calcite and dolomite by EPMA, and their equilibrium temperatures.

	SK 121-21			SK 121-24		
	Calcite		Dol	Calcite		Dol
SiO <sub>2</sub>	0.12	0.31	0.12	0.02	0.00	0.00
TiO <sub>2</sub>	0.00	0.00	0.00	0.04	0.03	0.02
Al <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.01	0.00	0.00
FeO	0.16	0.14	1.04	0.02	0.00	0.11
MnO	0.13	0.10	0.16	0.04	0.05	0.02
MgO	0.52	0.66	20.10	1.62	1.66	20.60
CaO	54.87	53.88	31.64	55.78	54.77	30.03
Na <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00
K <sub>2</sub> O	0.00	0.00	0.00	0.01	0.01	0.01
Total	55.80	55.09	53.06	57.54	56.51	50.79
T °C	357°C	385°C		448°C	499°C	

SK 121-21, 121-24: Forsterite marble near gneiss-marble contact.

Under the microscope, characteristic exsolution texture of dolomite in calcite host is often observed as shown in Plate 3. Co-existing calcite and dolomite were chemically analyzed by EPMA and their equilibrium temperatures were calculated based on RICE (1977) as shown in Table 1. The estimated equilibrium temperatures for carbonates are somewhat lower than the metamorphic grade of the surrounding gneissose rocks.

### 3. Mode of Occurrence of Skarn

Skarn types and mineral assemblages are summarized in Table 2. Field occurrence of the various types of skarns are as follows:

(A) In marble: Recrystallized impure marbles with graphite, which show an intensive metamorphic foliation defined by mineral arrangement of forsterite and phlogopite (Table 3), include various kinds of nodule-like skarn. These nodule-like skarns range from *ca.* 20 cm up to several meters in diameter, and display various constituent minerals (Table 2). Representative modes of occurrence of them are shown in Plates 2b, 2c, 4 and 5a, 5b. In general the nodules show a remarkable mineral zonation from core to rim and are thought to have originated from the interaction of gneissic rock fragments and dolomitic limestones. Spinel and scapolite are also significant

Table 2. Skarn types and their mineral assemblages.

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A)	In marble	
	i) Impure marble (recrystallized)	
	(a) Fo–Sp*	
	(b) Sp–Phl*	
	(c) Sal Px–Fo	* Graphite bearing
	(d) Ap–Di (–Phl)*	
	ii) Nodule-like	
	(a) Phl–Scap (–Sp–Cr)	
	(b) Phl–Sp	
	(c) Phl–Amp (–Sp)	
	(d) Phl–Tour–Anal (–Scap)	
	(e) Phl–An	
B)	Marble–gneiss contact	
	i) Massive green pyroxene skarn	
	(a) Sal Px(–Amp–Phl–Scap)	
	ii) Banded skarn	
	(a) Dol marble→Fo marble→Phl–Sp Skarn→Al Px–Sp–Scap skarn→Qz Gneiss	
	(b) Phl–Sp marble→Phl–Px Skarn→ Scap–Px Skarn→Ga–Bio Gneiss	
C)	Veinlets	
	i) In marble . . . Al Px–Phl–Amp–Pl	
	ii) In green pyroxene skarn . . . Phl (–Pl–Qz)	
	iii) In pale green pyroxene skarn . . . Amp–Cc	

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(Abbreviations) Fo; Forsterite, Sp; Spinel, Phl; Phlogopite, Sal Px; Salitic Pyroxene, Ap; Apatite, Di; Diopside, Scap; Scapolite, Cr; Corundum, Amp; Amphibole, Tour; Tourmaline, Anal; Analcime, An; Anorthite, Dol; Dolomite, Al Px; Fassaite Pyroxene, Qz; Quartz, Px; Clinopyroxene, Ga; Garnet, Bio; Biotite, Pl; Plagioclase, Cc; Calcite.

minerals in this type of skarn (A) as well as in type (B) skarn described below. Compositions of the minerals vary widely as shown in Tables 4 and 5, respectively. Chemical compositions of tourmaline and analcime in nodule-like skarn are also shown in Table 5.

(B) Near marble–gneiss contacts: Massive green pyroxene (salitic) skarn, with or without banded rocks composed of different mineral assemblages, are widespread. The association of zincian spinel and aluminous pyroxene (fassaite) is characteristic of this type (Table 2). The association tends to be distributed toward upper contact between marble and gneiss (Plate 2a). Chemical compositions of clinopyroxenes are shown in Table 6. They suggest that these skarns have been originated from sources relatively high in alumina such as lateritic materials.

(C) Veinlet skarns intrude the impure marble and/or the nodule-like skarn as shown in Plate 6. This mode of occurrence suggests that the veinlet skarns were formed probably after the main metamorphism which formed (A) and (B) type skarns. The presence of amphibole and phlogopite is a characteristic feature of this type. Chemical compositions of amphiboles (pargasitic) by EPMA are shown in Table 6 together with those from nodule-like skarn.

Table 3. Chemical compositions of olivine and phlogopite by EPMA.

	M-7	20	68	M-6	05D
SiO <sub>2</sub>	41.19	40.56	42.19	39.69	38.04
TiO <sub>2</sub>	0.01	0.00	0.71	1.22	1.21
Al <sub>2</sub> O <sub>3</sub>	0.00	0.01	14.47	17.23	16.42
FeO	5.59	12.16	0.20	2.83	9.13
MnO	0.04	—	0.01	0.00	0.00
MgO	53.70	42.97	26.15	24.07	20.31
CaO	0.02	0.01	0.07	0.00	0.01
Na <sub>2</sub> O	0.00	0.02	0.48	0.54	0.08
K <sub>2</sub> O	0.01	0.01	9.19	9.15	9.34
Total	100.55	100.04	93.48	94.74	94.54
Numbers of ions	O=4		(O, OH, F)=24		
Si	0.99	1.01	5.93	5.59	5.55
Ti	0.00	0.00	0.08	0.13	0.13
Al	0.00	0.00	2.40	2.86	2.82
Fe	0.11	0.25	0.02	0.33	1.11
Mn	0.00	—	0.00	0.00	0.00
Mg	1.92	1.74	5.48	5.05	4.41
Ca	0.00	0.00	0.01	0.00	0.00
Na	0.00	0.00	0.13	0.15	0.02
K	0.00	0.00	1.65	1.64	1.74

M-7, 20: Olivine; 68, M-6, 05D: Phlogopite.

M-7, 68, M-6: Nodule-like skarn, 20: Forsterite-clinopyroxene marble near gneiss-marble contact, 05D: Phlogopite skarn near gneiss-marble contact.

Table 4. Chemical compositions of spinels by EPMA.

	37	40	S-12	52	61	M-11
SiO <sub>2</sub>	0.12	0.14	0.16	0.00	0.25	0.25
Al <sub>2</sub> O <sub>3</sub>	70.34	70.41	69.29	71.74	64.75	65.21
FeO	3.39	5.86	9.82	2.05	2.43	6.01
MnO	0.04	0.03	0.10	0.00	0.05	0.07
MgO	26.62	22.46	21.34	25.90	21.09	13.09
CaO	0.01	0.00	0.28	0.00	0.00	0.01
ZnO	0.33	0.57	0.28	2.51	10.71	18.05
Total	100.84	99.49	100.99	102.20	99.29	102.69
Numbers of ions on the basis of 32 oxygen						
Si	0.02	0.03	0.03	0.00	0.05	0.05
Al	15.85	16.23	15.99	16.01	15.61	16.00
Fe	0.54	0.96	1.61	0.32	0.42	1.05
Mn	0.01	0.00	0.01	0.00	0.01	0.01
Mg	7.58	6.55	6.23	7.31	6.43	4.06
Ca	0.00	0.00	0.06	0.00	0.00	0.00
Zn	0.05	0.08	0.04	0.35	1.62	2.77

37, 40, S-12: Ferroan spinel; 52, 61, M-11: Zincian spinel.

37, 40, 52: Nodule-like skarn, 61, M-11: Aluminous skarn near gneiss-marble contact, S-12: Spinel-scapolite skarn from Skallen.

Table 5. Chemical compositions of scapolite, tourmaline and analcime by EPMA.

	35	57	70s	70t	70a
SiO <sub>2</sub>	44.65	46.16	48.52	36.37	53.71
TiO <sub>2</sub>	0.00	0.00	0.00	0.93	0.03
Al <sub>2</sub> O <sub>3</sub>	28.87	26.28	25.88	27.00	25.69
FeO	0.09	0.03	0.00	0.73	0.04
MnO	0.02	—	0.00	0.00	0.00
MgO	0.04	0.00	0.03	12.27	0.12
CaO	20.04	15.17	11.38	3.23	1.05
Na <sub>2</sub> O	2.02	4.80	6.94	1.21	9.12
K <sub>2</sub> O	0.24	0.39	0.70	0.01	0.87
Total	95.97	93.15	93.45	81.74	90.62
Numbers of ions		Si, Al=12		O, OH=31	O, OH=7
Si	6.81	7.18	7.37	6.15	1.97
Ti	0.00	0.00	0.00	0.12	0.00
Al	5.19	4.82	4.63	5.38	1.11
Fe	0.01	0.00	0.00	0.01	0.00
Mn	0.00	—	0.00	0.00	0.00
Mg	0.01	0.00	0.01	3.09	0.01
Ca	3.28	2.53	1.85	0.59	0.04
Na	0.60	1.44	2.04	0.40	0.65
K	0.05	0.08	0.14	0.00	0.04

35, 57, 70s: Scapolite; 70t: Tourmaline; 70a: Analcime.

35, 57: Scapolite-diopside(-apatite) marble, 70s, t, a: Nodule like skarn.

Table 6. Chemical compositions of pyroxene and amphibole by EPMA.

	68	M-13	39	20p	64	18	20a
SiO <sub>2</sub>	54.50	54.55	52.59	56.65	42.10	42.98	40.16
TiO <sub>2</sub>	0.11	0.10	0.00	0.14	0.90	1.27	3.03
Al <sub>2</sub> O <sub>3</sub>	0.70	2.68	0.84	4.46	19.01	15.53	15.78
FeO	0.14	3.17	11.53	2.19	0.85	8.85	10.10
MnO	0.02	0.10	0.19	—	0.00	0.11	—
MgO	17.56	15.80	11.48	22.28	17.91	14.09	12.01
CaO	25.37	24.68	23.60	13.58	12.89	12.67	11.97
Na <sub>2</sub> O	0.20	0.31	—	0.57	2.16	2.17	2.36
K <sub>2</sub> O	0.01	0.01	—	0.22	1.72	1.77	1.60
Total	98.62	101.42	100.23	100.09	97.54	99.48	97.37
Numbers of ions		O=6			O, OH=24		
Si	1.99	1.96	1.99	1.98	5.92	6.15	5.57
Ti	0.00	0.00	0.00	0.00	0.10	0.14	1.04
Al	0.03	0.11	0.04	0.18	3.15	2.62	2.58
Fe	0.00	0.10	0.36	0.06	0.10	1.06	1.17
Mn	0.00	0.00	0.01	—	0.00	0.01	—
Mg	0.96	0.85	0.65	1.16	3.75	3.01	2.48
Ca	0.99	0.95	0.95	0.51	1.94	1.94	1.78
Na	0.01	0.02	—	0.04	0.59	0.60	0.64
K	0.00	0.00	—	0.01	0.31	0.32	0.28

68, M-13, 39, 20p: Pyroxene; 64, 18, 20a: Amphibole.

68, 39, 64: Nodule-like skarn, M-13, 20, 18: Skarns near gneiss-marble contact.

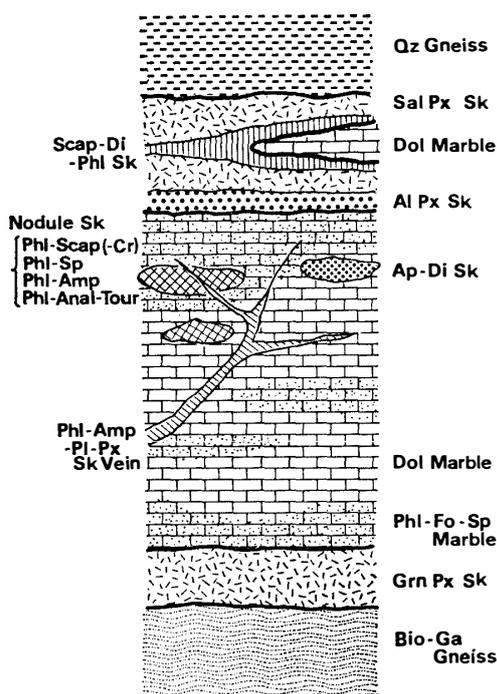


Fig. 3. Schematic section observed in the Skallevikhalsen skarn. Abbreviations are the same as those in Table 2. Dotted areas in the calcite marble roughly represent dolomitic facies.

Figure 3 is a schematic representation of the observations described above, and also summarizes the following characteristic features of the skarns; (1) nodule-like skarns are relatively more abundant in the upper horizon, (2) marbles are heterogeneous in composition, and range from dolomitic to calcitic, (3) the skarns are not symmetrically distributed in a mineralized zone interleaved between biotite gneiss (below) and quartz gneiss (above); this is probably due to compositional variations in the gneissic host rocks as well as in the marbles, (4) aluminous types appear to be concentrated in the upper horizon and toward the marble-gneiss contacts, judging from the occurrence of spinel and/or corundum in the assemblages there.

#### 4. Mineral Paragenesis

In order to understand the observed mineral parageneses and the zonal arrangements in the Skallevikhalsen marbles and skarns, representative rock samples were chemically analyzed (Table 7).

Marbles 1–3 contain some  $\text{SiO}_2$  and  $\text{MgO}$  in addition to the major  $\text{CaO}$  component and these constituents must have been involved in reactions to form magnesian silicate minerals, such as forsterite and/or phlogopite (Table 3), during the major granulite facies metamorphism. It is concluded that the marble precursors must have been more or less dolomitic in composition.

Nos. 4–8 are skarns accompanied by marbles as described above. They contain varying amounts of  $\text{Al}_2\text{O}_3$ , high  $\text{Al}_2\text{O}_3$  content being deduced from the presence of sporadic spinel. MATSUMOTO (1982) reported the occurrence of spinel whose  $\text{ZnO}$  content reached the maximum value of 3.24 wt% (gahnite component  $\text{ZnAl}_2\text{O}_4 = 5.9$  mol%) from the Skallevikhalsen, and further described a relationship between the

color of spinel and its Zn content. He concluded that Zn is more enriched in purplish spinels than in pinkish or greenish ones. In this paper the authors determined the high content of Zn in blue spinel (maximum 18 wt% ZnO) as shown in Table 4. The source

Table 7. Chemical compositions of marbles and skarns.

	1	2	3	4	5	6	7	8
SiO <sub>2</sub>	5.70	14.48	22.76	35.18	25.55	13.55	5.07	5.84
TiO <sub>2</sub>	0.00	0.09	0.05	0.38	0.49	0.43	0.18	0.09
Al <sub>2</sub> O <sub>3</sub>	0.78	0.81	0.72	10.99	27.61	40.83	48.70	45.58
Fe <sub>2</sub> O <sub>3</sub>	0.57	0.49	0.80	0.72	0.76	1.89	1.08	0.75
FeO	0.43	0.21	0.46	0.35	0.07	0.18	0.18	0.14
MnO	0.02	0.06	0.05	0.05	0.00	0.06	0.02	0.03
MgO	11.59	22.50	24.55	24.16	23.53	18.40	21.94	15.03
CaO	42.34	30.46	21.98	9.13	0.79	1.48	0.68	3.72
Na <sub>2</sub> O	0.36	0.71	1.52	0.46	0.77	0.65	0.58	0.40
K <sub>2</sub> O	0.10	0.49	0.54	7.76	5.34	2.75	0.15	0.10
Ig. loss	37.78	29.64	26.24	9.38	1.46	1.26	2.00	1.38
H <sub>2</sub> O (-)	0.10	0.37	0.76	0.25	0.14	0.23	0.20	0.13
P <sub>2</sub> O <sub>5</sub>	0.04	0.28	0.13	0.25	0.22	0.40	0.54	0.22
Zn (ppm)	24	60	136	174	120	735	230	300
Insolb.	—	—	—	—	12.60	17.75	19.00	25.85
Total	99.81	100.59	100.56	99.06	(100.00)	(100.00)	(100.00)	(100.00)

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1-3; Marble. . . . 1) Cc-Dol-Phl(80S26), 2) Fo-Phl-Cc-Dol(75082601), 3) Fo-Cc(75082604)

4-5; Phlog. sk. . . . 4) Phl(75082603), 5) Sp-Phl(79082306-1)

6-8; Spinel sk. . . . 6) Sp-Phl(79082305), 7) Sp(-Px-Cc) (80S17), 8) Sp(79082306-2)

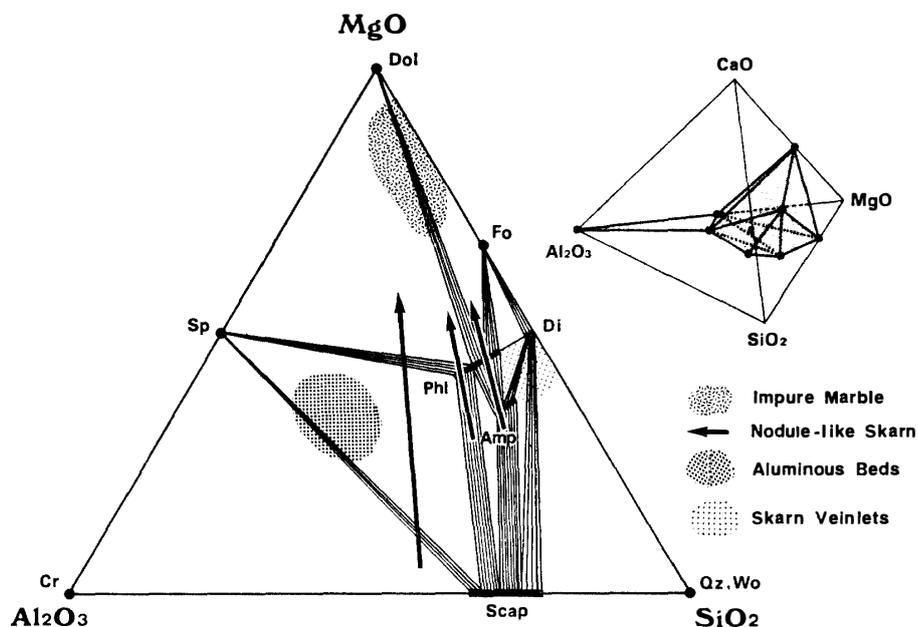


Fig. 4. MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> diagram showing the mineral parageneses in the Skallevikhalsen skarns. Arrows represent the type of zonal sequence from the core to the margin observed in each nodule-like skarn. Cordierite does not appear in the assemblage because of the silica-poor bulk composition.

of the Zn, however, is unknown at present. Detailed mineralogy and genesis of zincian spinel and corundum will be described in another paper (MATSUEDA *et al.*, in preparation).

The chemical analyses presented in Table 7 give some indication of the mineralogy to be expected. To test out this expectation, the mineral parageneses in the Skallevikhalsen skarns are considered (to a first approximation) in the system CaO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> (Fig. 4, see also Table 1). In this diagram the skarn minerals in question are projected on the MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> plane from the CaO apex. Each triangle bounded by tie lines indicates an observed skarn mineral assemblage. Three arrows in the diagram represent the types of zonal arrangement of minerals in individual nodules from the core to the margin. These relations account for some of the mineral parageneses in the Skallevikhalsen skarns.

### 5. Discussion

In the Skallevikhalsen region, various kinds of skarn nodules are observed in widely distributed crystalline marbles. Each nodule usually is concentrically zoned, each zone consisting of a specific mineral assemblage. Some of the nodules are relieved of skarnization and still retain biotite gneiss fragment in the core as shown in Plate 5b. On the other hand, fragmental biotite gneisses are scattered in hanging-wall gneissose granite adjacent to marble (Plate 5c). From these facts it is inferred that these nodules represent recrystallized portions of exotic rock fragments incorporated in siliceous dolomitic limestones prior to the main granulite facies metamorphism. Aluminous



Fig. 5. Reconstruction of Gondwanaland around the Skallevikhalsen and surrounding areas (after GREW and MANTON, 1979).

skarn developed near the gneiss-marble contact is assumed to have been derived from lateritic materials during metamorphism.

The observed systematic variation of mineral parageneses in the marbles and skarns suggests that they are largely controlled by chemical potentials (abundance) of Mg, Al, and Si in the original rocks. This is interpreted as evidence of an original dolomitic to calcitic chemical inhomogeneity in the siliceous limestones from which the skarns were formed, or in the case of the nodules, by incorporation of exotic rock fragments in the limestones.

Among the skarns in this region, vein type skarns are considered as later stage products. They intrude into other skarns and include amphibolite-phlogopite assemblages which indicate the low amphibolite facies condition.

The presence of jewel minerals such as blue corundum (sapphire) and spinels (ceylonite) in skarns from the Skallevikhalsen has some significance with respect to the continental drift. It has been suggested (*e.g.* GREW and MANTON, 1979) that the Skallevikhalsen and the surrounding areas existed adjacent to Sri Lanka and southern India in a reconstructed Gondwanaland (Fig. 5). As is well known, these countries have been famous since ancient times for the occurrence of many kinds of jewels. In connection with this, beryl (emerald—aquamarine) is also found in pegmatite from Kasumi Rock of the Prince Olav Coast (K. YANAI, personal communication). The mode of occurrence of these minerals is obscure because they are found mainly in recent alluvial concentrates. Since the blue-colored spinel and sapphire from the Skallevikhalsen are quite similar to those from Sri Lanka or India (*e.g.* SCHLOBMACHER and MEYER, 1931; ANDERSON and PAYNE, 1937; see also Table 4), it is suggested that the Sri Lanka and Indian minerals may have the same genesis as those cases of Lützow-Holm Bay.

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a. *Gneisses (cliff) and marbles (flat ground) near the Lake Dairi, viewed to the eastern part of Skallevikhalsen.*



b. *Marble cliff of northwestern coast of the Skallevikhalsen.*



c. *Intercalated marble layer ceasing into gneissose granite near northwestern coast. Clinopyroxene skarn is developed in both side of marble layer even in thin one.*



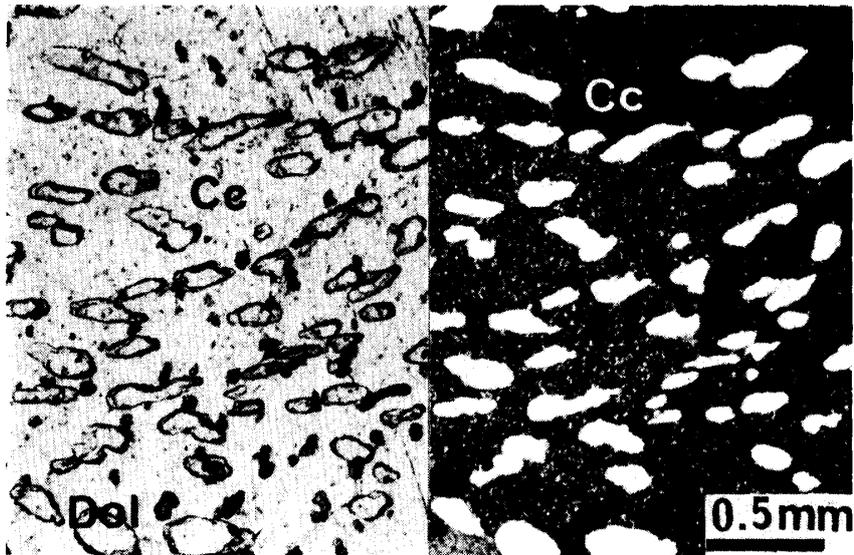
*a. Near marble-gneiss contact of the Skallen Lower Calcareous Formation. Aluminous skarns are well developed near the contact part.*



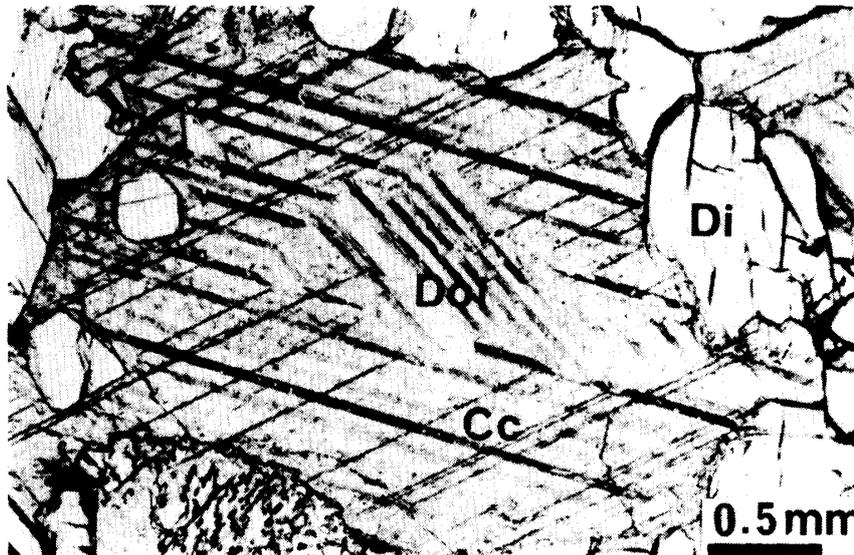
*b. Impure marble in contact with garnet gneissose granite. Marble is extremely abundant in skarn minerals such as forsterite and spinel as dissemination. Long dimension of photograph is about 1.5 meters.*



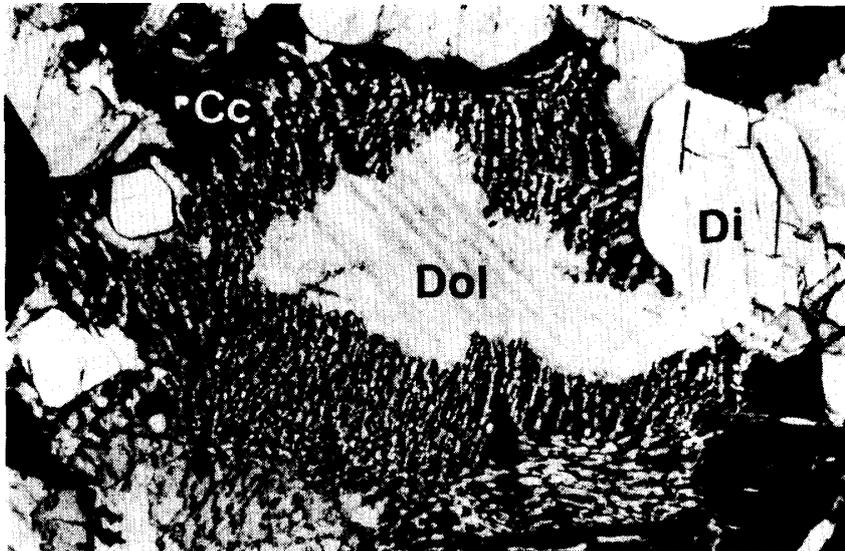
*c. Foliated impure marble composed mainly of forsterite and phlogopite.*



a. Photomicrograph of marble showing exsolution texture by dolomite (Dol) and calcite (Cc) left; Plane polarized light, right; Crossed polarized light.



b. Photomicrograph of diopside (Di) marble showing characteristic exsolution texture by dolomite (Dol) and calcite (Cc). Plane polarized light.

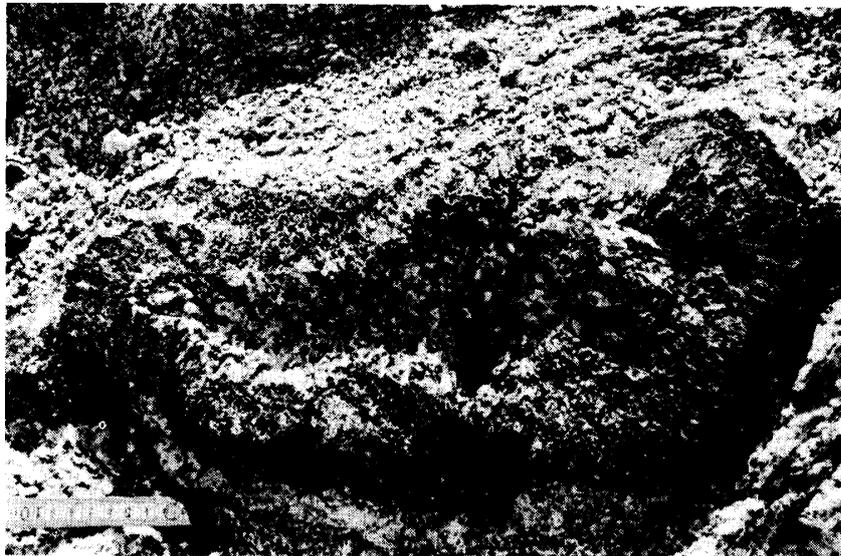


c. ditto. Crossed polarized light.

Plate 4



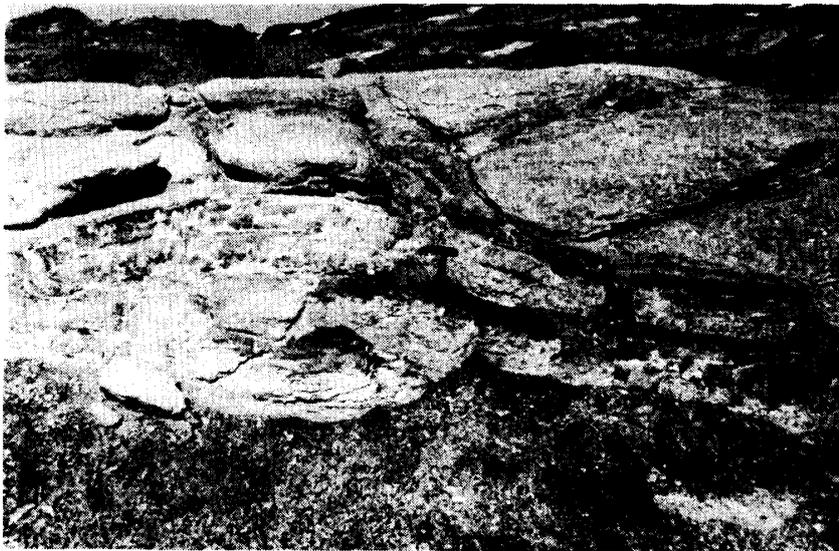
a. *The mode of occurrence of nodule-like skarn in dolomitic host marble. Mineral zonation in each nodule is recognizable. Long dimension of photograph is about 4 meters.*



b. *Nodule-like skarn. Clear mineral zonation from core (spinel-scapolite) to margin (phlogopite) is recognized.*



c. *Nodule-like skarn composed of pargasitic amphibole (core) and phlogopite (margin).*



a. Skarnized gneissose beds in marble. Phlogopite skarns surround the beds in the same manner as nodule-like skarn.



b. Nodule-like skarn with phlogopite margin. Biotite gneiss is still remaining as core.



c. Fragmental biotite gneiss in gneissose granite near the contact with marble.

Plate 6



*a. Phlogopite-calcite skarn veinlet in marble.*



*b. Amphibole-phlogopite-fassaitic pyroxene skarn veinlet in marble.*



*c. Skarn veinlet cross-cutting nodule-like skarns.*