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Geology of Skeids Area, Humboldt Mountains-,Wohlthat Range, Central Dronning Maud Land, East Antarctica

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Abstract

Geologically, the Skeids area is a Proterozoic metamorphic terrain exposing a dominant orthogneissic unit, which has been intruded by two granitic phases, observed as an earlier foliated granite and a later undeformed granite. The orthogneissic unit has been metamorphosed to upper amphibolite facies and has undergone at least three major deformational phases. The foliated granite represents a syntectonic intrusive phase with a foliation plane developed parallel to regional gneissosity S2. The occurrence of later undeformed granite conforms to the widely reported alkali granite intrusives from several parts of eastern Antarctica.

Introduction

The Wohlthat mountains exposed between south latitudes 70°40' and72°15' and east longitudes 11° and 15° in Central Dronning Maud Land, East Antarctica are being evaluated by Indian geologists since 1985. These outcrops were first studied and described by Ravich and Solovev (1966). During the Tenth Indian Expedition to Antarctica, the southern part of Humboldt mountain region, known as Skeids (Fig.1), was taken up for geological investigations. An attempt has been made in this paper to describe the relevant aspects of geology pertaining to Skeids area.

Regional Geology

Regional studies in Antarctica have indicated that basement complex has evolved through multiple events of metamorphism, migmatisation and deformation (Grew, 1978, 1983; Parker *et* al.,1983; Allen,1991; Shiraishi *et* al.,1991). Similar inferences have also been drawn for Schirmacher range (Sengupta,1988). The mineral parageneses in parts of Wohlthat region have indicated granulite facies metamorphism (Ravich and Kamenev,1975; Joshi and Bejarniya,1990; Pant,1991; Kaul *et al,* 1991) which has a later imprint of retrogression to amphibolite facies (Ravindra *et* al., 1989). The region is considered as representing a Proterozoic metamorphic complex having suffered peak metamorphism during 1100 Ma granulitic event (Grew, 1983).

The Wohlthat mountain region is divided into three sectors viz. the Gruber massif in the east, Petermann ranges I,II & III in the central portion and Humboldt mountains in the west.

The Gruber area is dominated by a large anorthosite massif with granulitic gneisses as basement rock (Mukerji *et al.,* 1988). The Petermann ranges have alkali granites and anorthosite dykes intruding the high grade para- and orthogneisses. In southern Petermann area the paragneisses are represented by pelitic, psammitic and calcareous sequences akin to khondalitic rocks and felsic charnockite-enderbite gneisses of igneous parentage. The younger intrusives are mainly monzo-gabbro/noritic rocks and pyroxene monzonite. The Humboldt mountains, in the west, expose dominantly high grade pelitic to psammitic rocks having affinity with khondalites. These are associated with two pyroxene granulites and amphibolites occurring as mafic bands along with bands of calc-silicates/marble. The other dominant unit is massive garnetiferous, clinopyroxene bearing gneiss and granulite having probable igneous parentage (Pant *et al,* 1991). In northern parts of Humboldt, the intrusive units are represented by the anorthosite/monzogabbro/norite/mangerite.

Geomorphology

The Skeids area is in the immediate vicinity of Polar plateau and is situated at an average height of 2000 metres above the m.s.l. The highest peak in the area is of 2895 m. The area is situated between Humboldt glacier in the east and a digitation of Somoveken glacier, known as Vestre Hogskeldet glacier, in the west. There are only two small patches of moraines in the area. The landform in the area exhibits subdued topography (Fig.2) in comparison with the northern parts of Wohlthat mountains. This feature is mainly due to greater thickness of polar ice sheet and the resultant glacial environment.

Geology

The Skeids area exposes metamorphic and plutonic rocks with minor dykes. The dominant gneissic unit is apparently banded due to varying amount of mafic mineral concentration. The gneissic rock is medium grained, light grey in colour and shows development of K-feldspar augens. The rock is essentially quartzo-feldspathic in composition with biotite and hornblend as mafic minerals, which mark the foliation planes. Dark coloured amphibolite bands are also present in the gneissic unit. Aluminosilicate rocks are conspicuously absent in the Skeids area. The field characteristics, mineralogy and geochemical parameters described later, suggest that the gneisses have an igneous parentage and hence described as Skeids orthogneiss.

GEOLOGICAL MAP OF SKEIDS AREA SOUTH OF HUMBOLDT, CENTRAL DRONNING MAUD LAND, EAST ANTARCTICA.

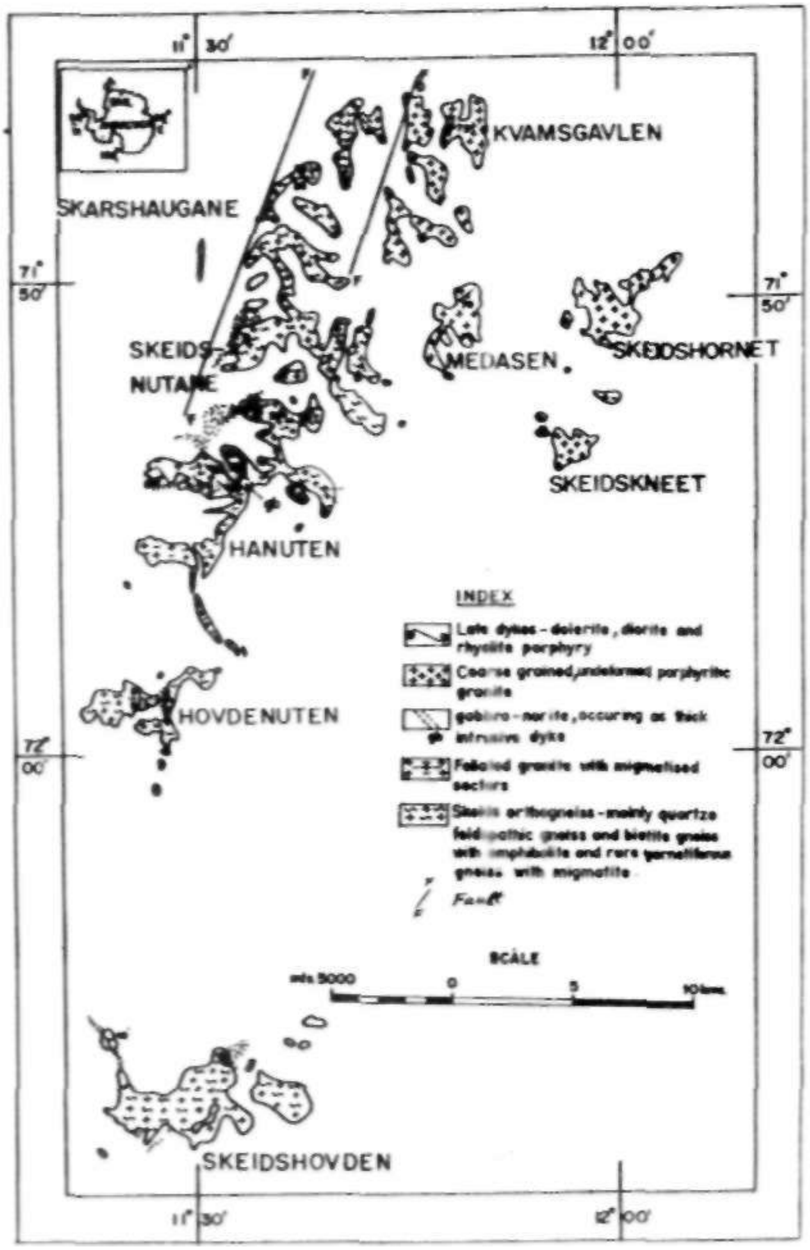


Fig.1. Geological map of Skeids area.

The Skeids Orthogneiss has been intruded by two phases of possibly genetically related granites emplaced under different tectonic setting and with a considerable time gap. On the basis of the field relationship, tectonic setting and texture the granites are described as an older Syn-tectonic foliated Granite and a younger Post-tectonic, undeformed Porphyritic Granite.

The foliated granite occurring in the Hanuten area is coarse grained, pinkish brown or flesh coloured rock (Fig.3). The foliation plane, nearly conforming to the regional gneissosity (S_2), is apparent due to aligned or swerving biotite grains around K-feldspar megacrysts which range in size from 1.5 to 3.5 cm. This unit, has within it, fine grained migmatised sectors which merge gradually into coarse-grained foliated granite.

The undeformed porphyritic granite occurring in Skeidshonet, Skeidsnet, Medasen and Hovdenuten is medium- to coarse-grained in texture, grey to pink in colour and contains enclaves of undigested orthogneissic rock.

Besides the major units described above, a thick gabbronorite dyke is exposed in the central part of the area, which also marks the contact between orthogneiss and foliated granite. This gabbronorite intrusive body, about 50 metres wide, trends in a ENE-WSW direction. Within the gabbronorite, a linear body of granite of about 2 metres width, is seen exposed. This granite contains cumulates of hornblende ranging in size from 5 to 10 cms. Minor basic dykes, dolerites and diorites; and a suspected rhyolite porphyry is also observed in the area.

A lithostratigraphic succession of the exposed rocks in Skeids area, based on field characteristics is given below. The lithostratigraphy is provisional and the units described pertain only to Skeids part of larger Humboldt region.

Lithounits	Description		
Late dykes	Dolerites, Diorites and : Rhyolite porphyry (?) dykes.		Post-tectonic
Undeformed Granite	Pink to grey nonfoliated, porphyritic granite & monzodiorite.		
Gabbro-Norite	Coarse grained, melanocratic rock, intruding the Orthogneisses.		
Foliated Granite and migmatites	Pink to flesh coloured, coarse, porphyritic, foliated granites with megacrysts of K-feldspars and associated migmatites.	:	Syntectonic (D2)
Skeids Orthogneisses	Quartzofeldspathic gneiss with mafic rich biotite gneiss and migmatites, retrograded garnetiferous gneiss and amphibolite.	:	(D1)

Fig.2. A panoramic view of Skeids area. Note the subdued landforms.

Fig.3. The foliated granite as it occurs in the outcrop. Note the K-feldspar megacrysts and the foliation plane in the rock.

Petrography

Skeids Orthogneiss

The thin sections of orthogneisses, studied under tne microscope, depict mineraalogical monotony and vary only in the modal amount of major minerals present. These rocks are essentially quartzofeldspathic gneisses, biotite gneisses and migmatites with intervening bands of amphibolites. The quartzofeldspathic gneiss has a negligible amount of hornblende content. The mafic rich parts of these gneisses are the biotite gneisses, wherein the plagioclase content is slightly more than K-feldspar. Garnet is rare and is observed only in two sections where its porphyroblasts are altered to biotite.

The texture depicted is inequigranular, porphyroblastic, gneissic to granulose. The mafics are aligned parallel to prominent foliation plane along with granular feldspar and quartz. The porphyroblasts are mainly of K-feldspar. In a few sections development of mylonitic texture is also noticed. The mineralogical paragenesis observed in these rocks is given below:-

Typical Assemblages in Skeids Orthogneiss

Quartzofeldspathic gneisses : i) Qz + Kf(myrmekite) + PI + Bi + Hb with Zr, Ap, Op, Sph and Spl as accessory.
ii) Qz + Kf(myrmekite) + PI + Gt + Bi with Zr as accessory. Secondary Bi after Gt also present.
Biotite gneiss : i) PI+ Kf+Qz + Bi+Hb with Sph, Ap and Zr as accessory.
Amphibolite : i) PI + Bi + Hb + Kf + Qz + Tr with Zr as accessory.

Mineral abbreviations: Ap, Apatite; Bi, Biotite; Gt, Garnet; Hb, Hornblende; Kf, K-feldspar; Op, Opaque; Pl, Plagioclase; Qz, Quartz; Sph, Sphene; Spl, Spinel; Tr, Tremolite; Zr, Zircon.

The gneissic unit does not have any characteristic mineral isograde due to monotony in mineral composition, suggesting igneous parentage. The presence of apparent banding may be due to metamorphic differentiation related to partial melting and anatexis. However, coarse-grained gneissic to granulose texture and granitic mineralogical composition with total absence of muscovite indicates that these rocks have suffered metamorphism, atleast, upto upper amphibolite facies.

Foliated granite

This rock is very coarse-grained and porphyritic in appearance. In thin sections, the observed texture is inequigranular, allotriomorphic to hypidiomorphic and porphyritic. The K feldspar occurs mainly as subhedral megacrysts set in a granular aggregation of K-feldspar, anhedral quartz and subhedral plagioclase. The mafics are concentrated along open stretched clusters (Figs 4 & 4A) imparting a foliation plane to the rock. This rock also contains recrystallized quartz veins which are parallel to the foliation plane. Myrmekitic intergrowth and perthitic alkali feldspar are commonly observed under the microscope. The migmatised sectors are fine-grained and depict granoblastic, allotriomorphic texture with slightly concentrated layers of mafics. The mineralogical composition of fine-grained migmatised rock and porphyritic foliated granite is almost similar. In comparison to the orthogneissic unit described earlier, this rock, besides having biotite, also has hornblende as its main mafic constituent. Orthopyroxene and clinopyroxene are often present. (Figs 5 & 5A). Zircon, spinel, sphene, alanite (Fig.6) and monazite are occurring as accessories along with deuteric apatite. Presence of modal hypersthene (2%) with perthite and quartz points towards felsic charnockitic composition of foliated granite in parts.

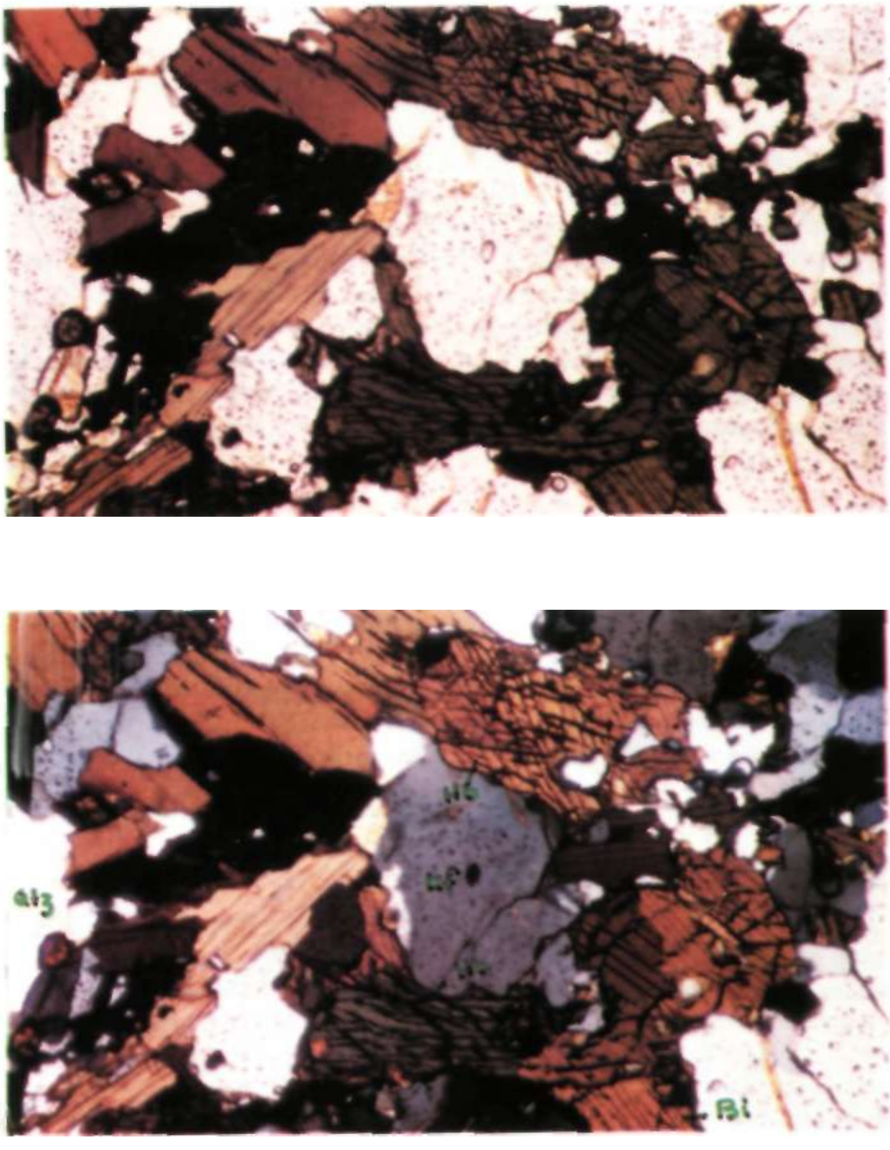
Gabbronorite

This rock unit occurs as a thick dyke in the central partof the mapped area. Megascopically, the rock is coarse-grained, granular in texture and grey in colour. Microscopic examination shows a hypidiomorphic granular texture. The plagioclase occurs as subhedral laths. Hypersthene occurs as elongated subhedral grains and is clustered together with clinopyroxene and biotite (Figs 7 & 7A). Intergrowth between ortho- and clinopyroxene is noted. The pyroxenes have been uralitised to a great extent.

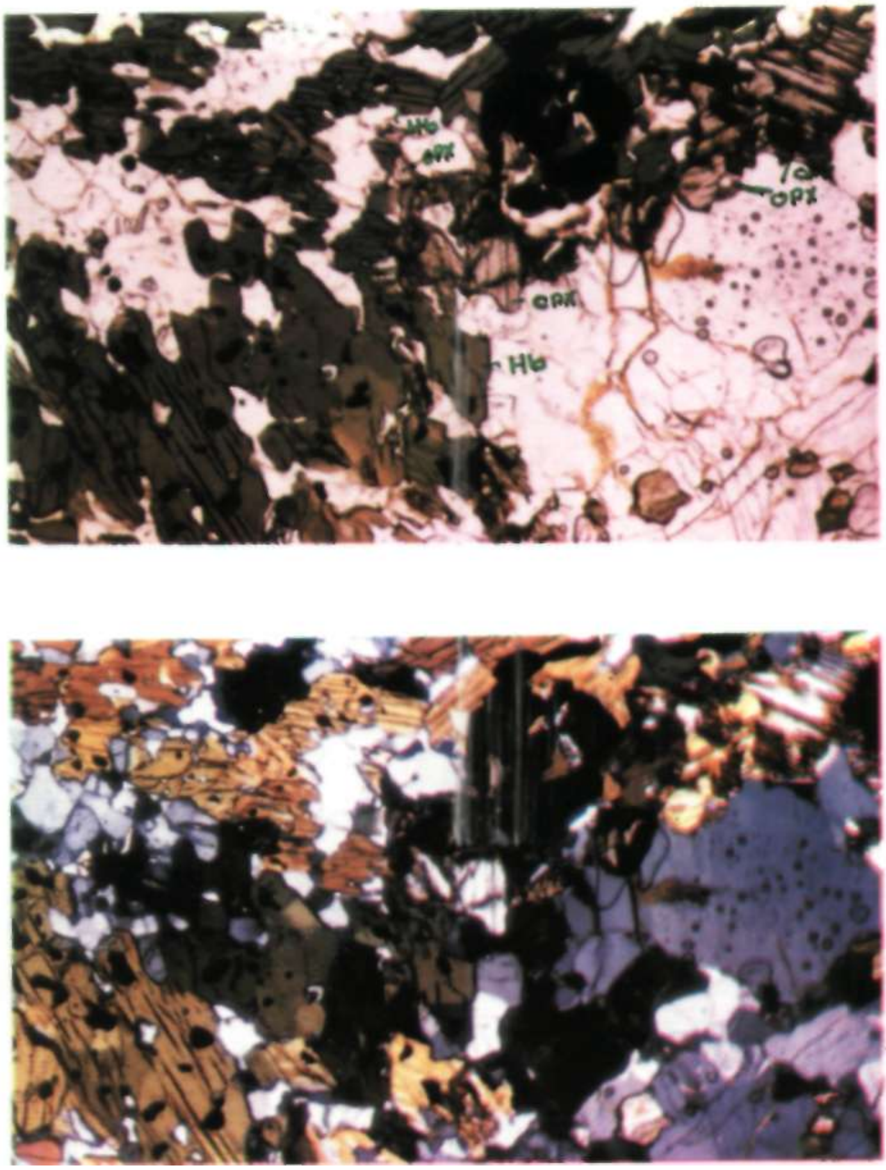
Undeformed Porphyritic Granite

This is an inequigranular, medium- to coarse-grained porphyritic rock, which depicts dominantly hypideomorphic texture. One thin section also shows allotriomorphic equigranular texture. The porphyritic granite is distinctly alkaline in nature as it contains megacrysts of K-feldspar set in a granular groundmass of quartz, subhedral plagioclase and K-feldspar. Hornblende and biotite are the main mafic constituents clustered together. The accessories present are zircon, sphene, opaques and apatite. Presence of relict altered orthopyroxene is seen in one of the thin sections.

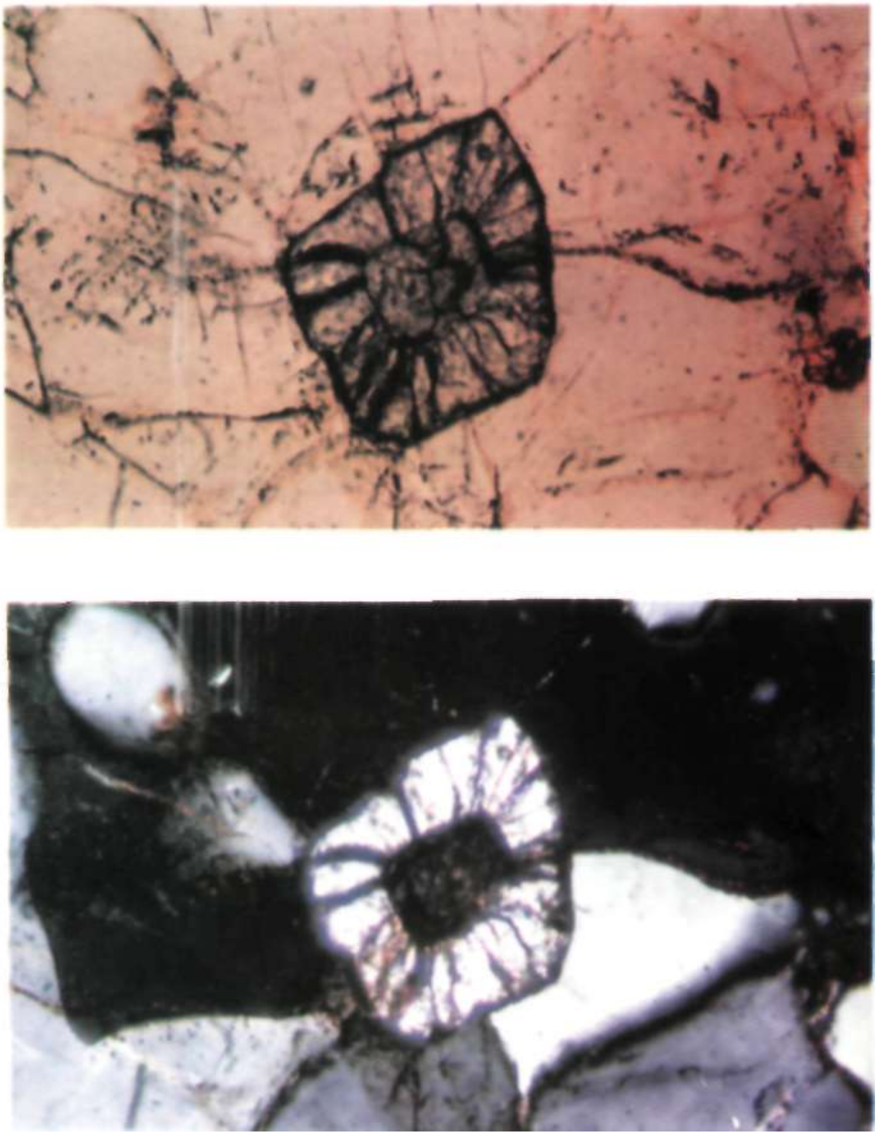
The granites of Hordenuten area, in contrast to the other porphyritic granites, contain abundant plagioclase (An30 to An40) with K-feldspar and quartz. The



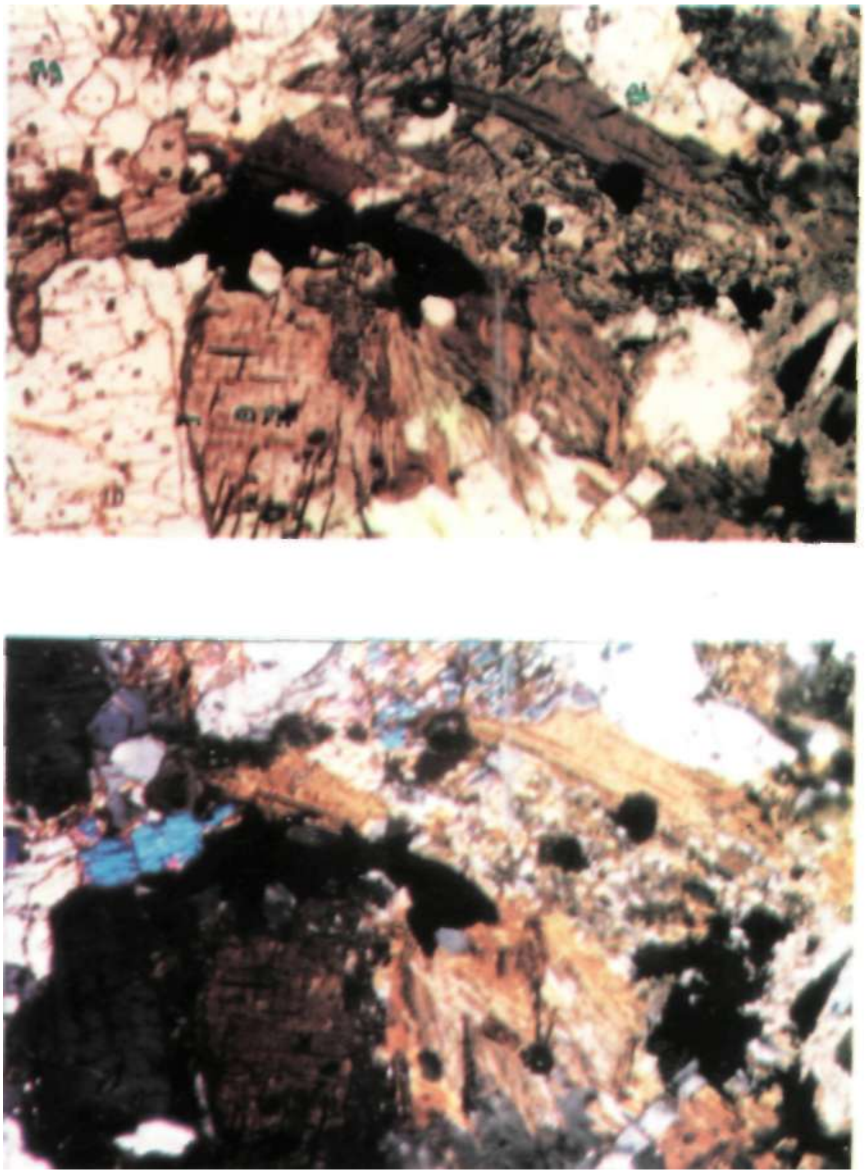
Figs.4 & 4A. Photomicrographs in plane polarised light and under cross nicols (4X) depicting nearly allotriomorphic granular texture. The mafics mainly hornblende and biotite are clustered toghter with K-feldspar and quartz.



Figs. 5 & 5A. Photomicrographs in plane polarised light and under cross nicols (4x) showing presence of orthopyroxene and clinopyroxene along with other mafics and opaques clustered together in foliated granite.



Figs.6 & 6A. Photomicrographs in plane polarised light and under cross nicols (20X) showing euhedral allnite in foliated granite.



Figs. 7 & 7A. Photomicrographs in plane polarised light and under cross nicols (4X). Orthopyroxene, clinopyroxene, biotite and opaques clustered together in dominantly plagioclase bearing gabbronorite.

mafics present are hornblende and biotite, which are clustered together. Zircon, apatite and sphene are the accessories.

Late Intrusives

Late basic dykes of doleritic and fine-grained dioritic composition are seen intruding the orthogneisses and foliated granites. One of the basic dyke contains megacrysts of sodic clinopyroxene, amphibole, biotite, perovskite, melilite and opaques set in a felsic groundmass composed of laths of plagioclase.

A significant occurrence of rhyolite porphyry as a vein has also been noticed in the area. The groundmass is fine-grained granular, containing mainly quartz, K-feldspar, plagioclase, sandine and biotite. The phenocrysts present are of subhedral plagioclase and rounded sanidine.

Geochemistry

The rocks from Skeids area were analysed for major oxides using conventional wet analytical method. Selective samples were also analysed for REE using AES technique on ICP and for trace elements on AAS, Representative whole rock analyses and their normative mineralogy are given in tables as referred below.

Skeids Orthogneiss

The quartzofeldspathic gneisses have Si02 content varying from 67.34% to 77.11% (Table 1) while the biotite gneiss (Table 2) has Si02 content varying from 60% to 62%. The gneisses show predominance of potash (1.74%-4.63%). The alumina content and major element chemistry of these rocks compare well with the average granitoids (Le Maitre,1976).

Geochemical parameters have been used to determine granite source criteria (Chappell and White, 1974; Hine *et al,* 1977). Recently a number of workers have also concentrated upon classification of granitoids based on their probable tectonic environment (Pearce *et al.,* 1984; Pitcher, 1983). White and Chappell (1977) proposed two granitoid types, S-type (Sedimentary) and I-type (Igneous) based on chemical criteria. This distinction between granites is based on the assumption that chemical differences are basically result of different source. The gneisses of Skeids area have been evaluated accordingly, on the basis of chemical criteria to determine its source and also to highlight the orthogneissic character of the rock. The Skeids gneisses show predominantly I-type characters (Figs 8 & 9) and suggest that they have been formed by metamorphism of granitic rock: The granitic composition of these rocks is also indicated by the normative plot of Q-Ab-Or (Fig. 10) and normative Q-A-P plot (Fig. 11). Paragenesis of these rocks based on total geochemistry is however, being attempted separately.

Table 1 : Geochemical analysis of Quatzofeldspathic gneisses (Skeids Orthogneiss)

	5A/X	6A/X	8A/X	8B/X	8D/X	9A/X	9C/X
SiO_2	70.27	73.58	76.59	68.90	76.29	68.09	68.86
TiO_2	0.20	0.20	0.40	0.64	0.12	0.08	0.25
Al_2O_3	14.71	11.07	8.73	15.07	12.15	16.36	14.99
Fe_2O_3	1.76	3.03	3.19	1.45	0.48	0.54	2.73
FeO	1.58	1.87	3.74	1.86	1.44	0.86	2.29
MnO	0.04	0.04	0.06	0.03	0.02	0.01	0.03
MgO	0.50	0.76	1.46	1.26	0.50	2.56	0.94
CaO	2.10	1.40	2.45	3.06	1.40	3.60	4.38
Na_2O	3.22	2.91	1.74	2.49	2.47	4.63	2.78
K_2O	4.84	4.50	1.47	3.93	4.25	3.09	2.18
P_2O_5	0.08	0.08	0.01	0.20	0.01	0.06	0.12
LOI	0.57	0.31	0.31	0.52	0.72	0.23	0.30
Total	99.87	99.75	100.15	99.41	99.85	100.11	99.85
CIPW Norms							
q	26.79	34.27	50.70	30.57	40.99	17.98	32.07
or	28.60	26.59	8.69	23.23	25.12	18.26	12.88
ab	27.25	24.62	14.72	21.07	20.90	39.18	23.52
an	9.90	3.85	11.67	13.87	6.88	15.28	20.95
C	0.55	0.00	0.00	1.64	0.97	0.00	0.38
di	0.00	2.18	0.36	0.00	0.00	1.73	0.00
hy	3.90	4.76	9.84	5.18	3.33	6.58	6.35
wo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mt	1.70	2.47	2.75	0.65	0.70	0.78	2.55
il	0.38	0.38	0.76	1.22	0.23	0.15	0.47
ap	0.19	0.19	0.02	0.46	0.02	0.14	0.28
Mg Number	21.20	22.50	27.90	49.12	32.00	77.00	25.50
In ppm.							
La	57.53	-	-	-	25.48	7.28	-
Ce	115.92	-	-	-	82.56	15.48	-
Pr	15.12	-	-	-	12.95	3.33	-
Nd	57.30	-	-	-	36.00	8.00	-
Sm	10.70	-	-	-	9.88	1.71	-
Eu	1.30	-	-	-	0.21	0.51	-
Gd	6.12	-	-	4.29	0.91	-	-
Tb	0.97	-	-	_	1.05	0.28	-
Dy	3.01	-	-	-	5.20	1.03	-
Ho	2,80	-	-	-	2.56	0.98	-
Er	1.76	2.95 0.11	-	-	1.10	3.63	2.16
Tm	0.33	-	-	-	0.53	0.06	-
Yb	1.11	_	-	-	3.80	0.30	-
Lu	0.32	-	-	-	0.55	6.05	-
Y	12.67	-	-	-	10.12	3.46	- .

* CIPW norms recalculated to 100% free of volatiles.

Table 2: Geochemical Analysis of Biotite Gneisses and Amphibolites (Skeids Orthogneiss)

	Biotite Gneiss			Amphibolite	
	7A/X	12A/X	8E2/X	8E1/X	19D/X
SiO_2	60.17	60.79	62.50	53.37	52.09
TiO_2	1.10	1.00	0.80	0.40	1.25
Al2O3	13.57	18.82	17.27	24.03	20.62
Fe_2O_3	6.47	0.80	2.40	0.10	2.98
FeO	4.52	6.18	5.32	6.89	7.76
MnO	0.52	0.11	0.09	0.10	0.17
MgO	3.70	1.64	1.76	2.83	4.28
CaO	4.20	2.94	4.21	7.44	5.96
Na_2O	2.21	3.63	1.47	2.15	1.87
K_2O	2.78	2.94	3.90	1.59	2.17
P2O5	0.20	0.08	0.08	0.90	0.08
LOI	0.75	1.11	0.63	0.53	1.42
Total	100.19	100.04	100.43	100.33	100.65
CIPW Norms					
q	15.51	15.61	24.47	10.33	9.07
or	19.80	17.37	23.05	11.76	12.82
ab	30.63	30.72	12.44	18.19	15.82
an	11.53	14.26	20.36	31.03	29.05
C	2.16	4.44	3.17	6.97	4.55
hy	14.43	13.32	11.26	19.14	21.44
mt	1.61	1.16	3.33	0.14	3.02
il	2.58	1.90	1.52	0.76	2.37
ap	0.12	0.19	0.19	2.09	0.19
Mg Number	49.90	29.40	29.37	42.20	43.70
In ppm.					
La		29.70	46.53		
Ce		71.63	115.92		
Pr		10.01	18.72		
Nd		40.00	79.20		
Sm		8.67	16.10		
Eu		1.43	2.86		
Gd		6.60	7.92		
Tb		0.97	1.75		
Dy		4.11	6.39		
Ho		2.21	3.64		
Br		1.75	3.74		
Tm		0.30	0.45		
Yb		1.30	2.44		
Lu		0.25	0.80		
Y		18.90	28.57		
Cu		8.00	7.00		
Zn		130.00	129.00		
Ni		0.00	8.00		
Co		10.00	7.00		
Rb		90.00	75.00		
Sr		130.00	360.00		
Cr		30.00	30.00		

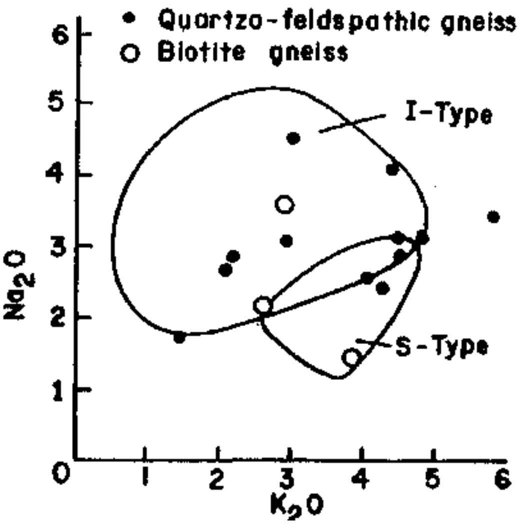


Fig.8. Plot of Na_2O vs K_2O showing the 1-type characteristics of Skeids orthogneisses. Fields of I- and S-type granitoids are from White and Chappell (1983).

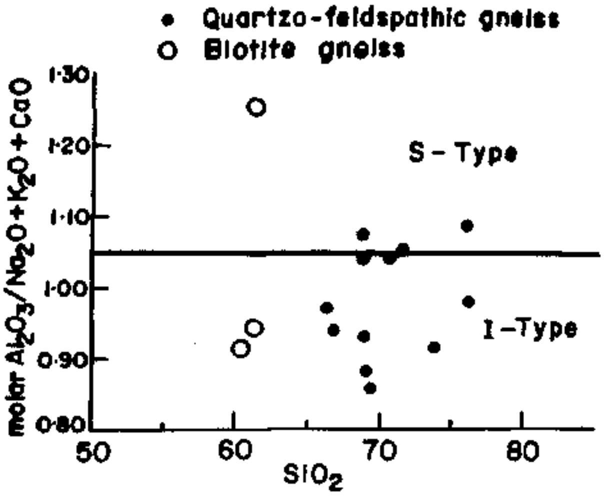


Fig.9. Plot of alkali-lime saturation index (A.S.I.) = molar Al_2O_3/CaO+Na_2O+K_2O) vs SiO_2 for Skeids Orthogneiss (quartzofeldspathic).

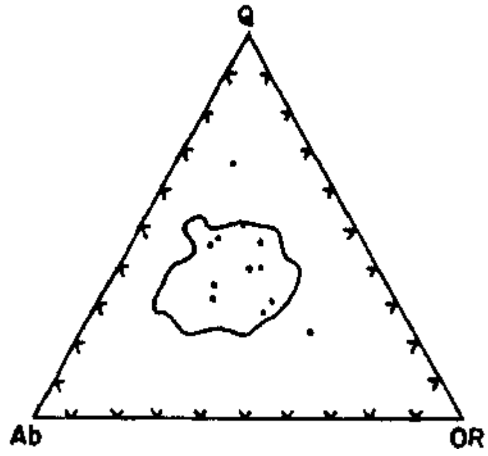


Fig.10. Plot of normative Q-Or-Ab for Skeids Orthogneiss (quartzofeldspathic). The field represents 86% of granitic rocks from a total of 1100 samples (Winkler, 1967). The plots can also be compared with Q-Ab-Or-H_2O system at 2 kb PH_2O of Winkler (1967).

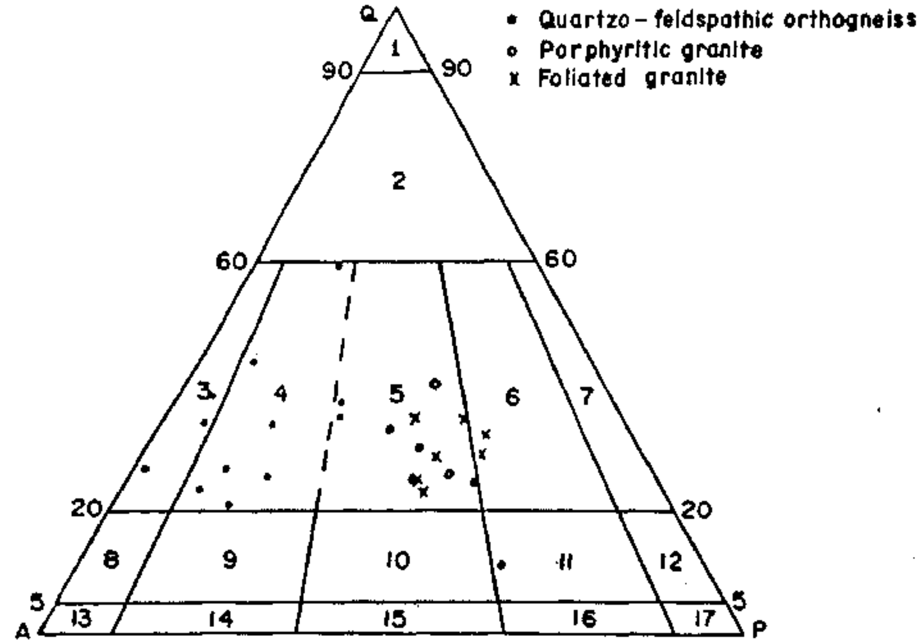


Fig.11. CIPW normative mineral contents of Skeids Orthogneisses, Foliated Granite and Undeformed porphyritic granite plotted on the Q-A-P diagram of Streckeisen (from Le Maitre, 1989). Fields are - 1. quartzolite (Silexite); 2. quartz-rich granitoids; 3. alkali feldspar granite; 4. syenogranite; 5. monzo-granite; 6. granodiorite; 7. tonalite; 8. quartz-alkali feldspar granite; 9. quartz-syenite; 10. quartz- monzonite; 11. quartz-monzodiorite; 12. quartz-diorite; 13. alkali feldspar syenite; 14. syenite; 15. monzonite; 16. monzodiorite; 17. diorite.

The REE element concentration in the orthogneisses show inconsistency and has a wide range of 40 to 274 ppm (REE). Similarly the La_n/Yb_n also varies from 5 to 34. The unusual concentration of REE in orthogneiss only reflects the mineralogical changes that took place due to metamorphism and associated metamorphic differentiation. However, the spidergram (Fig. 12) shows overall similarity in the distribution pattern of LREE and HREE, which is comparable with the foliated granite (Fig. 18).

Granitoids

The granitic rocks i.e. the foliated granite and the undeformed porphyritic granite, depict compositional similarities (Tables 3 & 4). The majority of these granites plot in monzogranite and granite fields of normative Q-A-P diagram (Fig. 11) of Streckeisen (1976). However, using the compositional plot of Cao-Na20-K_2O (Fig. 13) and K_2O-Na_2O (Fig. 14),majority of the granitoids plot in quartz-monzonite granite and granite- adamallite fields, respectively. In the AFM diagram (Fig. 15) the undeformed porphyritic granite plot well within the calc-alkaline field, while the foliated granite shows considerable spread. The tabulated analysis of granitoid also shows other relevant geochemical parameters like alkali saturation index (A.S.I.), total K_2O+Na_2O content, Rb/Sr, K/Rb and Mg-number for comparison.

As discussed earlier, chemical criteria of White and Chappell (1977) has also been applied to foliated granite to determine its source. A strong I-type character is depicted by this granite (Figs. 16 & 17).

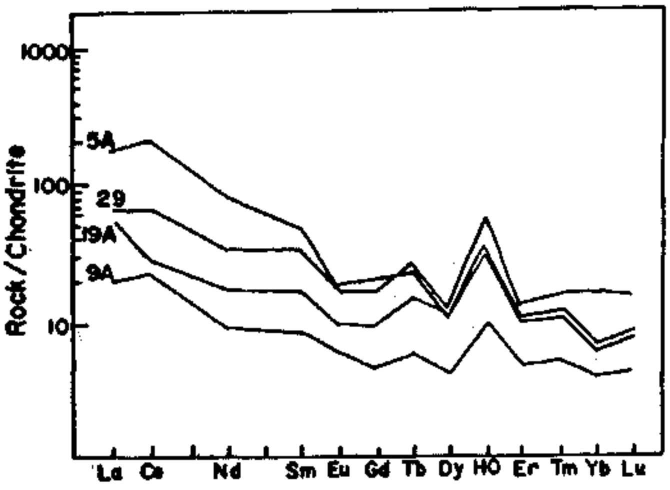


Fig. 12. Chondrite normalised REE plot of Skeids Orthogneiss after Taylor & Mclennan (1985).

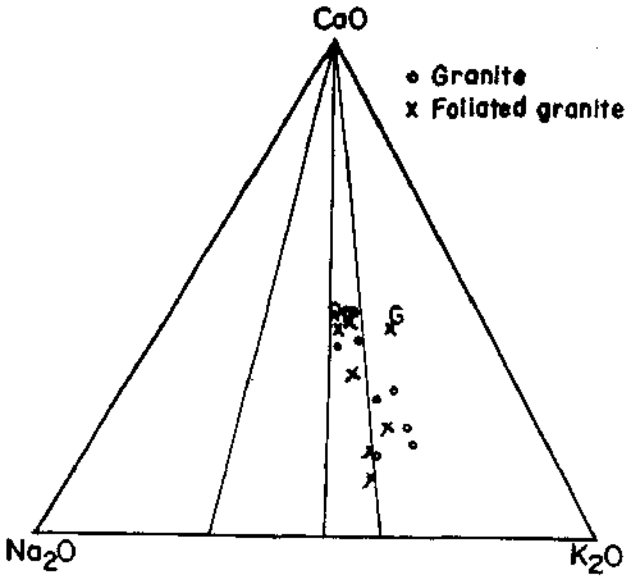


Fig. 13. CaO-Na_2O-K_2O plots of Foliated Granite and Undeformed Porphyritic Granite of Skeids area. The boudaries i.e. Qm- quarlzmonzonite, G-granite are from Barker and Arth (1976). Symbols as given in Fig. 10,

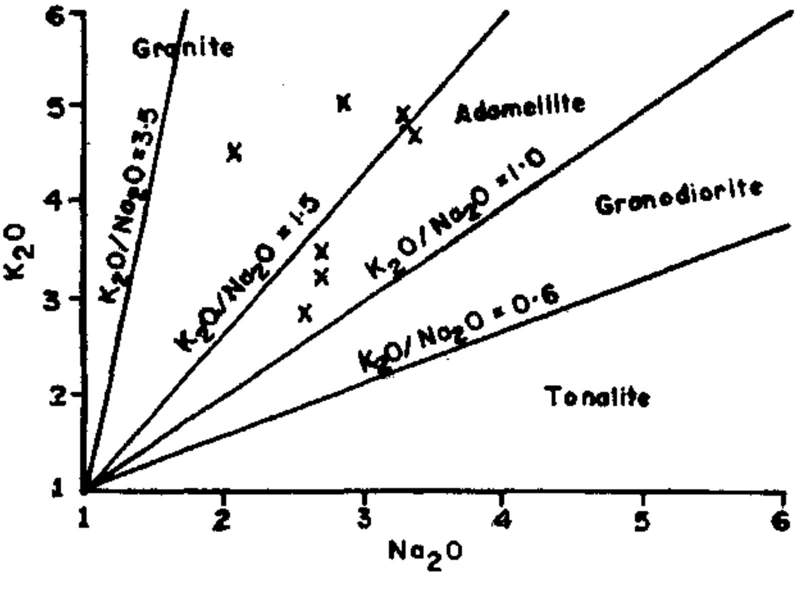


Fig. 14. K_2O vs Na_2O plot of Foliated Granite and Undeformed Porphyritic Granite of Skeids area.

Table 3: Geochemical Analyses of Foliated Granite

	1A	IB	1C	2B	20A	21B	21D
SiCh	63.53	65.61	69.44	73.70	65.61	65.19	65.9
$Ti0_2$	0.71	0.81	0.30	0.24	0.40	0.50	0.6
Al2O3	13.02	14.50	14.58	15.13	18.44	17.36	15.8
FeO	11.42	6.51	5.22	1.53	3.35	4.28	5.6
MnO	0.11	0.12	0.05	0.02	0.02	0.06	0.0
MgO	1.27	1.29	0.95	0.23	1.87	2.59	0.2
CaO	3.98	4.83	3.08	1.01	2.23	1.61	4.8
Na20	2.59	2.72	2.72	3.37	2.87	3.30	2.0
K2O	2.88	3.29	3.54	4.73	5.08	4.93	4.5
P2O5	0.50	0.25	0.12	0.05	0.12	0.17	0.1
Total	100.01	99.99	100.00	100.01	99.99	99.99	100.0
CIPW Norm*							
q	25.75	24.81	31.42	32.63	21.04	19.07	25.7
or	16.84	19.32	20.74	27.72	29.67	28.96	26.7
ab	21.75	22.85	22.85	28.26	24.03	27.75	17.3
an	15.25	17.52	14.40	4.63	10.13	6.83	19.9
C	0.00	0.00	0.94	2.74	4.41	4.04	0.0
di	0.87	3.87	0.00	0.00	0.00	0.00	2.4
hy	8.54	4.83	3.91	2.29	6.67	8.70	0.4
wo	0.00	0.00	0.00	0.00	0.00	0.00	0.0
mt	8.18	4.28	4.41.	0.42	1.99	2.80	4.8
il	1.33	1.52	0.57	0.46	0.76	0.95	1.1
ap	1.16	0.58	0.28	0.12	0.28	0.39	0.3
AN	41.21	43.40	38.66	14.09	29.65	19.74	53.3
In ppm							
Cu	10.00				9.00	8.0	
Zn	50.00				62.00	76.0	
Rb	65.00				140.00	220.0	
Sr	135.00				120.00	135.0	
Cr	30.00				20.00	60.0	
La	41.80				26.18	49.5	
Ce	81.38				48.16	78.1	
Pr	14.97				11.47	14.3	
Nd	60.00				34.00	52.5	
Sm	12.75				9.12	11.0	
Eu	2.49				1.52	2.1	
Gd	9.12				5.55	7.8	

Contd...

Table 3: *Contd.*

	1A	IB	1c	2B	20A	21B	21D
Tb	1.35				1.33	1.2	
Dy	6.06				5.85	5.6	
Ho	2.86				3.20	2.8	
Er	2.85				2.77	3,4	
Tm	0.43				0.34	0.4	
Yb	1.87				1.72	2.5	
Lu	0.40				0.31	0.3	
Y	27.54				19.84	28.9	
Eu/Eu*	0.71				0.65	0.7	
LaN/YbN	15.10				10.29	13.3	
K/Rb	330.78				170.18	78.4	
Rb/Sr	0.48				1.17	1,6	
A/NK	1.60	1.62	1.56	1.25	1.54	1.40	1.5
A.S.I.	0.96	0.94	1.08	1.12	1.23	1.19	0.9
K_20+Na_20	5.47	6.01	6.26	8.10	7.95	8.23	6.6
Mg No.	16,00	25.90	24.40	21.00	49.00	51.00	6.0

Table 4: Geochemical analyses of Undeformed Porphyritic Granite

	14A	15	16A	16B	27A	28
$Si0_2$	71.33	67.18	66.09	69.72	62.67	65.60
$Ti0_2$	0.44	0.51	0.61	0.35	1.60	0.60
AI2O3	11.38	15.09	14.33	15.95	14.65	16.54
FeO	6.20	6.56	6.38	4.08	6.92	5.60
MnO	0.03	0.09	0.03	0.04	0.07	0.05
MgO	0.28	1.78.	1.44	0.25	3.13	1.58
CaO	4.02	1.42	3.25	1.77	3.99	2.82
Na_20	2.50	2.81	2.51	2.36	2.63	2.75
K_20	3.67	4.47	5.24	5.38	3.64	4.28
P2O5	0.15	0.08	0.12	0.08	0.70	0.17
Total	100.00	99.99	100.00	99.98	100.00	99.99
CIPW Norm*						
q	35.38	24.75	21.99	29.88	19.53	22.43
or	21.63	26.06	30.49	31.38	21.57	25.12
ab	21.07	23.44	20.90	19.72	22.25	23.10
an	8.93	6.42	12.18	8.16	15.27	12.78
C	0.00	3.21	0.00	3.17	0.80	2.64
di	4.60	0.00	2.37	0.00	0.00	0.00

Contd...

Table 4: *Contd.*

hy	0.00	11.25	4.47	3.15	13.77	9.76
wo	1.89	0.00	0.00	0.00	0.00	0.00
mt	5.28	2.55	4.97	2.55	2.49	2.02
il	0.84	0.95	1.14	0.66	3.04	1.14
ap	0.35	0.19	0.28	0.19	1.62	0.39
AN	29.77	21.51	36.81	29.27	40.70	35.62
In ppm						
Cu	9.00	11.00	12.00	7.00	14.00	
Zn	118.00	121.00	115.00	82.00	108.00	
Rb	190.00	130.00	120.00	80.00	170.00	
Sr	145.00	165.00	150.00	180.00	230.00	
Cr	50.00	20.00	30.00	40.00	50.00	
La	189.20	255.53	101.78	278.30	72.88	
Ce	351.13	497.52	155.66	458.38	151.36	
Pr	48.45	61.92	33.67	5J.75	26.64	
Nd	192.50	254.40	102.00	207.50	94.00	
Sm	34.34	48.10	18.81	3.49	21.66	
Eu	3.26	2.86	1.79	3.26	2.23	
Gd	19.80	30.84	8.45	18.00	11.70	
Tb	3.00	4.87	2.03	2.70	2.59	
Dy	13.47	17.64	8.86	11.52	9.72	
Ho	8.32	19.04	6.72	10.14	6.40	
Er	6.53	8.58	3.48	5.43	4.44	
Tm	0.84	1.34	0.42	0.76	0.64	
Yb	4.54	4.92	2.17	3.64	2.95	
Lu	0.62	1.07	0,35	0.50	0.49	
Y	47.54	65.64	24.34	51.54	36.76	
Eu/Eu*	0.38	0.23	0.43	1.26	0.43	
LaN/YbN	28.16	35.10	31.69	51.67	16.69	
K/Rb	109.23	179.44	173.64	244.89	128.43	
Rb/Sr	1.31	0.79	0.80	0.44	0.74	
A/NK	1.23	1.38	1.22	1.36	1.56	1.56
A.S.I.	0.77	1.17	0.89	1.13	0.99	1.15
K_2O+Na_2O	6.17	7,28	7.75	7.74.	6.27	7.03
Mg No.	7.40	32.00	28.00	9.80	44.00	33.00

The REE concentration is far more in undeformed porphyritic granite than in foliated granite and orthogneisses (Tables 1, 3 & 4). The La_n/Yb_n values of undeformed granite are also more than the foliated granite. Spidergram of undeformed porphyritic granite (Fig. 19) shows a well fractionated pattern when compared to the foliated granite (Fig. 18). A moderately negative Eu anomaly

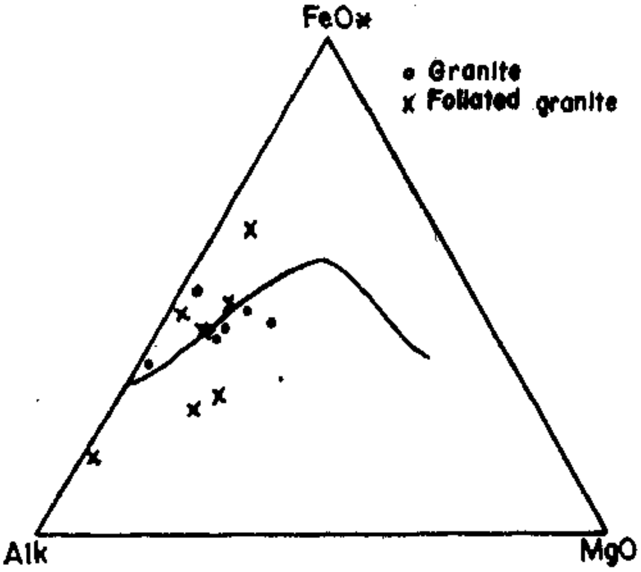


Fig. 15. The A-F-M plot for Foliated Granite and Undeformed Porphyritic Granite after Kuno (J 968). The fields Th-tholeiite; CA-calc-alkaline after Bargar (1971).

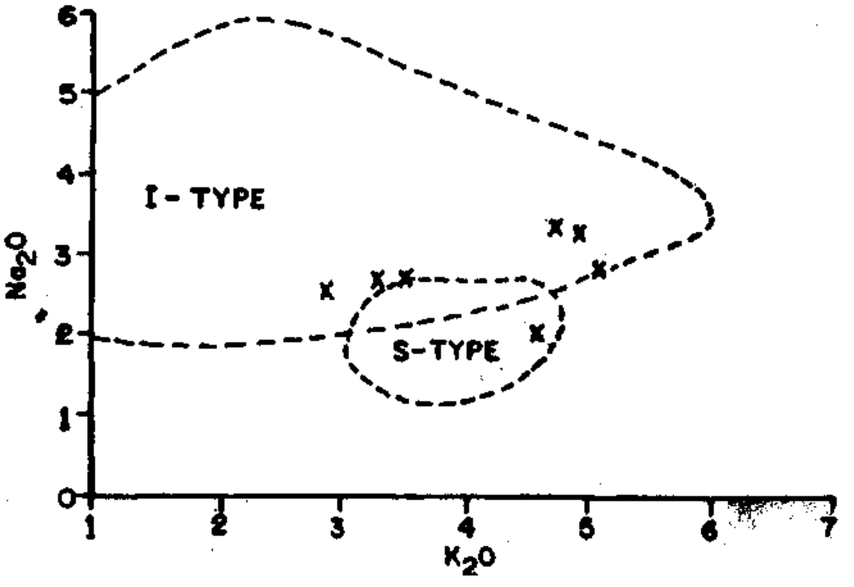


Fig. 16. Plot of Na_2O vs K_2O showing the 1-type characteristics of Foliated Granite. Fields of I and S-type granitoids from Mite and Chappell (1983).

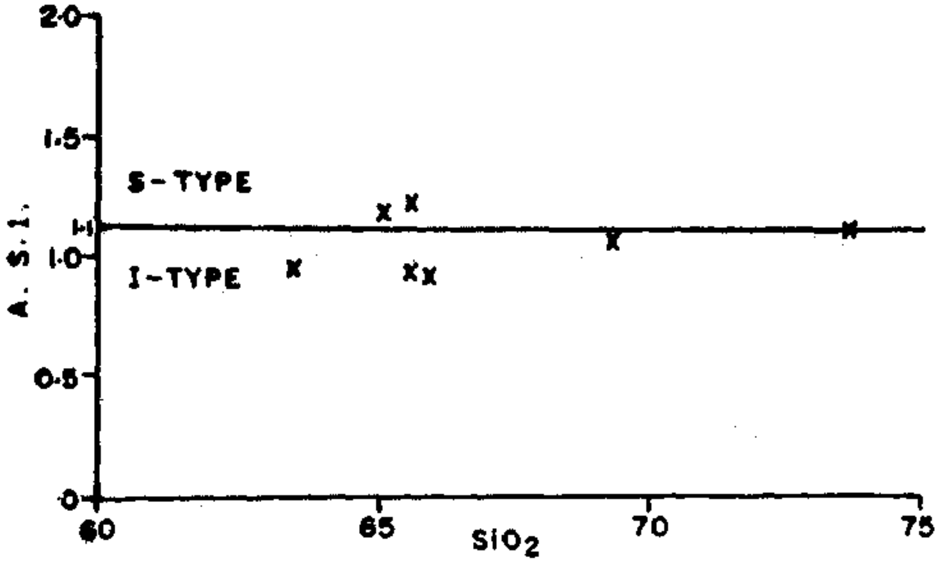


Fig. 17. Plot ofA.S.1. vs SiOifor Foliated Granite. Granitoid fields from White and Chappell (1983).

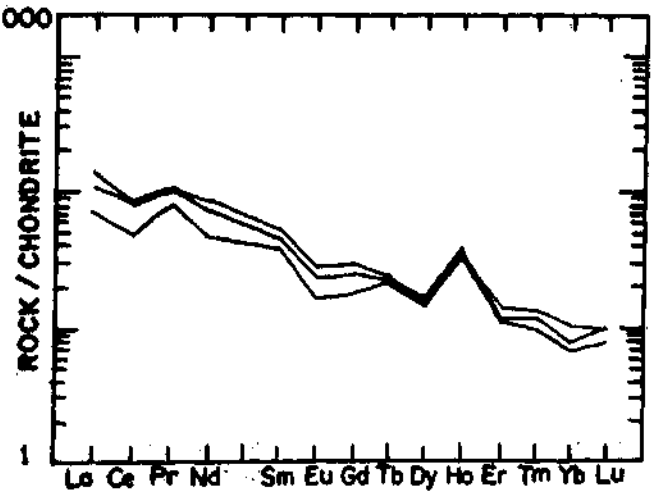


Fig.18. Chondrite normalised REE plot of Foliated Granite after Taylor and Mclennan (1985).

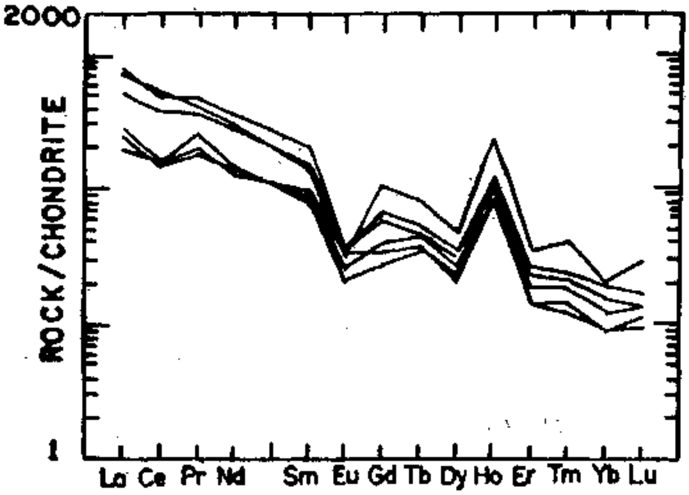


Fig. 19. Chondrite normalised REE plot of Undeformed Porphyritic Granite after Taylor and Mclennan (1985).

(Eu/Eu* = 0.23 to 1.26 for undeformed granite and 0.65 to 0.7 for foliated granite) is also present.

Gabbronorite

One analysis of gabbronorite (Table 5) is compared with the hypersthene gabbro from Bushveld complex (Von Gruenwaldt, 1989). The whole rock geochemistry of this rock is comparable, except for higher TiO_2 and FeO and slightly lower Al_2O_3 content shown by the gabbronorite of Skeids area.

Structure

Three phases of deformation are recognised in the Skeids Orthogneiss. The intrafolial tight isoclinal folds are considered as F_1 folds, superimposed on these are coaxial F_2 isoclinal folds with variable low angle plunge towards NNW and SSE. The axial plane cleavage of F_2 folds conform with the regional gneissosity S_2 of the area.

The megascopic F3 folds are occurring as broad warps and upright folds. The observed local swing in the regional gneissosity is due to the F3 deformational event. The foliation plane developed in foliated granite conforms with the regional

Table 5 : Geochemical Analysis of Gabbronorites

	4C/X	23D/X
SiO_2	51.43	52.28
TiO_2	1.30	0.15
M_2O_3	14.47	16.79
Fe_2O_3	8.14	0.45
FeO	4.45	6.88
MnO	0.12	0.18
MgO	6.61	8.62
CaO	**9.19**	11.62
Na_2O	2.76	2.49
K_2O	0.79	1.18
P_2O_5	0.60	0.01
LOI	0.47,	-
Total	100.33	100.65
In ppm.		
La	17.78	
Ce	24.51	
Pr	3.7	
Nd	20.4	
Sm	5.03	
Eu	1.38	
Gd	2.99	
Tb	0.63	
Dy	2.88	
Ho	1.6	
Er	1.68	
Tm	0.22	
Yb	1	
Lu	0.2	
Y	10.84	

gneissosity S2. Shear zones are intricately associated with the orthogneisses and also to lesser extent with foliated granite. A younger shear zone trending N60° E-S60°W is prominent along which unmetamorphosed pegmatite veins have intruded.

Discussion

The geology of Skeids area, in comparison with other parts of Humboldt mountains (Pant, 1991; Ravindra *et al,* 1994) is dominated by occurrence of rocks with igneous parentage. Comparable migmatised orthogneiss unit is reported from adjoining Muhlig-Hofmannfjella area of Western Dronning Maud Land (Moyes and Barton,1990; Grantham *et al,* 1991; Ohta, 1991) where these have been considered to have suffered peak metamorphism under amphibolite to granulite facies during 1100 Ma granule event. Upper Proterozoic (1000 to 1100 Ma) granulite event in Eastern Dronning Maud Land (Shiraishi and Kagami, 1991) has also been widely reported. Considering the geological similarities of Wohlthat mountain region with adjoining areas of western and eastern Dronning Maud Lands, the orthogneisses of Skeids area are being correlated with 1000-1100 Ma granulite event.

The precursor of orthogneisses must have been emplaced prior to D_1-phase of deformation. The gneisses have been subjected to upper amphibolite facies conditions of metamorphism under the influence of increased volatile phase which must have been associated with anatexis and partial melting. The millimetre scale layering visible in the gneiss may have developed due to metamorphic differentiation, as it defines only seggregation of mafic minerals. The presence of F_1 and F_2 folds in orthogneiss indicates that the M_1-metamorphism accompanied D_1-deformation episode or slightly preceded it. Similar observation has been reflected in the works of Allen (1991) for H.U.S verdrupfjella orthogneiss. Retrogression during D_2 deformational event under lower pressure is not pronounced in orthogneiss, as the mineral composition of the rock is stable under wider range of pressure-temperature. However, one section containing garnet shows retrogression with development of biotite.

The granitoids present in the area have been distinguished as syn-tectonic foliated granite and post-tectonic undeformed porphyritic granite in relation to D2-deformational event. The foliated granite, contains migmatitic sectors within it. This granite shows strong I-type characteristics. Igneous parentage of foliated granite is also reflected by its field characteristics. This rock contains megacrysts of K-feldspar, which are also subhedral in shape and may be reflecting a magmatic origin (Vernon, 1986).

The fractures contained in the megacrysts are aligned with the regional foliation plane suggesting post growth deformation. Elongated mafic enclaves (Fig.20) within this gneissic granite is also a characteristic feature of igneous origin.

The post-tectonic, undeformed porphyritic granite is associated with the wide spread magmatic activity in this region and in adjoining eastern and western Dronning Maud Land areas (Grantham *et* al.,1988; Joshi *et* al.,1991; Shiraishi *et al.,* 1991). This porphyritic granite is distinctly different from syn-tectonic I-type

Fig,20, Field photograph of elongated and foliated mafic enclave occurring within Foliated Granite,

foliated granite, as it does not contain any foliation plane and shows no sign of deformation.

The gabbronorite dyke is younger than the foliated granite and is older to undeformed porphyritic granite as indicated by its field setting. The ortho- and clino-pyroxenes, present in this rock, have been altered to amphiboles. The gabbronorite dyke is compositionally correlatable with massif type monzo-gabbronorite occurrence in adjacent south Petermann ranges (Joshi and Bejarniya,1990). The late basic intrusives occurring as minor dykes of doleritic and dioritic composition may be related to the Mesozoic age intrusive activity in the region (Harris *et al,* 1991; Kaiser and Wand, 1985).

It is significant to note that the paragneiss, which dominates the lithology of Humboldt mountains (Pant, 1991; Ravindra *et al,* 1994,) is conspicuously absent or unexposed in Skeids area.

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