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A Short Account of the Basic and Ultrabasic Rocks Occurring Between Schirmacher Hills and Gruber Massif, Central Queen Maud Land, East Antarctica

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Abstract

The rocks exposed in the Gruber massif area of eastern Wohlthat mountains and in the nunataks, which are exposed between Schirmacher hills in the north and Gruber massif in the south, are traversed by various dykes and sills of basic igneous intrusives. These have been identified mainly as dolerites and lamprophyres. In this paper an account of their petrology and petrochemistry has been presented. An isolated occurrence of a pyroxenite, north of Gruber massif, has also been reported.

Introduction

The Gruber massif forms the easternmost fringe of Wohlthat mountain chain. Between this massif and Schirmacher hills in the north there are several nunataks, of which eight are in the proximity of Schirmacher hills. The rocks of this entire terrain consist of a basement complex of gneissic rocks (quartzofeldspathic gneisses and granulites) which have been intruded by anorthosites and charnockites in the eastern part of Wohlthat mountains.

Details of these rocks have been described separately in this volume (Kaul, *et al.,* pp 57-97). The basement gneisses and the igneous complex have been later intruded by rocks of a basic suite, which occur as dykes and sills (Refer map in: Kaul *et al., op. cit.).* This paper presents an account of the field and petrological characters and petrochemistry of the basic intrusives.

Field Description

Dolerite dykes are the dominant intrusive basic rocks in Gruber massif. These dolerites, seen at least in ten different localities in the northern and central parts of Gruber massif, occur as steep, nearly vertical dykes varying greatly in thickness from a few centimetres to many metres. Widths of 2 to 5 metres are most common. There is also great variation in length, as seen at the surface, from a few metres to more than two kilometres. A number of closely spaced dykes occur east of Nedresjoen lake in Gruber massif.

Lamprophyre dykes and sills, varying in width from 30 to 200 metres, occur in some of the small nunataks. Occurrence of pyroxenite has been noticed only in one locality—Vasskilsata nunatak.

Petrology

Dolerites: The dolerites of this area are dark coloured, fine-grained and compact in nature. These are more or less transitional in grain size between aphanitic basalt and phaneritic gabbro.

Under the microscope, dolerites reveal a fine- to medium-grained holocrystalline texture. These are greenish brown to black in colour and are essentially composed of plagioclase, clinopyroxene, orthopyroxene, amphibole and olivine. Minor amounts of biotite, sphene, apatite and opaque ores are the accessory constituents. Subophitic texture is a common feature of these dolerites (Fig. 1).

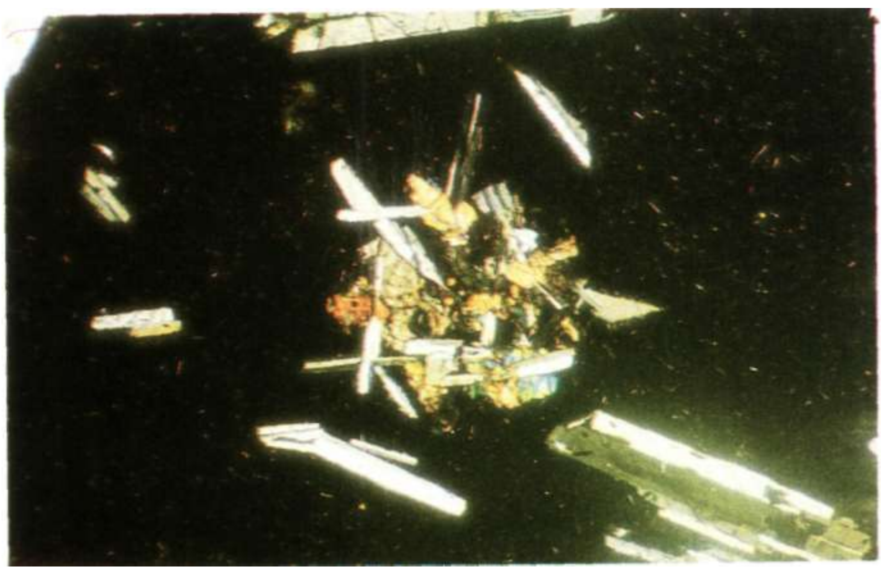

Fig. 1. Photomicrograph showing sub-ophitic texture in dolerite, Gruber massif (CN x *32).*

Clinopyroxenes are mainly diopsidic augite and titanaugite, a few crystals showing very clear twinning (Fig. 2). Titaniferous augite is pinkish in colour and pleochroic from pale brown to pink. It shows alteration to hornblende. In many cases the margins of augite grains are corroded.

Orthopyroxenes are characterized by straight extinction and their pleochroism is in shades of green and pink. Margins of most of the grains are corroded. A few grains are zoned and gaseous inclusions are also observed in some others.

Plagioclases are andesine-labradorite variety (An_{42-70}) and show albite and carlsbad twinning. These are sericitised along grain margins and cleavage traces.

Fig. 2. Photomicrograph showing Simple Twinning in pyroxene from dolerites of Gruber massif. (CN x *30)*

Hornblende is pleochroic in shades of green. In some specimens it has developed from pyroxenes and is pleochroic from pale brown to green. Often, it is altered to chlorite and is clouded.

Olivine occurring as polygonal grains showing high relief and irregular fractures, is seen only in a few thin sections of dolerites, located south of Nedresjoen lake in Gruber massif.

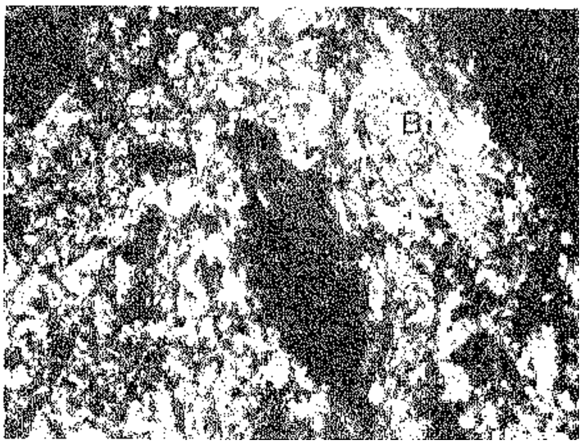

Fig. 3. Photomicrograph showing biotite pbenocrysts in a fine grained matrix of feldspar(CN x *30)*

Table I. Chemical Composition of Dolerite from Gruber massif, East Antarctica and other parts of the world.

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	52.80	57.01	52.21	51.80	55.68	48.80	47.00	40.36	49.40	48.76	48.09	44.65	46.48
Al_2O_3	18.80	16.74	15.37	15.10	15.98	12.07	11.92	12.72	14.50	13.37	10.61	10.42	13.86
Fe_2O_3	0.18	1.19	2.30	2.37	1.81	17.09*	17.81*	7.05*	2.60	13.68*	14.61*	4.42	2.59
FeO	7.20	6.66	7.86	7.63	7.01	—	—	—	7.75	—	—	8.80	9.52
MgO	5.16	6.48	6.06	6.78	7.17	4.49	4.0.3	10.87	8.50	6.96	10.51	11.15	9.74
CaO	10.20	5.97	9.95	10.51	9.42	9.75	11.20	23.14	6.75	10.43	9.18	12.05	10.38
Na_2O	1.84	0.92	2.78	1.75	2.34	2.03	1.63	Bld	1.77	2.38	2.02	2.94	2.82
K_2O	0.33	1.65	0.65	0.85	0.12	0.86	0.35	0.09	4.60	0.53	0.59	0.66	0.67
H_2O+	1.80	0.60	—	1.93	1.93	—	—	—	1.70	—	—	1.65	0.59
H_2O-	0.08	0.22	—	0.08	0.62	—	—	—	0.06	—	—	0.01	0.24
MnO	0.21	0.14	0.14	0.18	0.17	0.25	0.25	0.08	0.16	0.18	0.(9	0.18	0.12
TiO_2	1.00	1.90	1.60	0.97	0.80	3.36	3.45	3.15	1.92	1.78	2.59	2.24	2.70
P_2O_5	Tr	Tr	0.14	0.09	0.10	0.39	0.37	0.06	Tr	0.19	0.28	0.23	0.35
LOI						0.17	0.72	0.88	—	1.68	2.01	—	—
TOTAL	99.60	99.48	99.06	100.04	100.15	99.26	98.73	98.40	99.71	99.65	98.92	99.40	100.06
SI	35	38				18	17	60	33				

1°° Dolerite from 71°18'S:13°35'E
2°° Dolerite from 70°54'S:12°33'E
3 Dolerite from Bankura, India (Bandhopadhyay, 1982)
4 Dronning Maud Land dolerite (Von Brun, 1964)
5 Ferrar Dolerite(Gunn, 1962)
6°° Dolerite from 71°20'30"S:13°30'E
7°° Dolerite from 71°20'30"S:13°30'E
8°° Pyroxenite from 71°12'S:13°30'E
9°° Dolerite from 71°21'S:13°38'E
10 Dolerite from Kraul Mountain (Spaeth, 1987)
11 Dolerite from Ahlmann ridge (Spaeth, 1987)
12 Basic erratics from Schirmacher hills (Raina et at., 1985)
13 Average of 7 alkali olivine basalt from the Hawaiian Islands (Kuno et al., 1957)

* Total Fe as Fe_2O_3

SI is solidification Index

$$= \frac{MgO \times 100}{MgO+Fe_2O_3-FeO+Na_2O+K_2O}$$

°°From present area of study

Lamprophyres: Megascopically, lamprophyres of the area are mesocratic and medium- to coarse-grained containing phenocrysts of biotite and amphibole. Under the microscope, porphyritic texture is common. Main constituents are biotite and hornblende in a fine-grained matrix of feldspars (Fig. 3). Sphene and opaque ores are the accessory constituents.

Biotite flakes are very strongly pleochroic from yellowish brown to dark reddish brown. These often contain inclusions of apatite and opaque ores.

Feldspar is mainly plagioclase with minor amount of potash feldspar, constituting the groundmass.

Quartz is present as small grains, disseminated in the matrix. It also occurs as inclusions within biotite.

Petrochemistry

Dolerites: A comparative chart of the chemical compositions of dolerites from the present area of study and those from India and other parts of Antarctica is given in Table I. Normative mineral compositions are given in Table II.

Dolerites at Sl no. 1 and 2 in Table I, representing the present area, when plotted on the alkali-silica diagram of Kuno (1962), fall in the field of tholeiitic basalt (Fig. 4). Chemically these are similar to the dolerites of western Dronning Maud Land (Von Brun, 1964) and Ferrar dolerites of Victoria Land (Gunn,

Table II. Norms of Dolerites and Lamprophyres from Gruber Mountain and Nunataks

	1	2	3	4	5	6	7	8
Quartz	7.75	19.08	12.21	13.47	—	—	4.02	—
Orthoclase	1.95	9.75	5.08	2.07	—	27.18	19.80	35.40
Leucite	—	—	—	—	0.42	—	—	—
Albite	15.57	7.78	17.18	13.79	—	14.98	14.72	11.76
Perthite	—	—	—	—	5.21	—	—	—
Anorthite	42.07	29.62	21.28	24.18	34.44	18.04	23.01	8.35
Diopside	7.04	—	10.76	13.96	34.84	12.46	3.31	5.83
Hypersthene	21.18	24.51	6.19	3.56	—	0.97	27.84	16.75
Ilmenite	1.90	3.61	0.63	0.53	0.17	—	2.07	0.22
Haematite	—	—	17.09	17.81	7.05	—	—	7.31
Magnetite	0.26	1.73	—	—	—	3.77	—	—
Titanite	—	—	7.55	7.78	—	—	—	3.33
Apatite	—	—	0.90	0.86	0.14	—	1.55	2.39
Olivine	—	—	—	—	7.65	16.90	—	4.89
COS	—	—	—	—	7.60	—	—	—
Corundum	—	2.59	—	—	—	—	—	—

1. Dolerite 70°18'S:13°35'E
2. Dolerite 70°54'S: 12°33'E
3. Dolerite 71°20'30"S: 13°30'E
4. Dolerite 71°20'30"S: 13°30'E
5. Pyroxenite 71°12'S: 13°32'E
6. Dolerite 71°21'S: 13°38'E
7. Lamprophyre 70°58'S: 11°52'E
8. Lamprophyre 70°55'S: 12°15'E

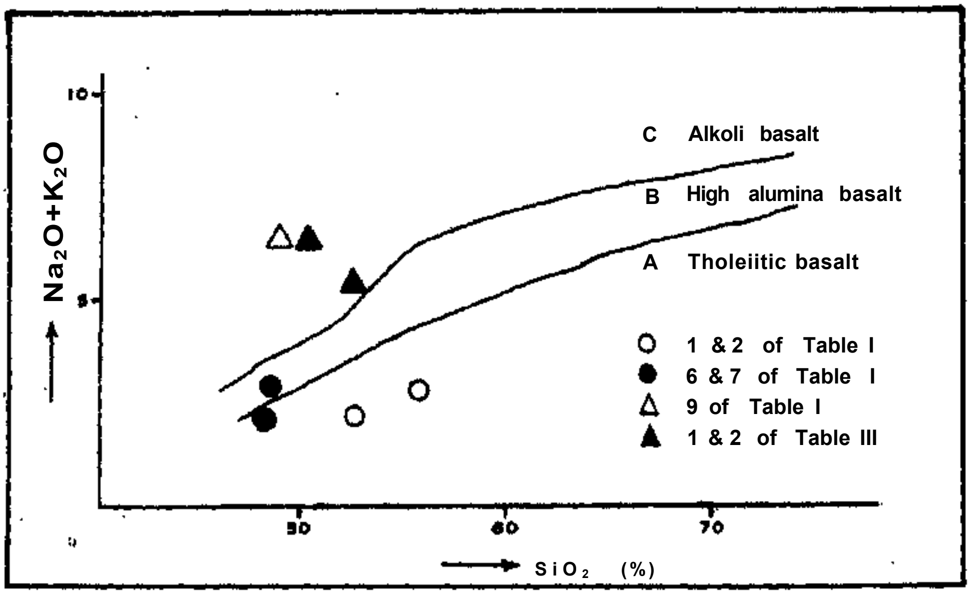

Fig. 4. *Alkali-silica diagram for basic intrusives of Gruber massif and Nunataks, Queen Maud Land, East Antarctica*

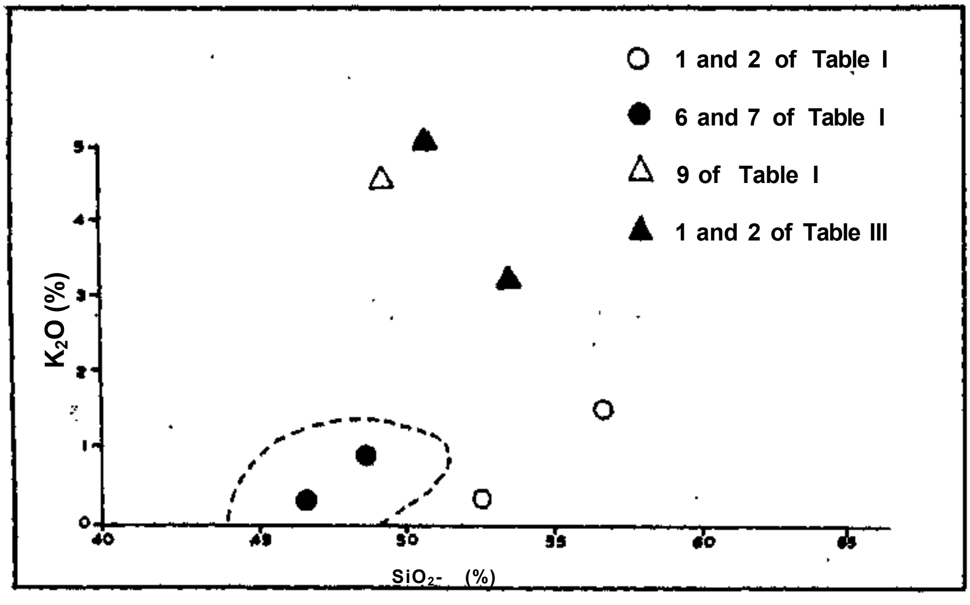

Fig. 5. Plot of K_2O versus SiO_2 for basic intrusives of Gruber massif and Nunataks, Queen Maud Land Antarctica Broken lines indicate sub-alkaline basalt field of New Schwabenland (Spaeth, 1987)

1962). These also compare well with the tholeiitic basalt intrusives into anorthosites of Bankura, India (Bandhopadhyay, 1982). These dolerites are characterised by higher silica and alumina, and low Fe-Mg than other tholeiitic dykes. Solidification index i.e. $(MgO \times 100)/(MgO+FeO+Fe_2O_3+Na_2O+K_2O)$, gives a reliable measure of the fractionation of a basalt magma (Kuno, *op. cit.)*. The SI of these dolerites are 35 and 38. Hence the dolerites (1 & 2 of Table I) were probably derived from a tholeiitic basalt magma with high alumina content.

Dolerites from Nedresjoen lake area (6 & 7 of Table I) are low in silica and MgO but have higher values of total iron and TiO_2. When plotted on an alkali-silica diagram (Fig. 4) they fall within high alumina basalt field, close to tholeiitic limits. K_2O-SiO_2 plot (Fig. 5) indicates their similarity with sub-alkaline basalt from western New Schwabenland, Antarctica (Spaeth, 1987)

Dolerite from Mentzelfjellet in Gruber massif (9 of Table I) has chemical resemblance with alkaline basalts. It has typically low Fe_2O_3+FeO contents and is rich in alkalies. When plotted on alkali-silica diagram, it lies in the alkali basalt field. It has got solidification index values of 33, indicating its derivation

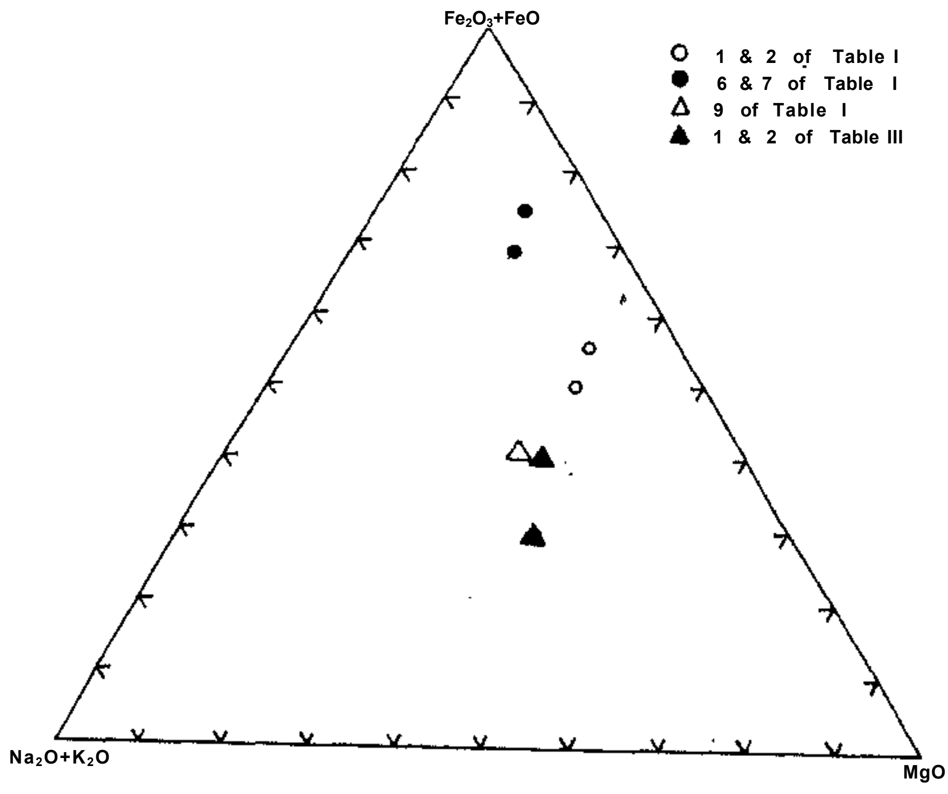

Fig. 6 AFM diagram for basic intrusives of Gruber massif and Nunataks, Queen Maud land, East Antarctica.

Table III. Chemical Composition of Lamprophyres from Nunataks of East Antarctica

	1	2	3	4	5	6	7	8	9
SiO_2	53.80	50.98	40.47	49.97	45.73	45.59	46.37	51.50	52.90
TiO_2	1.09	1.45	4.56	1.48	2.11	2.64	1.80	1.85	0.85
Al_2O_3	14.92	11.83	9.81	9.35	17.01	14.00	11.98	11.55	17.20
Fe_2O_s	1.00						5.05	2.38	
FeO	7.38	7.31	9.30	6.71	11.53	10.69	5.16	4.72	7.56
MnO	0.16	0.11	0.20	0.16	0.19	0.53	0.10	0.10	
MgO	7.32	10.61	10.24	8.18	5.43	6.98	8.38	7.90	3.60
CaO	6.34	5.50	8.15	9.57	8.20	8.56	9.33	9.10	6.40
Na_3O	1.74	1.39	1.10	0.76	4.32	4.41	2.84	2.55	3.50
K_2O	3.35	5.99	4.97	5.30	2.89	3.60	4.34	5.65	3.69
H_2O^+	1.76	—					2.17	1.10	
H_2O^-	0.16	—					0.71	0.45	
P_2O_5	0.67	1.03	2.56	0.20	0.72	0.61	1.34	0.96	—
BaO	—	0.97					0.31		
LOI		0.86							
Total	99.69	98.03					99.88	99.81	95.7

1* Lamprophyre from Nunatak Pevikhornet (70°58'S:11°52'E
2* Lamprophyre from Nunatak Sonstebynuten (70°55'S:12°15'E)
3 Average of 20 Gondwana Lamprophyres from India (Paul et al., 1984)
4 Average of 2 Lamprophyres from Sidhi-India (Paul et al., 1984)
5 Average of 4 Lamprophyres from Girnar alkaline complex, India (Paul et al., 1977)
6 Average of 4 Lamprophyres from Elchuru alkaline Complex, India (Bose and Nag, 1980)
7 Biotite-augite Lamprophyre Spanish peaks, Colorado (A.Knopf, 1936)
8 Minette, Shiprock, Northeast Arizona (Williams, 1936)
9 Average Shoshonite (Condie, 1976)
* From present area of study

from primary alkali basalt magma. In comparison to other alkaline basalts reported from Antarctica and average composition of Hawaiian alkaline basalts, this has higher alumina and lower MgO and CaO. However, a higher K_2O content could be because of assimilation and metasomatic enrichment of potash. AFM diagram (Na_2O+K_2O) - Fe_2O_3 - MgO of the rocks is given in Fig. 6.

Lamprophyres: The average composition of the lamprophyres from nunataks of the present area, is given in Table III along with the same for lamprophyres from India and U.S.A. High total alkali content (Na_2O+K_2O) characterise the lamprophyres occurring in the nunataks. These lamprophyres compare well with the lamprophyres from alkaline complexes of India except for the higher silica and lower Fe/Mg ratio in case of the former. The high K_2O/Na_2O ratio and low Fe/Mg of these lamprophyres give them a shoshonitic affinity, which is not reflected in the low SiO_2 content (Rock, 1977). These lamprophyres have lower Al_2O_3 content than the Indian lamprophyres of Girnar Complex, Gujarat, and typical shoshonites.

When plotted on the Alkali-silica diagram, lamprophyres of the area fall in the alkali basalt field (Fig. 4). The general similarity between the lamprophyres of this area and those of the alkaline complexes, are indicative of the fact that these might have been derived from an alkali basalt or related magma by fractional crystallization. The alkaline lamprophyres, in general, show petrochemical affinity to alkali basalts (Rock, *op. cit.).* Turner and Verhoogen(1960) have also assigned origin of lamprophyres to alkaline olivine basalt magma.

Trace element abundance of basic rocks (Table IV) of the area show enrichment of Cr, Ba and Sr compared to other basic intrusives in the region.

Ultrabasics

Xenoliths of pyroxenite occurring as pods and measuring in length on an average of 2 metres to a width of less than a metre within the rocks of Vasskilsata nunatak (Kaul *et al.,* this volume, pp 57-97) may be early cumulates of pyroxene crystals at the basal part of alkaline basalt magma, which were later brought up with the intrusion. The pyroxenite (8 of Table I) is low in silica and deficient in alkalies. Characteristically they are rich in calcium. Other constituents are more or less comparable with sub-alkaline and alkaline basalts.

Conclusion

The Study of basic intrusives, described above, has revealed that these rocks are apparently derivatives of at least three types of magmas—tholeiitic basalt type; high alumina basalt type; and alkali basalt type, which implies that the depth of the source of these rocks is varying, and the emplacement of basic intrusives in the Precambrian country rocks of the area might have spread over a considerable time span. Occurrence of lamprophyres as reported here open a new vista for detailed study of the intrusives in the nunataks of Queen Maud Land, as they, along with alkali basalt intrusives, may throw light on the source magmas which obviously had generated at great depths.

Table IV. Trace Element Abundance in Basic Rocks of Gruber Massif and Nunataks (in ppm)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Cu	Pb	Ni	Co	Mo	V	Cr	Ga	Bi	Ge	In	Ti	Zr	Ba	Sr	Be
1.	<10	<10	10	25	<10	600	70	10	<10	<10	<10	>1000	10	150	500	<10
2.	10	100	10	20	<10	350	500	20	<10	<10	<10	>1000	100	>1000	>1000	<10
3.	300	<10	80	60	5	500	50	15	<20				150	350	150	5
4.	300	<10	60	60	5	250	20	10	<20				150	150	100	5
5.	20	10	10	40	<5	120	40	10	<20				300	50	150	<5
6.	<10	10	25	25	<10	250	250	10	<10	<10	<10	>1000	15	350	400	<10
7.	10	40	30	25	<10	225	550	10	<10	<10	<10	>1000	100	>1000	>1000	<10
8.	20	20	160	40	2	150	700	10	<20				300	>3000	1600	5

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	As	Sb	La	Y	Se	W	Sn	Ag	Cd	Nb	Ta	Yb	B	Ce	Mn	Zn
1.	<1000	<200	<30	15	35	<100	<10	<1	<30	<20	<200	<10	<10	<500	400	
2.	<1000	<200	<30	40	20	<100	<10	<1	<30	<20	<200	<10	<10	<500	50	
3.	<300	<100	<30	30		180	10	2		<10						300
4.	<300	<100	<30	20		270	10	1		<10						300
5.	<300	<100	<30	40		120	20	1		<10						<300
6.	<1000	<200	<30	10	15	<100	<10	<1	<30	<20	<200	<10	<10	<500	350	
7.	<1000	<200	<30	30	20	<100	<10	<1	<30	<20	<200	<10	<10	<500	400	
8.	<300	<100	100	20		140	<10	1		10						300

1. Dolerite 71°18'S : 13°35'E
2. Dolerite 71°21'S : 13°38'E
3. Dolerite 71°20'30"S : 13°30'E
4. Dolerite 71°20'30"S : 13°30'E
5. Pyroxenite 71°12'S : 13°32'E
6. Dolerite 70°54'S : 12°33'E
7. Lamprophyre 70°55'S : 12°15'E
8. Lamprophyre 70°58'S : 11°52'E

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