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Anorthosites of Gruber Massif, Central Queen Maud Land, East Antarctica—An Appraisal

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Abstract

Anorthosites of Antarctica are by far the least studied of all the monomineralic rocks on our planet. This paper reports certain characteristic features of the anorthosites of Gruber massif, East Antarctica which have a close resemblance with those of Adirondack Mountains, U.S.A.

Introduction

The debate on the world-wide occurrences of anorthosites, their petrological characteristics, relation with the regional tectonic elements and the complexity of their genesis, has intensified in recent times. Many a commentary have been written on the various occurrences of this mono- or nearly monomineralic rock with several 'myths' still unresolved (Ashwal, 1988). The anorthosites of Antarctica are, however, hitherto not explored in great scientific depths. The manifold hurdles that are posed by the extraordinary conditions of the frozen continent are obviously the reasons for these lacunae in our knowledge about the Antarctic anorthosites.

An account of the anorthosites of Gruber massif of East Antarctic craton studied by the authors has been presented in this paper. Gruber massif which lies between latitudes 71°14'S & 71°29'S and longitudes 13°00'E & 14°03'E (Fig.1), forms a part of the eastern limits of Wohlthat mountain chain that extends across Queen Maud Land in an ENE-WSW direction. This mountain chain is dissected by vast stretches of polar ice and continental glacier.

Geology

The rock types exposed in the Gruber massif are Precambrian gneisses of granulite facies, basic granulites/charnockites and anorthosites. While the anorthosites are distinctly intrusives into the gneisses, the chronological order of basic granulites/charnockites and anorthosites is not very clear in the area studied. The contact of the two rock types is of hybrid nature. Although no distinct layering is noticed, anorthosites are foliated near the contact with basic granulites. Foliation is caused mainly due to shearing of the rocks, amply suggested by the presence of mylonitic bands in the contact region. Further south, i.e. away from the basic granulites/charnockites and gneisses, the anorthosite is of massive nature. Foliation is also well developed at a few isolated localities within the massif and near the contact of fine-grained anorthosite with coarse-grained variety. The anorthosites are granular in texture, almost totally composed of feldspars, light grey in colour, and devoid of mafic constituents. The grain size varies from fine to medium in the outer periphery of the complex to coarse in the central part of Gruber massif.

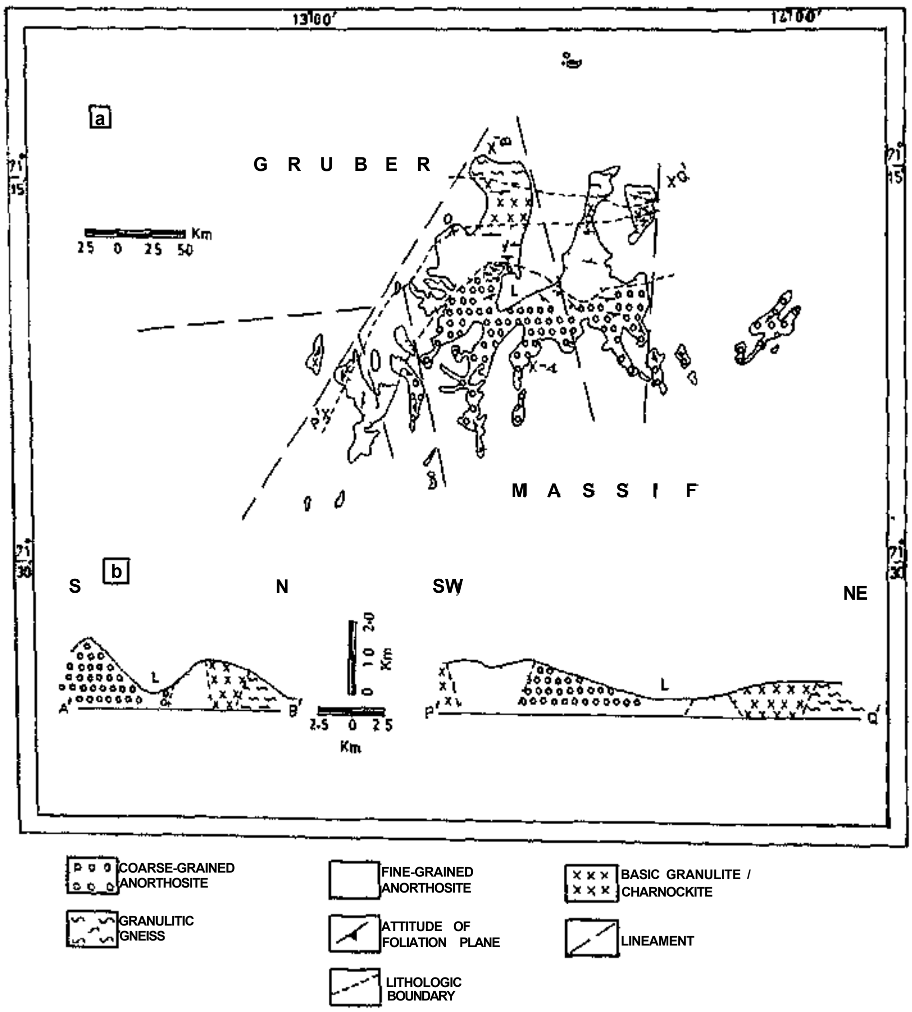

Fig. 1. (a) Geological map of Gruber Massif, Central Queen Maud Land, Antarctica (b) Schematic geological cross section along A'-B' and P'-Q'.

Although, in general, there is a paucity of ferromagnesian minerals in Gruber anorthosites, at the central part of the massif, occurrence of both, orthopyroxene and clino-pyroxene with or without garnet is noticed in many of the samples near the granulite-anorthosite contact and in some samples collected from further interior towards south. Biotite is mostly secondary after pyroxene.

Gruber anorthosites are intruded by a number of basic dykes which are doleritic in nature. Besides these, pegmatite and quartz veins are also common intrusives into the anorthosites. The contact of these intrusives with anorthosites is always sharp. Within the anorthosites, sporadic mineralisation of ilmenite is seen in the form of veins and stringers, occasionally associated with magnetite.

Petrography

Microscopic study of the anorthosites of Gruber massif reveals mineral composition of plagioclase-perthite ± antiperthite ± garnet ± clino- or orthopyroxene ±carbonates ± white mica ± quartz ±opaques. Plagioclase constitutes more than 90 volume percent of the rock. Magnetite/ilmenite are the main opaque minerals present in the rock. Carbonates, white mica and quartz are found to occupy fracture zones or spaces between feldspar grain boundaries. These are probably derivatives from a late granitic phase generated in the region. The anorthite content of the plagioclase varies from An_{28} to An_{55} as determined by Michel Levy method. Although these are the extreme values of An-content, in general, the variation is much less, the average composition being An_{37}. Plagioclase grain boundaries in majority of the cases are crenulated (Fig. 2). Recrystallization of feldspar along the sheared grain boundaries of coarse plagioclase

Fig. 2. Crenulated grain boundaries of plagioclase crystals, anorthosite, Gruber massif (CN × 32)

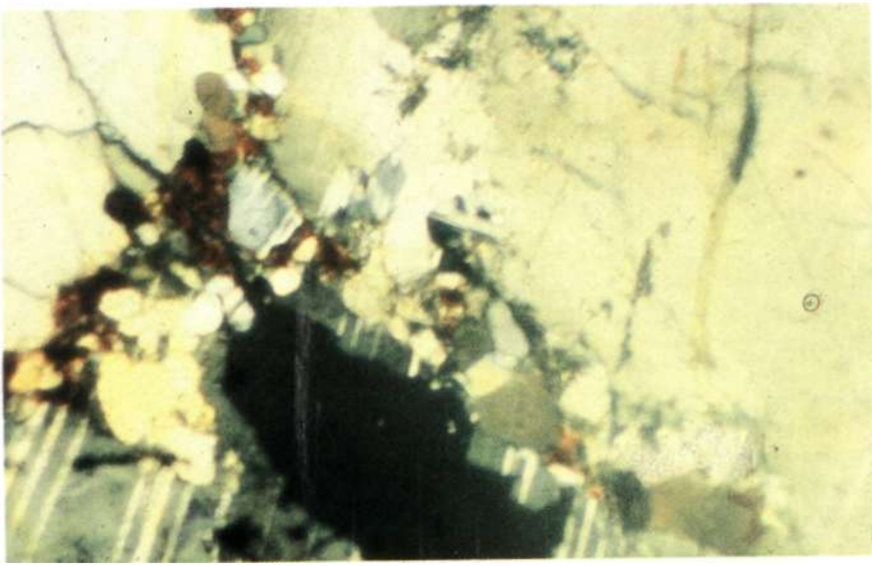

Fig. 3. Recrystallised feldspars along sheared grain boundary of a coarse plagioclase crystal, anorthosite, Gruber massif (CN x 32).

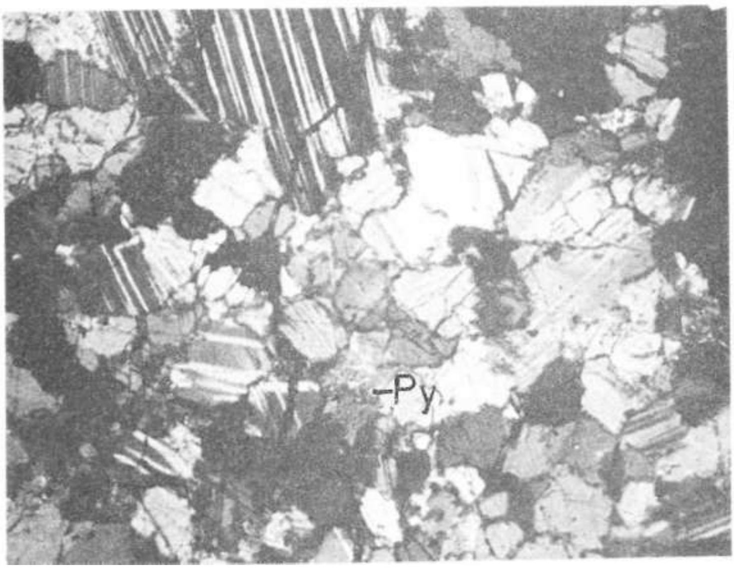

Fig. 4. The rare occurrence of pyroxene crystals within the Gruber anorthosites (CN x 30)

crystals is a very common feature of Gruber anorthosites. The recrystallized grains are in triple point contact presenting an equant, granoblastic fabric of the rock (Fig. 3). Mafics, though very rare, are yet discernible as small pyroxene crystals in very few anorthosite samples (Fig. 4).

Table I. Whole rock analyses by XRF of anorthosites of Gruber Massif, Wohlthat Mts., E. Antarctica (values in weight percent)

Oxides Sl No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sample No.	G-1	G-7	G-8	G-13	G-33	G-38	G-43	G-47	G-52	G-62	G-63	G-65	G-66	G-69
SiO_2	52.93	53.00	52.10	53.08	52.90	53.18	53.34	51.90	54.02	51.61	54.03	54.10	53.47	50.80
TiO_2	1.17	0.27	0.27	0.17	0.41	1.37	1.17	0.89	0.63	2.13	0.13	0.16	0.19	2.47
Al_2O_3	25.70	26.65	27.49	28.11	26.89	26.57	28.11	25.40	28.29	27.27	28.64	29.03	28.16	25.43
Fe_2O_3+	2.67	1.06	0.86	0.80	1.69	3.29	2.36	5.75	1.07	2.59	0.33	0.31	0.55	3.67
MgO	bld	bld	bld	bld	bld	0.68	bld	bld	bld	0.06	bld	bld	bld	bld
MnO	0.03	0.03	0.02	0.02	0.03	0.04	0.03	0.07	0.02	0.03	0.01	0.01	0.01	0.04
CaO	11.30	11.87	11.56	10.86	11.43	10.48	11.76	10.41	10.93	10.90	11.17	11.51	10.97	11.14
Na_2O	3.22	3.71	3.40	3.79	3.75	3.15	2.75	2.63	3.81	2.35	3.47	4.26	4.19	3.55
K_2O	0.82	0.88	0.54	0.84	0.81	0.78	0.81	0.77	0.89	0.95	0.96	0.93	1.00	0.84
P_2O_5	0.06	0.05	0.05	0.06	0.05	0.05	0.04	0.25	0.05	0.15	0.04	0.05	0.06	0.46
LOI	0.17	0.27	1.68	1.79	0.90	0.35	0.36	1.59	0.57	0.83	0.36	0.20	0.20	0.11
Total	98.07	97.79	97.97	99.52	98.86	99.94	100.73	99.66	100.28	98.87	99.14	100.56	98.80	98.51

+ : Total Fe as Fe_2O_3
bld : below level of detection
LOI : Loss on ignition.

Chemistry

In Table I are given chemical analyses of fourteen anorthosite samples from Gruber massif (see Kaul *et al.,* 1987). Most striking fact emerging from these analyses is the paucity of MgO in these anorthosites. The rare occurrence of pyroxenes and other mafic minerals in anorthosites further corroborates the extremely low amount of MgO in these rocks, which could not be detected in most of the samples by XRF method.

Normative values for these anorthosites (see Table II) indicate a general trend in the variation of couple of parameters. Salic/femic ratio is higher in the samples collected away from the anorthosite-basic granulite/charnockite contact than in the anorthosites occurring nearer the contact. Similarly, Q(quartz)/F(feldspar) ratio is lower in the samples collected away from basic granulite/charnockite than in the anorthosites in contact with the former. Not much variation is noticed in total alkali/CaO and K_2O/Na_2O ratios. This implies a fairly uniform compositional range of the plagioclases of Gruber anorthosites.

In Table III is given comparative averages of several chemical analyses of

Table II. Normative Calculations of Fourteen Anorthosite Samples from Gruber Massif, E. Antarctica

	G-1	G-7	G-8	G-13	G-33	G-38	G-43	G-47	G-52	G-62	G-63	G-65	G-66	G-69	
Q	7.52	3.85	5.62	5.36	4.11	8.54	9.15	1.05	5.17	11.28	6.35	1.23	1.93	4.70	S
Or	4.85	5.20	3.19	4.96	4.79	4.61	4.79	4.55	5.26	5.61	5.67	5.50	5.91	4.85	A
Ab	27.25	31.39	28.77	32.07	31.73	26.65	23.27	22.25	32.24	19.89	29.36	36.05	35.45	30.04	L
An	53.25	53.47	57.02	52.04	54.15	51.67	58.08	50.01	53.90	53.10	55.15	56.78	54.03	51.03	I
C	—	—	0.41	1.91	—	1.61	1.42	1.91	1.31	2.92	1.68	0.21	0.38	—	C
Di	—	0.01	—	—	0.01	—	—	—	—	—	—	—	—	—	
Hy	0.00	—	0.00	0.00	—	1.69	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	
Il	0.06	0.06	0.04	0.04	0.06	0.09	0.06	0.15	0.04	0.06	0.02	0.02	0.02	0.09	F
Hem	2.67	1.06	0.86	0.80	1.69	3.29	2.36	5.75	1.07	2.59	0.33	0.31	0.55	3.67	E
Ti	1.70	0.58	—	—	0.92	—	—	—	—	—	—	—	—	0.86	M
Ap	0.14	0.12	0.12	0.14	0.12	0.12	0.09	0.58	0.12	0.35	0.09	0.12	0.14	1.07	I
Ru	0.44	—	0.25	0.05	—	1.32	1.14	0.81	0.61	2.10	0.12	0.15	0.18	2.07	C
Wo	—	1.78	—	—	0.38	—	—	—	—	—	—	—	—	—	
Salic/femic	18.54	26.01	74.81	93.53	29.80	14.30	26.49	10.94	53.19	17.68	172.30	166.28	109.77	11.68	
Q/F	0.09	0.04	0.06	0.06	0.04	0.10	0.11	0.16	0.06	0.14	0.07	0.01	0.02	0.05	
T.Alk/CaO	0.36	0.39	0.34	0.43	0.40	0.37	0.30	0.33	0.43	0.30	0.40	0.45	0.47	0.39	
K_2O/Na_2O	0.25	0.24	0.16	0.22	0.22	0.25	0.29	0.29	0.23	0.40	0.28	0.22	0.24	0.24	

Q—Quartz; F—Feldspar; T.Alk—(Na_2O+K_2O)

anorthosites from Gruber massif and other parts of the globe (Kaul *et al.*, *op.* cit.). It can be seen that barring the amount of MgO content, Gruber anorthosites are chemically very close to those of Adirondack Mts., U.S.A. This is also shown by Alkali-Total iron-MgO variation diagram (Fig. 5) in which both,

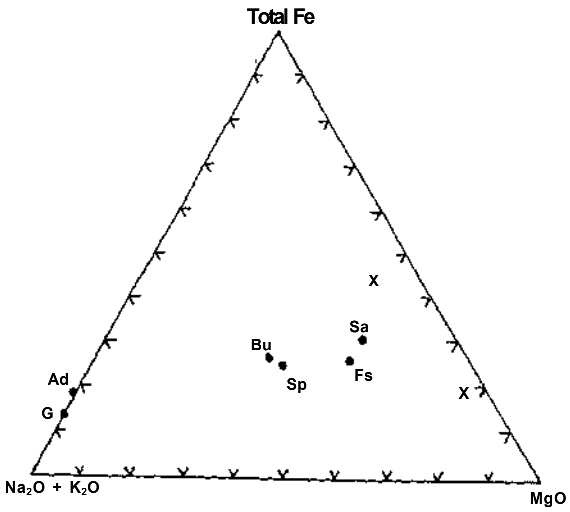

Fig. 5. Total Fe - (Na_2O + K_2O) - MgO variation diagram showing plots of anorthosites from G — Gruber Massif, Antarctica; Sp — Sittampundi, India; Bu — Bushveld, South Africa; Fs—Fiskenaesset. Greenland) Sa - Sakeny, Malagasy. Also ploteted are two samples of lunar anorthosites (marked X). G and Ad are plotted from chemical analyses presented in table III. Other plots are from Nambiar et al. (1982). (See Kaul et al., 1987).

Gruber and Adirondack anorthosites plot on total iron-alkali side of the triangle. Plots of the other terrestrial and lunar anorthosites lie far away from those of Gruber and Adirondack anorthosites.

Table III. Chemical Composition of anorthosites from various parts of the world.

	1		2	3	4	5
SiO_2	52.89	SiO_2	50.28	44.35	55.90	52.4.0
TiO_2	0.82	TiO_2	0.64	0.05	0.24	0.40
Al_2O_3	27.41	Al_2O_3	25.86	31.34	27.20	27.11
Fe_2O_3	1.93a	Fe_2O_3	0.96	1.06	—	0.49
MnO	0.03	FeO	2.07	0.82	1.28[c]	1.16
MgO	0.05[b]	MnO	0.05	0.02	0.02	0.01
CaO	11.15	MgO	2.12	1.12	0.21	1.05
Na_2O	3.43	CaO	12.48	18.18	9.65	8.77
K_2O	0.84	Na_2O	3.15	1.22	5.23	5.78
P_2O_s	0.10	K_2O	0.65	0.05	1.10	0.96
BaO	0.02	H_2O+	1.17	0.62	—	—
S	0.05	H_2O-	0.14	0.10	—	—
LOI	0.63	P_2O_5	0.09	0.01	—	0.27
		CO_2	0.14	0.20	—	—
Total	99.35		99.80	99.14	100.83	98.40

1. Mean chemical composition of 14 anorthosites from Gruber massif, East Antarctica (after Kaul *et al.,* 1987
2. Mean chemical composition of 104 anorthosites (after Le Maitre, 1976)
3. Mean chemical composition of 3 Archaean anorthosites from Sittampundi Complex, Madras, India (after Subramaniam, 1956) also contains 0.01 p.c. Cr_2O_3
4. Chemical composition of massif type anorthosite from Tahawas Marcy Massif Adirondack Mts, U.S.A (after Simmons & Hanson, 1978)
5. Chemical composition of 2 massif type anorthosites from Perinthatta, Kerala, India (after Nambiar *et al.*, 1982).

a. Total Fe as Fe_2O_3
b. MgO determined in two samples only out of 14.
c. Total Fe as FeO

Fig. 6 shows plot of all these anorthosites from various parts of the world in a SiO_2- (Na_2O + K_2O)-(CaO + Al_2O_3) variation diagram. Significantly, plots of Gruber anorthosites are lying clustered on or very close to albite-anorthite tie line confirming the petrographic observation that these anorthosites comprise more than 90% of plagioclases. Therefore, in accordance with the nomenclature adopted by Turner and Verhoogen (1960, pp 322), these can be called anorthosites proper. Here too the plots of Gruber anorthosites are in proximity of the Adirondack anorthosites.

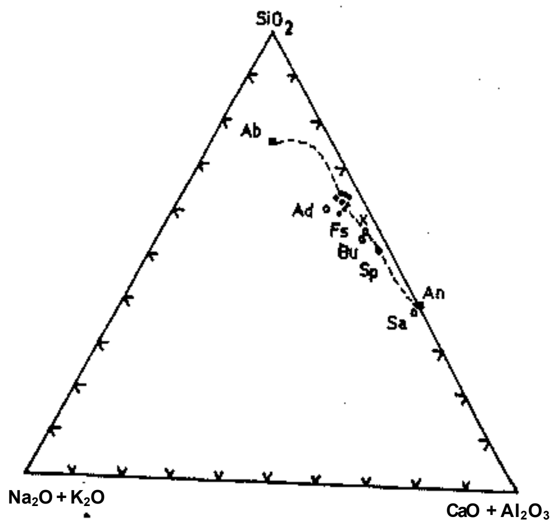

Fig. 6. SiO_2 — (Na_2O + K_2O) — (CaO + Al_2O_3) variation diagram showing plots of Gruber anorthosites of East Antarctica (solid sircles). Also plotted are anorthosites from other areas (sources and abbreviations as given in Fig. 5). Ab— albite; An— anorthite. (See Kaul et at, 1987).

Structure

The anorthosites of Gruber massif are well foliated at places. These foliation planes have resulted mostly due to shearing of anorthosites. Along these planes, preferred orientation of the needles or laths of opaque mineral (ilmenite?) are noticed in some cases. The foliation planes are mostly steeply dipping. Coarse-grained anorthosites at or near their contact with fine-grained anorthosites have shear/foliation planes dipping towards south or SSW at high angles of 50° to 80°. On the other hand, fine-grained anorthosites have shear planes dipping towards north in general at or near their contact with basic granulite/charnockite unit. The last mentioned rocks have again a southerly dip of their foliation planes at the contact with gneisses. This presents a horst and graben picture shown by the schematic geological cross sections drawn in Fig. 1, indicating block movement in the area. In the eastern and western flanks of the massif, strike of the foliation planes swing towards nearly N-S and they are dipping either towards east or west.

Few lineaments have been identified with the help of LANDSAT imageries. A major lineament in NE-SW direction separates Gruber massif from the Petermann ranges on the west and an ENE-WSW lineament appears to be the tectonic control for the geographical disposition of anorthosites. It is to be noted that anorthosite is not found anywhere north of Gruber; neither in the nunataks nor in Schirmacher hills.

Conclusion

Petrography of Gruber anorthosites discussed above reveals the presence of white mica and carbonates along fracture planes and space between feldspar grain boundaries. This is attributed to post-emplacement (anorthosite) acidic activity in the region. Quartz and pegmatitic veins traverse the anorthosites and granulitic gneisses in profusion.

From the chemical analyses and their application in variation diagram it is apparent that anorthosites of Gruber massif have undergone alkali enrichment and are also silica-rich as compared to other anorthosites of the world. The work carried out so far reveals that they are similar in their nature of occurrence and chemical composition to the massive anorthosites of Adirondack Mts., U.S.A.

It is not possible to assign an age to these anorthosites at this stage. However, their overwhelming similarity with the anorthosites of Adirondack Mts. can be used to guess that they belong to the clan of Mid-Proterozoic anorthosites.

Following Suwa's classification (1976), the Gruber anorthosites belong to Group II, i.e. Adirondack type. Small occurrences of Koraput anorthosites of Eastern Ghat mobile belt of India match well in their plagioclase composition, metamorphic environs and nature of occurrence with the anorthosites of Gruber massif (Balasubramanyam *et al.,* 1984, pp. 33). Anorthosites of Gruber massif are also found to be comparable with those occurring at Perinthatta in the south Indian craton (Kaul et al., 1987).

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