Geochemistry of Gneiss-Charnockite Association in the Nunataks South-East of Schirmacher Oasis, *cDML*, E. Antarctica

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Abstract

A dominantly gneissic suite with enclaves of charnockite and granulite and thin lamprophyre dykes is exposed in the four nunataks lying southeast of Schirmacher Oasis. While an alternating sequence of orthogneiss (biotite gneiss, biotite-hornblende gneiss) and para-gneiss (garnet- and garnet-biotite-sillimanite gneiss) is exposed in Baalsrudfjellet and Starheimtind nunataks, para-gneisses are conspicuously absent in the Sonstebynuten and Pevikhornet nunataks.

Analytical data and various chemical plots thereof, of the orthogneiss and charnockites show that they are igneous in nature while the garnet sillimanite gneisses have sedimentary parentage. The charnockites have low to moderate REE contents while the gneisses have comparatively higher REE contents. The variation diagrams of these rocks show clear trend of the progressive evolution of parent magma from charnockite to gneiss. This is corroborated by the R1-R2 plot of Batchelor-Bowden (1985). wherein the charnockite cluster in the pre-plate collision setting while the host gneisses plot in the syn-collisional field .Considering the similarity of lithological set up, distribution in the nunataks and their proximity to Schirmacher Oasis, the four nunataks are concluded to be extensions of the Schumacher itself.

Key words : East Antarctica, CDML, Nunataks, Charnockites, Gneisses, Geochemistry.

Introduction

The central Dronning Maud land (cDML) occupies the central space in the E. Antarctic craton with Rayner complex and Enderby Land to the east and western Dronning Maud Land (wDML) to the west. While high-grade metamorphic Archaean component dominates the Rayner complex, the granulite grade metamorphites with abundant of metasediments characterize the wDML set up (Tingey, 1991). The cDML thus holds the key to unravel the evolution of the E. Antarctic craton.

The cDML is predominantly Grenvillian gneissic terrain (with abundant charnockitic and granulitic enclaves) which has been intruded extensively by the Pan-African magmatic activity whose composition ranged from anorthosites to granites with lot of minor gabbroic, lamprophyric and pegmatitic dykes completing the set up (D'Souza et al., 1996). These are best seen in the Wohlthat-Humboldt-Orvin-Muhlig Hofmann Mountain ranges. The Schirmacher Oasis and the group of nunataks lying southeast of it represent 'the fringe zone of the cDML and are dominated by ortho- and para-gniess association with younger basic intrusives and pegmatites. The major Pan-African granitic/ charnockitic intrusive activity which is ubiquitous in the mountain ranges of cDML, is almost insignificant this fringe zone. The present study reports the geology and geochemistry of the gneissic suite in the group of four nunataks - Baalsrudfjellet, Starheimtind, Sonstebynuten and Pevikhornet, which occur 30 km to southeast of Schirmacher Oasis (Fig. 1).

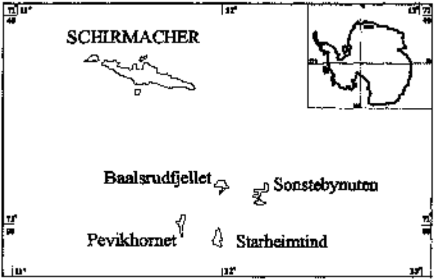

Fig.l *Location map of the four nunataks geologically mapped during the 19th Indian Antarctic Expedition.*

Geology

The broad lithology of these nunataks was first documented by Mukerji et al (1988). Of these, Baalsrudfjellet and Starheimtind are similar in their lithological set up - ortho-gneiss and garnet-sillimanite-gneiss are present, while in the Sonstebynuten and Pevikhornet nunataks, garnet-sillimanite-gneiss is conspicuous by its absence.

Baalsruldfjellet and Starheimtind

An alternating sequence of ortho gneiss (biotite gneiss garnet bioite gneiss biotite hornblende gneiss) and para gneiss (biotite sillimanite gneiss) is exposed in these nunataks (Fig 2) The general trend is ENE WSW with steep southerly to sub vertical dips Numerous enclaves of charnockites (Fig 4) and granulites are present. At many places, these enclaves have a very coarse to medium grained garnet rich rim Lamprophyres pegmatites and gabbroic dykes intrude the country rock The lamprophyres, 20- 60 cm wide, occur as dyke swarms, trending NE- SW with steep southerly to sub vertical dips and are traceable usually up to 50-60 m length. They have sharp contacts with the host rocks.

Sonstebynuten and Pevikhornet

Ortho gneiss with charnockitic and granulitic enclaves and thin lamprophyre dykes form the lithology of Sonstebynuten and Pevikhornet nunataks (Fig. 2). The general trend is ENE-WSW with steep southerly to subvertical dips

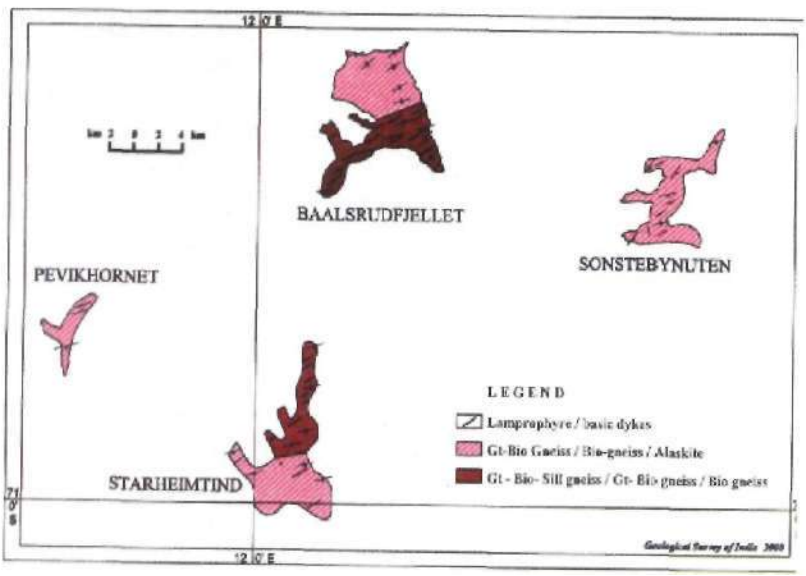

Fig 2 *Geological map of the four nunataks southeast of Schirmacher Oasis*

Rock Types and Petrography

Ortho-gneiss

Biotite gneiss and biotite hornblende gneiss are exposed in Baalsrudfjellet Starheimtind and Sonstebynuten. They are medium to coarse grained, show perfect compositional banding and occasionally augen structure . In thin sections, biotite is usually phlogopite - yellowish brown to brownish red. Hornblende shows yellowish to greenish pleochroic colours. Biotite and hornblende usually define foliation. Secondary biotite forming at the expense of primary hornblende grains with concomitant release of opaques, mostly magnetite is quite common (Fig. 3). Plagioclase is sodic in nature and orthoclase and microcline form the K-feldspar component. In the augen geniss, well developed augens of K- feldspars with foliation wrapped around is seen. Zircon and apatite form the accessory mineral assemblage.

Fig. 3 *Secondary biotite forming at the expense of hornblende with concomitant exsolution of opaques in the hbl-bio-bearing orthogneiss from Baalsrudfjellet (plane polarized light ; 10x)*

Garnet-Sillimanite-Gneiss

As stated earlier, the sillimanite bearing gneiss occurs only in Baalsrudfjellet and Starheimtind, while garnet-biotite gneiss and garnet-gneiss (Alaskite)- are exposed in Baalsrudfjellet Starheimtind and Sonstebynuten. In Pevikhornet, the garnet bearing gneiss is conspicuously absent. The garnet-sillmanite-gneiss shows well developed compositional banding and foliation. The mineral assemblage is garnet-biotite-sillimanite-feldspars-quartz. Garnet is reddish/pinkish brown, euhedrial to subrounded and does not contain inclusion of other minerals. Quite often, garnet grains are surrounded by biotite-chlorite rich rim. Sillmanite occurs as fine needles and as thick blades measuring up to 2 cm by 4cm. On the foliation plane, both biotite and sillimanite are randomly oriented. In thin section, sillmanite occurs as needles and prisms, colorless and show medium to high interference colours.

Charnockite

Occurs as dark greenish grey and greasy, medium to fine grained, weakly foliated with occasional gneissic banding. It occurs as enclaves, sometimes with a garnet-rich mafic rim around it, with-in the host gneiss. Under microscope, they usually show typical granuloblastic texture with grains having triple-point contacts. Biotite and hypersthene form the mafic assemblage. Plagioclase dominates the feldspathic component, thus making the charnockite enderbitic in composition.

Lamprophyre dykes

Lamprophyres are the most common intrusives in the area. All the lamprophyres are mesocratic to melanocratic, compact, fine grained, calc-alkaline in nature and show porphyritic texture (Keshava Prasad et al., 2001).

Geochemistry

Whole rock analysis of the samples was carried out at PPOD Laboratory of AMSE, Bangalore, using Phillips XRF instrument. The Trace Element analysis was done using ICP-AES at Chemical Laboratory, GSI, Faridabad and Rare Earth Elements were analyzed using Instrumental Nuetron Activation Analysis Technique at NAA Laboratory of GSI, at Pune. The representative analyses along with CIPW norm of charnockite and ortho-gneiss are given in Tables 1 and 2 respectively.

The SiO_2 content of the orthogneiss ranges from 62.71 to 71.05 wt% while A12O3 ranges from 12.95 to 14.99. The FeO (total) content is between 2.51 and 8.02 wt%. while total Alkali content is between 5.71 and 8.04 wt%. In contrast, SiO_2 in charnockite ranges from 48.91 to 55.87 wt% and $A1_2O_3$ from 11.95 to 15.61 wt%. The Fe-Mg values of charnockites are quite high, which range from 13.99 to 23.89 wt% while alkali content is low - between 2.85 to 4.14 wt% - as compared to the orthogneiss. In the variation diagram of various oxides, charnockite and orthogneiss define a trend line (Fig. 4). In the QAP plot of the gneiss and charnockite (Fig. 5), the gneisses plot in the monzo-granite to granite fields while the charnockites plot in the granodiorite to monzo-diorite-diorite fields.

In the K_20 vs SiO_2 (fields after Rickwood, 1989) the samples plot in the medium to high K- rocks field (Fig. 6). In the (Na2O+K20) - CaO vs SiO_2 diagram of Frost et al (2001), the gneiss and charnockite of the nunataks plot in the calcic-alkali to alkali-calcic fields (Fig. 7). In the AFM diagram, the gneisses have dominantly calc-alkaline trend while charnockites have distinctive tholeiitic trend.

The charnockites have low to moderate REE contents (S = 17.62 - 216.69) while the gneisses have comparatively higher REE contents (S = 150.11 -

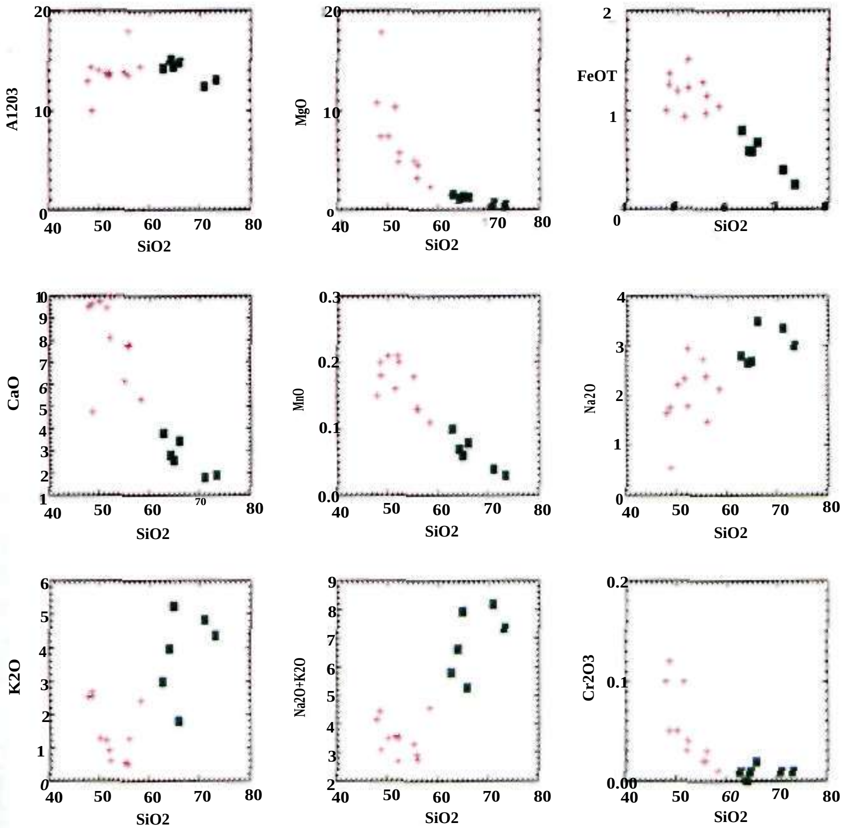

Fig. 4. Harker diagrams for the host orthogneiss and charnockite enclaves from the nunataks (Symbols: µ - Orthogneiss; + - Charnockite).

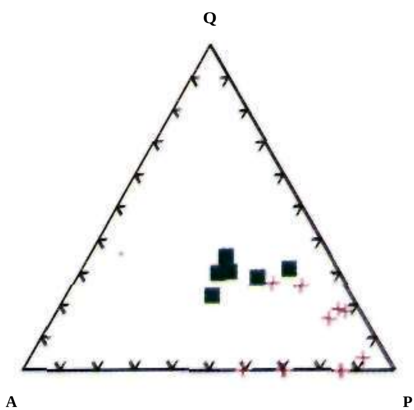

Fig. 5. ***QAP diagram of normative compositions of the Orthogneiss***

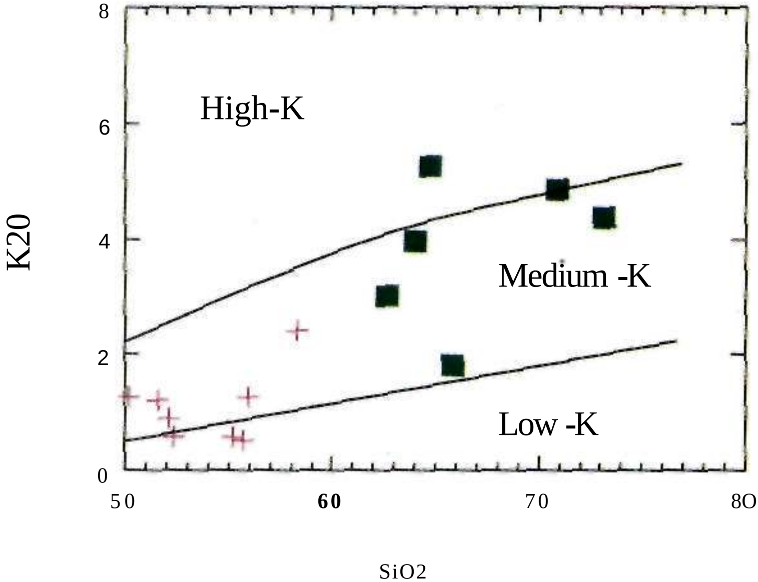

Fig.6. *K_2O vs. SiO_2 (wt%) diagram for the charnockite and gneiss of the nunataks; the limits given are after Rickwood, 1989.*

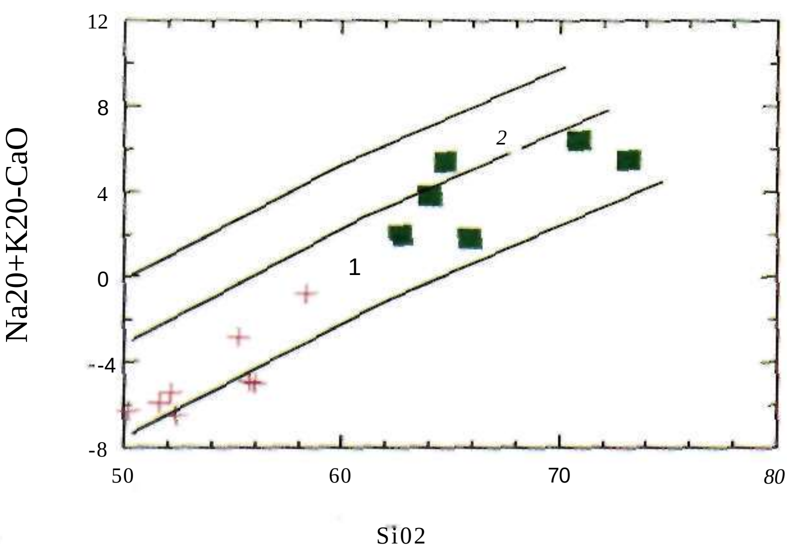

Fig.7. *Na_2O+K_2O- CaO vs.* SiO_2 *plot after Frost et al 2001, wherein the charnockite and gneiss plot in the calic-alkali (1) and alkali-calcic (2) fields.*

475.61). The Chondrite normalized REE plots (Fig. 8) show that both gneiss and charnockite are enriched in LREE as compared to HREE, resulting in the moderate to steep negative slope for the curves, indicating same degree of fractionation for both gneiss and charnockite. But the charnockites are relatively LREE-depleted than the gneisses which suggests the incompatibility of the LREE with respect to charnockite and the resultant partitioning of LREE in to the more granitic melt.

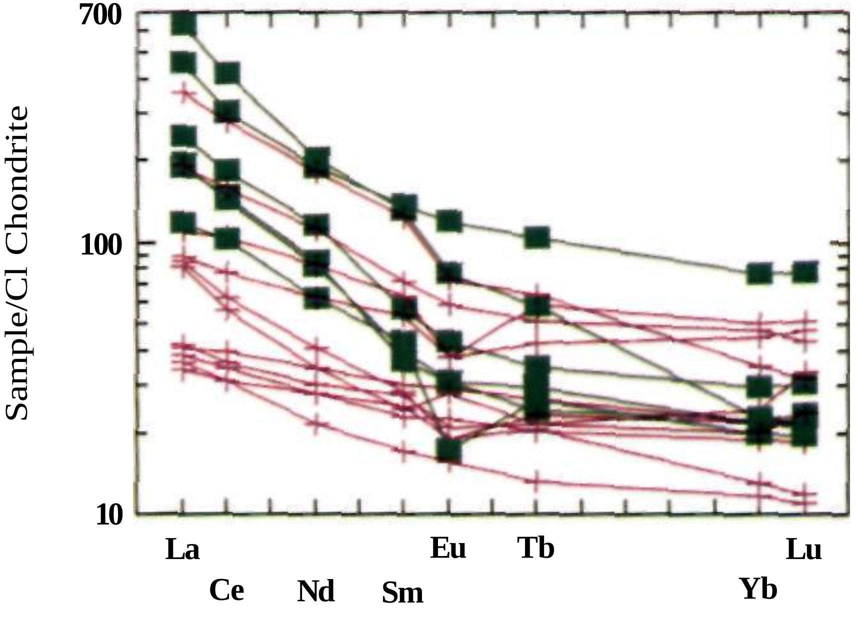

Fig.8. *Chondrite normalized REE pattern for the orthogneiss and charnockite of the nunataks.*

Discussion and Conclusion

In the variation diagrams of the orthogneiss and charnockite a clear trend of the progressive evolution of the charnockite and the gneiss from the parent magma is seen. This is further corroborated by the R1-R2 plot of Batchelor-Bowden (1985) wherein the charnockite which occurs as enclaves within the ortho-gneiss plot in the Pre-plate collision field while the host gneisses plot in the Syn-collsion field (Fig. 9).

The geological set up of the four nunataks is quite interesting. In Baalsrudfjellet and Starheimtind nunataks, the orthogneisses alternate with the sillimanite-gneisses whereas in the other two nunataks. the sillimanite gneisses are conspicuously absent. A comparison with the distribution of such rock types in the Schirmacher Oasis, which lies just 20 km north of these nunataks, may

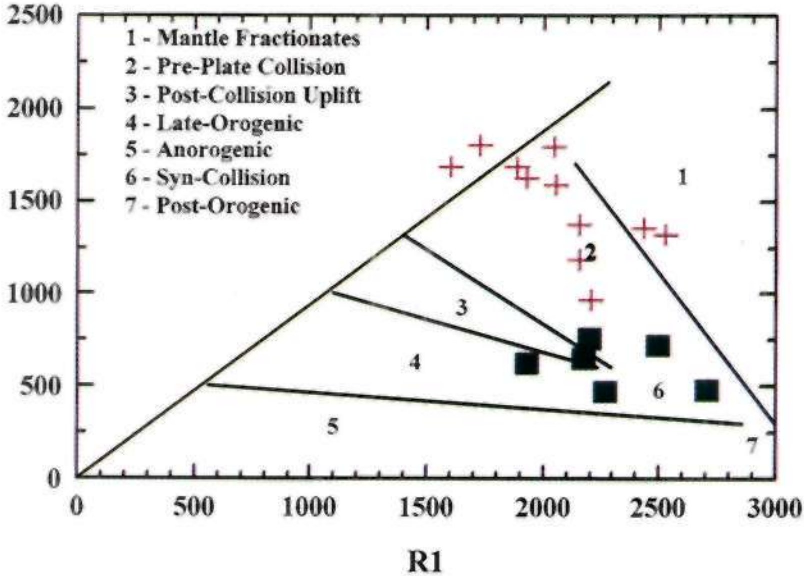

Fig.9. *RlR2 plot of Bachelor & BOW den (1985) for the orthogneiss and charnockite which clearly indicates a pre-collision setting for the charnockite and a syn- collision setting for the or orthogneiss*

throw some light. In Schirmacher, garnet-sillimanite gneisses occur in particular narrow zones (Fig. 10) in the west-central and eastern parts where ortho-gneiss (with all its variants) and garnet-sillimanite gneiss alternate. Thus the nunataks Pevikhornet and Sonstebynuten fall in the zones dominated by ortho-gneisses, while the nunataks Baalsrudfjellet and Starheimtind lie in the garnet- and

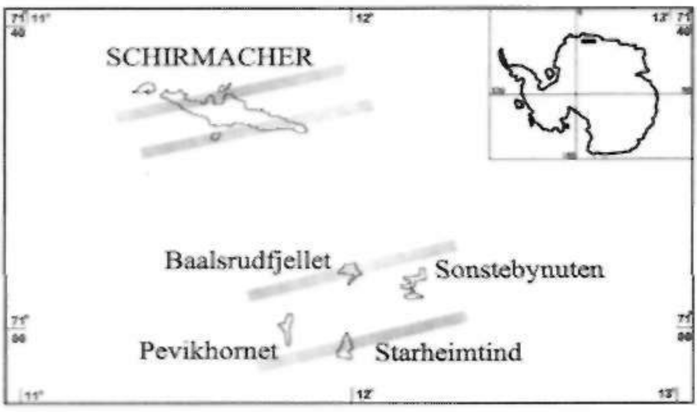

Fig. 10. *Map showing zones in which garnet- sillmianite gneiss (shaded areas) oooccurs; this probably explains the absence of pelitic gneiss in nunataks Pevikhornet and Sonestby-nuten.*

garnet sillimanite gneiss zone Since lithological set up in the nunataks is similar to that of Schirmacher and these nunataks are in close proximity to Schirmacher, it is concluded that the nunataks are extension of the Schirmacher Oasis.

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References

BACHELOR, R. A and BOWDEN, P (1985) Petrologic interpretation of granitoid rock series using multicationic parameters. Chem . Geol. v . 48 , pp. 43- 55

D' SOUZA, M .J. KUNDU, A. and KAUL, M. K .(1996) The geology of a part of cDML, E. Antarctica, Ind. Mm . v . 50 (4), pp. 323 -38

FROST, B. R BARNES, C. G COLLINS, W. J. ARCULUS, R. J ELLIS, D. J and FROST, C. D (2001, A geochemical classificat on for granitic locks J Petrol v 42 pp. 2033-2048

KESHAVA PRASAD,A. V BEG, M. J and ARUN CHATURVEDI ,(2001) Petrography of Lamprophyre dikes from nunataks southeast of Schirmacher Oasis cDML E Antarctica Curr. So v. 81(11), pp .1477- 79

MUKERJI, S. KAUL, M. K SINGH R.K SRIVASTAVA, D and JAYARAM, S. (1988) An outline of the geology of the nunataks between Eastern Wohlthat Ranges and Schirmacher Hills, Central Queen Maud Land, East Antarctica DoD Tech. Publ. No 5, pp. 121- 133

RICKWOOD,P. C (1989) Boundary lines within petrologic diagrams, which use oxides of major and minor elements, Lithos, v .22, pp. 247- 264

TINGEY, R. J (1991) The regional geology of Archaean and Proterozoic rocks of Antarctica. In 'The Geology of Antarctica ' Ed .RJ Tingey, Oxford Science Publishers , pp . 1- 73