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Geotechnical Properties of the Antarctic Rocks*

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Abstract

Representative rock samples of the terrain between Schirmacher hills and Wohlthat mountains were subjected to tests for identifying some of their geotechnical properties, on an experimental basis. The tests for petrographic character, physical properties and strength were carried out using standard test procedures. The results obtained are falling within the range of values generally acceptable for such rock types.

Introduction

An experimental programme was planned and executed to understand the geotechnical characteristics of some of the rocks occupying the terrain in the Schirmacher hills and Gruber massif regions of the Princess Astrid Coast of Queen Maud Land, Antarctica which are the bedrock areas nearest to the Indian research station, Dakshin Gangotri. Ten representative rock samples from this terrain consisting of granulites, granitoid, melasyenite and various types of gneisses were studied on an experimental basis. The details of their petrological nomenclature and regional location were supplied by the Leader of the Fifth Indian Expedition to Antarctica. These are presented in Table I and Fig. 1, respectively.

Table I. List of Samples

Sl.No.	Code of Study	Rock type	Regional location
1.	Drill core	Melasyenite	L1
2.	Gneiss A	Microcline porphyroblastic gneiss .	L1
3.	Gneiss A6	—do— (weathered)	L1
4.	Gneiss B	Garnet-bearing gneiss with mafics	L1

* Abridged by the Expedition Leader from the detailed report submitted by the authors,

Table I. (Contd.)

Sl.No.	Code of Study	Rock type	Regional location
5.	Gneiss C	Garnet-bearing porphyroblastic gneiss with pegmatite veins	L_1
6.	Gneiss D	Microcline rich granoblastic gneiss with foliation	L_1
7.	Augen gneiss	Augen gneiss	L_2
8.	Basic granulite	Basic granulite	L_2
9.	- d o -	—do—	L_2
10.	Gneiss N	Granitoid	L_2

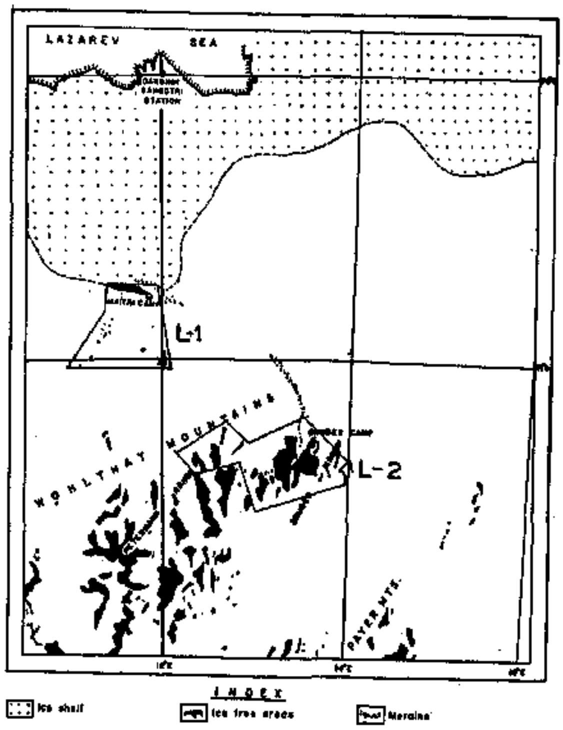


Fig. 1. location map

Tests Conducted

Keeping the scope of this study in view, the tests that were conducted and the procedures used are given below:

Purpose	Tests	Reference
Petrography	Thin section study X-ray diffraction analysis Scanning Electron Microscopy.	ISRM, 1978 ASTM using JCPDS indices
Physical Properties	Density determination Specific gravity determination, water absorption determination porosity determination, permeability	IS 2720 (pt.III) 1964 ISRM, 1972 ISRM, 1972 ISRM, 1978
Strength properties	Uniaxial compressive stength (o-C) Brazilian (Tensile) strength (o- tb)	ISRM, 1977 IS 9143, 1979 ISRM, 1978

ASTM = American Standard Testing Methods
JCPDS = Joint Committee on Powder Diffraction Standards (1972), Pennsylvania (USA)
ISRM = International Society of Rock Mechanics
IS = Indian Standards

Procedure

The related standard test procedure for different tests conducted are as follows:-

1. Petrography/mineralogy

(a) *Thin section studies:* For all rock samples thin sections were prepared to study the optical properties of these rocks. Textural and mineralogical observations were made for these sections under programmable camera inter-phased microscope of Niccon (Japan) with ordinary and polarised light at 100 A.S.A. exposure.

(b) *X-ray diffraction analysis:* X-ray diffractograms were obtained from the powder of rock samples (size 75M) using Rigabu Denki Co. Ltd. (Japan), Cat No. 4057 A2 machine. Copper target (λ = 1.54), *2* theta values upto 85° with a scanning rate of 2 deg/minute were adopted. During scanning the variation in electrical potential (voltage) intensity is interphased with computer. Thereafter, the programme is executed by the computer in order to number the major peaks and their 'd' values for the corresponding 2 theta values. Relative to the strongest peak of the diffractogram, feeble peaks upto 1 percent were scanned.

(c) *Scanning electron microscope:* In order to study the shape, size, orientation of grains, intergranular arrangement, fracture pattern and other related textural characteristics, advanced Cambridge Stereo Scan was employed.

2. Physical properties

Water absorption, saturated and dry densities, specific gravity and effective and absolute porosities were determined using standard procedures.

Effect of water head (confining pressure/cell pressure) on coefficient of permeability was studied at constant water heads equal to 1.38, 3.35 and 5.51 MP_a for all rock samples.

3. Strength properties

A very limited number of Brazilian and uniaxial strength tests of some rock samples were carried out. This was due to lack of sufficient quantity of rock specimens. For uniaxial compressive tests specimens of L/D = 1 and for Brazilian tests L/D = 0.5 were used to conduct these experiments. Axial, Ea and diametral Ed (lateral) deformations in unconfined compressive tests were measured using electrical resistance strain gauges fixed to the specimens. Two strain gauges for each type of strain were employed to get a better feel of the deformations. Strains were measured using SYSCON-31 digital strain indicator.

Results and Discussions

The qualitative and quantitative estimation of the composition of rock samples used in this study were made using the thin section studies, SEM and X-ray diffractograms. The studies indicate that the gneissic specimens are invariably rich in quartz, mica and feldspar. Amphibole, pyroxene and garnet are less abundant. Gneiss D and Gneiss A have very high quantity of kaolinite which indicates the active role of weathering on these rocks. The scanning electron microphotographs presented in Figs. 2 and 3 also supported the presence of high clay in these rocks. The basic granulites and augen gneisses are rich in plagioclase feldspars and pyroxenes in addition to quartz and micas. Typical textural features observed for some of these rocks, through electron microscopy are presented in Figs. 4 to 7. A typical X-ray diffractogram including the related data on a basic granulite is given in Fig. 8.

Representative physical properties of these rocks are presented in Table II. The average dry density values fall in a close range of 2.63 to 2.89. As expected the saturated density values are marginally higher than the dry values. It can also be observed from the table that the water absorption, the void index and effective porosity values are also low for these rocks. It is also clear that the rocks are fresh and very compact.

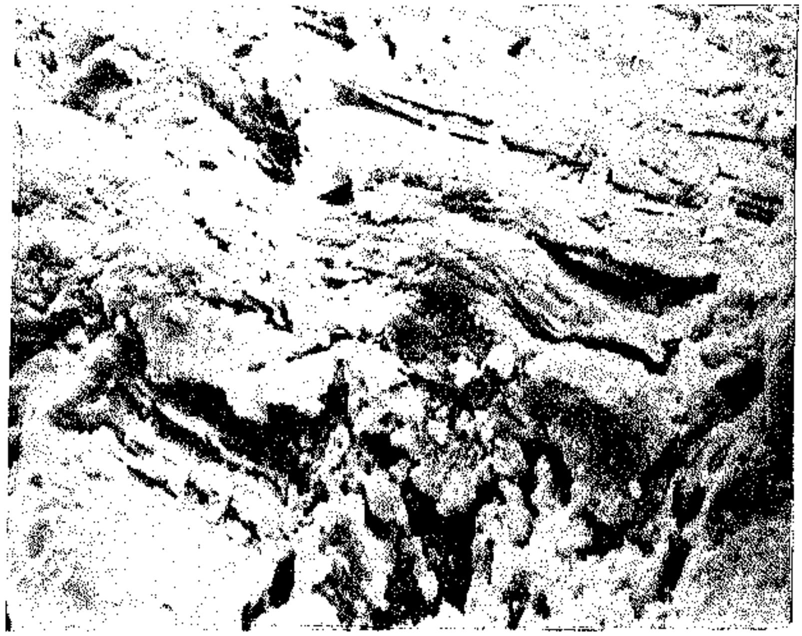


Fig. 2. *SEM* ***photograph of gneissD (magnification X 147)***

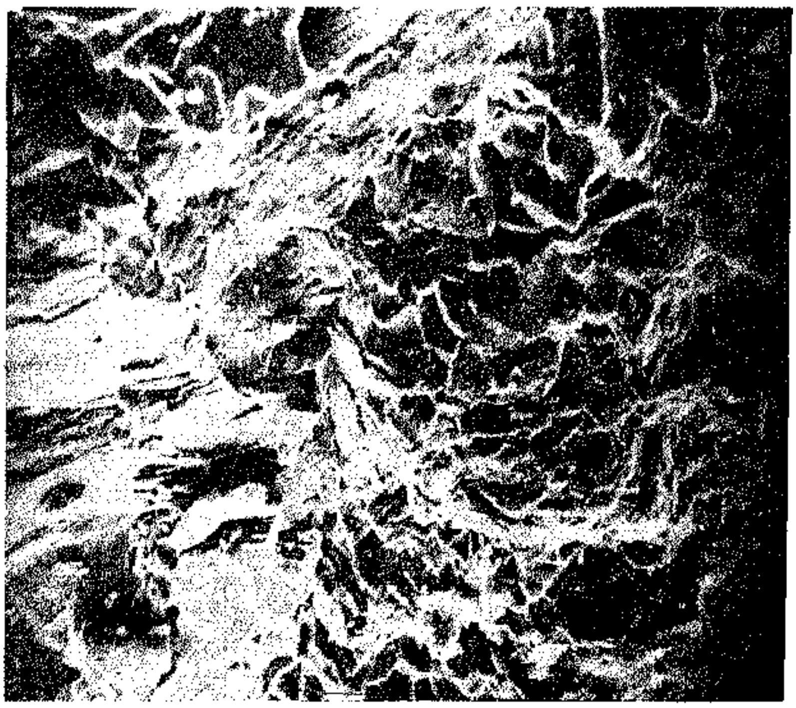
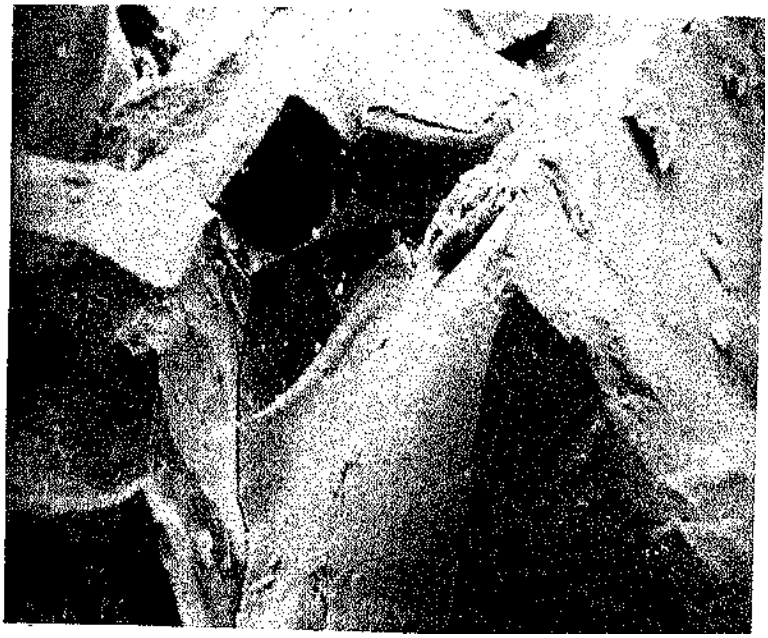


Fig. 3. SEM photograph of gneiss-A (magnification X 250)



Pig. 4. SEM photograph of gneiss N(magnification X 157)

Fig. 5 SEM photograph of gneiss A-6 (magnification X 510)

Fig. 6. SEM photograph of gneiss-N (magnification X 747)

Fig. 7. SEM photograph of melasyenite (magnification X 767)

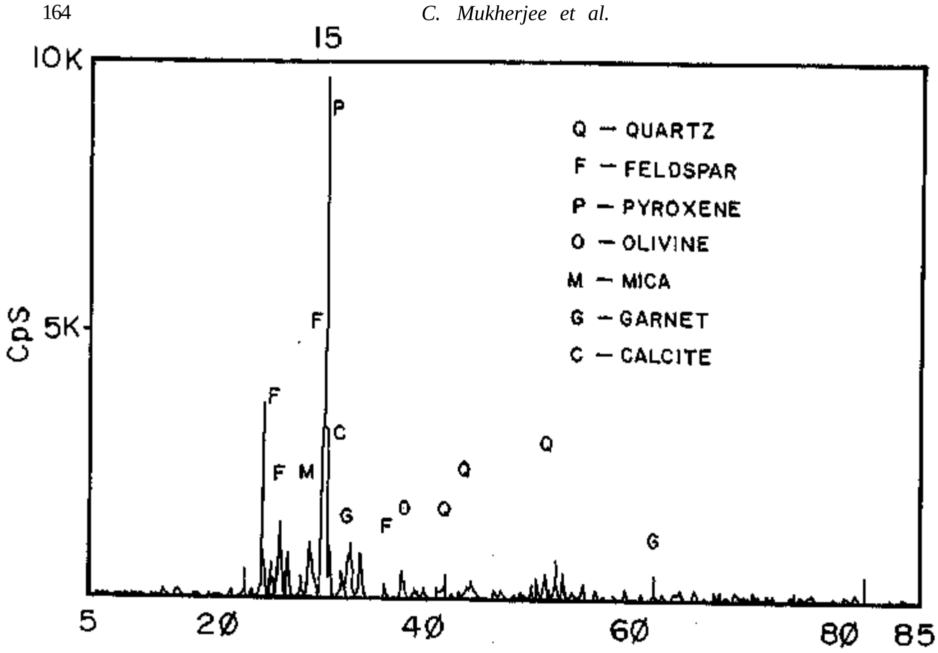


Fig. 8. X-ray diffraction pattern for basic granulite

Table II. Physical properties

Sample	Dry Density g/c.c.	Saturated Density g/c.c.	Grain Density g/c.c.	Water Absorption %	Void Index %	Effective Porosity %
Melasyenite	2.83	2.84	2.60	0.35	0.91	0.904
Gneiss - A	2.63	2.64	2.32	0.48	1.11	1.098
Gneiss - A6	2.67	2.71	2.62	1.65	4.32	4.143
Gneiss - B	2.79	2.81	2.57	0.50	1.29	1.270
Gneiss - C	2.70	2.71	2.57	0.38	0.98	0.975
Gneiss - D	2.89	2.91	2.74	0.73	2.00	1.957
Gneiss - N	2.66	2.67	2.49	0.29	0.73	0.721
Augen gneiss	2.84	2.86	2.88	0.74	2.12	2.077
Basic granulite	2.66	2.68	2.56	0.63	1.61	1.580
Basic granulite	2.66	2.68	2.85	0.70	2.00	1.964

Strength results from the limited number of tests of some of the rocks are presented in Table III. Tests could not be conducted on other rock samples due to non-availability of specimens. It is observed that the mean uniaxial compressive strength (σ c) and Brazilian tensile stength (o- tb) vlaues are 66 and 15 MP_a respectively for the Schirmacher hill range and Wohlthat mountain rocks. The

Table III. Strength parameter

Sample	UCS (MP_a)	Brazilian (MP_a) Strength	Young's Modulus (MP_a)	Poisson's Ratio
Melasyenite	11.88	—	—	—
Gneiss - B	66.88	—	273 X 10^3	0.31
Gneiss - C	65.15	15.36	235 X 10^3	0.68
Gneiss - D	—	14.19	—	—
Gneiss - N	—	7.80	—	—
Basic granulite	—	8.71	—	—

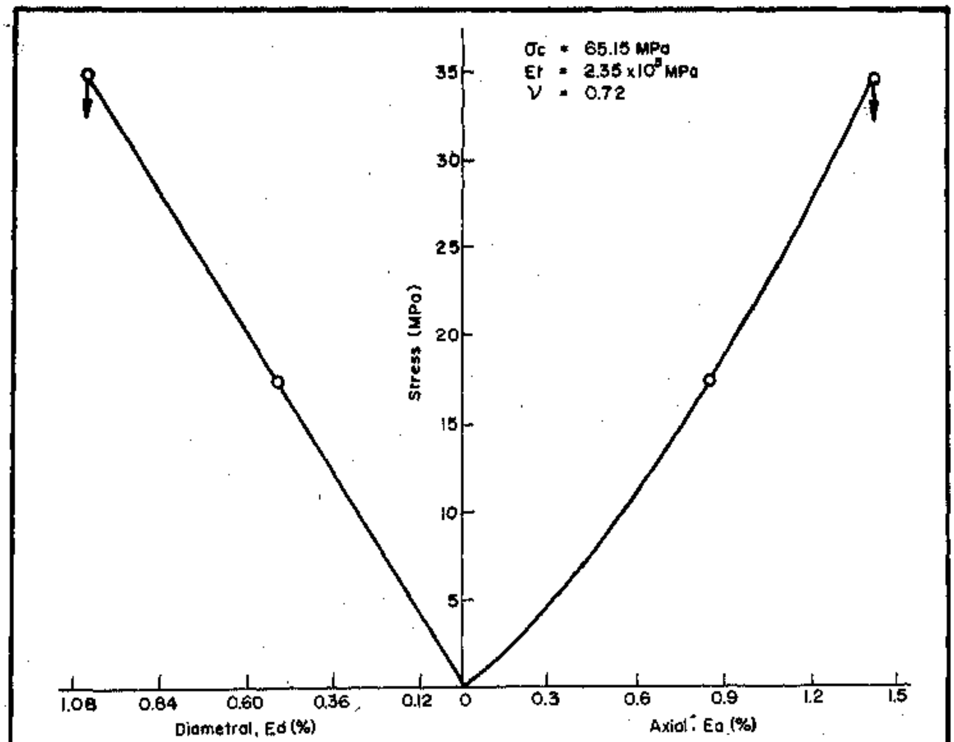


Fig. 9. Stress-strain curves for gneiss-B

Brazilian strength is 8 MP_a (approx.). These values are falling within the range of values generally suggested for such rock types with similar geological origin (Vutukuri *et al.,* 1974).

A typical stress-strain curve for Gneiss B is depicted in Fig. 9. The nature of the curve indicates the brittle behaviour of the rock. Young's modulii for Gneiss B and C are 273 X 10^3 and 235 X 10^3 MPa. Poisson's ratios of these are 0.31 and 0.68 respectively.

Permeability results obtained on gneisses and basic granulites are reported in Fig. 10. This shows the variation of coefficient of permeability K, with water head in pressure. For all rocks, it is clear that the permeability decreases with increase of water pressure. This is due to the fact that as the cell pressure increases the voids, microfissures in the rock specimens get closed resulting in the decrease of permeability. More or less the slope of the curves for all the rocks is same indicating similar effect of water pressure on the coefficient of permeability.

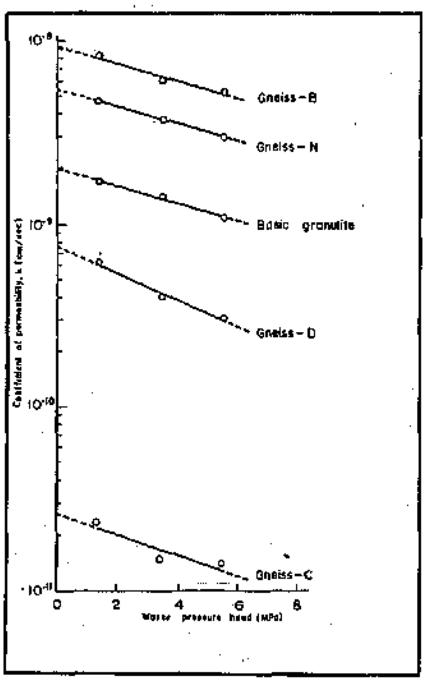


Fig. 10. Variation of coefficient of permeability with water head

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