Sedimentology of the Sea Bed Sediments from the Astrid Ridge, Princess Astrid Coast, Queen Maud Land, Antarctica

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ABSTRACT

Seabed sediments from the Astrid Ridge range from silty clay to sandy silt. The terrigenous component ranges from 72 to 95 per cent and the Feldspar/Quartz ratio from 0.54 to 2.7. The Scanning Electron Microscopy of quartz shows that the grains near the coast are sharp angular with conchoidal fractures while the grains away from the coast show V-shaped depressions and rounded edges. The angularity reflects the mechanical disintegration and transport by glaciers and ice sheets. The grains were subsequently locked up in ice which possibly led to the formation of V-shaped depressions later covered by deposition. Feldspar /Quartz ratio indicates the glacial aridity in the area and the predominance of plagioclases a gnessic schistose source i.e., the onshore Pre-Cambrians to the south. The predominent clay minerals are illite (73 to 91 per cent), chlorite (8 to 26 per cent) which are typical of the Antarctica sediments. The traces of smectite may represent derivation from Tertiary outcrops on the seabed, volcanic rocks in the Antarctica or even recent volcanic activity.

INTRODUCTION

The scientific programme of the First Indian Expedition to the Antarctica included marine research also. The marine geological and geophysical programme comprised bathymetry, side scan sonar, seismic profiling, magnetics and seabed sampling. The bathymetric and magnetic surveys were continued throughout the voyage of the vessel MV *Polar Circle* from India to the Antarctica and back. The side scan sonar and seismic surveys and seabed sampling were carried out in a limited area of the continental margin. The surficial sediment samples were collected from 7 stations ranging in depths from 227 m to 3580 m from the continental margin and adjacent seas of the Antarctica (Fig. 1). The samples were collected with a Peterson Grab with an area of 0.16 m^2. Five samples (G2-G6) were collected from the Astrid Ridge but samples Gl and G14 are away from the rest. The study and conclusions therefore are largely based on samples G2 - G6 while the results of analyses of other two samples have been used largely for comparison (Table I). The samples though limited in number add to the existing data base of the Southern Polar Seas and in addition provided the Indian Expedition an opportunity to study and compare the sediments of a completely different environment with those of the tropical seas surrounding the Indian subcontinent.

TABLE 1

Texture, clay mineralogy and carbonate content of these diment samples from the Astrid Ridge

Station No. and Location	G1	G2	G3	G4	G5	G6	G 14
Latitude(S)	67°13.5'	69°58.14'	69° 00'	68°43.5'	68°24.65'	67°46.37'	45°38.07'
Longitude(E)	39°12.3'	11°54.65'	13°41.05'	11°06.7'	11°11.67'	12°0.04'	40°24.62'
Depth(metres)	3580	227	2337	1661	2070	1990	1680
DATA PARAMETERS							
1. Sand (percent)	4.54	34.24	2.45	4.33	5.36	0.65	34.45
2. Silt (percent)	58.08	50.08	64.28	54.42	50.83	46.83	51.32
3. Clay (percent)	36.75	15.67	33.27	41.25	43.81	52.52	14.23
4. Texture	Clayey Silt	Sandy Silt	Clayey Silt	Clayey Silt	Clayey Silt	Silty Clay	Sandy Silt
5. Illite (percent)	61.4	73.5	89.8	88.0	91.1	84.5	12.2
6. Chlorite (percent)	38. 6	26.5	10.2	12.0	8.9	15.5	87.8
7. Terrigenous material (percent)	88.5	72.5	93.3	85.0	79.3	95.1	7.5
8. Peak height ratio F/Q	0.49	2.71	0.7	0.95	0.55	0.54	—
9. Peak height ratio PI/Or	0.9	2.27	3,64	4.5	2.67	3.53	—
10. Carbonate (percent)	11.46	27.55	6.74	14.98	20.67	4.85	92.52

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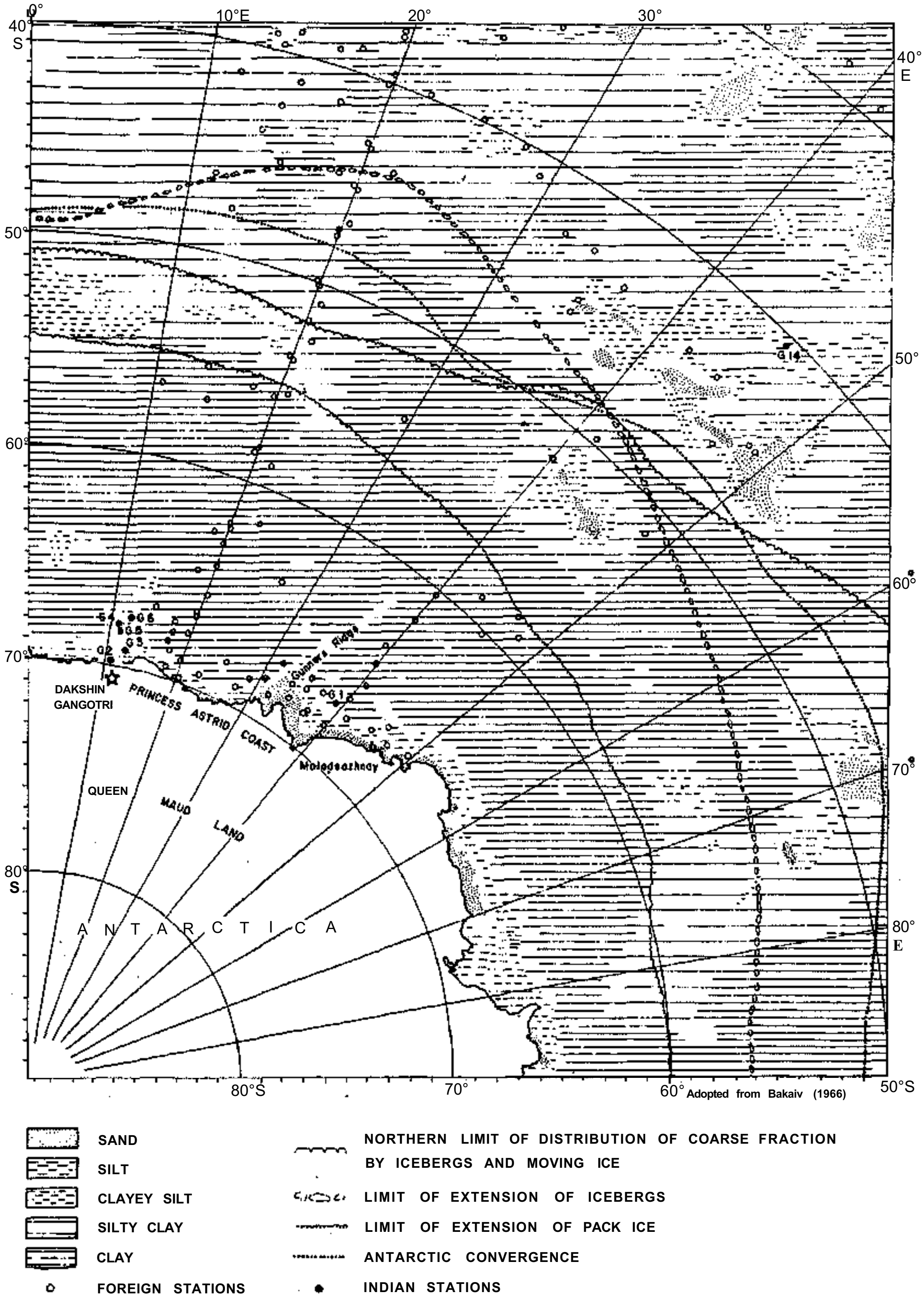

Fig. 1 : Map showing the distribution of sediments and stations on the continental margin, Queen Maud Land and the adjacent seas.

PREVIOUS WORK

The earlier work on the bottom sediments of the Antarctic continental margin and adjacent seas was carried out by Murray and Renard (1891), Murray and Philippi (1908) .and Philippi (1910) The major contribution to the study of bottom sediments was made during the International Geophysical Year when the Soviet RV *Ob* (1955-1959) and the US Expedition "Deep Freeze" (1954-1963) collected a large number of seabed samples. The results of studies on these samples by Lisitzin (1960 *a, b,* 1962, 1970), Goodell Mcknight, Osmond and Gorsline (1961) considerably enhanced the knowledge of the sediments of the Southern Seas. During 1968-1971 the USNS *Eltanin* and Lamont-Doherty Geological Observatory Expeditions on RV *Vema* and RV *Robert D. Conrard* collected more than 300 piston cores between Australia and Antarctica. The results of these studies were summarised by Hayes (1967), Conolly and Payne (1972), Payne and Conolly (1972). The sediment samples collected by the First Indian Expedition may be termed as a link in the same chain.

METHODS

The size analyses of the samples were carried out by conventional sieve and pipette methods tor the textural classification of sediments (Shepard, 1954). The clay fractions were separated and treated with dilute acetic acid and hydrogen peroxide to remove carbonate and organic matter respectively and oriented slides of clays were prepared. The slides were scanned from 3° to 30° 2θ to 2° per minute on a Philips PW 1130 X-ray Diffractometer using Ni filtered Cu K α radiations, proportional counter and pulse height analyser. The other instrumental settings were 20 mA, 40 kV, 4 second time constant and range of 200 counts per second. The relative proportion of the clay minerals was determined by measuring the area of their principal reflections.

The surface texture of the quartz grains was studied under a Scanning Electron Microscope (SEM). The sand and silt fractions of the samples were ground to less than 62µm for determining the ratio of quartz and feldspars (orthoclase and plagioclase) by X-ray diffraction. The sample powders were packed in aluminium sample holders and scanned between 25°and 30° 2θ for quartz, orthoclase and plagioclase.

RESULTS AND DISCUSSION

Texture of the Sediments

The results of size analyses (Table 1) indicate that based on Shepard's classification (1954) the samples range from silty clay to sandy silt. The sand fraction varies between 0.7 and 34.3 per cent, the silt fraction, the most abundant in the sediments, varies from 46.8 to 64.3 per cent and the clay fraction, the next abundant component, varies between 14.2 to 52.5 per cent. The sediments near the coast are sandy silt with pebbles while further seaward they tend to clayey silt and silty clay (Fig. 2). The petrology of the sand shows that quartz is the predominant component followed by feldspars, rock fragments, skeletal material (predominently foraminifera and few radiolarian and spicules etc.) and heavy minerals The composition of the.silt fraction is almost similar but the biogenous components (radiolarian and spicules) are considerably reduced. These sediments can be designated as terrigenous sediments because of more than 50 per cent clastic and clayey material (Lisitzin, 1972). The results are comparable with the generalized distribution of sediment types suggested by Hayes (1967) around Antarctica. According to

The relatively high percentage of sand (34.3 per cent) in the near cosatal samples is due to the deposition of the material locked in the ice sheets or iceberge while the fine grained glacialrock flour is carried farther from the coast and deposited in deeper waters.

Terrigenous material

Quartz and feldspar are themost common minerals of continentel rocks and their disturbution in an area reflect the extent of terrigenous contribution by differnnt transporting agencies. With

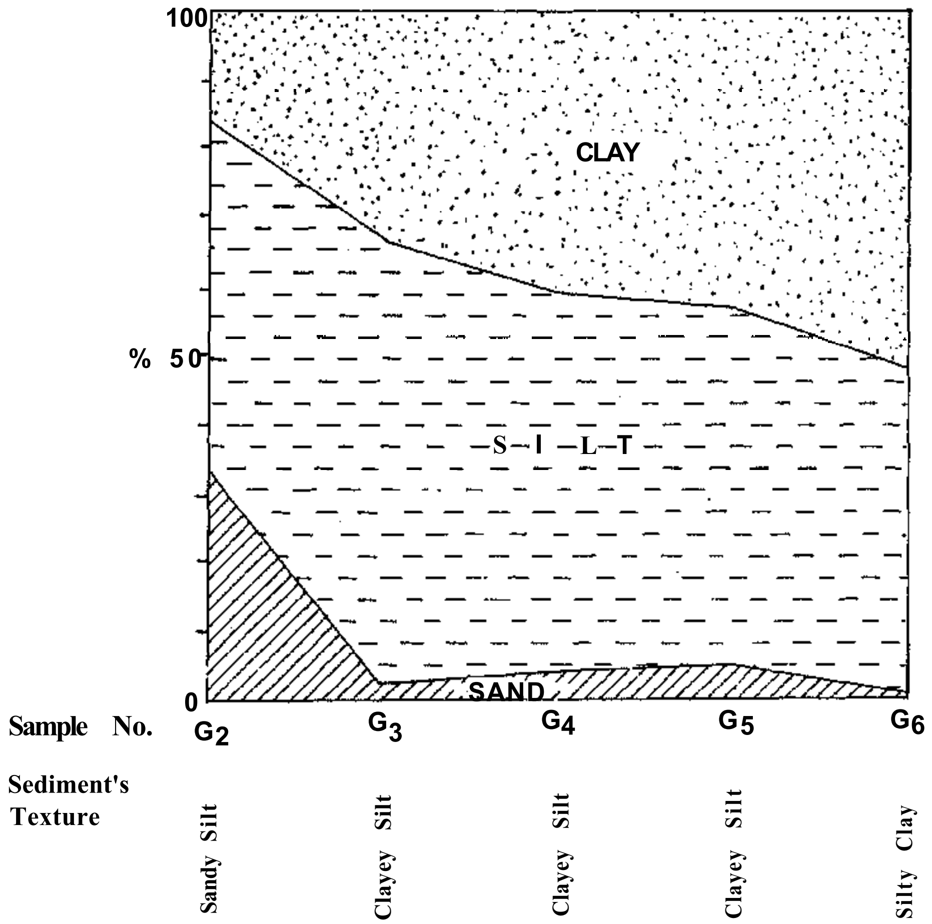

Fig. 2. Percentage of sand, silt and clay in the samples off the Princess Astrid Coast.

this view the relative distribution of these minerals were determined in the terrigenous material of the samples. The terrigenous material ranges from 72.5 to 95.1 per cent (Table 1, Fig. 3). The feldspar/quartz ratio in the sediments of the ridge decreases seaward (2.7 to 0.54) (Table 1, Fig. 3). The predominance of plagioclase indicates derivation predominently from gnessic and schistose rather than granitic rocks. The sediments are, therefore, derived from the Pre-Cambrian in the onshore areas to the south. The high percentage of the feldspars with higher plagioclase also confirms the glacial aridity in the area.

Surface texture of Quartz

The utility of the Scanning Electron Microscopy of the surface texture of quartz to decipher different sedimentary environments has now been very well established (Krinsley and Doornkamp, 1973). The samples contain little sand (excepting G2 and G14) but comparatively a large percentage of silt. SEM studies were carried out on representative quartz grains of sand and silt fractions prepared by the methods of Krinsley and Doornkamp (1973). Krinsley and McCoy (1977 a, b) have demonstrated that the silt grains though small are the broken fragments of the larger grains and thus retain some of the mechanical surface feature of the parent grain. The identification of quartz was confirmed by EDAX since in few cases unaltered feldspars also show similar fracture patterns and cleavage traces.

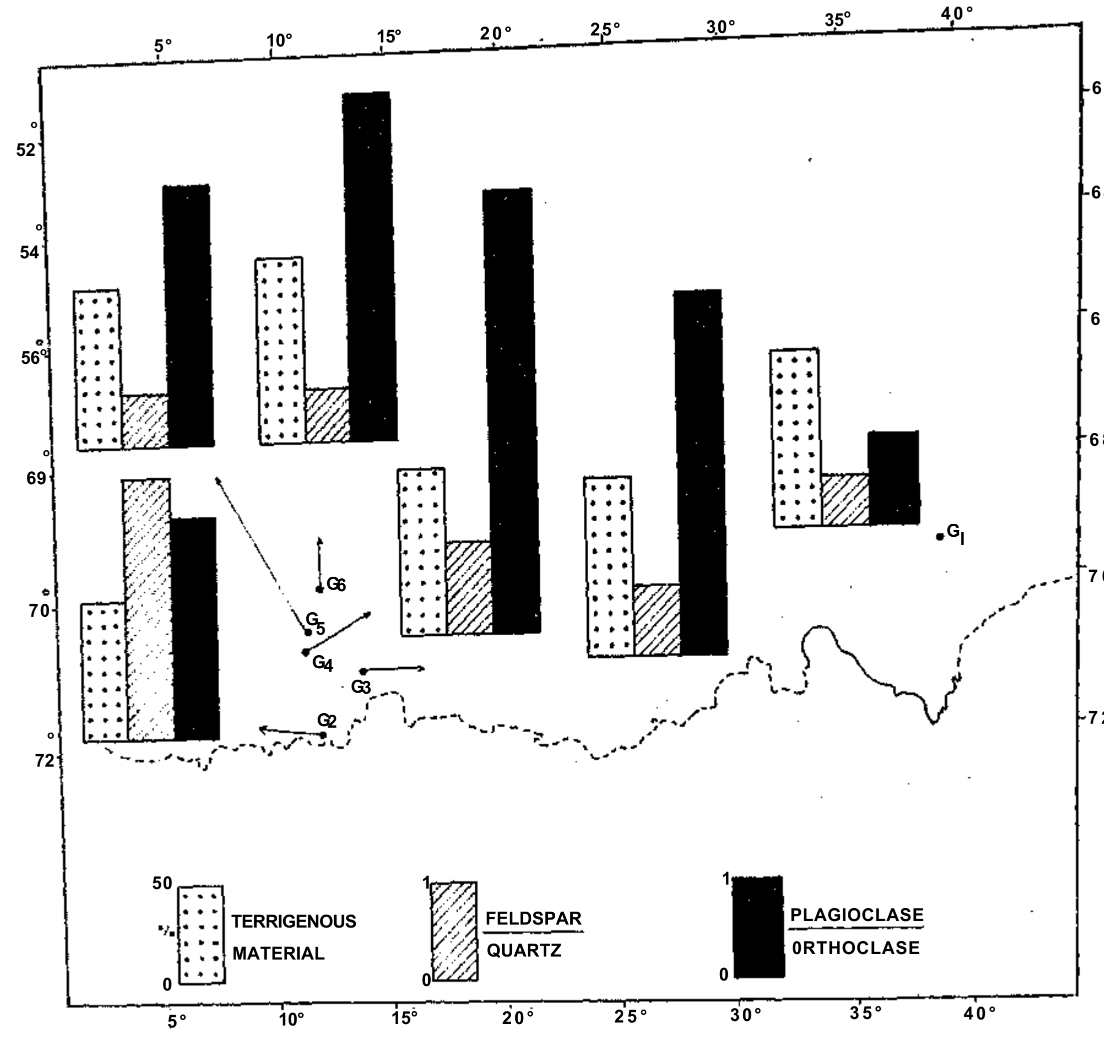

Fig. 3. Distribution of Terrigenous material, Feldspar/Quartz and Plagioclase/Orthoclase ratios.

The quartz in the samples near the coast (G 1 and G 2) is fresh, extremely angular with sharp edges and conchoidal fractures and shows very little effect of weathering (Fig. 4A). The conchoidal breakage patterns are irregularly distributed and vary in size and shape (Fig. 4B, 4C), the plates are thin and the edges are sharp (Fig. 4D, 4E). The particles adhering to the quartz grains are very flat, suggesting that they have at least one good cleavage. The surface on which these particles rest includes conchoidal breakage and upturned plates. Conchoidal breakage patterns are still seen in the grains away from the coast (Sample G6) but rounding of the edges and obscured features on the surface are conspicuous which could perhaps be due to solution and reprecipitation due to longer periods of locking in ice or subaqueous environment (Fig. 4F). A close observation of these grains shows numerous mechanical, subaqueous V-shaped depressions covered later by smooth solution - reprecipitation surfaces. This would seem to indicate that the sediments have passed through at least two different environments. The initial angularity and conchoidal fractures on the grains were developed due to mechanical disintegration and transport by ice and ice sheets. The grains subsequently were exposed to a subaqueous environment or locked in ice and

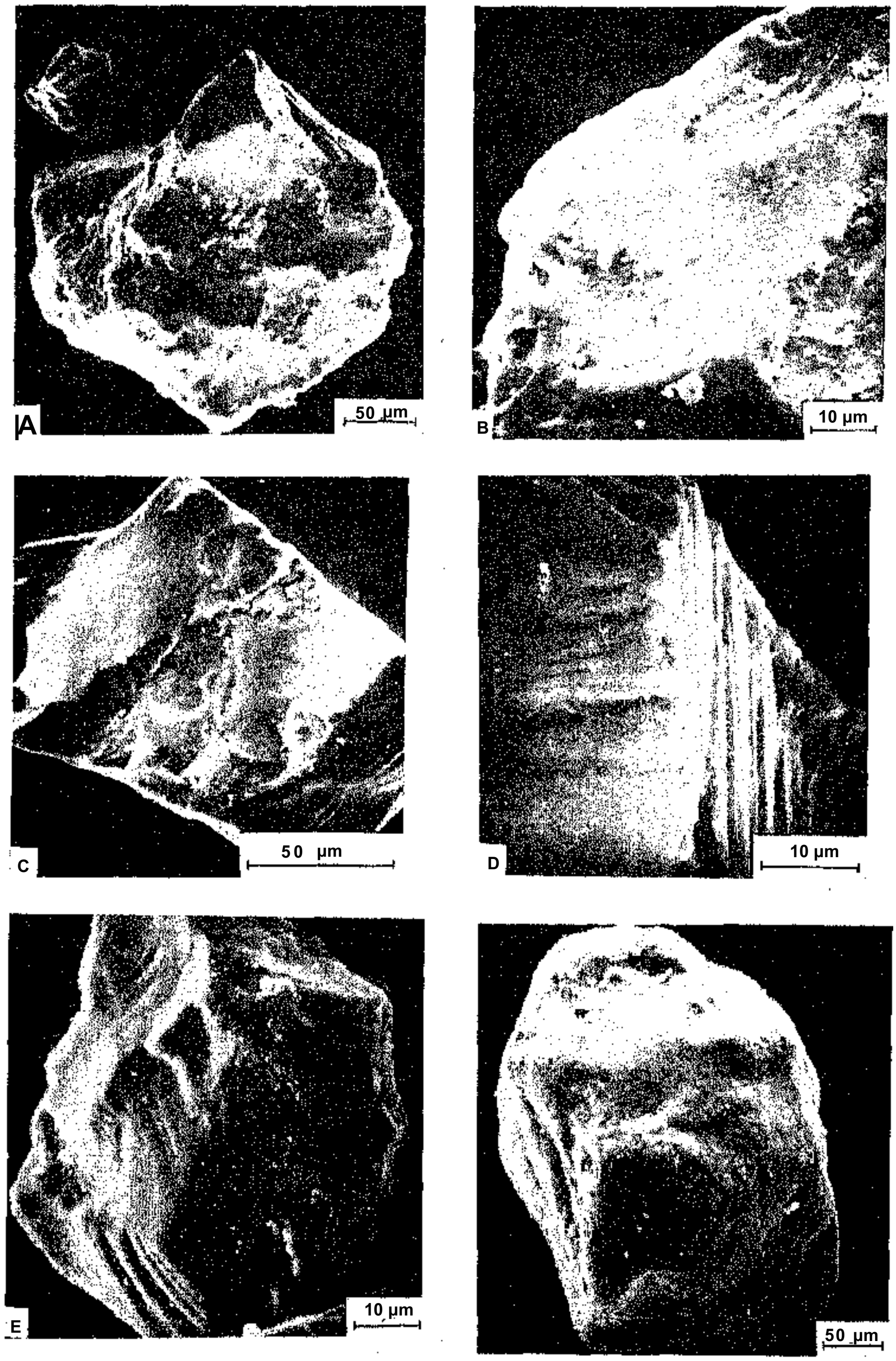

Fig. 4 : **Scanning Electron Photomicrographs of quartz grains from the sediment:
A-Fresh angular quartz grains with sharp edges and conchoidal fracture. B, C-Grains with irregular and varied conchoidal fracture. D, E-Sharp edge grains with thin plates. F-Conchoidal breakage pattern scattered over the surface, the edges are probably rounded by solution precipitation.**

transported by icebergs which led to the formation of V-shaped depressions and later covered by reprecipitation and deposition which also led to rounding of the angular edges.

Clay Mineralogy

The identifications of the clay minerals are confined in this paper to the group level of Brindly, Bailey, Faust, Forman and Rich (1968). The clay minerals present in the sediment samples are illite, chlorite and smectite. The non clay minerals recorded in the X-ray diffractograms are quartz, orthoclase, plagioclases and amphibolites. Illite is the dominant clay mineral (Table 1, Fig. 5) followed by chlorite while smectite is present in traces in samples away from the coast. These illites are well crystallised compared to those of the tropical region (Nair, Hashimi and Pumachandra Rao, 1982)

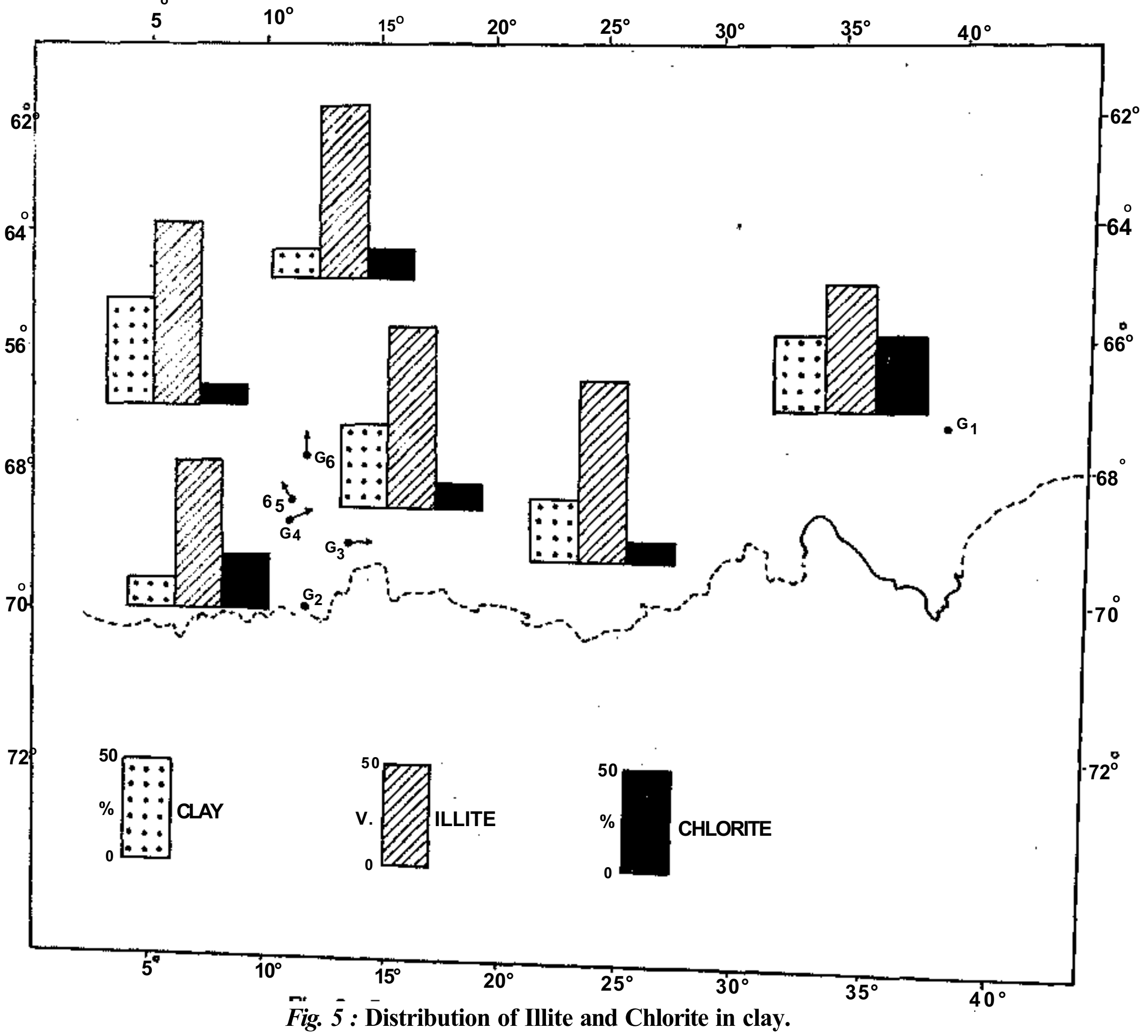

Fig. 5 : Distribution of Illite and Chlorite in clay.

The clay mineral assemblage off the Princess Astrid Coast is characterised by a very high percentage of illite (73.5 to 91.1 per cent) followed by chlorite (8.9 to 26.5 per cent) (Table 1, Fig. 5). Illite increases from the coast to seaward while chlorite decreases. This assemblage is common to glacial eroded rock flour from the Antarctica, while the traces of smectites are probably reworked from the Tertiary strata on the continental shelf and rise. (Moriarty, 1977) or probably represent the weathered and degraded products of onshore volcanic rocks (Bakaiv, 1966) or even recent volcanic activity (Fig. 6).

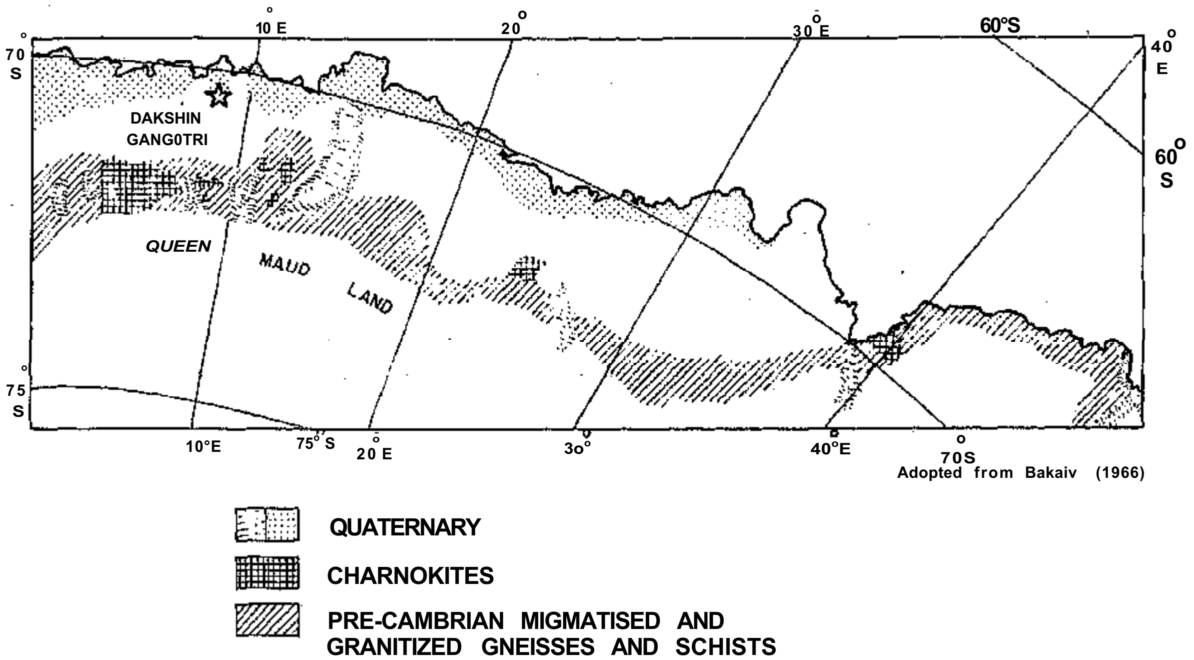

Fig. 6 : Geological map of Queen Maud Land, Antarctica.

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