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SCAR

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BULLETIN

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SCAR BULLETIN

No 15, September 1963

SOME ASPECTS OF THE CLIMATE OF ANTARCTICA

[Summary of a paper read at the Congress of the Australian and New Zealand Association for the Advancement of Science, Sydney, 1962.]

BY H. R. PHILLPOT*

CONTENTS

Introduction

A complete description of the climate of Antarctica should include a discussion of the main features of both the surface and upper air régimes of the entire region south of lat 50° S, i.e. including the sub-Antarctic islands as well as Antarctica itself.

Because of the limited amount of upper air climatological information available this summary has been confined to surface data.

The area south of lat 50° S may be conveniently subdivided into:

(*a*) the sub-Antarctic islands,
(*b*) the coastal strip of Antarctica, and
(*c*) the high interior of Antarctica.

Although the surface climate of the sub-Antarctic islands was considered in some detail by Fabricius (1957), and that of the continental coastal strip by Vowinckel (1957), investigators so far have not had the advantage of employing a uniform set of homogeneous meteorological data, particularly for the continent.

In the current investigation, an initial assessment is made of certain aspects of the surface climate of Antarctica, using principally the observations made by the network of reporting stations established for the International Geophysical Year (IGY), 1958, published in 1962 on a series of microcards by the World Meteorological Organization.

The method adopted is to use the surface observations for the four mid-season months—January, April, July and October—of 1958 to establish the degree of total cloudiness, the mean monthly surface temperature distribution and the behaviour of the surface wind. In addition, all available observations

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are used to derive the probable "long-term" values of mean monthly surface temperature. These elements are selected because of their importance in the daily analysis programme of the International Antarctic Analysis Centre. The network of reporting stations used is shown in the table.

Network of stations used

Station	Lat °S	Long	Station	Lat °S	Long
Puerto Santa Cruz	50° 01′	68° 32′ W	"Ellsworth"	77° 43′	41° 08′ W
Ushuaia	54° 48′	67° 45′ W	"Byrd"	79° 59′	120° 00′ W†
Stanley	51° 42′	57° 52′ W		80° 01′	119° 31′ W
Grytviken (South Georgia)	54° 17′	36° 30′ W	"Little America"	78° 12′	162° 15′ W
			"Roi Baudouin"	70° 26′	24° 19′ E
Signy Island	60° 43′	45° 36′ W	"Syowa"	69° 00′	39° 35′ E
"Orcadas"	60° 44′	44° 44′ W	Taylor	67° 27′	60° 52′ E
"Teniente Camara"	62° 37′	59° 57′ W	Mawson	67° 36′	62° 52′ E
"Almirante Brown"	64° 53′	62° 52′ W	Davis	68° 35′	77° 58′ E
"Melchior"	64° 20′	62° 59′ W	Mirny	66° 33′	93° 01′ E
"Decepción"	62° 59′	60° 43′ W	"Pionerskaya"	69° 40′	95° 40′ E
Argentine Islands	65° 15′	64° 16′ W	"Komsomol'skaya"	74° 05′	97° 29′ E
Marion Island	46° 53′	37° 52′ E	"Sovetskaya"	78° 24′	87° 35′ E
Iles Kerguelen	49° 21′	70° 12′ E	"Vostok I"	72° 08′	96° 35′ E
Heard Island	53° 01′	73° 23′ E	"Vostok II"	78° 27′	106° 52′ E
Auckland Island	50° 33′	166° 12′ E	"Oazis"	66° 16′	100° 44′ E
Campbell Island	52° 33′	169° 09′ E	"Wilkes"	66° 15′	110° 32′ E
Macquarie Island	54° 30′	158° 57′ E	"Dumont d'Urville"	66° 40′	140° 01′ E
"Sanae"/"Norway Base"	70° 30′	02° 52′ W	"Charcot"	69° 22′	139° 01′ E
			"Hallett"	72° 19′	170° 13′ E
"Lazarev"	69° 58′	12° 55′ E	"McMurdo"	77° 51′	166° 40′ E
"Novolazarevskaya"	70° 46′	11° 50′ E*	"Scott Base"	77° 51′	166° 45′ E
"Amundsen–Scott" (South Pole)	90° 00′				
Halley Bay	75° 31′	26° 36′ W			

* Site changed February 1961.
† Site changed February 1962.

Before discussing the climate of the continent, a brief summary is given of its principal physical features, and the general circulation of the atmosphere over the middle and high southern latitudes.

Principal physical features of Antarctica

Antarctica is some 5·3 million square miles in area (including the ice shelves in the Ross and Weddell Seas) and is almost completely ice-covered even in summer. It contains almost 90 per cent of the grounded ice in the world. During winter, when the surrounding ocean freezes, the ice sheet extends northwards and is thick enough to be regarded meteorologically as an extension of the continental ice sheet. In effect this doubles the area of the ice coverage.

There is a most pronounced ice contour gradient very close to the continental coastline. In "East Antarctica" the height of a very great part of the plateau exceeds 3 km, and probably reaches a little more than 4 km. This is illustrated in Fig. 1.

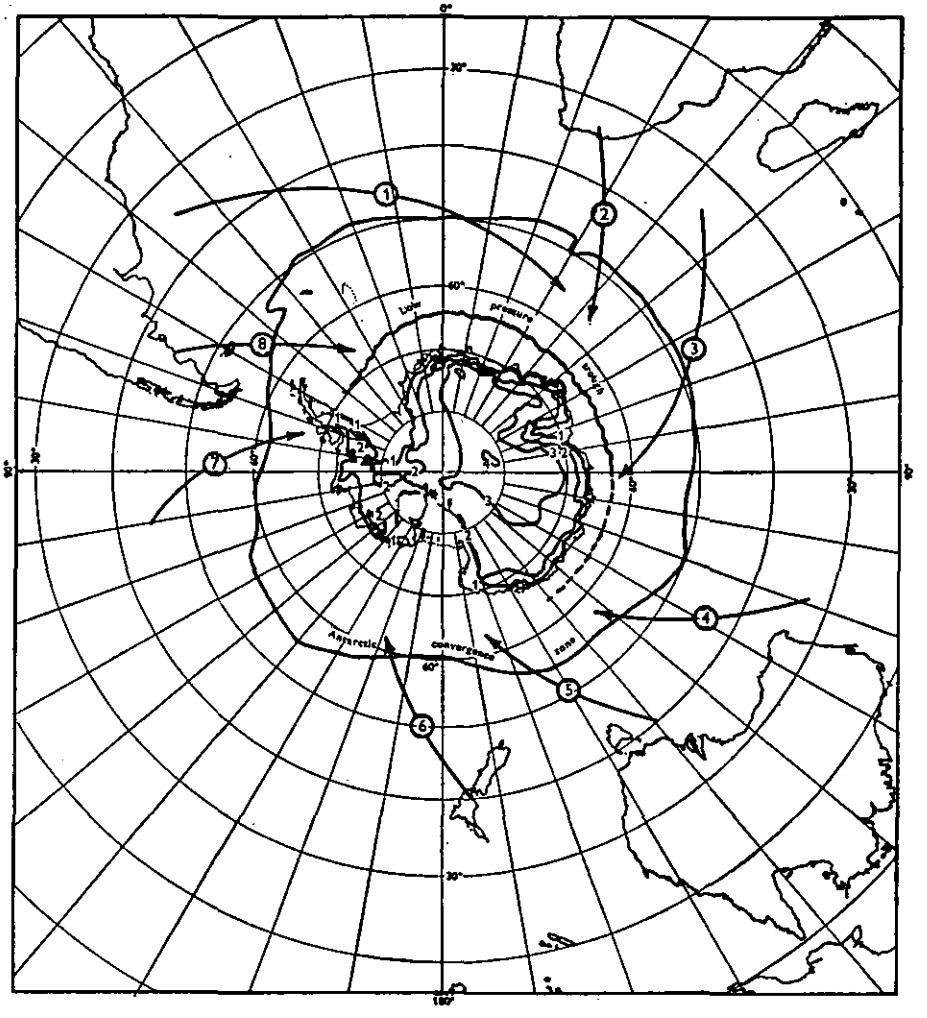


Fig. 1. (*a*) The approximate mean tracks of depressions approaching Antarctica, and the persisting low-pressure trough, (*b*) the Antarctic Convergence Zone and (*c*) the 1, 2, 3 and 4 km ice contours over the continent.

General atmospheric circulation

The main points are:

(i) There is, in general, a well-defined westerly air circulation between about lat 35° and 60° S, to the north of which is a belt of essentially migratory type anticyclones.

(ii) There is only a small variation in the middle latitude pressure gradient throughout the year, and the average zonal westerly index between lats 35° and 55° S varies only between 12 and 14 knots.

(iii) The westerly air circulation is deformed both by travelling cyclones and high-pressure ridges, but the behaviour and movement of the travelling cyclones is most important.

(iv) Although generalized mean tracks can be established for these depressions (see Fig. 1) the persistence of a low-pressure trough around the Antarctic coastline often makes it difficult to determine the precise path followed by a depression as it approaches the continent.

(v) Some depressions appear to move on to the continent, although most skirt it.

(vi) At a particular station, the approach of a depression is heralded by falling pressure, rising temperature and strong winds, but the severity of a blizzard cannot be assessed by the degree to which the pressure falls.

(vii) Antarctic depressions conform to the two main types observed elsewhere in the world, namely warm cored, where the low pressure axis has a marked poleward slope with height, and cold cored, where there is little slope to the axis. It is most important to identify each depression because the weather characteristics of each are markedly dissimilar.

Cloud over Antarctica

Although the observation of cloud amount in temperate regions is reasonably reliable, this is not always true in high latitudes. For example, in the Antarctic:

(*a*) a very thin haze, often observed over the whole sky, makes it difficult to determine whether the sky is clear or overcast; and

(*b*) the long periods of winter darkness make accurate assessment difficult.

From an analysis of the total cloud cover observed at all stations during each of the four months January, April, July and October 1958, a series of isopleths representing the average amount (in oktas, or eighths, of sky cover) of total cloud observed in each month, is shown in Fig. 2. Subject to the limitations imposed by the reliability of the observations, and the sparse network, the patterns appear reasonable, the total cover decreasing from an average of about 6 oktas in coastal areas to (suggested) minima of 1 to 3 oktas over the high plateau of "East Antarctica".

There is evidence of a decrease in total cloud amount over the inland area of the continent between January 1958 and July 1958, which may be partially accounted for by the extension of the ice sheet in winter. However, in July 1958, the average degree of cloudiness along the coast from Davis to Wilkes, and almost to "Dumont d'Urville", is higher than in January 1958.

Although the observational data from "West Antarctica" are limited to "Byrd" station, it would appear that this area is rather cloudier.

Surface air temperature

The probable mean monthly surface air temperature distribution has been determined:

(*a*) by using values for each of the months January, April, July and October 1958, to draw the four mean monthly surface isotherm charts; and

(*b*) amending the isotherms as necessary to conform to the "long-term" mean monthly values from stations with longer periods of record.

Maximum value is thereby derived from both the homogeneous observations obtained in 1958, and those representative monthly means obtained from records extending over other and longer periods.

The technique employed in drawing the isotherms is to give close attention to the ice elevation, and to endeavour to relate the positions of the isotherms and the ice contours.

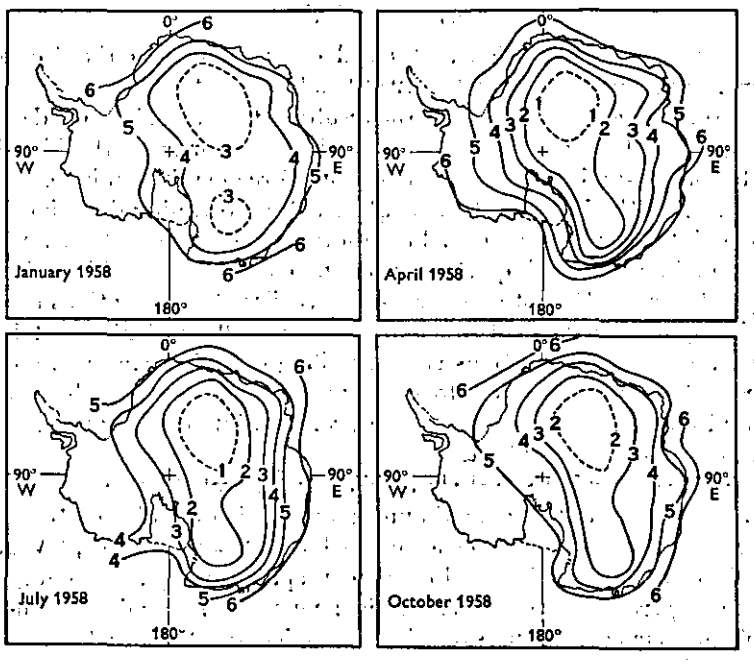


Fig. 2. Isopleths of the average amount (in oktas) of total cloud cover over Antarctica in January, April, July and October 1958.

Two points, neither of which is surprising, emerge:

(*a*) the mean surface air temperature decreases with elevation up the ice slope at a rate exceeding the dry adiabatic value (i.e. $\cong$ 10 °C/km); and

(*b*) there appears to be a small latitude effect, i.e. for a given altitude, the mean temperature decreases with increasing latitude.

The mean surface isotherms for each month—January, April, July and October—are shown in Figs. 3 and 4. In extending them over the sea, consideration has been given to the position of the Antarctic Convergence Zone, the available sub-Antarctic island observations, the mean extent of the surface ice pack, and the reports made by the ship located near lat 60° S, long 170° E during the summer months, when flying operations are conducted between Christchurch and "McMurdo".

The sources of data are described fully in the list of references.

Extreme maximum and minimum surface air temperature records suggest that in summer the maximum temperatures along the coast rise to about +8 °C, but inland on the high plateau the maxima, as shown by "Vostok II", do not rise above −21 °C (−5·8 °F). Winter minima of −30° to −40 °C are experienced on the coast whilst in the interior values fall to −70° to −80 °C. The lowest recorded temperature of −88·3 °C (−126·9 °F) is that experienced at "Vostok II" on 24 August 1960.

Surface wind régime

The surface wind direction and speed observed during the four months January, April, July and October 1958 has been analysed.

It is rather difficult to summarize the results of the analysis of wind direction. It is apparent that there is a general drainage of air from the high interior down to the coast with the coriolis deflecting force playing an important part. For stations in the interior of the continent the prevailing direction is determined mainly by the ice slope, but approaching the coastline, an easterly component increases in importance; on the coast the prevailing direction is largely between south-east and north-east. Whilst at most stations the surface wind throughout the year blows from directions falling within one fairly well-defined range, at some stations two prevailing direction ranges are observed. It is rare for wind direction to show marked variability. However, local topography undoubtedly exerts such a profound influence that it is unsafe to generalize to any great extent.

The analysis of wind speed shows that in general the mean is quite high. Even at the South Pole the maximum frequency is found in the 10 to 19 knot speed range. The three stations at higher levels, "Sovetskaya", "Vostok II" and "Komsomol'skaya" show lower mean speeds but (in the main) with no appreciable percentage of calms. Stations near the higher limit of the coastal escarpment, such as "Pionerskaya" and particularly "Charcot", show higher mean speeds.

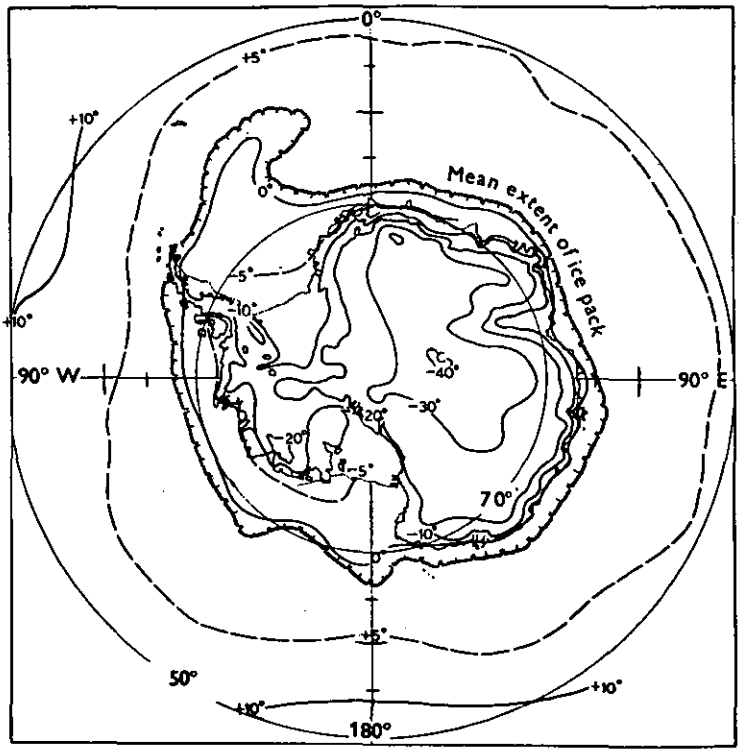
The high wind speeds experienced on the coast are well known. Vowinckel (1957) has pointed out that the mean annual wind speed of 40·2 knots found in the Cape Denison area is the highest in the world.

The precise extent along the coast of this very strong wind régime is not known; west of Terre Adélie the average appears to be about 15 knots, although at Mawson it is 23 knots.

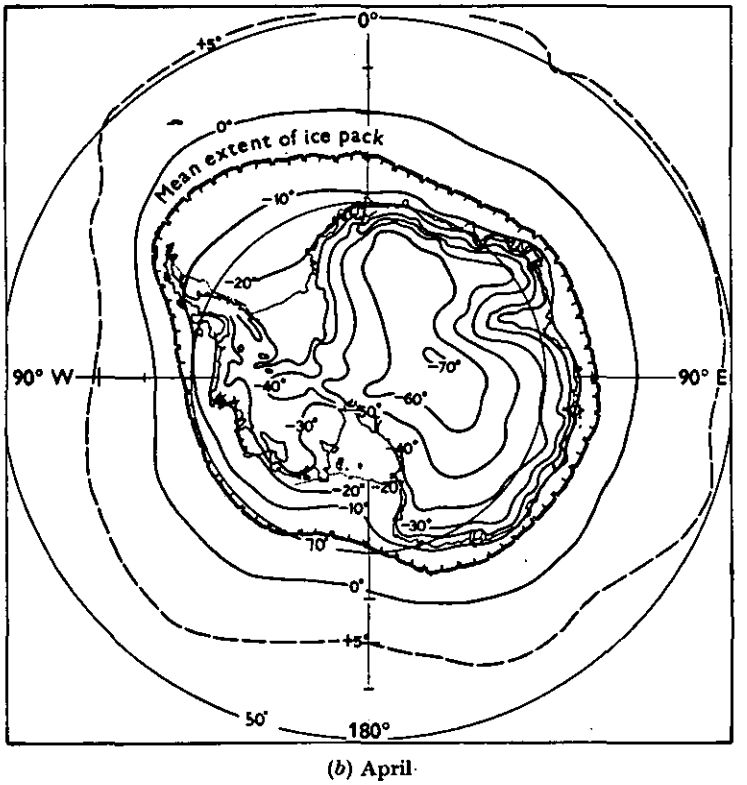
Observations from ships show that only a few miles off the coast the speed drops considerably. All coastal stations probably experience maximum wind gusts of the order of 100 knots. In the interior of the continent, the South Pole station has reported a maximum gust of 47 knots.

Conclusions

An examination of total cloudiness, surface air temperature, and surface wind for Antarctica, based on data for the four (mid-season) months of

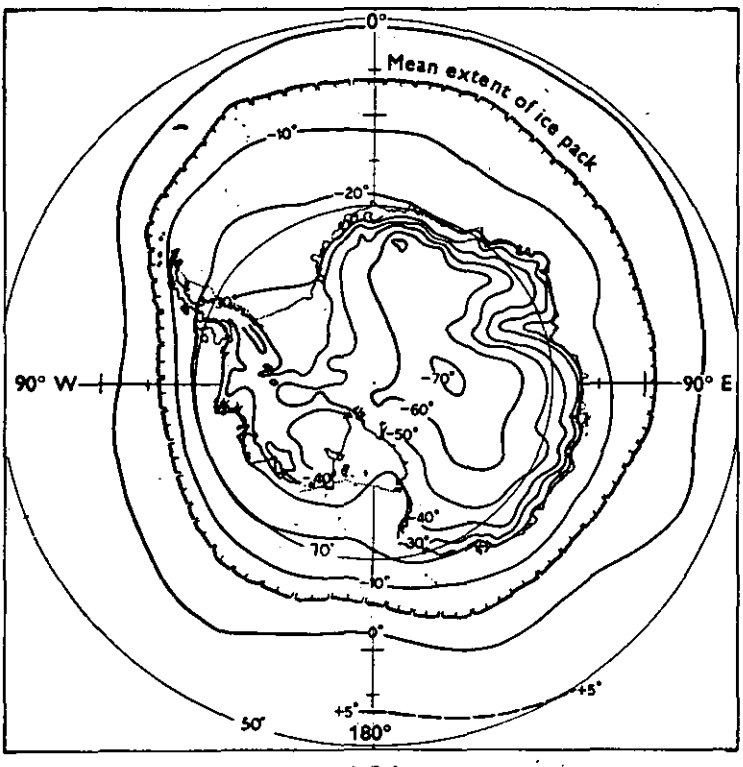


(*a*) January

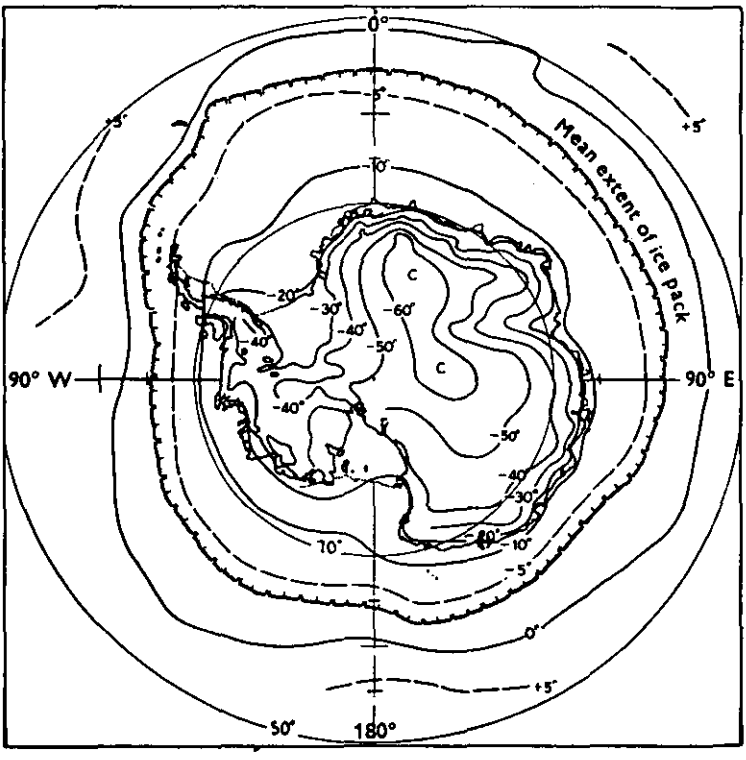


(*b*) April

Fig. 8. Mean monthly surface isotherms expressed in °C, January and April.



(*c*) July



(*d*) October

Fig. 4. Mean monthly surface isotherms expressed in °C, July and October.

January, April, July, October 1958, and additional air temperature observations shows that:

Total cloudiness

(i) There is a decrease from an average of about 6 oktas in coastal areas to minima of 1 to 3 oktas over the high plateau of "East Antarctica".

(ii) There appears to be a slight decrease over the inland areas in winter; and

(iii) The average degree of cloudiness appears to be higher over "West" than "East Antarctica".

Surface air temperature

(i) Mean temperatures around most of the coast of "East Antarctica" vary from near 0° C in midsummer, to −10° to −15 °C in autumn and spring, and reach nearly −20 °C in mid-winter.

(ii) In the higher latitudes of the Weddell and Ross Sea sectors, the values are −4° to −8 °C in summer, −18° to −28 °C in autumn and spring, and −27° to −36 °C in mid-winter.

(iii) North of the continental coastline the mean temperature increases with decreasing latitude, and in the vicinity of lat 50° S becomes about 5° to 10 °C in summer, about 2° to 7 °C in autumn and spring, and about 1° to 5 °C in winter.

(iv) Inland, surface temperature decreases with elevation, and in the highest areas mean values range from −25° to −35 °C (and perhaps −40° C) in summer; from −50° to −65 °C (and perhaps −70 °C) in autumn and spring, and from −60° to −70 °C in winter.

(v) Temperature extremes range from maxima in summer of +8 °C on the coast and about −20 °C in the high interior, to winter-time minima of −30° to −40° C on the coast and −70° to −80 °C in the high interior.

Surface wind

(i) The prevailing wind direction for stations in the interior of the continent is determined mainly by the ice slope, but on the coastline is mostly between south-east and north-east.

(ii) The prevailing wind throughout the year blows from directions falling within one fairly well-defined range at most stations, but at some stations two prevailing direction ranges are observed.

(iii) Mean wind speeds are generally high and even in the high interior, where the mean speeds are low, calms are infrequent.

(iv) On the coast, where the high winds are well-known phenomena, the highest values of annual average wind speed (40 knots or more) are found in the Terre Adélie sector, the general average is about 15 knots apart from the area near Mawson where it is about 23 knots.

(v) All coastal stations probably experience maximum wind gusts of the order of 100 knots; in the interior, the South Pole station has reported a gust of 47 knots.

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ABSTRACTS OF PAPERS TO BE READ DURING THE SYMPOSIUM ON ANTARCTIC GEOLOGY TO BE HELD IN CAPE TOWN, 16 TO 21 SEPTEMBER 1963

Place-names in these abstracts are those used by the authors of the papers. Since, however, some of these can only be found on maps which are not readily accessible, the name according to the policy followed by the *Polar Record* is added in square brackets when it is considered that such information will help the reader.

Section 1. Sub-Antarctic islands

TITLE: Recent data on the geology of Iles Crozet

AUTHOR: P. Bellair, Laboratoire de Géologie du SPCN, Paris

In the course of a recent summer expedition to the sub-Antarctic islands, Ile aux Cochons and Ile de la Possession were visited; Ile de l'Est was approached to within several metres but nobody could land there. Ile aux Pingouins and the great reef of Iles des Apôtres were only observed from a distance. The latter islands appear to be volcanic dykes aligned along a large fracture.

On Ile aux Cochons, Ile de la Possession and Ile de l'Est there is a raised marine level ±10 ft (±3 m) above the coastline, and probably equivalent to similar levels of the temperate seas (which could be interpreted as marking the last climatic optimum).

On Ile aux Cochons the volcanism is subactive with the rock compositions along the boundary between the andesites and the basalts; a small lapilli cone which overlaps the 10 ft (3 m) level has an age of less than 5000 years and is probably much more recent. On the contrary, volcanism at Ile de la Possession is much older, and at Ile de l'Est the volcanic features show more severe dissection.

On the surface of Mont Branca, on Ile de la Possession, there is an intensely indurated breccia which is certainly ancient, and the cliffs on the east of the island are composed of beds of coarse material alternating with bands of dark basalt. Certain of the flows show enormous augite crystals several centimetres in size and with perfect mineralogical form; some of these have been found isolated. Chemical analyses which are now in progress will define the magmatic character of these very isolated volcanoes of the southern Indian Ocean.

TITLE: The volcanism of Presqu'île Rallier du Baty (Iles Kerguelen)

AUTHORS: P. Bellair and J. Nougier, Laboratoire de Géologie du SPCN, Paris

In the rather monotonous group forming the major part of the Iles Kerguelen, Presqu'île Rallier du Baty in the west is an exception. Here there are granular quartzitic rocks with aplites and pegmatites at their margins containing vesicles with quartz and sodic amphibole crystals.

The whole forms a typical "volcano pluton" which injects the old fissure basalts (called trap basalt) constituting the base of the archipelago. At Presqu'île Rallier du Baty one can see the contacts (with magmatic stoping) on the 2625 ft (800 m) elevations. The acid granular rocks are certainly a magmatic differentiate of a basic formation.

Overlapping all these rocks are the products of a recent basaltic volcanic eruption with more acid pumice scattered about; the body cutting the acid granular rocks has only given rise to small pumice cones with a diameter often less than 325 ft (100 m), traversed in the final phase at depth by stocks of prismatic basalt but only rarely producing weakly developed offshoots. Certain of these embryonic volcanoes overlap recent moraines. Eruptions have never been recorded; only the fumaroles were seen in 1912 and rediscovered in 1962, and the bodies responsible for them have not been located.

It is probable that the granular rocks represent a deeper *in situ* phase of the magma of the phonolitic bodies described by Aubert de la Rüe a short time ago from the volcanoes forming the peaks in the peninsulas of the south-east of the archipelago (Jeanne d'Arc, Ronarc'h and Courbet). The detail of this peculiar volcanism is at present the subject of a study by J. Nougier in collaboration with whom the terrain was examined in January 1963.

TITLE: Some geological observations on Heard Island

AUTHOR: P. J. Stephenson, University College of Townsville, Australia

In the early months of 1963 an expedition sponsored by Australian National Antarctic Research Expeditions worked on Heard Island. The expedition visited parts of the island not previously explored geologically and in the light of these observations some re-interpretation of the island's geology is necessary.

The oldest rocks exposed on Heard Island are foraminiferal limestones of Lower Tertiary age, intruded by intermediate hypabyssal rocks. Thick glacial beds with interbedded volcanic rocks (numerous pillow lavas) rest unconformably on the limestones and intrusive rocks. In turn, the thick volcanic sequence composing the Big Ben volcano, 9000 ft (2750 m) high, lies above these glacial beds, in places with unconformity. Numerous dykes are associated with this volcano. The most recent volcanic activity has been from the excentric summit cone of Big Ben, and from numerous small cones distributed near the coast of the island.

Section 2. Geomorphology

TITLE: Sea-level changes in the Scotia Arc and Graham Land

AUTHOR: Raymond J. Adie, British Antarctic Survey, University of Birmingham, England

Contrary to earlier observations, there is abundant evidence of raised beaches, wave-cut platforms, sea caves and sea stacks along the coasts of the islands of the Scotia Arc (South Georgia, the South Sandwich, South Orkney and South Shetland Islands) and the Graham Land peninsula. An analysis of field observations and air photographs of this region shows that the oldest known raised beaches and wave-cut platforms are probably of late Pliocene age, whereas the youngest ones are of a late Recent age.

The progressive recession of a formerly more extensive ice sheet and the subsequent isostatic recovery of the southerly landmasses in this region are reflected in the older marine levels. Available evidence also indicates there have been at least three slight

re-advances in the general recession of the ice sheet. The rate of isostatic adjustment in this region is also discussed.

Although no information on the absolute dating of these levels is yet available, there is a general correlation between the marine levels of this region and those of East Antarctica.

TITLE: Volcanic activity at Deception Island

AUTHOR: Lorenzo Casertano, University of Chile, Santiago

Deception Island has been considered as a sequence of volcanoes. Can it be considered as being a single volcano? Both the bottom forms of the lagoon and the distribution of depth are accepted here as positive evidence favouring this interpretation. Glacial phenomena are responsible for much of the disturbance in the attitude of the pyroclastics and lava flows. The caldera can be considered as a form due to magma activity rather than the collapse of the central part by subsidence.

Present activity can also be considered as the product of a single centre. The presence of volcanic bombs on the ice cap of Mount Pond is strongly suggestive of recent paroxysmal activity.

Thermal and fumarolic activity were obvious to visitors long ago. Vapour emission in Pendulum Cove is greater at low tide. Temperature observations were done along a line parallel to the coast and observed temperatures range between 63° and 3 °C. The changes in volume are easily explained by melt water, in such a way that only one centre is accepted.

Observations carried out over several days showed that the augmentation of melt water was dependent on air temperature. As was pointed out by Hawkes, a connexion with the fluctuations of tides has been recognized.

In Fumarole Bay a temperature of 100 °C was observed on 1 February 1962. Observations carried out in other different parts of the island show that the main activity is located along a circular zone near the shore of the lagoon. This distribution is strong evidence favouring the idea of a single thermal centre on the island. The present-day activity can be considered as a final stage of evolution, and the island is considered as a still-active volcano.

TITLE: Coastal phenomena in the South Shetland Islands

AUTHOR: Humberto Fuenzalida, University of Chile, Santiago

Ice-free coasts are found at several places in the South Shetland Islands. Fragmental material is freely available to the surf and some features of an aggradation coast are developed.

In Bahía Chile [Discovery Bay, Greenwich Island] a platform of glacial detritus has been formed, perhaps by a further extension of ice in recent times. It forms a promontory. This platform shows some features developed by wave-action. Away from the shore some smooth ridges, suggestive of beach ridges, with a height of 1·5 ft (0·4 m) can be recognized. Two or three of the ridges are so developed that on their inner sides there is a depression, forming a lagoon of melt water during the summer.

Near this inlet the wave-action is ineffective, but along the outer part of the promontory a strong surf has been observed. The wave energy is able to transport glacial debris and round it. There is a gradual transition between etched and rounded stones along the shore, in the same proportion to the increase in the energy of waves. In the latter part the beach ridge is more prominent in character and more clear-cut.

Lateral transportation plays little part because the waves break parallel to the coast, but there is evidence that wave-action is quite competent to adjust the coastline. The exact process of rounding the rock fragments can be followed.

Phenomena of this nature are common in this island and some large features on the coast, such as Yankee Harbour on the southern side of Greenwich Island, have originated by the transportation of pebbles, and modelled by wash into fine spits.

TITLE: Pre-glacial geomorphology of Alexander Island

AUTHOR: L. C. King, University of Natal, Republic of South Africa

Alexander Island, 300 miles (480 km) long and situated in about lat 70° S, is separated from the main plateau of Graham Land by the rift valley of George VI Sound. As part of the circum-Pacific mountain girdle, the structure of the island is largely broken up into fault blocks; but the island has also behaved as a whole in such a manner that, like a dinghy weighted at the stern, the northern end (prow) rides high in mountains rising 10000 ft (3050 m) out of the sea, while the southern end sinks low and is ultimately submerged beneath accumulations of ice and snow.

The axial ranges are transected by three transversely faulted valleys at the Hampton, Grotto and Uranus Glaciers.

TITLE: The saline lakes of the Vestfold Hills, Princess Elizabeth Land

AUTHOR: I. R. McLeod, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia

The Vestfold Hills, one of the "Antarctic oases", is an area of bare rocky hills with numerous lakes.

Some of the lakes are very saline. Surface water samples have been collected at irregular intervals over a period of six years from four of these lakes which occur in an east–west trending valley. Samples collected at different times from the same lake show a considerable range in the content of total dissolved solids, due probably to the inflow of water from melted snow. The content of total dissolved solids may be as great as 27 per cent; the predominant ions are sodium and chloride.

The surfaces of all four lakes are below present sea level. Molluscan remains, of species still living around the Antarctic coast, are common in places around them.

The valley in which the lakes occur was originally an arm of the sea. The lakes were probably isolated by a eustatic fall in sea level and the sea water was subsequently concentrated by evaporation.

TITLE: Quaternary marine sediments and their geological dates with reference to the geomorphology of Kronprins Olav Kyst

AUTHORS: Hiroshi Meguro, Tohoku University; Kunihiko Kigoshi, Gakushuin University; Yoshio Yoshida, Ochanomizo University; Takayasu Uchio and Ken Sugawara, University of Tokyo, Japan

Many small ice-free rocky areas which have been subjected to glacial erosion by the inland ice are scattered along the Kronprins Olav Kyst in Dronning Maud Land, and show a rolling landscape. Raised beaches and low-lying terrace-like surfaces are found in ice-free areas. The maximum heights of them are about 66 ft (20 m) on Ongul (lat 69° 00′ S, long 39° 35′ E) and about 100 ft (30 m) above sea level on "Shin-nan iwa" (lat 67° 57′ S, long 44° 29′ E).

Sandy deposits found on the coast of Ongul below 50 ft (15 m) in height contain in places abundant shell fragments and the tests of Foraminifera. In places well-preserved fossil Pelecypoda (*Adamussium colbecki*) are embedded in the surface layer

of the deposits. Radiocarbon datings were carried out on the shells collected from the sediments. The date of the shell fragments obtained from the western coast of east Ongul about 17 ft (5 m) high was determined as over 30000 years B.P. The shells collected from the surface layer of beach deposit of the southern coast about 10 to 18 ft (3 to 4 m) high were dated as 3840 ± 110 years B.P. Further datings on related samples and others are now in progress.

The following geomorphological development of the area can be deduced from the above-mentioned facts. Inland ice in the "ice flood age" had once covered these areas and produced the glaciated landforms. After the recession of the inland ice, the uncovered rocks had been partly submerged beneath the sea and subjected to marine erosion and deposition. These areas were then uplifted to form the elevated beaches. As the terrace-like landforms and the sediments were not affected by glacial erosion by the inland ice, the retreat of the inland ice from Ongul took place at least 30000 years ago. The uplift process has lasted until recently, from at least a little more than 3800 years ago.

On the other hand, the following fact has been recognized from the study of the fossil Foraminifera. The composition of the genera of Foraminifera indicates that the sediments were deposited on a sea bottom at a depth of at least 330 ft (100 m). This fact is in contradiction to the topography of the elevated shoreline of 50 to 66 ft (15 to 20 m) in height. This problem remains to be solved in the future.

TITLE: Origin of chemical stratification in Lake Vanda, south Victoria Land

AUTHOR: Robert L. Nichols, Tufts University, Massachusetts, USA

Lake Vanda is located in the Wright Valley approximately 17 miles (27 km) west of the western terminus of the Lower Wright Glacier. It is about 4 miles (6·5 km) long, averages less than 1 mile (1·6 km) wide, and is more than 217 ft (66 m) deep. It is fed almost entirely by the Onyx River, a melt-water stream that originates at the western terminus of the Lower Wright Glacier. It occupies an undrained bedrock basin which was carved out by ice that moved from the Antarctic Ice Sheet eastward down the Wright Valley during the oldest glaciation recognized in the eastern end of the valley. The presence of saline lakes, surface and subsurface efflorescences of salts, calcite-veneered fragments and other features proves that the region is arid.

Angino and Armitage have recently shown that the upper 180 ft (55 m) of Lake Vanda is essentially potable, with less than 1000 ppm of dissolved salts, whereas that part below 200 ft (61 m) is more than three times as saline as sea water, with more than 100000 ppm of dissolved salts.

This chemical stratification was formed as follows:

During the full-bodied stage of Loop glaciation (the third-oldest glaciation recognized in the eastern end of Wright Valley) Lake Vanda was saline, as salts had been carried into it ever since its origin. It is not known whether the salts were uniformly distributed or whether the lake was chemically stratified at that time also. With the retreat of the Loop glaciers in late-Loop and post-Loop time, less melt-water was brought to the lake because of the reduced size of the glaciers. A new equilibrium between inflowing water and evaporation was established, and Lake Vanda decreased in size and at the same time increased in salinity. Finally, during Loop-Trilogy (youngest glaciation recognized in the eastern end of Wright Valley) interglacial time, the lake was reduced to a small saline pond, the waters of which are now found near the bottom of the present Lake Vanda.

During the Trilogy glaciation, increased quantities of melt water began to reach Lake Vanda, and it rose. As the saline waters had a specific gravity of approximately

1·2, the melt-water flowed out over the saline water with little mixing. The presence of elevated beaches, deltas and lacustrine cliffs proves that Lake Vanda in late Trilogy time was approximately 185 ft (56·5 m) higher than it is now. With the retreat of the Trilogy glaciers, the quantity of melt water brought to the lake decreased and the lake level dropped to its present position. The salts in the upper potable part of the lake have accumulated in Trilogy and post-Trilogy time.

There are more than 10 times as much dissolved salts in the lower saline part of the lake as in the upper potable part. Because the full-bodied stage of Trilogy time occurred approximately 10000 years ago, it seems likely that the basin of Lake Vanda was cut in pre-Wisconsin time.

TITLE: Geomorphology and glacial geology of the Sør-Rondane mountains, Dronning Maud Land

AUTHOR: T. Van Autenboer, Centre National Belge de Recherches Polaires, Université de Louvain, Belgium

Some geomorphological and glacial geological observations made in the Sør-Rondane during the Expéditions Antarctiques Belges of 1959 and 1960 are discussed.

The geographic setting of this mountain range (lat 72° 5′ S, long 20° to 30° E) is given. This east–west, wedge-shaped range is divided into its main topographic units by major glaciers draining the ice from the polar plateau.

The measured deficit of these plateau outlet glaciers is closely related to the ice supply from the plateau as revealed by aerial photographs.

In addition to these main glaciers, a local glacier system, independent of the plateau flow is developed. Its small ice caps, and mountain and cirque glaciers create the alpine character of the range.

Features such as blue ice fields, windscoops and snow drifts are briefly discussed.

There is a wealth of evidence to establish a former greater glacier cover: dry glacial valleys, extensive mammillated surfaces and vast moraine-covered areas are abundant throughout the range, while even higher peaks and mountain sides show ice-smoothed erratic-covered slopes. Both the plateau and the local glacierization show a considerable reduction. Some estimates of the minimum reduction in the ice thickness are given and compared with theoretical approaches to this problem. Some observations point to past glacial fluctuations. Evidence for little or no change in the ice cover since 1947 has been found.

The major landscape forms resulting from glacier action have been remodelled by frost-action, adding a spectacular touch to the landscape. Other minor features such as felsenmeere, frost-heaved stone fields, stone polygons and stone stripes have been encountered. The origin of the very pronounced honeycomb-weathering is discussed.

Section 3. Glacial geology

TITLE: Glacier fluctuations recorded by patterned ground, Victoria Land

AUTHORS: Robert F. Black and Thomas E. Berg, University of Wisconsin, USA

Patterned ground, consisting dominantly of ice-wedge and sand-wedge polygons, is common in all unconsolidated ground in Victoria Land. These polygons go through a predictable sequence of growth with surficial expression related to their ages. Polygons do not form and only rarely can be preserved beneath glaciers, but they grow immediately upon deglaciation and are all still active. No evidence of destruction of polygons by warmer climates has been found, and theoretically such warm climates do not seem possible at any time during the Pleistocene. Only locally is

internal heat flow sufficient to prevent or destroy permafrost and associated polygons. Consequently, it is possible to determine growth rates of wedges and use them for dating deglaciation, moraines and other features. The terminal areas of some glaciers lack unconsolidated deposits or their polygons are disturbed by lakes, outwash and other geomorphic phenomena.

Preliminary measurements of growth rates of wedges show an annual increase of width of wedges from less than 1 mm to more than 5 mm. Sand wedges seem to grow less rapidly as they age, but ice wedges probably grow more rapidly. Rates of growth of sand wedges depend particularly upon availability of sand and of moisture content of permafrost. Marked variations in any one micro-climate or geomorphic unit are seen. Average growths of 40 to 100 wedges in any one setting are needed for significant determinations.

Assuming growth rates of 300 wedges in five controlled sites measured to date are representative, the conclusion is reached that deglaciation of most of Victoria Land occurred perhaps only 10000 years ago. Old moraines, miles from present termini, commonly have wedges inside and outside of former fronts whose ages differ only by some centuries or a millennium and not whole glacial stages as has been postulated. According to polygons they advanced over, termini of some glaciers, such as Taylor Glacier, are as advanced as they have been for about 3000 to 5000 years. Furthermore, as recorded by youthful wedges whose orientations are controlled by termini, some fronts like that of the Taylor Glacier have been in their present positions for about 100 to 150 years. However, it is very obvious that many small alpine glaciers have retreated a few metres to many tens of metres during the last 100 to 200 years. No consistent trend or relationship of advance or retreat with size, exposure, altitude, etc., of glaciers has been established. Parts of many glaciers have advanced while other parts have stagnated or retreated at different times during the last several centuries.

TITLE: Present status of Antarctic glacial geology

AUTHOR: Robert L. Nichols, Tufts University, Massachusetts, USA

The two most important milestones in the study of Antarctic glacial geology are Arctowski's (1900) announcement that the Antarctic glaciers were once more extensive, and Péwé's (1958) discovery of evidence for multiple glaciation.

Péwé recognized four glaciations in the McMurdo Sound region. Deposits of the McMurdo glaciation (Kansan) are badly weathered and have little or no morainal form. Deposits of the Taylor (Illinoian) and Fryxell (Wisconsin) glaciations are found as well-preserved but subdued moraines. The Koettlitz glaciation is represented by well-preserved ice-cored moraines which are more than 6000 years old.

Bull, McKelvey and Webb (1962) found evidence for at least four glaciations in Wright and Victoria Valleys. Their first glaciation is represented by high-level glacial benches veneered with thin drift and their second by a lower series of benches and by subdued moraines on the valley floors. Thick moraines of the last two glaciations overlie older deposits on the valley floors.

Nichols (1961) reported four glaciations in the eastern end of Wright Valley. Ice of the oldest glaciation moved from the polar plateau eastward down Wright Valley. Three younger glaciations (Pecten, Loop, Trilogy) are marked by deposits laid down by glaciers which moved from McMurdo Sound and the coastal mountains westward up Wright Valley. The Trilogy glaciation, the youngest recognized, is Wisconsin, as ^{14}C determinations indicate that it occurred somewhat more than 7000 years ago.

An alluvial fan approximately 8 miles (13 km) west of the Lower Wright Glacier and the saline layer at the bottom of Lake Vanda were formed in interglacial time.

Solifluction deposits, felsenmeere, sand- and ice-wedge polygons, ventifacts, aeolian sand sheets and other periglacial features are common in the McMurdo Sound region.

Well-developed elevated beaches, wave-washed bedrock surfaces, and marine-boulder pavements are found in the McMurdo Sound region. The highest beach in this area is 67 ft (20·4 m) above sea level and the highest on the Antarctic Peninsula is 110 ft (33·5 m) above sea level. These beaches commonly rest on ice, are pitted and are characterized by other features not found in beaches formed in non-polar climates. It has long been recognized that this emergence is the result of isostatic adjustment to deglaciation.

A good start has been made on Antarctic glacial geology. Detailed and systematic studies are in order and the following problems, features and processes should now be studied: (1) elevated and modern beaches—marine limit; (2) solifluction deposits; (8) ice-cored moraines; (4) saline ponds and lakes; (5) hanging valleys—tectonic and glacial significance; (6) glacio-volcanic sequences; (7) aeolian erosion and deposition; (8) depth of permafrost; (9) submarine topography and deposits related to glaciation, glacio-marine sequences; (10) evidence for Tertiary glaciation; (11) geologic evidence for aridity—distribution; (12) multiple glaciation, correlation of glacial deposits in McMurdo Sound region and interglacial deposits; (13) rates and kinds of weathering; (14) cirques—position, climatic and tectonic significance; (15) collection of materials suitable for ^{14}C determinations; (16) ice margin features, glacio-fluviatile deposits, kame and ablation moraines; (17) felsenmeere and frost action; (18) seismic surveys of the thresholds of outlet glaciers; (19) development of techniques for dating glacial deposits of nearly the same age.

TITLE: The level of former glaciation near the mouth of Beardmore Glacier

AUTHOR: R. L. Oliver, University of Adelaide, Australia

Immediately to the east of the mouth of Beardmore Glacier several north–south trending ridges show evidence, in the form of morainic debris and of glacial striations, of having been overridden by ice at a maximum height of approximately 3200 ft (975 m) above the present ice level. The orientation of the striations suggests overflow from the valley of Beardmore Glacier. A large piedmont glacier is thought to have occupied the southern part of the Ross Sea "embayment" during Pleistocene times.

TITLE: The glacial geology of the Prince Charles Mountains

AUTHOR: D. S. Trail, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia

The Prince Charles Mountains, extending 375 miles (600 km) south from the Amery Ice Shelf between long 60° and 70° E, are exposed in a 6560 ft (2000 m) deep depression in the continental ice sheet apparently caused by the rapid drainage of inland ice to the sea by way of Lambert Glacier and adjacent glaciers.

The higher nunataks rise between 3280 and 8200 ft (1000 and 2500 m) above sea level and about 3280 ft (1000 m) above the ice surface. In the south, most nunataks have broad summit plateaux; in the north, many high nunataks have small summit areas. A few nunataks have flanking rock benches; all have cirques, most of which are abandoned.

The glacial deposits are subdivided according to their surfaces:

Unpatterned moraine lacks a regularly patterned surface; it is lateral moraine on active glaciers from the ice sheet, abandoned lateral moraine adjacent to glaciers from the ice sheet, and terminal moraine of extinct or receding mountain glaciers.

Hillocky moraine has a surface of steep irregular hillocks and probably lies on stagnant ice.

Patterned moraine has a surface of regularly spaced and similar, sub-conical mounds. It blankets most flat or gently sloping rock surfaces up to 3280 ft (1000 m) above the ice surface and extends beneath the ice surface. In places hillocky moraine and unpatterned moraine lie on patterned moraine.

Patterned moraine extends on gentle slopes from summit plateaux and benches to the floors of abandoned cirques. The cirques, benches and summit plateaux were formed before the deposition of this moraine.

Nunataks with small summit areas, which are generally lower than neighbouring nunataks with broad summit plateaux, appear to have been formed before the vertical maximum of the ice sheet by the enlargement and convergence of cirques cutting into broad summit plateaux.

Several cirques have cut into and through one prominent bench. The summit plateaux and some benches appear to pre-date the cirques and may be pre-glacial features representing not a peneplain, but a landscape of rolling hills and broad valleys.

The glacial history is apparently simple. First, mountain glaciers cut cirques in rolling hills and coalesced to form valley glaciers which overdeepened the central parts of valleys, leaving the margins as benches. The early ice sheet covered and protected the summit plateaux of the southern mountains, while cirque erosion and frost-weathering reduced the northern mountains. Later the ice sheet buried almost all mountains, then withdrew below its present level leaving a blanket-like deposit of moraine on which a pattern developed.

Since the formation of the pattern, renewed mountain glacier activity cut small valleys in the patterned moraine and the ice cap rose 164 or 328 ft (50 or 100 m) above its present level.

Throughout the glacial period the glaciers flowing from the ice sheet have continued to deepen their valleys, and the downward recession of ice from the Prince Charles Mountains will continue until the glaciers reach some base level and a stage of glacial maturity results.

Section 4. General geology

TITLE: Geological outline of the Ellsworth Mountains

AUTHORS: Campbell Craddock, John J. Anderson and Gerald F. Webers, University of Minnesota, USA

The Ellsworth Mountains lie 400 miles (650 km) east of "Byrd" station, between the deformed belt of the Antarctic Peninsula and the shield of East Antarctica. This mountain chain is 220 miles (350 km) long and as much as 55 miles (90 km) wide; it trends north-north-west. The northern range, the Sentinel, is dominated by a high massif with a gentle east slope and a steep, lofty escarpment on the west. The Heritage Range to the south consists of many smaller mountain groups separated by large glaciers. Horns and arêtes are characteristic landforms throughout the mountains, and the distribution of erratics and the freshness and position of bedrock striations indicate the ice surface has been at least 1000 ft (300 m) higher in the recent geologic past. Ice flows through the mountains from the high polar plateau on the west to the Filchner Ice Shelf to the east. A few dry valleys occur, and in the southern Heritage Range high winds have abraded and polished the bedrock.

The mountains are composed of a thick sequence of deformed sedimentary rocks. The thickness of the exposed stratigraphic section exceeds 20000 ft (6100 m). Continuing work may reveal the presence of disconformities, but thus far no unconformity has been established in this section. Most of the strata are clastic varieties,

especially quartzite, conglomerate and pelite; some of these contain material of volcanic derivation. A carbonate unit several thousand feet thick occurs near the base of the section. In the north-eastern Heritage Range basic sills occur in the sedimentary rocks.

All these strata have been deformed into folds of various sizes, whose axes roughly parallel the trend of the mountains. Most of these folds are asymmetric or overturned, and some are recumbent. Faulting is rare but a probable overthrust occurs in the central Heritage Range. Breccia bodies of diverse shape and dimension are abundant in the carbonate rocks. Slight to moderate metamorphism has produced quartzite and marble, and the pelitic rocks are argillite, slate and locally phyllite. Most rocks possess poor to good secondary foliation. Veins of white quartz, epidote and chlorite are common.

Fossils are scarce in the sedimentary rocks and most present are fucoidal impressions or probable worm borings. However, fossils or probable fossils have now been collected from four major rock units and include trilobites, gastropods, a probable cephalopod, plant stems and other forms. Preliminary study of these fossils suggests that most of the exposed section is of Palaeozoic age. The youngest bedrock formation is no older than middle Palaeozoic. The intense folding and the metamorphism of this formation presently provide the best information on the age of the orogeny.

TITLE: Geology of the Jones Mountains area

AUTHORS: Campbell Craddock, Thomas W. Bastien and Robert H. Rutford, University of Minnesota, USA

The Jones Mountains are located along the Eights Coast and lie about 60 miles (100 km) inland from the Bellingshausen Sea. They consist of a series of mainly rounded peaks of a few thousand feet in relief extending 40 miles (65 km) along an east-north-east alignment. Ice from the polar plateau flows seaward over the range, and most rock exposures occur along cliffs on the northern side.

The rocks of the Jones Mountains can be divided into a basement complex and an overlying volcanic series. A granite exposed near the centre of the mountains is believed to be the oldest rock in the basement complex. Younger rocks in the basement include felsites, trap dykes and highly altered igneous rocks, probably of volcanic origin.

The basement is truncated by a nearly flat erosional surface marked in several places by grooves and striations. It is possible this surface bears the scars of ancient glaciation, although no definite glacial deposits have been found in the overlying rocks. The volcanic series above this unconformity is mainly horizontal and consists of tuffs, agglomerates, flows and hypabyssal bodies, all of olivine-basalt composition. K/A age determinations suggest minimum ages of early Mesozoic for the granite, late Mesozoic for the felsite and late Cenozoic for the olivine-basalts.

Thurston Island, 90 miles (145 km) to the north-north-west, is mantled by ice and has been studied at only a few coastal localities. The bedrock consists of medium-crystalline quartz-diorite-gneiss, locally displaying marked compositional banding, cross-cut by numerous finely crystalline mafic dykes. Rb/Sr age determinations suggest a late Palaeozoic age for biotite from this gneiss.

Numerous outcrops of geologically young volcanic rocks occur to the south and west in this sector of West Antarctica. Along the Eights Coast, late Cenozoic olivine-basalts rest with marked unconformity on a basement of Mesozoic or older plutonic rocks. This part of West Antarctica cannot be considered a simple volcanic archipelago. Rocks characteristic of orogenic regions were formed here at least as long ago as the late Palaeozoic.

TITLE: Summary of the geology of the polar plateau between the Rennick, Aviator and Campbell Glaciers, northern Victoria Land.

AUTHOR: H. S. Gair, New Zealand Geological Survey, Wellington, New Zealand

The polar plateau in this area lies at a height of 7000–10 000 ft (2150–3050 m) above sea level and three major groups of rocks are present: (1) volcanics of late Tertiary and Quaternary age including kenyte and related rock types; (2) volcanics (mostly basalt) of Jurassic age; (3) Precambrian basement rocks consisting mostly of granite and gneissic granite with small areas of schist and marble.

The Tertiary volcanics are sufficiently young to form conspicuous features (mostly volcanoes) on the landscape and they all occur along the north-trending volcanic belt on the eastern margin of Victoria Land.

The basalts of Jurassic age are at least 4500 ft (1875 m) thick and both in field occurrence and lithology they very closely resemble the Drakensberg and Batoka Basalts of Southern Africa. Within the basalts and at the base are beds of arkosic Beacon Sandstone up to 60 ft (18 m) thick that are carbonaceous in parts and contain silicified tree trunks in place of growth. These lavas dip regionally at less than 5° to the north and are probably in fault contact with Precambrian granite-gneiss and schist on the west side of the Rennick Glacier.

The Precambrian rocks strike regionally north and dip 60–80° west, and were probably peneplaned (the Kukri Peneplain of Gunn and Warren (1962)) prior to the extrusion of the Jurassic lavas.

TITLE: Geological exploration in the Antarctic and sub-Antarctic regions by Norwegian or Norwegian-led expeditions

AUTHOR: Tore Gjelsvik, Norsk Polarinstitutt, Oslo

Geological results of the following expeditions are summarized: Roald Amundsen's South Pole expedition, 1910–12; Lars Christensen's expeditions, 1927–37; Norwegian–British–Swedish Antarctic Expedition, 1949–52; Norwegian I.G.Y. expedition (Norway Station), 1956–60.

A short survey of glaciological work by these expeditions is added.

TITLE: Outline of the geology of the Nimrod—Beardmore—Axel Heiberg Glaciers region, Ross Dependency

AUTHORS: G. W. Grindley, New Zealand Geological Survey, Wellington; V. R. McGregor, University of Auckland; and R. I. Walcott, Victoria University of Wellington, New Zealand

An outline of the geology of the southern Victoria Land mountains from lat 82° 30′ to 35° 30′ S and from long 155° E to 165° W, based on the work of the 1959–60 and 1961–62 New Zealand Antarctic expeditions is presented. The coastal ranges consist of strongly folded late Precambrian greywackes, phyllites and quartzites (Beardmore Group) intruded by post-tectonic plutons of microcline-biotite-granite (Hope Granite). Contact-metamorphosed marbles, calc-silicate hornfelses and biotite-hornblende-hornfelses are found along the coast between the Liv and Axel Heiberg Glaciers. Cambrian limestones and conglomerates containing Archaeocyathinae (Shackleton Limestone) crop out as a basement inlier at the "Buckley nunatak" at the head of the Beardmore Glacier, and form synclinal strips in folded greywackes of the Beardmore Group north and west of Mount Markham on the south side of the Nimrod Glacier. The inland ranges and nunataks around the head of the Nimrod Glacier consist of a 10 000 ft (3050 m) sequence of isoclinally folded garnet-biotite-plagioclase-gneisses, calc-gneisses and marbles, metaquartzites, diorite-

*ortho*gneisses and amphibolites, and feldspathized biotite- and hornblende-gneisses. These gneisses (Nimrod Group), although not found in contact with the Beardmore Group, are most probably of older Precambrian age. They are intruded by plutons of the Hope Granite, which have produced thermal aureoles of andalusite-sillimanite-hornfels and injection gneiss. Lamprophyre dyke swarms cut the metamorphic sequence at several localities.

The basement rocks were peneplaned in the early Palaeozoic and covered by at least 7000 ft (2150 m) of continental sediments of the Beacon Group of Gondwana age. Basal quartz-arenites of Carboniferous and/or Devonian age are overlain by early Permian or late Carboniferous glacial tillites, fluvio-glacial sandstone and dark shales, followed by Lower Permian coal measures with the *Glossopteris* flora. An Upper Permian—Triassic alternating sandstone-siltstone sequence overlies and is capped by basaltic lavas (Kirkpatrick Basalts). Triassic macrofloras containing *Dicroidium* are found at two localities south-east of the Beardmore Glacier in the higher part of the Beacon Group sequence. The Beacon sediments are extensively intruded by dolerite sills, dykes and plugs (Ferrar Dolerites), closely related to the basaltic lavas, and probably of Lower to Middle Jurassic age.

TITLE: Preliminary report on the geology of an area south-west of the upper Tucker Glacier, northern Victoria Land

AUTHORS: P. C. Le Couteur and E. C. Leitch, University of Auckland, New Zealand

In the area south-west of the upper Tucker Glacier three major lithologic subdivisions are recognized: (1) Ross System rocks of the Robertson Bay Group have the greatest areal extent, and consist mainly of tightly folded greywackes and argillites. (2) A sequence of *ortho*quartzites and quartz-conglomerates are of later age but of similar structural trend and style of folding. Tracks and borings of organic origin were found at one locality in the *ortho*quartzites. (3) Post-tectonic acid plutons of Tucker Granodiorite locally intrude and thermally metamorphose the Robertson Bay Group sediments, while minor dykes of varying composition have been found in both sedimentary rock types.

TITLE: An outline of the geology of the sector from longitude 45° to 80° E, Antarctica

AUTHOR: I. R. McLeod and P. W. Crohn, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia

The rocks in the sector of Antarctica between long 45° and 80° E, and north of lat 75° S, are predominantly metamorphic and can be divided into two major units, one of high-grade the other of low-grade metamorphic rocks.

The low-grade rocks occur in the southern Prince Charles Mountains and consist of quartzite, quartz-mica-schist, marble and amphibolite in the greenschist facies of metamorphism. Their general strike is about east–west. They have been intruded by large granite bodies.

High-grade metamorphic rocks occur throughout the rest of the sector. They can be broadly divided into rocks with charnockitic affinities (particularly common along the coast from the Robinson Group, east of Mawson, westward to Edward VIII Gulf, and in the Framnes Mountains, and in the Napier and Tula Mountains); biotite-quartz-feldspar-gneisses which are migmatized in places (common in the northern Prince Charles Mountains); and garnet-quartz-feldspar-gneisses (common along the east side of Prydz Bay). Each of these broad groups contains numerous mineralogical

and textural variants, and the groups are not mutually exclusive in any one area. Evidence is widespread that a metamorphism of quite high grade was superimposed on the pre-existing metamorphic rocks.

In the area extending for 100 miles (160 km) to the west and south of Mawson the general strike of the high-grade gneisses is about north–south. Elsewhere, with few exceptions it is about east–west. Dolerite dykes are very common in the Vestfold Hills. Isolated dykes of dolerite or basalt were seen at several places in Enderby and Kemp Lands and in the Prince Charles Mountains.

Permian sediments occur *in situ* at the south-west corner of the Amery Ice Shelf. Fragments of siltstones containing *Glossopteris* were found 168 miles (270 km) to the south of this in a moraine of Fisher Glacier.

TITLE: Geological observations at Plunkett Point, Beardmore Glacier

AUTHOR: R. L. Oliver, University of Adelaide, Australia

Rocks which outcrop in the vicinity of Plunkett Point are: (1) Well-stratified, roughly horizontal, shallow-water sediments of the Beacon Group.—(2) Dolerite, intruded into the Beacon Group sediments, mainly as sills, but also cross-cutting them.—(3) Moderately consolidated tillite, overlying Beacon Group sediments and associated dolerite and, in places, apparently intruded by the dolerite. (4) Loose surface morainic debris which includes blocks of fine-grained massive grey limestone containing Archeocyathidae the source of which is unknown.

TITLE: Some basement rock relations in Antarctica

AUTHOR: R. L. Oliver, University of Adelaide, Australia

Study of a small area just east of the mouth of Beardmore Glacier shows metagreywacke intruded by genetically related granite, granodiorite and quartz-diorite. It is suggested that the petrographically similar acid and intermediate plutonics, which are intrusive into metagreywackes at intervals along the whole of the west side of the Ross Sea "embayment", are similarly related to each other though they have, apparently, been emplaced at different stages in a late Cambrian—early Ordovician post-geosynclinal orogenesis. It is thought that these intrusives and the associated metasediments, together with similar rock assemblages in the Queen Maud Mountains, Horlick Mountains and Pensacola Mountains are geologically related to much of West Antarctica; they represent plutonics intruded into metasediments which have been deposited presumably in a series of parallel geosynclinal basins extending from the Antarctic Peninsula to Victoria Land, and, very likely, younging towards the Pacific Ocean. The relationship of the above metasediments to those of apparently equivalent age elsewhere in East Antarctica is obscure, though the suggestion that the latter are relatively shallow-water platform deposits seems a reasonable one.

TITLE: Outline of the geology between the Mawson and Priestley Glaciers, Victoria Land

AUTHOR: J. F. Ricker, Antarctic Division, D.S.I.R., Wellington, New Zealand

The polar plateau has an elevation of 3000 to 7000 ft (910 to 2150 m) in this region and is dissected by wide valley glaciers which support extensive floating ice tongues.

At the head of the Priestley Glacier up to 5000 ft (1525 m) of folded thermally altered slates and hornfelses strike north-west. Eastward, these give way to gneisses

and schists of sedimentary origin, and possible ancient granites. All are intruded by a plutonic complex including both gneissic and massive granites. These rocks make up a basement which underlies an extensive peneplain.

Remnants of Beacon Group continental sediments of uncertain age, rest locally on the peneplain and dip gently westward. These underlie 4000 ft (1220 m) of Jurassic Ferrar Group dolerites and basalts. Rafting of the Beacon Group by dolerite sills has occurred and may be responsible for some of the relatively thin sedimentary sections. The sediments are unfossiliferous except for silicified wood and coal on one horizon and carbonaceous debris on another.

The uppermost 2000 ft (610 m) of the Ferrar Group contain at least 800 ft (250 m) of basaltic flows with one thin sedimentary horizon.

Quaternary lavas and tuff derived from Mount Melbourne are present on the south side of the Campbell Glacier.

Quaternary glacial features include: moraines, patterned ground, lakes and unconsolidated raised beach deposits.

TITLE: Preliminary geology and structure of the Patuxent Mountains

AUTHORS: D. L. Schmidt, A. B. Ford, J. H. Dover and R. D. Brown, US Geological Survey, Washington, DC, USA

The Patuxent Mountains (lat 64° W, long 85° S) constitute the southern one-third of the Pensacola Mountains, which occupy a 200 mile (320 km) long by 50 mile (80 km) wide segment of the "Trans-Antarctic Mountains" along the south-eastern margin of the Filchner Ice Shelf. The oldest and most widespread rocks of three thick sedimentary units making up the Patuxent Mountains are intensely folded impure sandstone and slate. The greyish-green sandstone and slate are rhythmically interbedded and have characteristics of sediments deposited by turbidity currents in moderately deep water. The beds are disharmonically folded about north-trending axes which generally plunge less than 10° to the north or south on approximately vertical axial planes; an axial-plane cleavage is well developed.

A carbonate unit is much less widely exposed and consists of predominantly massive to thin-bedded limestone containing minor calcarenitic, oolitic, black carbonaceous and argillaceous interbeds. The carbonate rocks were probably deposited in moderately shallow water. Bedding in the unit dips homoclinally 35 to 65° south and strikes approximately normal to the trend of the fold axes of the sandstone-slate unit. Deformation of both units is presumably older than Devonian as both are overlain with angular discordance by flat-lying Beacon Sandstone.

The Beacon Sandstone, the third sedimentary unit, consists of a sequence of thick-bedded, coarse-grained red-weathering sandstone, thick-bedded, fine-grained white *ortho*quartzite, and thin-bedded grey siltstone. Repetitious black carbonaceous layers contain abundant plant debris which in the youngest beds includes *Glossopteris* and related leaf floras indicative of a late Palaeozoic age.

Three types of mafic igneous rocks cut the sedimentary units: (1) Brecciated and altered diabase (?) intruded the sandstone-slate unit probably prior to the late Palaeozoic. (2) Diabase sills, some more than 100 ft (30 m) thick, intruded the Beacon Sandstone and are correlated with the Jurassic Ferrar Dolerite of Victoria Land. (3) Black basaltic to lamprophyric dykes intruded the sandstone-slate unit probably at shallow depth as is suggested by pronounced viscous-flow structures, local palagonitic contacts, and essentially unaltered wall rocks. Their intrusion may have been as late as Cenozoic. Sporadic xenoliths of leucocratic gneiss and xenocrysts of quartz, biotite and garnet in the dykes suggest that a felsic crystalline basement underlies the sandstone-slate unit in the Patuxent Mountains.

TITLE: A summary of the geology of the region between the Byrd and Starshot Glaciers, south Victoria Land

AUTHOR: D. N. B. Skinner, University of Auckland, New Zealand

The present topographic framework comprises late Tertiary fault blocks modified by glacial erosion. Strongly folded Palaeozoic or older basement rocks are subdivided here into four formations, of which three (Shackleton, Dick and Douglas Conglomerate) constitute the Byrd Group, and are characterized by the absence of thermal metamorphism and only very low-grade regional metamorphism. The Shackleton Formation is predominantly calcareous with oolitic and algal limestone; the Dick Formation consists of shallow-water siltstones and grits. The Douglas Conglomerate contains pebbles derived from the Shackleton and Dick Formations as well as from an older igneous terrain that is not exposed. The fourth formation, Selbourne Marble, is more limited in extent, and is characterized by high-grade thermal metamorphism; its relationship to the Byrd Group is unknown. Post-tectonic dykes of quartz-porphyry are the only representatives of the Granite Harbour Intrusives. The peneplaned basement rocks are overlain by flat-lying arkosic sediments of the Beacon Group which have been extensively injected by thick sills of Ferrar Dolerite not seen in the basement.

TITLE: Geology of the region around Lützow-Holmbukta and the "Yamato Mountains"

AUTHORS: Tatsuo Tatsumi, University of Tokyo; Toru Kikuchi, Geological Survey of Japan; and Koshiro Kizaki, Hokkaido University, Japan

The geology of the region around Lützow–Holmbukta and the "Yamato Mountains" [Dronning Fabiolafjella] was surveyed by the first and the fourth wintering teams (1957–58 and 1960–61) of the Japanese Antarctic Research Expedition. The rocky areas visited are composed entirely of metamorphic rocks and granites.

These rocks are classified into the following ten units on the basis of their modes of occurrence and petrographic characters: (1) pyroxene-gneiss; (2) marble and quartzite; (3) metabasite; (4) hornblende-gneiss; (5) garnet-gneiss; (6) pyroxene-granite; (7) biotite- or microcline-granite; (8) pegmatites; (9) glacial morainic deposits; (10) fossil-bearing gravels and sand deposits.

Erratic boulders were found to include, in addition to the rocks exposed in the region, garnet-sillimanite-gneiss, amphibolite, epidote-amphibolite, hornblende-chlorite-schist, biotite-hornfels, garnet-muscovite-hornfels, quartzose sandstone and ilmenite-augite-basalt. The last four kinds of rock were possibly derived from the Beacon Sandstone formation and dolerite intrusives which are supposed to exist inland from the region surveyed.

Both structurally and petrographically, this region belongs to a part of the basement of East Antarctica. But the age of the metamorphism is thought to be Cambrian according to the results of absolute age determinations on some minerals from the metamorphic rocks and the pegmatites by Rb/Sr and U/Pb methods.

TITLE: The geology of Cape Hallett—Tucker Glacier district

AUTHOR: B. L. Wood, New Zealand Geological Survey, Wellington, New Zealand

This district forms the northern end of the "Trans-Antarctic Mountains" in the Ross Sea region, and is characterized by Alpine-type ranges rising to heights of 12500 ft (3800 m). A linear chain of coastal volcanic mountains, up to 5250 ft (1600 m) in height, is separated from the interior mountains by a topographic corridor extending from Robertson Bay through Edisto Inlet and Whitehall Glacier to Lady Newnes Ice Shelf. Vague accordance of summits of the interior mountains

suggests that they have been cut from a mature land surface, named the Hallett erosion surface, which is tentatively correlated with the pre-Devonian Kukri Peneplain of southern Victoria Land.

Summary of stratigraphy

Late Precambrian and early Palaeozoic	
Ross System	
Robertson Bay Group	Strongly folded geosynclinal metagreywacke and meta-argillite of greenschist facies, reconstituted to hornfels adjacent to Tucker Granodiorite; thickness 9850(+) ft (3000(+) m)
Granite Harbour Intrusives Complex	
Tucker Granodiorite	One or more subhorizontal sheet intrusions, 4900 ft (1500 m) thick, of granodiorite and tonalite, with numerous microdioritic dykes
Edisto Granites	Narrow subvertical siliceous dykes of aplite, microgranite, laumontized granite
Upper Tertiary and Quaternary	
McMurdo Volcanics	
Roberts Cliff Tuffite	Basaltic lavas, dykes, plugs and pyroclastics, phonolitic and trachytic rocks. Yellow-brown tuff and agglomerate
Herschel Tuffaceous Moraine	Lateral moraine and subglacial till, with basaltic tuff
Holocene and Pleistocene	
Whitehall Moraine	Low-level moraines of Whitehall Glacier
Seabee Hook and Ridley Beach Gravels	Beach gravels and cliff talus
Seabee Hook Guano and Ridley Beach Guano	Frozen surface layer of penguin bodies, guano and pebbles

The distribution of these rock units is shown on a small-scale geological map of the district.

Section 5. Stratigraphy

TITLE: Stratigraphic correlation in West Antarctica

AUTHOR: Raymond J. Adie, British Antarctic Survey, University of Birmingham, England

It is now generally accepted that Antarctica comprises two geological provinces, the Gondwana Province of East Antarctica and the Andean Province of West Antarctica, each of which has its own characteristic stratigraphic succession.

With increased interest in the geology of the less accessible parts of West Antarctica it is now becoming necessary to have some basis for stratigraphic correlation and adequate descriptive terminology for rock formations.

The stratigraphy of the Graham Land peninsula and the islands of the Scotia Arc is tabulated and compared with other parts of West Antarctica. The problems of stratigraphic correlation in West Antarctica are also discussed with a view to establishing a set of formational names that can be used in the future.

TITLE: Stratigraphic nomenclature and correlation in the western Ross Sea region

AUTHORS: G. W. Grindley and Guyon Warren, New Zealand Geological Survey, Wellington, New Zealand

The nomenclature of rock units recognized in the Ross Sea region of the "Trans-Antarctic Mountains" is summarized, and formal definition is attempted of the major rock groupings found useful in stratigraphic correlation through this region.

Major groupings in the pre-Devonian basement include:

(1) *Ross Supergroup.* This includes all sediments and metamorphics of the late Precambrian to Cambrian Ross geosyncline. At a few places they contain Cambrian Archaeocyathinae in their upper portion, and all were folded and metamorphosed in the late Cambrian to Ordovician Ross orogeny. Local group and formational units are listed.

(2) *Metamorphics of unknown age.* Metagreywackes, schists, gneisses and marbles of unknown age are found at many localities throughout the "Trans-Antarctic Mountains", and all are provisionally excluded from the Ross Supergroup until, for any formation, evidence of age or stratigraphic equivalence to a known unit of the Ross Supergroup becomes available. They include pre-tectonic granitic and dioritic *ortho*gneisses and migmatites that may in part have been developed during the early phases of the Ross orogeny and may in part be considerably older. The undated altered sediments may include rocks of the same age as, and rocks younger or older than, those of the Ross Supergroup. Local group and formational units are listed.

(3) *Granite Harbour Intrusives.* Syntectonic and post-tectonic granites, granodiorites, diorites and lamprophyres have intruded both Ross Supergroup sediments and the undated metamorphics during and following the Ross orogeny. Local formation names are listed for the many individual batholiths, plutons and dyke complexes that have been recognized and named on field and petrographic criteria.

The flat-lying continental sediments, volcanics and intrusives that overlie the eroded and usually peneplaned surface of the basement rocks are divided into two major groups:

(1) *Beacon Group.* Continental sediments containing fossils of Lower Devonian to early Jurassic age are widely developed in the "Trans-Antarctic Mountains" and are found also in a few places near the coast of East Antarctica. Local formational units found useful in the region are listed.

(2) *Ferrar Group.* Plateau basalts and intrusive dolerite sills, dykes and plugs, probably all of Jurassic age, overlie and intrude Beacon sediments throughout the "Trans-Antarctic Mountains". Lenses of volcanic-derived sediments interbedded with the lavas are included within the Ferrar Group. The rocks of the Ferrar Group were mainly emplaced or erupted following the Beacon sedimentation and divide naturally into intrusive and extrusive phases for which formational units are appropriate.

Quaternary rocks are divided into two divisions:

(1) *McMurdo Volcanics.* Quaternary volcanic rocks are present at numerous localities along the western margin of the Ross Sea from Cape Adare to Mount Discovery and also along faults within the mountains in the Koettlitz–Taylor Glaciers region and north of Terra Nova Bay. Formational units have been recognized locally by detailed mapping.

(2) Quaternary moraines and shallow-water marine deposits have been subdivided locally into formations.

TITLE: Cretaceous sedimentation in the "General Bernardo O'Higgins" area of north-west Antarctic Peninsula

AUTHOR: Martin Halpern, Geophysical and Polar Research Center, University of Wisconsin, USA

A new formation in the "General Bernardo O'Higgins" [Cape Legoupil] area has been found to be Cretaceous in age as revealed by the presence of *Platopis* sp. (?) and potassium-argon absolute ages of 116 ± 4 m. yr. for a diorite pebble from a pebbly mudstone unit, 86 ± 7 m. yr. for andesite flows which are inferred to overlie the

formation with angular unconformity, and 74·7 ± 2·8 m. yr. for an andesite dyke which cuts dynamically metamorphosed sediments of the formation. This formation includes argillite, quartz wacke, quartz-feldspathic wacke, quartz-feldspathic arenite, arkosic arenite, granule to pebble conglomerate and pebbly mudstone. Local occurrences of phyllite are believed to be the result of dynamic metamorphism of argillaceous sediments of the formation. A sedimentary breccia crops out in several isolated areas, but its stratigraphic relationship to the above-described formation is uncertain. Great abundance of quartz as the dominant sand constituent and paucity of volcanic and metamorphic detritus are somewhat in contrast to generally held views of eugeosynclinal sand deposits.

Compositionally, the sands of the formation are submature. Texturally, the wackes are micro-breccias. Localized occurrences of well-sorted arenite represent an unusual assemblage for eugeosynclinal accumulations, believed to have resulted from winnowing action in shallow water.

Cretaceous sedimentation occurred within a north-north-east trending eugeosynclinal belt. Eugeosynclinal characteristics include accumulation of a gross thickness of at least 13000 ft (4000 m) of clastic sediments, presence regionally of Jurassic through Tertiary volcanic and hypabyssal rocks, and presence of acidic and basic plutons. Cretaceous provenance areas consisted of nearby tectonic lands with acid to basic plutons and some associated metamorphics, and possibly lands farther south and east. A possibly north-west to south-east oriented bottom slope is assumed to have existed perpendicular to the north-east directed palaeocurrents. The varied nature of the sediments implies an ocean floor irregularly dispersed with troughs and rises, and although sedimentation was probably rapid, it was not restricted to a deep-water environment.

Potassium-argon dating of quartz-diorite and gabbro plutons yielded dates of 75 ± 8 and 100 ± 20 m. yr., respectively. Although pluton–sediment contacts are not visible, absolute ages imply that the quartz-diorite intruded the formation, whereas the gabbro body may have either intruded the sediments or acted as a source rock for them, assuming the gabbro lay exposed to weathering during the deposition of the formation. From absolute ages, major faulting in the area is inferred as intra-late Cretaceous.

Younger than the type ?Carboniferous Trinity Peninsula "Series", the new formation may be correlative with the Cumberland Bay type sediments of South Georgia. Varying in age, lithologies compositionally similar to the new formation can be traced from Chile through the Scotia Arc and Antarctic Peninsula as far south as the Sentinel and Pensacola Mountains. Tentatively, since the late Palaeozoic and probably earlier, a zone of sedimentation, intrusion, vulcanism and present seismicity was confined to the general area delineated by the present positions of southernmost Chile, the Scotia Arc and the Antarctic Peninsula. Present geologic knowledge of the peninsula neither demands nor denies large-scale continental drifting.

TITLE: A schematic geological map of Antarctica

AUTHOR: H. J. Harrington, University of New England, Armidale, Australia

Twelve major units are shown on a schematic geological map of the continent and are briefly described. About 90 per cent of the continent is sub-glacially concealed and the determination of its hidden geology is a major problem now coming into prominence. Inferences are presented as working hypotheses to be tested.

TITLE: Basement and sedimentary geology of the Darwin Glacier area

AUTHORS: T. R. Haskell, J. P. Kennett and W. M. Prebble, Victoria University of Wellington, New Zealand

The Brown Hills and Darwin Mountains are ice-free areas 175 miles (280 km) south of Ross Island. The basement in the Brown Hills is predominantly granitic rock cut by acid and basic dykes. Minor metasediments include 100 ft (30 m) of high-grade quartz-biotite-hornblende-schist with interbedded quartzites grading into the granitic rock.

Several granitic rock types have been mapped separately, but have broad gradational boundaries. Two coarse-grained types predominate and have an east–west foliation direction. The first is probably pre-tectonic, strongly to moderately foliated, mesocratic, porphyritic with common basic segregations, becoming more melanocratic, coarser and more strongly foliated towards the metasediments. The second type is probably syn-tectonic, non-foliated to weakly foliated, porphyritic with orthoclase megacrysts set in a quartz-biotite matrix. Composition varies from granite to granodiorite.

Three finer-grained post-tectonic types were distinguished. The first is fine- to medium-grained, equigranular, leucocratic, weakly foliated, lacks basic segregations and forms a pluton 4 miles (6·5 km) in diameter. Two generations of fine-grained leucocratic granitic dykes cut both of the coarse-grained types. The second generation dykes contain red garnets.

Medium-grained hornblendic meladiorite dykes intrude the fine-grained granite pluton and the syn-tectonic coarse granite.

Augite-biotite-lamprophyres cut the pre-tectonic coarse granite. The lamprophyres and meladiorite are both cut by a coarse-grained leucocratic pegmatite.

Another coarse-grained pegmatite, confined to the fine-grained granite pluton, cuts the meladiorite dykes.

A peneplane surface on the basement is overlain by about 4000 ft (1220 m) of mid-Palaeozoic to mid-Mesozoic sediments of the Beacon Group. The unconformity at the base of the Beacon Group exposed at Bastion Hill, Brown Hills, has undulating relief of 4 ft (1·2 m), and the basement is weathered to a depth of 4–15 ft (1·2–4·6 m).

Five new formations are proposed. In ascending order they are: Brown Hills Conglomerate, Hatherton Sandstone, Darwin Tillite, Misthound Coal Measures and Ellis Formation.

The base of the Beacon Group is exposed only at Brown Hills, where the Brown Hills Conglomerate, at least 150 ft (46 m) thick, consists of rounded quartz pebbles averaging 1 in (2·54 cm) in diameter.

At Darwin Mountains, 10 miles (16 km) to the south-west, the Hatherton Sandstone is the lowest part of the Beacon Group exposed, and consists of 2000 ft (610 m) of white quartz-arenite, strongly current-bedded in the upper part. Good specimens of *Beaconites antarcticus* are common.

The Darwin Tillite, 90 ft (28 m) thick, consists of 30 ft (9 m) of mottled green and red siltstone with scattered weathered boulders of granite and metasediments, overlain by 20 ft (6 m) of green cyclic sandstone and siltstone resembling varves; and 40 ft (12 m) of green siltstone.

The Misthound Coal Measures, 400 ft (120 m) thick, overlie the Darwin Tillite. Disconformity is indicated by a 6 in to 1 ft (15 to 30 cm) basal conglomerate of pebbles and boulders derived from the Darwin Tillite. The coal measures consist of current-bedded quartz sand, thin carbonaceous mudstone layers and impure coal. The lowest carbonaceous band contains poorly preserved leaf and stem impressions of *Gangamopteris*.

The Ellis Formation consists of light grey, finely banded mudstone and siltstone with occasional pebble bands and intraformational breccia.

Sills and dykes of the Ferrar Dolerite Formation intrude the basement complex and the Beacon Group.

TITLE: The stratigraphy of the Horlick Mountains

AUTHOR: William E. Long, Institute of Polar Studies, The Ohio State University, USA

The Ohio Range and the Wisconsin Range compose the area called the Horlick Mountains. Outcrops of sedimentary rocks are much more extensive in the Ohio Range than the Wisconsin Range. Two seasons of investigation in the Ohio Range have revealed a stratigraphic sequence which is generally similar to sequences of other Gondwana areas.

In the Ohio Range about 4000 ft (1220 m) of sedimentary rock rest unconformably upon a quartz-monzonite basement rock. The basal sedimentary unit, named the Horlick Formation, is composed of interbedded sandstones, siltstones and shales which range from 0 to 150 ft (46 m) in thickness. The beds contain invertebrate fossils and primitive paludal plant fossils (psilophytes) indicative of early Devonian age, and near-shore and swampy environments. The upper surface of the Horlick Formation commonly is grooved and striated and forms a basal glacial pavement below the Buckeye Tillite.

The Buckeye Tillite ranges in thickness from 700 to 900 ft (215 to 275 m) and is composed predominantly of lithified bluish grey boulder clay with several thin or lenticular deposits of bedded siltstone and sandstone. Exposures extend more than 20 miles (32 km) along the front of the Ohio Range. Boulder pavements and striac indicate a rather consistent direction of movement of ice from west to east. Erratics in the tillite range from sand size to about 20 ft (6 m) in diameter. The matrix is clay, silt and sand-sized material. The interbedded sandy layers probably resulted from outwash deposits during glacial recessions. The age of the tillite is uncertain but spores found in interbedded shales at the top of the Buckeye Tillite suggest a Permian age.

The Discovery Ridge Formation overlies the Buckeye Tillite with slight disconformity and can be divided into a lower platy shale member about 150 ft (46 m) thick, and an upper carbonaceous, fissile shale member about 400 ft (122 m) thick. Numerous trails of sizeable invertebrate animals provide the only fossil evidence from the hard silty shales of the lower member.

The Mount Glossopteris Formation is the uppermost sedimentary unit of the Ohio Range and is composed of about 2000 ft (610 m) of feldspathic sandstones, siltstones, shales and coals. An abundant but limited assemblage of fossil plants, including *Glossopteris*, *Gangamopteris*, *Schizoneura* and *Vertebraria*, is preserved in dark hard shales and as fossil logs in sandstones. *Glossopteris* has been found in association with branchiopod crustaceans. Numerous semi-anthracite coal beds are present, as much as 12 ft (3·7 m) thick and probably of limited horizontal extent. Fossil evidence indicates a Permian age for the Mount Glossopteris Formation. All evidence is consistent with fluviatile and paludal non-marine deposition.

In the Wisconsin Range, the details of the stratigraphic succession are still unknown but studies are planned there during the 1963–64 season. Studies made farther west in the Queen Maud Range by Doumani and Minshew during the last field season suggest that the Horlick Formation and Buckeye Tillite are absent, but beds resembling the Discovery Ridge Formation and the Mount Glossopteris Formation are represented.

TITLE: Reconsideration of the "Beacon" as a stratigraphic term in Antarctica

AUTHOR: Arthur Mirsky, Institute of Polar Studies, The Ohio State University, USA

The "Beacon Sandstone" of Ferrar was never defined and has no type section or description. The sedimentary rocks in southern Victoria Land include two distinct general lithologic types: relatively clean quartz-sandstone overlain by carbonaceous rocks. Although the name stemmed from Beacon Heights which is mostly quartz-sandstone, the name Beacon was also applied to the carbonaceous rocks. The Beacon is more complex than earlier reconnaissance study indicated, and its wide stratigraphic range, Devonian to Jurassic, far transcends the concept of a single formation or group. Moreover, a major unconformity representing most, if not all, the Carboniferous occurs within the Beacon, thereby further invalidating even the term Beacon System, which already does not conform with accepted usage in stratigraphic nomenclature. Application of Beacon terms (whether Sandstone, Formation, Group or System) to sedimentary rocks in Antarctica, especially outside southern Victoria Land, has been inconsistent, arbitrary and generally misused. Thus, in a recent interpretation, the term Beacon has been applied to carbonaceous strata but not to the underlying non-carbonaceous units, despite the primarily non-carbonaceous character of Beacon Heights.

The misuse of the Beacon is so ingrained in Antarctic stratigraphic thinking that re-definition now, even in accordance with rules of stratigraphic nomenclature, would probably compound the confusion. It is proposed here that present Beacon terms be abandoned, and the following nomenclature, resulting from recent detailed studies, be adopted as a useful and workable substitute:

(1) The flat-lying sedimentary rocks in southern Victoria Land include two sequences (Sloss's definition of strata bounded by major unconformities): the Fortress Sequence and the overlying Bastion Sequence, generally corresponding to clean quartz-sandstone and carbonaceous sandstone, respectively. The entire stratigraphic succession may be referred to informally as "Beacon Rocks".

(2) The Fortress Sequence includes all strata between the peneplaned late Precambrian to early Palaeozoic basement and the major unconformity representing the Carboniferous. All units in this sequence probably are Devonian. Basal beds representing initial deposition on the basement are included in the Windy Gully Formation. The overlying Razorback Formation forms the bulk of the Fortress Sequence and is mostly clean quartz-sandstone.

(3) The Bastion Sequence includes all strata between the Carboniferous unconformity and the post-Jurassic or Cretaceous unconformity at the top. All formations in this sequence are carbonaceous, and include Permian to Jurassic plant remains. The Permian Mount Bastion Formation, the lowest unit, dominates the sequence. The overlying Triassic Fleming Beds and Jurassic Carapace Beds are less well exposed.

Sequence names are applicable outside southern Victoria Land, because the delimiting unconformities are inter-regional. Formational names, however, are more restricted, and equivalent formations in other areas must be locally named.

TITLE: The geology of the "Zukkertoppen Nunataks", Ahlmannryggen, western Dronning Maud Land

AUTHOR: D. C. Neethling, Republic of South Africa

This paper is based on a reconnaissance geological survey which was completed during December 1962 of a part of western Dronning Maud Land, located along lat 72° S and extending approximately between long 2° and 3° W.

Sediments of probable Beacon Group age, which occur there, have been subdivided into a Basal Red Bed formation, a suspected tillite and fluvio-glacial conglomerate, and a succession of well-bedded clastic sediments. No diagnostic fossils were found. The stratigraphy, depositional environment and correlation within the area are discussed.

The Basal Red Beds consist dominantly of red quartzo-feldspathic mudstone and shale with minor interbedded feldspathic quartzite. The sequence is characterized by bands of intraformational conglomerate. A shallow-water continental environment with temporary withdrawal of the water is envisaged for the deposition of these sediments.

The Basal Red Beds are unconformably overlain by a well-developed, mixed-stone conglomerate, consisting of an assemblage of unsorted and irregularly spaced boulders and angular, heterogeneous rock fragments enclosed in a fine-grained, greywacke to sandy tillite-type matrix. This boulder-conglomerate is believed to be of glacial and fluvio-glacial origin, and attains a thickness of more than 300 ft (91 m) at the type locality to the west of "Tyndeklypa" nunatak.

Well-bedded, flat-lying clastic sediments of continental origin constitute the top part of the sedimentary assemblage and consist dominantly of interstratified beds of impure quartz-arenite and shale. The lower part of these sediments consists of cyclically deposited quartzitic shale and shaly sandstone, and is believed to be sediments of a deltaic or neritic environment.

Mafic sills, some with a differentiated top phase, intrude the sediments on a grand scale.

The structure of the area appears to be that of a sedimentary basin faulted down against the Basement Complex as exposed to the east of the Greenwich meridian.

Section 6. Mineralogy

TITLE: Some notes on mineralization in Antarctica

AUTHOR: George Mueller, University of Concepción, Chile

Old fumarole vents near the British station on King George Island contain pyrite, gypsum, limonite, halite and alum.

Veinlets and mineralized vesicles in basalts and andesites 1·25 miles (2 km) north-east of the Chilean refuge at Coppermine Island [Robert Island] contain abundant stilbite and subordinated natrolite, in addition to calcite and chalcedony.

Two veins occur near Soberanía station on González Videla Island [Greenwich Island]. They are composed of ankerite, barytes, calcite, magnetite and quartz as gangue minerals, but the metallic mineral constituents are chalcopyrite with its oxidation products. The average grade is less than 0·8 per cent Cu.

Mineralized erratic blocks containing epidote and zeolites are found near "Presidente Gabriel González Videla" station [Waterboat Point].

Lavas from the Porphyritic Formation (Chilean Andes) show vesicles filled with one of the hydrothermal minerals present. These structures ("candy box") are formed because mineral "A" in passing through the rock has a low nucleation probability, filling only some of the vesicles, whereas the others are filled later by minerals "B" and "C" in the same way. As a statistical rule for the Chilean Andes, it has been found that:

$$\frac{\text{number of vesicles filled with "B"+"A"}}{\text{number of vesicles filled with "A"}} \times \text{volume} = \text{constant.}$$

This shows that the probability of nucleation is proportional to the volume of the vesicle, and that the "dominant size" order coincides with the paragenesis in neighbouring veins.

The same structures have been found at Soberanía station [Greenwich Island], showing a paragenesis similar to the mineralization of the Chilean Andes:

Chile (350 samples from Antofagasta to Lonquimay): quartz, carbonates, zeolite, epidote, jasper (agate, etc.), haematite, chalcopyrite, chlorite.

Soberanía station (25 samples): quartz, zeolite, carbonates, epidote, jasper (agate, etc.), chlorite.

Some "levelled" vesicles were found at Soberanía station on González Videla Island [Greenwich Island]; they are filled with quartz up to a certain level and the empty space is filled by younger minerals (jasper, zeolite). Similar vesicles in the European Alps have been taken as horizontal indicators of mineralization; but the samples collected in the Antarctic were found in erratic glacial blocks, except for one outcrop.

"Candy box" structures can be explained as having been formed by the gradual cooling of fluids which have a low nucleation probability. These conditions were present in Chile and Antarctica, but in other places the vesicles show zoning with every mineral present in each one.

TITLE: Antarctic mineralogy

AUTHOR: Duncan Stewart, Carleton College, Minnesota, USA

Although names of rocks were mentioned occasionally in narratives and reports of the earlier expeditions to Antarctic waters, it was not until 1895 that the first paper on Antarctic petrography was published. Since then, some 200 mineral species, subspecies and varieties, as well as those of questionable occurrence have been reported from Antarctica.

Section 7. Igneous and metamorphic petrology

TITLE: Petrographic studies on the rocks from the area around Lützow-Holmbukta

AUTHORS: Shohei Banno, Tatsuo Tatsumi, University of Tokyo; Yoshio Ogura and Takashi Katsura, Tokyo Institute of Technology, Japan

The area around Lützow-Holmbukta is composed of metamorphic rocks and granites.

The metamorphic rocks are classified into the following five groups: basic granulite, pyroxene-gneiss, garnet-gneiss, marble and quartzite.

The basic granulites consist of ortho- and clinopyroxenes, hastingsitic hornblende and plagioclase. Garnet (pyrope-almandine) and biotite are often associated. The pyroxene-gneisses of dioritic composition consist of ortho- and clinopyroxenes, hastingsitic hornblende, plagioclase, potash feldspar, biotite and quartz. The garnet-gneisses of pelitic composition consist of garnet, biotite, plagioclase, potash feldspar and quartz. The marble contains forsterite, diopside, pargasite, phlogopite and scapolite along with calcite.

More than twenty rock-forming minerals, including garnet, ortho- and clinopyroxenes, hornblende and biotite, were analysed. All the analysed minerals have characteristics common to the granulite facies: the hornblende is hastingsitic, the garnet is rich in MgO, the biotite is rich in TiO_2 and the distribution coefficient of MgO and FeO between the ortho- and clinopyroxenes is in harmony with those of two-pyroxene assemblages in high-grade metamorphic rocks.

Perthitic and antiperthitic structures are common. The potash feldspar is orthoclase with (−) 2V ranging from 50° to 70°.

The mineral assemblages and the compositions of rock-forming minerals suggest that the metamorphic rocks in this area are isofacial and belong to the granulite facies.

TITLE: Note on some basic rocks in western Dronning Maud Land

AUTHOR: V. von Brunn, Republic of South Africa

Widely separated dolerite exposures appear to represent a single period of intrusion. Flows of amygdaloidal lava and intercalated tuffs are believed to post-date the dolerites. Basaltic dykes, which transgress both the dolerites and volcanics, are considered to represent the closing stages of igneous activity in this region. The possible age relationship between the basic igneous rocks and the sediments of western Dronning Maud Land is considered.

TITLE: The petrography of the igneous and metamorphic rocks of south Victoria Land: based on the collections made on the British Antarctic (*Terra Nova*) Expedition, 1910–13

AUTHOR: W. Campbell Smith, British Museum (Natural History), London

Work on the petrography of the great collection of rocks made by the geologists on Captain Scott's last expedition commenced in 1914, soon after the return of the expedition, but the last of the reports on the collections was completed only last year and is now in the press. The reports are published by the British Museum (Natural History).

The earlier geological reports dealt with palaeontology, sedimentary rocks and the petrography of the metamorphic, plutonic and hypabyssal rocks; the later reports describe the volcanic rocks of the Ross Archipelago and of Cape Adare. They add to previously published information on the kenytes, phonolitic trachytes, and basalts that constitute the McMurdo Volcanics and they give a full account of the Cape Adare volcanic rocks, previously known only from a few pebbles collected on the *Southern Cross* Expedition and by Borchgrevink on his brief first landing there in 1894. The rocks *in situ* are basalts. Alkali-trachytes occur as erratics and as pebbles on the beach. A phonolite, trachytoid phonolite and sanidinites in a remarkable boulder-bearing agglomerate are also described.

In the Terra Nova Bay region a few erratics of basalt and alkali-trachyte give clues to the types of volcanic rock forming Mount Melbourne, and erratics on the Priestley Glacier moraine are tholeiites, probably of the same age as the Ferrar Dolerites. The expedition added to the previously known occurrences of these extensive quartz-dolerite sills. Specimens of similar rocks were among those collected by the Polar Party on Beardmore Glacier on their return journey from the South Pole.

Plutonic rocks in the Terra Nova Bay region comprise a biotite-granite, and a diorite and microgranite. In the McMurdo Sound region two distinct granites are described with associated quartz-porphyry and lamprophyre dykes. Particular interest attaches to two large "dykes" of crystalline limestone apparently enclosed in the grey granite and to numerous, partly assimilated xenoliths of *para*-pyroxene-granulites. Some granitic rocks occur as erratics on Cape Adare and a great variety of plutonic rocks is represented among the erratics on Ross Island.

Metamorphic rocks were found *in situ* in the Kukri Hills and south of New Harbour and at small outcrops along the coast in the direction of Granite Harbour. These include cordierite- and sillimanite-bearing schists and crystalline limestones. Rocks that may belong to the same system are *in situ* also in the Terra Nova Bay region

and here also, in the western moraine of the Priestley Glacier, are erratics of quartz-granulites, *para*-pyroxene-granulites and graphitic mica-schists. These last, apparently of a lower grade of metamorphism than the metamorphic rocks seen *in situ*, may belong to a younger formation. They were not found in the moraines of any of the other three glaciers which flow down towards Evans Cove.

TITLE: Cordierite-bearing hypersthene-quartz-monzonite-porphyry in the Thiel Mountains

AUTHOR: A. B. Ford, US Geological Survey, Washington, DC, USA

Cordierite-bearing hypersthene-quartz-monzonite-porphyry is the principal rock throughout an area of nunataks of approximately 1500 sq miles (3900 km²) in the Thiel Mountains (lat 85° S, long 90° W) of interior West Antarctica. The porphyry makes up either a very homogeneous and thick volcanic pile, or, more probably, a shallow sill-like intrusive body. Previously reported lead-alpha ages of zircons from the porphyry indicate a late Precambrian age. The porphyry is intruded by coarse-grained porphyritic granodiorite and quartz-monzonite, probably of late Cambrian to early Ordovician age, as indicated by preliminary lead-alpha ages (470 ± 50 and 560 ± 60 m. yr.) of zircons from the intrusive rocks.

The porphyry is predominantly quartz-monzonitic but ranges to granodioritic; a typical mode is 30 per cent quartz, 25 per cent plagioclase, 32 per cent potassium feldspar, 5 per cent hypersthene, 3 per cent biotite, 3 per cent chlorite and 2 per cent cordierite, opaque and accessory minerals. The fine-grained groundmass of xenomorphic quartz and feldspar indicates surface or near surface crystallization. This primary groundmass has been variably recrystallized; locally it is coarser and granulitic, and the rock has the appearance of a charnockite. Poikiloblastic rims on potassium feldspar phenocrysts are probably related to the recrystallization of the groundmass. The porphyry has escaped complete recrystallization, even in the charnockitic varieties, as evidenced by the preservation of delicate, euhedral oscillatory zonation in euhedral or fragmented plagioclase phenocrysts; by the presence of large, rounded and deeply embayed (resorbed) quartz phenocrysts; and by the presence of large, angular to rounded (resorbed?), mostly anhedral phenocrysts of cordierite, which in many rocks appear to be xenocrysts.

The porphyry has been folded, as indicated by faint light and dark layers which define anticlines and synclines at two widely separated localities. The folds probably record a period of deformation prior to the emplacement of the Upper Cambrian to Lower Ordovician granitic body. Later high-angle faults may be related to Cenozoic block-faulting.

TITLE: Diabase sheets differentiated by liquid fractionation, Taylor Glacier region, south Victoria Land

AUTHOR: Warren Hamilton, US Geological Survey, Denver, USA

Sheets of diabase 300 to 1500 ft (90 to 460 m) thick were intruded into nearly undeformed Beacon Sandstone during Middle Jurassic time. Each sheet has alternating concordant and discordant segments and in places cuts obliquely through several thousand feet of strata. Some segments end against vertical faults which break the roofs but not the floors. The thick peneplain sill was intruded along or just above the base of the Beacon Sandstone, and the basement sill followed subhorizontal exfoliation joints developed during pre-Beacon time in granitic basement rocks. Roof weight squeezed intruding single sheets of low-viscosity magma out to subuniform thicknesses over areas of at least several thousand square miles.

The entire Beacon Sandstone was recrystallized slightly by the sheets, although obvious hornfelses are only a few feet thick. Basement rocks also were altered broadly but slightly. The diabase and sandstone section has been arched into a north-trending dome whose apex is the Royal Society Range and has been broken by a few normal faults with maximum displacements of 1500 ft (460 m); there is no "Great Antarctic Horst" here.

The basement sill was sampled systematically where it is 700 ft (210 m) thick, and it was studied in thin section and in fourteen analyses for both major and minor elements. Chilled-margin specimens that crystallized from liquid free of crystals at the time of intrusion have 55 per cent SiO_2, a low content of alkalis and little opaque oxide. The gabbro forming most of the interior of the sill contains more magnesian pyroxene and more calcic plagioclase than does the chilled rock; the magma was partly differentiated as a liquid prior to intrusion. (The sill is not composite, and changes contra-indicate wall-rock assimilation except as a contributor to granophyre.) Differentiation after intrusion was due largely to upward migration of volatiles and associated rock-forming elements. Granophyric diorite-pegmatite schlieren are abundant high in the gabbro. A silicic granophyre zone at the top of the gabbro (beneath the upper chilled zone) was produced by a combination of differentiation and hybridization of xenoliths of quartz-monzonite floating at that level. There is no evidence for crystal settling.

Sheets within the Beacon Sandstone are also high in silica and low in alkalis and opaque minerals. The peneplain sill has diorite-pegmatite but no silicic granophyre near its top. A thick inclined segment of a sheet at Pyramid Mountain shows systematic increase inwards of potassium, aluminium, ferric iron and titanium, components easily transported with volatiles, whereas magnesium and calcium decrease inwards, and sodium and ferrous iron are unchanged. Liquid fractionation is again indicated.

Thin dykes have more oxidized (but not total) iron than do thick sheets, and hence have more magnetite and less ferroan pyroxene.

Trace elements vary with major elements in ways predictable from crystal chemistry and the thermodynamics of the differentiation mechanism proposed. Liquid fractionation may be the dominant process of differentiation in most tholeiite sheets elsewhere.

TITLE: Granitization and charnockitization in the "Yamato Mountains"

AUTHOR: Koshiro Kizaki, Hokkaido University, Japan

The "Yamato Mountains" [Dronning Fabiolafjella], located between lat 71° 14′ S and 71° 45′ S and between long 35° 25′ E and 36° 05′ E, form a mountain arc extending over 30 miles (50 km), and consist mainly of seven massifs, which have been temporarily named "A", "B", "C", "D", "E", "F" and "G" from south to north. These massifs are surrounded by nunataks, and are separated from each other by several glaciers flowing down from east to west. A subsidiary mountain arc composed of linearly arranged small nunataks is connected to the main arc at massif "A". These massifs consist of various plutonic and metamorphic rocks, of which each rock species is rather zonally arranged parallel to the mountain arc.

Granitization and charnockitization have been observed in the pyroxene-gneiss and pyroxene-granite of massifs "E", "F", "C" and "A".

In the massifs "E", "F" and "C" the following series have been established: biotite-gneiss-diopside-biotite-gneiss—oligoclase-porphyroblast pyroxene-gneiss (enderbitic gneiss)—orthoclase-porphyroblast pyroxene-granite—pyroxene-bearing microcline-granite. The biotite-gneiss with intense schistosity grades gradually into the massive microcline-granite.

It is obvious that the latter half of this series shows a kind of static granitization associated with "porphyroblastesis" of feldspars due to the influx of granitic solutions. However, the formation of pyroxene in the biotite-gneiss indicates a progressive metamorphism towards the granulite facies. Therefore, the metamorphic facies which once culminated at the stage of the enderbitic gneiss may have been lowered by the granitization.

In the massif "A" the series is somewhat modified as follows: biotite-gneiss—diopside-biotite-gneiss—enderbitic gneiss—pyroxene-granite. It has been noticed that the pyroxene-granite, which mobilized without forming feldspar porphyroblasts, includes blocks of the biotite-gneiss and enderbitic gneiss.

Therefore, it is clear that mobilization in the amphibolite facies may have occurred after the granulite facies had been reached.

TITLE: Petrography of rocks from the Nimrod Glacier—Starshot Glacier region, south Victoria Land

AUTHOR: M. G. Laird, New Zealand Geological Survey, Wellington, New Zealand

Sedimentary and metasedimentary rocks of the region consist of Cambrian and Upper Precambrian limestones, conglomerates, sandstones and shales (Byrd Group), together with metagreywackes and meta-argillites (Beardmore Group). Two facies of contact metamorphism can be distinguished in metasediments of the latter group: an albite-epidote-hornfels facies and a hornblende-hornfels facies. This alteration has been caused by intrusion of acid magmas (Granite Harbour Intrusives) which range in composition from hypersthene-granodiorite to microcline-biotite-granite. Limestones of the Holyoake Range have been intruded by stocks of gabbro, whose relationship to the acid rocks of the Granite Harbour Intrusives is uncertain. The account is accompanied by a geological map.

TITLE: The high-grade metamorphic rocks of the MacRobertson Land and Kemp Land coast

AUTHORS: W. R. McCarthy, Australian Mineral Development Laboratories, Adelaide, Australia; and D. S. Trail, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia

Rocks collected from the MacRobertson Land and Kemp Land coast (long 64° to 57° E) and from several nearby north–south trending ranges during 1961 have been grouped into basic and intermediate charnockites, metamorphosed sediments and banded gneisses. The mineralogy of each group is described.

The charnockites are compared to the basic and intermediate varieties of Holland's charnockite series. The basic charnockites are thought to be metamorphosed basic igneous rocks. The intermediate charnockites are of uncertain petrogenesis.

Metasediments and hybrid (?) rocks occur within, and at the western extremity of, the outcrop area of the intermediate charnockites. The sediments have been metamorphosed under granulite-facies conditions. Interpretation of the metasediments and charnockites is discussed in the conclusions of the paper.

The banded gneisses consist of alternating felsic and mafic bands, and have been intensely folded. Banding is irregular and mafic bands contain hypersthene. Metamorphosed impure calcareous sediments, which occur within the gneisses, appear to have been metamorphosed under almandine-amphibolite-facies conditions. Differences in composition, e.g. water content, of the calcareous rocks are thought to be responsible for the lower facies assemblage.

A second period of metamorphism, probably of regional extent, has affected the area and is thought to have occurred between 490 and 660 m. yr. ago. Pegmatite activity accompanied or followed this metamorphism.

TITLE: Geological observations in Oates Land

AUTHOR: I. R. McLeod, Bureau of Mineral Resources (Geology and Geophysics) Canberra, Australia

The geology of several localities near the coast of Oates Land between long 157° and 166° E is described. The rocks of the western Wilson Hills and Magga Peak (several miles farther west) are fine-grained banded biotite-quartz-feldspar-gneisses containing numerous small migmatitic veins. The veins generally are of granitic composition, but they show a wide range in texture and in the proportions of constituent minerals. Adamellite containing numerous inclusions occurs in part of the eastern Wilson Hills.

Near Cape Williams, micaceous schists of the almandine-amphibolite facies have undergone a later thermal metamorphism. No igneous rocks were found in the vicinity, but adamellite occurs on a large island 14 miles (24 km) to the north-west.

The rocks of the Cape North area are sediments which have been tightly folded and metamorphosed under greenschist-facies conditions. Massive biotite-granodiorite which occurs at several places to the north-east and south-east of Cape North is probably younger than the metasediments.

Potassium/argon dates indicate Lower Palaeozoic metamorphism and igneous intrusion in the region.

TITLE: Charnockites of East Antarctica

AUTHORS: M. G. Ravich, L. V. Klimov and D. S. Soloviev, Research Institute of Geology of the Arctic, Leningrad, USSR

The charnockites are widespread in the lower structural stage of the Antarctic platform basement, composed of pre-Riphean rocks and metamorphosed in the granulite facies. Their outcrops, discovered and studied by the authors, extend along the east Antarctic coastal belt for a distance of 4350 miles (7000 km) from Pencksøkket (Dronning Maud Land) to the Mertz Glacier (George V Land).

The Antarctic charnockites involve a wide range of mainly orthopyroxene granulitic rocks, formed as a result of a granulite facies ultrametamorphism. According to the mode of their emplacement we can distinguish: (1) Phantom charnockites (highly granitized hypersthene-plagiogneisses) formed mainly as a result of metasomatic granitization of early schists and igneous rocks *in situ*. (2) Rheomorphic charnockites, formed during intrusive movement of partially melted granulitic rocks (including phantom charnockites) under ultrametamorphism.

The phantom charnockites, mainly formed at the expense of pyroxene-plagioclase-schists and plagiogneisses are widespread over enormous areas of the Bunger Hills, on the Ingrid Christensen Coast, in Enderby Land and in other regions. They show relict banding and gneissic structure of the substratum and in places they contain relics of schists and plagiogneisses. Their inhomogeneous composition, gradually ranging from pyroxene-plagioclase-schists to dominant ferrohypersthenic leucogranites, implies various degrees of alkali-silica metasomatism of granulitic rocks.

The distinct phantom charnockites are highly granitized gabbroids forming great intrusive bodies in the Bunger Hills. Within these bodies hypersthene-norites and gabbro-norites are gradually altered to ferrohypersthene-granodiorites and granosyenites, showing distinct evidence of feldspathization and silicification, and in places exhibiting a relict gabbro-ophitic texture.

The most widespread rheomorphic charnockites form massifs in area more than several thousand square kilometres. These massifs show intrusive contacts with adjacent migmatized and granitized schists. The charnockites composing them are partially formed by means of crystallization of the ultrametamorphic melts, but most of them have resulted from alkali-silica metasomatism of the incompletely melted substratum and crystallization products of melts, which proceeded during intrusive movements. The mineralogical and chemical compositions of the rheomorphic charnockites vary from leucodiorite to specific granosyenite, with eulite and fayalite, as the metasomatism intensity increases. Considerable melting of the granulite substratum and extensive intrusive movements gave rise to the appearance of the magmatic features of the resulting charnockites. However, in this case the specific peculiarities of their composition and structure are influenced mostly by comparatively later metasomatism, but not earlier magmatism.

Irrespective of their mode of emplacement, the evolution of all charnockite types is associated with sub-alkaline granites with the specific mineral assemblage of oligoclase-andesine, essentially sodic orthoclase, highly ferrous orthopyroxene (eulite) and fayalite. The essentially metasomatic character of these processes allows us to regard charnockitization as a specific form of granitization of rocks in the granulite facies, caused not only by high total pressures and temperatures, but also by low partial pressures of water and oxygen, and high activity of alkalis (potash in particular).

TITLE: Geological-petrographical study of the western end of 25 de Mayo Island [King George Island], South Shetland Islands

AUTHORS: Osvaldo C. Schauer and Nestor H. Fourcade, Instituto Antártico Argentino, Buenos Aires, Argentina

In this work results are given of geological and petrological research on the western end of 25 de Mayo Island [King George Island], the area between Suffield Point and Fildes Strait.

During the field work, forty geological samples were collected and from them the same number of thin slides have been made. The microscopical study of each one has established a predominance of effusive rocks (andesites and basalts). In a smaller proportion there are volcanic conglomerates, tuffs, clays and sandstones.

The clays and sandstones are not abundant in the area studied, but they are of great importance because they contain fossil plants belonging to the Middle Miocene (low Magellaniano).

The andesite volcanic rocks have a marked predominance over the basaltic ones and, according to their position in relation to the sedimentary beds, their age can be given as late Miocene or early Pliocene; on the other hand, the basaltic rocks could be from late Pliocene to Pleistocene in age.

Two faults, possibly due to the third phase of the Andean movements, have been inferred.

TITLE: Schist and granite in the southern Princé Charles Mountains

AUTHORS: D. S. Trail, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia; and W. R. McCarthy, Australian Mineral Development Laboratories, Adelaide, Australia

The Prince Charles Mountains extend south from lat 70° S for about 375 miles (600 km) between long 60° and 70° E. The northern mountains are formed by the high-grade metamorphic rocks typical of East Antarctica. A large area in the

southern mountains contains nunataks formed by sediments metamorphosed under greenschist-facies conditions, and by large bodies of granite.

Quartzite, quartz-mica-schist, marble, ferruginous rocks and amphibolite comprise the metamorphosed sediments. They are mainly altered sandstone, limestone, and silty and limy mudstone. The ferruginous rocks may be metamorphosed chert. Some amphibolites are metamorphosed basic igneous rocks.

Some rocks near granite have been metamorphosed under albite-epidote-hornfels or hornblende-hornfels conditions.

Large bodies of biotite-granite with accessory tourmaline and fluorite crop out within the metamorphosed sediments. Quartz veins and reefs and tourmaline-bearing pegmatites in the southern mountains are probably related to these granites.

In the sediments a first phase of deformation is represented by isoclinal and recumbent folds. Axial-plane schistosity of these folds is plicated by a second phase of deformation. Granite and adjacent metamorphics at Mount Bayliss have a marked cataclastic foliation.

The sediments were first regionally metamorphosed under greenschist-facies conditions. A period of widespread thermal metamorphism followed, possibly with mild deformation, during which biotite and perhaps cordierite crystallized. This metamorphism accompanied the emplacement and cataclasis of the Mount Bayliss granite and probably the emplacement of the other granite bodies.

The undeformed nature of the metamorphosed basic intrusions suggests emplacement between the regional and thermal periods of metamorphism.

The regional metamorphism may be the same event as the metamorphism dated between 500 and 650 m. yr. on the MacRobertson Land and Kemp Land coasts. The emplacement of the granites may be a post-kinematic feature of this metamorphism.

TITLE: Igneous and metamorphic geology of the Ohio Range, Horlick Mountains

AUTHOR: Samuel B. Treves, University of Nebraska; and Institute of Polar Studies, The Ohio State University, USA

During the 1961–62 Antarctic field season the igneous and metamorphic rocks of the Ohio Range of the Horlick Mountains were investigated. This study was concerned with the pre-Devonian basement rocks and the diabase sills that intrude the Devonian and post-Devonian sedimentary rocks.

The basement rocks here are part of the Antarctic shield. They are exposed in a series of north-facing scarps that bound the range and in some outlying nunataks. In this area the basement rocks are unconformably overlain by Devonian marine sedimentary rocks.

The basement consists primarily of a pink, coarse-grained, slightly gneissic, porphyritic quartz-monzonite that is intrusive into a grey-white, medium- to coarse-grained, gneissic, locally porphyritic granodiorite. The field relationships and mineralogical characteristics indicate that the granodiorite is closely related to the quartz-monzonite and that it is probably an early phase or marginal facies of the main intrusive mass. These basement rocks contain inclusions of biotite-schist, epidotized metadiabase, metadiorite and other rocks, and are cut by broad aplite dykes and garnet-bearing pegmatites. All of these older rocks are cut by diabase dykes.

The geological relationships here are broadly similar to those described in other areas of the "trans-Antarctic mountain chain" where the margins of the shield are exposed. These granitic basement rocks, therefore, are most likely early Palaeozoic in age. Absolute dates are currently being determined and should soon be available.

The sedimentary rocks of the Ohio Range are locally capped by an 800 ft (245 m) thick remnant of a diabase sill. The sill is cut by the same faults that are responsible for the block-like character of the range. This sill is similar to those that intrude the "Beacon" rocks in other parts of Antarctica and is probably correlative with them.

TITLE: Outline of the geology and petrology of the Sør-Rondane mountains, Dronning Maud Land

AUTHORS: T. Van Autenboer, Centre National Belge de Recherches Polaires, Université de Louvain, Belgium; J. Michot, Laboratoire de Pétrologie, Université de Liège, Belgium; and E. Picciotto, Service de Géologie et Géochimie Nucléaires, Université Libre de Bruxelles, Belgium

Geological reconnaissances were carried out in the Sør-Rondane mountains (between long 20° E and long 30° E, lat 72° S) during the three Expéditions Antarctiques Belges of 1958, 1959 and 1960.

The mountain range is composed entirely of crystalline rocks in which a gneissic complex can be distinguished from an igneous one.

(1) The gneissic complex is formed by a wide variety of gneisses (granitic, adamellitic, dioritic), and migmatites (epibolite, diadysite, embrechite, anatexite, agmatite) associated with typical anatectic granitic masses. It also includes thick beds of pure marble as well as Ca-silicates and forsterite-bearing rocks, graphite-bearing schists with scapolite nodules, and beds of quartzite. Lenses of gabbroic composition are also present.

A typical locally important facies is formed by stockworks of pegmatitic and aplitic dykes cutting the gneiss and forming migmatites *sensu stricto*.

The general orientation of the structures is east to west with a variable dip to the south. In detail, however, most outcrops show intense deformation. Some zones are characterized by cataclastic and mylonitic structures.

This gneissic series represents metamorphosed sediments of quartzo-pelitic and arkosic composition including more or less pure limestone, and containing basic intercalations of different kinds.

The mineral facies of regional metamorphism is typical of the upper catazone, but it has been subjected to a retrometamorphism to the mesozone.

(2) The second and younger complex is composed of igneous rocks forming homogeneous bodies displaying typically intrusive characteristics. These rocks are primarily represented by granite and diorite as well as syenite and monzonite.

A preliminary sketch map, which indicates the general structure and the main rock types, is given.

In the absence of dated sediments, the evidence from the field does not indicate the age of these various rocks. The ages obtained by radiometric dating methods are discussed in another paper.

Section 8. Geophysics

TITLE: Geophysical investigations in the Scotia Arc

AUTHOR: D. H. Griffiths, University of Birmingham, England

In collaboration with the British Antarctic Survey geophysical investigations are being made in the Scotia Sea, on the islands of the Scotia Arc and on the mainland of Graham Land. A reconnaissance gravity survey of the South Shetland Islands and the coastal regions of the northern part of Graham Land has been completed. This is based on a network of primary stations located at the British Antarctic Survey bases. A connexion has been established between this network and a station

at Buenos Aires (Ezeiza international airport) where the absolute value of gravity is known. The general pattern of the Bouguer anomalies, which are all positive, is simple. The contours follow the trend of the arc and there is a general and steady rise from the south-east to the north-west. This rise culminates in a narrow ridge of high gravity over the South Shetland Islands.

Numerous magnetometer traverses have been made across the Scotia Sea, and a relatively detailed survey of Bransfield Strait has been completed. In the Scotia Sea the distance between traverses is too great for correlation between individual anomalies to be possible, but a statistical method has been devised by means of which the region has been divided up into areas of different and sometimes sharply contrasting magnetic character. It is believed that the various magnetic types may have geological significance, and that the boundaries which have been delineated are related to structure. Many of the anomalies appear to be caused by bodies of basic igneous rock with upper surfaces at or not far below the sea floor, and one explanation of their origin is the existence of rugged sub-bottom topography.

A number of seismic refraction lines have been surveyed in Bransfield Strait. Seismic lines have also been surveyed on a south to north traverse across the Scotia Sea. This work has not yet been fully interpreted but it seems that over a considerable distance crustal velocities are particularly low when compared with those of a typical oceanic area.

TITLE: Report on the gravity measurements by the Japanese Antarctic Research Expedition, 1957–62

AUTHORS: Ichiro Murata, Geographical Survey Institute of Japan; Tsutomu Saito, Yoichiro Fujii, University of Tokyo; and Yoshimichi Harada, Geographical Survey Institute of Japan

In accordance with resolution No 18 adopted at the 13th general conference of IUGG in Helsinki (1960), a gravimetric tie measurement between Japan and Antarctica via Cape Town would be carried out by the Japanese Antarctic Research Expedition. The observations were done by means of a new GSI pendulum apparatus. The gravity difference between Tokyo and "Syowa base", Antarctica, was determined and results were as follows:

Period, 1961–62

Location, GSI	Pendulum gravity station ("Syowa base")
Lat = 35° 38·6′ N	Lat = 69° 00·3′ S
Long = 139° 41·3′ E	Long = 39° 35·4′ E
Ht = 28·0 m	Ht = 14·0 m

Gravity difference:

relative to

$$g_{\text{Syowa base}} - g_{\text{GSI, Tokyo}} = 2762{\cdot}4 \pm 0{\cdot}5 \text{ mgal}$$

$$g_{\text{GSI, Tokyo}} = 979{\cdot}7770 \text{ gal},$$

$$g_{\text{Syowa base}} = 982{\cdot}5394 \pm 0{\cdot}0005 \text{ gal}.$$

Worden gravimeter observations

Gravimetric connexions between Mowbray and "Syowa base" were made twice in 1959 and 1960, and the following results were obtained:

1959: $g_{\text{Syowa base}} = 982{\cdot}5434$ gal,

1960: $g_{\text{Syowa base}} = 982{\cdot}5460$ gal,

relative to

$g_{\text{Mowbray}} = 979{\cdot}6470$ gal.

The Bouguer anomalies in this area are distributed about in the range from −10 to −15 mgal.

The results of the gravimetric observations on the close pack ice off Lützow-Holmbukta about 95 miles (150 km) from Ongul show that free air anomalies in this area exceed +50 mgal. This means that the gravitational gradient in this bay is considerable.

The other gravity survey on the continent was made during the wintering season of 1961 and is reported elsewhere.

TITLE: Gravity measurements in the Sør-Rondane mountains, Dronning Maud Land

AUTHOR: T. Van Autenboer, Centre National Belge de Recherches Polaires, Université de Louvain, Belgium

A gravity survey supported by aircraft was carried out in the Sør-Rondane mountains during the Expédition Antarctique Belge of 1960.

Elevation and planimetric determination of the stations had been carried out during a general reconnaissance in 1959. Secondary stations were tied in by oversnow traverses and the mountain survey was tied in by an oversnow traverse to "Base Roi Baudouin", where the absolute value had been established previously. A Worden geodetic type gravity meter (No 453) was used. Gravity values and station descriptions are listed.

TITLE: Terrestrial geophysical studies in Antarctica

AUTHOR: G. P. Woollard, Geophysical and Polar Research Center, University of Wisconsin, USA

The programme of geophysical studies in Antarctica which originated with the British Antarctic Expedition, 1910–13, and reached its maximum development during the International Geophysical Year and during the subsequent three-year period can be divided on the basis of seismological observatory observations, traverse observations for defining the depth and configuration of the underlying bedrock surface, seismic refraction studies of the upper crust and geology, airborne magnetic observations, station magnetic observations, and gravity control observations.

The results of these various studies have shown: (1) that eastern Antarctica is a typical continental landmass having a mean crustal thickness of about 25 miles (40 km); (2) that western Antarctica is actually an island archipelago that is a continuation of the Andean–Scotia Arc tectonic province; (3) that the two areas are separated by a major break in surface physiography, geology and crustal thickness; (4) that the continental craton area is bounded by mountain ranges; (5) that there has been extensive vulcanism and probable strike-slip motion on the major break between eastern and western Antarctica represented by the Queen Maud Mountains; (6) that Antarctica, despite the evidence for both horizontal and vertical displacement of the crust, is not seismically quiet; (7) that the present magnetic pole is migrating rapidly; (8) that it is not possible to project the diurnal change in magnetic field over any considerable distance; (9) that the mean thickness of ice present is about 9850 ft (3000 m); and (10) that there is no well-defined embayment linking the Ross Sea with the Weddell Sea, although there may be locally narrow connecting channels.

Section 9. Geochemistry

TITLE: The geochemistry of Graham Land

AUTHOR: Raymond J. Adie, British Antarctic Survey, University of Birmingham, England

A number of rock types belonging to suites of different ages from the Graham Land peninsula have been chemically analysed for major and trace elements. These analyses have been grouped and plotted on variation diagrams, from which the parentage and lineal descent of each rock suite can be inferred.

The overall geochemistry of the metamorphic, volcanic and intrusive rocks of the Graham Land peninsula is discussed with special reference to the petrological implications, and compared with that of other regions of West Antarctica and with South America. All of these rock suites possess distinctive geochemical characteristics which are typical of the Andean Province.

Geochemical comparisons between the igneous rocks of West and East Antarctica show many important differences.

Section 10. Geochronology

TITLE: Antarctic orogenic belts as delineated by absolute age dates

AUTHOR: Ernest E. Angino, Department of Oceanography and Meteorology, A and M College of Texas, USA

A frequency plot compiled from over 215 published and unpublished age dates clearly details four widespread and several areally limited metamorphic-plutonic episodes in eastern Antarctica. To date, the earliest Antarctic orogenic activity is indicated by several dates of 1275–1840 m. yr. from the Vestfold Hills (lat 68° 35′ S, long 78° 21′ E). Two dates of 1530 and 1543 m. yr. from Terre Adélie suggest a possible extension of this belt east to long 142° E. More widespread activity is represented by a belt of rocks of 900–1100 m. yr. age extending from the Bunger Hills area (lat 66° 18′ S, long 100° 45′ E) to Porpoise Bay (lat 66° 45′ S, long 128° 45′ E). Some evidence for dividing this into two episodes is present. A late Precambrian orogeny (~700 m. yr.) affected these same regions and extended the orogenic activity to Ainsworth Bay (lat 67° 48′ S, long 146° 45′ E).

From Antarctica in general there have been over 75 isotopic age dates reported in the 450–550 m. yr. range and over 75 in the 400–500 m. yr. range. An extensive period of metamorphism-plutonism occurred during the early Palaeozoic with a peak of activity indicated in the Lower Ordovician (475 m. yr.). Five metamorphic belts of this age occupy the peripheral areas of eastern Antarctica: (1) the Conradfjella (lat 72° 0′ S, long 9° 30′ E) through the Sør-Rondane mountains (lat 72° 15′ S, long 21° 26′ E) to Lützow-Holmbukta (lat 68° 50′ S, long 37° 30′ E); (2) Mawson (lat 67° 40′ S, long 63° E) to Prydz Bay (lat 69° 0′ S, long 78° 19′ E); (3) Pingvin Island (lat 65° 45′ S, long 81° 50′ E) to Bunger Hills (lat 66° 18′ S, long 100° 45′ E); (4) Ainsworth Bay (lat 67° 48′ S, long 146° 45′ E) to Cape North (lat 70° 40′ S, long 165° 30′ E); (5) southern Victoria Land. A Middle Palaeozoic orogeny is suggested by a few dates (305–350 m. yr.) from Oates and George V Lands. Folding of the "Bellingshausen" geosyncline that affected most of western Antarctica, including the Palmer Peninsula and Scotia Arc area, is dated by a few determinations of 170–200 m. yr. from the South Orkney Islands. Probably contemporaneous intrusion of dolerite sills occurred in parts of eastern Antarctica as indicated by dates of 191 m. yr. from the Horn Bluff area in George V Land and dates of 150–168 m. yr. from the McMurdo Sound region. Recent activity is indicated by dates of 6, 20 and 75–100 m. yr. from Mount Sidley, Gaussberg and Antarctic Peninsula, respectively.

TITLE: Sr/Rb dating on basement rocks from Victoria Land; evidence for a 1000 million year old event

AUTHORS: S. Deutsch, Service de Géologie et Géochimie Nucléaires, Université Libre de Bruxelles, Belgium; and P. N. Webb, Victoria University of Wellington, New Zealand

Sr/Rb age measurements were carried out on biotite, as well as on feldspar and total rock, of basement rocks cropping out in Wright and Victoria Valleys. They comprise twelve samples of schist, gneiss, granite, pegmatite, aplite and a porphyry dyke.

All the biotites, except one, give approximately the same age, 480 m. yr. (434–495 m. yr.). A biotite taken from a schist in the vicinity of a dolerite dyke yields an age of 340 m. yr., obviously lowered by the contact metamorphism.

The feldspar age of a granite (Irizar granite) is 475 ± 80 m. yr., similar to the total rock age on an associated aplite (535 ± 120 m. yr.). The total rock and feldspar ages of a porphyry dyke, cutting the Olympus granite-gneiss, are found to be 1000 ± 100 m. yr., whereas its biotite age is only 480 m. yr., like all the other biotites in the area.

The data on the biotites confirm the existence of an extended metamorphic episode affecting the gneissic complex, an episode already known from published K/A ages. Moreover, the total rock and feldspar ages on the Irizar granite and aplite are taken as evidence for important magmatic activity at this same time.

The results on the porphyry dyke are especially interesting as they are the first indication in this region of an older event of approximately 1000 m. yr. They also suggest that the 500 m. yr. ages on biotites are not related to the general metamorphism of the gneisses but have to be ascribed to a later event.

Complementary age measurements and field investigations are needed before reaching any definite conclusions.

TITLE: Geochronology of the Sør-Rondane mountains, Dronning Maud Land

AUTHORS: S. Deutsch, P. Pasteels and E. Picciotto, Service de Géologie et Géochimie Nucléaires, Université Libre de Bruxelles, Belgium

Until now, nearly all the ages of the Antarctic continent have been measured by Sr/Rb on biotite and by K/A on biotite and on the total rock. It is a well-known fact that these ages are easily affected by metamorphism.

Presented here are the results of a geochronological investigation carried out on a limited area, where other methods which are known to be less sensitive to metamorphic effects have been applied simultaneously.

This study included sixteen samples of rocks representative of the principal petrographic types which crop out in the Sør-Rondane mountains (long 20° to 30° E). The geology and petrology of this area are the subject of another paper. This region is formed entirely of crystalline rocks, namely, gneisses intruded by bodies of igneous rocks. The metamorphic facies of the gneisses is upper catazonal with retromorphism in the mesozone.

The Sr/Rb isotopic ratio has been measured on 19 biotites, one muscovite, three feldspars, two total rocks and the Pb/U isotopic ratio on zircons from four granitic rocks.

All Sr/Rb ages of biotites are between 500 and 450 m. yr., whatever the source rock. The Pb/U measurements yield nearly concordant ages ranging from 600 to 500 m. yr., and the two total rock Sr/Rb ages are within the same limits.

These findings confirm the existence in this area of the 500 m. yr. old metamorphic episode recognized in numerous regions of Antarctica and especially in Dronning

Maud Land. Moreover, they provide the following complementary indications: the emplacement of the intrusive-type bodies may be dated at 550 ± 50 m. yr., based upon the zircon age; the migmatization and metamorphism of the gneisses are equally dated at 550 ± 50 m. yr., based upon Sr/Rb measurements on total rock and on muscovite.

It is concluded that the magmatic activity and the general metamorphism belong to the same Ordovician cycle. Up to now, there is no geochronological evidence of a previous cycle in this region.

The Sr/Rb ages on biotites are slightly but systematically younger, and this difference is beyond experimental error. It could be ascribed to the effect of a late phase, the geological significance of which still remains obscure.

TITLE: Bibliography of absolute age determinations in Antarctica

AUTHORS: E. Picciotto and A. Coppez, Service de Géologie et Géochimie Nucléaires, Université Libre de Bruxelles, Belgium

A brief account is given of the radioactive dating methods and of their importance in Antarctic geology.

The authors review fifteen articles dealing with age determinations on Antarctic rocks. 180 determinations are compiled in a table giving the following information: location, rock sample, mineral analysed, method, published age and age recalculated with λ_e, $^{40}K = 5{\cdot}85 \times 10^{-11}$ yr.$^{-1}$ and λ_β, $^{87}Rb = 1{\cdot}47 \times 10^{-11}$ yr.$^{-1}$.

All the data are also given on a map.

The majority of the ages have been obtained by the K/A method on total rock. These ages probably represent the lower limits of the real ages. The youngest dated rock is the Gaussberg basalt (20 m. yr.). The dolerite dykes cutting the Beacon Series are about 180 m. yr. (Lower Jurassic); the oldest ages measured are 1800 m. yr. The ages most widely distributed are grouped around 480 m. yr. (Ordovician). The magmatic and metamorphic features of most of the East Antarctic crystalline basement are consequently post-Cambrian. The geographical distribution of the absolute ages shows an "old" sector located between long 70° and 150° E, surrounded on each side by 500 m. yr. old rocks.

(Cf. E. Picciotto and A. Coppez. 1963. Bibliographie des mesures d'âges absolus en Antarctique. *Annales de la Société Géologique de Belgique*, Tome 85 (for 1961–62), Bull. 8, p B263–308.)

TITLE: Absolute ages of rocks from East Antarctica

AUTHORS: M. G. Ravich and A. J. Krylov, Research Institute of Geology of the Arctic, Leningrad, USSR

We now have available more than 200 absolute age determinations on rocks from East Antarctica. K/A age measurements have been made on bulk rock samples. Check measurements on micas and radioactive minerals (K/A and U/Pb methods) in most cases give figures exceeding by 10–20 per cent the ages determined on the bulk rock by the K/A method.

140 age determinations have been made on samples of crystalline basement rocks of the Antarctic platform, taken from outcrops in fifteen areas of East Antarctica from east Terre Adélie to Dronning Maud Land and extending along the continental margin for more than 4350 miles (7000 km). Age determinations have been made on samples from three groups of associated rocks, i.e. migmatite, charnockite and veined granite-pegmatite. The ages of the migmatites usually exceed by 10–20 per cent those of the charnockites and the ages of charnockites exceed by

the same amount those of the veined granites. Only the ages for the latest metamorphism of single blocks (to 500 m. yr.) of the crystalline basement, for all the above-mentioned three groups of rocks, appear to be almost the same.

The migmatites from the Vestfold Hills and Terre Adélie have the highest age values (to 1500 m. yr.). The ages of two younger groups of rocks from the Bunger Hills are 1100–1200 and 700–800 m. yr., despite the similarity of the geological structure. The older rocks (to 1200 m. yr.) were found in the Bunger Hills, Grearson Hills, etc., and the younger rocks (to 800 m. yr.) at Mount Strathcona, Oygarden Group, etc. The age of the youngest rock is 450–500 m. yr., determined for gneisses, migmatites and charnockites from Dronning Maud Land and for the rocks in the vicinity of the Mirny observatory.

If we consider these values as being the true ages of rock emplacement, then there might have been four periods in the formation of the crystalline basement from the Lower Proterozoic to the Lower Palaeozoic, inclusive. However, the rock compositions and the uniformity of the geological structure of the crystalline basement as a whole do not yet provide the possibility for considering the geological time of formation of its separate constituents as being of different ages. Moreover, the crystalline basement of the Antarctic platform, according to geological and petrological evidence, is considered to be of Archean age similar to the crystalline basements of many other platforms of the Earth, e.g. the Russian and the Siberian platforms. Thus, the highest age values exceeding 1500 m. yr. must be considered as due to rejuvenation, and we may expect higher age values to be obtained for the crystalline basement rocks. It is difficult to say what was the cause of this rejuvenation. Some parts of the basement are believed to have undergone block displacements that caused the loss of different amounts of radiogenic argon (and similar elements) from rocks of different blocks.

The ages of phyllite and micaceous quartzite which comprise the middle structural stage of the platform (in particular the Victoria Land fold belt) cover the range 425 to 530 m. yr., corresponding to the Lower Palaeozoic, and hence may be considered as the true age of rock formation. The granitic intrusions occurring within the early Caledonian fold systems of the Antarctic horst are of the same age, which also represents the true time of their formation.

The ages of the platform type of igneous rock units indicate the time of their crystallization. The latter include the minor granitic intrusions and nepheline-syenite in Dronning Maud Land (200–300 m. yr.), dolerite sills from the Beacon Group in George V Land (175–180 m. yr.) and leucite-basalt from the extinct Antarctic volcano of Gaussberg (20 m. yr.)

TITLE: On the age of the euxenite from Antarctica

AUTHORS: Nobufusa Saito and Kazuo Sato, University of Tokyo, Japan

Age determinations have been made on a sample of euxenite collected from a granitic pegmatite on the east coast of Lützow-Holmbukta. The age pattern of the euxenite was studied, because only a few examples on the use of euxenite for isotopic uranium–lead and thorium–lead age determinations have been reported. A mass-spectrometric isotope dilution method was applied to determine the lead content in the euxenite. The isotopic composition of non-radiogenic lead was estimated on the basis of a current model of the origin of terrestrial lead. The results are 485 ± 5, 468 ± 16, 458 ± 26 and 375 ± 29 m. yr. for $^{206}Pb/^{238}U$, $^{207}Pb/^{235}U$, $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{232}Th$ ages, in that order. A Rb/Sr age of 515 m. yr. was reported for biotites from the same locality by other investigators (Nicolaysen *et al.* 1961). From these data it is concluded that the most reliable age of the euxenite is the $^{206}Pb/^{238}U$ one. In order to obtain some geochemical interpretation on the discordant age pattern of

the euxenite, an acid-leaching experiment was carried out on powdered samples. The result of the determinations of lead isotopic composition in the acid-soluble part shows that non-radiogenic lead is more easily leachable than radiogenic lead and the isotopic composition of the acid-soluble radiogenic lead is nearly the same as that in the mineral. The results suggest that some loss of lead from the euxenite in geological time cannot explain the discordant ages of the mineral unless different stabilities are assumed for the respective radiogenic isotopes.

TITLE: Potassium–argon dates from Vincennes Bay region and Oates Land

AUTHORS: A. W. Webb, Bureau of Mineral Resources (Geology and Geophysics), Canberra, Australia; I. McDougall and J. A. Cooper, Australian National University, Canberra, Australia

Potassium–argon dates on biotites from granitic and metamorphic rocks from the Vincennes Bay region range from 1050 to 1140 m. yr. The spread in measured age may have been caused by loss of radiogenic argon during reheating at the time of emplacement of the youngest granitic rocks, or may be the result of variable argon leakage because of mild reheating at some subsequent time. Plagioclase from a gabbro in the Balaena Islands, Budd Coast, has a measured age of 510 m. yr. Biotite dates of 420 and 450 m. yr. were found from two metamorphic rocks in the Wilson Hills area, Oates Land. Two samples of adamellite from islands near Cape North, Oates Land, have measured ages of 340 and 360 m. yr. The Oates Land results indicate that metamorphism and emplacement of granitic rocks probably occurred in Lower Palaeozoic times.

Section 11. Palaeontology

TITLE: The significance of two separate Tertiary plant assemblages from King George Island, South Shetland Islands

AUTHOR: C. M. Barton, British Antarctic Survey, University of Birmingham, England

At King George Island plant remains occur in water-lain tuffaceous sediments interbedded with volcanic rocks of Tertiary age.

Two entirely separate types of floral assemblage are recognized. The flora west of Admiralty Bay is characterized by lanceolate and trilobed leaves similar to the fossil leaves of Río Pichileufú and Cerro Mirador in northern Patagonia. In sharp contrast, these leaf types are absent in the flora east of Admiralty Bay, where leaves of *Nothofagus* species are extremely common. Field evidence suggests that, of the two floras, the west King George Island assemblage is the older.

Analysis of the dicotyledonous leaves indicates that the west King George Island flora is warmer in character than that of east King George Island, and that both floras existed under predominantly cool conditions.

Tertiary connexions between King George Island and South America are supported by the similarities of the floras and the probable lines of communication along the Scotia Arc.

The west King George Island flora probably originated in South America and was established by a southward spread of the Río Pichileufú floral type along the western regions of the continent and the Scotia Arc. Polar cooling appears to have been initiated before the beginning of the Miocene. *Nothofagus*, already established in Tierra del Fuego in the Upper Oligocene, would have extended southwards along the Scotia Arc and as conditions became progressively more frigid would have replaced the older flora of King George Island.

Allowing for a time lag in the migration of the floras from Patagonia to Antarctica, it is concluded that the west King George Island floras extend from the Eocene to the lower part of the Upper Oligocene. They were replaced by the east King George Island flora in the upper part of the Upper Oligocene or Lower Miocene, after which time the climate became too frigid to support forest vegetation.

TITLE: Archaeocyatha from loose material at Plunkett Point at the head of Beardmore Glacier

AUTHOR: Dorothy Hill, University of Queensland, Australia

Loose pebbles of bioclastic limestone collected by Dr R. L. Oliver in 1961 from Plunkett Point, at the head of the Beardmore Glacier, contain fragments of cups of the archaeocyatha *Ajacicyathus* ? sp., *Coscinocyathus* sp., *Coscinoptycta bilateralis* (Taylor), *Thalamocyathus trachealis* (Taylor), *Formoscocyathus antarcticus* sp. nov. and *Flindersicyathus* sp. These are described and a Lower Cambrian age is deduced for the limestone.

TITLE: Correlations between early Permian sediments of northern and southern continents

AUTHOR: Gerhard O. W. Kremp, Geochronology Laboratories, University of Arizona, USA

Stratigraphic correlations between early Permian sediments of the northern and southern continents are essential for understanding such important geologic events as the Permo-Carboniferous ice age and the *Glossopteris* flora of Antarctica. Many previous correlations should be re-evaluated because of new evidence.

Late Carboniferous and early Permian stratigraphy in Europe is based primarily on palaeobotanical interpretations. The First International Congress on Carboniferous Stratigraphy (Heerlen, 1927) selected the seed-fern *Callipteris conferta* Brongn. as diagnostic of lowermost Permian. Continental formations elsewhere have been correlated on this basis. Years later, Russian and American workers chose the fusulinid *Schwagerina* ex gr. *moelleri* Raus. as the indicator of lowermost Permian (Dunbar *et al.* 1960). Marine sediments around the world have been correlated using this time marker.

Unfortunately, the fusulinids have not been subsequently keyed to *Callipteris conferta* beds to any great extent. Fomichev (1960) showed that in the Donetz Basin the fossil faunal boundary seems to be 4250–6250 ft (1300–1900 m) above the fossil floral boundary.

Independently, the author has recognized a similar condition in Texas and South Dakota, where spores which are dated as Permian in continental deposits were found among beds considered Carboniferous on the basis of marine invertebrates.

Palynology has the most cosmopolitan of fossils in the ubiquitous spores and pollen which settle out from wafting winds over both land and sea. Our research might aid in establishing not only more accurate and universal stratigraphic correlations, but also in better defining the palaeo-plantgeography of late Palaeozoic times.

Isolated, individual efforts are not likely to suffice in this undertaking. Complementary and co-operative programming of research is more likely to be effectual.

TITLE: The fossil flora of the surroundings of Ardley Peninsula [Ardley Island], 25 de Mayo Island [King George Island], South Shetland Islands

AUTHOR: Hector A. Orlando, Instituto Antártico Argentino, Buenos Aires, Argentina

Fossil plant impressions (with "flora of *Nothofagus*") found at a new Antarctic locality in the vicinity of Ardley Peninsula [Ardley Island], and their correlation with the Antarctic flora of Seymour Island and similar strata of the southern portion of South America are being studied. From an analysis of the flora the predominance of angiosperms and a relative absence of conifers, represented by only one species, can be observed. This Middle Miocene (low Magellaniano) flora is preserved in sandstones and clays which have been slightly metamorphosed by andesite dykes.

TITLE: Palaeobotany of Antarctica

AUTHOR: Edna P. Plumstead, University of the Witwatersrand, Republic of South Africa

In any review of the palaeontology of Antarctica fossil plants must play an exceptionally important role because of the great preponderance of continental and fresh-water formations in which plants form the only reliable stratigraphical markers. *Trans-Antarctic Expedition, 1955–1958, Scientific Report* No 9, "Geology. 2. Fossil floras of Antarctica" should prove a useful source of reference not only because the plants described are from opposing margins of the continent but also because by great good fortune the specimens cover a vertical range from Lower-Middle Devonian to Middle Jurassic. They comprise two collections—one made by the crossing party from four sites in the Weddell Sea area, and one by the New Zealand party from twelve different sites in the Ross Sea area–and include twenty-five genera and forty-six named species plus twenty others too poorly preserved to allow of more than a broad classification. Of these more than half are of Permo-Carboniferous age, a few of Devonian and Jurassic respectively and the rest Triassic.

In addition to this extensive Trans-Antarctic Expedition collection, fossil plants from fourteen other sites, collected by earlier expeditions or by United States IGY geologists prior to 1960, will be discussed briefly, and a preliminary report of two new Triassic sites and fifteen of Permo-Carboniferous age discovered by New Zealand geologists since 1960 will be given.

Of all known plant fossil sites, six are in West Antarctica. All are from Graham Land and associated islands and their time range is from Middle Jurassic to Lower Tertiary. The remaining forty-one sites are in East Antarctica and the vast majority are from the 2000 mile (3200 km) long "Great Antarctic Horst" where the best as well as the thickest exposures have been found. There are, however, enough representatives from other parts to establish with reasonable certainty that the whole of East Antarctica fell within a single floral unit which must have formed part of the Gondwana Province, for the chronological sequence of the fossil plants as well as all known genera and species have proved that a very close relationship existed between Antarctica and other Gondwana countries. Comparisons with fossil plants from North America and Europe have only a general evolutionary value.

The very existence of large vascular land plants in such an environment is of great climatic significance. Sediment in which the Antarctic plant fossils were impressed often suggests a lithological comparison with homotaxial fossil horizons in Africa which may be regarded as a reflexion of a similar environment, but may also indicate the much greater former proximity of the lands which shared a common floral history over so great a span of time.

Section 12. Structural geology and tectonics

TITLE: The Southern Ocean as a structural entity

AUTHOR: B. B. Brock, Republic of South Africa

The Southern Ocean makes an oceanic frame round the cratonic continent of Antarctica. The boundary of the ocean is a clean-cut structural feature (the Antarctic Ridge), whose structural character is accentuated by the coincidence, in large part, of linear zones of seismic activity, and the closure may thus be interpreted as outlining a relatively stable crustal plate with an identity of its own.

With the crustal plate as a model, each continent in turn was considered on the same basis: where ocean-bound, the median ridge was considered as the limit, but elsewhere (where continents come close to abutting) a strong seismic zone separates them.

The Southern Ocean served as a model for the world. The manner of comparing structural units of like size entailed tracing the model on a transparent hemisphere which fits snugly over a geological globe. This simple device supplies convincing evidence in the form of repetitive patterns that the fragmentation of the crust is not haphazard. On each continent in turn the outline of the Southern Ocean makes a surprisingly good fit either with the median ridge, the seismically marked limit or with the coastline itself; or more often with a combination of these three types of well-marked structural lines.

A study of the geology of Antarctica, with so much of it masked by ice (and transport difficulties) is akin to submarine geology based on bathymetry, geophysics and a few samples of rock. The sparse rock exposures in both cases cannot be expected ever to result in a clear structural picture. A "wide angle" approach, with the emphasis on form and analogy, has already yielded some spectacular results. This is thought to be the mere beginning of an important study, which could appropriately be called "crustal geometry".

TITLE: Volcanoes of the Executive Committee Range, Marie Byrd Land

AUTHOR: George A. Doumani, Institute of Polar Studies, The Ohio State University, USA

The chief rock types collected from the Executive Committee Range are andesite, trachyte, basalt and lapilli tuff. A Middle Pliocene age (6·2 m. yr.) is assigned to the earlier stages of volcanic activity. Later stages of extrusion occurred in the form of sub-aqueous eruptions or injections under ice. The volcanoes show a remarkable north–south linearity, and a north to south migration of volcanic activity. After considering *collapse, creep, vertical movement* and *transcurrent movement*, and eliminating the mechanisms inapplicable to these volcanoes, it is deduced that linearity and migration were controlled by planes of dip-slip reverse cross-faults dipping northward. Such cross-faults occur *en échelon* in a wide fracture zone resulting from counter-clockwise transcurrent movement initiated by clockwise rotational movement of the Antarctic continental mass. This movement is responsible for setting aside this part of the Antarctic which is merely a volcanic archipelago, peripheral to the main Antarctic mass (eastern Antarctica). It is decidedly younger than the rest of Antarctica and possesses marked petrologic and structural differences.

TITLE: Tectonic map of Antarctica

AUTHOR: Warren Hamilton, US Geological Survey, Denver, USA

TITLE: Geological structure and genesis problems of the Antarctic platform crystalline basement

AUTHORS: M. G. Ravich, L. V. Klimov and D. S. Soloviev, Research Institute of Geology of the Arctic, Leningrad, USSR

Antarctica is an ancient platform more than 3 900 000 sq miles (10 000 000 km²) in area surrounded by an Alpine mountain system on the Pacific coast. The platform occupies the whole of East Antarctica and a significant part of West Antarctica. There are three structural stages in the Antarctic platform: the lower stage or the pre-Riphean crystalline basement, the middle stage or the early Caledonian fold belt, and the upper stage or Riphean–Mesozoic cover of the platform.

The crystalline basement of the platform is exposed in the coastal block mountains, extending discontinuously for more than 4350 miles (7000 km) along the coast of East Antarctica from long 1° W to 145° E. It consists of a folded rock sequence (about 12·5 miles (20 km) thick) and granulite-facies schists in various degrees of granitization and migmatization, in places with abundant marble and calciphyre beds, metabasic rock bodies and charnockite intrusions. The rocks of the crystalline basement have been formed by regional metamorphism and ultrametamorphism (selective melting, migmatization, granitization, mobilization and rheomorphism) of the oldest geosynclinal complex of clastic carbonate sediments intercalated with volcanic and pyroclastic formations of basaltic magma.

The Caledonian fold belt, which extends for more than 2200 miles (3500 km) from George V Land through south Victoria Land and the Queen Maud Range to the South Pole and perhaps farther eastward, is characterized by a very complex structure. At its base there is a deformed sequence, which consists of two-mica- and garnet-gneisses of amphibolite facies. It consists mainly of the folded Riphean-Lower Palaeozoic slate-greywacke sequence of greenschist facies containing quartzites and Cambrian limestones less than 2·5–3·1 miles (4–5 km) thick. These deposits are intruded by amphibole- and mica-granites and granodiorites. The sedimentary and volcanic Beacon Group (Silurian–Triassic) and the Mawson Formation (Jurassic–Cretaceous), penetrated by the Ferrar Dolerite sills and dykes (Mesozoic trap formation), rest almost horizontally on the Caledonian fold system.

The continental deposits of the platform cover are represented by the sequence (1·3 miles (2 km) thick) consisting of various interbedded sandstones, silts, siltstones and shales, including some conglomerates, and scarce limestones. The upper part of the sequence is rich in coal seams among coaly-clayey shales and siltstones.

During the deposition of the platform cover a magma of different composition intruded the basement and the upper structural stages along the faults, leading to the emplacement of granitic and syenitic rocks in the Upper Palaeozoic and the injection of sills and dolerite dykes into the Mesozoic.

The most conspicuous feature about the geological structure of the Antarctic platform is its similarity to Brazil, Australia, Equatorial and South Africa, and India. Formations of almost the same continental-type sediments containing a similar *Glossopteris* flora and the remains of specific reptiles, were deposited in all of these regions at least from the Upper Palaeozoic until the Middle Mesozoic. During that period, in all these continents, uniform magmatic activity resulted mainly in the formation of trap volcanics. Thus, all these regions are considered to be parts of a single Gondwanaland. Furthermore, we may consider the crystalline basements of these now separated continents to have the same geological history, because of obvious similarities between their rock units, i.e. granitized gneiss complexes of granulitic facies with abundant charnockite masses.

TITLE: Tectonics and neotectonics of Antarctica

AUTHOR: P. S. Voronov, USSR

Before the beginning of the IGY there were considered to be three main geostructural elements in Antarctica: (1) The east Antarctic post-Proterozoic platform, coinciding with the territory of East Antarctica. (2) The folded alpine zone of West Antarctica. (3) The Ross–Weddell Sea depression.

Up to that time the following major problems concerned the structure of the Antarctic continent: (1) The exact boundaries of East Antarctica and its marginal folded zones. (2) The inner structure of the post-Precambrian folded zones (especially of the alpine zone) and the nature of the Ross–Weddell Sea depression. (3) The role of the regional faults (lineaments) in the structure of Antarctica. (4) The manifestations of the neotectonics and the isostatic uplifts in the morphological structure of the continent. (5) The reasons for the aseismicity of Antarctica.

Nowadays the views on the structure of the Antarctic continent differ considerably from those of 1957–58, thanks to the efforts of the geologists of many countries whose investigations during the last five years have contributed a lot to the solving of the above-mentioned problems.

On the basis of the field results, palynological data and absolute age determinations on rocks from East Antarctica, it is possible now to distinguish a coastal zone of the Caledonides which surrounds the central post-Proterozoic platform. The Caledonides are most fully developed at the limits of Oates Land and Victoria Land, while in the coastal area of the central and western sectors of East Antarctica they are not so well preserved.

Along the outer margin of this Caledonian belt there seem to be present Hercynides in the form of relicts, which are most probably preserved in Marie Byrd Land, West Antarctica.

The Alpinides cover the whole Antarctic Peninsula, but in the region of the Ellsworth Highland they seem to virgate partly towards the Amundsen Sea and partly towards the Ross Sea, surrounding the Hercynian (?) central massif of Marie Byrd Land. The greater part of the west Antarctic crust is supposed to have been subjected to "oceanization" during the Cenozoic.

The Ross–Weddell Sea depression may be considered as most probably a modification of a foredeep of the Alpine-folded zone of the Antarctandes.

The regional faults (lineaments) play a most significant role in the formation of the Mesozoic–Cenozoic block structures of Antarctica. They determine the configuration of its continental slope, inner shelf troughs, the zones of the block mountains in the eastern part of the continent, a series of central downwarps, etc. Among these lineaments the north–south and east–west faults predominate and form the global radial-concentric system situated symmetrically in relation to the South Pole.

Neotectonic movements of great amplitude are fully developed in Antarctica. These movements are largely controlled by the isostatic uplift of huge crustal blocks which have been under the influence of the colossal load of the central ice cover. All these factors have been responsible for the main features of the present morphological structure of the continent.

The paradox of the aseismicity of the Antarctic continent seems to have resulted from the widespread plastic deformation of the Antarctic crust under the ice load, and by the general decrease in temperature of the lithosphere under the ice cover. The absence of earthquakes with shallow foci may also be explained by the binding of the lithosphere blocks to the plastic masses of the continental ice sheet.

With the aim of exploring the structure of Antarctica further, it is necessary to concentrate the main efforts on the geology of the most important regions, among which are the Executive Committee Range and the mountains of the Ellsworth

Highland, the western part of the Queen Maud Range and Coats Land, and the head of the Lambert Glacier. It is also of great importance to determine as soon as possible the absolute age of rocks from the above-mentioned regions and of West Antarctica, in particular. A series of regional aeromagnetic traverses of the continent and numerous seismic profiles (by the refraction method) across the most important areas should be carried out.

Section 13. Submarine geology

TITLE: A description of bottom sediments in Lützow-Holmbukta

AUTHOR: Hideo Kagami, University of Tokyo, Japan

The second and fourth Japanese Antarctic Research Expeditions (1957–58 and 1959–60) collected thirteen bottom sediment samples on the slope off the Kronprins Olav Kyst, from the upper part of the slope at the mouth of Lützow-Holmbukta, and from the submarine ridges north of Riiser-Larsenhalvøya.

The samples were analysed in order to determine the variation of grain-size, heavy mineral assemblage and clay mineral content.

On the basis of the mechanical size distribution, the bottom sediments are divided synthetically into four groups: Lützow-Holmbukta silty gravel or gravel silty sand, shallow submarine ridge sand and gravel, deep submarine ridge sandy silt or silty sand, and lower slope clayey silt. There is a greater proportion of fine sand (0·2–0·063 mm in diameter) in the shallow submarine ridge and the deep submarine ridge provinces, that shows the presence of a weak current sufficient to disturb the bottom surface. However, as the deep submarine ridge province has a coarse silt mode, the current in this area is weaker than that in the shallow area. Medium silt size is the maximum grade class of the lower slope sediments. In Lützow-Holmbukta, sediments of coarse and medium silt grade are concentrated, and this area is also characterized by a large concentration of gravels. Ice-rafting seems to explain the presence of these erratic gravels most plausibly.

The dominant heavy minerals in the particles between 2 and 4 ϕ are apatite, biotite (phlogopite), diopside, epidote, forsterite, garnet, hornblende, hypersthene (bronzite), magnetite, rutile, sphene, spinel and zircon. Augite, hypersthene, garnet and hornblende may be derived from pyroxene-gneiss, garnet-gneiss, granite and the basic metamorphic rocks which are found extensively along the Kronprins Olav and Prins Harald Kysts. Phlogopite, diopside and forsterite may be from the marble in the gneiss formation. The garnet/hornblende ratio agrees well with the grain-size distribution, because garnet is a mineral resistant to winnowing action, while hornblende is mobile in a weak current and concentrates in silt-size particles. A high ratio is found in the shallow submarine ridge province near Gunnerusbanken, and there is a low ratio in the deep submarine ridge and Lützow-Holmbukta provinces.

X-ray diffraction analyses of the $-2\ \mu$ fractions were carried out and following treatment with ethylene glycol, hydrochloric acid, ammonium nitrate and magnesium acetate solutions, and heat treatment they were re-examined. The clay minerals of the bottom samples under consideration can be identified as illite, chlorite, kaolinite, metahalloysite and montmorillonite. In a few samples vermiculite, biotite, muscovite and amorphous silica form a smaller part of the clay minerals. Quartz, feldspar and calcite are intermixed in all samples. By counting the relative intensity of diffraction diagrams it has been found that illite is the dominant clay mineral in this area.

TITLE: New data on submarine geology of Antarctica

AUTHOR: A. P. Lisitsin, USSR

TITLE: Submarine topography off the Kronprins Olav Kyst

AUTHORS: Yoshio Yoshida, Ochanomizu University; Sadanori Murauchi, National Science Museum; and Kenzo Fujiwara, Hiroshima University, Japan

During the six Japanese Antarctic Research Expeditions of 1956–62, echo-soundings and dredgings were done on board the expedition ship near the Kronprins Olav Kyst and Lützow-Holmbukta in Dronning Maud Land. Soundings by wire and seismic shooting were carried out by the wintering teams in 1959–61, in the fast ice region of Lützow-Holmbukta. Though the results are not always satisfactory for a knowledge of the submarine topography of this whole area, the following features can be pointed out:

(1) The continental shelf off the Kronprins Olav Kyst generally lies at a depth of 600 to 1300 ft (200 to 400 m), and its surface is not always flat but has a considerable relief. Its breadth is about 37 miles (60 km), extending nearly parallel to the coastline.

(2) Near the coast around Lützow-Holmbukta, depths of 660 to 1300 ft (200 to 400 m) are found over a relatively wide area, but a rather deep floor of 1650 to 2000 ft (500 to 600 m) stretches to the south in the middle of the mouth of the bay. A depression of 2300 to 3000 ft (700 to 900 m) exists near the floating ice tongue of Shirasebreen at the head of the bay, but it does not seem to continue to the continental slope in the form of a submarine canyon. There is a rise to 300 to 600 ft (100 to 200 m) depth adjacent to Ongul, but a depression below a depth of 1650 ft (500 m) occurs at the narrow strait between Ongul and the continent. The direction of the extension of this depression is conformable with that of the courses of the glaciers on the east coast of the bay, suggesting that the depression may be related in part to the geological structure.

(3) The ridge known as Gunnerusbanken spreads to the north off Riiser-Larsenhalvøya. The depth of the shelf margin is about 1650 to 2000 ft (500 to 600 m) from the central part of the mouth of the bay to just off Riiser-Larsenhalvøya.

TITLE: Tectonic and relief maps of the sea floor in the Southern Ocean

AUTHOR: Alexander V. Zhivago, Institute of Geography, USSR

Tectonic and geomorphological maps of the Southern Ocean on a scale of 1:20000000 have been compiled from echo-sounding data and results of marine geological and seismo-acoustic research carried out by different countries in the Antarctic during the IGY and IGGU.

The principles of compiling a tectonic map of the ocean differ somewhat from those used for land maps, because the age of folding can be established only for littoral areas. Differences in the type of crust under the ocean floor serve as the main taxonomic principle. Thus, the shelf, along the margin of the Epi-Proterozoic platform of eastern Antarctica is characterized by purely continental features. To the transition between the continental and oceanic areas belongs the continental slope of the Antarctic continent, the zones of island arcs, as well as the basins of marginal seas. The structural areas of the oceanic crust are represented by gigantic depressions and arched uplifted parts of the ocean bed (basins and swells), by the linear folded block structures of the median ridges, oceanic trenches and their marginal swells.

On the geomorphological map of the Southern Ocean *morphostructures* are distinguished, i.e. large relief elements and expanses of uniform relief, in the formation of which tectonic movements and volcanism played a decisive role (oceanic swells, basins, ridges, trenches, etc.).

Forms of smaller scale are represented by *morphosculptures* determined by the action of exogenic forces (wave action, turbidity currents, bottom currents, subaqueous slumping, accumulation of iceberg sediments, etc.).

The map also shows *submerged peneplanation planes*, which include horizontal, sub-horizontal and inclined surfaces of a complex origin, formed during a lengthy period of compensation of endogenetic processes by exogenetic ones, and classified by the main planation agent of the relief (abrasion-aggradation shelf plains, abyssal accumulation plains, etc.).

The legend and classification determinations for both maps are based on the independence principle of structural plans for the seas and continents. Examples of accordant structures are known only for the area of a transition crust, where island arc structures are associated both with the structures of the continents and with the abyssal oceanic trenches fringed by marginal swells.

Section 14. The relationship of Antarctica to the southern continents

TITLE: Importance of Antarctica in the hypothesis of Continental Drift

AUTHOR: L. C. King, University of Natal, Republic of South Africa

Antarctica is shown to be the central locking piece of the Gondwanaland jig-saw puzzle. The late Palaeozoic and Mesozoic stratigraphy of its shield area corresponds with that of the other southern continents; and the broken subglacial terrain of West Antarctica (as now known) makes an essential part of the Gondwana circumvallation.

TITLE: Antarctica, the climate of the Tertiary, and a possible cause for our ice age

AUTHOR: Gerhard O. W. Kremp, Geochronology Laboratories, University of Arizona, USA

Coal deposits in Antarctica proper (Crohn, 1959; Schopf, 1962) and *Nothofagus* pollen in Graham Land (Cranwell, 1962) are indisputable evidence of rich plant life there in the geologic past. Need we resort to continental drift or shifting geographic poles to account for warmer climates in that area? Not necessarily.

Palaeogene plant fossils are found throughout the Northern Hemisphere, including most of the ice-bound islands ringing the Arctic Ocean (Cain, 1944; Manum, 1962). The tropical-subtropical palm belt of the Palaeogene was nonetheless centred at the present Equator as it is today. Is it not plausible that the apparently less-extreme climatic patterns of the Northern Hemisphere were reflected in the Southern Hemisphere in each point of time, i.e. late Palaeozoic to Tertiary? In such case *Nothofagus* would have grown readily in Graham Land at precisely its present latitudinal position. Likewise, late Palaeozoic coals in the Antarctic need no complicated explanation.

Uplift to 13100 ft (4000 m) of vast areas of Antarctica (subglacial relief map, American Geographical Society, 1962) during the late Tertiary, perhaps identifiable with the Alpine, Himalayan and Rocky Mountain orogenies, may be one cause of the current ice age. Initial mountain glaciers in Antarctica would have grown to vast ice sheets that calved icebergs at the shores. These and other contributing factors in turn chilled the seas for millions of years. Fluctuating solar radiation (Milankovitch, 1941) and/or the mechanism described by Ewing and Donn (1956) then were able to trigger the Nebraskan and the subsequent ebb and flow of glacial stages.

NOTICE

The SCAR Bulletin is published in England in January, May and September each year as part of the *Polar Record*, the journal of the Scott Polar Research Institute.

Contributions are invited, and should consist of factual notes on the membership, equipment and activities of Antarctic parties; articles on matters of particular interest in connection with these activities are also welcome. Contributions should be sent to the Editor, Scott Polar Research Institute, Lensfield Road, Cambridge, England.

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