STRATIGRAPHY OF THE THERON MOUNTAINS

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ABSTRACT. The oldest rocks exposed in the Theron Mountains comprise 700 m. of terrestrial, water-laid clastic sediments consisting of arkosic, feldspathic and quartzitic fine-grained sandstones and siltstones with thin shales and mudstones, and subordinate carbonaceous beds and coals. Minor hiates may represent variations within the depositional environment. A glossopterid flora indicates a Lower Permian age.

These sediments were intruded by great thicknesses of Jurassic dolerite. The occurrence of minor local tilting and faulting was associated with and subsequent to intrusive activity, and pervasive thermal metamorphism of most of the sediments occurred. Post-Jurassic tectonic activity is not known but some block faulting may have elevated the Theron Mountains.

THE Theron Mountains, which are situated on the inland edge of the Filchner Ice Shelf (Fig. 1), trend north-east to south-west for about 120 km. The area described here (Figs. 2 and 3), between lat. 78°45′S., long. 26°50′W., and lat. 79°30′S., long. 30°20′W., includes the whole mountain range.

PREVIOUS INVESTIGATIONS

The Theron Mountains were first visited during the Trans-Antarctic Expedition (Stephenson, 1966) and much of the area was photographed during early exploratory flights by this expedition. Subsequently, a map was compiled and published in 1963 by the Directorate of Overseas Surveys.

Stephenson (1960, 1966) published brief accounts of the geomorphology and geology of the mountains and Blundell (Blundell and Stephenson, 1959; Stephenson, 1966) investigated the palaeomagnetism of dolerite samples. Coal samples were examined by Brown and Taylor (1960), and Plumstead (1962) reported on the plant fossils. Rex (1971) has reported K-Ar age determinations on dolerite specimens collected by the author. In December 1967 and January 1968, the U.S. Navy squadron VXE6 completed trimetrogon air photography of the entire mountain range.

The first detailed field mapping of the Theron Mountains was undertaken by the author in 1966–67. Glaciological, biological and geomorphological observations during this investigation have been described by Wornham (1969), Lindsay and Brook (1971), Brook and Beck (1972) and Brook (1972).

As a more detailed study of the Jurassic dolerite intrusions will be published separately (Brook, in press), this paper describes only the stratigraphy and sedimentary geology of the Theron Mountains.

STRATIGRAPHY

The stratigraphy of the Theron Mountains is summarized in Table I, and Figs. 3 and 4 illustrate the geology of the area and the stations visited. Because no Basement Complex is present, the

TABLE I. SUMMARY OF THE STRATIGRAPHY, METAMORPHISM AND TECTONIC HISTORY OF THE THERON MOUNTAINS

Age	*Rock types*	*Metamorphism*	*Tectonic events*
Recent			Erosion
(?)			(?) Faulting
Jurassic	Dolerite sills and dykes	Thermal metamorphism of sediments	Minor tilting and faulting associated with intrusion
Lower Permian	Victoria Group sediments, including coals (continental)		Sedimentation with some penecontemporaneous erosion

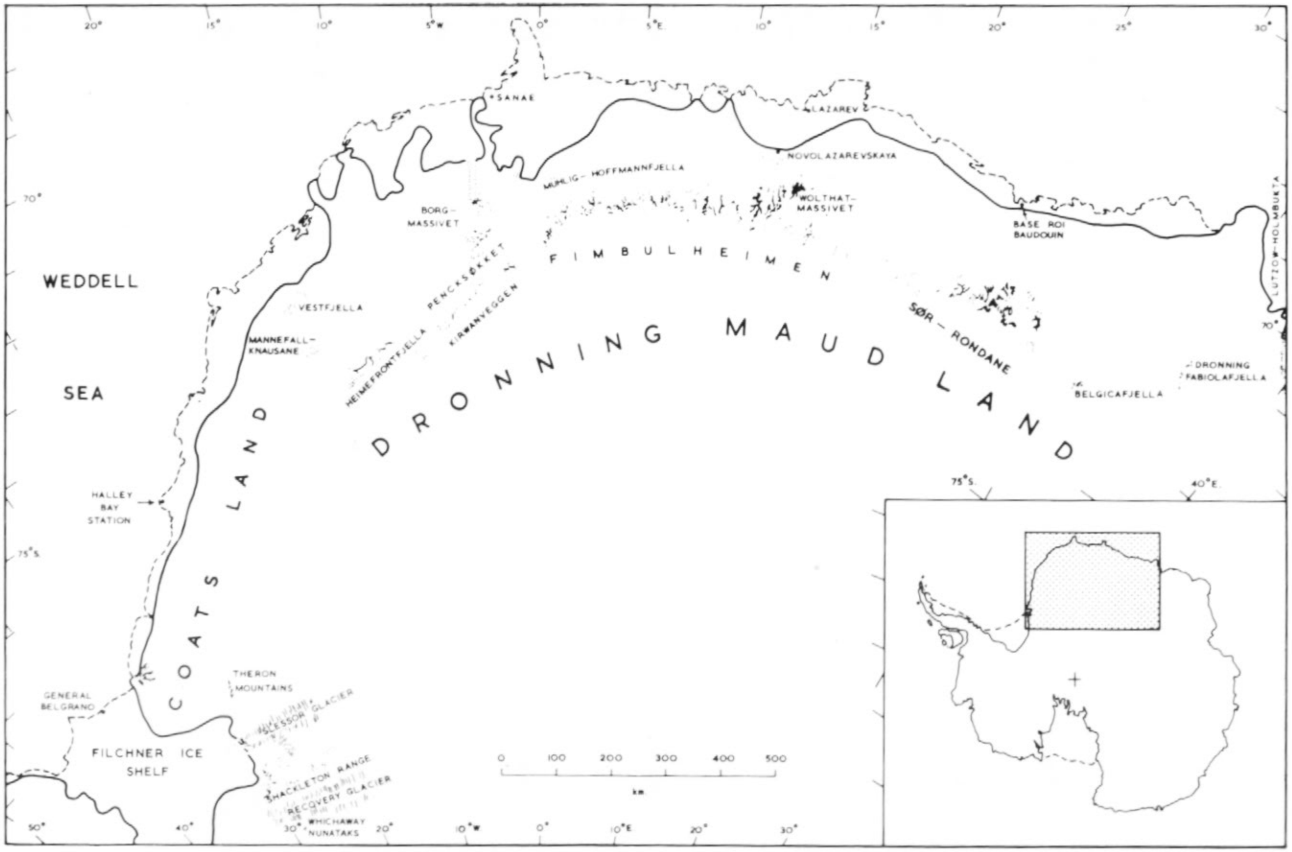


Fig. 1. Sketch map of Coats Land and Dronning Maud Land showing the location of the Theron Mountains and nearby mountain groups; the inset shows the general location of this area in Antarctica.

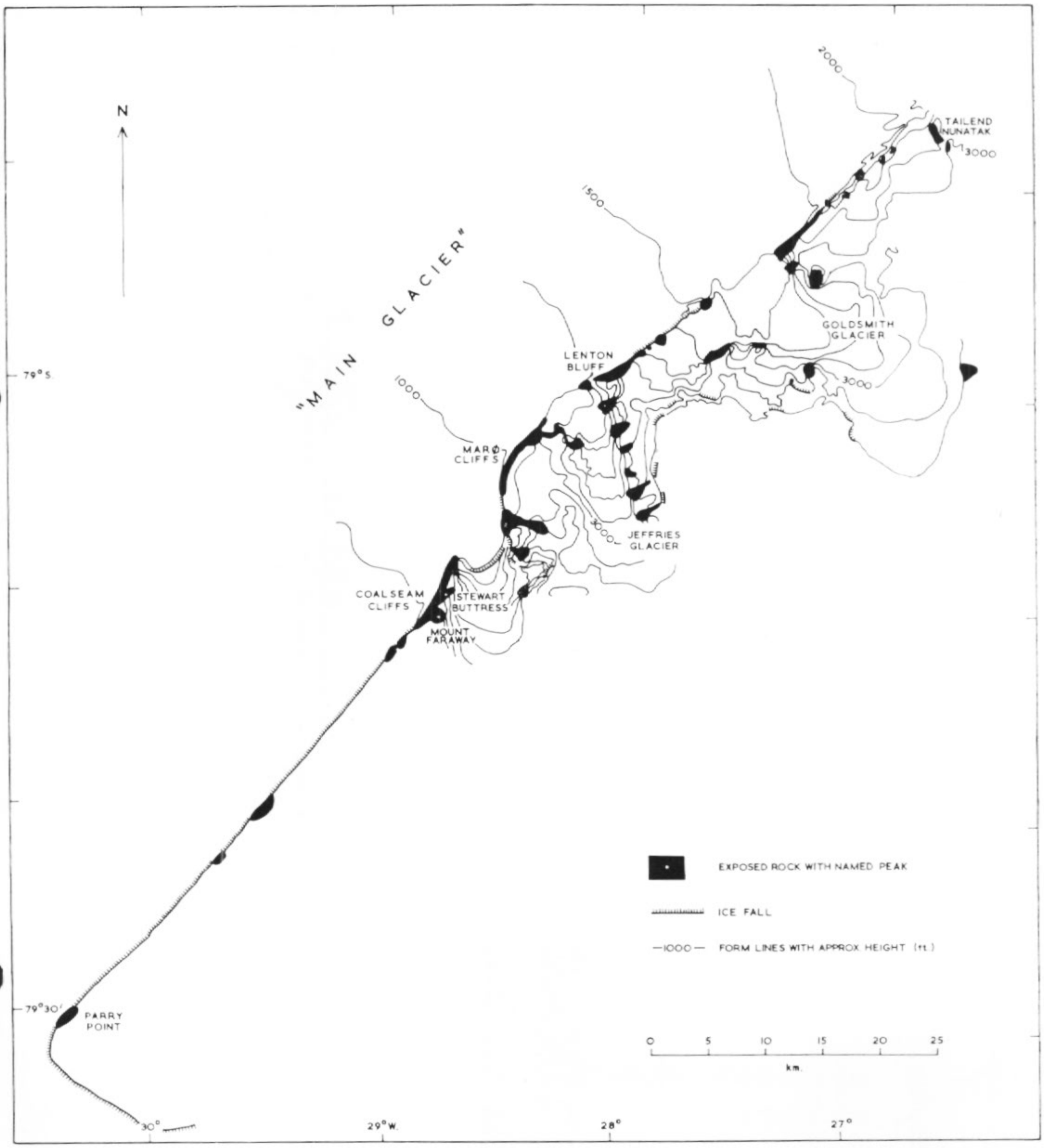


Fig. 2. Topographical sketch map of the Theron Mountains giving the place-names used in the text; the form lines are at 250 ft. (76 m.) intervals.

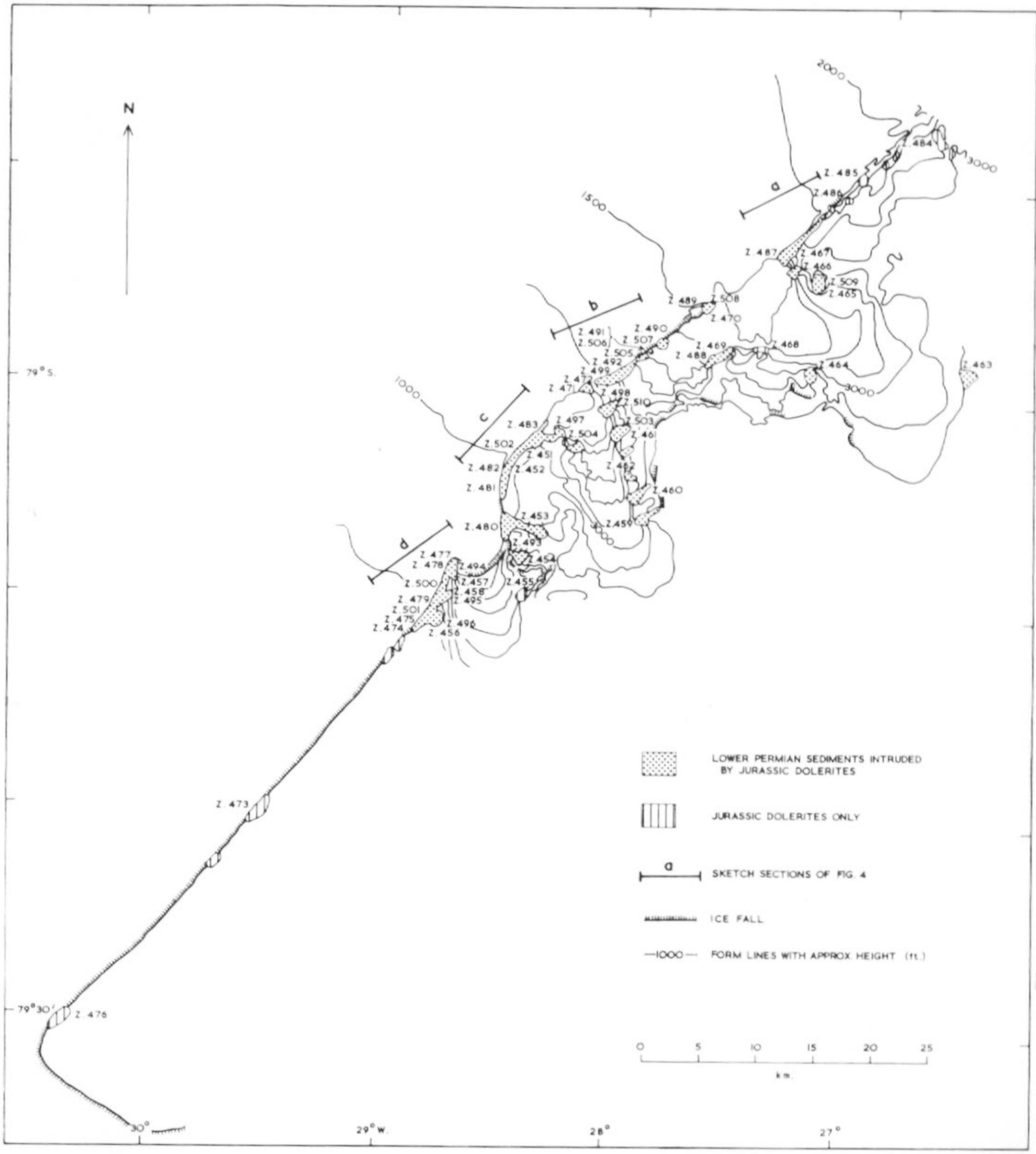


Fig. 3. Geological sketch map of the Theron Mountains showing the distribution of Lower Permian sediments and Jurassic dolerite intrusions, geological stations visited and the locations of the sketch sections in Fig. 4; the form lines are at 250 ft. (76 m.) intervals.

stratigraphy is relatively simple, comprising Lower Permian sedimentary rocks intruded by Jurassic dolerites.

Lower Permian sediments

On the basis of the glossopterid flora collected during the Trans-Antarctic Expedition, the sedimentary rocks are probably not younger than Lower Permian (Plumstead, 1962). Because of facies changes, an absence of distinctive lithological marker horizons, minor local faulting and the variations in the stratigraphical position, thickness and altitude of dolerite sills, a detailed stratigraphical succession for the sediments is difficult to establish.

The term "Theron Formation" was proposed by Stephenson (1966) to include all the sedimentary rocks of the Theron Mountains. This term is not used here because it is considered not to be in accordance with accepted codes of stratigraphical nomenclature such as outlined by the American Commission on Stratigraphic Nomenclature (1961) which defined a formation as "a body of rock characterized by lithologic homogeneity; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface". In the Theron Mountains, no type section or boundaries have been established, and the shape and dimensions of the sedimentary unit are unknown. Since neither the base nor the top of the sedimentary sequence is exposed, it cannot be defined as a formation. The sediments are a mappable unit only in that they are distinct from the Jurassic dolerite intrusions and they are lithologically variable. Furthermore, they are not sufficiently distinct from other Lower Permian successions in eastern Antarctica to be classified as a separate formation, except by virtue of their geographical isolation. Although no units of formational significance have been distinguished by the author, more detailed mapping may prove their existence. As the whole sequence cannot, therefore, be referred to as a single formation, the sediments are referred to here as the Lower Permain sediments of the Theron Mountains.

Continental sediments of Devonian to Jurassic age, described as the Beacon Group (Grindley and Warren, 1964), are widespread in eastern Antarctica. Subsequently, Barrett and others (1971) re-defined the *Beacon Supergroup* as "largely a flat-lying, non-marine sequence from Devonian or older to Jurassic in age. It rests unconformably on a Precambrian and Lower Palaeozoic basement, and is intruded and overlain by Jurassic basaltic rocks". They subdivided it into the *Taylor Group*, a quartzose sandstone succession of Devonian or older age, and the *Victoria Group*, a heterogeneous sequence of glacial beds, carbonaceous and non-carbonaceous alluvial-plain sediments and volcaniclastic strata of Permo-Carboniferous to Jurassic age. The Lower Permian sediments of the Theron Mountains are equivalent to parts of the Victoria Group.

Correlation with beds of Lower Gondwana age in other Southern Hemisphere continents is confirmed by Plumstead's (1962) palaeobotanical work.

Jurassic dolerite intrusions

The Lower Permian sediments of the Theron Mountains are intruded by numerous sills and dykes of Jurassic age (Rex, 1971). The different intrusive phases are not separable on the basis of whole-rock K-Ar age determinations, all of which lie in the range 154–169 m. yr. (Rex, 1971), although they can be distinguished on field, petrographical and geochemical evidence (Brook, in press). No extrusive equivalents occur within the mountain range but basaltic flows crop out in nearby Dronning Maud Land (Aucamp and others, 1971; Juckes, 1972).

The term "Faraway dolerites" was proposed by Stephenson (1966) to include all of the dolerite intrusions of the Theron Mountains. This term is not used here because, like the term "Theron Formation", it does not conform to accepted stratigraphical nomenclature. Some of the dolerite intrusions of the Theron Mountains are radically different petrographically and geochemically from other Jurassic dolerite intrusions of eastern Antarctica, whereas others cannot be distinguished from them on mineralogical, textural or geochemical grounds. The almost complete gradation between these end members eliminates the possibility of subdividing the intrusions into separate formations and the variation in characteristics makes the use of a single formational name impracticable. They are, therefore, referred to as the Jurassic dolerite intrusions of the Theron Mountains.

Jurassic dolerites, which are co-extensive with sediments of the Beacon Supergroup and widespread in eastern Antarctica have been referred to as the "Ferrar dolerites" (Harrington, 1958). Grindley (1963) re-defined the *Ferrar Group* to include the Ferrar dolerites and their extrusive equivalents, the Kirkpatrick basalts.

Correlatives in other Southern Hemisphere continents include the Jurassic dolerites of Tasmania and the Karroo dolerites and basalts of South Africa. Closely related but of a different age are the Serra Géral Formation of South America and the Rajmahal and Sylhet traps of India.

LOWER PERMIAN SEDIMENTS

Distribution and field relationships

Most of the outcrops in the Theron Mountains consist of sub-horizontal sediments intruded by dolerite sills and dykes of variable thicknesses. The majority of sedimentary exposures are in the cliffs of the escarpment (Figs. 3 and 4) and beside the tributaries of "Main Glacier". Because of ice and scree cover, exposures are poor on the cliff tops and in the few outcrops south-east of the scarp front.

North-east of Goldsmith Glacier, sediments are sparsely distributed, occurring only in the outcrops immediately north-east of the glacier above the scarp-capping sill (Fig. 4a). Between Goldsmith Glacier and the unnamed southern glacier (Fig. 4b and c), sediments occur above the scarp-capping sill only at the summit of Lenton Bluff (Z.499), at two or three stations on top of Marø Cliffs (Z.451 and 452) and in the outcrops south-east of the escarpment. At the outcrops on the eastern flank of the unnamed southern glacier (Z.453, 454 and 493), the maximum thickness exposed is 120–150 m.

Below the scarp-capping sill between Goldsmith Glacier and the unnamed southern glacier, varying thicknesses of sediments are intruded by other dolerite sills. Over 200 m. of sediments crop out at Lenton Bluff and a similar thickness of rocks occurs at Marø Cliffs but here dolerite sills are thicker and more numerous and form about half the sequence. South-east of the escarpment, sediments crop out below the scarp-capping sill only near the mouths of Jeffries Glacier (Z.497 and 504) and the unnamed southern glacier (Z.480).

South-west of the unnamed southern glacier, the thickest sedimentary sequence in the Theron Mountains is at Coalseam Cliffs (Fig. 4d). Over 700 m. of sediments, intruded by dolerite sills $<$1–60 m. thick (and totalling 200–250 m.) are exposed. About halfway up the sequence, the sedimentary "break" described by Stephenson (1966) occurs. This "break" cannot be traced for any distance along the cliffs north-east of Stewart Buttress or south-west of Mount Faraway and it is considered to represent an hiatus of only local significance. Alternatively, its absence elsewhere in the Theron Mountains may indicate that this horizon is not represented north-east of Stewart Buttress because of the disruption caused by dolerite intrusion.

No sediments are exposed south-west of Coalseam Cliffs.

Lithology

Most of the outcrops represent only a part of the succession, the thickness and horizon exposed being variable, and nowhere in the Theron Mountains is either the top or the base of the succession exposed. No units of formational significance have been distinguished within the sediments and any hiates present are apparently of only local significance.

When viewed from a distance, the succession at any one exposure appears relatively simple to determine because of the different weathering colours. However, on closer inspection, this simplicity is only apparent as the colours of weathered faces frequently vary independently of the lithology. Lateral and vertical lithological variations are usually gradual and no persistent distinctive lithological units have been observed. Some units are traceable across part of the cliff face but the variation in the location, frequency and thickness of dolerite sills makes them unsuitable as marker bands. Minor local faulting and intrusion-faulting also hinder correlation. Because of this, the lithology of these Lower Permian sediments is described geographically and only a generalized correlation is attempted (p. 79).

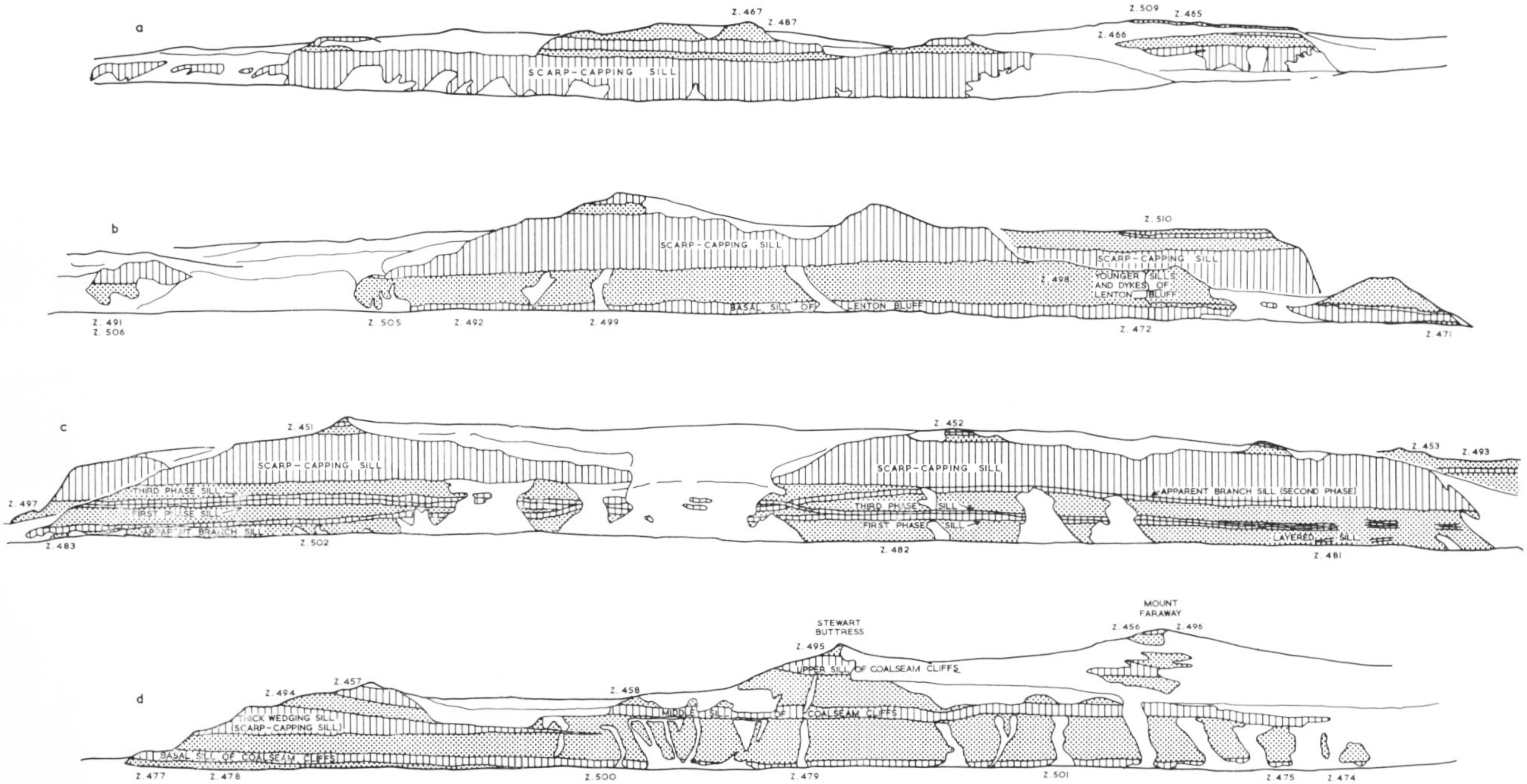


Fig. 4. Sketch sections drawn from photographs taken from the north-west of the four main cliffs of the escarpment of the Theron Mountains, showing the distribution and nomenclature of the major Jurassic dolerite intrusions, Lower Permian sediments and geological stations visited. The shading is as in Fig. 3; unshaded areas are scree- and/or snow-covered.

a. Cliff north-east of Goldsmith Glacier.
b. Lenton Bluff.
c. Marø Cliffs.
d. Coalseam Cliffs.

Area north-east of Goldsmith Glacier

North-east of Goldsmith Glacier, sedimentary exposures are poor and only a thin sequence is seen in this area. A composite section showing approximate thicknesses is given in Table II.

TABLE II. COMPOSITE LITHOLOGICAL SECTION OF THE AREA NORTH-EAST OF GOLDSMITH GLACIER, THERON MOUNTAINS

Station number	*Lithology*	*Approximate thickness* (m.)
Z.463	Dark greenish grey, fine-grained calcareous sandstone, yellow-brown weathering medium-grained sandstones	10
	Snow-covered gap between outcrops	150
Z.465	Yellow and reddish brown weathering, flaky fine-grained sandstones and sandy mudstones, some dark grey to black shales with fragmental plant remains	20
	Dolerite sill	6
	Snow-covered gap between outcrops	20
Z.487	Alternations of dark shales and siltstones, and light grey siltstones and sandstones	20
	Slight local disconformity	
	Light grey laminated siltstones and fine-grained sandstones, darker grey mudstones with plant fragments and thin coals	30
	Dolerite sill	30
	Alternations of light grey to buff siltstones and fine-grained sandstones with thin dark shales; some thin beds appear to wedge out laterally	20
	Dolerite sill (scarp-capping sill)	200

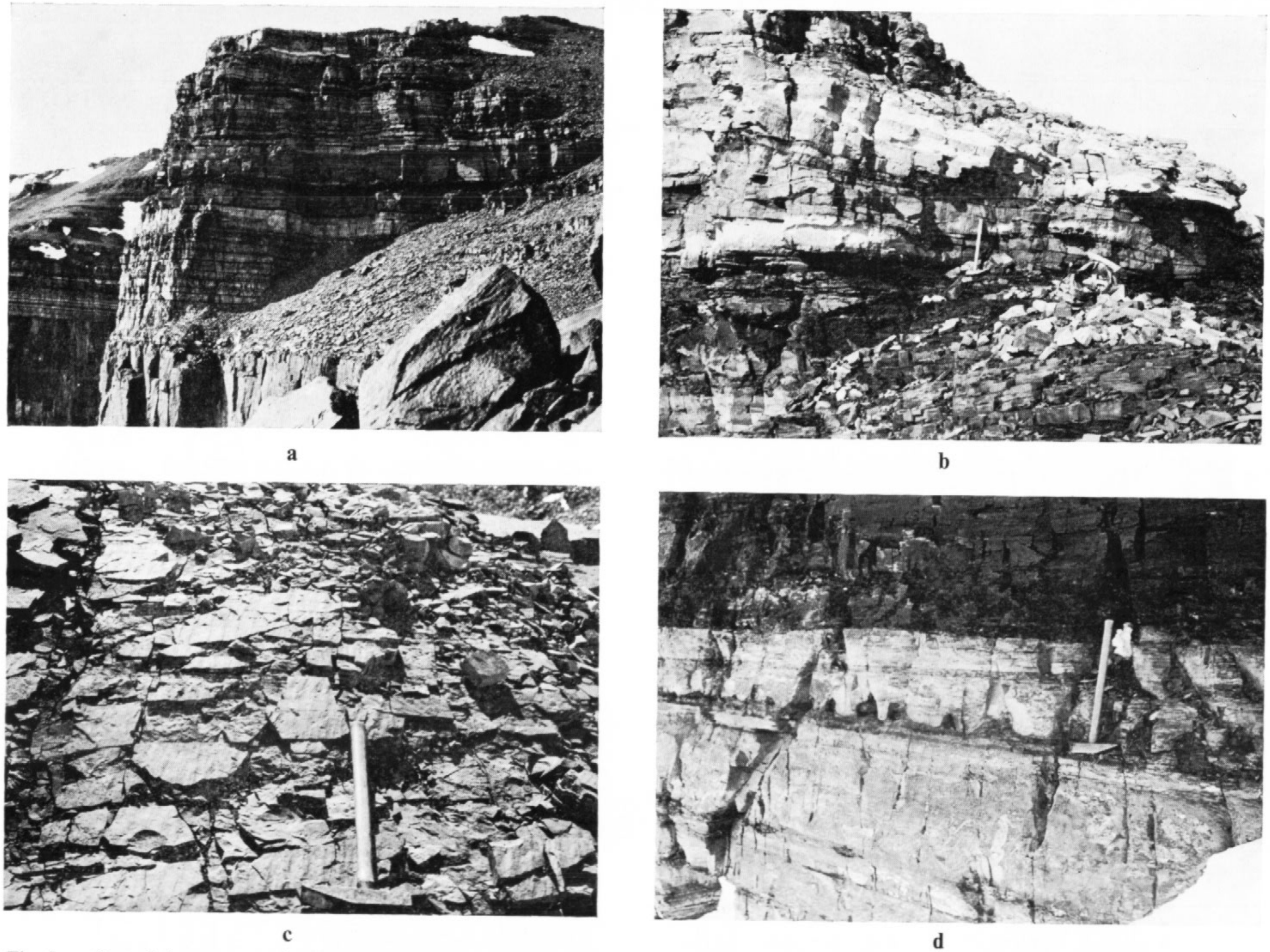
At station Z.487, the sediments above the 30 m. thick sill (Fig. 5a) are commonly cross laminated, and slump bedding and slump balls characterize some horizons. The interbedded black and shaly mudstones contain abundant plant fragments and thin coal streaks, the latter often only several millimetres thick.

The slight local disconformity at station Z.487 which overlies dark grey to black shales and mudstones containing plants is very slightly transgressive (Fig. 5b). Above this disconformity, lenses of light yellow-grey, slightly calcareous arkosic sandstone and friable, light grey, faintly laminated arkosic sandstone are intercalated between dark grey medium-grained sandstones with black mudstone fragments (forming in places a mud-flake breccia). These are overlain by medium to dark grey, laminated medium-grained sandstones with occasional light grey mudstone pellets. The disconformity, probably of only local significance, may have been caused by a slight local increase in erosion due to the migration of a stream channel.

At station Z.465, micro-faulted muddy siltstones occur, the normal faults dipping north-eastwards at 30–60° with an easterly downthrow of 5–15 cm. These micro-faults, which are extremely localized, were probably caused by slight movements during the deposition of the siltstones, though they may have resulted from stresses set up during intrusion of the dolerites.

Area between Goldsmith and Jeffries Glaciers

Between Goldsmith Glacier and Lenton Bluff, up to 100 m. of sediments crop out beneath the scarp-capping sill and 200 m. occur at Lenton Bluff. South-east of the escarpment, about



a b c d

Fig. 5. a. Part of the sequence of sediments exposed above the upper 30 m. thick sill at station Z.487. The black shaly mudstone in the middle of the sequence is about 1 m. thick.

b. Slight disconformity, overlain by mud-flake breccia and coarse arkosic sandstone 15–20 m. below the summit of station Z.487. The sandstones above the disconformity are irregularly bedded and impersistent; the hammer shaft in this and subsequent figures is 55 cm. long.

c. Ripple marks trending approximately north–south on the surface of a siltstone at the top [illegible] Lenton Bluff (Z.498).

d. Load casts at the base of a thin sandstone in the middle of the sequence at station Z.507.

50 m. of sediments, intruded by thin dolerite sills, occur above the scarp-capping sill but none are exposed below it (Table III).

TABLE III. COMPOSITE LITHOLOGICAL SECTION OF THE AREA BETWEEN GOLDSMITH AND JEFFRIES GLACIERS, THERON MOUNTAINS

Station number	*Lithology*	*Approximate thickness* (m.)
Z.459	Light grey to white, yellow and some reddish, medium-grained sandstones and thinly bedded, light grey to black mudstones and shales	10
Z.460	**Dolerite sill**	<10
	Light grey to yellow medium-grained sandstones	10
	Dark grey, iron-stained shaly mudstones with thin flaky sandstones	5
Z.461	**Dolerite sill**	<5
	Interbedded yellow to red sandy mudstones and dark shales	10
	Dolerite sill	5
Z.488	Buff-weathering fine-grained sandstones and sandy mudstones, some dark shales with poorly preserved plant material	10
	Dolerite sill (scarp-capping sill)	200
Z.507 and 498	Interbedded light grey laminated siltstones and dark grey shales and mudstones with thin coals	20–30
Z.507 and 499	Massive, thick-bedded, light grey to buff, fine- to medium-grained sandstones with interbedded coals and black mudstones	50
Z.499 and 498	Alternating thin-bedded laminated siltstones and shales; thin dolerite sills (up to 5 m. thick)	80
Z.471, 472 and 498	Light grey to buff fine-grained sandstones and siltstones	20
	Laminated siltstones with thin dark shales	15
	Dolerite sill (basal sill of Lenton Bluff)	30
Z.471 and 472	Alternations of light and dark grey laminated siltstones, dark grey to black shales and mudstones and occasional buff, fine-grained feldspathic and quartzitic sandstones	20

Many of the siltstones contain laminae of carbonaceous and micaceous material and small-scale cross lamination is common. Ripple marking, probably oscillation ripples with amplitudes of 2–4 mm., wave-lengths of 3–5 cm. and orientations varying between individual beds, is fairly frequent at the upper bedding planes of fine-grained sandstone intercalated between siltstones and shales (Fig. 5c). Occasionally, soft and friable calcareous sandstones rest on an uneven surface of irregularly laminated siltstone or fine-grained sandstone. Calcareous and ferruginous mudstone bands and nodules, often surrounded by deformed bedding, occur within the shales, and scour-and-fill structures and load casts (Fig. 5d) characterize some horizons. In the massive sandstones at station Z.499, 2–10 m. long lenses of yellow-weathering medium-grained sandstone occur and slumping of laminated medium-grained sandstones is common (Fig. 6).

Several shales and mudstones have interbedded coal streaks and carbonaceous paper shales, and carbonized plant remains are common at some horizons. At least ten 1–2 m. thick coal horizons are present in the 50 m. sequence of massive sandstones at station Z.499. Individual coal bands <3–20 cm. thick, which are separated by medium to dark grey mudstones (Fig. 7a), are usually more abundant near the top of the mudstones.

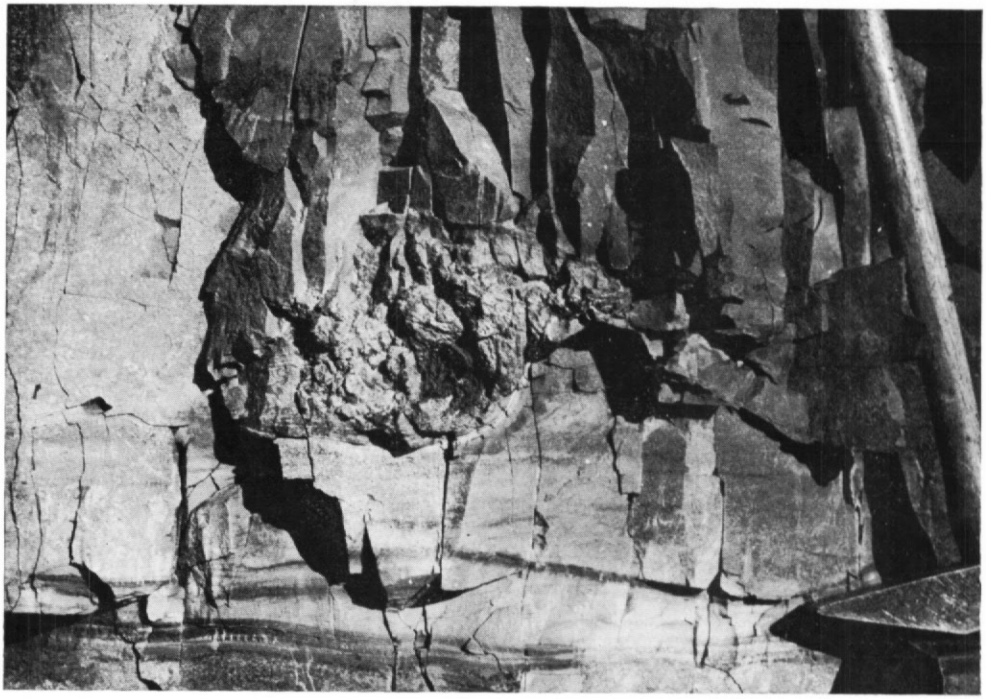


Fig. 6. Slump ball of laminated medium-grained sandstone in more homogeneous fine-grained sandstones and siltstones in the middle of Lenton Bluff (Z.499); about 10 cm. of the hammer head is visible.

Area between Jeffries Glacier and the unnamed southern glacier

The sediments and dolerites exposed below the scarp-capping sill at Marø Cliffs and on the south-western margin of Jeffries Glacier are similar in thickness to those at Lenton Bluff but the proportion of dolerite is far greater. Sills are more abundant, thicker and more persistent than at Lenton Bluff and their location is more variable. As a result, it is difficult both to correlate within the outcrop and to compile a composite section.

Lithologically, the sediments are similar to those at Lenton Bluff (p. 75), consisting largely of alternating light and dark grey siltstones and shales and more massive, light grey to buff fine- to medium-grained sandstones. Carbonaceous shales and coals are commonly interbedded with laminated siltstones and fine-grained sandstones. Most of the coals have been thermally metamorphosed by the intrusion of the dolerites. Ripple marks, cross lamination and wedging out of thin beds are common, and scour-and-fill structures and load casts are also present.

On the eastern margin of the unnamed southern glacier (Z.453, 454 and 493), the upper part of the sequence above the scarp-capping sill is less variable and consists almost entirely of light grey and yellow, fine- to medium-grained flaggy sandstones with some siltstones near the top.

Area south-west of the unnamed southern glacier

The thickest sedimentary sequence in the Theron Mountains is at Coalseam Cliffs. During the Trans-Antarctic Expedition, the ridge between stations Z.477 and 457 was cursorily traversed by Stephenson (1966), who also described from photographs the sedimentary "break" beneath Stewart Buttress. Specimens were collected from the lower part of Coalseam

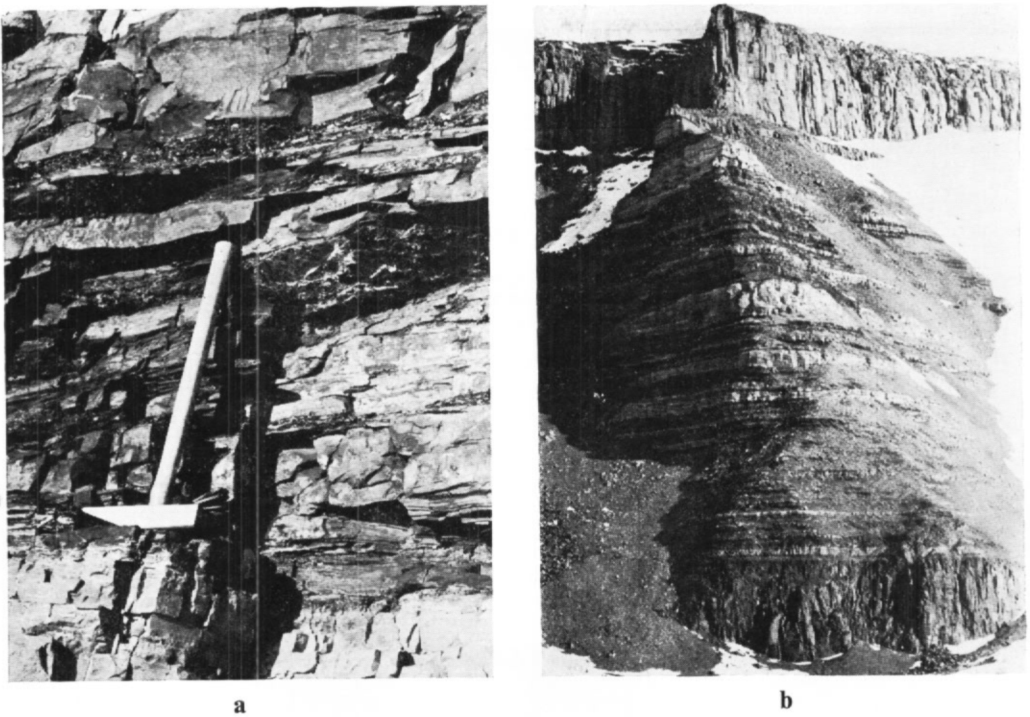


Fig. 7. a. Part of the 1·2 m. thick coal 3 m. below the scarp-capping sill in the middle of Lenton Bluff (Z.499); 2–3 cm. coal bands are separated by black carbonaceous mudstones.
b. Sedimentary sequence between the basal and middle sills of Coalseam Cliffs at station Z.475; about 250 m. of sediments occur between the two sills.

Cliffs near station Z.477 by V. E. Fuchs and these were included in Stephenson's descriptions. Dolerite sills varying in stratigraphical position and persistence have been omitted from the composite section (Table IV).

Throughout most of the sequence, well-indurated, quartzitic, arkosic and slightly calcareous sandstones and siltstones are present and these are often laminated. Cross lamination is common, and irregular and contorted laminations are also present. Slump bedding characterizes some siltstones interbedded between shales. Calcareous or ferruginous nodules and bands are present at some horizons. The wedging out of thin sandstones and shales is common but it is usually gradational and scarcely perceptible.

The massive buff-weathering sandstones of stations Z.475 (Fig. 7b) and 501 vary in thickness of bedding and they often exhibit a faint lamination comprising carbonaceous partings. Coals are more abundant in this part of the sequence than elsewhere, at least ten coals or coal shales up to 1 m. thick occurring in the 60 m. thick sandstone sequence at station Z.501. The coals are usually underlain and often overlain by dark grey laminated mudstone or black shale, frequently containing plant remains.

The 4–5 m. thick carbonaceous mudstone and coal at station Z.475 has hexagonal jointing imposed by the dolerite sill immediately above it. About 3 m. of black carbonaceous mudstone with recognizable plant stems and thin interbeds of coaly paper shales are overlain by 1 m. of coal which is muddy, the proportion of mud decreasing upwards.

The sedimentary "break" beneath Stewart Buttress and Mount Faraway has been described, mainly from photographs, by Stephenson (1966). It was visited only at station Z.479, and it is not as pronounced as it appears from the photographs. The overlying beds appear to be cross-bedded on a megascopic scale before passing upwards into more "normal" sediments at stations Z.479 and 458. The "break" cannot be traced for any distance along the cliffs

TABLE IV. COMPOSITE LITHOLOGICAL SECTION OF COALSEAM CLIFFS, THERON MOUNTAINS

Station number	*Lithology*	*Approximate thickness* (m.)
Z.456 and 495	Thin-bedded light grey siltstones and fine-grained sandstones, mainly mantled by scree; occasional dark shale horizons	>100
	Light grey to buff, medium-grained cross-bedded sandstones with thin bands of friable, white arkosic and calcareous sandstones	30
Z.479 and 458	Alternating light to dark grey siltstones and fine-grained sandstones, light grey to buff, more massive sandstones and dark grey to black shales and mudstones with interbedded coals and fragmental plant remains	120
Z.479	Fine- to medium-grained sandstones showing cross bedding on a megascopic scale	50
	Sedimentary "break"	
Z.479 and 494	Alternating light and dark grey siltstones and shales, light grey to buff and dark grey siltstones, and fine-grained sandstones, thin coals and coal shales	60
Z.475	Black carbonaceous mudstone and coal	4–5
	Massive, buff arkosic sandstones with thin interbedded siltstones and shales	30
Z.475 and 478	Thin alternations of light and dark grey siltstones, buff feldspathic sandstones, dark grey mudstones and shales, occasional thin coals and coal shales; sandstones thicker but less common in the lower part but increase rapidly in frequency near the top	80–90
Z.475, 474 and 501	Three units of massive buff-weathering sandstones and siltstones with interbedded coals and shales separated by alternations of light grey siltstones and fine-grained sandstones and dark grey shales and mudstones with thin coals	70–80
	Alternating light grey siltstones and sandstones and dark grey shales and mudstones with thin coals; thickness and frequency of sandstones increase upwards	70
Z.474	Dark shales and mudstones and medium to dark grey mudstones and muddy siltstones, subordinate massive quartzitic sandstones and light grey siltstones	5–10
Z.477, 478, 500 and 501	Alternating light to medium grey siltstones and fine-grained sandstones and dark grey shales and mudstones	10–15

and it is considered to represent a deltaic influx or migrating meander channel restricted to the immediate area of Coalseam Cliffs. Stephenson's (1966) suggestion that it was relatively insignificant is supported by Plumstead's (1962) discovery of *Phyllotheca* in the sediments above the depositional "break".

The sediments above the sedimentary "break" are similar to those below it except that carbonaceous beds are apparently less frequent.

Summary

The sediments examined are almost universally of fine grade and show varying proportions of three basic lithological types: light grey to buff fine-grained sandstones, light and dark grey laminated siltstones, and dark grey shales and mudstones. These often grade into one another or are thinly interbedded. Occasional medium-grained sandstones and calcareous sandstone lenses are present but no conglomerates were observed. Coals and carbonaceous shales are ubiquitous throughout the succession but they are more abundant interbedded with thick sandstone sequences. Calcareous and ferruginous bands and nodules, probably of concretionary origin, occur at some horizons. Flame, scour-and-fill and slump structures, ripple marks and cross lamination are common, and cross bedding also occurs. Lateral lithological variations are pronounced though difficult to detect, and wedging out of thin beds commonly occurs.

The sediments in all exposures examined are almost horizontal and there is no evidence of major faulting between individual exposures. It seems likely, therefore, that the thinner sedimentary sequences exposed throughout the Theron Mountains are equivalent, in whole or in part, to the thickest succession in the area, i.e. at Coalseam Cliffs. The sequences north-east of Goldsmith Glacier and south-east of the escarpment between Goldsmith Glacier and the unnamed southern glacier are probably equivalent to the middle and/or upper parts of the succession at Coalseam Cliffs, while those along the scarp front between Goldsmith Glacier and the unnamed southern glacier are probably equivalent to the lower parts of that at Coalseam Cliffs. It is not apparent whether the horizon of the sedimentary "break" is exposed north-east of Stewart Buttress or whether intrusion of the scarp-capping sill has caused beds equivalent to those below the "break" to be present at a greater altitude than at Coalseam Cliffs.

egional lithological correlation

The Lower Permian sediments of the Theron Mountains are lithologically similar to the Victoria Group coal measures of eastern Antarctica and to the Lower Gondwana coal measures of other Southern Hemisphere continents.

In Heimefrontfjella, Juckes (1972) described a 160 m. thick sequence of Permo-Carboniferous sediments overlying peneplaned basement rocks, and his middle and upper units are similar to some of the sediments of the Theron Mountains, though probably slightly older. In the Whichaway Nunataks (where coals are absent and shales uncommon) the sandstones are lithologically similar to those of the Theron Mountains (Stephenson, 1966).

Cross-bedded quartz-sandstones with carbonaceous beds and thin coals have been described from the Patuxent Mountains (Schmidt and others, 1964) and cross-bedded arkosic sandstones with silty sandstones, dark shales with plant remains and seams of high-ash coal occur in the Horlick Mountains (Long, 1964), in the mountains on the eastern margin of the Ross Ice Shelf and in Victoria Land. Carbonaceous shales in the Mount Glossopteris Formation of the Horlick Mountains (Long, 1964) are closely associated with coals, the latter grading upwards and downwards into carbonaceous shales. In the Pecora Formation of the Pensacola Mountains (Williams, 1969), the impure coals with streaks and lenses of brittle vitrain in a dull, massive, brownish black matrix are similar to those of the Theron Mountains.

The Middle Ecca Coal Measures of the Karroo System of South Africa (Du Toit, 1954) are also similar in many respects but they differ in containing more frequent beds of a coarser grade. Moreover, the majority of the coals possess sandstone floors and pass upwards into shaly coals and dark shales with thin sandstones, whereas the coals of the Theron Mountains grade upwards and downwards into dark mudstones and shales with plant remains. Close ithological and stratigraphical correlatives are also found in the other Southern Hemisphere continents.

Petrography

The sediments of the Theron Mountains are mainly siltstones and fine-grained sandstones of variable compositions within fairly narrow limits. Any matrix or cement is recrystallized due to diagenesis, load metamorphism (to the lower zeolite facies) or to thermal metamorphism by the dolerite intrusions.

Grain-size and sorting have been estimated visually in thin sections, sphericity by comparison with fig. 2 of Wadell (1932) and roundness by comparison with pl. I of Krumbein (1941). Mineral percentages have been estimated visually.

Sandstones

In thin section, most of the sandstones are well sorted and of fine grade with an average grain diameter of 0·2 mm. The lamination of many finer-grained sandstones is often a sorting characteristic, though it may also be accentuated by concentrations of carbonaceous material. The sphericity varies between 0·60 and 0·85, and does not appear to be correlated with grain-size. Roundness similarly varies indiscriminately with grain-size, ranging from 0·3 to 0·5 and only rarely attaining 0·7.

The major constituents of the sandstones are quartz, feldspar and lithic fragments, and there is abundant carbonaceous matter. Any cement is siliceous and only rarely calcareous. Most sandstones have a partly recrystallized matrix of quartz, sericite and chlorite. The heavy mineral fraction (estimated from thin sections) is variable but it includes garnet, zircon and mica, with smaller amounts of tourmaline and haematite.

Quartz is usually in excess of 40 per cent of the rock. Grains with undulose and uniform extinction occur in about equal proportions and they may occur either together or separately. Some grains are composite. Overgrowths of secondary silica are common and they often increase in abundance in the vicinity of dolerite sills.

Feldspar comprises <10 to >35 per cent of the rock. Acid plagioclase and cloudy sericitized alkali-feldspar occur in about equal amounts. The latter is dominantly orthoclase but microcline and microperthite have also been observed. The plagioclase is well twinned on the albite law and combined Carlsbad-albite twins are rare. Some grains have curved twin lamellae (cf. Barrett, 1969*a*, fig. 4) and others have been fractured *in situ*.

Lithic fragments are scarce and they are usually fine-grained, altered and unidentifiable. However, quartz mosaics and quartz-feldspar intergrowths are present and rare grains have a vague igneous appearance. Volcanic arenites similar to those figured by Barrett (1969*a*) are absent. Many of the lithic fragments, such as the muddy siltstone pellets and mud-flake breccia of specimen Z.487.13, are locally and penecontemporaneously derived.

Carbonaceous material is ubiquitous in the sandstones as minute grains and flakes, and often forms a coating between other mineral grains. It is commonly systematically distributed in such a way as to impart a lamination to the sandstones which may be accentuated by concentrations of heavy minerals (e.g. Z.498.13), i.e. like a graded bedding based on density rather than grain-size.

Detrital mica flakes 0·8–1·0 mm. long are abundant in some sandstones and are often bent and twisted between other grains. They are usually muscovite but some are a mixture of muscovite and chlorite. Biotite is virtually absent. Sub-rounded grains of garnet 0·1 mm. in diameter are abundant in some specimens. Small clusters of minute angular garnet grains appear to represent sub-rounded grains fractured *in situ*. Well-rounded zircon is also common, and tourmaline and haematite were occasionally observed. In specimen Z.487.13, muddy siltstone pellets are "armoured" with heavy minerals, particularly garnet (Fig. 8a); the abundance of garnets elsewhere in the rock is relatively low (Fig. 8b).

The fine-grained matrix of the sandstones which is often recrystallized, unidentifiable and variable in amount usually consists of minute quartz grains, chlorite (most commonly penninite) and sericite. Interstitial authigenic sphene occurs in many of the sandstones, and in some both the matrix and much of the feldspar have been largely replaced by clinozoisite and prehnite.

Other sediments

In thin section, the siltstones differ from the sandstones largely on grain-size, although there are minor differences in composition. Sorting, sphericity and roundness vary but there is no apparent correlation of these parameters with grain-size. Many of the siltstones are finely laminated (Fig. 8c). They are usually feldspathic or arkosic, and carbonaceous material is probably more abundant than in the sandstones. The matrix is more recrystallized than that of the sandstones, and sericitic mica and authigenic sphene are common.

Most of the mudstones and shales sectioned were derived from xenoliths or at contacts with dolerite intrusions and these have been thoroughly thermally metamorphosed. Mudstones, even some distance from intrusive contacts (Z.502.5), are largely recrystallized with abundant sericitic mica.

Many of the coals, notably at Marø Cliffs, have been burnt by the dolerites and one specimen is hexagonally jointed (p. 77). Specimens from the contacts of sills at Marø Cliffs (Z.501.5) and Coalseam Cliffs (Z.478.6) represent intimate mixtures of dolerite and coal with hydro-

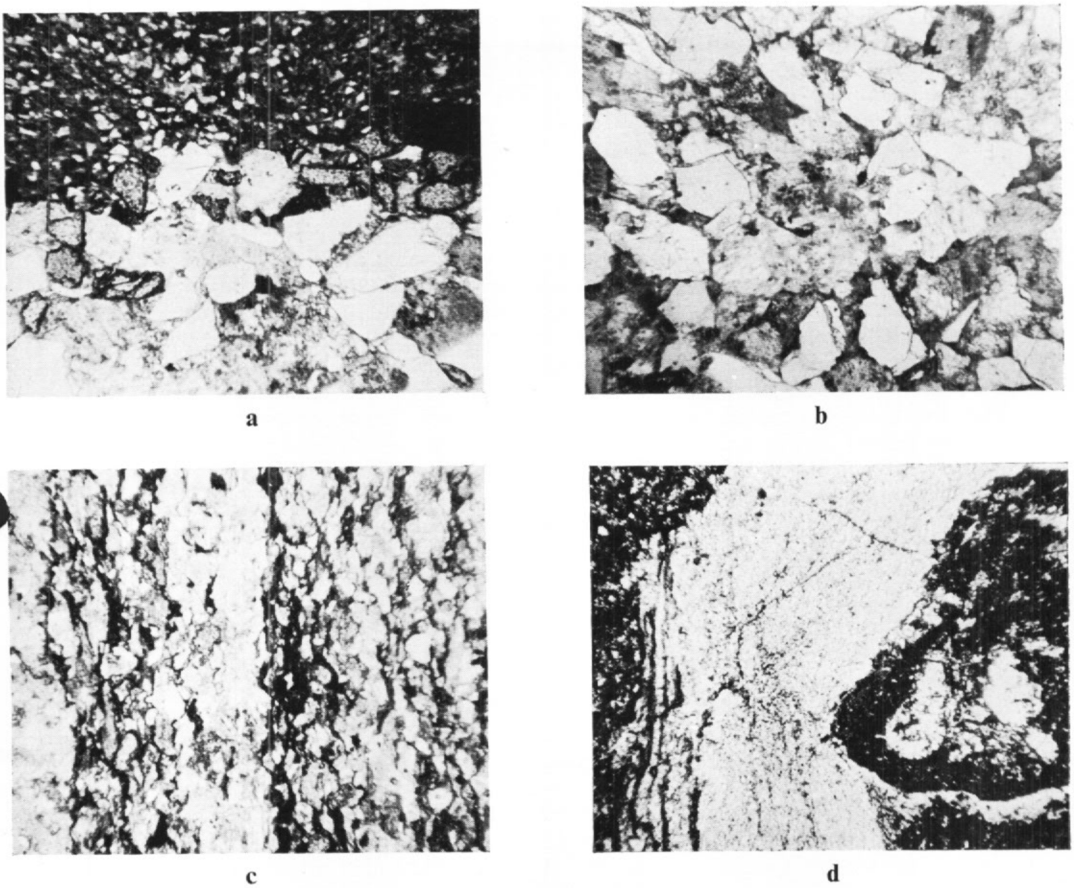


Fig. 8. a. A muddy siltstone pellet in medium-grained sandstone (which grades into a mud-flake breccia) bordered by heavy minerals, notably garnet (Z.487.13b; ordinary light; × 30).
b. Medium-grained sandstone 1 cm. from the muddy siltstone pellet in Fig. 8a, showing the general sparsity of heavy minerals (Z.487.13b); ordinary light; × 30).
c. Finely laminated siltstone in which the lamination is defined by carbonaceous material (Z.471.2; ordinary light; × 30).
d. Thermally metamorphosed sediment at the lower contact of a sill in Marø Cliffs; hydrothermal effects are pronounced (Z.483.1b; ordinary light; × 30).

thermal quartz and calcite. Abundant vesicles occur in the coal but these were not found in the coal samples collected by the Trans-Antarctic Expedition. Brown and Taylor (1960) suggested that these samples had been thermally metamorphosed to different degrees under strong confining pressures and that the coals were of bituminous rank prior to metamorphism.

Thermal metamorphism of the sediments

Megascopically, thermal metamorphism is visible for <1 m. from intrusive contacts, whereas petrographically it is shown to be more extensive.

Mudstones and shales at intrusive contacts are baked to hard flinty rocks with a conchoidal fracture (Z.497.2) which are almost completely recrystallized in thin section, and the coals have been thoroughly coked. Hydrothermal effects are pronounced at some contacts (Fig. 8d).

Many of the original minerals and textures of the siltstones and sandstones have been preserved, except in the matrix, which is completely recrystallized. Although the feldspars are cloudy, they occur adjacent to contacts, and while quartz grains are often corroded, and secondary overgrowths apparently increase as intrusive contacts are approached, suturing is rare. Fusion of siltstone to a glass (cf. Ackermann and Walker, 1960) is rare but there is some micropegmatite adjacent to some of the dolerites. The most pronounced thermal effect on these sandstones and siltstones is a recrystallization of the matrix to an indeterminate, fine-grained, cloudy, quartzo-feldspathic aggregate. Even remote from intrusive contacts, prehnite and calcite occur with minor clinozoisite.

Discussion

The Lower Permian sediments of the Theron Mountains are fine-grained. They range in composition from feldspathic to arkosic sandstones and siltstones with subordinate carbonaceous, quartzitic and calcareous sandstones, siltstones and mudstones. Mudstones, shales and coals are, like the fine-grained matrix of sandstones and siltstones, slightly metamorphosed. This metamorphism may be due to the combined effects of overburden pressure and the thermal reaction accompanying the dolerite intrusions. In many cases the latter has occurred but other instances some distance from intrusive contacts are more difficult to interpret.

Hamilton (1965) considered that all of the sediments of the Beacon Supergroup near its type section in Victoria Land had been slightly metamorphosed by dolerite sills which were intruded at temperatures near 1,000° C. Metamorphism is obvious in the field as hornfelsed or metasomatized rocks within 1–2 m. of contacts. At a greater distance from the intrusions, the sediments appear unaltered in the hand specimen but in thin section pervasive metamorphism is apparent. The argillaceous fractions have been reconstituted to fine-grained mica, much of the feldspar is sericitized and most of the quartz is marginally recrystallized. The bituminous to anthracitic character of the coals is also probably due to thermal metamorphism. Between Byrd and Starshot Glaciers, Skinner (1965) also concluded that the regional alteration of the sediments of the Beacon Supergroup was due to the widespread effects of dolerite sill injection. At intrusive contacts, the sediments are metamorphosed to the albite-epidote-hornfels facies.

In South Africa, Du Toit (1954) observed that alteration of coals by dolerite intrusions extends a distance equal to the width of the intrusion, even though other sediments in the same succession appear to be unaffected. However, sediments in contact with intrusions are invariably metamorphosed.

The coals of Mount Glossopteris in the Horlick Mountains appear to be unaffected by igneous activity. Schopf and Long (1960) implied that their semi-anthracitic rank is proportional to the maximum previous overburden, indicating a greater thickness of cover at Mount Glossopteris than elsewhere in eastern Antarctica, South Africa or eastern Australia.

Mudge (1968) suggested that nearly all concordant igneous masses in flat-lying sedimentary rocks were intruded at a depth of 915–2,290 m. The thickness of overburden (915–2,240 m.) of dolerite sills in the Taylor Glacier area of Victoria Land implies a lithostatic pressure of 200–500 bar, which may be sufficient to impart some load metamorphism.

The large-scale load casts in the sediments of the Theron Mountains and the bituminous rank of coals prior to thermal metamorphism suggests there may have been some loading accompanied by metamorphism. The pervasive alteration of the Lower Permian sediments of the Theron Mountains is thus probably due to the progressive increase in intensity of load metamorphism induced by the thermal effects of dolerite intrusion.

Palaeobotany, age and correlation

The only fossils in the sediments are leaf and stem impressions, and coals. These occur throughout the succession and the mountain range. No invertebrates or trace fossils similar to those described by Vialov (1962) from Victoria Land were observed.

Distribution of plant fossils

North-east of Goldsmith Glacier, the most prolific locality for plant fossils is station Z.487. About 7 m. below the summit of the ridge, carbonaceous impressions of leaves and stems occur in coarse-grained siltstones and some of these have been tentatively identified as *Glossop-*

teris and *Vertebraria*. Despite the coarseness of the matrix, details of leaf venation can be seen. Lower in the succession, in dark shaly mudstones, there are orange-brown carbonized impressions of whole leaves, fragmental material and woody stems showing cell structure.

Between Goldsmith Glacier and Lenton Bluff, well-preserved leaf and stem impressions occur in thin shale and mudstone partings in the siltstones (Z.508) and in thin coaly shales higher in the sequence (Z.507). Coal- and plant-bearing mudstones and shales up to 3 m. thick crop out at Lenton Bluff. Although the majority are fragmental and poorly preserved, occasional horizons contain well-preserved whole leaves. Because the coals and coal shales have been so thoroughly metamorphosed by dolerite intrusion at Marø Cliffs, few plants are preserved.

Fossil material from three horizons in Coalseam Cliffs has been described by Plumstead (1962) (Table V). In the lower part of the succession (Z.477), well-preserved whole leaves and stems occur as orange-brown carbonized coatings on the mudstones. Higher up, however, plants are less well preserved and more fragmental, except in the thin black shale about 5 m. below the thick wedging sill. Above the sedimentary break at Stewart Buttress, coals and fragmental plants are present but not abundant.

TABLE V. FLORA IDENTIFIED BY PLUMSTEAD (1962) FROM FOSSIL SITES COLLECTED DURING THE TRANS-ANTARCTIC EXPEDITION

Upper horizon (above the sedimentary "break" above the middle sill of Coalseam Cliffs, near station Z.458)	*Phyllotheca australis* Brong.
Middle horizon (below the thick wedging sill of Coalseam Cliffs, near station Z.478)	*Glossopteris* cf. *longicaulis* Feist. *Glossopteris browniana* Brong. *Glossopteris stricta* Bunb. *Glossopteris fuchsii* Plumstead *Glossopteris parallela* Feist. *Glossopteris* cf. *cordata* Dana *Glossopteris antarctica* Plumstead *Cordaicarpus* Geinitz sp. *Arberiella* Pant sp. *Arberia* cf. *minasica* White (?) *Hirsutum* Plumstead sp. Scale leaves of *Glossopteris* Unidentifiable stems Insect wing cases
Lower horizon (below the basal sill of Coalseam Cliffs, near station Z.477)	*Annularia* Sternberg sp. *Glossopteris formosa* Feist. *Vertebraria indica* Royle Unidentifiable stems Algal markings or worm tracks (?)

Age and correlation

The identifications of Plumstead (1962) (Table V) indicate an Upper Carboniferous to Lower Permian age, and there is no evidence other than for a Lower Permian age for all the sediments of the Theron Mountains. The sediments represent part of the Victoria Group of the Beacon Supergroup (Barrett and others, 1971), and homotaxial formations are the Lower Gondwana sediments of the other Southern Hemisphere continents.

Juckes (1972) has described Victoria Group sediments from Heimefrontfjella and Plumstead (in press) has considered the flora to be probably of Upper Carboniferous age and possibly the oldest *Glossopteris* flora yet discovered in Antarctica. The sediments of the Whichaway Nunataks show certain floral affinities with those of the Theron Mountains (Plumstead, 1962), but they are probably slightly older.

In the Horlick Mountains (Long, 1964), the Shackleton Glacier area (La Prade, 1970), the

Queen Alexandra Range (Grindley, 1963), the Beardmore Glacier area (Barrett, 1969*b*) and southern Victoria Land (Allen, 1962; Hamilton and Hayes, 1963; Webb, 1963; and others), a more complete sequence of the Beacon Supergroup is exposed. This includes Devonian sandstones and siltstones with marine intercalations, Upper Carboniferous glacial beds, Permian sandstones and coal measures, Triassic arkosic arenites and coal measures, and Upper Triassic to Jurassic volcaniclastic strata. The Permian coal measures are of the same age as those of the Theron Mountains (Lower to Middle Permian) except for the Mount Glossopteris Formation of the Horlick Mountains, which has been considered by Doumani and Tasch (Long, 1964) to be Upper Permian in age, and the Pecora Formation of the Pensacola Mountains (Williams, 1969).

The Lower Gondwana sediments of the other Southern Hemisphere continents are of an Upper Carboniferous to Jurassic age. Formations considered to be homotaxial with the Permo-Carboniferous plant-bearing formations of eastern Antarctica have been listed by Plumstead (1964).

Provenance

The orientation of such features as cross bedding, cross lamination and ripple marks varies between individual beds but it generally indicates a south-westerly provenance, as inferred by Stephenson (1966). This is similar to the current directions in the post-glacial Permian of the Victoria Group in the Transantarctic Mountains (Barrett and others, 1971).

The mineral composition of the sediments, especially the abundance of garnet in the heavy mineral fraction, is consistent with derivation from a metamorphic terrain. Colourless and pale pink garnets occur in some of the rocks of the Shackleton Range (Stephenson, 1966), and the gneisses, schists and amphibolites of the Shackleton metamorphics seem to have been a likely source for many of the constituents of the sediments. A certain admixture from an acid volcanic source is possibly indicated by the presence of combined Carlsbad-albite twins in some of the plagioclases and by some of the finer-grained lithic fragments. The volcanic material is not as common as in the Beardmore Glacier area (Barrett, 1969*a*, *b*; Barrett and Elliot, 1971).

The sphericity and roundness of the mineral grains indicate moderate transportation and the generally fine grain-size of the sediments suggests a relatively remote source area that was probably unaffected by deep weathering. Thus only a moderate amount of re-working had occurred.

Depositional environment

The complete absence of marine fossils and the presence of coal and plant remains suggested to Stephenson (1966) that the sediments were deposited in a terrestrial environment. No features strongly indicative of aeolian deposition were observed in the field and the sediments are probably wholly water-laid clastic deposits.

As the continental land surface on which the sediments were deposited is not exposed, it is not known whether glacial conditions preceded sedimentation, as they did elsewhere in eastern Antarctica. Although there is no direct evidence for the climatic conditions prevailing during sedimentation, the absence of tillites and evaporites suggests a temperate climate.

Large- and small-scale lateral and vertical lithological variations indicate variable local environments. Although several lithologies are repeated throughout the succession, it is unlikely that cyclic sedimentation similar to that in the Falla Formation of Victoria Land (McGregor, 1965) took place.

As no plants were found in their growth positions and as many of them are macerated (especially in association with coals), they were probably transported some distance before deposition. Plumstead (1962) suggested a paludal environment for the upper fossiliferous horizon collected by Stephenson. The thin interlaminations of coal and mudstone (Fig. 7a) and the separation of mudstones by carbonaceous partings suggest that the coal is allochthonous.

The fine lamination of many of the siltstones, the occurrence of bands and nodules of ironstone and the iron-stained shales and plants indicate that there were small areas of relatively shallow stagnant water. The lamination of many of the sandstones and siltstones is, however, irregular and scour-and-fill structures indicate penecontemporaneous erosion. This is supported by the slight local disconformity and thin mud-flake breccia at the base of a sandstone at station Z.487 (Fig. 5b). Armoured mud balls similar in size to those figured by Juckes (1972) were not seen but the mud pellets armoured by garnets (Z.487.13; Fig. 8a) are probably of a similar origin and may indicate the lateral shift of a stream channel. Load casts associated with several beds probably filled original irregularities caused by scour and fill. Cross bedding on a megascopic scale above the sedimentary "break" at Stewart Buttress suggests a local deltaic influx or migrating meander channels. Additional large-scale cross bedding was observed and small-scale cross bedding and cross lamination are common.

Slump balls and slump-bedded units throughout the succession indicate the presence in some areas of moderately steep slopes covered by metastable unconsolidated sediments. The small-scale faulting at station Z.465 may have resulted from slumping of the underlying beds while these were partly consolidated. Penecontemporaneous deformation is also seen in other units.

The variable local environments suggest that deposition was probably fairly rapid with occasional intervals of quiescence under fluvial, fluvio-deltaic and lacustrine environments (cf. Webb, 1963; Williams, 1969; Matz and others, 1971).

JURASSIC DOLERITE INTRUSIONS

The Jurassic dolerite intrusions will be discussed elsewhere (Brook, in press) but a brief summary is included here for completeness.

During the Jurassic (154–169 m. yr.; Rex, 1971), the sedimentary sequence was invaded by great volumes of dolerite which can be correlated with other Mesozoic tholeiitic rocks of the Southern Hemisphere. The intrusions were largely as sub-horizontal sills <1 m. to >200 m. thick and averaging 30–40 m. The distribution and nomenclature of the major sills is shown in Figs. 3 and 4. A few impersistent dykes 1–6 m. wide also occur. At least three phases of intrusion are recognizable on field, petrographical and geochemical evidence. Layering of two types, probably due to flowage differentiation and crystal settling, occurs in sills beside Jeffries Glacier and Marø Cliffs.

Intrusion was accompanied by minor local tilting and faulting, by thermal metamorphism of the intruded sediments (p. 81) and by some hydrothermal mineralization. All xenoliths are of local sedimentary origin and are generally restricted to the basal sill of Lenton Bluff, although they occur in other intrusions.

The dolerite intrusions vary petrographically, both between and within individual intrusions. Many are olivine-bearing throughout and the majority have olivine or altered olivine phenocrysts in chilled marginal rocks. Others are characterized by a felsic mesostasis and granophyric quartz-dolerites are common, especially in the scarp-capping sill. The dolerite intrusions are more similar petrographically to the Karroo dolerites of South Africa than to either the Ferrar dolerites of eastern Antarctica or the Jurassic dolerites of Tasmania.

The dolerite intrusions are chemically variable. Fractionation is largely shown by an increase in total iron relative to magnesia with only a slight increase in alkalis relative to lime. Many of the variation diagrams show a tendency towards two separate trends, individual intrusions lying either on one or other trend depending on which element is plotted. The scarp-capping sill appears to be consistently separable from other intrusions in the Theron Mountains.

Whereas geochemical comparison with the Mesozoic tholeiitic rocks of the Southern Hemisphere supports the hypothesis that two major basaltic provinces occur in the Southern Hemisphere (Compston and others, 1968), their geographical limits require modification. On the basis of mean analyses, frequency distributions of oxide weight percentages, variation diagrams and isotopic and minor-element ratios, the Jurassic dolerites of the Theron Mountains and Dronning Maud Land differ significantly from the Ferrar dolerites elsewhere in eastern Antarctica. It is therefore suggested that they form an extension of the Karroo–Serra Géral province of Compston and others (1968), which would be expected from their present and former positions in any reconstruction of Gondwanaland.

The petrogenesis of the Jurassic dolerites of the Theron Mountains is inextricably linked with that of other Mesozoic tholeiitic rocks of the Southern Hemisphere. The relationship of the magmatism of the Karroo–Serra Géral and Ferrar–Tasmanian provinces to the break-up and dispersal of Gondwanaland is considered to be significant. This is discussed elsewhere (Brook, in press).

STRUCTURE AND TECTONICS

The structure of the Theron Mountains is relatively simple, the tilting and faulting usually being on a small scale and of local significance.

The sediments are sub-horizontal and only rarely can accurate estimates of their dip be made. Their localized tilt is due solely to the effects of dolerite intrusion and there is no evidence that the Weddell orogeny (Ford, 1971) had any effect in this area.

Faults are uncommon. On the ridge leading eastwards from station Z.453, a small north–south-trending reversed fault with a westerly downthrow of 20 m. offsets a 15 m. thick sill above the scarp-capping sill. A 1–2 m. wide dyke is emplaced along the fault plane. Near the south-western end of Marø Cliffs (Z.481), a reversed fault with a southerly downthrow of not more than 10 m. trends north-east to south-west and parallel to the cliff face. It is of small extent and traceable for only 50–100 m. along the cliffs. In the two buttresses where it is exposed, the contacts are obscured by a scree-filled gully (Fig. 9).

There is no evidence to suggest any faulting along the tributaries of "Main Glacier". The variation in altitude of dolerite sills is apparently caused by variation in stratigraphical position rather than by faulting. The absence of certain sills in some cliff sections at approximately the same horizon is attributed to their localized extent rather than to them being faulted out.

Stephenson (1966) interpreted the linearity of the escarpment of the Theron Mountains as a fault scarp downthrown to the north-west. A crevassed ice scarp parallel to the mountain range and about 50 km. north-west of it supports the suggestion that "Main Glacier" follows the line of a graben. There is, however, little evidence of faulting and no direct evidence of major

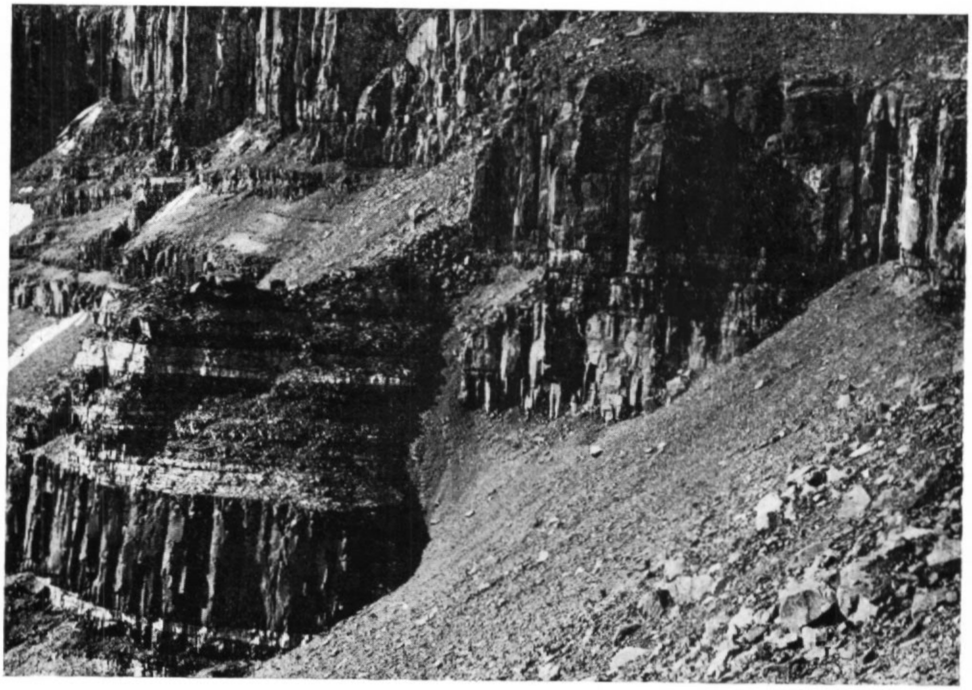


Fig. 9. View from the south-west of a reversed fault cutting dolerite and sediments in Marø Cliffs (Z.481); the apparent downthrow is to the south. The unexposed fault plane follows the scree-filled gully.

down-faulting to the north-west. The linearity could represent planation by an over-deepened "Main Glacier" in the recent past.

As block faulting is common in the Transantarctic Mountains and in the mountains of western Dronning Maud Land, it is probable that the Theron Mountains represent a fault block separated from its nearest neighbours by faults, or possibly graben, which are occupied by "Main Glacier" and Slessor Glacier. If this is the case, the age of the faulting is unknown although it is definitely post-Jurassic. Although Stephenson (1966) suggested that the sharp profile of the escarpment was a youthful feature, the intensity of erosive processes under present climatic conditions may also have formed such a profile.

SUMMARY AND CONCLUSIONS

Pre-Permian events in the Theron Mountains are unknown. Permian and later events are summarized in Table I.

During Permian times a sequence of continental water-laid clastic sediments was deposited. These are of fine grade and consist of fine-grained sandstones, siltstones, mudstones and shales with subordinate carbonaceous beds and coals. They comprise arkosic, feldspathic and quartzitic beds and were probably derived from a metamorphic terrain of gneisses and gneissic granites with some slight admixtures from an acid volcanic source. Their source area lay to the south-west and probably included the Shackleton Range. Deposition was probably fairly rapid with occasional intervals of quiescence under fluvial, fluvio-deltaic and lacustrine conditions. Glacial and fluvio-glacial deposits and volcaniclastic strata are absent. Hiates, including the sedimentary "break" at Coalseam Cliffs (Stephenson, 1966), are of local significance.

The Lower Permian age of the *Glossopteris* flora within the sediments (Plumstead, 1962) confirms the lithological and structural correlations made with the Permian sandstones and coal measures of the Victoria Group of the Beacon Supergroup (Barrett and others, 1971) found elsewhere in eastern Antarctica. The Karroo and other Lower Gondwana sediments are homotaxial in the other Southern Hemisphere continents.

There is no record of tectonic events between the Permian and the Jurassic, but the sediments were probably subjected to some diagenesis and metamorphism due to the depth of overburden. These imparted a bituminous rank to the coals. The Lower Permian to Jurassic Weddell orogeny (Ford, 1971), which affected the sediments of the Pensacola Mountains, does not appear to be represented in the Theron Mountains.

During the Jurassic the sediments were intruded by dolerite sills and dykes. These metamorphosed the whole sedimentary succession, notably the coals.

Since the end of the Jurassic, block faulting may have preserved the sediments and dolerites of the Theron Mountains at a lower altitude than in nearby mountain areas.

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