AUSTRALASIAN ANTARCTIC EXPEDITION
1911-14

UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, D.Sc., F.R.S.

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SERIES A.

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PART 11.

SEDIMENTARY ROCKS

BY

DOUGLAS MAWSON

WITH FIVE PLATES.

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PART 11.

SEDIMENTARY ROCKS

BY

DOUGLAS MAWSON.

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SERIES A.

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SEDIMENTARY ROCKS.

BY

DOUGLAS MAWSON.

I. INTRODUCTION.

It is the aim of this contribution to deal with the sedimentary rocks such as are not sufficiently metamorphosed to come within the scope of other collaborators who have contributed to the volume and the preceding one which deal with the petrology of the Antarctic rock collections. Such rocks fall into two classes: those collected *in situ* and others found only as erratics in the moraines.

Of the former, apart from recent unconsolidated debris such as the moraines, only one important occurrence was met, namely in the neighbourhood of the Horn Bluff in King George Land where Dr. Madigan's sledge party came upon a sedimentary series typified by sandstones underlying a gigantic sill of dolerite. An interesting feature of these Horn Bluff beds is that they carry coal which, however, has been greatly altered by subjection to heat from the igneous intrusion.

The erratics recorded here are pebble, gravel and sand rocks. Other older and more metamorphosed sand rocks together with marbles and phyllites, occur in the region visited by the Expedition but have been dealt with by Stillwell, Tilley, Kleeman and others.

An interesting point in connection with the ancient marble series, abundant erratics of which appear amongst the morainic debris at Cape Denison, is that in one case (No. 316), a forsterite marble now serpentinised, there is figured on the face of the rock outlines of what may very well have originally been fossil archaeocyathinae. The outlines are recorded in yellow-green serpentine which shows up against the white rock. As Cambrian archaeocyathinae limestones have already been recorded in other sectors of the Antarctic, the above contention is greatly strengthened. This makes it appear probable that the metamorphosed limestones described by Tilley and Glastonbury are of Lower Cambrian age.

Several small specimens of lignite with the general character of brown coal were dredged up with glacial mud from the sea floor at two locations off the west side of the Mertz Glacier Tongue. Therefore, either brown coal occurs as a bed on the sea floor at this point (in process of erosion by the ice tongue) or else the fragments have been transported from the land with other morainic debris. The existence of a brown coal formation in that neighbourhood either beneath the sea or beneath the land ice is indicated.

II. SEDIMENTARY FORMATIONS MET WITH *IN SITU*.

A. Unconsolidated Surface Deposits.

These are almost entirely of the nature of morainic materials deposited as terminal moraines. Even so, there is an absence of any large quantity of such debris deposited on the land anywhere within the areas examined during the progress of the Expedition. Only in the neighbourhood of Cape Denison were notable moraines encountered. All along those Antarctic coasts the ice is still carrying its rocky burden out to sea before releasing it.

In this division come the extensive screes below the thousand-feet cliffs in the neighbourhood of the Horn Bluff (Plate XVI, fig. 1) where vast quantities of fragmentary dolerite are heaped below the gigantic sill of columnar dolerite.

In none of the penguin rookeries visited is there any really notable accumulation of guano, for the high winds carry off most of what, under other circumstances, would have accumulated in vast rookeries distributed at intervals along the coast.

The Moraine Deposits.

As the ice-cap of Antarctica normally descends into the sea, its load of rocks and rock flour becomes ultimately a submarine off-shore deposit. Only in isolated spots distributed at fairly wide intervals along the coast is the downward- and outward-moving ice sheet dissipated before actually reaching the sea. The rock outcrops thus exposed are littered with morainic matter transported by the ice and deposited along its terminal face.

At Cape Denison in addition to the general litter of erratics distributed over all the exposed rock area there is a well-defined terminal moraine belt adjacent and parallel to the ice-front. In general this is all coarse material including some boulders many tons in weight. This accumulation does not, however, represent, so far as its mechanical nature is concerned, the average mixture transported by the ice; for, as the rocky debris is released from the ice, all the finer material is quickly removed by one or other of two agencies. Firstly, summer thaw water, though very limited in that region, flows away milky white with suspended fine material. Secondly, the violent off-shore hurricane winds readily lift and transport to sea all particles up to about 1 centimeter in diameter. It is only in quite favoured spots on the land that morainic accumulations with an appreciable proportion of fine material can be found.

Stillwell in his general account of the geological features of the Cape Denison area refers to the general features and distribution of the moraines. He records* the typical glacial moraines of the higher levels in that locality and distinguishes them from the "Lower Moraine" which is an old raised beach at 40 feet above the present sea level. This latter beach is characterised by accumulations of wave-worn boulders most of which were derived from the local rocks.

*This series—Vol. III, Part 1; pages 19–21.

A fragment of sand rock (No. 702) containing marine calcareous organic remains,* such as foraminifera and a milioline, which was discovered on the ice surface near the back of the living Hut, is taken by him to represent the finer sandy deposit of this old raised beach level. This may be so; but the specimen was not found *in situ*, and I do not recall having seen anything like it *in situ* in the neighbourhood. The parent formation may, however, be under the ice nearby. If this should be so, it is queer that it should contain particles of palagonite which has not been met in our exhaustive investigation of the local moraines.

Some special observations were made with regard to the moraine material at Cape Denison, to be detailed herewith.

In order to secure what might be more nearly an average grade of morainic matter released from the ice, a sample of the debris freshly set free from the terminal face of the inland ice sheet by thaw during a spell of hot, still weather in midsummer was collected. This had not been subjected to wind scour, but undoubtedly a small quantity of impalpably fine rock flour had been carried off by slowly moving trickles of water. The sample so collected did not include any larger boulders, some of which were observed at the time to be in process of actual release at isolated points along the ice-front.

The sample collected may, therefore, be said to represent the average mechanical grade of rock debris transported by the ice, less a little of the finest rock flour and less a proportion of the coarse material, namely the larger pebbles and boulders.

The absence of a proportion of the extremely coarse and of the extremely fine material probably has little bearing upon the aggregate chemical composition. The sample collected may therefore, so far as chemical composition is concerned, be regarded as furnishing a close approximation to the average of that of the entire glacial load transported in the vicinity of Cape Denison.

The object of collecting this sample was to investigate its total mechanical and chemical nature. With this object, on return to Australia, the sample was submitted to the chemical laboratory of the Department of Agriculture in Sydney, where Mr. F. B. Guthrie, F.I.C., kindly undertook to have it examined. The general turmoil that ensued with the advent of the War greatly delayed action being taken and eventually resulted in a somewhat different treatment of the sample than had originally been contemplated. The morainic material was subjected to the usual treatment accorded to the regular soil samples submitted to the Department, with the exception that a complete analysis was made of the finer "soil" material. However, the data eventually supplied from Mr. Guthrie's Department has very considerable value and consequently is printed below in full.

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* Chapman in Stillwell's account, pp. 21–22 and Plate XIII, figs. 1 to 4.

ANALYSIS OF SOIL FROM ADELIE LAND (ANTARCTICA).

By R. M. PETRIE, Assistant Chemist, Chemist's Branch, Dept. of Agriculture, Sydney.

Locality of soil	Cape Denison, Adelie Land.
Geological formation	The rock formations from which the soil has been culled by the ice are ancient metamorphosed sediments and igneous rocks.
Nature and depth of soil	Debris from the melting terminal face of the ice cap.
Colour of soil	Grey.
Reaction of soil	Alkaline.
Capacity for water	9·5 per cent. (very low).
Capillary power	11½ inches in 3 hours (excellent).
Absolute weight per acre (6 inches deep)	1,273 tons.

MECHANICAL ANALYSIS.

Root fibres	Nil.
Stones (over ¼ inch diameter)	27·82 per cent.
Coarse gravel (more than 1/10 inch diameter)	18·53
Fine gravel (more than 1/50 inch diameter)	20·48
Fine soil: sand	29·66
impalpable matter	3·51
	100·00

ANALYSIS OF FINE SOIL.

Moisture	0·50
Volatile matter, principally water of combination	0·75

PERCENTAGES OF FERTILISING SUBSTANCES.

			General Value.
Nitrogen	Nil		Nil.
Soluble in Hydrochloric Acid (Sp. gr. 1·1).	Lime (CaO)	0·645	Very good.
	Potash (K_2O)	0·116	Satisfactory.
	Phosphoric Acid (P_2O_5)	0·166	Satisfactory.

COMPLETE ANALYSIS OF "SOIL" FROM CAPE DENISON.

By E. GRIFFITHS, B.Sc., Assistant Chemist, Chemist's Branch, Department of Agriculture, Sydney.

SiO_2	67·86 per cent.
Al_2O_3*	14·12 ,,
Fe_2O_3	3·76 ,,
FeO	2·50 ,,
MgO	1·66 ,,
CaO	2·60 ,,
Na_2O	2·05 ,,
K_2O	3·84 ,,
H_2O above 110° C.	0·56 ,,
H_2O below 110° C.	0·10 ,,
CO_2	0·50 ,,
MnO	0·03 ,,
P_2O_5	0·55 ,,
S	0·06 ,,
ZrO_2	0·02 ,,
	100·21 ,,

* This precipitate contains titanium which was not determined quantitatively.

Copper is present in minute quantity. Barium is absent. Sulphates are absent. The analysis was carried out on air-dried material.

NOTES ON SOIL FROM CAPE DENISON.

By F. B. GUTHRIE, Director, Chemical Laboratory, Department of Agriculture, Sydney.

The sample does not represent a true soil from an agricultural view-point, being a gravelly sand, with a considerable proportion of stones, and destitute of clay and humus. The climatic conditions in these latitudes make the weathering of rock into soil a very lengthy process, and under natural conditions it would take a very long time to develop the plant-growth necessary to form humus and to convert the weathered rock into soil.

The actual germinating power of the soil, under conditions favourable to germination, is quite normal, and it should be possible to convert this debris in course of time into a true arable soil by planting seeds of grasses or other plants which could be relied on to make a growth under the prevailing climatic conditions.

For a sandy soil of this character it is remarkably well supplied with soluble mineral plant food (lime, potash and phosphoric acid) the lime being particularly high and imparting an alkaline reaction to the soil.

The result of the analysis by the fusion method shows that there is a considerable store of such insoluble plant-food which would become available as weathering proceeds. There appears to be no substance present likely to be injurious to plant-growth. In a germinating test a number of grains of wheat were sown. A hundred per cent. germinated and developed normally until the plants were several inches in height, when they were accidentally destroyed.

Analysis of soils from every locality in New South Wales, particularly from the Hawkesbury sandstone and Wianamatta shale of the Blue Mountains and the South Coast, shows that many of them differ very little in mechanical condition from this sample, and are much less well supplied with mineral plant-food. Crops are successfully grown on these soils. Such samples, however, always contain some humus and consequently nitrogen.

The following table, taken from analyses of sandstone and Wianamatta Shale soils quoted in H. I. Jensen's " The Soils of New South Wales," will serve to draw attention to this point.

Table showing mineral plant-food (soluble in Hydrochloric Acid) in certain typical farmers' soils in New South Wales.

	Lime.	Potash.	Phosphoric Acid.
Typical County Cumberland soils—			
(*a*) Hawkesbury sandstone	·106	·066	·137
(*b*) Wianamatta shale	·136	·133	·096
Central Tableland (Blue Mountains)	·087	·048	·108
South Coast (Coastal Plains)	·100	·078	·109
Pilliga Scrub (sandy drift soils)	·067	·045	·075

All the above, which represent the average of a considerable number of soils of the respective types, are much poorer in mineral plant food than the Cape Denison (Antarctica) debris, and there is no reason why this latter should not ultimately provide a fairly rich soil on weathering.

The production of humus in this soil is the necessary preliminary to its conversion into cultivable land, and this requires to be done artificially and in a systematic manner.

The chemical analysis of the " soil " made by E. Griffiths, as quoted above, undoubtedly applies to the fraction of the complete sample represented by " Sand and Impalpable Matter " amounting in all to 33·17% of the whole.

As glacial erosion is a grinding process and as, so far as we know, the rocky crust under the ice everywhere in the region around Cape Denison is that of ancient hard rocks without any softer constituents than some silicated marbles and phyllites, it is probable that the chemical composition of the fine material of our morainic sample is not far from the average composition of the whole of the glacial load in that neighbourhood. This being so the analysis has considerable value in relation to the petrology of glacial sediments as a whole.

B. Consolidated Rocks.

At the Horn Bluff on the coast of King George Land, in the vicinity of longitude 150° E., Dr. Madigan discovered a thickness of about 500 feet of sediments, chiefly sandstone with a minor amount of shale and some coal, underlying a mighty wall of columnar dolerite (Plate XVI, fig. 1 and Plate XVII, fig. 1) rising above them as a cliff for a further 500 to 600 feet. How much thicker these sedimentary rocks may be, extending below sea-level, cannot be conjectured. My own sledging party saw, at a great distance, the continuation of that formation extending for a distance of 30 miles to the west to the point mapped as " Organ Pipe Cliffs."

On account of great scree slopes of dolerite tumbled from the cliffs above, the sedimentary formation is, for the most part, buried. Only here and there do white fretted beacons of the sandstones outcrop through the scree debris. On this account only fragments of the formation were presented for examination (Plate XVII, fig. 2).

The nature of the completely buried portions is unknown, but it is suggested that a greater development of the softer shaley beds and coal may there be expected.

The sand beds, in part at least, exhibit current bedding (Plate XVI, fig. 2) and there are bands in the series rich in heavy minerals including cassiterite, zircon, kyanite and garnet; the latter being widely distributed throughout the beds. These sands have evidently been deposited by strong currents of water. Originally many of the bands have been rich in felspar (arkoses), but this mineral has suffered subsequent alteration to secondary products.

Plant remains more or less altered by the heat of intrusion occur at intervals along the bedding planes and embedded locally in the sandstone, as if portions of ligneous matter had been washed down and engulfed in the depositing sands. No definitely recognisable plant fossil has been retrieved but Dr. Madigan reports that many of the rock fragments showed the vague outline of plant fossils.

It seems most likely that this formation corresponds with the topmost division of coal-bearing sandstones already recorded* in the Ross Sea region.

In its general character and field relations to the dolerite sill, which latter appears to correspond to similar intrusions in Tasmania, there appears to be strong reason to anticipate that the Horn Bluff series is the Antarctic equivalent of the Ross sandstones of Tasmania, which are taken to be early Triassic in age.

Some petrological details of the specimens collected are recorded below.

Rock. No. 1175.—This is a breccia band of the Horn Bluff sedimentary series. In it there are large angular pebbles of quartz as much as 5 cms. in diameter. Another fragment 2·5 cms. diameter is of decomposed schist. These pebbles are embedded in a coarse arenaceous grit, the average size of the grains of which is about 1 mm. or somewhat less.

* *Vide:* " The Sedimentary Rocks of South Victoria Land," by F. Debenham, also " Antarctic Fossil Plants," by A. C. Seward; both appearing in Geology, Vol. I, of British Antarctic (" Terra Nova ") Expedition, 1910.

The groundmass on examination under the microscope is found to be composed of the following minerals (Plate XX, fig. 4). Quartz is the most abundant mineral and is usually the coarsest of the particles; it exhibits undulose extinction and is obviously derived from metamorphic rocks. The coarser quartz is all subangular but the finer quartz particles are more angular, some being quite splintery.

There is a certain amount of interstitial white clayey matter no doubt mainly derived from the alteration of original felspathic particles, kaolinised since deposition. With this in patches is a little amorphous carbonaceous matter, derived from the alteration of plant remains probably affected by the heat of intrusion of the superimposed dolerite sill. Pyrites is present in scattered centres; it has been introduced in solution after the formation of the rock and is moulded around the sand grains; it is now much oxidised to limonite.

Of the accessory arenaceous constituents garnet is the most abundant; it is in angular to somewhat subangular grains. It is present in two varieties: The first is puce coloured to faintly amethystine, but under the microscope it is almost colourless; the second is of a darker colour, namely, red-brown when in mass but very light brown in the microscope section. A Rosiwal estimate showed garnet to be present to the extent of about 5 per cent. Zircon is present in small amount. It is grey coloured in the slide, and appears in square cross-sections of high relief.

Kyanite is a not uncommon constituent appearing in colourless rectangular fragments of high relief. It is a biaxial negative with a large optic axial angle. The D.R. is about ·011. Traces of cleavages are distinguishable. It is present in the fine groundmass of the rock to the extent of about 1 per cent.

Odd grains of tourmaline and ilmenite are present.

The most interesting feature, however, is the occurrence of cassiterite which appears in the thin slide as rounded, yellowish brown grains. It exhibits high R.I. and D.R., is non-pleochroic, and is uniaxial positive. A Rosiwal measurement shows that cassiterite is present in the sandy base of this rock to the extent of about 0·2 per cent. which is equivalent to about 20 lb. of cassiterite to the cubic yard of sand. This sand, however, amounts to not more than 50 per cent. of the entire rock, the rest being coarse pebbles.

Rock No. 1174.—This is an example of the typical sandstone occurring in the beacons below the dolerite cliffs at the Horn Bluff. In the hand specimen it is a white even-grained, medium to coarse grained sandstone with a rough feel. With the aid of a pocket lens the kaolin-like white appearance is seen to be in large measure due to secondary minerals coating the sand grains and occupying spaces between them.

In microscope section the average grain size of the original sand particles is seen to be about 0·5 mm. with a large proportion of particles 1 mm. diameter. The original quartz grains are seen to be angular and amount to about 33 per cent. of the volume of the rock: many of them exhibit shadowy extinction pointing to a derivation from pre-existing stressed rocks. Garnet in pale, splintery fragments is present in very small amount. Scattered through the slide to the extent of about 10 per cent. there are reddish brown stained areas which are evidently the loci of original ferruginous minerals which have been broken down partly to carbonate and partly to limonite.

For the rest there is much interstitial secondary material, and secondary alteration products of original felspar granules. There was probably a notable proportion of felspar in the original sand, the grains of which are now represented by speckled reconstituted areas. The secondary minerals are apparently mainly kaolin, zeolites and quartz. Border zones of the latter are sometimes seen to have built on to original quartz grains of the rock.

Evidently the great heat of the immense sill of dolerite intruding these coal-bearing porous beds has profoundly altered the coal and invaded the sandstones with hot carbonated waters which have done the rest.

Rock No. 1179.—A sandstone with carbonised plant remains from the Beacons at the Horn Bluff. The carbonaceous matter is principally distributed along certain of the bedding planes. None of the fossil forms are sufficiently well preserved for determination though one of them can be said to be almost certainly Phyllotheca.

Under the microscope the average grain size is seen to be about 0·5 mm. The quartz grains are angular; most are quite sharply angular but some are subangular. Original quartz grains constitute about 40 per cent. of the rock and somewhat more than this amount was originally represented by felspar grains; these latter are now altered to secondary minerals. Grains of heavy minerals are numerous in certain bands, garnet being most noticeable.

Rock No. 1171.—This specimen is in the main similar to No. 1174 but most of it is of a dark grey colour. This colour appears to have arisen from diffused carbonaceous matter evidently originally invading the porous rock in the gas state: the hydrocarbon gases being the result of the destructive distillation (by igneous heat) of coal remains, a fragment of which is still seen adhering to the specimen on one edge. The "coal" probably represents original fossil wood embedded in the sand rock. It is now practically in the state of anthracite; it is brilliant and will not mark paper.

Rock No. 1177.—Half of this specimen is a white sandstone like No. 1174 whilst the other half is black. Most of the latter is an impure coal with a mat appearance, but embedded in it is some bright coal of higher grade. This coal is not a normal type but shows evidence of subjection to heat.

Rock No. 1172.—An impure dull coal that has suffered from the heat of intrusion of the dolerite. Slickensided surfaces are seen on the specimen. It is closely similar to the dull coal in No. 1177.

Rock No. 1173.—What resembles fragments of an annular plant stem preserved as a dense, brownish-black, dull coaly material. If they do represent such, the diameter of the stem would be 5 cms. and the thickness of wall 0·5 cm. Microscope sections, however, do not reveal any internal cell structure. Nevertheless, such may have been completely destroyed by the heat to which it has been subjected.

Rock No. 1176.—A dark-grey shale underlying the sandstones of one of the Beacons at the Horn Bluff. This is fine-grained, argillaceous rock darkened by carbonaceous matter.

Rock No. 1178.—A chocolate-coloured shale, underlying No. 1176 at the Horn Bluff. This is a typical shale breaking without difficulty into very thin laminae. It is much more highly consolidated than No. 1176 and may actually be considerably older.

Under the microscope it is seen to be a dense, fine, even, argillaceous sediment. Small quantities of chlorite in very fine particles are seen to have been developed in it.

III. ROCKS FOUND ONLY AS ERRATICS.

A. Rudaceous Types.

Rock No. 327.—This is a coarse reddish brown conglomeratic rock found as an erratic in the moraines at Cape Denison. The pebbles which reach a length of 3 cms. are mostly roughly rounded. As seen in the hand specimen, the pebbles are of the following types: quartz, unaltered white felspar, pink orthoclase, red acid porphyry and one case of vein quartz with green apatite embedded in it.

A microscope slide (Plate XVIII, fig. 1), chiefly representative of the finer matrix of the conglomerate, further reveals the presence of the following: grey-blue transparent grains of tourmaline, large grains of microcline, wisps of muscovite, grains of clouded orthoclase, some magnetite and leucoxenised ilmenite; also, of course, abundant grains of quartz which regularly exhibit strain shadows. Included in the section also are pebbles of much-altered quartzites, some of which are felspathic. The rock particles are all angular to subangular.

This is an arkosic type. In the sandy base, felspar is present to the extent of 12 to 15 per cent. It is to be observed, therefore, that chemical decomposition of the minerals was evidently quite subordinate to mechanical disintegrating agencies.

Rock No. 729.—Another arkosic conglomerate allied to No. 327 but somewhat coarser. The fragments of which the conglomerate is formed are subangular. They are chiefly of quartz but some are quite large pieces of felspar; other fragments are of quartzite, chert, etc.

Rock No. 315 is still another conglomerate very like No. 327 (Plate XIX, fig. 2).

Rock No. 400.—A coarse grained rock intermediate between the foregoing conglomerates and the coarse arkose grits typified by No. 537. In this the mineral fragments are subangular and of an average grain-size of ·5 cm. A noteworthy feature is the abundance of large pieces of pink felspar. The bedding planes are outlined by bands rich in magnetite.

Rock No. 537.—This rock and a number that follow are coarse gravel rocks. They are arkosic in character. The particles are either quite angular or but little rounded. They are all of a reddish or brown colour. The specimen (No. 537) is quite typical; it is a coarse reddish-brown arkosic gravel. The rock is of quite distinct character, and is not uncommon in the moraine debris at Cape Denison. It contains coarse mineral particles and small pebbles up to 0·75 cm. diameter, and consequently is in character on the borderline between the pebble and the gravel rocks.

In the microscope slide (Plate XX, fig. 3) the average grain-size is seen to be only about 1 mm. but some reddened, clouded particles up to 6 mm. diameter are present which are taken to be pellets of silicified acid porphyry. Quartz grains are abundant, almost all exhibiting undulose extinction. It is not unusual to meet particles composed of several interlocked quartz grains exhibiting undulose extinction. Such pellets are evidently fragments of some pre-existing stressed rock. There are fragments of nice fresh microcline, but very little of detrital mica. Some tiny hexagons of apatite and a very little magnetite are to be noted. There are some secondary decomposition products, apparently chiefly from felspars, which are reddened with haematite stains.

A rough Rosiwal determination of the volume percentages represented in the slide resulted as follows :—

Quartz	57%
Microcline	7%
Other recognisable felspar	13%
Mica	3%
Stained alteration products, etc.	20%
	100%

It is obvious that this sediment has been accumulated from the disintegration of stressed gneisses and acid igneous rocks.

A further example of this type of rock, so parallel in character that it must represent part of the same original formation, was collected from the moraines at Cape Denison in 1931 when we again called there in the progress of the B.A.N.Z.A.R. Expedition. This rock (B.A.N.Z. No. 391) is a coarse, reddish-brown arkose similar to the above but contains more small composite pebbles which are also more effectively rounded.

Microscopically examined the mineral content is observed to be very similar to that of No. 537 but there is less felspar and all the grains show more evidence of rounding by water transport. More effective water sorting is further evidenced by a greater evenness of grain size. In this case the average grain size is about 0·7 mm.

Rock No. 311.—This is a coarse, brown, pebbly, arkose gravel. In this, pebbles occur up to 1·3 cms. diameter and they show very definite water wearing. Dark haematitic stains are strongly evidenced along the bedding planes.

Rock No. 744.—A very coarse arkose in mechanical character ranging between Nos. 311 and 537. It has a mottled appearance, darker brown spots are distributed through the mass of the rock which is of general lighter colour (Plate XVIII, fig. 2).

Rock No. 663.—This is another coarse reddish-brown arkose of the same general character.

Rock No. 1145 is a light red, medium- to coarse-grained, sandstone exhibiting current bedding. The specimen, which is a large one, contains a patch of flattened, ferruginised pebbles (up to 4 cms. diameter). The general character of this rock suggests for it a Palaeozoic or early Mesozoic age (Plate XIX, fig. 1).

All these rudaceous rocks are free from evidence of great antiquity and it seems likely that they are of later Palaeozoic age.

The mineral contents indicate that they post-date in age the great period of granitic and granodioritic intrusions of which the Cape Denison rocks are an instance. Also it is indicated that they post-date the extrusion of the red, acid porphyries which are a feature of the moraine suite in Adelie Land.

B. Arenaceous Rocks.

Rock No. 1182.—This is an even-grained, mottled freestone; areas stained reddish-brown are distributed over the general lighter colour of the rock. The colouration of this and indeed most, at least, of these arenaceous and rudaceous rocks is largely the result of secondary processes affected after deposition.

Microscopically examined it is seen to be fairly even-grained, with some grains tending to be distinctly larger than the average. These larger grains which average 6·5 mm. diameter are obviously more rounded than the rest of the material. The mean of the finer-grained material has a diameter of 0·2 mm.

The grains of quartz mostly exhibit undulose extinction. Felspar is significantly absent.

Rock No. 1185.—A fine even-grained, cream coloured freestone, which is of the same general character as No. 1182. It is of uniform colour excepting in one thin band along a bedding plane which is stained to a red-brown.

Rock No. 317A.—This is another light-coloured, even-grained freestone with only a slight trace of bedding planes. Besides quartz, it carries a little felspar, of which microcline is the most obvious, and a few wisps of mica and grains of magnetite.

The mineral grains average 0·25 mm. diameter and are all angular.

Rock No. 665.—A very even, dense, fine-grained, pink arkose from the moraine, Cape Denison.

Microscopically examined it is revealed that, whereas quartz is very abundantly represented in the constituent particles, yet quite 50 per cent. is constituted of felspar, partly fresh and partly turbid through partial decomposition. Besides orthoclase and microcline much of it is plagioclase. Small fragments of muscovite and specks of chloritised biotite are represented. In reflected light reddish stains are seen to outline crystal boundaries and invade the decomposition products of the felspars.

The very fine grain of the rock is notable, the average size being about ·16 mm. diameter. Further, the particles are all splintery, suggesting a glacial origin.

Rock No. 1286.—A dense fine-grained arkose related to No. 665 but lighter in colour.

Rock No. 751.—A light red, even-textured freestone with some evidence of bedding in that it splits in parallel sheets when fractured. It is rough to the feel.

Examined in the microscope slide it is seen to bear a relation to the type (No. 1182) in that it exhibits two distinct kinds of grain : Firstly, large rounded grains of about 0·5 mm. diameter distributed more abundantly in certain laminae; secondly, much finer splintery particles forming a general base in which the rounded grains are embedded. The average grain size of the more general finer grains is about ·16 mm. The quartz particles exhibit strain polarisation acquired prior to reassembly to form this rock.

The characters here outlined suggest that this is a fluvio-glacial sediment accumulating in a depositing area fed by streams from two sources; one the wash from a neighbouring glacier, the other arriving only after long water-borne transport.

Rock No. 131.—A fairly even-grained, fine-textured, reddish brown freestone. The parts less exposed are of a lighter colour. Similar evidence is available in the case of other specimens of these sandstones indicating that weathering by exposure, since transportation, is greatly responsible for the colouration of these rocks.

This particular rock, though notably even-grained, on careful examination exhibits slightly coarser alternated bands of about 1 inch in thickness.

Rock No. 125c.—This rock is of the same general character as No. 131 so far as exhibited in the hand specimen, except that it is of a deeper red colour.

In the microscope slide it is seen to be constituted of a general mass of small angular grains averaging 0·17 mm. diameter, with scattered larger grains of a different character, being well rounded and up to 1 mm. diameter. Besides quartz there is present about 4 per cent. of fresh felspar, chiefly microcline, and very little acid plagioclase. A few flecks of mica are to be seen.

Rock No. 1184 is related to No. 125C but exhibits some coarse, alternating arkosic laminae.

Rock No. 1181 is also related to No. 1182. A mottled rock in which the bedding planes are faintly outlined by recurrence along them of patches of dark staining. On the bedding planes the staining is slightly suggestive of faint markings but, apparently, inorganic.

Rock No. 337 is somewhat related to No. 1181, bearing queer stainings.

Rocks Nos. 319 and 1187 are closely related, and have abundant red-brown splotches on the bedding planes.

Rock No. 1188.—This appears to be related to the above, and has staining along the bedding planes. Some of the markings are suggestive of plant impressions.

Rock No. 125A.—Reddish-brown sandstone of medium to coarse grain. The bedding is well defined by an alternation of coarser and finer grained bands. The average grain size is 0·25 mm. Here again large rounded grains are associated with smaller more angular particles.

The next group of arenaceous erratics present characters which suggest somewhat greater age than the foregoing and may be early Palaeozoic or even older. Some of them that are finer grained (and therefore more prone to be more densely cemented and altered) may, however, be members of the same formation that has yielded the before-described, red, arenaceous types.

Rock No. 312.—This is a brown, even-coloured and even-grained arkose. It is without marked tendency to split on the bedding planes. On the bedding planes mica flakes are obvious to the naked eye.

In the microscopic section it is seen to have a grain size of about 0·15 mm. and the grains are sharply angular. Between the grains there is a little very fine irresolvable base material filling cracks and spaces. The mineral constituents are the following: Quartz, in angular fragments exhibiting strain shadows, is present to the extent of almost 50 per cent. of the volume. Felspar is abundant, amounting probably to somewhat over 30 per cent. of the slide; orthoclase, microcline and acid plagioclase are all recognisable. Detrital muscovite is observable and some fine secondary sericite. Secondary epidote present to the extent of about 7 per cent. has arisen at the expense of original calcic felspars or out of calcareous rock flour of the base. Of the latter, there still remains some stained argillaceous material or rock flour.

*62850—B

The development of epidote in this rock argues considerable age so that it is unlikely that it is newer than the Palaeozoic. Comparison with other Antarctic rocks of known age suggests that it is older Palaeozoic or pre-Palaeozoic. Its arkosic character, plus angularity of grain, strongly favours a fluvio-glacial origin.

Rock No. 313.—A light red-brown, fine-grained arkose, very similar to No. 570 but without the interformational conglomerate bands. Traces of bedding are discernible. It is densely cemented and apparently of considerable antiquity.

Rock No. 1183.—This is an even-coloured, chocolate arkose of a very fine and even grain size; so fine grained, indeed, as to approach a siltstone in character. It is a freestone in type but has a poorly developed tendency to break along the bedding planes upon which minute glistening flakes of mica can be seen with the aid of a pocket lens.

The microscope slide (Plate XX, fig. 2) illustrates the very fine-grained character of the rock, actually about 0·07 mm. The grains are quite angular and fit tightly into each other. Under higher power there is seen to be some green chloritic material cementing the grains but for the most part this has become reddened by oxidation. Besides quartz, grains of felspar including acid plagioclase, and rather abundant black specks of magnetite are seen to be present.

This rock shows a close relationship with No. 312 and remarks made relating thereto in the matter of genesis and age apply here also.

Rock No. 570.—This is an exceedingly fine-grained, closely-cemented, light-red-coloured arkose. A band of flattened pebbles (up to 5 cms. diameter) of chocolate shale occur in it as a local discontinuity of the nature of an interformational conglomerate. The fine base of this rock is similar to No. 1183.

Rock No. 450 is a reddish brown sandstone whose general appearance suggests that it is likely to be of the same age as Nos. 1183 and 312.

Rock No. 125B.—This is a chocolate-brown coloured sandstone. The bedding is discernible owing to the intercalation of bands of a finer texture and deeper colour.

Under the microscope (Plate XX, fig. 1) a definite chocolate-brown pigment is observed around the mineral grains causing them to be strongly outlined. In this rock practically all the particles are of quartz sand, in which shadowy extinction is fairly general. Some of the particles are composite.

As in some others of these rocks larger rounded grains of about 1 mm. diameter are studded through a general matrix of quite angular and much finer particles.

Rock No. 125.—A light-coloured, gritty sandstone with bedding planes outlined by reddish-brown streaks. On breaking the rock along the bedding planes, irregular reddish-brown splotches appear suggestive as possibly representing indefinite traces of fossils. However, nothing can be definitely claimed in this respect and the probability is that they are loci of deformed argillaceous pellets which have selectively absorbed more of the ferruginous staining solution than the arenaceous base of the rock.

The splotches are up to 2·5 cms. across though usually 2 cms. or less. They have a definite thickness across the bedding not exceeding 0·5 mm.

Examined under the microscope this rock is observed in general to be composed of very fine subangular grains. The grain-size is, however, irregular, ranging from lamellae averaging 0·1 mm. diameter alternating with coarser bands of 0·2 mm.

The quartz grains show undulose extinction. A small proportion of the particles are of felspar. Traces of mica and some minor accessories are present also.

Rock No. 385.—A densely cemented, light brown quartzite, with recurrent bands rich in flattened, angular, chocolate coloured fragments of a fine pelitic character. These latter may originally have been clay pellets. The effect is that of an interformational breccia.

Rock No. 731.—A gravel rock strongly bound together by a dark chocolate coloured cement. The particles are subangular and nearly all are quartz. The larger particles measure 1·25 cms. in diameter. It is interesting to note that several of the quartz particles are of the blue quartz type met with in some of the ancient primary rocks of the same region.

The balance of the psammitic erratics represent greater variation in type than those already dealt with, and they exhibit characters suggestive of an age at least as ancient or older than any of the foregoing. They would appear to date from early Palaeozoic or pre-Palaeozoic time. Certain other more highly altered arenaceous sediments have already been described as metamorphic rocks; for example certain quartzites referred to in Part VII of this volume.

Rock No. 309.—This is a grey quartzite, densely cemented and uniform in character. Bedding planes are not discernible.

In the microscope slide the grains are observed to be intricately dovetailed and the quartz exhibits very marked shadowy extinction. Besides quartz there is present a little acid plagioclase, some muscovite flakes and a lot of angular grains of magnetite. There are also some grains of a colourless garnet, dark tourmaline and grey zircon.

The above characters indicate that this rock is either early Palaeozoic or pre-Palaeozoic in age.

Rock No. 133.—This is a light coloured arkosic quartzite traversed by numerous quartz veins, some reaching as much as ·5 cm. in thickness.

In the slide this rock is seen to be composed of quite angular fragments, the general run of which have a mean diameter of about 0·5 mm. Between these grains is packed much finer but still angular material so that a glacial or glacio-fluvial origin is suggested. The mineral fragments are largely quartz exhibiting shadowy extinction but there is also present quite a lot of microcline and some acid plagioclase.

Rock No. 862.—In the hand specimen this appears as a dark coloured, strongly silicified, indefinite rock. The microscope reveals that it is composed in the main of angular fragments of quartz and some felspar. These particles are set in finer material that may at one time have been a paste but has since recrystallised and is largely represented by chlorite and chloritised mica.

This rock is very much altered, obscuring its origin. It may have originated as a mylonite or even as a glacial mud.

Rock No. 582 is a hard, grey sandstone. It is well cemented and from its state of consolidation and general appearance might be expected to be of Palaeozoic age.

Distributed through it on bedding planes are dark splotchy markings which appear to be due to organic agencies but no definite fossil forms can be recognised.

Rock No. 434.—An even medium-grained, light reddish brown arkose with definite bedding planes. The particles of felspar are much whitened by kaolinization.

Rock No. 452.—A dense, grey quartzite, evidently of considerable age; probably at least as old as earlier Palaeozoic.

Rock No. 655.—A dense, well cemented, light grey quartzite. A certain amount of secondary yellow epidote is developed suggesting considerable antiquity.

Rock No. 1190.—A dense, splotchy, light brown quartzite, probably early Palaeozoic or older.

Whilst in face of the present dearth of knowledge concerning the sedimentary formations represented in Antarctica, it is impossible to ascribe with certainty these rocks collected from the moraines to any existing formations, the probability is that the less ancient examples have been transported by the ice from beds of Devonian to Triassic age. The direction of movement of the ice transporting these rocks to Cape Denison was towards the N.N.E. and N.E.; consequently formations of such rocks must exist under the ice somewhere to the south-west of Commonwealth Bay.

The general absence of rounding of the grains in these rocks is evidence that running water played but a minor part in their transport and accumulation. There is, however, some evidence of water action in the rough sorting and current bedding exhibited even in the rudaceous types.

A large proportion of these rocks are highly arkosic; being rich in particles of minerals which under ordinary conditions of weathering would have suffered chemical decomposition. The freshness of the felspar fragments and other easily chemically changed minerals argues frost action or glacial grinding.

The red colour of so many of these rocks suggests deposition during a period of aridity. When dealing merely with erratic blocks which, since release from the transporting ice, have been subjected to atmospheric agencies for a considerable time, there is some uncertainty as to how much of the red colour is original and distinctive of the parent body. Making allowance for probable heightening of the red colour by exposure, there remains no doubt that at least one formation exists thereabouts which is characteristically a red sandstone formation.

DESCRIPTION OF PLATES XVI TO XX.

PLATE XVI.

Fig. 1. The thousand-feet high rock cliffs facing the frozen sea at the Horn Bluff, King George Land. Dr. Madigan, standing on the sea ice below, is contemplating the columnar dolerite formation which overlies an almost horizontally disposed coal-bearing sandstone formation which, in the picture, is nearly completely hidden by the talus at the foot of the dolerite cliffs. The light-coloured patch at the top of the talus slope seen at one spot in the picture is an outcropping beacon of this sandstone.

Photo., A. L. McLean. Neg. Q. 707.

2. A close view of the face of the sandstone formation at Horn Bluff. Its current-bedded nature is well exemplified in the picture.

Photo., A. McLean. Neg. Q. 709.

PLATE XVII.

Fig. 1. View looking steeply upwards at the cliff face at Horn Bluff. Below is the white sandstone formation, against which Dr. Madigan is standing, to indicate scale. Above is the columnar dolerite.

Photo., A. L. McLean. Neg. Q. 697.

2. A close view of a face of a beacon of the sandstone formation at Horn Bluff. The figure is Dr. Madigan.

Photo., A. L. McLean. Neg. Q. 710.

PLATE XVIII.

Fig. 1. General view of the arkose conglomerate (327). The scale is in inches.

2. Photograph of the face of a hand specimen of the coarse arkose (744). Current bedding is well exemplified. The scale is in inches.

Photo., H. E. C. Brock.

PLATE XIX.

Fig. 1. Showing a layer of pebbles distributed along a bedding-plane surface of sandstone (1145). The photo. is taken natural size.

2. General view of a specimen of the conglomerate (315). The view is that of a somewhat finer grained portion of the rock. Magnified $1\frac{1}{2}$ diameters.

Photo., H. E. C. Brock.

PLATE XX.

Fig. 1. Microphotograph of the sandstone (125B), which is characterised by exhibiting two types of sand particles: (*a*) large rounded ones; (*b*) small angular particles constituting the general base of the rock. Magnified 23 diameters.

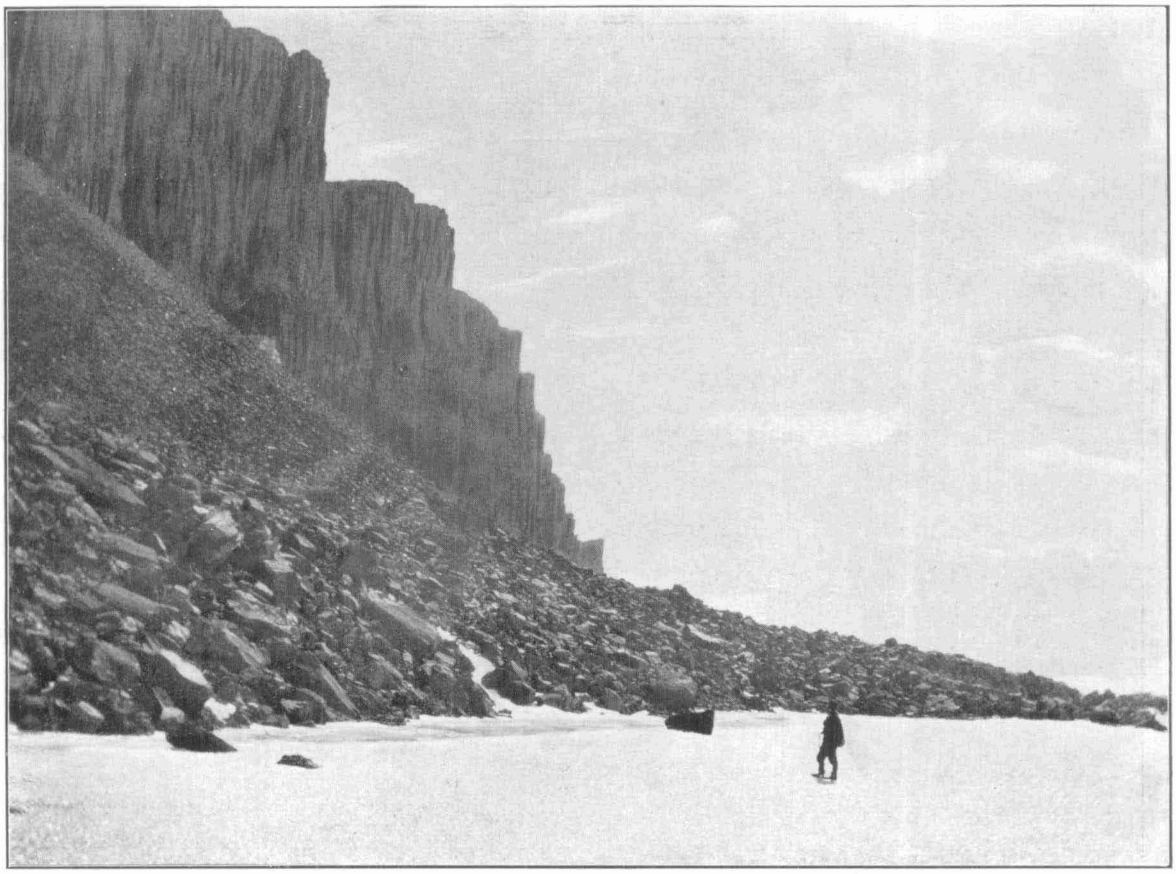
2. Microphotograph of the fine-grained, fluvio-glacial, arkosic grit (1183). Magnified 58 diameters.

3. Microphotograph of the very coarse arkose (537) viewed under crossed nicols. Large fragments of microcline felspar are shown up on insertion of the analyser. Magnified 22 diameters.

4. Microphotograph of the finer base of the sedimentary, quartzose breccia (1175) found *in situ* as part of the great sandstone formation at the Horn Bluff. The finer material of this rock is rich in heavy minerals, such as garnet, cyanite, cassiterite, etc., which are seen standing out in high relief in the photo. Magnified 16 diameters.

Photo., H E. C. Brock.

Sydney: Thomas Henry Tennant, Government Printer—1940.



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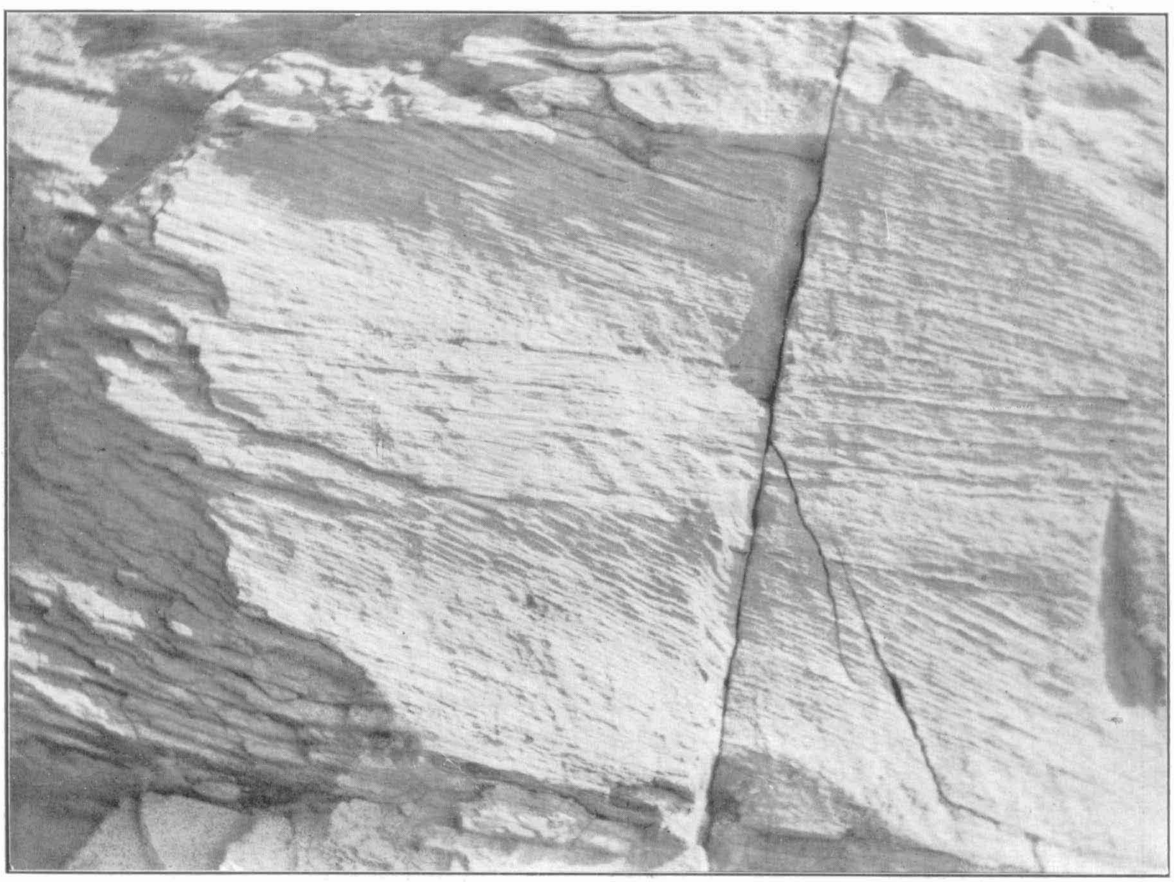

Fig. 2.

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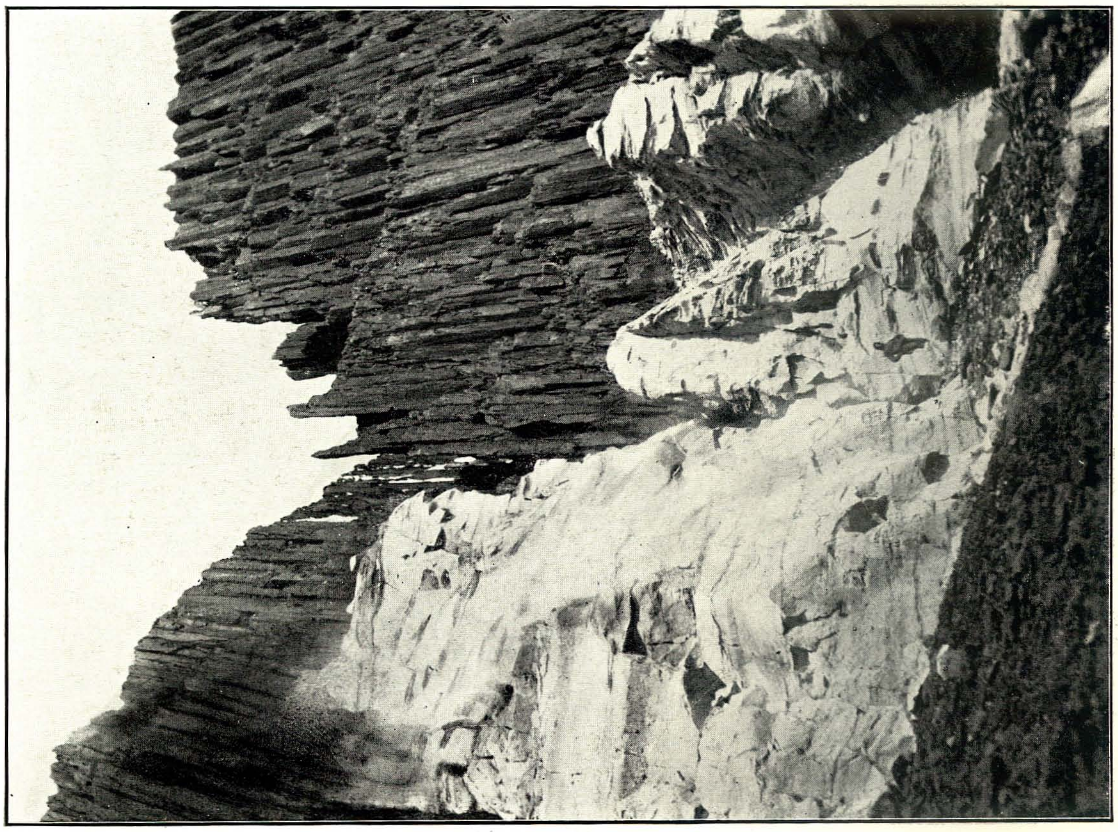
Fig. 2.



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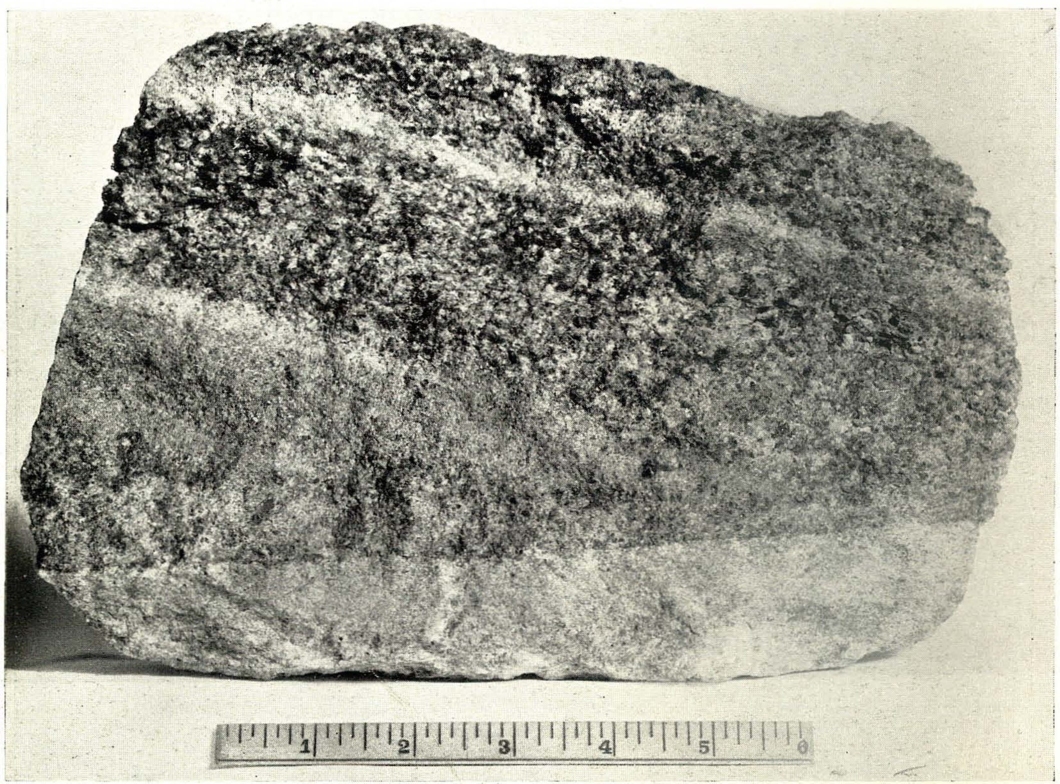

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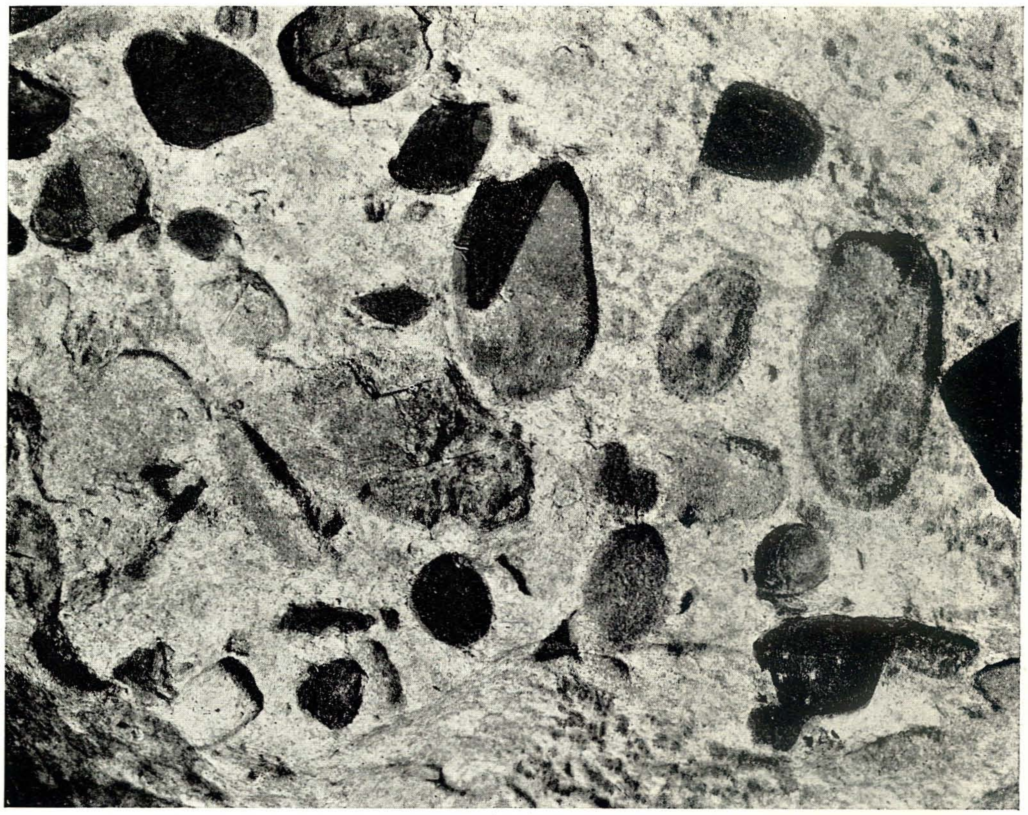

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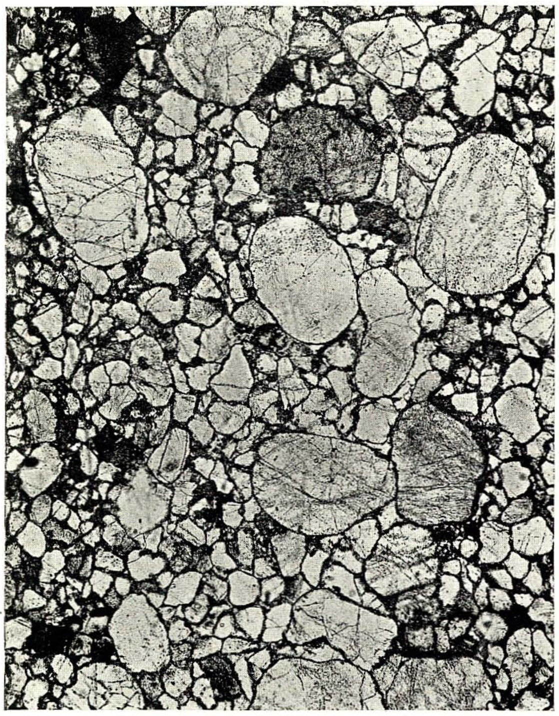

Fig. 1.

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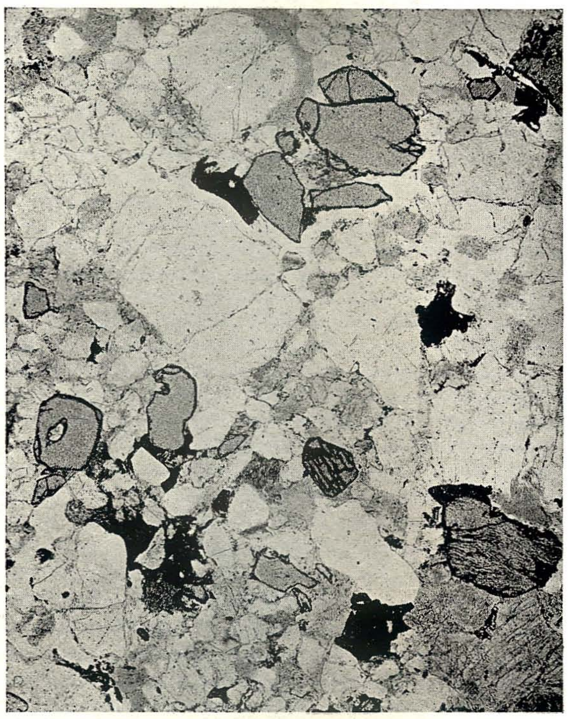

Fig. 4.

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