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THE SEDIMENTARY ROCKS OF SOUTH VICTORIA LAND.

No. 4a.—THE SANDSTONE, ETC., OF THE McMURDO SOUND, TERRA NOVA BAY, AND BEARDMORE GLACIER REGIONS.

BY

F. DEBENHAM, O.B.E., B.A. (Cantab.), B.Sc. (Sydney), F.G.S.
Fellow of Gonville and Caius College, Cambridge. Geologist on the Expedition.

No. 4b.—THE SLATE-GREYWACKE FORMATION OF ROBERTSON BAY.

BY

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AND
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WITH EIGHT FIGURES IN THE TEXT AND ONE PLATE.

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TABLE OF CONTENTS.

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INTRODUCTION. (R.E.P.)

In February 1911, the Northern Party of the Scott Antarctic Expedition of 1910–13 was landed at Cape Adare, Robertson Bay, to occupy its time surveying this region until it could be picked up and transferred to a more favourable area. During the year attempts were made to sledge northward along the coast towards Smith's Inlet and Cape North, but these were frustrated by unfavourable ice conditions.

As late as August breaks in the sea-ice north of the bay were taking place continually, the whole sheet being constantly on the move. The pools, leads, and "polynia" that were continually being opened up by the screwing of the "pack" and by the frequent gales of hurricane force were at once covered over with a tough skin of new ice which rendered sledging and boating alike impossible.

Under the circumstances, the attention of the sledge parties was necessarily confined to the relatively inaccessible shores of Robertson Bay. Several trips were made south and west from Cape Adare, but all were comparatively short as can be seen from the accompanying map (Fig. 8, p. 122). The observations made during this spring and early summer are therefore strictly local in their application. They are, however, of interest because they apply to a portion of South Victoria Land structurally different from the other regions to the south which have been examined in some detail by the British expeditions.

This difference probably also applies to the regions to the north, for the country north of Smith's Inlet, although presumably exposed to almost the same weathering and denuding agencies (though possibly exercised in rather different proportions owing to climatic variation), is of an entirely different type.

* In No. 4b, R. H. Rastall has described the specimens, and R. E. Priestley has supplied the notes on the field-geology.

Robertson Bay is bordered on its west, and older, side by the Admiralty Range of mountains comparatively little dissected and with the spurs of their foothills dipping steeply to the sea. This range differs markedly in its broader external characters from

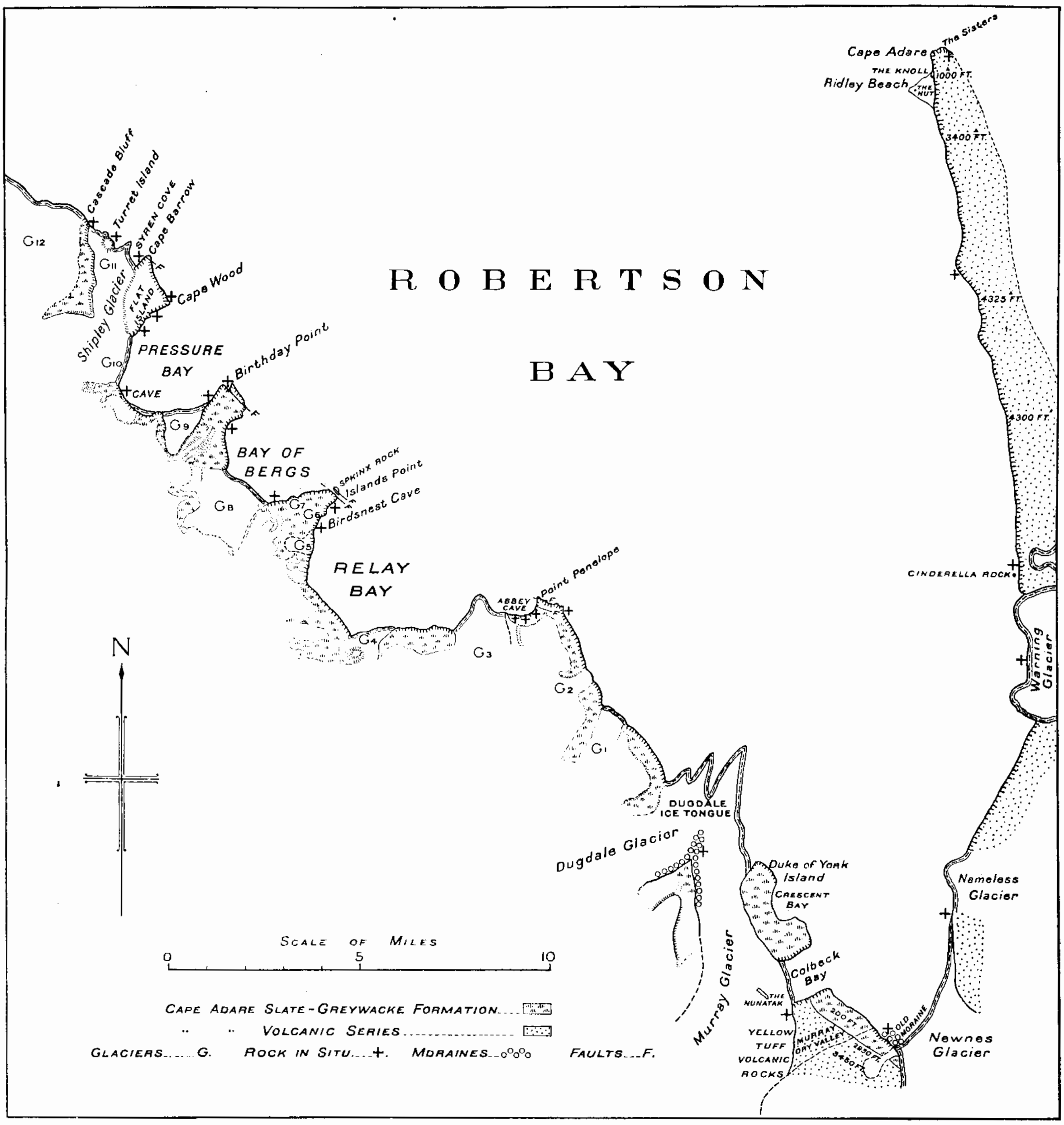

FIG. 8. Map of Robertson Bay region.

the portions of the Antarctic horst both to the south and to the north. Its only near analogue can be seen in the Royal Society Range which has Mounts Lister and Huggins of about the same order of height as Mounts Minto and Adam in the Admiralty Range. To the south a much lower phase is seen in the tabular mountains whose most northern representatives visible from the coast are Mounts Larsen and Nansen and which owe their characteristic shape to the fact that they are capped by the horizontally-bedded Beacon Sandstone.

To the north of Smith's Inlet again, the mountains are also much lower and they are bordered on their seaward side by a broad plateau, one or two thousand feet above sea-level, which is strongly suggestive of a fault parallel to the main coastal fault bordering the sunken area of the Ross Sea. A long strip several miles broad seems to have been dropped some thousands of feet in relation to the main horst behind.

It was unfortunate that heavy pack-ice prevented a nearer approach in this latitude, for the country, in addition to its greater interest tectonically and probably petrologically, appeared much more accessible to sledging parties than that immediately round Cape Adare.

The question arises, in view of the main features of the geology of the Cape Adare region which are touched upon in the following pages, whether the foothill region, at any rate, of the Admiralty Range belongs essentially to the same tectonic unit as those regions farther to the south which have been examined. In the Beardmore Glacier, the Koettlitz-Ferrar area, the Granite Harbour region, and the Terra Nova Bay district, the essential formations are practically the same, though differing somewhat in facies as might be expected. The resemblance is very striking leaving no doubt of the tectonic unity of the whole coastline from 85° S. to 74° S. In Adelie Land, again, the Mawson Expedition has proved the existence of the Beacon Sandstone formation, the dolerite sills, the granite intrusions, and the Archaean basal complex.

In the Robertson Bay area, however, the most striking of these formations—the first and last mentioned above—are conspicuous by their absence except for one or two possible examples in the high-level moraines which belong to a period of far greater glaciation than the present.

The scanty evidence for and against the hypothesis that the whole of this somewhat important region consists of a great boss flanking the old Continental Shield of East Antarctica will perhaps be better seen after a short description has been given of the formations actually present. It is the only geological problem of any great interest which awaits solution in this particular area. Other observations, and particularly those pertaining to the later tectonic history of the area, are simply confirmatory of much that is now known with fair certainty from the other areas mentioned.

Whatever may be the truth about the early history of the district, it is certain that in Tertiary and Recent times it has behaved as a portion of the main South Victoria Land complex. For instance, it has taken part with the latter in the block-faulting with accompanying volcanic activity which produced amongst other marked features the South Victoria Land horst and the sunken area known to geographers as the Ross Sea.

GENERAL DESCRIPTION OF THE SLATE-GREYWACKE FORMATION.

The oldest rocks met with in this area—apart from certain erratic blocks—are a series of sediments ranging from fine-grained slates, through more or less massive mudstones and flagstones, to a type of rock best described as a rather coarse greywacke.* They show everywhere a prevailing greyish-green or green colour, and are of very compact texture, the finer varieties being very strongly cleaved and much slickensided, often with a silky lustre, but never sufficiently crystalline to be called phyllites. The main cleavage lines run in a north and south direction, more or less parallel to the coast (Plate 1, Fig. 1). As seen in the field, the bedding is much obscured by the cleavage, but in places it is clear that the whole series is thrown into anticlines and synclines, the axes of which appear to run in a general N.E.-S.W. or N.-S. direction. In Plate 1, Figs. 2, 3, and 4, the bedding is clearly seen and the folding is also conspicuous. This folding was in all probability produced by pressure from an easterly direction, crumpling and compressing the rocks against the more rigid continental mass to the west. It is also more pronounced towards the south of the area, the anticlines and synclines further north being much shallower than those of Duke of York Island. The folds can be best seen on the north face of this island, but unfortunately no good photograph was here obtained.

The formation was examined along the coast at intervals from the rocky bluff between the George Newnes Glacier and the Murray Glacier northwards to Turret Island beyond the entrance to Robertson Bay. Exposures of rock were numerous, but at only two places was it possible to ascend the cliffs without special climbing equipment. These places were Duke of York Island, and the most southerly bluff of all where the basalt of the Cape Adare volcanic series cuts across the sediments in a dead straight line, with features suggesting a fissure eruption on a small scale. Unfortunately at both these places the rock-exposures were limited to isolated bluffs cut off from the hinterland, in the former case by a glacier, and in the latter by a field of highland ice of considerable extent.

Specimens of rock *in situ* were collected at a considerable number of points, as indicated by crosses on the map (Fig. 8). The most important localities were as follows:—Duke of York Island, Penelope Point, Relay Bay, Islands Point, north side of Birthday Point, Pressure Bay, Cape Barrow, and Turret Island. On examination of specimens and slices it was found that the whole series showed a remarkable degree of uniformity, though in a general way they can be referred to three types:—coarse greywackes, fine greywackes, and well-cleaved slates.

* Specimens of some of these rocks, mostly from Duke of York Island, were collected by the "Southern Cross" Antarctic Expedition and have been briefly described by G. T. Prior [Report on the Collections of Natural History made in the Antarctic Regions during the Voyage of the "Southern Cross." London, 1902, p. 325].

PETROGRAPHY OF THE ROCKS. (R.H.R.)

Microscopic examination of thin-sections shows that in the great majority of the specimens the grains rarely exceed 1 mm. in diameter, and most are finer than this. As a rule the grains in any one layer are very uniform in size, although in the same section there is often considerable variation in this respect from one layer to another. The most striking general characteristic of the rocks as a whole is the extreme angularity of the constituent grains: the significance of this feature is discussed later. The textures of the coarser types are about what in a less consolidated rock would be called a sandstone and none of the specimens found *in situ* are sufficiently coarse to be described as conglomerates.

In all the specimens examined of whatever grade the commonest clastic mineral is quartz. This is obviously derived from two distinct sources; from vein-quartz and from quartzites. In some instances the vein-quartz contains vermicular chlorite.* The quartzite-quartz in some instances is derived from rocks of exceedingly fine texture, and in many specimens small chips and grains of mudstone and slate are common. In the coarser types (greywackes) a small proportion of felspar is almost invariably present, including both orthoclase and plagioclase with a small extinction angle. White mica is very abundant in flakes of all sizes: in the greywackes the larger flakes are certainly original and clastic, but the finer-grained rocks contain a good deal of obviously secondary sericitic mica along cleavage planes. Very rarely flakes of almost fresh biotite are seen, and in some specimens large flakes of chlorite most probably represent detrital biotite. Thus quartz, felspars, and micas, with rock-chips, are the main constituents of the coarser rocks, and it may be inferred that the same applies to the finer types. In none of the numerous thin-sections examined was discovered any of the usual "heavy minerals" or a single mineral grain which could be definitely attributed to rocks that have undergone a high grade of metamorphism, either thermal or dynamic. The rocks are not adapted to examination by crushing methods, owing to their hardness and high degree of cementation.

It is noticeable that in the majority of specimens of the coarser types the edges of the larger grains are not quite sharp: each grain is as a rule very slightly corroded at the edges, as if by reaction with the constituents of the ground-mass, thus indicating a very low grade of metamorphism. This effect is extremely common in the coarser arenaceous sediments in general when somewhat crushed and sheared.

The principal mineral constituents of the finer matrix of the rocks, the cementing

* Prior (*loc. cit.*) noted the development of vermicular chlorite near the contact of contorted quartz veins with the equally contorted slates.

material, are, so far as can be determined, quartz, mica, chlorite, and carbonates. It is to the chlorite in the cement that the prevailing green colour is due. Of these constituents the most interesting are the carbonates, which in very many specimens are more or less aggregated into spots, and often markedly so. In some specimens the carbonate is mainly calcite, but it is usually chalybite, with probably some dolomite or ankerite. This abundance of iron carbonate is one of the most noteworthy characters of the rocks, when fresh. In more weathered specimens the chalybite is oxidized and hydrated and gives a still more strongly spotted appearance.

The finer-grained rocks are even more monotonous and uniform in character than the coarser-grained greywackes described above, the principal variations here being in the amount of cleavage. The less cleaved varieties may be described briefly as chloritic and rather calcareous mudstones, while the more cleaved slates usually show a large proportion of sericitic mica, which accounts for the appearance of sheared and slickensided surfaces. Some of the finer gritty rocks also show a certain amount of shearing, often confined to particular bands, and along these shear-bands mica is also developed.

A few specimens of slightly aberrant character from various localities are worthy of very brief mention. A rock of unusually light colour from Duke of York Island (713) is a quartzite of very irregular and uneven texture: in some shear planes the distinction between grains and matrix has disappeared and it is difficult to make out how much of the quartz is secondary. Another specimen from Islands Point (844) is best described as a felspathic sandstone with a calcareous cement. The carbonate here is calcite, not chalybite. Another specimen from Turret Island (815) is of almost similar character. Some specimens from Pressure Bay show a pronounced nodular structure, with concentric banding, at first sight very suggestive of fossils, but a careful examination by Mr. H. Woods yielded no definite evidence of organic structure. The rock (890–895) is a fine grit or mudstone and the banding consists of lines and specks of iron oxide, often with a rhombohedral outline and thus obviously derived from crystals of chalybite.

At several localities cubes of pyrites * are found in the slaty rocks in varying quantity, and the rocks are often stained brown by its oxidation products.

The whole of the slate-greywacke formation is permeated by lenticles, veins, and stringers of quartz, associated with chlorite, calcite, dolomite, chalybite, and pyrites (Plate 1, Fig. 5). Careful examination in the field and in the laboratory indicate that these veins are barren of mineral deposits of economic importance, only an occasional small crystal of blende or galena having been observed in them.

The weathered surfaces of these rocks often show a curious type of fretting probably due to wind-action (Plate 1, Fig. 6), and on this pitted surface the quartz veins stand out strongly.

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* The "Southern Cross" specimens (*loc. cit.* on p. 124) were mainly of this type since they were collected by C. E. Borchgrevink as ore-specimens on account of the iron-pyrites they contained.

PETROGRAPHY OF THE ERRATICS OF SEDIMENTARY ROCKS. (R.H.R.)

The greater part of the erratics seen on the Newnes and Murray Glaciers consisted of rocks of the slate-greywacke formation, most of them in all essential features identical with the types just described. There is, however, one rock from the Newnes Glacier of considerable interest, represented by several specimens, and worthy of a detailed description.

This rock is a conglomerate of remarkably even-grain and variegated appearance. Under the microscope the pebbles (mostly 3 mm., rarely over 4 mm. in diameter) are seen to consist of vein-quartz, quartzite of varying grades, mudstone and greenish slate, quartz-calcite rocks (not markedly schistose), fresh felspar especially plagioclase, and, most interesting of all, brown to red lavas of various kinds showing typically characteristic fine-grained trachytic and orthophyric structures. Most of these volcanic rocks are very fresh. Many of the fragments in the conglomerate are remarkably angular, though some of the larger ones are somewhat rounded. The fine cementing material is mainly of a muddy nature, but includes a good deal of calcite.

Two or three specimens from the Murray Glacier may also be mentioned briefly. One is a micaceous sandstone which contains flakes of fresh biotite and may perhaps be best described as an arkose since it has more felspar than usual. Another is a fine-grained, chloritic, gritty rock, with marked current-bedding clearly brought out by alternating green and cream-coloured or pale-brown bands. It is roughly cleaved at right angles to the bedding, producing a kind of flaggy structure.

A grey, silky-looking, and much crumpled rock shows very numerous pink and white oval spots of chalybite up to about 2 × 1 mm. This rock may perhaps be described as a spotted phyllite and suggests a somewhat higher degree of metamorphism than the other specimens. Removal of the carbonates by boiling with acid increased the general phyllitic and crystalline appearance of a small fragment. Another spotted rock when examined microscopically showed that the spots were rhombohedral crystals of carbonates, with zones apparently containing varying proportions of iron.

EXTENT OF THE SLATE-GREYWACKE FORMATION.

As before stated, specimens of the slate-greywacke formation *in situ* were only obtained at points along the coast of Robertson Bay, but a considerable inland extension of the same rock-types is indicated by the fact that the existing glaciers carry a large amount of débris from this formation, together with blocks of the younger volcanic series and of a granite which has broken through it and which may form the main mass of the mountains behind. Some high-level moraines on Cape Adare carry blocks of schist, a quartzite similar to that of the Beacon Sandstone, a typical dolerite, and a coarse porphyritic gneiss like that found *in situ* in the Terra Nova Bay region and as an erratic at Cape Irizar. This suggests that at the last glacial maximum the ice-streams brought material from beyond the limits of the slate-greywacke outcrop, which we may thus infer is bounded to the west by the basal Archaean complex overlain by the Beacon Sandstone with its dolerite sills. How far inland this boundary may be is unknown.

ORIGIN AND AGE OF THE FORMATION.

From the foregoing descriptions it is obvious that these rocks belong to a typically sedimentary series of very uniform character, the chief variation being in the degree of coarseness of the material, which in its turn has determined the susceptibility or otherwise to cleavage. The rocks are notably well-stratified, sometimes showing false-bedding, and the material is well graded. The general appearance of the rocks, with their prevailing grey and green colours, suggests a considerable age: in fact they present the characteristics usually associated with Palaeozoic or Algonkian sediments. Among British formations their nearest analogue is to be found in the Ingletonian series, to which indeed they show a strong resemblance. If the erratics of conglomerate are assumed to belong to the slate-greywacke formation, the resemblance is still stronger, as this is very like the coarser grit of Chapel-le-Dale, Yorkshire, known commercially as "Ingleton Granite."

Actual definite evidence of age however is scanty. The slate-greywacke rocks certainly look older than the Beacon Sandstone and its underlying shales with Devonian fossils. Hence it would appear to follow that the slate-greywacke series is at least as old as Lower Palaeozoic. The actual mineral composition of the rocks does not afford much help in this direction. It is pretty safe to say that they have not been formed directly from a series of crystalline schists, since the larger included rock-fragments, when identifiable, are mainly quartzites of a low grade of recrystallization and sericitic clay-slates without recognizable metamorphic minerals. In fact they seem to be made up of the débris of another rock-series very like themselves, with a small addition of igneous material possibly volcanic.

The most characteristic secondary minerals are chlorite, carbonates (especially chalybite), and pyrites, which indicate only a mild degree of metamorphism.

As to the origin of these sedimentary deposits, it is clear that, however they were formed, there was little or no rolling action. The extreme angularity of the grains suggests frost-shattering, and the freshness of the felspars is also another important point indicating a minimum of chemical weathering. However, the even-grading of the sediment and the regularity of the bedding are against actual deposition by ice, and this leaves wind only as a possible agent of deposition.

Such extremely angular fragments and clear unweathered felspars as occur in the coarser bands in these sediments can be exactly paralleled in the residual frost and thaw deposits of Cape Adare and Ross Island. The size of the fragments in these localities is equally uniform, though generally greater. This is due to the sifting action of the present-day gales and blizzards which blow all material below a certain size into the sea. The finer texture of these ancient sediments indicates that at the time of their formation the winds of this region were less violent than they are now. The common occurrence of false-bedding presents no difficulty, since it is prevalent in dune-deposits, and is also commonly observed in silt-deposits forming in modern glacier-streams.

These old sediments, therefore, suggest the shoreward phase corresponding to the deposition of sand, silt, and mud in the adjacent seas of the period, and they are also indicative of a climate certainly of dry type and probably cold, approximating somewhat closely to the conditions at present prevailing in the Polar regions.

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PLATE 1.

FIG. 1.—Cleavage-planes in slate-greywacke formation. Turret Island. (p. 124).
FIG. 2.—Syncline in slate-greywacke formation. Coast N. of Robertson Bay. (p. 124).
FIG. 3.—Bedding and fault-planes in slate-greywacke formation. Relay Bay. (p. 124).
FIG. 4.—Cave in slate-greywacke formation. Relay Bay. (p. 124).
FIG. 5.—Quartz veins standing out in weathered greywacke. (p. 125).
FIG. 6.—Fretting of rock produced by wind-weathering. (p. 126).


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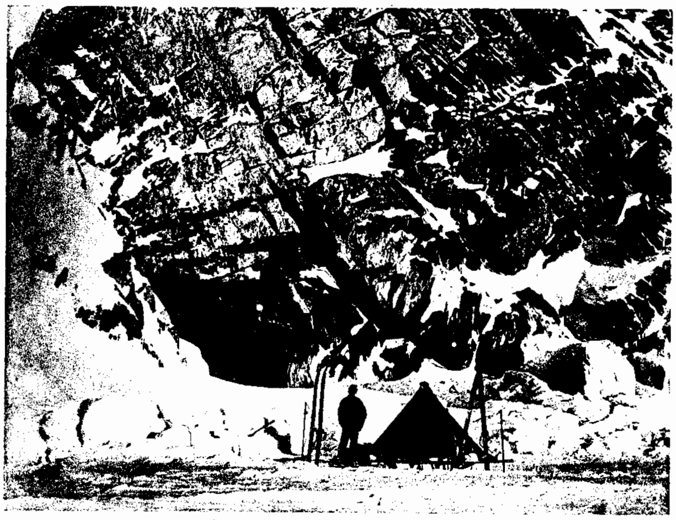
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