Some results of the British Antarctic Expedition 1907—1909.

By

R. N. Rudmose Brown, D. Sc.

The ultimate verdict on the work of any exploring expedition must rest not on its more striking. and may be sensational results, entailing no doubt an adventurous story, but on the amount of real scientific work accomplished. Judged on this basis the recent Antarctic expedition of Sir E. H. Shackleton has been most successful. It would be premature to discuss details before the completed publication of the scientific reports, but some general indications are possible.

The long southern journey to 88° 23′ S. had some striking geographical results. It proved that the lofty mountains fringing the edge of the Victoria Land plateau, which Captain Scott had traced to nearly 83° S., extend with a south-easterly trend to about 86° S., thus passing to the Pacific side of the Pole. On their further extension we can only speculate. All along this range occur heights of from 8000 to over 12,000 feet, and at intervals great glaciers descend to the east from the polar ice-cap. Up the largest of these — the Beardmore Glacier — the southern party ascended from the surface of the Ross Barrier to the level of the great plateau. Throughout the whole length of Victoria Land from north to south these mountains show a marked uniformity in structure indicating that the northern and southern plateaus are identical. The altitude varies from 7000 to over 10,000 feet and rises towards the south and southwest. Shackleton has proved beyond doubt that the Pole is on this plateau at a probable elevation of nearly 12,000 feet. The attainment of the Pole along this same route cannot be expected to divulge any great geographical discovery: in fact science would have gained but little had Shackleton succeeded in accomplishing the 90 miles further to his goal. The plateau formation was also obvious in the 45 miles of new coast-line added to the west of Cape North, though no close examination was possible there. This plateau must obviously extend far beyond the Pole towards Coats Land, Enderby Land and Wilhelm Land. It is not impossible that the heights seen by certain of the members of the Scotia expedition far in the interior of Coats Land are on the edge of the plateau. The proof of the great area of this plateau finally dispells a doubt, if indeed any still remained, of the continentality of Antarctic lands.

The flanking range of mountains of the plateau seems to be of the nature of a horst which is breached in places by great glaciers, but which otherwise dams back the ice-cap of the interior.

Some interesting problems in the structure of Victoria Land are raised. Along the whole coast-line from Cape North to 85° S. sedimentary rocks in almost horizontal beds cap the ranges, and since Palaeozoic times at least there has been no folding. A great meridional fault or series of faults is responsible for this abrupt ending to the plateau: the Ross Sea area is a region of down-throw. The absence of a shoaling sea-bottom at the west and the existence of deep water to near in-shore confirm this contention. From Cape Adare southward to the Ross Island group and Mounts Discovery and Morning a series of volcanoes occurs along the edge of the plateau. These occur on faults parallel or sub-parallel to the coast-line but transverse lines of weakness crossing the main faults seem in many cases to determine their location. From Mount Morning to 86° S. no evidence of volcanic activity was discovered.

Of the volcanic rocks of Victoria Land, which are all of comparatively recent date, the basalts, including those of the Ross Sea islands are proved to be of the Atlantic type: the kenytes exactly resemble these of Mount Kenia, and the dolorites found by the Discovery in the Balleny Islands resemble these of Cape Adare and the Ross Archipelago, which are closely related to those of Tasmania and South Africa. In short, all the volcanic rocks of Victoria Land seem to be of the kind associated with the Atlantic type of coast. The same applies to the volcanic rocks of the Auckland Islands, and Prior has pointed out the relationships of the Victoria Land volcanic rocks with those from Dunedin, that is from that southern part of New Zealand which shows the Atlantic structure. The only exception in this region seems to be the Macquarie Islands whose volcanic rocks are said to be older and show little relation to those of Victoria Land.

On these grounds Professor David and Mr. Priestley agree with Philippi that the coast-line of Victoria Land is of the Atlantic type, and not the Pacific type to which Reiter long ago referred it. Now the general structural features of Victoria Land strongly suggest that modification of the Pacific type of coast-line which has been termed the secondary Pacific, as developed on the western side of the Pacific Ocean. The true Pacific type seems to find its southern limit in New Zealand against the plateau of Otago. Professor Gregory maintains (Geogr. Journal XXXIV, p. 674) that if the coast of Victoria Land is of the Atlantic type so also are the eastern coasts of Australia and Asia and the distinction between the two coast types breaks down. In Graham Land the true Pacific type certainly borders the Pacific Ocean.

Messrs. David and Priestley hold that the fold lines of the Andes, if continuous from Graham Land across Antarctica to New Zealand, pass to the east of the Ross Sea and probably east of Edward Land. In this way the Pacific type of coast-line would be continuous practically round the entire Pacific Ocean. On the other hand there is much to be said for the idea that the Andean folds somewhere to the south-west of Charcot Land are lost by faulting, since if the Andean zone of disturbance were to reach the hard

Archaean and Palaeozoic shield of Antarctica it would more likely traverse it as a series of faults than as a line of folds. The termination of the Pacific fold lines in southern New Zealand would tend to support this theory by suggesting that the Pacific folds are not continuous from New Zealand to the Antarctic coasts of the Pacific Ocean. The problem has been made more complex by the discoveries of the Shackleton expedition, and a final solution cannot be expected until we know the structure of Edward Land and more about the bathymetry of the seas south of Australia and New Zealand. In any case the former connection of Antarctica and Australia is definitely established by the Discovery and Nimrod expeditions.

The discovery of the south-eastern trend of the coast of the plateau in 86° S. has done something towards defining the extent of the Ross Sea. It is to be hoped that Capt. Amundsen on his present expedition will be able to define the eastern boundary from Edward Land southward. That is a piece of work of the greatest importance. Important in relation to this is Shackleton's statement that from the edge of the Barrier there appeared to be "high snow-covered land on the 163rd meridian" where slopes and peaks, entirely snow-covered and rising to a height of 800 feet, were seen. But he was unable to take soundings or to land, and so could arrive at no definite conclusion.

In a discussion of the tidal observations of the expedition, Sir George Darwin, basing his belief on the period of the sea-seiche, holds that the Ross Sea must extend "past the South Pole and a little to the east of it as far as latitude 80°." In all probability the Weddell Sea extends at least to 75° or 76°: Mossman believes that it reaches to 77° or 78° (Scottish Geogr. Mag., vol. XXVI, p. 417) which would give a very narrow neck of land between the two seas. That may be unlikely, though not impossible from what we know of the structure of Antarctica. However the length of the bay necessary to account for the seiche is by no means certain: it is quite possible that the thick ice of the Barrier would serve to damp out oscillations of sea-level, a suggestion which Sir George Darwin makes but to which he does not give his adherence. At any rate none of the many discoveries of Shackleton's expedition give evidence of a strait across Antarctica, such as Penck has suggested, or even hint at such a feature. Darwin admits that with such a strait the seiche at Cape Royds would be much the same as with a deep bay. "Such a conclusion is interesting", he continues, "but it would not be right to attribute to it a high degree of probability, because there are elements of uncertainty on every side". In fact all decisive evidence that we have points to the non-existence of such a strait.

The geological observations amplify and supplement those of Mr. Ferrar and Dr. Koettlitz of the Discovery. Further evidence was obtained bearing on the nature and age of the volcanic rocks from Minna Bluff to Mount Melbourne which proves them to be relatively young. The succession of lavas seems to have been trachyte, kenyte, and olivine basalts latest: all these eruptions antedate the epoch of greatest recent glaciation.

The Beacon sandstone formation has been proved to extend from at least as far north as Mount Nansen, in about 75°, to 85° and to attain in

places a thickness of fully 2000 feet. The first determinable fossil known from Victoria Land was found in a piece of this sandstone picked from a moraine in 85° S. On examination it proved to be a fossil of coniferous wood which would admit of the Beacon sandstone being Upper Devonian. In 85° S. on the sides of the Beardmore Glacier valley coal was found in this sandstone. There were seven seams alternating with bands of black shale. This points to a warmer climate in Antarctica in Palaeozoic times. The researches of Nordenskjold in Graham Land had already proved this for Jurassic times by the discovery of ferns, cycads, and conifers at Hope Bay. The discovery of water-worn quartz pebbles in the lower beds of the Beacon sandstone point to the same conclusion. Limestone was discovered in 85° 15′ S. in horizontal beds several hundred feet thick but so highly metamorphosed that it could not be expected to yield fossils. Messrs. David and Priestley suggest that it is derived from the Beacon sandstone, but its relation to that formation could not be determined with certainty. Small casts resembling radiolarians occur in it, while it is possible that the erratics of radiolarian chert found at Cape Royds may belong to this limestone series, which Professor David dates as Lower Cambrian.

Several raised beaches were found at heights varying from 20 or 30 to 180 feet above sea-level. Professor David and Mr. Priestley suggest that during the period of maximum glaciation there was a subsidence of the crust due to the superincumbent weight, and that, with the diminution of glaciation there was a gradual re-emergence. This would supply an explanation of the raised beaches.

The expedition has thrown further light on the vexed question of the Ross Ice Barrier. Captain Scott had already proved that its seaward end is afloat, that it is composed largely of snow, and that its surface towards the south shows no perceptible rise. The geologists of the Nimrod again insist on the snow structure of the Barrier and on the absence of glacier ice in the bergs that break away from it. The land-ice which pours off the Antarctic plateau by the Beardmore and other great glaciers seems to be depressed beneath a layer of snow as it advances northward in the Ross Sea. The average snowfall is estimated at not more than one foot a year and the average rate of movement was found to be $^1/_8$ mile a year. Now the Barrier certainly has an extent of 300 miles southwards from its face, and in all probability more. The snowfall on any point 300 miles from the face would take 900 years to reach the edge, and during this time 900 feet of snow would accumulate: an amount quite sufficient to depress the glacier ice below sea-level. But the question remains: Is the water of the Ross Sea warm enough to melt this underlying land-ice? If not, there must be a great shovel of glacier ice piled up with snow, and it does not appear that there is any evidence of this. The land-ice at the back must certainly be the propelling force which moves the Barrier northward, and the pressure ridges and cracks along its edge show undoubtedly that it is afloat, probably for not less than 400 miles from its edge, but we would like to see the level nature of the Barrier surface, which Scott and Shackleton claim, more clearly demonstrated by accurate levellings.

From an examination of the structure of the bergs, the depths of water around stranded bergs, and the proportion of bergs immersed, the members of

the expedition conclude that the bergs are principally of snow and not of solid ice. That is no doubt quite true as regards the bergs derived from the Ross Barrier, the probable source of all the large bergs in the Ross Sea; but we cannot agree with Professor David when he extends this opinion to the icebergs of the Antarctic in general. Captain Scott commented on the smallness of Ross Sea bergs compared to the prevalent idea of the dimensions of Antarctic bergs, and he also noted their snow structure. However in the Ross Sea area the ice-cap nowhere descends to the sea, except by glaciers pouring through valleys in the fringing range of the plateau. On the other hand in the Weddell Sea, where the largest bergs occur, the ice-cap seems to meet the sea in long ice-cliffs. Along Coats Land this cliff extends for 150 miles at least. On that side of Antarctica the typical Antarctic berg certainly occurs. Bergs of a mile in length are frequently seen, and those of three or four are not uncommon, while exceptional ones of 12, 20, or 30 miles have more than once been measured; nor does there seem any reason to doubt that they are composed of solid ice and not snow. However it should be noted that some true icebergs are said to occur in the Ross Sea.

The Nordenskjold Ice Barrier tongue, the Drygalski Ice Barrier tongue and the Ross Island Glacier tongue were carefully examined and the conclusion was arrived at that they were afloat. If this is the case it is difficult to believe that such narrow peninsulas of ice could show any persistency when one considers the slow rate at which they are fed from the ice-cap: yet they have certainly maintained their position for six years at least. The Nordenskjold Ice tongue is said by Professor David not to communicate with the ice-cap at its inland end, but from the charts of the expedition it certainly appears to be the seaward continuation of Mawson Glacier. The Drygalski tongue is fed by a number of large glaciers. The depths of water alongside these tongues and the height of ice they show above sea-level certainly suggest that they are afloat, yet there seems to be some indication of tide cracks in places. It would be difficult to prove that they are not aground on reefs or islets which, despite the nature of the Ross Sea depression and the depths of its waters, might rise to or near to the surface. A careful bathymetrical survey of the Ross Sea would throw more light on this question.

The recent diminution in glaciation, which seems general in all parts of Antarctica, was commented on by the expedition everywhere in Victoria Land. McMurdo Sound was at one time filled with a branch of the Ross Barrier whose general surface was 1000 feet above sea-level in contrast to about 150 feet now. Messrs. David and Priestley suggest that the coastal shelf found by the Discovery, which extends 150 miles northward of the latitude of Cape Royds, may be due to the overriding of the foothills of the coastal range and a ploughing of them out by a former extension of the Barrier. On the other hand it is quite possible to ascribe this shelf to step faulting. On this coastal shelf from Mount Discovery to the Drygalski Ice Barrier tongue extends a great piedmont glacier which appears to be on the wane. This may be a relic of the former extension of the Barrier or, as Professor David and Mr. Priestley suggest, it may result from the coalescing of a number of small névé-fields developed in the cirques among the foothills of the ranges.

Much cartographical work has resulted from the expedition. In addition to the survey of the plateau edge from Captain Scott's "furthest" to 86° S., the coast-line from Mount Erebus and Ferrar Glacier to Mount Melbourne was triangulated by Dr. Mawson, and some new features added to Captain Scott's map. A careful survey was made of the land round Ferrar Glacier, and 45 miles of new coast-line west of Cape North were charted. A detailed exploration of Mount Erebus was made and its volcanic phenomena examined. A successful ascent of the mountain proved its height to be 13 370 feet.

The South Magnetic Pole was reached in 72° 25′ S., 155° 16′ E. and was found to have moved in a northerly and westerly direction since the Discovery values were determined. Numerous observations were made on the Aurora Australis, a phenomenon that is comparatively common on the Australian side of Antarctica, but which is practically never seen on the American and Atlantic sides.

The meteorological observations, especially these relating to high air currents, promise to be of great importance. Readings of the instruments were taken every two hours at Cape Royds and hourly on the journey from New Zealand to the Antarctic. A comparison of the temperature records with those of other recent expeditions shows the uniform nature of all Antarctic regions in summer independent of latitude: it is only in winter that latitude has much significance. On the southern journey extremely low summer temperatures were experienced, but it must be remembered that south of the Beardmore Glacier the temperatures were taken at altitudes varying from 7000 to 10,000 feet. Strong southerly and south-easterly winds were continuously experienced, on the plateau, with much drifting snow, but no fresh falls were observed on this part of the journey. In fact the snowfall, nowhere great in Antarctica, seems to be strikingly small in Victoria Land, an equivalent of about 7 to 9 inches of rain. This scanty precipitation in Antarctica, first noted by the Belgica, raises difficult problems with regard to the thickness of the ice-cap and the former extension of glaciation. The crevases on the plateau ridges suggest to Sir E. H. Shackleton that the land does not lie very far beneath the ice-sheet, and furthermore Professer David and Mr. Priestley believe that the whole surface is being reduced in level through the snow being drifted off by the wind or removed by the slow process of ablation. In whatever way it occured there seems to be no escape from the conclusion that the former snowfall in Antarctica was greater than it is to-day.

The prevailing winds on the plateau as judged from the trend of the sastrugi seem to be south-south-east. These strong southerly winds, even in 88° S., are not incompatible with an Antarctic high-pressure area, but indicate that it contracts considerably in summer and certainly is not centered on the geographical Pole. Nor was this to be expected considering the disposition of Antarctica with regard to the Pole. An interesting point is the rapid rise in temperature associated with the southerly blizzards: at Cape Royds changes of from -30° F ($-34{,}5^{\circ}$ C) to $+45^{\circ}$ F ($7{,}2^{\circ}$ C) were recorded within 24 hours on such occasions.

The smoke cloud over Mount Erebus at an elevation of over 13,000 feet served as an excellent wind-vane and demonstrated the direction of the air

currents and admitted of an estimate of their height. When these observations are published they will prove of great value. Mr. Murray notes the unreliability of spirit thermometers in polar regions and their erratic and unaccountable inaccuracies which whatever may be the cause make them very difficult and unsatisfactory to work with.

The biological results promise to be of great interest, but some time must necessarily elapse before a discussion of the invertebrate collections is possible. The only pity is that the Nimrod did not manage to dredge in the deep waters of the Ross Sea. Except for the collections of the Belgica and the Scotia we have a dearth of deep water Antarctic records: some from the Ross Sea and the adjacent Southern Ocean are much required.

Mr. James Murray touched almost a new field in Antarctic research in his investigations into freshwater life. His collection of Rotifers yield the first recognizable ones from Antarctic regions. Of the 16 species at least 5 were new and all were from fresh water. A prevalent red colour, supposed by Murray to be related to the nature of the food, may sometimes account for "red snow". The most striking results are however on the vitality of these rotifers. For the greater part of the year they are frozen into ice, and revive when the ice is thawed. When dried and exposed to the lowest air temperatures [about -16^0 F ($-26{,}7^0$ C)] for a long time they were not killed, and even when thawed and refrozen at weekly intervals for several months did not die. Some lived a month in sea-water. Some were dried in the Antarctic and revived a year later in London. A number survived $-108{,}4^0$ F (-78^0 C) for many hours, and a percentage of these lived after the bottle containing them in a dry state had been immersed in boiling water for a short time.

Mention must be made of Mr. Murray's invaluable researches on the Tardigrada, resulting in a monograph of all species collected by the expedition not only in the Antarctic but in all extra-polar lands visited.