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# The Geographical Journal.

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## RESULTS OF THE NATIONAL ANTARCTIC EXPEDITION.—

### I. GEOGRAPHICAL.\*

By Captain ROBERT F. SCOTT, C.V.O., R.N.

IN the following paper I propose to confine myself mainly to the purely geographical results of the Antarctic Expedition, in considering the distribution of land, water, and ice within the area allotted to us for exploration. I do so because a true estimate of these conditions will be arrived at, not so much by a close study of records as by a free discussion of observations and ideas, which, crude as they may be, can be advanced at once without prejudice. I avoid referring otherwise than in the most general terms to the results of the other scientific work carried out by our specialist investigators, partly because I realize my inability to cope with such a task in a satisfactory manner, partly because the main outline of much of the work has already been given by the officers concerned, but mainly because the time at my disposal is inadequate to do more than consider the subject which I have chosen. I believe that the matter which I propose to set before you is of general interest, and had I attempted further digressions, not only must it have been robbed of its interest, but too large a field would have been opened to the discussion which I hope may follow. I must assume, in all that I have to say, that the published reports of the history of the expedition are known.

#### *Pack Ice.*

The ice-conditions in the Ross sea have been observed in the course of five different summers. Although differences in date make it impossible to closely compare those seasons, one is led to believe that four

\* Read at the Royal Geographical Society, February 27, 1905. The provisional map in vol. 24, p. 248, may be referred to; a finished map is in preparation, and it is hoped will be published in the *Journal* before the end of the year.

were very similar and constitute the normal condition, whilst one, the summer of 1902-3, was exceptional. The normal condition seems to be that the sea becomes completely frozen over in the winter, the movement of the ice-sheet leaving narrow spaces of open water only at its edge in such places as the northern face of the Great Barrier, and possibly in occasional rents, which are speedily refrozen. The emperor penguin undoubtedly takes advantage of the continual strip of open water that fringes the barrier.

The gales at Cape Crozier grow excessively violent towards the end of September and in October, and by this time the sun has taken some effect on the ice-sheet. The general break-up which results has been witnessed on two occasions by our sledge parties; on one day they saw the sea completely covered with ice, and on the next looked forth on a clear sheet of open water. The ice thus freed drifts to the north, and forms that belt of pack through which ships must pass to reach the sea in the early summer. Drifting under the influence of wind, loose pieces of ice will always travel faster than the main pack, and consequently the southern edge of the band will generally be a hard and fast line, where loose pieces are crowding on the main pack, and the northern edge will be free, where loose pieces are tending to detach themselves from it.

Towards the end of December and the early part of January this belt extends from the Antarctic circle for about 200 miles to the south, and, as Captain Colbeck has said, is probably best attacked on the meridian of  $178^{\circ}$  to  $180^{\circ}$  E. To the westward of this the pack would be augmented by the coastal ice of Victoria Land, and to the eastward by conditions which are not well known, but on which the discovery of Scott island and the difficulties experienced by Ross seem to throw some light.

The ice probably leaves the Ross sea in large fields, and is broken by the ocean swell, which penetrates the pack for a very great distance; and this accounts for the fact that the floes increase in size as one approaches the southern edge, nowhere exceeding 1 or 2 miles in length. In this connection it is interesting to note the large fields, 4 or 5 miles across, which Captain Colbeck saw north of the Balleny islands in 1900.

The character of the ice frequently changes, giving the impression that a quantity of ice of a previous season is caught when the sea freezes over; but none of the ice met with is formidable—all is more or less rotten and decayed.

The exceptional ice-conditions of the summer of 1902-3 seem to have arisen from causes commencing at a very early date in the winter of 1902. What must be considered an abnormal succession of southerly gales again and again broke up the ice in McMurdo sound, and even late in the winter there was open water within a few miles of the *Discovery*. The continual formation of fresh sheets of ice must have tended to congestion, which the exceptionally fine-weather conditions of December and January failed to relieve, so that the greater part



CAPTAIN ROBERT FALCON SCOTT, C.V.O., R.N.,  
COMMANDER OF THE NATIONAL ANTARCTIC EXPEDITION.

of the Ross sea remained filled with ice, and not only had the *Morning* great difficulty in getting to the south, but the sea was never sufficiently open to admit of the swell, on which we depended to break up the fast ice in McMurdo sound and free the *Discovery*.

In connection with the latter fact, it is of interest to note that, though the main pack drifts to the north early, there is an eddy in McMurdo sound in which a mass of ice is detained throughout December and January. At the end of January in 1902 and 1904 this mass was suddenly carried to the north, but it did not disappear until nearly a month later in 1903. When this occurred there was a noticeable change in the drift of the surface waters through the strait.

Continuing to drift northward, the main pack is dissipated by the beginning of February, and during this month a ship, by coming directly south on the 178th meridian, could reach the Great Barrier without encountering any pack ice. The sea-ice met with on the coast of Victoria Land is of a quite different character from that found in the main pack. It is very hard, very solid, comparatively free from snow, and, except where dust and grit have settled on the surface, very little decayed. Its uniform smoothness shows that there is very little pressure. In the bays and inlets we noticed that the floes had a great regularity of outline, and especially in Granite harbour we found that the ice-sheet had broken into almost perfect rectangular rectilinear figures. In all the coast ice there were large quantities of diatoms, which gave a yellowish-brown appearance to the underside of the floes. The pack ice met with in the vicinity of King Edward's Land was very heavy, but differed in character. Some floes were much hummocked, and were evidently more than one season old, whilst others were of comparatively recent growth. It appears probable that a large quantity of pack is detained amongst the numerous grounded bergs and ice islands in this region, where also the snowfall seems heavier than to the west.

The region south of the Balleny islands will probably always be found heavily packed. Our course from Robertson bay to the north, and then to the west past Sturge island, practically gives the eastern limits of this pack at the end of February, 1904, although Ross found, at the same season in 1841, that it did not lay beyond the 168th meridian.

### *Icebergs.*

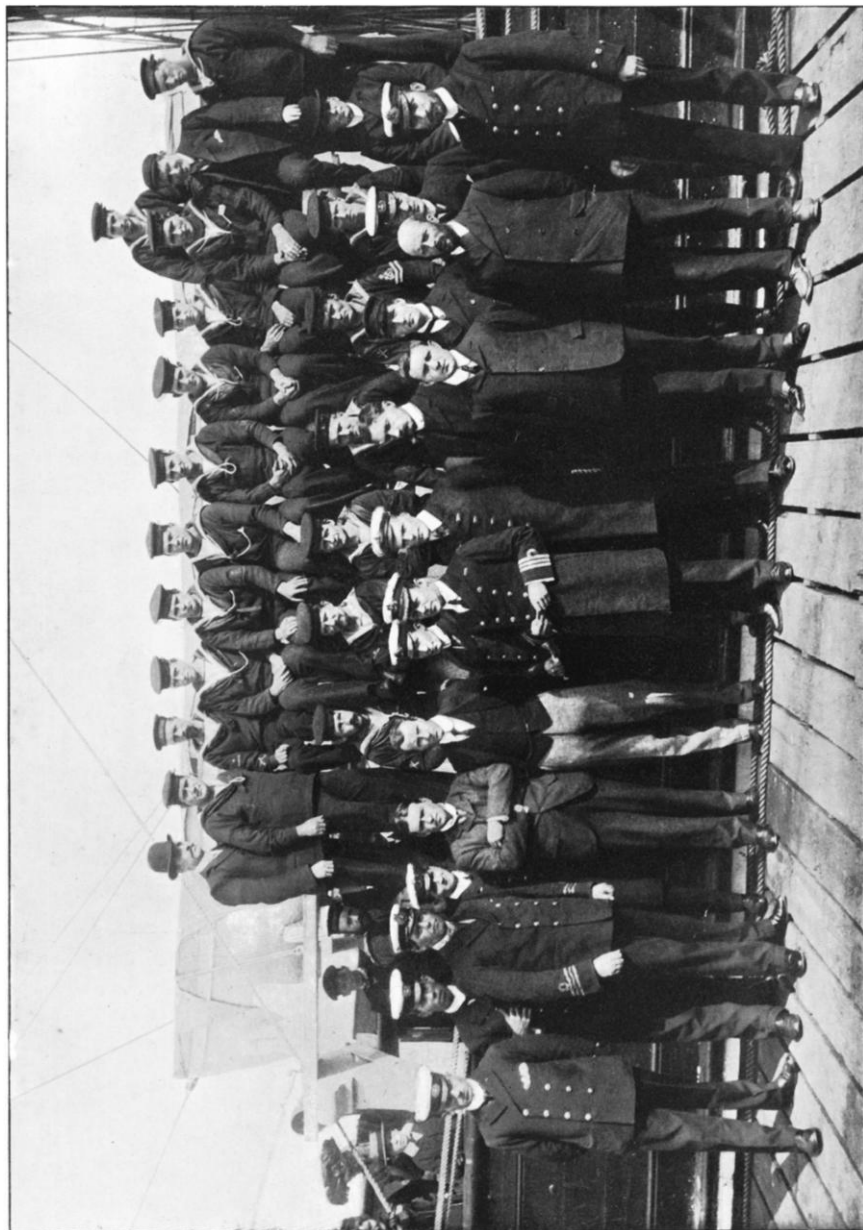
The main supply of icebergs in the Ross sea is from the Barrier and the eastern land. The glaciers on the coast-line of Victoria Land are in an extraordinary condition of stagnation, and nearly all the bergs met with along the coast have undoubtedly come from the east. From Cape Adare to Cape Crozier there are only two ice-flows capable of giving off a clean tabular berg of any dimensions. The rate at which various regions give off bergs can be to some extent gauged by the comparative newness of the exposed faces of the ice-cliffs.

Innumerable bergs are aground on the shoals off the eastern land, and some are very large. We saw one or two small ones in the act of calving from the high cliffs in that direction, but we did not see any being detached from the Great Barrier, and gathered from an examination of the edge that it must break away in very large pieces.

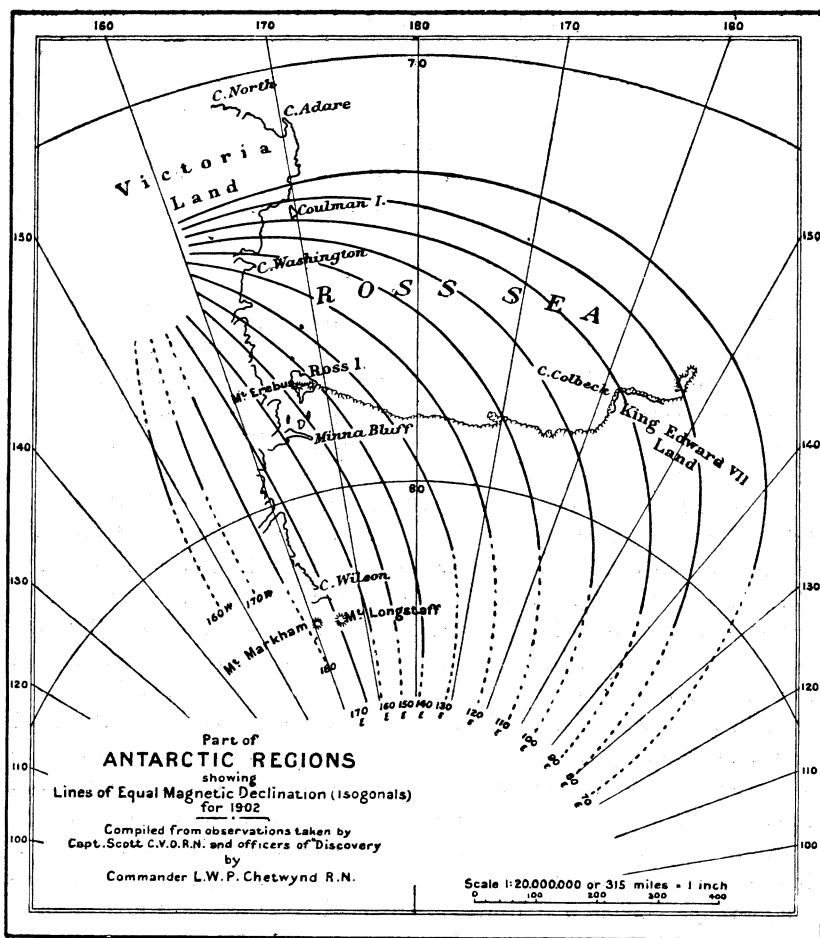
A stream of small bergs, with an occasional large one, sets along the barrier and turns north along the western land. They are delayed in the larger bays and inlets, and hung up on such shoal patches as exist off Cape Crozier, Cape Washington, and Cape Adare. From the latter especially there extends a long string of grounded bergs, where they have appeared to attempt to turn the corner too sharply in an effort to follow the coast. To the westward of Cape Adare, stretching toward Cape North, we saw immense quantities of bergs; but after turning to the north we saw none until we had passed to the westward of the Balleny islands, when they were fairly numerous. I cannot think that the bergs we saw before entering the pack in January, 1902, can have any connection with the Ross sea, but they probably originate to the eastward, and it is interesting to note those seen by Captain Colbeck to the eastward of Scott island.

The size of Antarctic icebergs has been the subject of some discussion, and there is much excuse for exaggeration. Of the many hundreds seen by us very few exceeded a mile in length or 150 feet in height; the vast majority were less than a quarter of a mile across and less than 120 feet high. The largest iceberg we saw was off King Edward's Land, apparently aground. We estimated it as about 5 or 6 miles in length, and it seemed to run back for an equal distance. In this region we also saw some very high bergs, and one is logged as 240 feet.

The proportion of the submerged to the visible part of an Antarctic iceberg was estimated by Sir John Murray as about 7 to 1. I am inclined to think that it is much less, but I have no exact measurements to adduce. My opinion is founded, firstly, on general observation of the depths in which bergs ground (120 to 150 feet bergs do not seem to touch bottom in more than 100 to 120 fathoms); secondly, on an eye estimate of the proportion as indicated in an overturned berg; and, thirdly, on the nature of the ice itself as exposed in the face of the berg or of the cliff from which it has come, the transition from snow to ice is very gradual, and strongly impresses one that the mass throughout must contain large quantities of air. For the above reasons, I am inclined to place the proportion as not greater than 5 to 1. Mr. Ferrar has some data concerning the aëration of ice taken from different parts of a berg, which might help to give an approximation. This factor appears to me of great importance, not only in calculating the mass of bergs, but as giving an indication of the thickness of the ice-sheet covering many parts of the Antarctic lands.



OFFICERS AND CREW OF THE "DISCOVERY."





*Current.*

The general drift of the current in the Ross sea is indicated by the direction taken by the bergs. We had the good fortune to recognize a berg on our return along the barrier which we had seen on the outward journey. It had drifted 70 miles to the west in twelve days; but the surface water had been moving at a greater speed, as we could tell by its effect on the ship. The tidal streams do little more than accelerate or retard this current, and it was only occasionally that we were helped in our journey to the south and east by a favouring stream. To the eastward of the Balleny islands the surface water is moving towards the north, but the absence of bergs seems to show that there is no deeper stream in this direction. To the westward of the Balleny islands we did not notice any marked current, and the bergs were much scattered.

*The Inland Ice.*

The main geographical interest of the *Discovery* expedition must lie in the practical observation of a coast-line from Mount Melbourne, in lat.  $74\frac{1}{2}^{\circ}$ , to Mount Longstaff, in lat.  $83^{\circ}$ , and of the conditions which lie to the east and west of this line. Our previous knowledge extended only to that part which lies between Mount Melbourne and McMurdo sound, and of this we had but the vaguest description.

The outline of the coast and the positions and heights of the mountain ranges are shown on the chart. It will be seen that the coastal mountains are comparatively low between Mount Melbourne and the Ferrar glacier, and it was the tabular structure of these that first indicated to us the horizontal stratification of the mainland. But low as the mountains are, in one place only does the internal ice-sheet seem to pour any volume of ice into the sea, whilst the mountains themselves form an effective screen to the conditions which exist behind them. I have one note only that throws light on these. Looking back over the ice-river in lat.  $75^{\circ}$ , one saw its surface rise sharply to a ridge between the coastal mountains, and I wrote, "Beyond this the surface still seemed to rise, and bare patches of rock could be seen at a greater altitude, but it was impossible to estimate the exact distance or height of these." As we journeyed inland and upwards on the Ferrar glacier the mountains on our right gradually rose in altitude, and when we reached the interior plateau, at a height of 9000 feet, we observed nunataks to the northward standing above our own level. From these observations, I think there can be little doubt that the land rises beyond the coastal mountains of the whole Prince Albert range, and that the interior ice-cap nearly maintains the altitude which it has to the southward. To the south of the Ferrar glacier there are a number of detached mountain ranges of great altitude that flank the coast. In the distance at which we first saw them they bore all the appearance of islands, but

closer approach not only narrowed the glaciers which lay between them, but showed us further mountains which lay beyond them, and revealed an extensive mountain region, beyond which must lie an ice-cap of great altitude and extent.

It is known that we travelled to the westward over a plain which did not vary in altitude more than 60 or 70 feet for 200 miles, but it will be remembered that one's view on such a plain is very limited, and it would be impossible to state definitely that the conditions are the same for many miles north or south of the line taken. The mild undulations of the plain were sufficient to make a slightly wavy horizon, which could be detected by swinging the levelled telescope of the theodolite, and I am inclined to think that on an average the northern horizon was slightly lower than the southern, but this was not a definite observation.

We did not reach the inland plateau of 8900 feet until we were fully 60 miles from the coast, and it is, therefore, extremely improbable that the full height of the ice-cap of Victoria Land could be seen anywhere from the sea or from the barrier surface. It is certain that the ice-cap is of very great extent, and the evidences which I have briefly sketched serve to increase the impression of its vastness, and to indicate that it maintains a great and approximately uniform level over the whole continent.

Whether we accept what our imagination must suggest, or whether we pause at the actual facts which have been discovered, this great ice-sheet is still unique. The reason for its unexpectedly level surface, the possible maximum thickness, and many other details concerning it, would seem to me to offer a fruitful field for discussion, and on such points I for one should be most grateful for the opinion of experts.

#### *Glaciers.*

There are innumerable glaciers on the coast of Victoria Land, but the great majority merely discharge local *névé* fields lying in the valleys of the coastal ranges. Very few run back to the inland ice, and these may be divided into two classes—the living and the dead. In the long stretch of coast between Cape Adare and Mount Longstaff, over 11° of latitude, there appears to be only four living ice-discharges from the inland. The first falls into Lady Newnes bay, the second is the ice-river in 75° S., to which I have already referred, whilst the Barne and Shackleton inlets form channels for the other two. The Skelton and Murdock inlets may actively discharge from the inland ice, but this is doubtful. From observations to which I have referred, there can be little doubt that the movement of the more northerly of these discharges is very slow, but judging by the movement of the barrier, the southern ones are more active.

The Ferrar glacier is typical of the dead glaciers; the ice lies in the valley practically stationary, and gradually wasting away from the

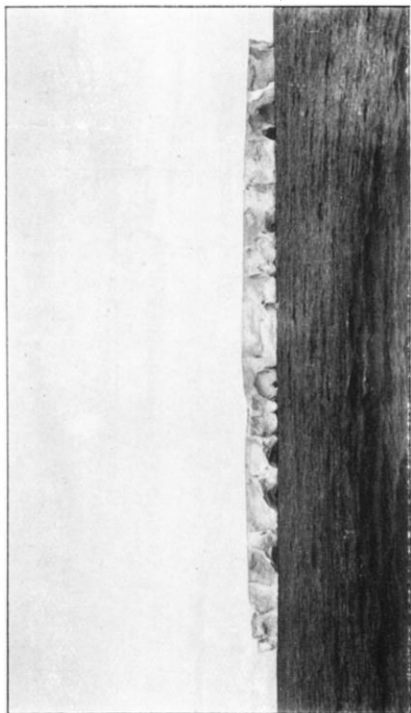
summer thawing. It is to all intents and purposes a dead limb. From lack of time for its construction, the inset chart does not very clearly show the ramifications of this glacier. Several discharges from the inland enter a common basin, from which two arms run towards the sea. Time does not permit me to touch on many interesting points concerning these details, but I may be permitted to refer to an exploration which I made of the "north" arm on my return from the west. Various observations on our outward journey, and whilst our ideas were yet unformed, had led me to suppose that there must be a considerable discharge of ice down this arm, and on my return I determined to explore it. After a day's journey down the glacier the ice became very rough, and we were obliged to leave our sledges and proceed with care. As we continued to descend, the glacier gradually dwindled, and then suddenly ended in the tamest manner in a wall of no great height. In the valley beyond we found some frozen lakes, and yet further in the narrow deep gorges, long lines and confused heaps of morainic *débris*. We walked on, hoping to gain sight of the sea, but were unable to do so. Perhaps in this valley, more than anywhere, lay the evidences of what was happening and what had been.

There lay the glacier inert and dead, whilst the summer sun slowly wasted its huge mass; on either side its shrinking tributaries had already severed their connection and receded up the steep mountain sides; one could no longer doubt a receding glaciation. Not only at our feet lay the morainic heaps to show what the glacier had once been, but thousands of feet up the hillsides they ran, till a clear-cut line showed the extreme limit to which it had once extended.

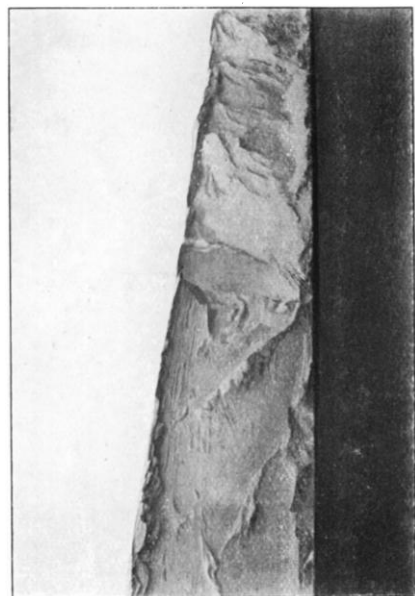
Here also I saw long morainic heaps 60 or 70 feet in height in the floor of the valley clean cut through by old watercourses, which now contain only the most modest streams; many of the boulders, well clear of the present streams, were quite smooth and rounded, whilst others at a greater height were sub-angular. This water-action must have been quite recent, *i.e.* since the glacier receded.

Mr. Ferrar has, I believe, measured the ancient high-tide mark of his glacier to be between 3000 and 4000 feet above its present level in places, but, of course, found the difference was less in the higher reaches.

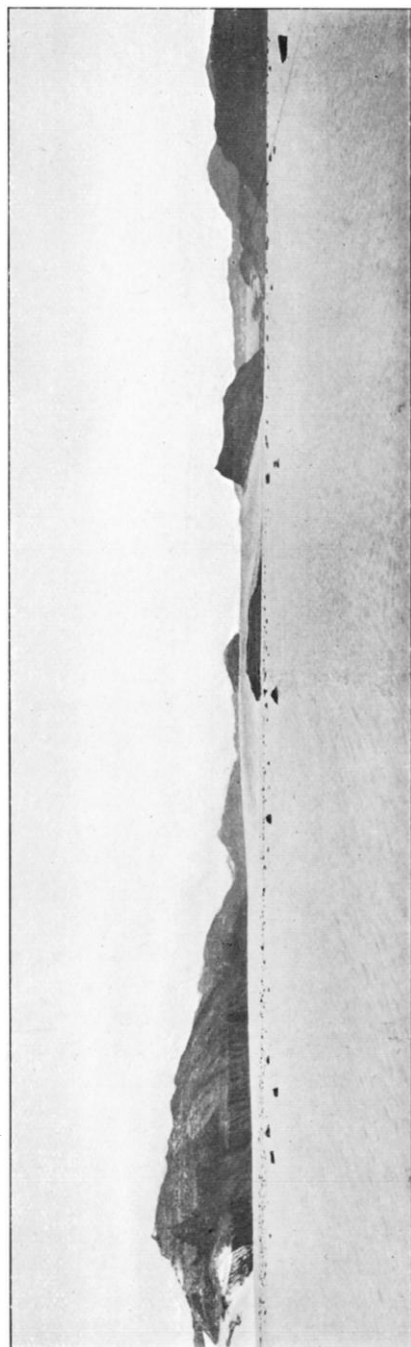
The Ferrar glacier probably contains as much ice as any hitherto known in the world; the Barne and Shackleton glaciers contain a great deal more, and since they are now in such a diminished state, it is interesting to think what vast streams of ice they must have been at their maximum. To what extent the inland ice sheet stood above its present level is also interesting to surmise; one would submit a possibility of 400 or 500 feet.



TYPICAL ANTARCTIC ICEBERG.



THE GREAT ICE-BARRIER.



THE WESTERN GLACIER.

*The Great Barrier.*

It is already known that I believe the greater portion of this great ice-sheet to be afloat. I will endeavour to give my reasons for this belief.

In considering the northern edge on the chart, if the figures showing the height in feet be taken as giving the depth in fathoms, a proportion of 6 to 1 for the submerged part will be allowed, and this I have already given reason for showing is an ample allowance. Since the soundings are given in fathoms, it will be seen that some hundreds of fathoms of water still intervene between the bottom of the ice at the barrier edge and the floor of the sea; but the barrier edge sixty years ago was in advance of its present position, in places as much as 20 or 30 miles, and therefore our soundings lie directly beneath Sir James Ross's barrier, and a considerable distance from its edge. The part that has broken away must therefore have been water-borne, and this, at least, shows the possibility of the remainder of the ice-sheet being afloat for an almost indefinite distance to the south. Had there been any doubt about the flotation of the barrier edge, it must have been dispelled by the fact that during our stay in the eastern inlet, although we had evidence of considerable tidal movement, the ice rose and fell with the ship.

Our long journey to the south was made practically over a level plain. Of this the gradual disappearance and reappearance of land masses over a continually level horizon could leave little doubt, but a yet clearer indication was the uniformity of the barometric pressures. The aneroid readings were recorded three or four times a day, and were frequently checked with the hypsometer. On returning from the southern journey, I tabulated the readings on each half degree of latitude, in comparison with simultaneous readings taken in the ship, applying the necessary corrections. When an empirical correction for a height of 200 feet is applied to the barrier readings, the comparative differences are extremely small, and if anything, the barrier readings are the greater, showing a fall in level, or what is, of course, a more probable explanation, a rise in the barometric gradient. It is fair to remark, however, that this comparison of pressures cannot be an exact method of determining levels under such circumstances. A small difference of pressure may be due to the normal barometric gradient, to local disturbance, or to instrumental error, as well as to a small difference of level. The point I wish to make is that a difference of level of 400 or 500 feet would introduce a discrepancy which could not be overlooked, and no such discrepancy occurs in our observations.

Incidentally, I might remark that the barometric observations made on our sledge journeys are noted in the meteorological record, and it would be of advantage if those taken to the south and west could be

extracted and tabulated, with a view to discovering differences of level. In the somewhat cursory examinations to which I have referred, I omitted to mention that there was an indication of a rise of level at the end of our journey; at this time we were close to the land, in the entrance to Shackleton inlet, where such a rise might well be expected.

As the great ice-sheet moves along the coast of Victoria Land, the thrust of the immense glaciers in the Shackleton and Barne inlets tends to push it from the land, and vast chasms are left between the ice-sheet and the land, partly filled with blocks of *névé* falling from the snow-capped foothills. For many miles from the entrances to these inlets the ice is waved into long curved undulations, and as one approaches them, the waves become more marked, the confusion increases, and cracks and crevasses grow numerous. Within 10 miles of the coast-line at any place there are signs of disturbance, and it can be easily understood that such a region is ill adapted for the sledge traveller.

But without the region of these disturbances, or some 10 to 15 miles from the land, the barrier moves with tranquillity, no ridge or crevass or other irregularity is met with, and the surface presents one monotonous even plain of snow. I submit that, if possible, it is improbable that a mass of ice could be pushing over the land in such an even, undisturbed fashion.

Where the ice-sheet is pushing past the Minna bluff and around the north and south ends of the White island, it is starred into long radial crevasses, running from 10 to 20 miles out from the land. The rifts are so straight, and close so gradually, that on crossing them the sides appear to have been mathematically ruled straight parallel lines. It is scarcely imaginable that such extraordinary uniformity of fracture should occur in an ice-sheet that was resting on the land, where there must be some irregularity in friction and ice-tension tending to divert the straightness of the rents.

In one of these crevasses extending from the north end of White island, Mr. Royds took some serial temperatures. Close to the land he found that the temperature fell with the depth to a mean level of  $-9^{\circ}$ , but at a distance of 10 miles from the land he got a different result. Here at first the temperature fell, but deeper it gradually rose again, until at a depth of 19 fathoms the thermometer showed  $0^{\circ}$ . Deeper than this he could not go, on account of the snow in the crevass. But I think it must be conceded that the only reasonable cause for such a rise of temperature as was observed is the presence of water beneath the ice.

After our observation of the stagnant condition of the ice about our winter quarters and in the Ferrar glacier, the report of the barrier movement came as a surprise. Its discovery was more or less accidental. In September, 1902, I established Dépôt A on the exact alignment of a sharp volcanic peak on the extreme end of the Minna bluff with the summit of Mount Discovery, the line running about west-

north-west and east-south-east. On visiting this spot in 1903, Mr. Barne found that the alignment was no longer "on," and thirteen and a half months after the establishment of the *dépôt* he carefully measured its displacement from the original line, and found it to be 608 yards. The direction of its movement must be a little to the east of north, and consequently this figure probably represents the whole movement during the period.

The direction of movement of the ice-sheet is indicated by the vast ridges encountered off the eastern slopes of Mount Terror; here the sheet is pressing up and shearing past the land-ice, raising numerous parallel pressure ridges. It would almost seem possible that the movement was taking place along the inner or outer of these ridges according to the state of the tide. Dr. Wilson, who had the greatest opportunity of examining this region, thinks that there must be a submarine land ridge between Mount Terror and White island, checking the flow of ice in that direction. He also observed that glaciers on the south side of Erebus and Terror, where there is an exceptionally heavy snowfall, are pressing towards the south-west, eventually finding relief around Cape Armitage. That there was some pressure from the barrier around White island was shown by the pressure ridges which were formed on the eastern side of our peninsula. There are many points of interest in the junction of the barrier and the land, wherever it may be, and Mr. Barne has written an interesting account of the ice-disturbances which he saw on his southern journey, which, however, is too long for reproduction here.

I am inclined to place the eastern limit of the floating portion of the barrier near the inlet which we entered in long. 163° W. It is noticeable that the ice-cliff immediately to the east of this has not broken away since Sir James Ross traced it. Mr. Ferrar thought he actually saw a crack about which there was a differential movement of the ice, or, in other words, a tide crack. I reported the barrier surface to the south of this inlet to be undulating; it would perhaps be more correct to describe it as a plain intersected by valleys running east and west, and descending almost to the sea-level; the valleys do not occur at regular intervals, nor are their slopes regular. This disturbed condition of the normally level plain is, without doubt, due to King Edward's Land, but it is not easy to see why the effect should be precisely what it is.

The full extent of this great sheet of ice must, for the present, be merely a matter of surmise. At our most southerly point we saw long snow-capes running out beyond Mount Longstaff and meeting the level horizon; and farther still the mirage threw up small patches of white, indicative of still more distant capes and mountains. The scene to the south was much what it was to the north, and the weather was so bright and clear that we can make at least one statement with certainty. The high mountainous coast-line does not turn to the east, north of the

84th parallel, beyond the slight trend it already has in that direction.\* But at such distances one can only speak of the high land. Whether the level surface of the barrier continues to skirt the coast-line for that distance, it is impossible to say, but, for my part, I am strongly inclined to think that it does.

#### *Distribution of Land.*

If the high coast-line be carried for 100 miles beyond our position in the direction in which we saw it, it will be seen to be making directly towards Graham Land, and I cannot but think that it continues to do so. If so, the geographical pole would be situated 200 miles or more from it and on the high ice plateau, which must continue behind if we allow for the comparatively rapid movement of the barrier.

The alternative theory held by many is that the coast sweeps round somewhere and joins King Edward's Land; if so, the turn, as I have pointed out, must be made a very long way south. Unfortunately, our knowledge of King Edward's Land is cursory. Judged by the outline of the hills and the blackness of the rocks, it appeared to be of the same comparatively recent volcanic formation as the land in the immediate vicinity of our winter quarters, but pieces of granite were brought up with the lead from the shallow water in its vicinity. In the region of Cape Colbeck the land is covered with a high-domed snow-cap, but to the eastward we had a long clear view of numerous peaks. Beyond those which fronted the coast-line were others at a greater distance, which gave a depth to the view. But we saw nothing like the wild rugged mountain scenery of Victoria Land.

#### *Speculation on Former Conditions.*

It is obvious that when the southern glaciation was at a maximum, when the glacier valleys were filled to overflowing, and when through all of them the great reservoir of inland ice was pouring vast masses into the Ross sea, the Great Barrier was a very different formation from what it is at present, and, as Mr. Ferrar has pointed out, there are abundant evidences of its great enlargement. Granite boulders are found on Cape Royds and high on the slopes of Terror, erratics, which can only have come from the mainland. On the slopes of Terror Dr. Wilson found morainic terraces 800 feet above the present barrier surface. Mr. Ferrar has shown that nearly the whole of the Cape Armitage peninsula was at one time submerged in the ice mass, and, in fact, on all sides of us, and everywhere, were signs of the vastly greater ancient extent of the ice-sheet.

It is not until one has grasped the extent of the former glaciation

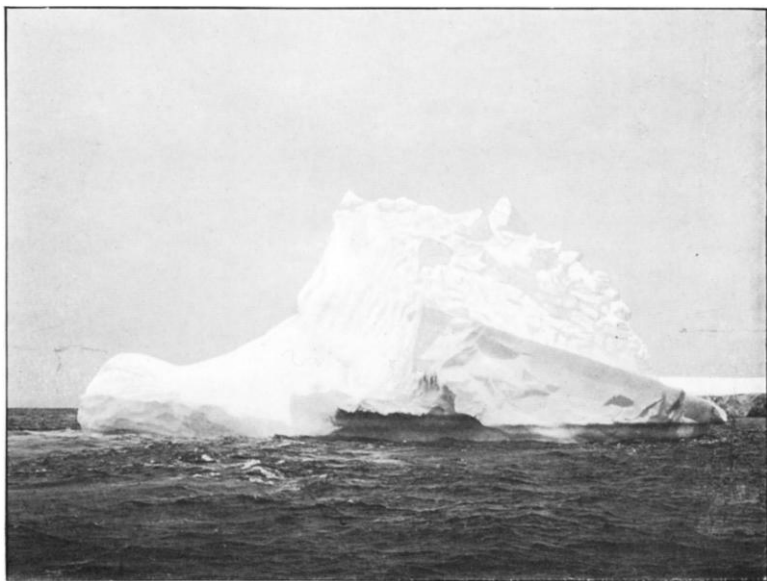
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\* As showing how far objects may be seen in the clear atmosphere of the Antarctic, at one and the same time we saw Coulman island and Mount Erebus, although separated by 4° of latitude.





SOUTHERN EDGE OF PACK-ICE AND OPEN ROSS SEA, LOOKING SOUTHWARDS.



OVERTURNED ICEBERG.

and the comparatively rapid recession of the present that one can hope to explain the many extraordinary ice-formations that now remain in the Ross sea. I advance such an explanation with all deference to the distinguished audience which I address. I do not doubt that there will be disagreement with my conclusions, but if it leads to discussion, we may all benefit.

I am of opinion that at or near the time of maximum glaciation the huge glaciers, no longer able to float in a sea of 400 fathoms or more, joined hands and spread out over the whole Ross sea, completely filling it with an immense sheet of ice. At that time the edge of the sheet, and the first place at which the ice could become water-borne, bordered on the ocean depths to the north of Cape Adare. Then followed the receding ice-conditions, and at length a time when the ice-sheet was very curiously circumstanced. The Ross sea is very uniform in depth, north and south; the ice-sheet that pressed out over this level bottom would consequently be more or less uniform in thickness, and finally, the wastage would be more or less uniform over the whole area. As a natural consequence of such conditions there came a time when the whole ice-sheet became buoyant, and either it had to break away with great rapidity or to float whilst remaining fast. It floated and broke away gradually, and the present rapidly diminishing barrier is all that remains of the great ice-sheet; or rather, it is not all that remains, because I think that the whole coast bears signs and remains of the old barrier in curious ice-formations which can be accounted for in no other way. Lady Newnes bay is filled with a fragment of the barrier; the present ice discharges are wholly insufficient to account for such a sheet; moreover, its surface is not gradually inclined, but advances in long and steep undulations, the outer waves cut off by deep hollows from the interior mass. A single deep sounding in an inlet showed that here, too, the greater part of the ice-mass is probably afloat, and that it is held in by its exceptional land surroundings.

A still more curious fragment is the long tongue of ice, extending from the land in lat.  $75^{\circ}$ . Not only is its plan outline against the supposition that it can be fed by the ice-sheet, but at the outer end it is considerably higher than at the inner. Off the outer end we got soundings of 400 fathoms, which increases the difficulty of accounting for the continuance of such an unsupported mass of ice in its present position. But in this respect the same difficulty was emphasized in connection with a more wasted ice-tongue of the same description which jutted out from the slopes of Erebus within 8 miles of our winter quarters. This was a very long lathe-like tongue with serrated edges, and afforded us many arguments. I was with Captain Colbeck when he sounded off the end and at various spots on either side; nowhere could we get anything but very deep water. But the problem of how these

tongues remain at anchor has no bearing on their origin, and is, therefore, somewhat of a digression.

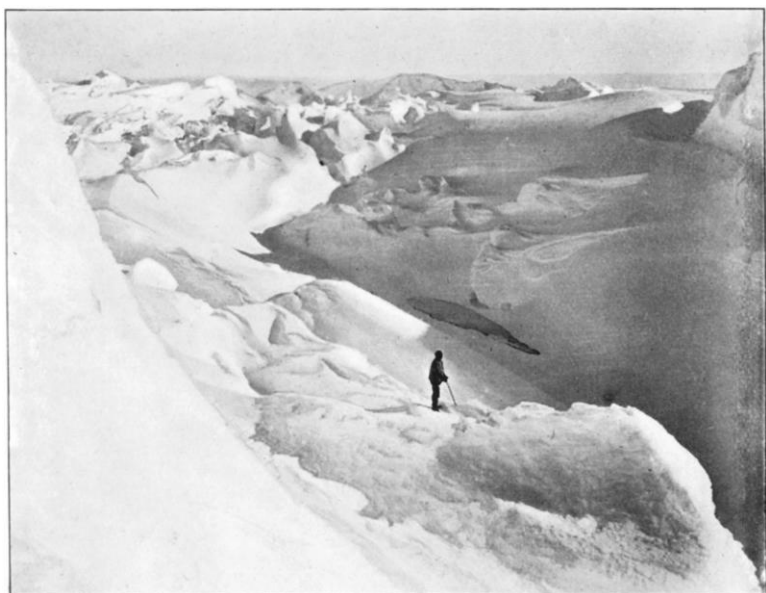
I would take, as another typical remnant of the greater ice-extension, one of the numerous steep snow-slopes that fringed the sea about our winter quarters. They start on a steep bare hillside, and, wedge-shaped in section, gradually increase in thickness till they end in a perpendicular cliff dipping into the sea. This feature in a modified form is reproduced along the whole coast-line as far south as the northern end of the White island. Yet one other formation deserves mention, namely, that which, for want of a better term, I may call the fan-shaped glaciers which lie under such steep cliffs as those of Coulman island. These are to some extent fed by the ice-cap above, but their size is out of proportion to such a supply, and they end in steep high cliffs often more than 100 feet above the sea. These too, I think, must be regarded as the last clinging remains of the old barrier.

I have probably wasted too much of your time in attempting to elucidate these ice problems, but I feel that the subject is one of great interest and worthy of discussion. I do not know that I have advanced anything startlingly new, but what I wish to generally impress is, that the majority of curious and often vast ice-formations met with in the Ross sea must be regarded, not as the result of present-day conditions, but as the rapidly wasting remnants of a former age.

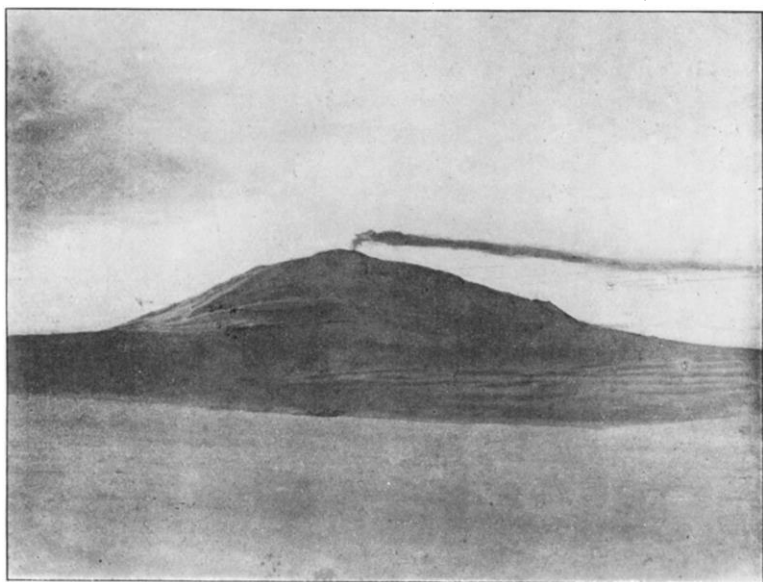
#### *Climate.*

It has been a surprise to me to find that the idea that a great glacial epoch is the result of a comparatively mild climate is supported by much authority. Both Mr. Ferrar and I arrived at this conclusion independently when in the Antarctic. The chief argument is, of course, that it is physically impossible for cold air to contain much moisture, but, living in a severe climate, it was impossible not to realize that greater severity would have meant more sterile ice-conditions. In this connection it is interesting to note that our greatest snowfall occurred in the summer, and that the Balleny islands are more actively glaciated than Victoria Land. We observed two large avalanches of *névé* as we passed Sturge island. There can be little doubt that at the period of heavy glaciation the climate of Victoria Land was far milder than it is at present.

I should like to contribute some facts which may be of interest to meteorologists. Mr. Shaw has congratulated us on the possession of such an excellent beacon as Mount Erebus, from which we could gather the direction of the upper air currents. In this connection there were some interesting evidences to be gathered from the surface of the snow on the high level plateau of Victoria Land. The high hard winter sastrugi uniformly point between west by south and west-south-west; when we arrived on the summit, the wind was a little



THE GREAT CHASM.



MOUNT EREBUS WITH SMOKE.

south of west-south-west, and fresh light sastrugi had formed in that direction. During our stay the wind crept gradually round to south-west, and once or twice it went further south, with a rise of temperature and light snowfall. I gathered, firstly, that throughout the winter the wind blows from west-by-south, but during the summer creeps more to the southward; and, secondly, that there is no snowfall except in the summer, and on the rare occasions when the wind blows almost due south.

Erebus smoke blew almost persistently to the east, but we could not always exactly gauge its direction. It is curious to find that every sketch made by the Ross Expedition shows it going to the west, and Sir Joseph Hooker can remember it going in no other direction.

I understand that Mr. Shaw is of opinion that the south-east winds recorded in our winter station are not merely local. I should be glad to think it was so, but the weather conditions about the *Discovery* seemed to me too confused to allow it. It was often possible to see very varying weather conditions simultaneously at different places within our view. For instance, at one time a bank of heavy nimbus cloud overhung Cape Bird; the northern slopes of the western range were in calm and sunshine; clouds of drift were being swept from the slopes of the *Discovery* by a southerly wind. The wind was south-east at the ship, whilst off Cape Armitage and a mile or two to the eastward of our peninsula it was again calm. The same confusion was shown by the snow-waves. As a rule, in the vicinity of the ship they pointed to the south-east; outside White island they were very confused, from west-south-west to south-south-east; south of White island and to the Bluff they were south, at the dépôt south-west, and off the eastern slopes of Terror again south.

At the eastern end of the barrier the winds we experienced were certainly east and south-east, but if this is the prevalent direction over the whole barrier, it is difficult to see where the body of air goes to unless it turns to the north on arriving at Victoria Land; it certainly does not go over the mountains and plateau. It is certainly deplorable that there should be no way of measuring the Antarctic snowfall. The most efficient instrument, however, would have been useless in the vicinity of the ship, as our small bay was a focus which received far more than its due share of snow. When the ice about Cape Armitage was a year old, it occurred to me that we might get a rough idea of the net annual deposit by measuring the depth of snow at various points on its surface. This was done with difficulty, owing to the sastrugi and varying nature of the snow, but I calculated that a rough average of the results would represent between 4 and 5 inches of hard-packed snow. Rough as it is, this figure is something of a guide, for it means that the surface of the barrier is annually augmented by about this amount. It may be added that excavations into the surface of the barrier invariably revealed a succession of crusts at irregular intervals. The amount of snow between

the crusts was not much in disagreement with the deposit above mentioned. Even an annual increase of this amount would account for an absence of boulders or dirt in any visible portion of the barrier edge.

In mentioning the deposition on the barrier, I cannot refrain from carrying the same problem to the ice-cap and hazarding a solution for a curious condition of the surface which puzzled me much at the time. In journeying to the west we crossed numerous slight inequalities. Where the surface inclined to the east, it was covered with hard sharp-edged sastrugi, but elsewhere it was quite smooth and covered with a shiny crust traversed by innumerable transverse cracks, which gave it a scaly appearance such as may be seen in the mud of a dried pond. I felt at the time that this was no recent formation, but it was only much later that it occurred to me that this might be a sign that there was no net deposit of snow on this great plateau, or, in other words, that the climatic conditions were such that the evaporation equalled or exceeded the deposition. Before quitting the subject of meteorology, which I am very loathe to do, I must add that the warm snow-bearing southerly winds which we experienced have not yet been explained. Even in the depth of winter this wind had sometimes a temperature of  $+10^{\circ}$  to  $+15^{\circ}$ . Presumably the air was in the process of being rapidly cooled, and was depositing its moisture. If it had been heated adiabatically, whence comes the moisture? Mr. Royds may have had some such idea in his mind when he spoke of a "föhn" effect, and I am not quite clear as to Mr. Shaw's reference to this. He remarks, "Wind in those regions may carry snow with it without being necessarily a very moist wind." If this implies that the snow was only drift-snow, I fear he is not quite apprised as to the conditions. Although it was impossible to measure the snowfall, it was generally easy to distinguish between snowfall and snowdrift, and in the case of our southerly winds there is no doubt whatever they are accompanied with falling snow. It will be noted, also, that a comparatively warm southerly wind brought snowfall on the summit of Victoria Land, and at our farthest south position we experienced precisely the same effect.

I must regret that since my return to England I have not had time to keep myself fully informed of the progress of the scientific work of the expedition, in which we all, whether scientists or laymen, must continue to take a deep interest; but we know that it is in good hands, and can hope that the best will be made of the raw material which has been brought back.

It is a disappointment to all that Mr. Ferrar's fossils should not have been in a fitter state for identification, but it is some consolation to know that it is the fault of nature, and not of the discoverer, that they should tell so little; and it is a great satisfaction to find that geologists have already found so much that is interesting in Mr. Skelton's photographs and in Mr. Ferrar's brief summary, that we may look for much

light being thrown on the geological formation of this great land mass when the latter's voluminous notes are brought into shape. Mr. Ferrar has already described how he found an immense sandstone formation, 2000 feet in thickness, practically horizontally bedded on a granitic base and capped with basalt; the simple horizontal structure seems to have been wholly unexpected, and the absence of lateral pressure in the formation of such a huge and extensive range of mountains appears most remarkable. It cannot but be regarded as singularly fortunate that we should have found such an excellent natural geological section of the range as was exposed in the steep cliffs of the Ferrar glacier, and if the simple formation thus discovered be regarded as typical of the whole mountain range (and there is some evidence that it may be), the geology of the Antarctic continent will have received an immense addition.

The more recent volcanic outburst which has thrown up the high conical peaks of Erebus, Terror, Melbourne, Discovery, and a thousand minor craters along the coast-line, must also be of great interest. It occurs to me to add here that geology will owe much to the careful charts which are now being prepared by Lieut. Mulock from a very large amount of survey data.

I am glad to have been informed that an unfortunate error with regard to the hours named for term day magnetic observations is not of such importance as was at first imagined, and, of course, the curves taken under normal conditions are of unimpaired value. It must be long before the full magnetic results are known, but Captain Chetwynd has already found that the observations for "variation" taken at sea and on sledge journeys work in remarkably well.

Dr. Wilson's work on vertebrate zoology, in a region where vertebrate zoology ends, is already fairly well known, but all who have listened to him or have seen his sketches must realize that he will have much more yet to say on his subject. Mr. Hodgson has already furnished a preliminary paper to this Society, and his work must necessarily take a long time to investigate.

I am not aware of the fate of the seismic, the pendulum, or the auroral observations, or of those taken for atmospheric electricity; but as I know all were taken conscientiously, I feel sure all must be of value. I am also in ignorance at present with regard to tidal observations; very great care was taken to eliminate or to allow for all chances of error in these observations, and it is therefore to be hoped that they will yield good results.

Time has obliged me to leave many interesting points untouched in this paper, but I must briefly refer to our geographical exploration to the northward and westward of Cape North. I have already shown the probable cause of Ross's error in imagining the Russell islands to be a separate group from those discovered by Balleny, and I have

described our course to the westward. But with reference to the latter, I would add that, whilst it is certain that we must reject Wilkes Land to the eastward of Adélie Land, Wilkes' soundings still remain as a guide to the limit of the continental plateau in this region. Our own uniform soundings of 250 fathoms to the south, together with his, show that there is a considerable extent of shallow sea, limited more or less by the track of Wilkes' ships.

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After the paper, Sir JOHN MURRAY said: I do not propose to offer any remarks by way of criticism, but I should like to express my very high appreciation of the manner in which the work of this expedition has been carried out, and the large additions to knowledge which it has furnished. I have listened with very great interest indeed to the interpretation which the leader of the expedition has given to very many of these observations. No doubt he has studied the thing upon the spot, and is, therefore, very much more capable of forming a judgment as to the general distribution of the land and the ice than any one else. Still, it seems to me that, so far as he has been able to place the observations before us, I would not like to say that he has conclusively shown that all that great ice-barrier over which he travelled was necessarily afloat—that is to say, that it had salt water underneath it. That it is afloat at its outer edge, and that salt water may extend for 30 or 40 miles underneath is quite probable, but I should not like to admit that the whole of that barrier was really afloat. This ice barrier has, it appears to me, a direct connection with the great mass of snow on that high land. Thus alone can I account for its motion to the north as observed by the members of the expedition. One thing I quite agree with, and all the observations which have been made go to show that at the present time there is a retreat of the ice in this region. That it has retreated all over the Antarctic Regions is extremely probable; but it is certainly in a dying-out condition—that is, it is far from being at its maximum at the present time. That, I think, may be admitted as thoroughly proved. With respect to where the great mass of the land lies, I should say that it lies in the direction that has been indicated by the leader of the expedition. The rocks that the *Challenger* dredged up within the Antarctic circle consisted of all the kinds of rocks that are usually found upon continents, and we all of us firmly believed that within that region there was a great continental mass. That has now been proved by the observations of the *Discovery*, and that, I think, is a very great point indeed. I have read some of the other communications that have been given by other members of the expedition of what has been accomplished in the various departments, and I for one will yield to no one in the appreciation I have of the most excellent work that has been done by this expedition, and the great contributions to human knowledge which it has furnished.

Mr. J. J. H. TEALL: I am very glad of the opportunity that you have given me of associating myself most thoroughly and completely with the remarks which Sir John Murray has made as to the importance of the results which this expedition has brought forth. Like him, I do not feel able to enter into anything like a discussion of the problems which are suggested by this communication. It is given to all expeditions of this kind to extend our knowledge, to push back the boundary between the known and the unknown, and in doing so to set at rest a number of points on which we were previously in doubt, and to bring prominently to the front new problems which we wish to have solved. I think, sir, that so far as regards actual results achieved, this expedition will certainly rank with any other expedition of its kind, and so far as problems suggested are concerned it is