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The exploration of the Antarctic Regions

John Murray

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tion as of life—and the one is only an epitome and compressed symbol of the other—that for us all it is

> "Glad sight whenever new and old
> Are joined through some dear home-born tie:
> The life of all that we behold
> Depends upon this mystery."

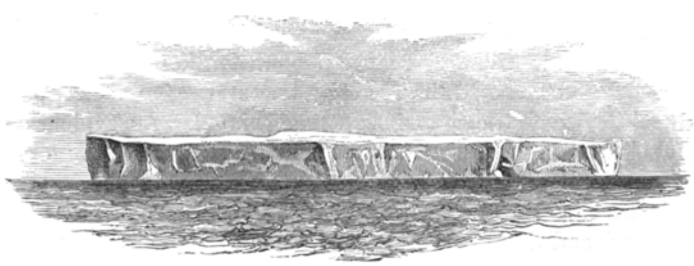
The passion of hunting is the strongest passion in human nature: can we gratify this passion in the schoolroom? I think we can; and Geography is one of the happy hunting-grounds in which we may be able to gratify it.

THE EXPLORATION OF THE ANTARCTIC REGIONS.

By John Murray, *of the "Challenger" Expedition.*

At the Aberdeen Meeting of the British Association last year a committee was appointed, with Admiral Sir Erasmus Ommanney as secretary, to consider what steps should be taken with the view of promoting further exploration in the Antarctic Regions. The appointment of this committee has had the effect of again directing much public attention to these interesting, unexplored regions, and to the necessity for carrying to a successful issue the objects for which the committee was appointed. As evidence of the interest taken in the matter, it is sufficient to refer to the resolutions of the Geographical Society of Australasia, published in the last number of this Journal, and to the resolutions of the Councils of the Royal Society of Edinburgh and the Scottish Geographical Society, which are appended to the present paper. The spirited action of the Australian Society is in every way commendable, and deserves energetic support. Should the Australian Governments be induced to vote, say, £10,000 each towards the outfit of an Antarctic expedition, on the condition that the Imperial Parliament vote the remainder of the necessary £150,000, then the success of the undertaking is almost assured. Other colonies might follow the example of the Australians, and the Imperial Government could not then refuse to take the recommendation into consideration. This would be a first great step in the direction of Imperial Federation. While all who have considered the matter admit that the first steps towards federation between the mother country and the colonies should be taken with great caution, it is not likely that anything difficult, delicate, or dangerous will be urged against the co-operation here suggested. To unite for the purpose of fitting out a properly equipped exploring expedition to the Antarctic Regions, that would acquire much new knowledge, and enrich every branch of science by its observations, is surely a noble object, well calculated to create new ties and interests between the different peoples of our great Empire. It might prepare the way for that closer union which is much talked about and is very desirable; though against every definite proposal that is made some objections can at the present time be raised. Active participation in a work of this kind would make the colonists feel that they are to take an active part in the future history of the Empire, as they now regard the past history of the United Kingdom as part of their common heritage. All success, then, to the Australians in their present proposals for Antarctic research and exploration.

It is desirable to review briefly at this time the existing state of our knowledge concerning that portion of the earth's surface lying near and within the Antarctic Circle. The accompanying Equal Surface Projection Map exhibits this region, and on it Mr. Bartholomew has placed the geographical and physical characteristics, so far as these can be graphically represented.[1] The whole of the area within the Antarctic Circle may be said to be covered with a white shroud of snow and ice, which has hitherto prevented any detailed examination of either the solid land or of the ocean waters. A continuous and very deep ocean surrounds for many degrees of latitude the South Polar land in the latitude of about 60° S., which is often called by geographers the Southern Ocean. Its average



Iceberg seen from H.M.S. *Challenger*, February 11, 1874—Lat. 60° 52′ S., long. 80° 20′ E.

depth is probably a little over two miles. Southward of Australia and the Indian Ocean it gradually shallows to the Antarctic land, which is there met with, in some points at least, a short way within the Antarctic Circle. A few degrees to the eastward and westward of the longitude of the South American Continent there is evidence that the ocean is very deep even in the latitude of 70° south. In the former position Ross, who knew perfectly well how to take deep soundings, records a depth of even 4600 fathoms, with no bottom; so that, although such a great depth may not be confirmed by future observations, yet we may be quite satisfied that here the ocean is very deep. Wilkes and Ross obtained many soundings during their expeditions, and these, together with those obtained by the *Challenger* and other expeditions in the Southern Ocean, have been utilised in laying down the contour lines of depth and the supposed position of the Antarctic Continent on the map, a careful inspection of which will be more instructive than any detailed description.

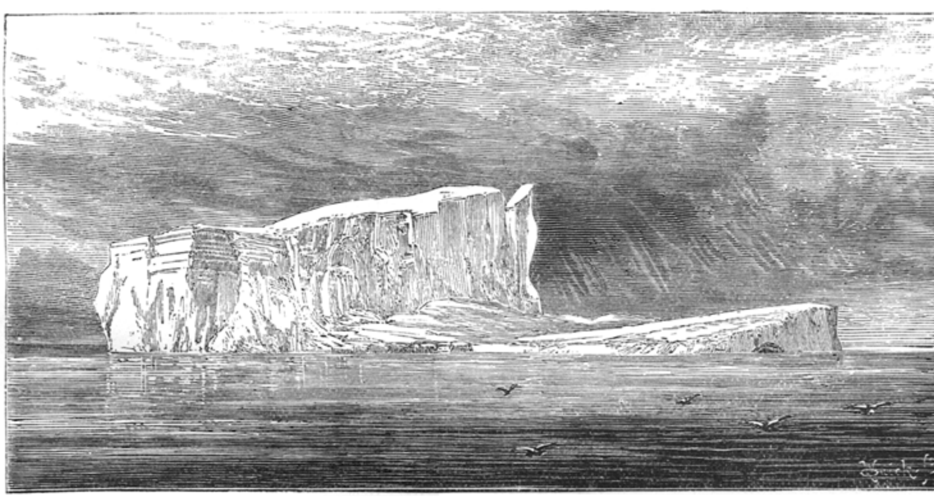
Five expeditions have been despatched from this and other countries

[1] A brief description of this projection will be found in the article on "Drainage Areas" in this number of the *Magazine*.

to explore the Antarctic Regions, that of Cook in 1772-75, of Bellingshausen in 1819-21, of D'Urville in 1837-40, of Wilkes in 1838-42, of Ross in 1839-43, and the *Challenger* crossed the Antarctic Circle in 1874.

The captains of ships which have penetrated these regions in search of whales and seals, or other purposes, have, however, supplemented our knowledge in many ways, notably Smith and Bransfield in 1820, Powell in 1821, Weddell in 1822-24, Morrell in 1823, Foster in 1828-29, Biscoe in 1830-32, Balleny in 1839.

Only three of these navigators have succeeded in crossing the parallel of 70° S.:—Cook, in 1774, reached 71° 10′ S.; Weddell, in 1823, penetrated to 74° 14′ S.; and Ross crossed the parallel of 70° three times in three different years. In 1841 he sailed in the month of February as far as 78° S., where he was stopped by an icy barrier, 150 to 200 feet in height,



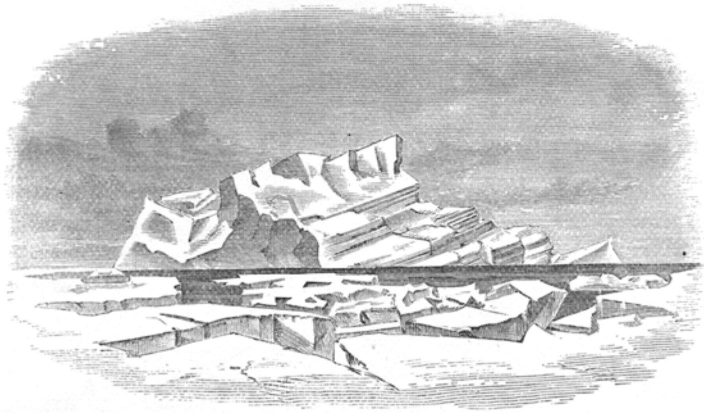
Iceberg seen from H.M.S. *Challenger*, February 21, 1874—Lat. 63° 30′ S., long. 88° 57′ E.

which he traced in an east and west direction for a distance of 300 miles; in 1842 he again reached 78° S., and was stopped by a barrier about 70 miles to the eastward of his position in the previous year; in 1843 he was stopped in his progress south by an impenetrable pack at 71° 30′ S., 16½° W. Wilkes, Bellingshausen, D'Urville, and others, crossed the Antarctic Circle, and reached to within a few miles of 70° S.

It must be remembered that Sir James Ross was the only one of these explorers who had ships properly fortified for southern exploration, so that they would not have been justified in sailing through close pack-ice, as Ross did with such conspicuous bravery. No steam-vessel has visited the Antarctic area except the *Challenger*, and she was quite unprotected for ice work.

The majority of Antarctic voyagers have discovered land south of the 60th parallel. Cook probably saw land in 71° S., 107° W. Bellingshausen discovered Peter Island and Alexander Land; D'Urville discovered Adelie Land; Wilkes found land extending from the 100th to the 160th meridian of E. long., between the parallels of 65° and 67° S.; Ross discovered Victoria Land, extending from the 70th to the 78th parallel, between the meridians of 160° and 171° E.; Smith and Bransfield discovered the South Shetlands; Powell, the South Orkneys; Biscoe, Enderby's Land; Balleny, the Balleny Islands and Sabrina Land.

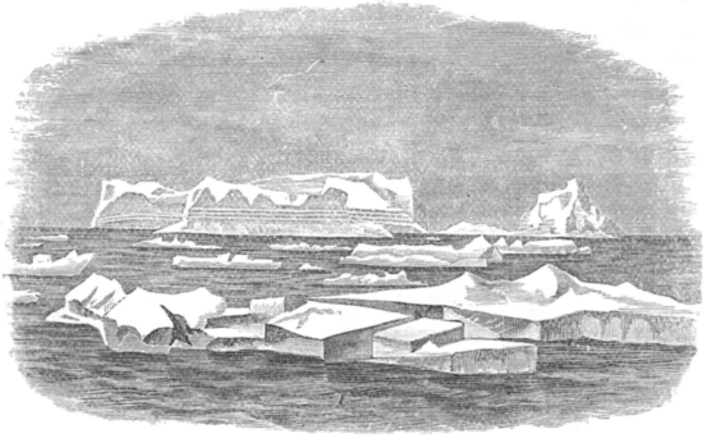
Ross and D'Urville are the only two of these bold navigators who have succeeded in setting foot on land within the Antarctic Circle, and neither of them remained longer on shore than was sufficient to allow them to gather a few specimens of rocks. The nature of the coast, and the numerous icebergs did not permit them to bring their ships to an anchor; a quick return to the ships was necessary to avoid being caught by one of the sharp gales, or enveloped in the fogs that prevail in the



Iceberg and Pack Ice seen from H.M.S. *Challenger*, February 25, 1874—Lat. 63° 49′ S., long. 94° 51′ E.

Antarctic seas. Both Wilkes and Ross got frequent soundings in comparative shallow water, when close to the ice-barrier, which showed that land was at no great distance. If we except some off-lying islands, all the land is described as being completely ice-bound. Where the coast is low, there is a line of perpendicular icy cliffs, 150 to 200 feet in height, rendering hopeless any attempt at landing. This is known as the "Ice-Barrier."

In other places, where the land is high and mountainous, there is no "ice-barrier" proper, but the coast is protected by land ice, five or six feet above the level of the sea, in most cases extending many miles from the shore. Ross evidently believed that he could have landed on, and travelled over the Antarctic Continent had he been able to secure a harbour for his ships. He says: "To the north-westward we observed a low point of land, with a small islet off it which we hoped might afford us a place of refuge during the winter, and accordingly endeavoured to struggle through the ice towards it until 4 P.M., when the utter hopelessness of being able to approach it was manifest to all, the space of fifteen or sixteen miles between it and the ships being now filled up by a solid mass of land ice. . . . Had it been possible to have found a place of security upon any part of this coast, where we might have wintered in sight of the brilliant burning mountain, and at so short a distance from the magnetic pole, both of these interesting spots might easily have been reached by travelling parties in the following spring. . . . It was nevertheless painfully vexatious to behold at an easily accessible distance under other circumstances the range of mountains in which the pole was placed, and to feel how nearly that chief object of our undertaking had been accomplished; and few can understand the deep feelings of regret with



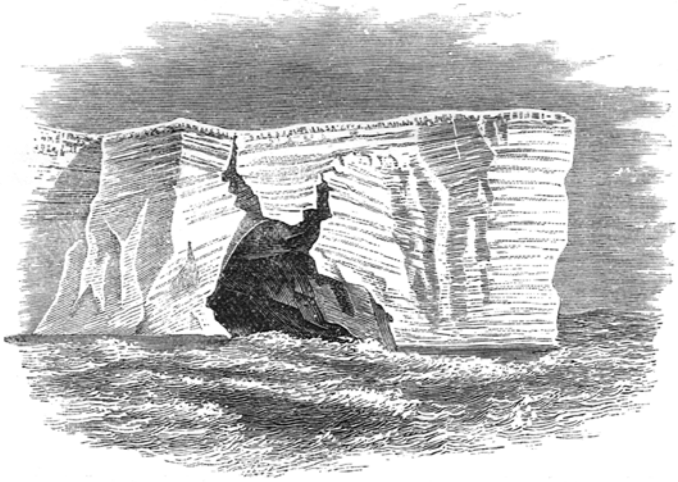
Icebergs and Pack Ice seen from H.M.S. *Challenger*, February 25, 1874—
Lat. 63° 49′ S., long. 94° 51′ E.

which I felt myself compelled to abandon the perhaps too ambitious hope I had so long cherished of being permitted to plant the flag of my country on both the magnetic poles of our globe."[1]

Ross says Franklin Island, where he landed in lat. 76° 8′ S., "is composed wholly of igneous rocks. The northern side presents a line of dark precipitous cliffs, between five and six hundred feet high, exposing several broad, white, probably aluminous, bands of several feet in thickness. Two or three of them were of a red ochre colour, and gave a most strange appearance to the cliffs. We could not perceive the smallest trace of vegetation, not even a lichen or piece of sea-weed growing on the rocks: and I have no doubt from the total absence of it at both places we have landed, that the vegetable kingdom has no representative in Antarctic

[1] Ross, *Antarctic Regions*, p. 245.

lands." The rocks at the points where other landings have been effected were also apparently of volcanic origin. Ross, however, dredged up blocks of grey granite, and various other rocks of a granitic structure, and the *Challenger* has dredged up fragments of mica-schists, quartzites, sand-stones, compact limestones, and earthy shales, which leave little doubt that within the Antarctic Circle there is a mass of continental land quite similar in structure to the other continents. The stupendous mountain range of Victoria Land, peak after peak, rising from 7,000 to 10,000 feet above the sea, and terminating seawards in bold capes and promontories, which did not afford attachment to either ice or snow, are not at all likely to be composed entirely of volcanic materials like the burning volcano, Mount Erebus, which is over 12,000 feet in height. Indeed, we have the best



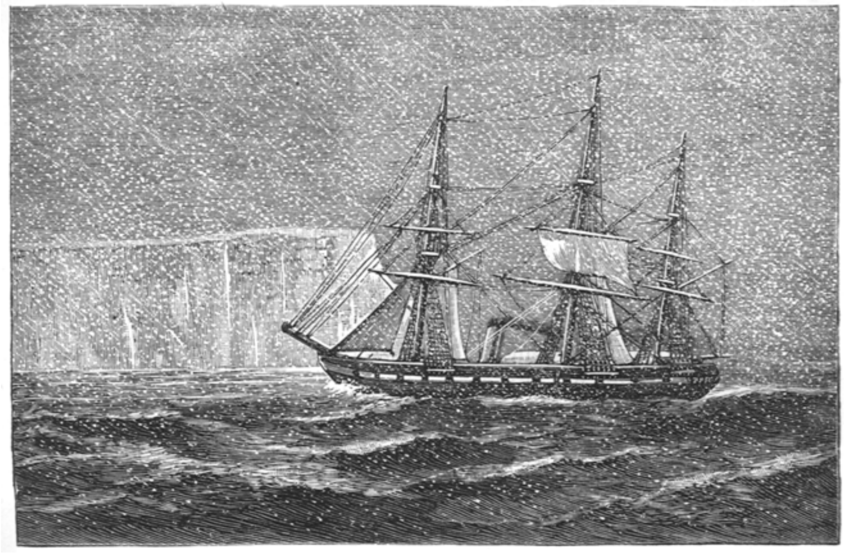
Iceberg seen from H.M.S. *Challenger*, February 23, 1874—Lat. 64° 18′ S., long. 94° 47′ E.

evidence in the mineral particles and rocks which have been distributed over the ocean's floor [1] by the icebergs, that this is not the case. It may be regarded as conclusively proved that there is a great mass of continental land within the Antarctic Circle. Its probable position and extent is indicated on the map. Ross, as already stated, believed the vegetable kingdom to be quite unrepresented on Antarctic land. And no land animals have been observed.

The snow and ice enveloping Antarctic land, and shed from it into the ocean in the form of immense, flat-topped, table-shaped icebergs, have a most fascinating interest not only from the great magnitude, terrific grandeur, and beauty of the phenomena, but also from the scientific questions connected with the ice-cap and the icebergs still remaining unanswered.

[1] See Paper on "Drainage Areas" in our present number, p. 548.

Off the steep escarpments of Victoria Land, and off other portions of Antarctic land, where high mountains are close to the coast, there is no true "Ice-Barrier," but here and there, descending from the ravines of the mountain ranges, glaciers are pushed considerable distances into the sea. The perpendicular cliffs of ice 150 and 200 feet in height, that is to say, the true Ice-Barrier, would appear to occupy all the coast-line where the land is low, and to be the terminal portions of the great ice-cap, which descends from the interior of the continent to all the lower lands. This great mass of continental ice cannot reach the ocean where the coast is lined by high mountains, but following the bends of the great valleys, is pushed seawards over the plains, and off these eventually gives birth to the tabular, stratified icebergs so characteristic of the Southern Ocean.



H. M. S. *Challenger* after collision with an Iceberg, February 24, 1874—about lat. 64° S., long. 94° E.

The edge of the barrier seen by Ross was nearly water-borne, and therefore just in a condition to generate icebergs. The height of the ice cliffs above the water-line was, on the average, about 175 feet, whilst the depth of the water within a mile of them was 260 fathoms. Supposing the specific gravity of ice at 32° to be 0·92, and that of sea-water at the same temperature to be 1·027 (distilled water at 39° being equal to 1), a floating iceberg will have 89·6 per cent. of its volume immersed, if it have the same temperature and consistency throughout. It may be said then that 90 per cent. of the volume of an iceberg will be under water, and 10 per cent. above. The edge of the barrier would accordingly be just about water-borne in the depth of 260 fathoms which Ross found off it.

The uniform height of about 175 feet of the icebergs in high southern latitudes has struck all observers, and there can be no doubt that they have been derived from the icy barrier which is gradually pushed out to sea.

As these bergs float northwards with the currents they become tilted and gradually lose the regular tabular appearance which they have nearer their source in higher latitudes. The waves dash against them as against a rocky shore, and they are cut into gullies, caverns, and caves; the water as it washes in and out of these makes a resounding roar which is very loud when many bergs are around the ship. The pinnacled bergs have often very large bases, which run out into spurs and irregular projections, and these bergs are sometimes higher than the tabular ones. The highest berg seen by Cook was from 300 to 400 feet high. Ross does not mention any very high berg; Wilkes estimates his highest at 500 feet; the highest seen by the *Challenger* was only 248 feet. The tabular bergs are frequently four or five miles in length; the stratification is extremely fine at the water's edge, but the strata becomes thicker and the blue lines further apart as they are traced to the summit of the cliffs. The naturalists of the *Challenger* did not observe any rocks or marine matter on any of the bergs, however these have been seen by Ross and other voyagers. The colouring of these southern bergs is magnificent: the general mass has an appearance like loaf sugar; the crevices, caves, and hollows are of the deepest and purest azure blue; at night they have a luminous glow, and there are reasons for believing that many are to some extent phosphorescent. The pack-ice, brash-ice, and pancake ice of the Antarctic do not differ essentially from the same kinds of ice in the Arctic Seas, though the pack is usually less heavy.

The ice-cap in the southern hemisphere may, it is asserted, be several miles in thickness near the pole, and it is in connection with this that some of the most interesting scientific investigations require to be made. For some scientific men doubt if it be possible, under the conditions, for so great a depth of an ice-cap to be formed. Did we know more about the temperature of the regions and of the condition of the rocks and soil on which the ice rests, a more satisfactory conception of the probable state of matters would be possible. Assuming the permanent temperature of the surface or sub-surface of the ice-cap to be 80° F. below the freezing-point, then, according to the rate of rise of temperature observed in temperate regions, the freezing-point will only be attained at a depth of 4320 feet. Further, from the observed rise of temperature in polar ice within moderate depths, it could be determined at what depth the ice would be just about to melt. The thermal conductivity of ice could be determined with accuracy by finding the daily and annual variation of temperature at various depths below the surface. From the thermal conductivity, and the observed rise of temperature with increase of depth, the rate of out-flow of heat per unit of ice-surface can be immediately calculated.

Professor James Thomson's experiments showed that the melting-point of ice was lowered 0°·0075 C. or 0°·0135 F., by each additional atmosphere of pressure, therefore to lower the melting-point 1° C. 133½ atmospheres are needed; to lower it 1° F. 74$\frac{2}{27}$ atmospheres. Theoretically 37·7 feet of ice are equal to one atmosphere, but on the assumption that 40 feet of ice are equal to one atmosphere, ice barely 1500 feet high could rest on a soil of 31°·5 F. without melting; and ice barely 3000 feet high on a soil of 31°·0 F. without melting. It is most probable that pressure is unequally distributed through the ice-cap at different times; that at certain points the pressure may be sufficient to melt the ice, but regelation immediately takes place. By a process like this we may probably account for the compact ice in the deeper parts of the table-bergs and its more areolar structure near the upper surface. These subjects are here mentioned to show how great an addition to knowledge a continued series of observations on the Antarctic Continent would effect, and how much they would tend to settle many vexed scientific questions.

We have much more definite information about the Antarctic and Southern Ocean than about the Antarctic Continent, although a much fuller knowledge of these waters is very desirable at different seasons of the year; for it must be remembered that all the voyages to these regions have been made during the summer months of January, February, and the first weeks of March. The observations during these months indicate that there is a permanently low barometer towards the South Pole, that the prevailing winds blow in towards it in a cyclonic manner, and that there is almost constant precipitation as far as 70° south.

The mean temperature of both the air and sea surface south of the parallel of 62½° S. is even in summer at or below the freezing-point of sea water. Between 60° and 62½° S. a sensible rise takes place; temperatures as high as 38° F. have been recorded of both air and sea in March between these parallels. Temperatures below the surface of the sea were taken by Cook, Ross, and Wilkes, but as the thermometers were not protected from pressure the results obtained are not very satisfactory; there is, however, one marked peculiarity about the results obtained by those unprotected thermometers:—the temperature at a depth of 100 fathoms was either the same or lower than that at the surface, and was at or below the freezing-point of fresh water. The object of the *Challenger's* excursion into the Antarctic in 1874 was not to reach a very high latitude, but chiefly to make observations on the depth, temperature, and specific gravity of the sea in the vicinity of the ice, and her observations are of the greatest value, though not exhaustive or completely satisfactory in every respect.

The important serial temperature observations taken during this southern cruise are shown in the following table (page 536), with full details.

An examination of this table shows that throughout this part of the Antarctic and Southern Ocean there was a cold layer of water sandwiched between a warm one on the surface and another warm one at the bottom.

Table of Temperatures obtained in the Antarctic Regions.

Depth in Fathoms.	14th February. Lat. 65° 42′ S.				19th February. Lat. 64° 37′ S.				21st February. Lat. 63° 30′ S.			
	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.
	°	°	°	°	°	°	°	°	°	°	°	°
Surface	.	.	.	29·5	.	.	.	32·0	.	.	.	32·0
10	.	.	.	.	.	.	.	.	32·0	32·0	31·5	31·5
20	.	.	.	.	.	.	.	.	32·0	32·0	31·0	31·0
25	.	.	.	.	.	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.	.	35·0	35·0	30·0	30·0
40	.	.	.	.	.	.	.	.	32·5	32·5	29·3	29·3
50	30·2 30·2	30·0 30·5	29·0 29·0	29·0	31·4	32·0	29·2	29·2	32·5	32·5	29·3	29·3
60	.	.	.	.	.	.	.	.	.	.	.	.
70	.	.	.	.	.	.	.	.	.	.	.	.
80	.	.	.	.	.	.	.	.	.	.	.	.
90	.	.	.	.	.	.	.	.	.	.	.	.
100	30·2 30·2	30·0 30·5	29·0 29·0	29·0	31·6	31·8	29·0	29·0	.	.	.	.
150	.	.	.	.	.	.	.	.	.	.	.	.
200	30·2 30·2	30·5 30·5	29·0 28·8	30·5	.	.	.	.	.	.	.	.
250	.	.	.	.	.	.	.	.	.	.	.	.
300	30·2 30·2	32·0 32·0	29·0 29·0	32·0	33·0	33·8	29·4	33·8	.	.	.	.
400	.	.	.	.	.	.	.	.	.	.	.	.
500	30·2 30·2	32·8 32·8	29·0 28·8	32·8	.	.	.	.	.	.	.	.
Bottom	30·0 30·0	33·0 33·0	28·8 28·8	Un-certain.	31·0 31·5	32·9 33·0	29·3 29·0	Un-certain.	.	.	.	.

Depth in Fathoms.	26th February. Lat. 62° 26′ S.				11th February. Lat. 60° 52′ S.				3rd March. Lat. 53° 55′ S.			
	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.
	°	°	°	°	°	°	°	°	°	°	°	°
Surface	.	.	.	33·0	.	.	.	34·5	.	.	.	37·2
10	.	.	.	.	35·5	35·5	34·0	34·0	40·0	40·5	36·8	36·8
20	.	.	.	.	35·8	35·8	33·5	33·5	42·0	42·0	36·8	36·8
25	.	.	.	.	.	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.	.	40·8	40·5	36·6	36·6
40	.	.	.	.	.	.	.	.	41·0	41·0	36·6	36·6
50	.	.	.	.	35·5	35·6	32·0	32·2	41·0	41·0	36·6	36·6
60	.	.	.	.	36·5	36·5	32·2	32·2	40·5	40·5	36·6	36·6
70	.	.	.	.	36·0	35·2	32·2	32·2	41·5	41·5	33·0	33·0
80	.	.	.	.	34·5	34·5	32·5	32·2	42·5	42·0	32·5	32·5
90	.	.	.	.	35·0	34·8	32·8	32·2	42·0	42·0	32·5	32·5
100	31·8 32·0 32·5	31·8 32·0 32·8	31·8 32·0 31·8	31·9	35·0 35·0 35·8	34·0 34·8 35·8	32·0 32·0 32·0	32·0	40·5 43·0	42·5 43·2	32·7 32·8	32·5
150	33·5 33·0	34·0 34·0	32·0 32·0	34·0	35·5	36·0	31·8	35·0	.	.	.	Uncertain.
200	31·0 32·5	34·0 34·0	31·0 31·8	34·0	34·0 34·0 35·5	35·0 35·2 35·8	32·0 32·8 32·0	35·3	42·5	43·0	33·0	
250	.	.	.	.	.	.	.	.	.	.	.	
300	.	.	.	.	34·0	35·5	32·2	35·3	42·5	42·5	33·0	
400	.	.	.	.	.	.	.	.	42·8	43·0	32·6	
500	.	.	.	.	.	.	.	.	42·5	42·5	32·8	
Bottom	.	34·0	31·3	Un-certain.	41·0 41·0	41·0 41·0	32·0 32·0	Un-certain.	41·0 41·0	41·0 41·0	32·0 32·2	32·1

The temperature of the lower warm stratum could not however be accurately determined, owing to the construction of the instruments, for as the thermometers were maximum and minimum ones, and had, for instance, passed through a warm surface layer of 37°·2, and a cold layer of 32°·5, at 80 fathoms (in lat. 53° 55′ S.), they were unable to record any alteration between those temperatures at greater depths. Had the *Challenger* been supplied with the reversing thermometers now in use for sea work, the temperature of the deep warm stratum could have been accurately recorded. The general results may be thus stated :—A cold intermediate stratum was traced as far north as 54° S., where its temperature was 32°·5 at a depth of 80 fathoms; further south it decreased, until in lat. 66° S. it was 29° from immediately below the surface to a depth of 200 fathoms, nearly as low as the freezing-point of salt water. It may be said then that there stretches northwards a wedge of cold water for more than twelve degrees of latitude, underlying and overlying strata at a higher temperature. The base of the wedge is situated south of 66° south, where the water is very probably 29° or under from surface to bottom, for the temperature of the lower stratum decreases as higher latitudes are reached. The remarkable fact brought out by these observations is that in lat. 50° south the bottom water has a temperature of 33°·5 F., which is but little different from that of the bottom water all over the Indian and other oceans.

Mr. Buchanan's observations on the density of sea-water, and his experiments on the formation of sea-water ice throw much light on the causes of this remarkable distribution of temperature. The observations on density are collected in the following table, which contains all the observations made on water from the bottom or intermediate depths with the density of the surface water at each station.[1]

Density of Water at 60° *F.* (*Distilled Water at* 39°·2 *F.*=1).

Depth from which water was taken.	A Station 143.	B Station 144.	C Station 147.	D Station 154.	E Station 156.	F Station 157.	H Station 158.	K Station 160.	L Station 152	M Station 153.	N Station 159.
Surface, . .	1·02653	1·02508	1·02506	1·02452	1·02501	1·02501	1·02514	1·02560	1·02505	1·02409	1·02554
50 fathoms, .	623	..	..	527	..	499	511	563	..	..	..
100 " .	611	515	504	} 140 fths 1·02542	{ 552	529	533	554	..	..	..
200 " .	587	524	528		{ 557	..	538	563	..	..	..
300 " .	566	524	526	553	556	..	534	550	..	..	..
400 " .	572	530	528	555	556	..	..	546	..	..	..
Bottom, . .	601	514	542	520	507	550	545	559	552	560	553
Depth (fathoms),	1900	1570	1600	1800	1975	1950	1800	2600	1260	1675	2150
Latitude S., .	36° 48′	45° 57′	46° 16′	64° 37′	62° 26′	53° 55′	50° 1′	42° 42′	60° 52′	65° 42′	47° 25′
Longitude E., .	19° 24′	34° 39′	48° 27′	85° 49′	95° 44′	108° 35′	123° 4′	134° 10′	80° 20′	79° 49′	130° 32′

[1] See *Voyage of H.M.S.* "*Challenger*," *Narrative*, vol. i. p. 423.

It will be observed that the densities in column A are higher than in any other column; the water from surface to bottom bears evidences of having been warmed and concentrated in tropical regions: the position being where the warm water of the Indian Ocean is carried southwards of the Cape of Good Hope. The densities of all the other columns are from stations within the zone of Southern Icebergs, and it will be observed that the density of the surface water increases as a higher latitude is approached, and also that, generally speaking, there is a rise of density with increasing depth. It is therefore probable that the bottom water in the deeper regions of the Antarctic Ocean is due to a mixture of water cooled to a low temperature in these regions with water drawn in from a lower latitude with a higher temperature.

The effect produced on a sea when its surface is frozen over is an important consideration in discussing these relations of temperature and density. Sea-water ice is composed of a mixture of ice and salt crystals and mechanically enclosed brine, so that ocean water is divided by freezing into two saliniferous parts—one liquid, one solid,—which are of different chemical compositions: a striking feature of the freezing process being that the ice is richer in sulphates and the brine in chlorides.

In the act of freezing, then, sea-water separates into ice which contains less salt and into brine which contains more salt than the parent sea-water, and it may be assumed that both the ice and the brine have the same temperature (29° F.). The brine being denser than the surrounding water, sinks into it, and by mixing with it renders it more salt, and, at the same time, lowers its temperature. The tendency is, in a sea isolated from circulation, to produce a uniform temperature of about 29° F. throughout its depth, and this is actually what is observed in the Norwegian Sea, which is separated from the Atlantic by a ridge, with a maximum depth of 250 fathoms of water over it.

In the portion of the Antarctic Ocean traversed by the *Challenger* there is only a very slight and gradual shoaling of the water from the Indian Ocean towards the Antarctic Circle. Hence there is no impediment to the free circulation of the water between high and low latitudes. The effect of the winter cold in high latitudes is in one respect the same as that of heat in tropical regions—it removes water from the sea, and thus produces concentration; in the tropics the water is removed as vapour; in the polar regions it is removed as ice, leaving a salter water at the freezing temperature of the ice, which sinks and cools the deeper water by convection. In summer, when the ice breaks up, some of it melts, and forms a layer of less saltness, but low temperature, at the surface. This layer, along with the melting pack-ice and icebergs floating in it, is generally driven in part far to the northward of the place where it was formed. Its place must be supplied from below by water coming from lower latitudes, unless the supply of land ice from the Antarctic continent were sufficient to supply the deficiency.

In the Atlantic, Indian, and Pacific Oceans the return currents of dense warm tropical water, which run southward along the eastern shores of South America, Africa, and Australia, penetrate southwards into the regions of the Great Southern Ocean, and the effect of these currents can evidently be traced in the distribution of the southern ice at its northern limits. The water of these currents has such a high salinity that it can bear much dilution, and still sink through the water of high latitudes at the same temperature. It is very probable, therefore, that the cold water of the bottom of the ocean, which mostly comes from the southern hemisphere, leaves the surface between the parallels of 42° and 56° of south latitude. From this zone the water is drawn northward, to make good the deficiencies caused in the tropics by surface currents and evaporation; and there can be little doubt that it also flows southward to supply the place of the ice and cold surface water drifted northward. The comparatively warm water which reaches the Antarctic Circle at depths greater than 200 fathoms can only come from such a source; its temperature being, of course, lowered by being drawn into Polar areas. If there were in the Antarctic Ocean basins like that of the Norwegian Sea, cut off by submarine ridges from general ocean circulation, their waters would have the same low temperature of 29° F. from surface to bottom. The brisk superficial circulation which is kept up in the Arctic Ocean by the extension of the Gulf Stream waters along the coast of Norway, and the return of cold Polar currents, removing ice by the eastern coast of Greenland and Baffin's Bay, keeps that ocean comparatively open to a very high latitude. A similar circulation appears to be entirely wanting in the Antarctic Seas, hence their ice-bound character. Ross mentions a strong tidal current between Possession Island and the mainland of Victoria, but we have on the whole very little information about the tides, and no well-marked surface currents have been recorded.

Although vegetation appears to be quite absent from Antarctic land, yet at the surface of the ocean, Diatoms, microscopic plants with siliceous coats, are met with in enormous abundance. They belong to many genera and species, and are the chief source of food for the animals living in these seas. The tow-nets were on some occasions so filled with them that the whole contents, when dried over a stove, formed a felt-like mass. Associated with the Diatoms were very many Radiolarians, minute animals with beautifully fenestrated siliceous shells and skeletons. At times the Antarctic Ocean has a very peculiar green colour, and when the water is examined, it is found to be filled with little spherical jelly-like bodies, about 0·1 mm. in diameter, which contain four yellowish or greenish spots. When a glass jar of the water is held in certain lights, these minute algæ can be seen with the naked eye. Whenever the ship passed out of these greenish bands, the minute spheres could not be seen in the water.

South of the latitude of 50° S. three species of *Globigerina* were met with in considerable abundance at the surface, viz., *Globigerina* *bulloides*, *Globigerina dutertrei*, and *Globigerina inflata*. Among other pelagic creatures, minute Crustaceans are very abundant in the Antarctic Ocean, such as Copepods, Ostracodes, Amphipods, and Schizopods. Pteropods and pelagic Annelids and Ascidians are also met with in great numbers. Whales and grampuses have been seen by all Antarctic voyagers, and seals and penguins are seen both in the water and resting on the ice. During her stay among the ice, the *Challenger* procured specimens of the following aquatic birds :—

Oceanites oceanicus, Kuhl.
Thalassœca glacialoides, Smith.
Thalassœca antarctica, Gaim.
Ossifraga gigantea, Gm. (Giant Petrel).
Pagodroma nivea, Gm. (Snow Petrel).
Daption capensis, Linn. (Cape Pigeon).
Prion desolatus, Gm. (The Prion).
Diomedea (Phœbetria) fuliginosa, Gm. (Black Albatross).
Stercorarius antarcticus, Less. (Skua).

Four kinds of deposits were met with by the *Challenger* during her Antarctic trip,—viz., blue mud, Diatom ooze, Globigerina ooze, and red clay.

The first of these was found in depths of 1675, 1800, and 1300 fathoms, at the most southern latitude reached by the *Challenger*, between lat. 64° and 66° S. These blue muds contained less than 11 per cent. of carbonate of lime, which consisted chiefly of the dead shells of *Globigerina dutertrei*, and about 20 per cent. of the remains of siliceous organisms, chiefly Diatoms. The mineral particles consisted of quartz, felspars, hornblende, garnets, glauconite, mica, tourmaline, and fragments of granitic, amphibolic, and other rocks. From the depth of 1675 fathoms the dredge brought up many kinds of rocks and pebbles, some of them showing distinct marks of glaciation, and many of them having a coating of peroxide of manganese on that part which had projected above the mud when lying at the bottom. The rocks belonged to the following lithological types :—granitites, quartziferous diorites, schistoid diorites, amphibolites, mica-schists, grained quartzites, and partially decomposed earthy shales.

To the northwards of the Stations at which blue mud was found, or between lat. 64° and 53° S., in depths of 1260, 1975, and 1950 fathoms, the deposit was a Diatom ooze, usually of a yellowish straw colour, which, when dried, had the aspect of flour, the particles being extremely fine, and the whole taking the impress of the fingers when pressed, gritty particles being now and then recognisable. One of the samples contained as much as 22 per cent. of carbonate of lime, consisting chiefly of the dead shells of *Globigerina bulloides*, *Globigerina inflata*, and *Globigerina dutertrei*. The mineral particles were similar to those in the blue muds just mentioned, and appeared to make up from 15 to 20 per cent. of the deposits, the whole of the remainder consisting of the frustules of Diatoms and the skeletons of Radiolarians. The dredgings in these deposits yielded, in addition to all the varieties of rocks mentioned in the blue muds farther south, several fragments of pumice-stone, basaltic volcanic rock, palagonite, and one or two fragments of a compact limestone and sandstone.

Between lat. 53° and 47° S. two soundings were obtained in 1800 and 2150 fathoms. The deposit in each case was a whitish Globigerina ooze, containing respectively 85 and 89 per cent. of carbonate of lime, which consisted chiefly of Coccoliths, Coccospheres, and pelagic Foraminifera, belonging to the species *Globigerina bulloides*, *Globigerina inflata*, *Globigerina dubia*, *Pulvinulina micheliniana*, and *Orbulina universa*, together with other Foraminifera and fragments of Echinoderms. The mineral particles appeared to make up 2 to 4 per cent. of the deposit, and consisted of hornblende, magnetite, felspar, vitreous fragments, and a few quartz grains. There were 4 or 5 per cent. of Diatoms and Radiolarians in these Globigerina oozes.

The remaining variety of deposit (red clay) was obtained in lat. 42° S. at a depth of 2600 fathoms. It contained 18 per cent. of carbonate of lime, consisting of fragments and perfect shells of *Globigerina bulloides*, *Globigerina inflata*, *Globigerina rubra*, *Pulvinulina micheliniana*, *Orbulina universa*, a few other Foraminifera, Coccoliths, and fragments of Echinoderms. The mineral particles made up 19 per cent. of the deposit, and consisted of felspars, hornblende, augite, magnetite, pumice, and fragments of volcanic glass, grains of peroxide of manganese, with a mean diameter of about 0·05 mm., while a few rounded fragments of quartz reached a diameter of 0·5 mm. The remainder of the deposit consisted essentially of argillaceous matter, with very minute fragments of crystals and pumice. There was a larger percentage of carbonate of lime in the upper layers of the deposit than in the lower ones. The trawl brought up 10 or 12 litres of manganese nodules, pumice-stones, fragments of palagonite, ear-bones of cetaceans, and sharks' teeth.

From the foregoing description it appears that the deposits forming at the most southerly points reached by the *Challenger* are composed chiefly of continental débris carried into the ocean by the floating ice of these regions, and that this material makes up less and less of the deposit as the distance from the Antarctic Circle increases, until it completely vanishes, as a deposit, about lat. 46° or 47° S., although ice-borne fragments are sparingly found in deposits as far north as the 28th parallel at some points. The deposits along the Antarctic Ice Barrier, which have been called blue muds, resemble in many respects the deposits formed at similar depths off the Atlantic coast of British North America. The nature of the rock fragments dredged in these latitudes conclusively proves the existence of continental land, probably of considerable extent, within the Antarctic Circle. One of the fragments of gneiss dredged from a depth of 1950 fathoms measured 50 by 40 centimetres, and weighed more than 20 kilogrammes. The deposits found by Ross and Wilkes along the edge of the ice barrier appear to have been quite the same as those found by the *Challenger*. In the region occupied by the Diatom ooze, northward of the blue muds, the predominant feature of the deposit is due to the innumerable frustules of Diatoms and skeletons of Radiolarians which have fallen from the surface and sub-surface waters of the ocean. Farther north, again, the pelagic Foraminifera predominate in the deposit, except at the depth of 2600 fathoms, where the greater part of them has been removed by the solvent powers of the sea-water, as is usual at great depths in the ocean.

The dredgings and trawlings during the Antarctic trip were exceedingly productive, and yielded many new genera and species belonging to nearly all the invertebrate groups. In the Zoological Reports of the *Challenger* already published species are described belonging to about thirty new genera and sixty-four new species.

In this connection it is interesting to point out that Ross dredged up many animals from 300 and 400 fathoms, and even greater depths in the Antarctic long before the Norwegians, Americans, and the expeditions of the *Lightning* and *Porcupine* of our own country, although his results have been overlooked, in consequence of the specimens not having been preserved and carefully described. Ross, referring to his dredgings in 1841, says: "It was interesting amongst these creatures to recognise several that I had been in the habit of taking in equally high northern latitudes; and, although contrary to the general belief of naturalists, I have no doubt that from however great a depth we may be able to bring up the mud and stones of the bed of the ocean, we shall find them teeming with animal life; the extreme pressure at the greatest depth does not appear to affect these creatures; hitherto we have not been able to determine this point beyond a thousand fathoms, but from that depth several shellfish have been brought up with the mud."[1]

From the fact that the same species were to be found at both poles, and that these animals are very sensitive to a change of temperature, he suggested that it would be possible for them to pass from one frigid zone to another, provided the temperature of the intervening sea bottom had a range not exceeding 5° F. Ross's observations confirmed his idea that the temperature at the bottom of the open sea was uniform in all latitudes, and subsequent investigations prove it, generally speaking, to be correct.

Sir James Ross was an indefatigable zoological collector, but it is to be regretted that his large collections of deep-sea animals, which he retained in his own possession after the return of the expedition, were found to be totally destroyed at the time of his death. Had these been carefully described during the cruise or on the return of the expedition to England, the gain to science would have been immense, for not only would many new species and genera have been discovered, but the facts would have been recorded in the journals usually consulted by zoologists,

[1] *Antarctic Voyage*, pp. 202, 203.

instead of being lost sight of, as was the case. A large number of zoological drawings made by Sir Joseph Hooker during this Antarctic expedition were recently handed to the various naturalists engaged in working up the *Challenger* collections, and these show that some of the *Challenger* discoveries had been anticipated by Ross. Sir Joseph Hooker, whose botanical researches are so well known, recorded the existence of immense numbers of Diatoms on the surface of the Antarctic Ocean, and pointed out that the mud at the bottom, as observed in Ross's dredgings, consisted largely of their dead remains.

APPENDIX I.

Report of Royal Society of Edinburgh on Proposed Scheme of Antarctic Explorations.

The Royal Society, Edinburgh,
9th July 1886.

At a meeting of Council, of this date, it was resolved that the communication from Sir Erasmus Ommanney be referred for consideration and report to a Committee consisting of the Secretaries of the Society, Professors Tait, Sir William Turner, and Crum-Brown, with Professors Sir William Thomson, James Geikie, Lord M'Laren, Messrs. J. Y. Buchanan, Alex. Buchan, and John Murray, *Convener*.

21st July 1886.

The Committee recommend that an answer be returned to Sir Erasmus Ommanney, stating that the Council will support heartily any movement having for its object the fitting out of an expedition for the thorough exploration of portions of the Antarctic Regions. The Committee have drawn up a number of suggestions as to the investigations that should be attempted during such an expedition, which they propose should be forwarded for the consideration of the British Association Committee.

General.—The principal object of the proposed expedition would be to investigate the physical and biological conditions of the seas and lands to the south of latitude 50° S.

The highest southern latitude has been attained by Ross, namely 78° S., in the meridian of New Zealand, the distance from Otago to Mount Erebus being about 2000 miles. The next highest latitude, 74° S., was attained by Weddell in longitude 35° W. Here he turned northwards in a sea free of ice, and with only four icebergs visible. In another year Ross was stopped by impenetrable ice before he got within 10° of this latitude. Weddell's furthest is within 1500 miles of the Falkland Islands.

Judging from the actually discovered land known to extend for a long distance about the parallel of 65° S., it is probable that a ship would have best chance of success in attempting to penetrate far south in one or other of the above localities. Much valuable information for the guidance of the commander of such an expedition would be furnished by sending a pioneer down to report on the distribution of the ice in the early spring, before it has begun to break up. Hitherto expeditions have not usually started till the middle of December, and have rarely attained their highest latitudes until the advanced season, and the consequent rapid formation of young ice, warned them to retire. It might perhaps be advantageous to make the ships of the expedition their own pioneers, and start them away south about the equinox. They would thus have the advantage of the long days in the opening season to explore a considerable extent of the ice-belt in its wintry state. As a result of these explorations they would be able to take up their position in the most advanced open water of the season, and to push southward from the most advantageous starting-point the moment the ice began to break up. The whole season would thus be available for work in the Antarctic regions proper. It is the advantage of the Antarctic over the Arctic regions that they can be approached, circumnavigated, and surveyed during the whole year. It would of itself be a matter of great interest to investigate the condition of the ice-belt in its winter state, and to know how far the enormous icebergs floating and probably moving in the ice-park helps to keep it open or to break it locally.

The expedition should consist of two ships, with good steam and sail power, and thoroughly protected both as to hull and propellers. Their equipment and provisioning would be regulated by Arctic experience. Both should penetrate in company as far south as possible, preferably until a suitable wintering station is found, when the second ship would turn over to the first all the coal and other stores she could spare, and then make her way to the starting port. The first ship would then proceed to make arrangements for the winter, and if possible for sledge journeys in the early spring. The second ship would return next season to the assistance of her consort.

It should be one object of such an expedition to render as complete an account as possible of the configuration of the bottom of the sea over which it passes. It would therefore be necessary that both ships should be furnished with complete duplicate wire sounding machines fitted with steam-winding gear. They should also be supplied with a sufficient quantity of the very best (*Challenger*, or other) sounding-line for temperature purposes, and a steam winch to work it. Also a wire dredging-rope, with rule and other suitable fittings.

Thermometers, piezometers, and water-bottles would of course be taken.

Meteorology.—The most remarkable feature perhaps of the meteorology of the globe is the permanently low atmospheric pressure in the Southern Hemisphere south of latitude 40°, with its attendant phenomena of strong

W. and N-W. winds, large rain and snow falls round the South Pole, and the enormous icebergs of southern seas.

Owing to the small number of observations hitherto made, which are necessarily much restricted as to the season of the year and the locality, our knowledge of the meteorology of the Antarctic regions is most imperfect. It is scarcely necessary to refer to the importance of this knowledge as regards the climates of the globe, more particularly the climates of geological areas. Among the points most desirable to be known is the geographical distribution of mean atmospherical pressure through the seasons, so as to reveal the region or regions where the mean pressure is least and where it is greatest, relatively to the general distribution of pressure over the Antarctic regions.

Observations hitherto made seem to point to the existence in certain parts of the Antarctic regions of a mean pressure considerably under 29·000 inches, whereas in the same latitude elsewhere pressure is considerably higher. Should this state of things be shown to hold good, it follows, reasoning from what obtains in the Arctic regions, that open water extends far south in certain quarters, whereas in others there is no open water, but a uniform sheet of snow and ice to the South Pole.

Another inquiry is an investigation of the low-pressure areas, or cyclones as they are usually designated, of the Antarctic regions, their relative depths to the surrounding low pressure of those southern regions, their relative frequency in different regions and seasons, and the nature and amount of the precipitation accompanying them.

The regions of greatest and of least precipitation would thus be disclosed, and possibly also the distance an excessive precipitation extends polewards.

If an expedition similar to that of the *Challenger* were fitted out for a three or four years' cruise in the Antarctic regions, one of whose objects was the investigation of the meteorology, results of the highest importance might confidently be looked for.

The observations would be similar to those made hourly by the *Challenger* in the Antarctic regions in 1874; and an effort should be made to place barographs and thermographs, constructed to go several months, in different suitable situations. It is believed that although there are difficulties connected with this last suggestion, yet they may be overcome, and the experiment is well worthy of a serious trial.

Sea Temperatures.—As regards sea temperatures, these should be taken very frequently at all depths, as well as regularly at the surface. It is scarcely possible to exaggerate the importance of the new results that would be obtained by the use of the improved deep-sea thermometers, such as Negretti and Zambra's with the Scottish frame, as well as with the improved Miller-Cassella's of Buchanan's pattern. The results recently obtained by these instruments in Loch Fyne revealed the existence of a stratum of cold water sandwiched between two considerably warmer strata. Seeing that the *Challenger* was not able to ascertain or observe such a condition of things in the Antarctic during her cruise, the importance of ascertaining if such a condition exists is of prime importance on the question of oceanic circulation and other questions of ocean physics.

Deep-Sea Deposits.—These should be carefully examined and preserved whenever obtained. A deposit of very pure diatom ooze appears to surround the Antarctic land about the outer edge of the ice-fields. As the Antarctic continent is approached, detritus from the continent is mixed up with the diatoms, so that the deposit becomes a blue mud with all the mineral particles and rock fragments usually found close to land. The *Challenger* found in these deposits granitites, quartziferous diorites, mica-schists, quartzites, and earthy shales. An examination of these deposits taken in connection with the depths, would enable the position and extent of the Antarctic to be mapped out with great certainty. If the rocks dredged from the bottom of the sea be carefully preserved and the localities noted, and they be procured at a sufficient number of points, they will give a fair notion of the rocks that underlie the great ice-sheet.

Geological Observations should embrace the following:—

A. *Glacial Phenomena.*—1. Existing glacial conditions to be examined, particularly in such islands as Kerguelen's Land, Georgia Island, etc. Traces of former more extended glaciation will probably be found in all those islands, as in the islands in the far north of our own hemisphere. Evidences of such extended glaciation are *roches moutonnées*, erratics, perched blocks, boulder clay, terminal moraines, etc. Glacial deposits occurring on the low-lying parts of such islands (valleys) should be examined for the possible occurrence of interglacial or infraglacial accumulations of fresh water, terrestrial, or marine origin. Alternations of ice and alluvial deposits should be looked for. 2. *Icebergs.*—Size and form; character of the ice. Look for stones, earth, etc. Icebergs and land ice should, in these regions, be regarded and studied as a more or less homogeneous rock forming the outermost layer of the earth's crust. If water be observed running away from beneath the ice-cap or from beneath glaciers, its appearance and temperature should be carefully noted. In the event of excursions being possible on the surface of the continental ice, a careful and detailed description of all the appearances should be given.

B. *Peat or Bogs.*—Good-sized specimens of peat to be obtained. Search for relics of "scrub," etc., under peat. Under the peat of many Arctic regions traces of small trees (juniper, etc.) have been discovered, indicating milder conditions of climate than now obtain. Possibly similar evidence may be encountered in the islands of high southern latitudes. That mild and even genial conditions of climate extended far into the Arctic Circle in Pleistocene and Postglacial times—and that these conditions alternated with severe glacial conditions—appears well established. It would be extremely important to ascertain whether any evidence of similar climatic changes occurs in the corresponding latitudes of the Antarctic.

C. *Raised Beaches.*—Low and high level deposits containing marine organisms occur on the coast lands within the Arctic Circle. It is important to know whether similar evidence of oscillation of the relative level of land and sea occurs within the Antarctic Circle. The *Challenger* observed raised beaches on Nightingale Island, Tristan d'Acunha Group.

D. Rock Specimens.—The rock specimens brought from the Antarctic lands by Sir J. C. Ross appear to have been all volcanic. It would be important to obtain a good collection of such rocks, and to search for any trace of rocks of aqueous origin, such as sandstones, limestones, etc. If aqueous rocks are met with, they should of course be searched for fossils.

Physical Observations.—Under General Physics, the following are worthy of special consideration :—

1. Depth of ice-sheet. Temperature of it at different depths, as found by boring—*horizontally* in the wall of a crevasse if possible. If serial temperature observations could be taken in such borings in the ice-cap, they would be of great value. Lowest temperature of earth's surface as found by thermometer, either buried or laid on it, and covered by a very thick layer of badly-conducting material. Such thermometers should be left for months. There would be most valuable results to be had from even a single set of temperature observations in bore, say 100 feet deep in the surface-strata. Specimens of the material bored through must be obtained for determination of conductivity, specific heat, etc., so that the amount of heat annually coming from the interior may be calculated.

2. The tides and tide currents at island stations—the smaller and more isolated the island the better. These should be carried out at each station for a lunation, at least, if possible.

3. The usual magnetic elements, wherever and whenever possible.

4. Pendulum observations, wherever possible, should be made.

5. Atmospheric electricity.

Zoology and Botany. — The *Challenger's* observations on the marine fauna and flora of these regions are of great interest, and it is exceedingly important to extend them. All the organisms obtained by dredging should be carefully preserved. It would also be very desirable to give special attention to the minute pelagic algæ living in the surface waters, and frequently discolouring them. The bones of seals and whales, which are often found in considerable numbers on the shores of these southern islands, should be collected and sent home.

APPENDIX II.

Excerpt from the Minutes of the Council of the Scottish Geographical Society.

"Edinburgh, *7th August* 1886.

"The Council of the Scottish Geographical Society met on Friday, 6th August 1866, to consider the best means for promoting further Antarctic research; and, in connection therewith, the Report of a Special Committee of the Royal Society of Edinburgh was laid upon the table.

"The Council, concurring in the finding of the Committee, and warmly approving of the recommendations contained in its Report, unanimously resolved to support any movement having for its object the careful exploration of the Antarctic Regions, as being certain to result in large and important accessions to our knowledge of Geography, Oceanography, Meteorology, and other branches of Physical Science. The Council are, moreover, of opinion that any expedition despatched to the Antarctic Regions in the prosecution of these objects, should be undertaken at the expense of Her Majesty's Government. It may, however, be worthy of consideration, whether the co-operation of the Governments of Australia, New Zealand, and Tasmania might not be invited in an expedition such as this, which is of an Imperial character.

"The Council would suggest that a Conference be held in London at an early date, composed of delegates from the leading Scientific Societies in Great Britain and Ireland, to consider the scheme, and draw up a joint memorial to Her Majesty's Government in support of the expedition.

"The Council directed that copies of this Resolution be forwarded to the Special Committees of the British Association, the Royal Society of Edinburgh, the Royal Society of Victoria, and the Australasian Geographical Society—who have already drawn public attention to the advisability of further Antarctic research—and also to the Royal Society of London, the Royal Irish Academy, the Royal Geographical Society, and other learned bodies."

DRAINAGE AREAS OF THE CONTINENTS AND THEIR RELATION TO OCEANIC DEPOSITS.

By John Murray.

(*Read before the Royal Society, Edinburgh.*)

When engaged in the study of the Physical Geography of the Globe, it is frequently essential to represent the various areas and data which are being dealt with on maps, for thus we often arrive at a more just conception of the relation of these areas or data to one another. The choice of the kind and size of the map to be used is a matter of first importance, and is usually determined by the nature of the facts to be represented.

Some time since, when working at the description and distribution of oceanic deposits, my attention was specially called to the choice of a map for the purpose of representing the areas occupied by the various deposits.

The sphere being non-developable, the exact representation of any portion of its surface upon a plane is impossible. We must choose between a map which preserves the angles and form of any area, but in which the areas are not proportional to the surface of the map representing them, as, for instance, in Mercator's projection, or one, in which all