

a right or left hole passes, the corresponding pricker falls into the hole, and in doing so lifts a spring through the opening *l* or *l'* into the rim of the revolving wheel *O O'*. The spring being caught in the rim of the wheel is obliged to remain there until the wheel makes one complete revolution, and the opening in the rim returns to free it. The wheel makes one revolution while one space passes the pricker. When the spring is lifted into the rim of the wheel it makes connection between the battery and another set of springs. The latter set of springs are acted on by a double cam, *I I'*, which is connected with the same shaft as *O O'*, and revolves with it. During one revolution this double cam by means of the second set of springs sends first one current from the battery into the cable, and immediately afterwards a second current of the opposite name and of rather shorter duration. The first current is the signal and the second is the curb current. If a left-hand hole in the punched paper passes, and the corresponding pricker falls into it, a positive current will be sent first, followed by a negative current, but if a right-hand hole passes, the first current will be negative, followed by a positive one.

Fig. 6 shows the appearance of the punched paper when it is prepared for the Automatic Sender. The specimen represents the signal "understand" and the first seven letters of the alphabet.

#### ON THE CONDITIONS OF THE ANTARCTIC<sup>1</sup>

MY principal object in this evening's lecture is to direct your attention to some of the peculiarities in the physical conditions of the Antarctic regions, and to put you in a better position to contrast these with the more generally known phenomena of the Arctic; and it seems specially appropriate to allow our thoughts to travel for an hour towards that other fortress of the Ice King, a fortress apparently even more hopelessly impregnable, now while the pulse of the nation is still throbbing in sympathy with the brave little band who have just added another chapter to a long and terrible record of daring and self-sacrifice, and have succeeded in the face of almost unparalleled hardships in once more planting the Union-Jack nearest to the North Pole. The propriety is all the greater seeing that Capt. Nares, the gallant leader of the northern explorers, is also the last of the few navigators who have crossed the Antarctic Circle.

I will first of all then give you a brief sketch of our Antarctic experiences in the *Challenger*, and then go on to consider what may be the most probable explanation of some of the most striking of the appearances which we observed.

After spending about a month at Kerguelen Island, making meteorological and other observations, and selecting a suitable spot for the observation of the transit of Venus by the English astronomical party in the following season, the *Challenger* left Christmas Harbour on January 31, 1874, and on February 6 we reached the desolate little group of the Heard Islands, and on the 7th continued our course southwards.

Early on the morning of the 11th a large iceberg was observed bearing south-south-east about six miles off. The berg was table-shaped, the top perfectly flat and covered with a dazzling layer of snow. The perpendicular ice-cliffs bounding it were of a delicate pale blue, apparently perfectly clear, with some caves and slight recesses, where the blue was of a deeper shade. The height of the berg above the sea was 219 feet, and its extreme length by angular measurement was 2,202 feet; so that, supposing it to be symmetrical in shape, the contour of the visible portion being continued downwards, its depth below the

<sup>1</sup> The substance of a lecture by Sir C. Wyville Thomson, F.R.S., delivered in the City Hall, Glasgow, on November 23, under the arrangements of the Glasgow Science Lecture Association.

water may probably have been about 1,500 to 1,800 feet. In the afternoon Lord George Campbell observed during his watch a large piece come off the side, dashing up the spray, and we afterwards saw a quantity of fragments floating off.

The 12th was misty, with a breeze force = 3-4 from the north-west by west. Many icebergs came in sight from time to time and quickly became obscured in the mist. The position of the ship at noon was lat. 62° 36' S., long. 80° 4' E.

Towards evening we passed close to a very beautiful iceberg. One part of it was rounded and irregular in form, putting us in mind of the outline of the Sphinx, and another portion, separated from the first by a fissure, the sea dashing through between them, was like a fragment of a colossal cornice. As the sun sank the ice took a most lovely pink or mauve tint, and when we came close up to the berg it showed out veined in a wonderful way with lines of deep cobalt blue. The ice was perfectly pure and clear. The bergs which we were passing at this time seemed to be breaking up very rapidly; some large fragments had been detached from this one shortly before we reached it, for a quantity of *débris* was floating at a little distance. The pieces washing about in the water very soon lose their edges and angles, and get rounded, and shortly disappear.

The 13th was a fine day, with a light wind from the north-north-east and occasional snow showers. There were some large tabular icebergs along the southern horizon. In the afternoon we passed close to a beautiful berg, very irregular in form, all the curves and shadows of a most splendid blue. The lower portion of the side of the iceberg next us formed a long steep slope into the water, and up this slope the surf ran with every heave of the swell, taking in its course the glorious blue of the ice and ending at the top of the glacia in a line of glittering foam.

The evening fell grey and slightly misty, with a number of icebergs looming through the mist. One or two of us were standing on the bridge about midnight looking at what seemed to be a low bank of white fog coming down upon us, when all at once a universal grating and rasping sound and sensation seemed to pervade the ship, and looking over the side we found that instead of sailing in open water we had passed into the edge of the pack, and as far as the eye could reach to the eastward the sea was closely covered with blocks of ice of all sizes up to six or seven feet in length among which the ship ground her way. A cold-looking moon struggled faintly through the cloud and mist and showed the pack vaguely for a mile or so ahead, covered with a light fog through which we could just see several icebergs looming right ahead of us and on either bow, and the masses of ice becoming larger and forming a closer pack as we passed inwards from the outer edge.

It was a wonderful and in a certain sense a beautiful sight, but one which would certainly require for its full enjoyment very fine weather such as we had, or a specially strengthened ship.

The necessary orders were given, and we veered round and slowly passed out of the pack and into open water; and we hung about beyond the line of wash-ice for the short Antarctic night.

On the following morning there were icebergs all round us, some of them of very fine forms. One which we saw all day on the port quarter was gable-shaped with a glorious blue Gothic arch in the centre, and a separate spire over 200 feet high. It was like a gorgeous floating cathedral built of sapphire set in frosted silver.

All day the pack could be seen from the deck stretching away to the east and south as far as the eye could reach, a mass of rugged glittering blocks one piled on the top of another. The ice-blink, a beautiful and characteristic phenomenon, was very marked above the pack—a clear

band of white reflection rising some  $12^\circ$  above the horizon, and frequently bounded above by a dark rolled cloud.

The 15th was clear and calm, with a light wind from the south-east. There were innumerable icebergs in all directions, some with their blue cliffs entirely visible from the bridge, and the blue waves lapping about their base, and springing up into fissures and recesses in jets of dazzling foam; some only rising above the horizon and slowly developing their varied outlines, and for a time deluding us into the idea that they were low-sloping gently from the water, and that it might be possible to land upon them. All the very large bergs, and some of them were one or two miles in length, were table-topped, evidently retaining their original position.

About 10 o'clock in the evening our attention was called by the officer of the watch to a very beautiful effect of light. There had been a fine crimson sunset, and now a dark curtain of cloud had sunk almost to the water's edge, leaving between it and the sea a long open line of the most vivid flame-colour, broken here and there by an iceberg, which, according to its position, took a rosy glow from the sky, or merely interrupted it with its cold grey outline.

During the forenoon of February 16 we passed on under sail through a splendid double chain of icebergs, most of them table-topped, and showing little evidence of change of form; and all day, on the southern horizon, berg after berg rose solemnly out of the water, at first a white line only, the blue bounding-cliff growing in height as we ran southwards. Shortly after noon we crossed the Antarctic circle, and a little later we reached our most southern point, lat.  $66^\circ 40'$  S.; long.  $78^\circ 22'$  E. exactly fourteen hundred miles from the South Pole.

As the season was advancing, and as there was no special object in our going further south—a proceeding which would have been attended with great risk to an unprotected ship, since, while the temperature of the surface-water ranged between  $-1^\circ 67$  and  $-2^\circ 0$  C. ( $29^\circ$  and  $28^\circ 4$  F.), very close to the freezing-point of sea-water, the temperature of the air fell to  $-4^\circ 44$  C. ( $24$  F.), and once or twice the water began to show that sludgy appearance which we know sets so rapidly, converting in a few hours an open pack into a doubtfully penetrable barrier—Capt. Nares decided upon following the edge of the pack to the north-eastward, towards the position of Wilkes' "Termination Land."

From our most southern point the sea was tolerably clear of ice for at least twenty miles in a south-westerly direction. The whole of the horizon to the south-east was closed by a chain of very uniform and symmetrical flat-topped bergs, all about 200 feet high above the water, one upwards of three miles in length, and several between one and two miles.

During the next week we were making our way slowly to the north-east, along the edge of the pack, sometimes dipping into it a little way, or crossing outlying loose patches.

The pieces of ice on which we were bumping every now and then were 10 to 20 feet in length, rising from 1 to 2 feet out of the water. Most of them were covered with a smooth layer of lately fallen snow, which had apparently not even got splashed with the water which was lapping round the blocks, it was so pure and white.

When the ship struck a block, the ice was usually driven aside unbroken; but the crust of snow was shattered and fell into the water. At the line where the water broke against the ice-blocks, they were all more or less honeycombed and worn-looking, and along this line many of them were of a dirty-yellow colour, probably from the washing of diatoms and crustaceans into the spongy ice. The temperature of the air averaged about  $-4^\circ 7$  C. ( $23^\circ 5$  F.) in the shade; and that of the surface of the sea  $-2^\circ 78$  ( $27^\circ$  F.); every overhanging ledge of an iceberg was fringed with delicate new icicles, and the

"gummy" look of the surface, threatening the formation of young ice, was very evident. The sea was usually a splendid deep blue.

The weather changed during the night of the 23rd, and at daylight on the morning of the 24th the wind was rising fast with a cloudy sky and frequent snow-showers. We were very anxious to get a haul of the dredge in this position, and Capt. Nares had it put over in the hope of getting it up before the weather became too boisterous. The wind and sea rose so fast, however, that it was found necessary to shorten the operation. The dredge was got in safely, but, as we anticipated, it was empty, and had probably never reached the bottom. During the forenoon the weather got rapidly worse. The snow became continuous, and was so thick—blinding clouds of singularly beautiful wheel-like crystals, which stung the face as if they were red hot—that we could scarcely see the length of the ship. We tried to get under the lee of an iceberg; but while reefing an eddy caught the ship and dragged her towards the berg, which she fouled, carrying away her jibboom. At three P.M. things were nearly as bad as they could be. The wind was blowing from the south-east by east, with a hurricane force, in the squalls; the sea was running very high; the temperature had fallen to  $-6^\circ 11$  C. ( $21^\circ$  F.); we were surrounded with icebergs, which we could not see for the sheets of blinding snow, but we could hear the dull boom of the surf dashing upon them. When the gale was at its height we saw the loom of an iceberg on the lee-bow, and we were drifting directly upon it. As there was no time to steam ahead, Capt. Nares went full-speed astern with the four boilers, and set the reefed main topsail aback, and under this sail the ship fortunately gathered stern-way, keeping broadside to the wind, and we drifted past the berg. Towards evening the wind fell a little, and we moved about all night between two bergs, whose position we knew, keeping as much as possible under their lee till daylight.

On the morning of the 25th this storm, which was one of the most trying and critical episodes in the whole voyage, was entirely over, and the air was calm and clear. We pushed a couple of miles into the pack to the north-east. We were now about fifteen miles from the position of Termination Land on the chart sent by Lieut. Wilkes to Capt. Ross. The sky was clear to the southward and eastward, the direction of the supposed land, but there was nothing which could be taken even for an "appearance of land." A sounding taken close to the edge of the pack had given a depth of 1,300 fathoms, and there was no trace of land *débris* on any of the icebergs. We were forced to conclude that Lieut. Wilkes had been in error, and that there was no land in this position. We now ran on steadily in a north-easterly direction towards Cape Otway, and on March 4 we passed a low irregular iceberg, the last we saw during our southern cruise of 1874. We sighted Cape Otway on March 16, and on the 17th we anchored off Sandridge Pier, in Hobson's Bay.

In these high southern latitudes, at all events at the point where we crossed the Antarctic circle, it seems that originally all the icebergs are tabular, the surface perfectly level and parallel with the surface of the sea, a cliff on an average 200 feet high bounding the berg. The top is covered with a layer of the whitest snow; now and then a small flock of petrels take up their quarters upon it, and trample and soil some few square yards, but after their departure one of the frequent snow showers restores it in a few minutes to its virgin whiteness. The upper part of the cliff is of a pale blue, which gradually deepens towards the base. When looked at closely, the face of the cliff is seen to be traversed by a delicate ruling of faint blue lines, the lines more distant above, and becoming gradually closer. The distance between the well-marked lines near the top of the berg may be a foot, or even more; while near the surface of the water it is not more than 2 or 3 inches, and the spaces between

the blue lines have lost their dead whiteness and have become hyaline or bluish. The blue lines are very unequal in their strength and in their depth of colouring; sometimes a group of very dark lines gives a marked character to a part of a berg. Between the stronger blue lines near the top of the cliff a system of closer bands may be observed, marking the division of the ice by still finer planes of lamination, but these are blended and lost in the narrower spaces towards the water-line. The blue lines are the sections of sheets of clear ice; the

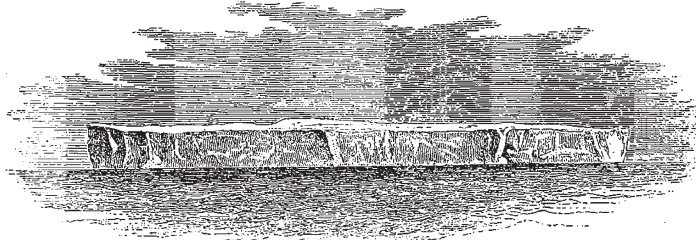


FIG. 1.—February 11, 1874. Lat.  $60^{\circ} 52' S.$ , Long.  $80^{\circ} 20' E.$

white intervening bands are the sections of layers of ice where the particles are not in such close contact—ice probably containing some air.

The stratification in all the icebergs which we saw, was, I believe, originally horizontal and conformable, or very nearly so. In very many of them the strata had become inclined at various angles, or vertical, or reversed; in many they were traversed by faults, or twisted or contorted or displaced, but I never saw a single instance of deviation from the horizontal and symmetrical stratification which could in any way be referred to original structure; which could not, in fact, be at once accounted for by changes which we had an opportunity of observing taking place in the icebergs.

I think there can be no reasonable doubt from their shape, and from their remarkable uniformity of character,

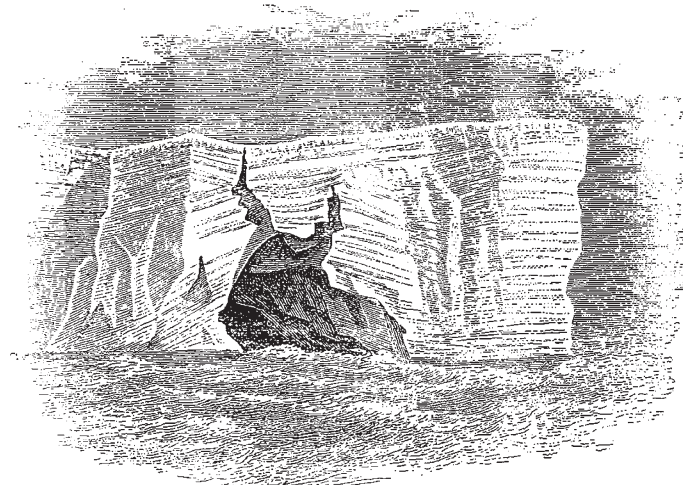


FIG. 2.—February 23, 1874. Lat.  $64^{\circ} 15' S.$ , Long.  $93^{\circ} 24' E.$

that these great table-topped icebergs which we saw all around us, and closing in our southern and eastern horizon at the southernmost point of our voyage, and breaking down and melting a little further to the north, are prismatic blocks riven from the edge of the great Antarctic ice-sheet, portions of whose vertical cliff were seen by Ross in January, 1841, and in February, 1842, in lat.  $78^{\circ} 4'$  and lat.  $77^{\circ} 49' S.$  to the southward of New Zealand, and by Lieut.-Commandant Ringgold in the U.S. ship *Porpoise*, on February 1 and 2, 1840, in long.  $130^{\circ} 36' E.$

lat.  $65^{\circ} 49' S.$  There is unfortunately great difficulty in determining when the wall of ice to which the term "ice-barrier" was restricted by Capt. Ross was seen by Lieut. Wilkes or any of his party, since Lieut. Wilkes applies the term indiscriminately to the solid ice-walls and to the masses of moving pack by which his progress was from time to time interrupted. The wall is satisfactorily described at one or two points only.

I believe that the stratification of those portions of the icebergs which were visible to us is due entirely to successive accumulations of snow upon a nearly level surface. The spaces between the transverse blue lines on the bergs may possibly represent approximately the snow accumulation of successive seasons. The direct radiant heat of the sun is very great in these latitudes, and during summer the immediate surface of the snow is frequently melted in the middle of the day, the water percolating down among the snow beneath and freezing again at night, or when it has trickled down into the shade. This process repeated every clear day for the two or three months of summer might well convert a very considerable belt of snow into ice more or less compact. That the process does go on we had ample evidence in the icicles fringing the snow which was lying upon flat pieces of the pack, which dropped rapidly in the sun even when the thermometer in the shade was several degrees below the freezing point.

The finer laminations may probably indicate the more feeble results of the same process after successive snowfalls. As I have already said there was not, so far as we could see, in any iceberg the slightest trace of structure stamped upon the ice in passing down a valley, or during its progress over *roches montonnées* or any other form of uneven land; the only structure except the parallel stratification which we ever observed which could be regarded as bearing upon the mode of original formation of the ice-mass was an occasional local thinning out of some of the layers and thickening of others, just such an appearance as might be expected to result from the occasional drifting of large beds of snow before they have time to become consolidated.

We certainly never saw any trace of gravel or stones or any foreign matter necessarily derived from land on an iceberg; several showed vertical or irregular fissures filled with discoloured ice or snow, but when looked at closely the discoloration proved usually to be very slight, and the effect at a distance was chiefly due to the foreign material filling the fissure reflecting light less perfectly than the general surface of the berg. In one or two distant bergs there seemed to be thick horizontal beds of ice deeply coloured brown or bottle-green, but this was also, I believe, chiefly an effect of light.

In the pack, which is made up of fragments of all sizes of berg-ice mixed with masses of salt-water ice, the berg-ice is almost always either white with pale-blue streaks, blue with a white opalescence, or rarely deep blue, or still more rarely black from absolute transparency; it is seldom soiled in any way. It is so occasionally; on the 10th we passed, not far from our turning-point, a piece of berg-ice with a small flock of penguins upon it. The birds had evidently been there for some time for the snow on the surface of the ice was trampled into a dirty brownish mud; another fall of snow would have converted this layer into a discoloured vein in the block.

C. WYVILLE THOMSON  
(To be continued.)