CHAPTER XI.

History of Southern Exploration—Antarctic Temperatures—Density of the Sea Water south of the 60th parallel—Icebergs—Deposits—Surface Organisms—The Hexactinellida—The Tetractinellida.

FIVE expeditions only have been despatched from this or other countries to explore the Antarctic regions, viz., those of Cook 1772–75, Bellingshausen 1819–21, D'Urville 1837–40, Wilkes 1838–42, and Ross 1839–43.

Our knowledge of the Antarctic Ocean does not, however, rest on the reports of the commanders of these expeditions, as other captains, though not despatched expressly for the purpose, have penetrated beyond the Antarctic Circle in search of Whales or Seals, or for some scientific purpose, and have published narratives or papers of their proceedings, accompanied in many instances by charts showing their tracks. The most notable of these voyages are those of Smith and Bransfield 1820, Powell 1821, Weddell 1822–24, Morrell 1823, Foster 1828–29, Biscoe 1830–32, and Balleny 1839.[1]

Of these Antarctic voyagers three only have succeeded in crossing the parallel of 70° S. Cook, in January 1774, penetrated to 71° 10′ S. on the meridian of 106° 54′ W., but was then stopped by field ice, which, to use his own words, "extended east and west as far as the eyes could see, amongst which ninety-seven icebergs were counted in addition to those outside the field, many of them very large and looking like ridges of mountains rising one above the other until they were lost in the clouds." From this description it appears probable that Cook really saw land, covered by an ice cap, although he does not expressly say so.

Weddell, in February 1823, penetrated to the parallel of 74° 14′ S. on the meridian of 34½° W., and then had only four icebergs in sight, although he had passed numerous bergs previously farther north. Evidently, therefore, a much higher latitude might have been reached had it been Weddell's object to proceed as far south as possible, but being on a sealing and not on an exploring voyage, he turned back at the 74th parallel, and proceeded to South Georgia to complete his cargo.

Ross passed the 70th parallel on three occasions and in three different years. First, in January 1841 on the meridian of 174½° W., when he penetrated to the parallel of 78° S., where he was stopped by an icy barrier, consisting of cliffs of ice 150 to 200 feet in height, which he traced in an east and west direction for a distance of 300 miles. Second, on the meridian of 169° W., on the 7th February 1842, when he again reached the parallel of 78°, again to find himself arrested by the icy barrier 70 miles east of his easternmost position in 1841; and the third time on the meridian of 16½° W., when he

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[1] See Cook's Voyage, Bellingshausen's Voyage, D'Urville's Voyage, United States Exploring Expedition, 1838–42; Ross's Antarctic Voyage, Weddell's Voyage, Morrell's Voyage, Voyage of the "Chanticleer"; *Nautical Magazine*, vols. iv., viii., and ix.; *Proceedings of the Royal Geographical Society*.

reached the parallel of 71° 30′ S. on the 5th March 1843, where he met an impenetrable pack.

Of the other explorers Bellingshausen reached within a few miles of the 70th parallel on three occasions, viz., on the meridians of 2° W., 77° W., and 93° W. D'Urville's highest latitude was 66° 30′ S. on the meridian of 140° .E, and Wilkes just reached the 70th parallel on the meridian of 100° W. The highest latitude reached by Morrell was 70° 14′ S., in March 1823, on the meridian of 40° W., by Foster 63° 45′ S. on the meridian of 62° W., by Biscoe 69° 20′ S. on the meridian of 13° E., and by Balleny 69° S. in 172° E.

It must be borne in mind that none of the ships despatched for southern exploration were properly fortified except those of Sir James Ross, and that, therefore, they were not justified in attempting to sail through a close pack as Ross did on each occasion when he penetrated to the 78th parallel.

Nearly all the Antarctic voyagers have discovered land south of the 60th parallel. Cook, as before observed, probably met with land in 71° S. 107° W. Bellingshausen discovered the islands of Alexander and Peter the Great; D'Urville discovered Adelie Land; Wilkes discovered land extending from the 100th to the 160th meridian of east longitude, and between the parallels of 65° and 67° S. Ross discovered Victoria Land, extending from the 70th to the 78th parallel and between the meridians of 160° and 171° east longitude. Smith and Bransfield discovered the South Shetlands, Powell the South Orkneys, Biscoe Enderby's Land, and Balleny the Balleny Islands and Sabine Land. Weddell and Morrell did not discover any land, and Foster only visited the South Shetlands for scientific experiments. Although so many of these bold navigators have seen land, and numbers of them have visited the islands immediately south of Cape Horn, viz., the South Shetlands, South Orkneys, &c., which appear to be accessible nearly every season, Ross and D'Urville are the only explorers who have actually landed on any portion of the Antarctic regions proper, that is on land south of the Antarctic Circle. Wilkes, Biscoe, and Balleny never succeeded in reaching the shore, although Wilkes could not have been far from it when in the "Vincennes" he struck soundings in 30 fathoms in Pincis Bay. Neither Ross nor D'Urville remained longer on shore than was sufficient to enable them to gather specimens of the rocks, &c., for the nature of the coast, and the numerous icebergs, precluded the possibility of the vessels anchoring, so that a quick return was necessary to avoid being separated by one of the frequent fogs or short, sharp gales that prevail in the Antarctic seas. All explorers agree in describing the Antarctic land as being icebound; sometimes a line of icy cliffs 150 to 200 feet in height runs along the coast, rendering hopeless any attempt to obtain a footing on the shore, whilst in other places a solid mass of land ice, which is not more than 5 or 6 feet above the surface, and, therefore, probably not more than 50 feet in thickness, stretches a considerable distance into the sea.

Ross, D'Urville, and Wilkes saw both kinds of ice in the vicinity of the land, and both Ross and D'Urville agree in stating that the icy cliffs, which are now known as the "Ice Barrier," are not to be seen when the land is high and mountainous; for instance, Ross saw no barrier until he reached the extremity of the ridge of mountains running irregularly north and south through Victoria Land, and D'Urville saw no icy barrier opposite Adelie Land, but traced it for 60 miles on the coast of what he supposed to be Clarie Land, where Wilkes also saw it. Wilkes himself does not say where he saw the ice cliffs and where the land ice, but calls them both the icy barriers. That they both form a barrier to the land is undeniable, and so Wilkes was entitled to call both descriptions of ice the "Barrier"; still it would have been an advantage to succeeding investigators had Wilkes distinguished between the land ice which may by heavy gales or some cause be broken up occasionally, and the ice cliff which one might as well attempt to pass or to sail through as the Cliffs of Dover, and which is now the only description of ice called the "Barrier." It does not appear that any other explorer except Ross, D'Urville, and Wilkes has seen the icy barrier, although most southern explorers have seen the ice extending from the foot of the land.

From the fact that two explorers only have succeeded in effecting a landing on Antarctic shores proper, and that the land there is almost entirely covered with perpetual snow and ice, it is evident that our knowledge of the geography and geology of the Antarctic regions must necessarily be very limited. That a very considerable tract of land exists south of the 65th parallel and between the meridians of 100° E. and 180° E., and also between the meridians of 45° and 60° E., cannot be doubted, but whether this land is continuous or broken up into a series of islands with shallow water between cannot at present be stated with any great degree of certainty, for the ice in the vicinity of the land so blocks up all approach to the coast and hides the shore that it is next to impossible to say, with accuracy, where the land begins. It can, therefore, only be conjectured from the state of the ice and the observed temperatures what the condition of the land is.

Antarctic Temperatures.—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 fresh water.[1] Between 60° and 62½° S. a sensible rise takes place, and a reading as high as 38° has been recorded of both air and sea in March between these parallels. Temperatures below the surface south of the 60th parallel had been taken by Cook, Ross, and Wilkes before the Challenger Expedition, but as the thermometers used were not protected from pressure, the results obtained are not of much value, as they are combinations of temperature and pressure due to depth. There is, however, one marked peculiarity about the results obtained with these unprotected thermometers,

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[1] Contributions to our knowledge of the Meteorology of the Antarctic Regions. Published by authority of the Meteorological Committee, 1873.

viz., that by all three observers the temperature at 100 fathoms was either the same or lower than that at the surface, and was at or below the freezing point of fresh water, whilst at 150 fathoms the mean temperature was only on one occasion less than that of the surface, or below 32°, the mean of the sixteen observations at that depth being 34°·3, and higher than the temperature of the surface. The coldest submarine temperature obtained was by Wilkes, who registered 27½° at a depth of 320 fathoms,[1] but as serial temperatures were not obtained there is no reason for believing that this temperature existed at the depth of 320 fathoms, as the thermometer might, and probably did, pass through a stratum of water at that temperature before it reached the depth of 100 fathoms.

During the voyage of the Challenger from Kerguelen to Australia five serial temperature observations were obtained south of the 60th parallel; and as these observations are highly important, a full notice of them is appended in order to afford every possible facility for future discussion, and also to indicate the data still required as well as the kind of instrument necessary to obtain those data. The general result of the observations seems to show that from the most southerly Station a wedge of cold water stretches northwards for more than twelve degrees of latitude, underlying and overlying strata at a higher temperature than itself. The temperature of the water below the lower warm stratum is uncertain, because it lies between the maximum and minimum observed at lesser depths. These results receive confirmation from the imperfect observations of Cook, Ross, and Wilkes (see Diagram 9).

On the 14th February 1874, in lat. 65° 42′ S., long. 79° 49′ E., the most southerly Station at which temperature observations were obtained, the temperature of the surface water was 29°·5 and that of the air 33°. The ship was about 1½ miles from the edge of the pack ice with many icebergs around, forty-eight being counted within a horizon of 4 miles; the average height of the bergs out of the water was 150 to 200 feet, most of them were tabular, and had changed little from their virgin state, they must, therefore, have extended to a depth of from 200 to 300 fathoms below the surface. The temperature of the water at 50, 100, 200, 300, 500, and 1675 fathoms (bottom) was determined. For this purpose two thermometers, Nos. 66 and 67, were sent successively to each of these depths, having been cooled to a temperature of 30°·2 before immersion. At 50 and 100 fathoms each thermometer registered a slight change in the maximum index, which is probably due either to an error in reading off or to a slight defect in the instruments, as it has been frequently found that the maximum indices alter their positions slightly on entering cold water.[2] The minimum index of each fell to 29° proving that they had entered or passed through a stratum of cold water. At the greater depths of 300, 500, and 1675 fathoms the thermometers registered a decidedly

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[1] Wilkes' U. S. Expl. Exp., vol. ii. p. 299, 1845.

[2] Or this may be due to the glass contracting suddenly before the temperature has reached the spirit in the bulb of the thermometer, and so forcing the index up slightly.

higher maximum temperature, showing distinctly that they had entered or passed through a warmer stratum of water than had been indicated between the surface and a depth of 200 fathoms. The minimum indices all registered 29°, agreeing exactly with what had been found at lesser depths. At 200 fathoms the thermometers both showed a slight, but only a very slight, rise in the maximum index; but as they both agreed exactly, it is probable that at this depth the warm underlying strata commenced. It is impossible that the thermometers could have been affected in their momentary passage through the air (which was at a temperature of 33°) from the sounding bridge to the surface of the water, as the utmost care was taken to keep the outer case filled with the cooling mixture until the instrument was immersed, and on recovering each thermometer it was detached and read off before the mercury had sufficient time to attain a higher temperature than that of the surface water (29°·5), besides, if they were affected by the air, all the instruments would have registered higher on the maximum side, whereas only those lowered to depths exceeding 200 fathoms did so. The temperature of the bottom water ranged between 33° and 28°·8, these being the temperatures registered by the maximum and minimum indices of the instrument sent to 1675 fathoms.

On the 19th February, in lat. 64° 37′ S., long. 85° 49′ E., the temperature of the surface water was 32°, and that of the air 30°. A large number of icebergs were in sight. At a depth of 50 fathoms the maximum index, which before immersion registered 31°·4, rose to 32° (the temperature of the surface water), and the minimum index fell to 29°·2, indicating a colder stratum of water. At 100 fathoms the maximum index rose to the temperature of the surface water, the minimum fell to 29° which was slightly colder than that at the depth of 50 fathoms; but as two other instruments sent down to greater depths, which, therefore, passed through this cold stratum did not register 29°, the temperature of 29°·2 has been adopted for 100 fathoms. The maximum index of the one thermometer sent to 300 fathoms rose from 33° to 33°·8, but as the two sent to the bottom, which must have passed through this stratum, only registered 33°, that reading has been adopted. On the other hand, this might indicate that the stratum of 33°·8 F. is so limited that the bottom thermometers passed through it without attaining the full temperature. The bottom temperature at 1800 fathoms, as registered by two thermometers, was between 33° and 29°.

On the 21st February, in lat. 63° 30′ S., long. 88° 57′ E., and under the same circumstances of air and surface water temperature, a few observations showed a regular decrease in the temperature from 32° at the surface to 29°·3 at 40 fathoms.

On the 26th February, in lat. 62° 26′ S., long. 95° 44′ E., the temperature of the air was 35°·5, and that of the surface water 33°. A large number of icebergs were in sight. Previously to immersion the thermometers were cooled with ice and salt to a low temperature. At 100 fathoms the thermometer indices remained the same as on immersion, viz., 31°·8 and 32°, although this temperature was lower than that of the surface water, owing probably to their having passed too quickly through the narrow belt of superheated water. A third instrument which, before immersion, was set at 32°·5 was afterwards sent to the same depth, when the maximum index registered 32°·8, or approximately the surface temperature; and the minimum 31°·8, or the same temperature as previously obtained. This reading has, therefore, been assumed as the temperature at 100 fathoms. At 150 fathoms two thermometers registered a warm stratum of 34°, and the minimum indices showed that they had passed through the cold intermediate stratum of 32°. This was also confirmed by the two instruments lowered to 200 fathoms and the one sent to the bottom, for each of them registered a maximum temperature of 34°, and a minimum of at least 31°·8. The bottom thermometer, indeed, registered on its minimum side 31°·3, but unfortunately its temperature on immersion was not noted, and as it was cooled by the mixture of salt and ice, it may have stood at the temperature of 31°·3 when immersed. The bottom temperature is, therefore, uncertain, but must be between 34° and 31°·3.

On the 11th February, during the passage southward, in lat. 60° 52′ S., long. 80° 20′ E., with three icebergs in sight, serial temperatures were taken. The temperature of the air was 35°·5, and that of the sea surface 34°·2. Before immersion the thermometers, with the exception of those sent to the bottom and to the depth of 25 fathoms, were cooled to as low a temperature as was deemed necessary. The lowest temperature registered was 32° at 50 fathoms, and this continued certainly to the depth of 100 fathoms. At 150 fathoms the thermometer registered 36° on the maximum side and 31°·8 on the minimum. At 200 fathoms the thermometers registered from 35° to 35°·8 on the maximum side and 32° to 32°·8 on the minimum. At 300 fathoms the thermometer gave the same result as at 200 fathoms. Here, therefore, a rise of temperature took place at 150 fathoms, which reached its maximum at 200 fathoms. The bottom temperature is uncertain, as the thermometers which, on immersion, registered 41° came up showing 41° on the maximum and 32° and 33° on the minimum side.

On the 3rd March, in lat. 53° 55′ S., long. 108° 35′ E., the temperature of the air being 37°·8, and that of the sea surface 37°·2, serial temperatures were again obtained. No icebergs were in sight, but some were seen on the 2nd, and one was passed on the 4th. The thermometers were lowered to every 10 fathoms from the surface to 100 fathoms, and showed little alteration to the depth of 60 fathoms, registering there 36°·6, or only 0°·6 less than the surface temperature. At 70 fathoms a sudden fall of 3½° took place, and at 80 fathoms the temperature was 32°·5, below this depth the temperature is uncertain, as the instruments registered on their maximum side the temperature of immersion, and on their minimum the temperature at 80 fathoms. If a stratum of warm water commenced at 150 fathoms of the same temperature as that of the 26th February, viz., 34°, as there is every reason to believe, it could not, owing to the construction of the instruments, be detected, for, as the thermometers had passed through the surface stratum of 37°·2 and the cold stratum at 80 fathoms of 32°·5, they were unable to record any alteration between those temperatures at greater depths.

The bottom thermometers showed the temperature of immersion on their maximum side, and 32°·2 and 32°·0 on the minimum. As this is a colder result than any other instrument showed between the surface and 500 fathoms, it is probably justifiable to assume the mean (32·1) to be the correct bottom temperature at this position.

The result of the foregoing observations may be briefly stated thus :—

On the passage towards Cape Otway the cold intermediate stratum was traced as far north as 54° S., where its temperature was 32°·5 at a depth of 80 fathoms. Farther south it decreased until in lat. 66° S. it was 29° from immediately below the surface to a depth of 200 fathoms, or nearly as low as the freezing point of salt water.

The warmer stratum of oceanic water underlying it also gradually decreased in temperature as higher latitudes were reached, and it is possible that farther south the temperature of the water from the surface to the bottom will be found nearly uniform at probably 29° or 30°; but in that case it is somewhat difficult to account for the rise in temperature of the bottom water to 33°·5 in lat. 50° S., long. 123° E., only about 1200 miles from its source, as it is known that this temperature is retained with little alteration for 3000 miles, for Captain Shortland obtained bottom temperatures of 33½° in the Arabian Sea with unprotected thermometers. This will be referred to again when discussing the specific gravity of the sea water of the Southern Ocean.

During the winter season the ice at the surface must necessarily be colder than the water underlying it; it seems therefore highly probable that the cold wedge of water found near the surface is merely the remains of the winter-cooled sea, which has not sufficient time during the short summer to recover its temperature; it is also probable that during winter the solar-heated surface belt is entirely removed, and that the sea as far north, at least, as the 63rd parallel of south latitude becomes frozen over, the frequent gales breaking up the field ice and converting it into pack. It is noticeable that the temperature of the underlying stratum was on each occasion found to be warmer than the surface water. This fact is also confirmed by the observations of Cook, Ross, and Wilkes.

The fact that the cold wedge above referred to extended north just as far as the icebergs did in March 1874 points to there being some connection between the temperature and the presence of melting icebergs. The lowest bottom temperature registered between the Cape of Good Hope and Melbourne, north of the 54th parallel, was 33°·5, at the 54th parallel it was 32°·1, and at all Stations farther south of this, it cannot be said with absolute certainty what the bottom temperature was, as the thermometers below 300 fathoms came up with exactly the same readings as at that depth.

During the time the ship was near the edge of the pack ice the surface temperature was from 28° to 29°, and remained uniform to a depth of upwards of 200 fathoms, rising to 33° or 34° at 300 fathoms. At a short distance from the pack, but when surrounded by icebergs, the surface temperature was generally about 32°, but decreased to 29° at a depth of 40 fathoms, and retained that temperature to nearly 300 fathoms as in the pack.

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.				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.	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	–	–	–	33·0	–	–	–	34·5	–	–	–	37·2
10	–	–	–	–	–	–	–	–	32·0	32·0	31·5	31·5	–	–	–	–	35·5	35·5	34·0	34·0	40·0	40·5	36·8	36·8
20	–	–	–	–	–	–	–	–	32·0	32·0	31·0	31·0	–	–	–	–	35·8	35·8	33·5	33·5	42·0	42·0	36·8	36·8
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–	35·0	35·0	30·0	30·0	–	–	–	–	–	–	–	–	40·8	40·5	36·6	36·6
40	–	–	–	–	–	–	–	–	32·5	32·5	29·3	29·3	–	–	–	–	–	–	–	–	41·0	41·0	36·6	36·6
60	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	–	–	–	–	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	36·5
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	30·2 30·2	30·0 30·5	29·0 29·0	29·0	31·6	31·8	29·0	29·0	–	–	–	–	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	40·8 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	30·2 30·2	30·5 30·5	29·0 28·8	30·5	–	–	–	–	–	–	–	–	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	30·2 30·2	32·0 32·0	29·0 29·0	32·0	33·0	33·8	29·4	33·8	–	–	–	–	–	–	–	–	34·0	35·5	32·2	35·3	42·5	42·5	33·0	
400	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42·8	43·0	32·6	
500	30·2 30·2	32·8 32·8	29·0 28·8	32·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42·5	42·5	32·8	
Bottom	30·0 30·0	33·0 33·0	28·8 28·8	Uncertain.	31·0 31·5	32·9 33·0	29·3 29·0	Uncertain.	–	–	–	–	–	34·0	31·3	Uncertain.	41·0 41·0	41·0 41·0	32·0 33·0	Uncertain.	41·0 41·0	41·0 41·0	32·0 32·2	32·1

Density of the Sea Water.—The observations of the density of the water in this part of the cruise are of considerable interest. They 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. They are reduced to their value at 60° F. (15°·56 C.)—distilled water at 39°·2 F. (4° C.) being unity.

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′

Immediately on leaving the Cape, the course of the ship passed through the well-known Agulhas Current, the water of which is warm and dense. The first deep sounding was in 1900 fathoms, rather to the westward, or on the Atlantic side of the Agulhas Bank. Here the current coming from the Indian Ocean bends round the Cape, and its waters enter the Atlantic. The sounding was taken in a position where great changes of surface temperature are frequently observed (see p. 290), which indicate the meeting and imperfect mixture of waters brought from sources remote from each other. The densities observed at this Station are given in column A of the Table. It will be seen that they are all higher than those in any of the other columns. The temperatures also observed at the different depths are higher than at the other Stations. The water from the surface to the bottom bears evidence of having been warmed and concentrated in tropical regions. Between this Station and B the temperature and the density of the surface water fall at first gradually then rapidly, the great fall taking place while the ship was passing through a strong current, setting to the north and east between the 40th and 45th parallels. At Station B, which is already within the zone where icebergs may be met with at any season of the year, the surface density has fallen to 1·02508. During the whole sojourn of the ship in Antarctic waters, the surface density varied between 1·0250 and 1·0248, except where pack ice was met with, and then both the temperature and the density of the surface water were lower, the temperature being from 29° to 30°, and the density 1·0240. Station D, the most southerly where serial waters were collected, shows the distribution of density in the neighbourhood of the pack. The comparatively light stratum of water at the surface is of but little thickness, at 50 fathoms the density has already risen from 1·02452 (its value at the surface) to 1·02527; at 140 fathoms it is 1·02542, and at 300 fathoms 1·02553. While thus the density steadily increases with the depth, at least as far as 400 fathoms, the temperature of the water falls from 32° at the surface to 29°·2 at 50 and 29°·0 at 100 fathoms; at 300 fathoms it has risen to 33°·8. At Stations B and C, both approximately on the same parallel, the rise of density with increasing depth is less marked, and there is no such irregularity in the distribution of temperature. At Station C, which is 14° of longitude to the west of B, the temperature at all depths is very decidedly lower than at the corresponding depths at B, while much farther east, at Station H, the water is much warmer and denser than even at B, though the position is 5° farther south. No serial waters were obtained on the way south between the 47th and the 64th parallel. At Stations D and E, waters and temperatures were taken in the vicinity of the pack. It will be seen that the temperature falls to a minimum at about 100 fathoms, while the density rises to about 1·0255 at that depth, and remains nearly constant at greater depths, while the temperature rises to 33° or 34° at 300 fathoms according to the latitude. The density of the bottom water was usually from 1·0254 to 1·0256. The observations at B, D, and E are exceptions. At B and E the densities observed are almost identical with those of the surface water at the same locality, and at D it is identical with that of water between the surface and 50 fathoms. The only risk attending the collection of bottom water is that due to the possibility that the water-bottle may close at or near the surface, and thus enclose surface water which it would take to the bottom and bring back again. Although there is no reason for believing that this took place at each of these three Stations, it is possible that it may have done so, and the results may be considered as doubtful, and the bottom water may be assumed to have an average density of 1·0255. It must be observed that the collection of the intermediate water is attended by no such danger. At the bottom the temperature was, owing to the nature of the thermometers, uncertain, but there can be little doubt from the indications which it was possible to have, that it was lower than at 300 fathoms, though it may not have reached the minimum of 29° observed in the superficial water. In regions free from ice the temperature of the bottom water was found to be somewhat above the freezing point of fresh water, namely, 33°, and as this temperature persists at the bottom without sensible alteration as far as equatorial regions, it is 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 and with a higher temperature. This will be easily understood if the effect which will be produced on a sea when its surface is frozen be considered. For this purpose some knowledge of the nature of sea water ice is necessary.

During the short time spent in the neighbourhood of the ice pack, Mr. Buchanan made a number of experiments principally with the view of deciding the question whether sea water ice is or is not a mixture of pure fresh ice with brine. The experiments consisted in determining the temperature at which sea water ice melted, and the amount of chlorine contained in the water so formed.

The ice made by freezing sea water in a bucket was found to have formed all round the bottom and sides of the bucket, forming a pellicle on the surface, from which and from the sides and bottom the ice had formed in hexagonal planes, projecting edgewise into the water. The water was poured off, the crystals collected, washed with distilled water, pressed between filtering-paper, and one portion melted. It measured 9 c.c., and required for the precipitation of its chlorine 4 c.c. silver solution, corresponding to 0·0142 gramme chlorine, or 1·5780 gramme per litre. The other portion was used for determining the melting point. The instrument used was one of Geissler's *normal* thermometers, divided into tenths of a degree Centigrade, the zero of which had been verified the day before in melting snow. The melting point of the ice crystals was found to be 29°·7 (−1°·3 C.). The temperature of the melting mass was observed to remain constant for twenty minutes, after which no further observations were made.

In the same way the melting point of the pack ice was determined. The fresh ice began to melt at 30°·2 (−1° C.); after twenty minutes the thermometer had risen to 30°·4 (−0°·9 C.), and two hours and a half afterwards it stood at 31°·5 (−0°·3 C.), having remained constant for about an hour at 31°·3 (−0°·4 C.). The temperature of another portion of the ice rose more rapidly, and when three-fourths of the ice was melted the thermometer stood at 32° (0° C.).

The piece of pack ice examined was clear, with many air-bells, most of them rather irregularly shaped. Two portions of this ice were allowed to melt at the temperature of the laboratory, which ranged from 35° to 45°. The melting thus took place very slowly, and made it possible to examine the water fractionally. The experiments consisted in determining the chlorine in the water by means of tenth-normal nitrate of silver solution, and observing the temperature of the ice when melting.

A lump which, when melted, was found to measure 625 c.c., was allowed to melt gradually in a porcelain dish. When about 100 c.c. had melted, 50 c.c. were taken for the determination of the chlorine; they required 13·6 c.c. silver solution, corresponding to 0·0483 gramme chlorine. When 560 c.c. had melted, 50 c.c. were titrated, and required 1·6 c.c. silver solution, corresponding to 0·0057 gramme chlorine. The remainder (65 c.c.) of the ice was then melted and 60 c.c. titrated; they required 0·39 c.c. silver solution, corresponding to 0·0014 gramme chlorine. There were then in the first 50 c.c. 0·0483 gramme chlorine, in the next 510 c.c. 0·0579 gramme, and in the last 65 c.c. 0·0015 gramme. Hence the whole lump (625 c.c.) contained 0·1077 gramme chlorine, or, on an average, 0·1723 gramme chlorine per litre. A qualitative analysis of the water showed lime, magnesia, and sulphuric acid to be present.

Another piece of the ice was pounded and allowed to melt in a beaker. When about half was melted, the water was poured off and found to measure 95 c.c.; 75 c.c. were titrated with silver solution, and required 1·9 c.c. The remainder, when melted, measured 130 c.c., and required 0·9 c.c. silver solution. Hence the first portion of water (95 c.c.) contained 0·0085 gramme chlorine, and the second (130 c.c.) 0·0032 gramme chlorine. The whole quantity (225 c.c.) of ice therefore contained 0·0117 gramme chlorine, or, on an average, 0·0520 gramme per litre.

These determinations of the temperature of melting sea water ice show that the salt is not contained in it only in the form of mechanically enclosed brine, but exists in the solid form, either as a single crystalline substance or as a mixture of ice and salt crystals. Much additional light has recently been thrown upon this subject by the investigations of Dr. Pettersson, published in the Reports of the "Vega" Expedition under Nordenskiöld. Dr. Pettersson observed that sea water ice exhibited the extraordinary property of contracting with heat at temperatures a little below its melting point; he also noticed that the latent heat of sea water ice is much inferior to that of pure ice. In the course of his chemical investigations he also found that specimens of sea water ice vary greatly in their composition, and the result of his investigations may be summarised as follows:—

Ocean water is divided by freezing into two saliniferous parts, one liquid and one solid, which are of different chemical compositions. The most striking feature of the freezing process is that the ice is richer in sulphates and the brine in chlorides. The extraordinary variation both in saltness and in chemical composition of every individual specimen of sea-ice and sea-brine depends on a secondary process by which the ice seems to give up its chlorides more and more but to retain its sulphates. Hence the percentage of chlorine is no indication of the saltness of the ice, though it may to a certain extent be taken as an index of its age.

Professor Guthrie in his work on cryohydrates[1] gives the following Table:—

Cryohydrate of	Contains	Solidifies at
Chloride of Sodium, ...	76·39 per cent. water.	− 22° C.
Chloride of Potassium, ...	80·00 " "	− 11°·4 C.
Chloride of Calcium, ...	72·00 " "	− 37°·0 C.
Sulphate of Magnesia, ...	78·14 " "	− 5°·0 C.
Sulphate of Soda, ...	95·45 " "	− 0°·7 C.

Supposing that these cryohydrates are formed in the freezing of sea water, it is easy to see how as the temperature rises the chlorides melt out first and leave the ice richer and richer in sulphates.

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[1] *Phil. Mag.*, ser. 4, vol. xlix. p. 1, 1875.

Dr. Pettersson analysed a large number of samples of sea water ice and found the ratio $Cl : SO_3$ to vary from 100 : 12·8 to 100 : 76·6, the average proportion in sea water being 100 : 11·88.

In the act of freezing, 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° throughout its depth, and this is actually what is observed in the Arctic regions in the Norwegian Sea, which is separated from the Atlantic by a ridge with a maximum depth of 300 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 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, which is very unlikely. On the return of winter the surface water will still be less dense than that below, and the brine separated from it on freezing will also be less dense, and therefore have less power to penetrate the deep water.

Further, the covering of ice is a very powerful protection to the water below. The thickness of the ice formed round the "Vega" during the winter that she was frozen in, in the Siberian Sea, was 162 centimetres, and the water below it was no colder than it had been in summer. Pettersson has found the latent heat of freezing sea water to be less than that of fresh water; but even if it were identical with it, the formation of 162 centimetres (0·875 fathoms) of ice would only be thermally equivalent to the reduction of the temperature of 125 fathoms of water, by 1° F. Such an effect is much inferior to that produced by the moderate winters of temperate latitudes where no ice is produced. In order that the winter cold at the surface be freely transmitted to the deeper water, it is important that the salinity of the surface water be greater than that of the water below it. The importance of this factor in promoting convection downwards was pointed out by Mr. Buchanan in a paper on the Vertical Distribution of Temperature in the Ocean,[1] in which more especially attention is paid to the effect of the surface climate on the waters of the subtropical North Atlantic. Here the surface of the ocean is exposed to the action of the northeast trade wind, which blows from colder to warmer regions, so that while it is continually taking up moisture it is continually increasing its power of doing so. In this region the removal of water from the ocean is effected in the form of vapour, in polar regions it is effected in the form of ice. In whichever way it is removed the effect is the same, the remaining water is salter than the original water, and therefore denser at the same temperature. In other words, the concentrated water will have the same density as the original water at a higher temperature, and it will have power to sink into or penetrate the original water before it has sunk to the same temperature. In this way the high winter temperatures of subtropical regions and the low temperature of freezing sea water, tend to be propagated downwards. In the Atlantic, Indian, and Pacific Oceans, there are return currents of dense warm water from tropical seas, along the eastern shores of South America, Africa, and Australia. The high salinity of this water gives it when cooled great penetrative power, as it can bear much dilution and still sink through the water of high latitudes at the same temperature.

It is probable therefore that the cold water at the bottom of the ocean, in so far as it is drawn from the southern hemisphere, leaves the surface between the parallels of 40° and 55° of south latitude. From this zone the water is drawn northwards to make good deficiencies, and it no doubt flows southward also in order to replace the ice and cold surface water drifted northward in the summer. The comparatively warm water which reaches the Antarctic Circle at a depth of 300 fathoms can only come from such a source. Its temperature is of course lowered by being drawn into polar regions, but it probably persists as a warmer stratum until it is arrested by the shoaling of the water. If within the Antarctic Circle there are seas like the Norwegian Sea within the Arctic, that are almost completely shut off from the general oceanic circulation, their waters will certainly have the same low temperature of about 29° F. from surface to bottom. In the Arctic Ocean a brisk superficial circulation is kept up by the warm North Atlantic current which penetrates it along the eastern side of the Norwegian Sea, and is in a measure compensated by cold polar currents which leave the Arctic Ocean along the eastern coast of Greenland and by Baffin's Bay along its western side, removing with them a large portion of the winter's ice. A circulation similar to this appears to be entirely wanting in the Antarctic regions; hence their ice-bound character.

Icebergs.—Sir James Ross, in his celebrated voyage, having discovered Victoria Land, sailed along its coast to the southward as far as the 76th parallel, where he

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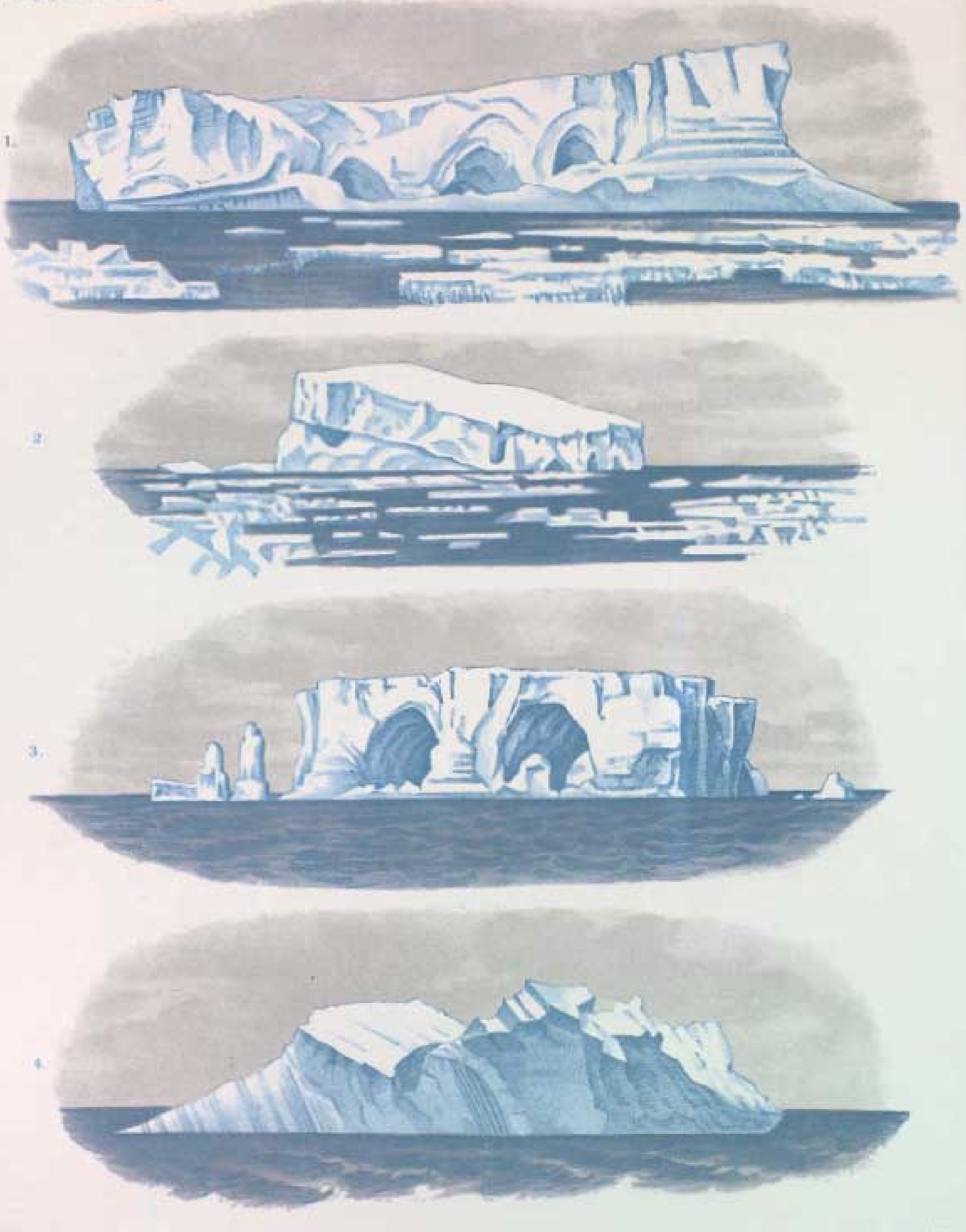
[1] *Proc. Roy. Soc. Lond.* vol. xxiii. p. 124 (1874), 1875.



J. J. Wild del.

F. Huth, Lith. Edin.

ANTARCTIC ICEBERGS.

1-3, seen February 14th 1874, Lat. 65° 42' S., Long. 79° 49' E. 4, seen February 15th 1874, Lat. 65° 59' S., Long. 78° 24' E.

was stopped by an icy barrier extending upwards of 300 miles east and west, the perpendicular cliffs of which attained an altitude of from 150 to 200 feet, whilst the depth of water close outside these cliffs ranged between 180 and 410 fathoms. This icy barrier began at the foot of Mounts Erebus and Terror, which appear to be the southern peaks of a range of hills stretching irregularly to the northward at moderate distances from the coast as far as Cape North, in lat. 71° 30′ S. Off the coast of this high land there was pack ice; and here and there, descending from the ravines of the mountain ranges, were glaciers which extended some distance into the sea, and ended in perpendicular cliffs of considerable height, but there was no such barrier as extended west from the foot of Mount Terror.

That the edge of the icy barrier seen by Ross is nearly, if not quite, water-borne, and therefore just in a condition to generate icebergs is evident, for the height of the ice cliffs above the water-line varies from 150 to 200 feet (mean 175 feet), whilst the depth of water within a mile of them is 260 fathoms. Now, 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), an iceberg floating will have 89·6 per cent. of its volume immersed, that is supposing it to be of the same temperature and consistency throughout, or in round numbers 90 per cent. of volume will be under water, and 10 per cent. above. Taking this as the basis of calculation, it is found that the icy cliffs of the barrier will be water-borne at 260 fathoms, or precisely the depth found by Ross close to them. This also will be the draught of water of a tabular iceberg detached from the barrier whose height above water is 175 feet. This uniform height, about 175 feet, of the tabular icebergs in high latitudes cannot fail to strike even the most ordinary observer, and can only be accounted for by supposing them to have been generated by the icy barrier.

The highest berg seen by Cook was in lat. 59° S., long. 92° E., 300 to 400 feet high, but was only half a mile round. Ross does not mention any very high iceberg, and Wilkes estimates his highest at 500 feet, but this was not a tabular berg, and although very high table-topped icebergs have been seen far north, they were always in a rapid state of dissolution. In fact they sometimes break up in high latitudes, for Biscoe observed one fall asunder in lat. 65° S., long. 116° W.

The icebergs met with in the Challenger were usually from a quarter to half a mile in diameter, and about 200 feet high; the highest measured was 248 feet, but it was evidently an old berg floating on a large base. The largest, which was seen farthest south in latitude 66° 40′, was 3 miles in length, and was accompanied by several others nearly as large. It is remarkable how few were fallen in with to the westward of the 80th meridian of east longitude, or to the northward of the pack ice there, which was probably a detached pack, similar to that sailed through by Ross in 1841.

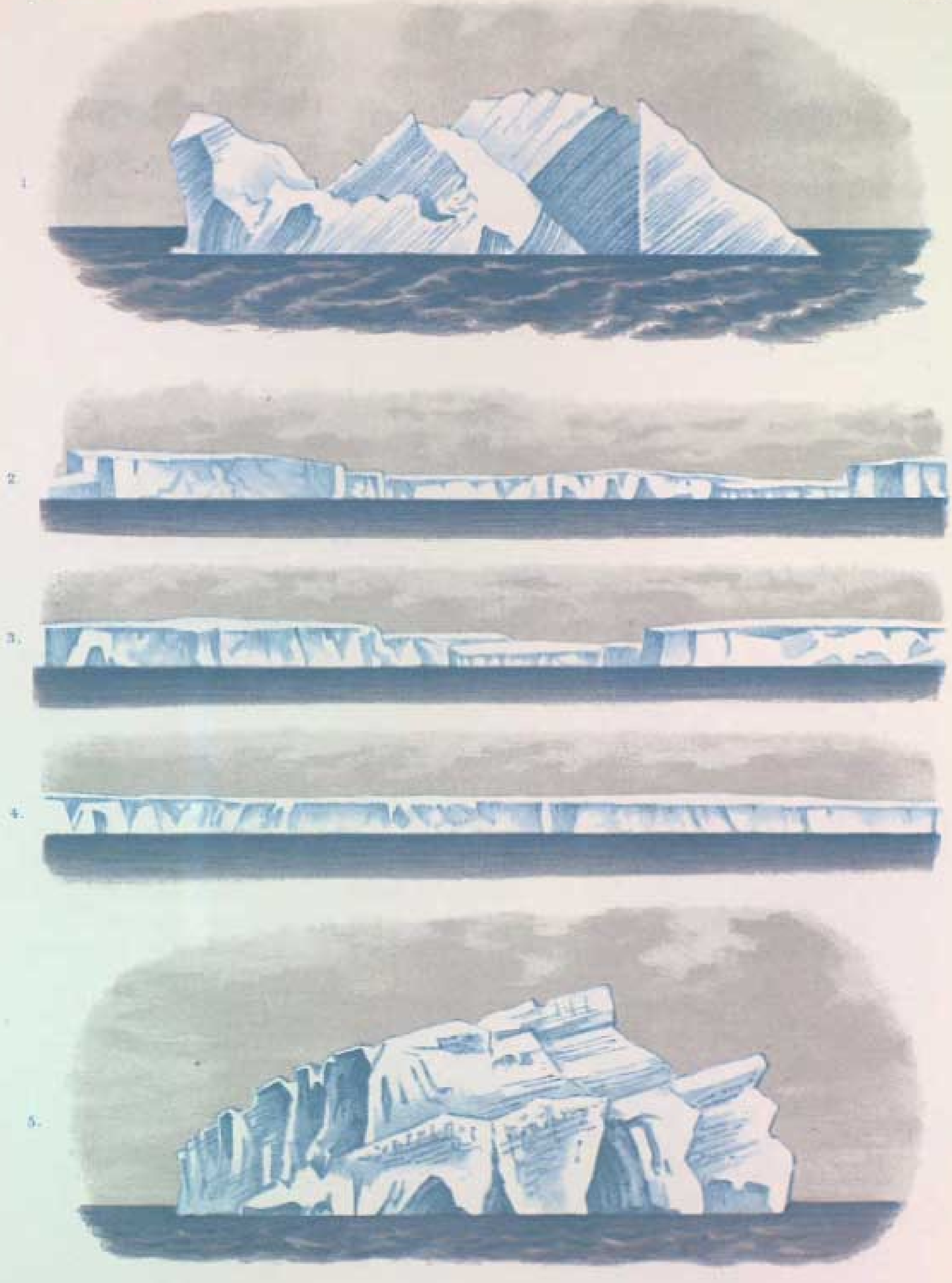
To the eastward of the meridian of 92° E. icebergs were very numerous, and continued so as the ship ran to the eastward even at a distance from the pack. Their absence farther to the westward, between 70° and 80° E. longitude, except when close to the pack edge, was so marked that, coupled with their absence on the same meridians in lower latitudes as shown by the ice chart, it seems to indicate that there can be no land for a considerable distance south in that neighbourhood, and that a very high latitude could be gained there if desired.

The pack ice consisted chiefly of small salt water ice pieces, which could scarcely be called floes, from 30 to 50 feet in diameter; 100 miles within the pack edge Ross found them to be 600 feet in diameter. The single season's ice was about 3 feet in thickness, the hummocky ice, formed by several layers heaped one upon another and frozen compactly together, was from 7 to 8 feet thick, the upper surface of each piece being covered by a layer of snow about a foot in thickness. Scattered about in the pack were a few blue coloured berg pieces of all sizes, some of them frozen into the salt water ice. All the latter was much honey-combed by melting, but the ice was evidently still of sufficient strength to give a very dangerous blow if impelled against a vessel's side, or to a vessel forcing her way through the pack. A properly fortified ship could nevertheless have easily made way through it.

In the pack were numerous icebergs, but they were not in greater numbers than in the open water, and certainly not numerous enough by themselves to create the nucleus for the pack to form around.

A very large proportion of the bergs were, as stated, flat-topped and maintained their original balance. Very many were bounded by a single range of cliffs washed by the waves all round (fig. 122 p. 377; Pl. D. fig. 3). In some these ranges were evidently old and very much indented. Many were highly complex, combining two stories, lines of caves, talus slopes, and evidences of having been tilted to various angles from the original line of flotation once or twice (Pl. B. fig. 1; Pl. D. fig. 4); some were excessively worn and weathered, having apparently been long in warmer regions, and were pinnacled and broken up by deep gullies or channels bounded often by rounded ridges projecting at their mouths on either side. One much weathered pinnacled berg was passed which had its entire surface shining and polished as if it had recently toppled, and no fresh snow had fallen since this had occurred. Several were seen with the parts which had been below water partially exposed by tilting; the surfaces of these were always polished and smooth; but no berg was seen to tilt or turn over during the voyage. One was noticed divided into three separate columnar masses so far as the part above water was concerned, no connection between the columns being visible.

The platforms under water at the bases of the bergs often run out into spurs and irregular projections, and these may be dangerous to ships going too near. Soundings were taken on one of these platforms and gave 7 fathoms at some distance from



J. J. Wild del.

F. Huth Lith. Edin.

ANTARCTIC ICEBERGS.

1, seen February 15th 1874, Lat. 65° 59' S., Long. 78° 24' E. 2–4, seen February 16th 1874, Lat. 66° 40' S., Long. 78° 22' E.

5, seen February 19th 1874, Lat. 64° 37' S., Long. 85° 49' E.

the berg and 3½ fathoms nearer in. Nearly all the flat-topped bergs showed numerous crevasses in their cliffs near their summits, and these were always widest towards the summits, and were irregularly perpendicular in general direction. The flat tops of the bergs had usually rather uneven surfaces, being covered with small hillocks, apparently formed by the drifting of snow, or showing irregularities where they covered over the mouths of crevasses. The surfaces in fact, looked just like those of the "Firn" or "Névé," the cracked snow-fields at the heads of European glaciers, and appeared as if they would be equally dangerous to traverse, except by a party roped together. The second stories of bergs were always covered with snow, which had fallen on them after their emergence.

The stratified structure of the bergs is best seen in the case of flat-topped rectangular bergs, where an opportunity is afforded of examining at a corner two vertical cliff faces meeting one another at a right angle. The entire mass shows a well-marked stratification, being composed of alternate layers of white opaque-looking, and blue, more compact and transparent, ice. The late Dr E. L. Moss, R.N., Staff-Surgeon on the recent Arctic Expedition, describes a similar stratification as occurring in Arctic ice. He had opportunities of examining the ice closely at leisure, and describes each stratum as consisting of an upper white part merging into a lower blue part, the colour depending on the greater or less number and size of the air-cells in the ice.[1]

Towards the lower part of the cliffs, the strata are seen to be extremely fine and closely pressed, whilst they are thicker with the blue lines wider apart, in proportion as they are traced towards the summits of the cliffs. In the lower regions of the cliffs the strata are remarkably even and horizontal, whilst towards the summit, where not subjected to pressure, slight curvings are to be seen in them corresponding to the inequalities of the surface and drifting of the snow. In one berg there was in the strata at one spot the appearance of complex bedding, somewhat resembling that shown in the Æolian calcareous sand formations of Bermuda. The strata were often curved in places, but always in their main line of run, horizontal, *i.e.*, parallel to the original flat top of the berg. The strata in the cliff at the level of the wash-line of a rectangular berg 80 feet in height were so thin and closely packed that they looked almost like the leaves of a huge book at a distance, for by the lap of the waves the softer layers had been to some extent dissolved out from between the harder. In one berg where the face of the cliff was very flat and seen quite closely with a powerful glass, the fine blue bands were seen to be grouped, the groups being separated by bands in which no lines were visible, or where these were obscured by the ice fracturing with a rougher surface, not with a perfectly even and polished one, as existed where the blue bands showed out. The cliff surfaces, where freshly fractured, showed an irregular jointing and

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[1] Observations on Arctic Sea Water and Ice, *Proc. Roy. Soc. Lond.*, vol. xxvii. p. 547, 1878.

cleavage of the entire mass, very like that shown in a cliff of compact limestone. In one or two bergs a fine cleavage lamination was noticed like that of slate or shale, the laminæ being parallel to the face of the cliff, and breaking up at their edges with a zigzag fracture, resembling diamond cleavage of slate; this condition may have been produced by a peculiar exertion of pressure in these particular bergs.

When the lower cliff of a two-storied berg (Pl. D. figs. 1, 2) had a shot fired into it, large masses of ice fell, raising a considerable swell in the sea. The pieces of the cliff split off in flat masses parallel to the face of the cliff, just as was noticed in the case of the splitting of the glacier cliffs at Heard Island, and did not tumble forward but slid down the face of the cliff, keeping their upper edges, parts of the old plateau surface, horizontal. The ice floated round the ship in some quantity; it was opaque and white-looking, somewhat like white porcelain, and the shattered fragments had remarkably sharp angular edges, showing that the ice was very hard and compact, far more so than its appearance in mass would lead one to suppose, since it looked at a distance as if it were hardly consolidated, but merely closely pressed snow. Its manner of cleavage only gives evidence at a distance of its very compact nature. Many of the floating fragments were traversed by parallel veins of transparent ice, those which, when seen on a cliff surface, looked blue.

During the short time that the ship was amongst the icebergs not one was met with that bore upon it any moraines or rocks which could with certainty be determined as such, but on the 24th February a large rock was reported on one. The scarcity of such appearances has been remarked by former voyagers. Nevertheless, there are numerous instances in which observers have met with rocks on southern bergs. Wilkes and Ross saw many; and the latter on one occasion landed a party on a berg on which there was a volcanic rock weighing many tons, and covered with mud and stones.[1] Mr. Darwin published a note on a rock seen on an Antarctic iceberg in lat. 61° S.[2] Dr. Wallich[3] remarks on the similar scarcity of the appearance of stones or gravel on northern bergs; not one in a thousand shows dirt, stones, or rocks. He attributes this to the very small disturbance of their centres of gravity which icebergs undergo when floating freely. Stones and gravel may be present in most cases, but generally remain invisible under water in the lower parts of the bergs.

On three occasions discolorations of bergs were seen. In one case there was a light yellow band on one surface of a cliff high up, possibly the result of birds' dung which had fallen on the snow when the layer was formed, or it might have been due to a fall of volcanic dust; it was too high up to be due to Diatoms. On another occasion two bergs were passed at a distance, which showed conspicuous black-looking bands, appa-

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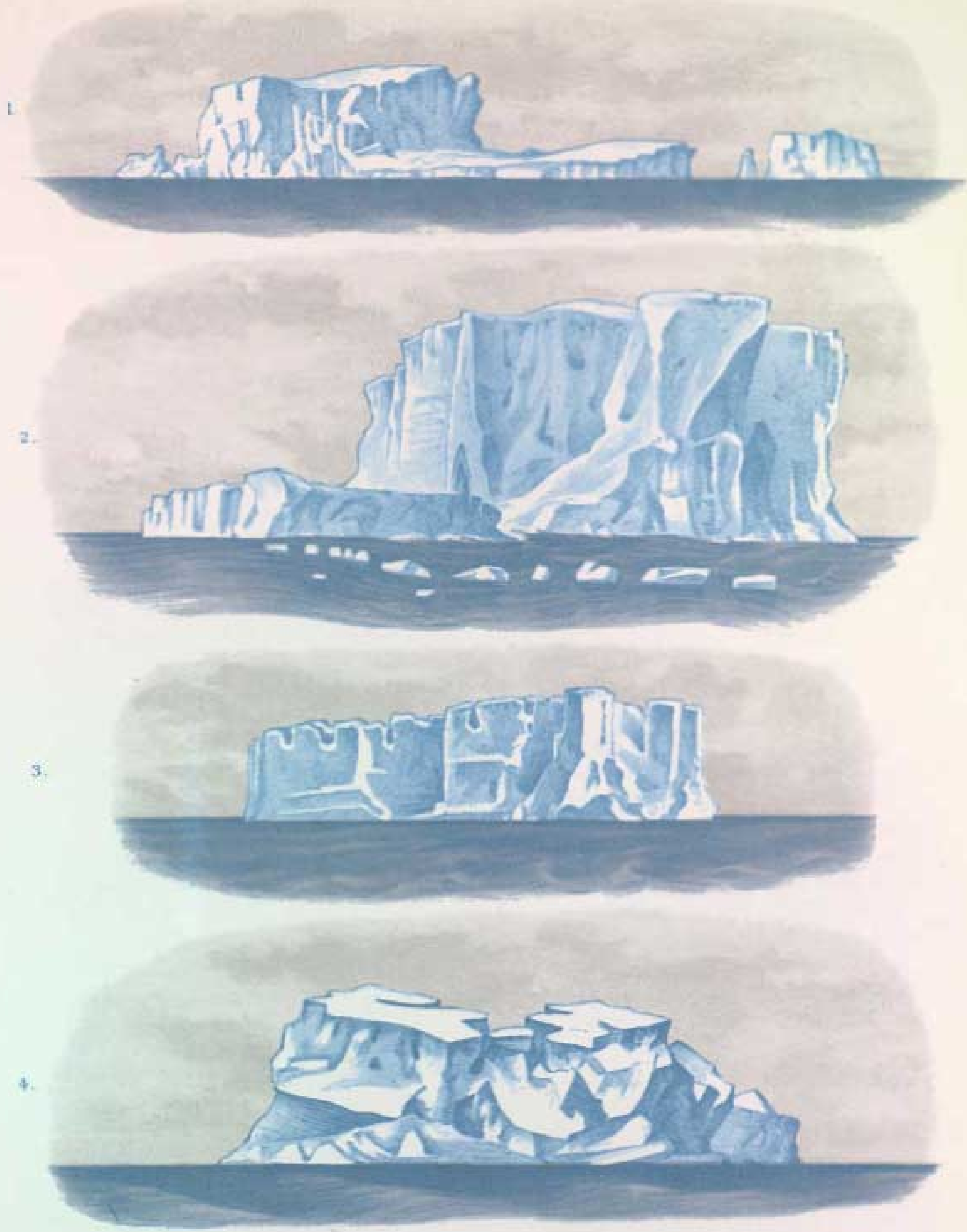
[1] Ross's Antarctic Voyage, vol. i. p. 173, London, 1847.

[2] C. Darwin, Notes on a Rock seen on an Iceberg in lat. 61° S., *Geogr. Soc. Journ.*, vol. ix. pp. 528, 529, 1839; see also Journal of Researches during the Voyage of H.M.S. "Beagle," p. 251, ed. 1879.

[3] G. C. Wallich, The North Atlantic Sea Bed, pt. i. p. 56, London, 1862.



J. J. Wild del.

F. Huth, Lith^r Edin^r

ANTARCTIC ICEBERGS.

1 & 2, seen February 21st 1874, Lat. 63° 30′ S., Long. 89° 6′ E. 3, seen February 22nd 1874, Lat. 63° 30′ S., Long. 90° 47′ E.
4, seen February 25th 1874, Lat. 63° 49′ S., Long. 94° 51′ E.

rently dirt bands. In one of the bergs there were two or three such bands, very broad, parallel to the blue bands, and separated by considerable intervals, in which the berg showed the usual stratification. In another two black bands existed at one end of the berg and one at the other. Both were parallel in direction to the blue bands, but the stratification at the end where the two black bands were situated was inclined at an angle to that of the remainder of the berg, as if a dislocation of a part of the berg had taken place. These bergs were too far distant to allow of the exact nature of the black bands being determined.

In none of the numerous bergs was there seen any bending or curved vertical bands, giving evidence of a former differential motion in the mass, such as are to be seen on every land glacier. How far the absence of these characteristic lines of motion may be explained by the fact that only about the uppermost tenth of the entire height of the bergs is seen, it is difficult to say.

The colouring of the southern bergs is magnificent. The general mass has an appearance like loaf sugar, with a slight bluish tint, except where fresh snow resting on the tops and ledges is absolutely white. On this ground colour there are parallel streaks of cobalt blue, of various intensities, and more or less marked effect, according to the distance at which the berg is viewed. Some bergs with the blue streaks very definitely marked have, when seen quite close, exactly the appearance of the common marbled blue soap. The colouring of the crevasses, caves, and hollows is of the deepest and purest azure blue possible (Pl. B. figs. 1, 3). None of the artists on board was able to approach a representation of its intensity; it seemed a much more powerful colour than that which is to be seen in the ice of Swiss glaciers. In the case of the bergs with all their sides exposed, no doubt a greater amount of light is able to penetrate than in glaciers where the light can usually only enter at the top. A large berg full of caves and crevasses, seen on a bright day, is a most beautiful and striking object. One small berg was passed at a distance which was of a remarkable colour; it looked just like a huge crystal of sulphate of copper, being all intensely blue, but it seemed as if attached to, and forming part of, another berg of normal colour. Possibly it was part of the formerly submerged base, and of more than ordinary density. Only one other such berg was seen. The intensity of the blue light received from the bergs is ordinarily such that the grey sky behind them appears distinctly reddened, assuming the complementary tint, and the reddening appears most intense close to the berg. At night bergs appear as if they had a very slight luminous glow, suggesting that they are to a very small extent phosphorescent. The sea at the foot of the bergs usually looks of a dark indigo colour, partly, no doubt, in contrast to the brighter blue of the ice. Where spurs and platforms run out under water from the bases of the berg cliffs, the shallow water is seen to be lighted up by reflection of the light from them.

The surf beats on an iceberg as on a rocky shore, and washes and dashes in and out of the gullies and caverns, and up against the cliffs. Washing in and out of the caves, it makes a resounding roar, which, when many bergs surround the ship, is very loud. So heavy is the surf on the bergs, and so steep are they as a rule, that none was seen on which landing could have been effected from a boat. As the waves wash up into the wash-lines of the bergs they form icicles, which are to be seen hanging in rows from the upper border of these grooves. A line of fragments is always to be seen drifting away from a large berg; these are termed wash-pieces. They are very instructive as showing the vast relative extent of submerged ice required to float a small portion above water, the parts of the fragments below water being visible from a ship's deck.

The scenic effects produced by large numbers of icebergs, some in the foreground, others scattered at all distances to the horizon and beyond it, are very varied and remarkable, depending on the varying effects of light and atmosphere. On one occasion, as the pack ice was being approached, some distant bergs were seen to assume a most intense black colour. This was due to their being thrown in shade by clouds passing between them and the sun, and the heightening of this effect by the contrast with brilliantly lighted up bergs around them. They looked like rocks of basalt.

Deposits.—In the cruise between Heard Island and Australia four kinds of deposits were met with, 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. (see Sheet 23). 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 northward of the Stations at which blue mud was found 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 deposit, 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 about lat. 46° or 47° S. 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. 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 subsurface 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 the great depths in the ocean.

Surface Organisms.—South of lat. 50° S. Diatoms were occasionally met with in the surface nets in enormous abundance. The most abundant were various species of *Chætoceras*, but there were also many other genera. The tow-nets were on some occasions so filled with these that large quantities could be dried by heating over a stove when a whitish felt-like mass was obtained. Associated with the Diatoms were many species of Radiolarians.

At other times, when the sea was of a pale greenish colour, the water was filled with little spherical jelly-like bodies, about 0·1 mm. in diameter, which usually contained four greenish or yellowish spots. When held in a certain light in a glass jar, these little spheres could be seen by the naked eye filling the water. Similar minute Algæ have been found in the Arctic regions. Whenever the ship passed out of the greenish bands of water these minute spheres could not be observed. Coccospheres and Rhabdospheres, which were found so abundantly in the surface water of the warmer parts of the Atlantic and Southern Oceans, were not met with south of lat. 50° S., either on the surface or in the deposits at the bottom. The same remark applies to *Orbulina universa*, *Pulvinulina*, and several species of *Globigerina*. South of lat. 50° S. the only pelagic Foraminifera found on the surface were *Globigerina bulloides*, *Globigerina dutertrei*, and *Globigerina inflata*, and these were the only pelagic species found in the deposit at the bottom. Copepods, Ostracodes, Hyperids, *Euphausia*, *Alciope*, *Tomopteris*, *Sagitta*, Pteropods, *Salpa*, and *Appendicularia* were also met with in considerable abundance in the surface nets south of lat. 50° S.

The following birds were noticed while the Challenger was amongst the Antarctic ice:—

Oceanites oceanicus, Kuhl.
Thalassœca glacialoides, Smith.
Thalassœca (Aeipetes) antarctica, Gm.
Ossifraga gigantea, Gm.
Pagodroma nivea, Gm.
Daption capensis, Linn.
Prion desolatus, Gm.
Diomedea (Phœbetria) fuliginosa, Gm.
Stercorarius antarcticus, Less.

Penguins were very often seen in the water, and on one occasion sitting on the ice, but it was impossible to make out the species. Off the pack ice, and especially near the Antarctic Circle, whales (apparently all of one species, a "Finner," probably *Physalus* *australis*) were very abundant. Smaller Cetaceans, probably a kind of Grampus (*Orca*), were also abundant near the Antarctic Circle, with a high dorsal fin placed at about the middle of the length of their bodies.

The dredgings and trawlings during the Antarctic voyage were exceedingly productive, and yielded many new genera and species belonging to nearly all the invertebrate groups. In the Zoological Reports already published, species are described belonging to about twenty-five new genera and fifty new species.

The Hexactinellida.—Professor Franz Eilhard Schulze, who is engaged in preparing a Report on the Hexactinellida collected during the Expedition, has supplied the following notes :—

"The Hexactinellida collected by the Challenger Expedition, which were entrusted to me for the purpose of scientific investigation, were dried, or more or less well-preserved in alcohol of various degrees of strength. Only a few specimens, however, were quite perfect, most of them having been injured in some way or other. Sometimes there were parts entirely wanting, sometimes the sponge was torn, crushed, or the outside had been rubbed off, or sometimes the soft parts had suffered from the invasion of mud or had become dried, as indeed might have been expected considering how most of the specimens had been obtained. Of many species only fragments, and of others only isolated spicules were obtained. It was a fortunate circumstance that no means of cleansing, such as washing, maceration, or the like, had been adopted ; by these processes the specimen gains, it is true, in elegance, but, in general, the isolated spicules which are so important for the scientific determination of the species are lost. For the study of the soft parts of the Hexactinellida, which were

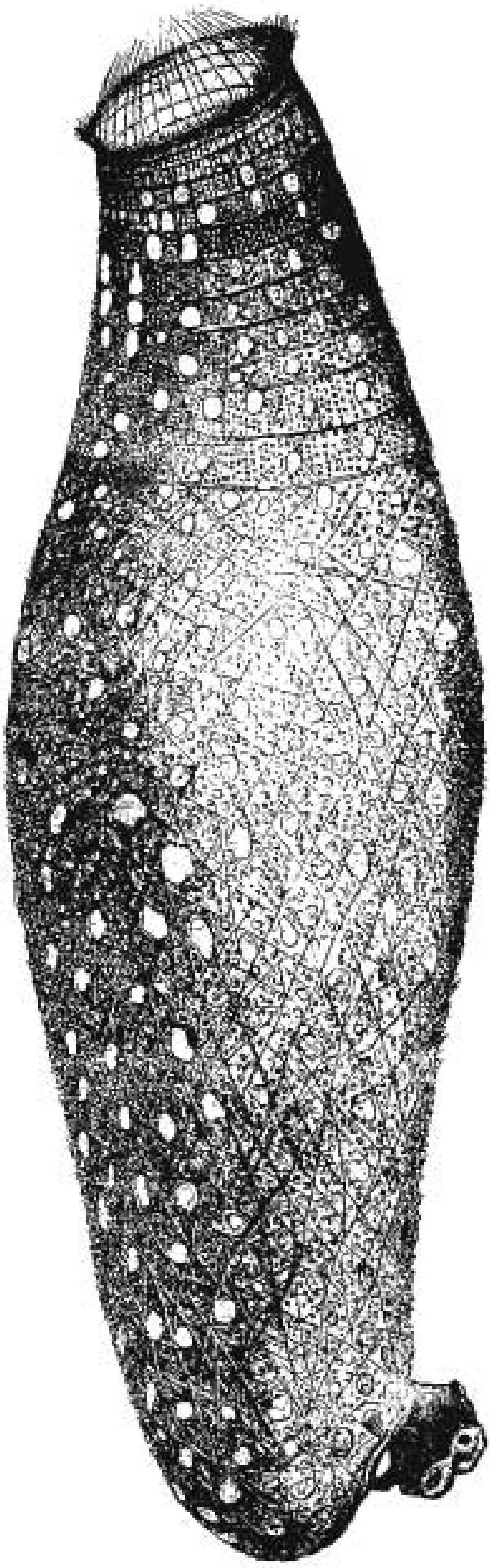


Fig. 158.—*Taegeria pulchra*, n. gen. et sp. a representative of the Euplectellidæ.

hitherto almost unknown, and in the present instance demanded special attention, those specimens which had been hardened in absolute alcohol proved specially favourable; also those portions which had been preserved in a relatively large volume of spirit of the usual strength had to some extent retained their original structure, better when voluminous or very compact than when thin and loose in structure.

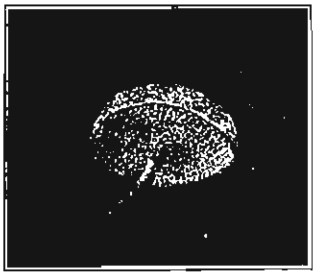


FIG. 159.—*Caulophacus elegans*, n. gen. et sp., a representative of the Asconematidæ.

"A serious drawback, however, arose from the fact that the isolation of the different species had not always been found possible. Even in the operation of dredging the different sponges had undoubtedly come into violent contact with each other; in many instances fragments of one sponge remained attached to the surface of another, or whole portions of one had penetrated into the body of another. But in those cases in which several individuals had been preserved in the same vessel it was afterwards found that the microscopic siliceous spicules, which are so important for diagnostic purposes, had, in consequence of their lying loosely scattered in the soft parts, become separated from one sponge and embedded in another lying either beside or beneath it. Obviously such intruding strangers, which may be only too easily mistaken for natives, materially increase the difficulty of fixing the character of the species or the determination of a solitary portion, especially when new and hitherto unknown forms are being treated of, whose characteristic spicules must be determined for the first time. It is true this danger of error is materially diminished by comparative examination of the various portions of the same sponge, or better still of several specimens of the same species if they are to be had, but even then there remain quite a sufficient number of instances in which a certain conclusion can be drawn only by the preparation of numerous fine sections, in which the disposition of the spicules in question will decide whether they are really in their normal situation.

FIG. 160.—*Hyalonema elegans*, n. sp., a representative of the Hyalonematidæ.

"The investigation began by a careful separation and arrangement of all the specimens; these were then placed according to the order of the dredging stations, and then one by one, thoroughly studied both with respect to their coarser as well as to their microscopic structure. The numerous preparations, drawings, and notes which were accumulated by this last difficult and tedious task form the foundation of the whole work. It was desirable not only to establish the characters of the various species, but, as far as possible, to discover the general plan of organisation of this curious and little known group of animals. Only by the application of various oftentimes very complicated methods (often newly devised for this special purpose) and instruments was it possible to arrive at a clear understanding as to the minute structure of the indifferently preserved specimens. Obviously just those portions have caused the most trouble which were the worst preserved, or only came to hand in small fragments.

Fig. 161.—*Poliopogon amadou*, Wyv. Thoms., a representative of the Hyalonematidæ. One-third the natural size. Attached to branches of *Corallium* (see p. 125).

"As a rule small pieces selected from various regions of the sponge were first soaked for some time in concentrated hydrochloric acid and then boiled in it for a few minutes, washed out with water and alcohol, dehydrated by alcohol of increasing strength, cleared by oil of cloves, and finally after teasing and careful spreading out mounted in Canada balsam. In this manner the isolated siliceous spicules and the small fragments of continuous skeletons were perfectly cleaned and exposed to view; also pieces from different parts of the sponge were, after short treatment with hydrochloric acid and subsequent washing with water and alcohol, dehydrated *en masse*, soaked in spirit of turpentine or xylol, embedded in paraffin and cut into sections by means of the microtome in various directions, but principally perpendicular to the surface. Such sections, in which all parts of the skeleton stood out clearly in the perfectly transparent soft parts, served principally for ascertaining the situation and distribution of the separate siliceous portions as well as for deciding whether the spicules which would have become separated in complete maceration were in their normal situation.

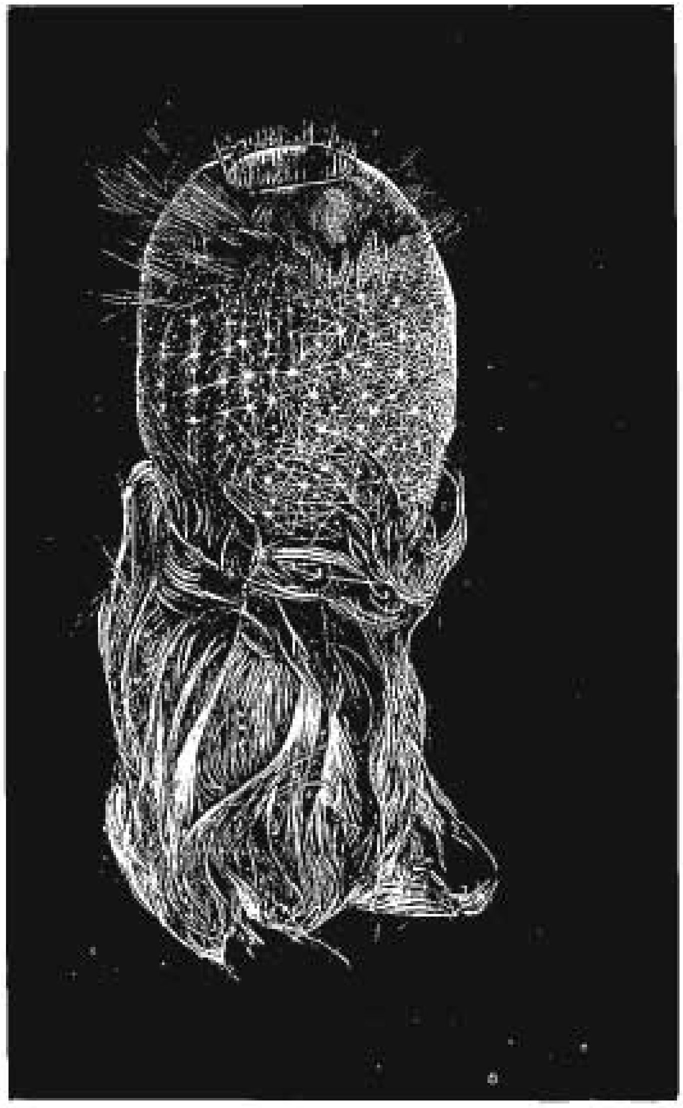


Fig. 162.—*Pheronema carpenteri* (Wyv. Thoms.), a representative of the Hyalonematidæ.

"Finally the exceedingly delicate soft parts were successfully examined, both with respect to their most minute characters as well as with reference to their relation to the skeletal structures. In addition to the usual methods of teasing and cutting into sections, it has been found advantageous to stain the specimen with some colouring matter, especially with picrocarmine, alum-carmine, and hæmatoxylin. For this purpose portions, about the size of peas or beans, were stained whole, then thoroughly washed out with alcohol of gradually increasing strength, and finally dehydrated with turpentine or xylol, embedded in paraffin and cut into sections of varying thickness with the microtome.

"In some cases it was desirable to obtain in the section not only the delicate soft-tissues but also the hard and brittle flinty skeleton as a complete network; but the well-known curling up of the thin sections was a serious hindrance, inasmuch as although the delicate, yet elastic, soft tissues were easily retained in connection, the brittle siliceous web was always obtained in fragments. I sought to discover a means by which this detrimental curling of the sections might be prevented, and after many attempts constructed that small accessory to the microtome which I have described and figured under the name of 'Schnittstrecker';[1] by means of this simple instrument it was possible to obtain sections, not only of very firm and compact pieces, but also of more delicate and brittle objects, such as the tubes of the genus *Farrea*, in which not only the soft parts but also the brittle siliceous trabeculæ were retained in their normal positions. The sections prepared in this manner proved of assistance in

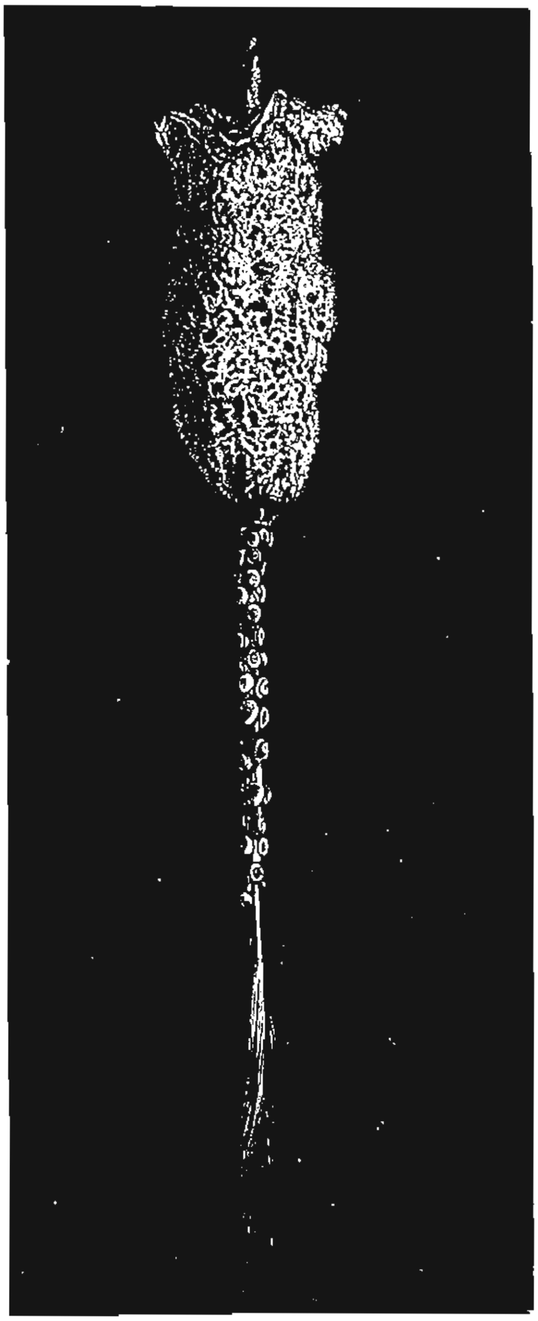


FIG. 163.—*Hyalonema lusitanicum*, Bocage, a representative of the Hyalonematidæ.

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[1] *Zool. Anzeiger.*, Jahrg. vi. p. 108, 1883.

the comprehension of the plan of organisation and the structural relations, but they were less applicable to the study of minute histological details, which undergo alteration by treatment of the object with turpentine and embedding in paraffin. For this purpose therefore other preparations were used, which were simply teased out or cut by hand after being stained and then mounted in glycerin.

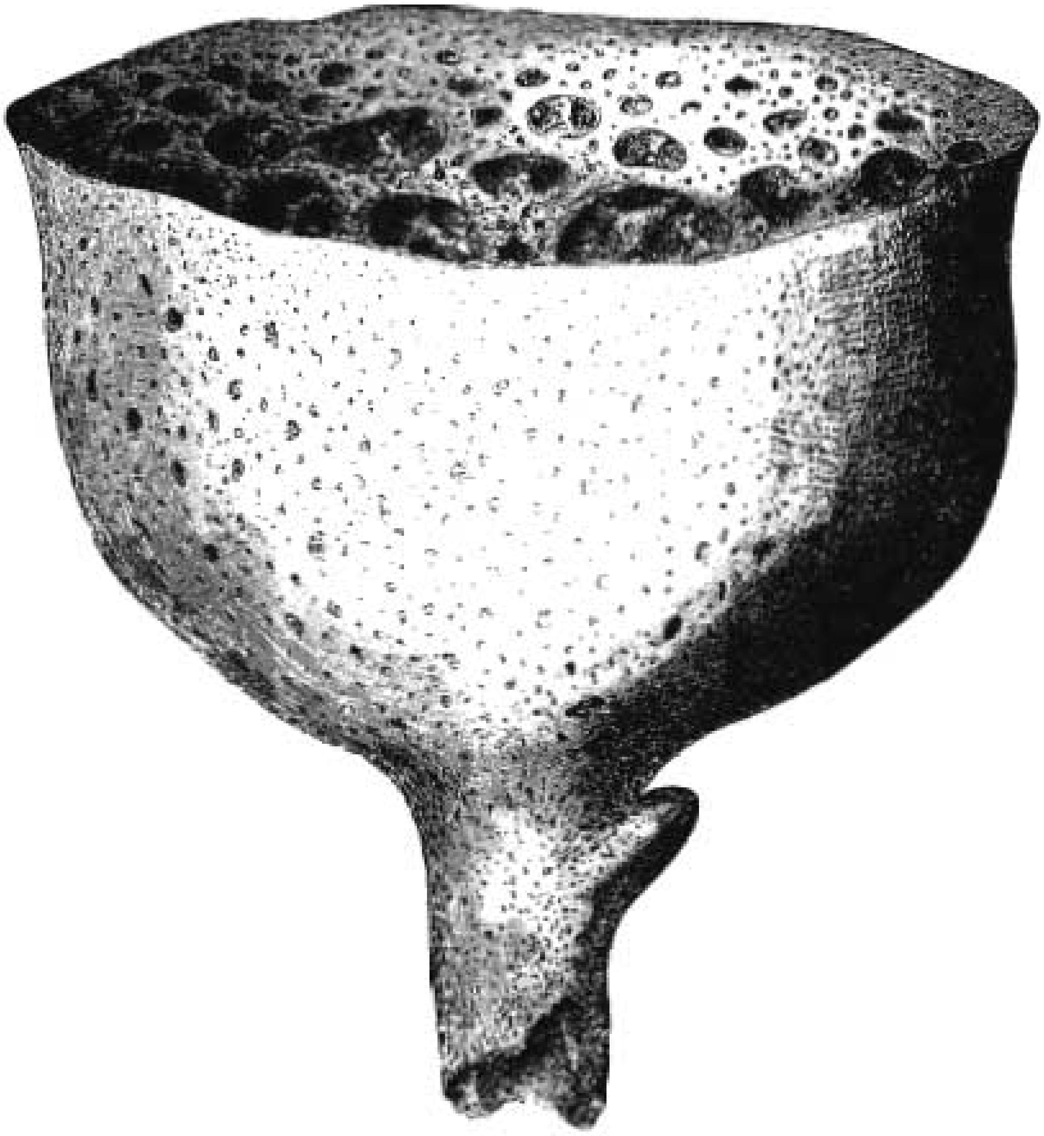

FIG. 164.—*Crateromorpha murrayi*, n. sp., a representative of the Rossellidæ.

"The glycerin has the advantage over balsam not only in that the delicate outlines of the cells may be more easily recognised, but also because, in consequence of its refractive index agreeing very closely with that of the siliceous skeleton, this latter becomes almost invisible, and thus the soft tissues stand out much more prominently.

"As one of the most important results of the carrying out of these detailed investigations, the fact has been established that the Hexactinellida, which were first clearly marked off and characterised by Oscar Schmidt in 1870, form a division of the siliceous sponges, definitely bounded on all sides, whose members are intimately united by a common plan of structure. The subclass Hexactinellida is, however, principally characterised by the triaxial or six-rayed type, which underlies the forms of its spicules, and also by the close agreement of the organisation of its soft parts. In no single instance was I ever in doubt whether I had before me a Hexactinellid or not; for even when many isolated spicules and the several parts of a connected trabecular skeleton did not show the typical Hexactinellid structure without further investigation, yet on careful examination this could be demonstrated, and spicules were found showing either the usual six-rayed form or an easily recognisable derivative from it. As Oscar Schmidt was the first to point out, the determination of the axial-relations of the central canal is of special importance; by means of studying it in every connected trabecular skeleton the individual six-rayed spicules, already partially united, are always easily recognised; even in the case of many highly modified isolated needles, the central canal gives a clue to the derivation from the typical six-rayed form. However great the number of forms of the spicules in the Hexactinellida may be, yet there are fundamentally but few principles of modification which have been carried out. These are—(1) unequal elongation of the individual rays, in which may be found all degrees of shortening, even to complete atrophy of one or more rays; (2) division of the rays into two or more branches; (3) flexion of the rays or their branches; (4) unequal thickening of the rays or their branches, which may lead to the development of swellings of various forms, hooks, teeth, or the not infrequent terminal knobs or toothed plates.


Fig. 165.—*Lefroyella decora*, Wyv. Thoms. (natural size), a representative of the Euretidæ.

"As in the case of the skeleton, so also in the general structure of the soft parts, a predominant principle might be recognised. In all Hexactinellids, that surface (usually the outer) which serves for the ingress of water, is covered by a thin perforated skin or membrane (which is supported by a special system of regularly arranged spicules), according to the form of the latter either a flat surface or one covered with numerous conical elevations is formed. A similar and similarly perforated membrane is found also on the opposed surface of the body-wall, the surface of egress, which indeed generally encloses an internal gastric cavity, but may also, as in the case of many flattened or mushroom-shaped sponges, be quite free and form an upper or lateral surface.

"Between these two perforated boundary-surfaces there extends the simple strongly folded layer of the ciliated cavities, which usually manifest a saccular shape, as I have already described in *Euplectella aspergillum*,[1] but in some cases, as in the family Hyalonematidæ, diverge to some extent from this. The delicate wall of the cavities allows the square lattice-marking to be perceived as in *Euplectella*, and is also more or less thickly but irregularly perforated by round pores. This system of ciliated cavities is connected with the two boundary-surfaces by means of a wide-meshed tissue of delicate anastomosing trabeculæ, which are suspended and stretched between them. Since, then, all the chambers are in direct communication, and since their convex surfaces are always turned towards the entering water, this latter must flow through them in such a manner that it enters through the pores and passes out through the wide oral opening.

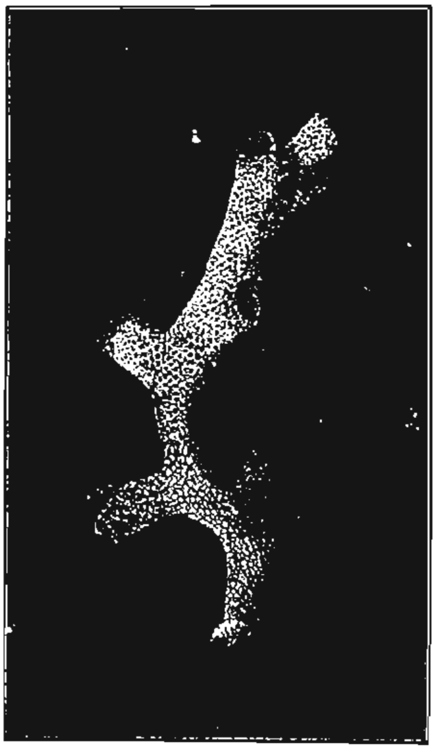

FIG. 166.—*Melittiaulus ramosus*, n. gen. et sp., a representative of the Uncinataria.

"On account of the great uniformity in the structure of the soft parts, I have only been able to use these for systematic purposes in a few cases, such as in the definition of the Hyalonematidæ. For such purposes the form and arrangement of the siliceous skeleton, which has hitherto been almost exclusively applied by all spongiologists, is most significant.

"The two primary divisions of the Hexactinellida, LYSSACINA and DICTYONINA, which Zittel founded some years ago in his important work on fossil sponges, I retain with the same significance, but in consequence of my investigations I have been obliged to modify his original definitions to some extent.

"Zittel regards as LYSSACINA those Hexactinellida in which the whole skeleton consists of spicules which are only connected by means of the sarcode (exceptionally, however, irregularly by means of flattened siliceous bodies), and in which the spicules of the soft parts are for the most part very plentiful and highly differentiated.

"The DICTYONINA he defined as those Hexactinellida whose spicules are so united that

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[1] *Trans. Roy. Soc. Edin.*, vol. xxix. pp. 661–673, 1881.

each arm of a six-rayed spicule is applied to the corresponding arm of a neighbouring spicule, both spicules thus becoming enclosed by a common siliceous covering. The connected skeletons of the DICTYONINA consist of a lattice-work with irregularly cubic meshes. Spicules belonging to the soft parts may be present or absent.

"In many sponges which, according to the rest of their organisation, belong without doubt to Zittel's 'Dictyoninen,' I have failed to observe that union of neighbouring spicules by the enclosure of the corresponding approximated branches in a common siliceous coating, which he mentions; on the contrary I found in these cases the spicules either united crossing each other quite irregularly or disposed in a different manner, which also has been already observed by Oscar Schmidt and Zittel; that is to say, the rays of the spicules were fused with other spicules in the angles between their rays, and thus united into a firm skeleton.

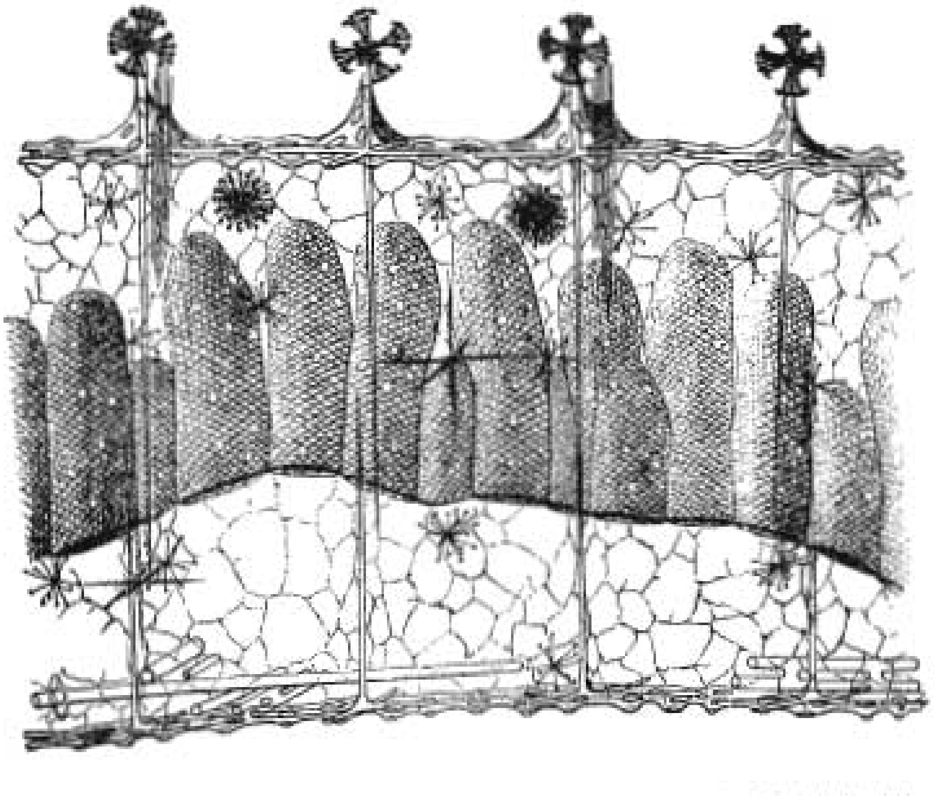

FIG. 167.—Section of the wall of *Walteria flemmingii*, n. gen. et sp., a representative of the Euplectellidæ $\left(\frac{70}{1}\right)$.

"On the other hand, in not a few LYSSACINA, I have, like Oscar Schmidt, met with a firm union of spicules of a particular kind, sometimes in a very irregular disposition, sometimes by lateral soldering, sometimes of closely approximated parallel spicules connected by transverse pieces (synapticulæ); this may take place only in the basal portion or throughout the whole body, as in *Euplectella aspergillum*, in its mature condition. I can, therefore, regard neither the union of spicules into a continuous trabecular skeleton, nor that particular mode of their union by means of the opposition of the corresponding branches of spicules and covering with a common envelope, as a sufficiently constant character for the diagnosis of the DICTYONINA, and for the division of the Hexactinellida into two primary classes, although I do not wish to deny that there are certain differences in the mode of union of the rays of the spicules between the DICTYONINA on the one hand, and the LYSSACINA, which are provided with a firmly united skeleton, on the other.

FIG. 168.—*Mylusia callocyathus*, Gray, a representative of the Inermia.

"On the contrary I find the chief difference between the above mentioned divisions of the Hexactinellida to be this—that in the DICTYONINA the skeleton is already deposited during the formation and growth of all the parts of the body, and hence typically and necessarily by the union of certain spicules in more or less regular arrangement, whilst in the LYSSACINA either a continuous trabecular skeleton is entirely wanting or only formed at a later stage, partly by the enclosing of irregularly disposed spicules at their points of crossing or of

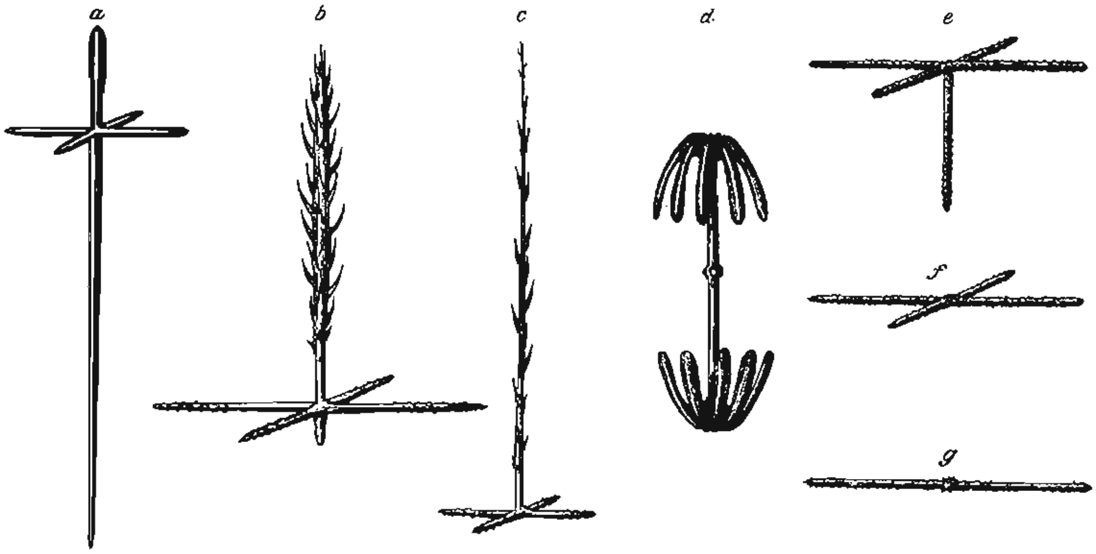

FIG. 169.—Characteristic forms of the dermal spicules of the four families of Lyssacina.

a, dagger-shaped spicule of *Walleria flemmingii*, n. gen. et sp. (a Euplectellid); *b*, "Pinulus," fir-tree shaped spicule of *Sympagella nux*, O. Sch. (an Ascoнematid); *c*, "Pinulus," and *d*, "Amphidisk" of the external surface of *Hyalonema sieboldi*, Gray (a Hyalonematid); *e*, *f*, *g*, dermal spicules of *Rossella antarctica*, Carter (a Rossellid).

contact, partly by transverse connecting trabeculæ (synapticulæ) between closely approximated parallel spicules; so that the adhesive process commences at one portion of the sponge, and is gradually continued to a greater or less extent.

"The order Lyssacina may be divided into four families—(1) Euplectellidæ, (2) Asconematidæ, (3) Hyalonematidæ, (4) Rossellidæ—which, apart from numerous other characters, may be easily distinguished as follows by the radially or tangentially directed spicules of the external membrane.

"The Euplectellidæ possess in the external membrane dagger-shaped six-rayed spicules with an elongated proximal ray.

"The Asconematidæ have 'pinuli,' that is six- or five-rayed spicules, whose strongly developed distal ray is in the form of a pine-tree, while the proximal ray is either entirely wanting or only feebly developed; 'amphidisks' are entirely wanting in this group.

"The Hyalonematidæ possess both pinuli and amphidisks.

"The Rossellidæ bear spicules in which the distal ray is either entirely wanting or much reduced, while the proximal ray is either strongly developed or also wanting; indeed two rays belonging to the same tangential axis may both be wanting, so that only simple tangentially directed rods remain.

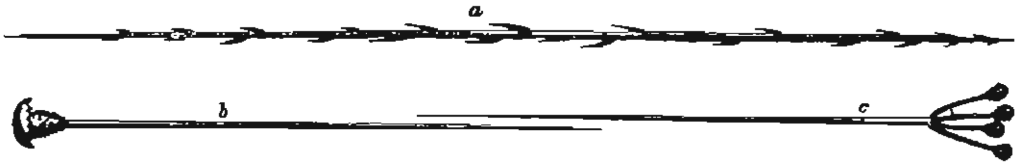

Fig. 170.—Characteristic spicules of the Uncinataria.
a, "Uncinatum," *b*, "Clavula" of *Farrea haeckelii*, n. sp.; *c*, "Scopula" of *Eurete carteri*, n. sp.

"The Dictyonina may be divided into two suborders, Uncinataria and Inermia. The former are characterised by the possession of sharply pointed rods, 'uncinata,' which are abundantly provided with proximally directed recurved hooks; the latter are devoid of such 'uncinata.'

"In the first family of Uncinataria, the tubular or calyciform Farreidæ, there are found in the external membrane radially disposed acicular rods, the 'clavulæ,' while the five remaining families, instead of such 'clavulæ,' possess 'scopulæ,' that is radially directed structures formed like brooms or forks, with from two to eight prongs, the latter are termed Scopularia, whilst the former are called Clavularia.

"To the Scopularia belong—

"1. Euretidæ, in the form of a branched anastomosing tubular structure, or of a goblet with lateral outlets.

"2. Melittionidæ, of goblet or tubular form, with honeycomb-like walls.

"3. Chonelasmatidæ, flat or beaker-shaped, with straight funnel-shaped canals which perforate the walls perpendicularly and open alternately on either side.

"4. Volvulinidæ, tubular, goblet-shaped, or massive, with crooked canals, more or less irregular in their course.

"5. Sclerothamnidæ, whose arborescent body is perforated at the ends and sides of the branches by round narrow radiating canals.

"The Inermia, which are devoid of either uncinata, clavulæ, or scopulæ, are divided into the following four families:—

"1. Myliusidæ, in form of low wide beakers, whose wall is complexly folded and forms lateral exhalent tubes.

"2. Dactylocalycidæ, of goblet or flat saucer shape, with thick wall, consisting of numerous parallel anastomosing tubes of equal breadth, which end on the same level without and within.

"3. Euryplegmatidæ, in the form of goblets or ear-shaped saucers, in whose walls there run parallel to the surface a number of dichotomously branching canals or partially covered-in grooves, which are due to a deep longitudinal folding.

"4. Aulocystidæ, of massive rounded form, consisting of a system of anastomosing tubes, which pass outwards from the sides of an axial cavity, and have intercanals between them. These latter, as well as the lateral terminal apertures of the tubes, are covered by a thin membrane which is provided with slit-like openings over the lamina of the tubes, and thus assumes a sieve-like character.

"A critical examination of all recent Hexactinellida, hitherto described, has led me to the conclusion that forty-two species have been sufficiently accurately defined for recognition, those being excepted which were described by Professor Wyville Thomson in preliminary communications from the Challenger Expedition; whilst in the rich material which was brought home by this Expedition I have been able to distinguish seventy-nine species, of which nineteen had been already described, while the remaining sixty are new. It is seen therefore that the investigations of the Challenger have raised the number of known species of Hexactinellida from forty-two to one hundred and two.

"The forty-two species previously known belonged to thirty genera, so that there were on an average 1·5 species to each genus; the sixty species which I have constituted are distributed in thirty genera, allowing on an average two species to each genus, whilst the total number of one hundred and two species, at present known, belong to fifty-three genera. Hence, as the result of the Challenger Expedition, the ratio between the numbers of the genera and species has been diminished from 3:4 to almost 1:2.

"This is readily understood when we consider that the first forms of a large and hitherto unknown group of animals which chance to be obtained, will as a rule belong to different divisions of the group; whilst the more this group becomes known the greater is the probability that the newly acquired species will be closely allied to forms which are already known, that is, the average number of species in each given genus will increase.

"Since the Challenger made an investigation of the great depths of all the important oceans, except the Arctic Ocean and the northern part of the Indian Ocean, a general view of the results obtained with respect to the geographical and bathymetrical distribution of the Hexactinellida will be of special value.

"I will therefore proceed to summarise the distribution of the Hexactinellida so far as the results of the Challenger dredgings permit. The number of dredging and trawling stations amounted altogether to about two hundred and eighty, of which fifty-three, that is about one-fifth, yielded specimens of Hexactinellida.[1] In many cases only one or two specimens were taken at each Station, but sometimes as many as fifty or more were obtained. If, however, not the number of specimens but (what is more important) the number of species found at each Station be reckoned, then a careful enumeration shows that of the fifty-three Stations—

32	gave each	1	species.
11	,,	2	,,
3	,,	3	,,
3	,,	4	,,
1	,,	5	,,
2	,,	6	,,
1	,,	18	,,

This last Station, rich both in individuals and in species, is Station 192, near the Ki Islands, southwest of New Guinea.

"The fifty-three Stations are distributed among the three principal oceans, so that

17	belong to the	Atlantic	Ocean.
27	,,	Pacific	,,
9	,,	Southern	,,

"From an examination of these Stations it appears that species of Hexactinellida are most numerous in the Southern Ocean, least so in the Atlantic; but on the other hand the number of species at particular places is greatest in the Pacific.

"The fact, which has been remarked in many other classes of animals, repeats itself here, namely, that the number of forms which live together in any given place is in general greatest in the tropics; the tropical zone of the Pacific being most remarkable

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[1] It must be observed that in some cases (*e.g.*, Stations 149, 164) one number includes several dredgings which ought, perhaps, to be reckoned as so many different Stations; I have, however, reckoned each number as one Station.

in this respect. It is very probable, however, that the tropical zone of the Indian Ocean, which has not hitherto been investigated, will prove to be richer in species than that of the Pacific, since in its south temperate zone, which at present is alone available for comparison, it has shown itself to be richer. Hence we may anticipate that an investigation of the tropical region of the Indian Ocean would yield specially rich material as regards the Hexactinellida.

"Finally I will give the principal results of an inquiry undertaken to find out the dependence of the Hexactinellida upon the nature of the sea-bottom. For this purpose the Stations were classed according to the nature of the deposit found at each.

"When the different groups of Stations were examined it appeared that the Diatom ooze was specially favourable to the Hexactinellida, and also that Radiolarian ooze and blue mud were more or less adapted to their existence; while they appeared to be entirely wanting upon bottoms of sand and gravel, which is perhaps owing to the fact that deposits of this kind usually occur at depths of less than 100 fathoms, which are too shallow for these animals.

"It is also worthy of remark that several Hexactinellida, which came from great depths, were filled with Diatoms and Radiolarians, although the bottom at these Stations was not a Diatom or Radiolarian ooze."

The following is a list of the genera contained in the above mentioned families and subfamilies.

Type CŒLENTERATA.

Subtype Spongiæ.

Class SILICISPONGIÆ. Subclass *Hexactinellida.*

- Order I. LYSSACINA, Zittel.
  - Family I. EUPLECTELLIDÆ.
    - Subfamily 1. Euplectellinæ.
      - (1) *Euplectella*, Owen.
      - (2) *Regadrella*, Osc. Schmidt.
    - Subfamily 2. Holascinæ.
      - (1) *Holascus*, n.
      - (2) *Malacosaccus*, n.
    - Subfamily 3. Tægerinæ.
      - (1) *Tægeria*, n.
      - (2) *Walteria*, n.
      - (3) *Habrodictyum*, Wyv. Thoms.
      - (4) *Eudictyum*, Marshall.
      - (5) *Dictyocalyx*, n.
      - (6) *Rhabdodictyum*, Osc. Schmidt.
      - (7) *Rhabdopectella*, Osc. Schmidt.
      - (8) *Hertwigia*, Osc. Schmidt.
  - Family II. ASCONEMATIDÆ.
    - Subfamily 1. Asconematinæ.
      - (1) *Asconema*, Sav. Kent.
      - (2) *Aulascus*, n.
    - Subfamily 2. Sympagellinæ.
      - (1) *Sympagella*, Osc. Schmidt.
    - Subfamily 3. Caulophacinæ.
      - (1) *Caulophacus*, n.
      - (2) *Trachycaulus*, n.
  - Family III. HYALONEMATIDÆ.
    - Subfamily 1. Hyalonematinæ.
      - (1) *Hyalonema*, Gray.
      - (2) *Dictyosphæra*, n.
      - (3) *Pheronema*, Leidy.
      - (4) *Poliopogon*, Wyv. Thoms.
    - Subfamily 2. Semperellinæ.
      - (1) *Semperella*, Gray.

Family IV. ROSSELLIDÆ.
- Subfamily 1. Rossellinæ.
  - (1) *Lanuginella*, Osc. Schmidt.
  - (2) *Polylophus*, n.
  - (3) *Rossella*, Carter.
  - (4) *Acanthascus*, n.
  - (5) *Bathydorus*, n.
- Subfamily 2. Crateromorphinæ.
  - (1) *Crateromorpha*, Gray.
  - (2) *Rhabdocalyptus*, n.
- Subfamily 3. Aulochoninæ.
  - (1) *Aulochonen*, n.
- APPENDIX.
  - *Hyalostylus*, n.
  - *Aulocalyx*, n.

Order II. DICTYONINA, Zittel.
- Suborder 1. UNCINATARIA.
  - Tribe I. Clavularia.
    - Family I. FARREIDÆ.
      - (1) *Farrea*, Bowerbank.
  - Tribe II. Scopularia.
    - Family I. EURETIDÆ.
      - (1) *Eurete*, Semper.
      - (2) *Periphragella*, Marshall.
      - (3) *Lefroyella*, Wyv. Thoms.
    - Family II. MELITTIONIDÆ.
      - (1) *Aphrocallistes*, Gray.
      - (2) *Melittiaulus*, n.
    - Family III. CHONELASMATIDÆ.
      - (1) *Chonelasma*, n.
    - Family IV. VOLVULINIDÆ.
      - (1) *Volvulina*, Osc. Schmidt.
      - (2) *Tretodictyum*, n.
      - (3) *Fieldingia*, Sav. Kent.
    - Family V. SCLEROTHAMNIDÆ.
      - (1) *Sclerothamnus*, Marshall.
- Suborder 2. INERMIA.
  - Family I. MYLIUSIDÆ.
    - (1) *Myliusia*, Gray.
  - Family II. DACTYLOCALYCIDÆ.
    - (1) *Dathylocalyx*, Gray.
    - (2) *Scleroplegma*, Osc. Schmidt.
    - ?(3) *Margaritella*, Osc. Schmidt.
  - Family III. EURYPLEGMATIDÆ.
    - (1) *Euryplegma*, n.
    - ?(2) *Joannella*, Osc. Schmidt.
  - Family IV. AULOCYSTIDÆ.
    - (1) *Aulocystis*, n.
    - (2) *Cystispongia*, Rœmer.

The Tetractinellida.—Professor W. J. Sollas, who is preparing a Report on the Tetractinellid Sponges collected by the Expedition, writes as follows :—" Although my investigation of the Tetractinellida of the Challenger Expedition is by no means yet complete, it is sufficiently advanced to show that considerable additions have been made to our knowledge of this group. The excellent state of preservation in which the spirit specimens have been brought home has afforded me an opportunity of ascertaining the anatomy and histology of most of the recognised genera of the group. This is especially fortunate in the case of the Lithistidæ, of the soft parts of which next to nothing was hitherto known. These sponges conform in all essential characters of the canal system to the complicated racemose type which occurs in the majority of sponges, and neither in the characters of the pores, subdermal cavities, nor of the flagellated chambers, offer anything markedly distinguishing the group from the non-cortical Choristid Tetractinellids.

" The Choristidæ have not only afforded rich material for working out the relations of the genera of the group, but furnish also some new forms of considerable interest on account of the reduction and other modifications presented by the Tetractinellid spicules characteristic of the order.

" It would be premature to discuss questions of distribution before the practical study of the collection is concluded; so far I will content myself with stating that the majority of the Tetractinellid Sponges are not usually inhabitants of very deep water, they rather affect shallow water, say from 10 to 50 fathoms, but occasionally extend to greater depths, such as 1000 fathoms. There is only one characteristic exception to the rule, viz., in the case of the genus *Thenea*, which is usually found at depths of from 1000 to 1800 fathoms, but sometimes enters shallower water; in one case it was obtained from the comparatively shallow depth of 95 fathoms.

"Tetractinellid genera appear to be of world-wide distribution, but certain subgeneric groups of species appear to be restricted to particular areas. Thus, such a group as the Stellettina, characterised by a particular form of minute spicule, occurs along the track of the Challenger at various points between Australia and Japan. Another group appears to be confined to Southern Australia.

"Although I expect to add much on distributional questions when I have completed my study of the collection, I consider that the chief additions to our knowledge will be found to bear on problems of histology and minute anatomy."