II. "Preliminary Report," by Dr. WILLIAM B. CARPENTER, V.P.R.S., "of Dredging Operations in the Seas to the North of the British Islands, carried on in Her Majesty's Steam-vessel 'Lightning,' by Dr. CARPENTER and Dr. WYVILLE THOMSON, Professor of Natural History in Queen's College, Belfast." Received October 22, 1868.

In accordance with the request of the President and Council of the Royal Society, conveyed in the Letter written by their direction to the Secretary to the Admiralty on the 18th of June (Appendix), the Lords Commissioners of the Admiralty were pleased to give their sanction to the scheme for Deep-sea Dredging therein proposed, and to furnish the means of carrying it out as effectively as the advanced period of the season might permit.

2. The Surveying-ship 'Lightning' was assigned for the service, and was furnished with a "donkey-engine," and with all other appliances required for the work, together with the most approved Sounding-apparatus* and Thermometers. The vessel was placed under the charge of Staff-Commander May, who had been much engaged in exploratory service elsewhere; and the instructions given to him were so framed as to enable him to carry out my wishes in every practicable way.

3. I was accompanied by my friend Professor Wyville Thomson, with whom the idea of this inquiry had originated †, and to whose zealous and efficient cooperation I have been greatly indebted in the prosecution of it. His large previous experience in Dredging-operations, and his extensive knowledge of the Marine Fauna, not merely of Great Britain, but of the Scandinavian and Boreal provinces, have supplied much that would otherwise have been deficient on my own part; and he has shown himself ever ready to relieve me of the more laborious part of the work we had jointly undertaken. Although it has been deemed fitting that, as it was by me that the proposal for this inquiry was brought before the Royal Society, and as I was entrusted by the Admiralty with the direction of it, this Report of its proceedings should proceed from myself, I have the satisfaction of saying that it has the full concurrence of my able Coadjutor.—I was permitted to take with me one of my sons as an Assistant; and we were all three considered as in the Public Service, and liberally provided for accordingly.

4. It is with great pleasure that I am able to state that the results of

* The Sounding-apparatus which we employed was that known as "Fitzgerald's Sinker," and we found it to answer perfectly. It carries down a weight of either 56 lbs. or 112 lbs., which detaches itself on reaching the bottom, so that the sinker (the weight of which is itself small) can be brought up by a small line; and this sinker is provided with a scoop, which brings up a sample of the bottom in a wedge-shaped box furnished with a cover that falls down and closes it when it has struck the ground.

† See his Letter of May 30 in the Appendix.

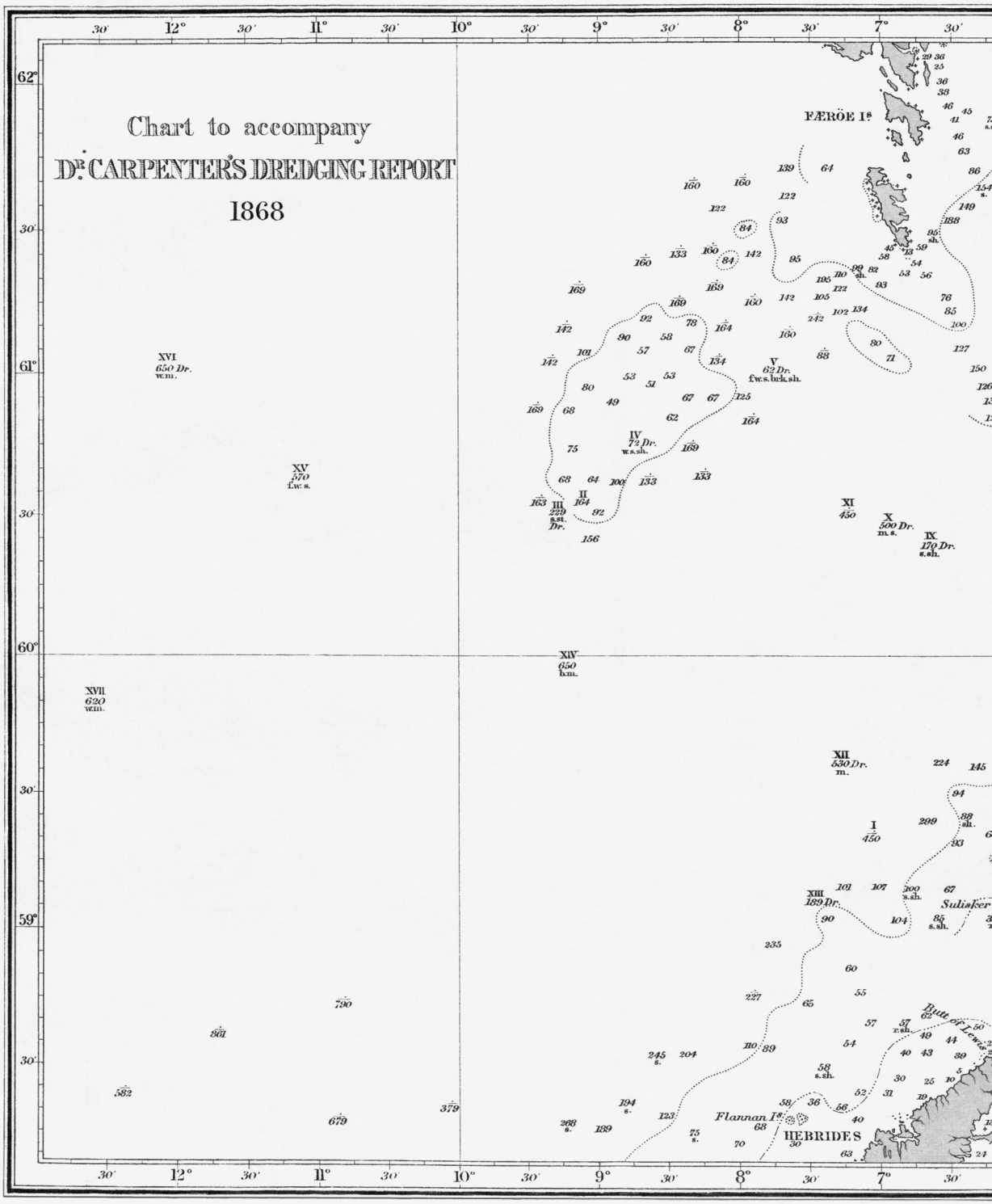
Chart to accompany
Dr. CARPENTER'S DREDGING REPORT
1868
FÆRÖE Is
Flannan Is
HEBRIDES
Butt of Lewis
Sulisker
XVI 650 Dr. w.m.
XV 570 f.w. s.
XIV 650 h.m.
XVII 620 w.sh.
I 450
II 164
III 229 s.sl. Dr.
IV 72 Dr. w.s.sh.
V 62 Dr. f.w.s. brk.sh.
X 500 Dr. m.s.
XI 450
XII 630 Dr. m.
XIII 189 Dr.
IX 170 Dr. s.sh.
62°
61°
60°
59°
30'
12°
11°
10°
9°
8°
7°

Engraved by Malby & Sons

our inquiries have been, in all essential particulars, fully as satisfactory as we had ventured to anticipate. The lateness of the date at which the Expedition started (its departure from Stornoway having been necessarily delayed until August 11th), and the consequent limitation of the time during which deep-sea dredging would be likely to be practicable, precluded the idea that the present inquiry could be more than tentative, anything like a systematic exploration of the Marine Zoology of the area we proposed to traverse being scarcely to be expected. In point of fact, during the *four weeks* which elapsed between our first departure from Stornoway and our return to it on September 9th, only *nine days* were available for dredging in the open ocean ; and on only *four* of these were we on a bottom exceeding 500 fathoms [914 mètres] in depth ; and in our second cruise of a week's duration, we only dredged once. Yet, as will hereafter appear, we have been enabled, by this very limited amount of work, not only to add many new and interesting facts to science, in regard both to the Physics and the Animal Life of the Ocean ; but also to correct serious errors which have been sanctioned by high authority, and to lay a definite foundation for more extended inquiries directed towards the solution of various general questions of the highest importance.

5. On the day after our first departure from Stornoway (August 12) we were met by a breeze from the N.E., so strong that, although a sounding was obtained in lat. 59° 20′ N. and long. 7° 5′ W., which indicated a depth of at least 500 fathoms [914 mètres], with a *minimum* temperature of 49° [9°·4 Cent.], the temperature of the surface-water being 54½° [12°·5 Cent.], any attempt to dredge was out of the question.

6. This breeze lasted with considerable force for three days, during which, being compelled to lie-to under canvas, we drifted to the northward of the deep water; our first soundings after its abatement (August 15th) giving depths of 229 and 164 fathoms [419 and 300 mètres] respectively, with a *minimum* temperature of 48° [8°·9 Cent.], the temperature of the surface-water being 54° [12°·2 Cent.]. As we were then approaching the Faroe Banks, we considered it expedient to devote a couple of days to the examination of the distribution of Animal Life at these comparatively moderate depths, and then to proceed to the Faroe Islands, reserving the deeper water for our return voyage.

7. The average depth of the Faroe Banks is about 60 fathoms [110 mètres], and their *minimum* temperature was found to be about 50° [10°·0 Cent.] when the temperature of the surface was 53° [11°·6 Cent.]. The character of the Marine Invertebrate Fauna of this region exhibited the admixture of British and of Boreal types, which might be expected from its temperature and geographical position, the former decidedly predominating. The common *Ophiocoma rosula* of our own shores (*Ophiothrix fragilis* of Müller and Troschel) presents itself in very great abundance, and probably furnishes an important part of the food of the Cod which frequent these banks.

8. We reached Thorsaven on the morning of August 17th; and, as the weather was then fine, we applied ourselves without delay to the exploration of the Fiords in its vicinity, using for this purpose the boats of the country, with native boatmen, whose knowledge of the tides and currents was indispensable to us. Unfortunately the weather again became so unfavourable as to prevent us from extending our inquiries to more distant localities, at the same time that the low state of the barometer rendered it inexpedient to put to sea again for the prosecution of our special object *. We found, however, that the Shells of the straits and fiords of the Faroes had been carefully collected by Sysellman Müller, who has long been in the habit of availing himself of the opportunities for dredging afforded by his official visits to different parts of the group; and that a List of the Mollusca found in them has been recently published by Dr. O. A. L. Mörch †. The result of our own dredgings, taken in connexion with the information obtained from these sources, leads us to believe that further exploration in this locality is not likely to bring out facts of any special interest. The tides and currents in the Straits between the islands are so strong as to render the deepest parts of the mid-channels (in which alone could any novelty be anticipated) an unsuitable habitation for Marine Invertebrata; and in the long narrow fiords which extend from these between the elevated ridges of Trap that traverse the interior of the islands the water is seldom of any considerable depth, and probably contains a large admixture of fresh water from the almost continuous rainfall which here prevails. The general character of the Marine Zoology of the Faroes, as of their adjacent banks, seems to be just what might be expected from their position on the border between the British, Scandinavian, and Boreal provinces.

9. At the first indication of improvement in the weather, we left Thorsaven on the 26th of August, with the intention of reaching the deep channel which we expected to find lying E. and W., between the North of Scotland and the Faroe Banks, as soon as possible, and of exploring this channel as completely as we might be able. At the end of our first day of steaming southwards, however, we encountered a gale from the S.W., in the course of which the barometer fell to 29 inches, and which was severe enough to do much damage to our ship; and it was not until the afternoon of August 29th that, after lying-to for nearly three days under canvas and drifting to the N.E., we were able to obtain a Sounding in lat. 60° 45′ and long. 4° 49′. This gave us a depth of 510 fathoms [933 mètres]; and the two thermometers sent down with the

* We learned on our return home that heavy gales had been experienced at this date in British seas.

† Faunula Molluscorum Insularum Færoënsium. Beretning om de hidtil fra Færoerne bekjendte Blöddyr: Af O. A. L. Mörch (Aftryk af Naturhistorisk Forenings Vidensk. Meddel. Nos. 4–7, 1867. Kjöbenhavn).—Dr. Mörch gives a very elaborate comparative Table of the distribution of the Mollusca in Greenland, Iceland, the Faroes, Scotland, England, and Denmark.

lead gave a *minimum* of 33° [0°·5 Cent.] and 34½° [1°·4 Cent.] respectively, the temperature of the surface-water being 52° [11°·1 Cent.].

10. This very remarkable indication was fully confirmed the next morning, when we sounded again in lat. 60° 7′ and long. 5° 21′, and found the depth to be 500 fathoms [914 mètres], and the *minimum* temperature, as given by the mean of three thermometers * (showing 31½° [−0°·2 Cent.], 32° [0° Cent.], and 33° [0°·5 Cent.] respectively), to be 32°·2 [0°·1 Cent.], the temperature of the surface-water being 51° [10°·5 Cent.].

11. We here for the first time had an opportunity of working our Dredge at this great depth, and found no difficulty in doing so. The bottom consisted of sand and stones; and it is important to remark that the same kind of bottom was met with in all our subsequent soundings and dredgings in the "cold area" (§§ 12–14).—As might have been anticipated from the extraordinary reduction of the Temperature, there proved to be a comparative scantiness of Animal life; and of the forms which did present themselves, several belonged to the Boreal Fauna. Still there were examples of several different groups; and there was not that predominance of low forms which some have supposed to characterize the Fauna of great depths. Indeed the *Rhizopoda*, of which we afterwards encountered an extraordinary development at the like depth, but in a much warmer temperature, were almost entirely absent. It is worthy of note that a specimen of *Astropecten* of a bright red colour came up adherent to the dredge-line at a distance of 250 fathoms [457 mètres] from the dredge, about 1200 fathoms [2195 mètres) of line being out. As this animal is entirely unprovided with swimming-organs, and was found to be of such specific gravity as to sink immediately when placed in a jar of sea-water, it can scarcely have been taken up anywhere else than from the sea-bottom; and if this be admitted, it is obvious that at least 250 fathoms [457 mètres] of the dredge-line must have been lying on that bottom. Not only on many subsequent occasions did *Ophiurida* come up on the like part of the dredge-line, but in our last dredging (§ 19), from a depth of 650 fathoms [1189 mètres], there came up attached to it, at a distance of about 50 fathoms [92 mètres] from the dredge, two pieces of a *Siliceous Sponge*, which most assuredly could not have been drawn from any other source than the sea-bottom †, and which included many small living *Ophiurida*.

* It had been our intention to make a careful comparison of each of these Thermometers with an accurate standard on our return, and thus to have determined with greater precision the temperatures they respectively indicated; but two of them were unfortunately lost in a subsequent Sounding (§ 19).

† From this it is obvious that the Dredge-rope, so far from buoying up the Dredge, must effectually assist in sinking it, especially when the rope has been solidified by previous repeated immersions at great depths. I find the specific gravity of a portion of our dredge-rope, which has been thus subjected to a pressure of 118 atmospheres, to be 1347, that of Sea-water being about 1029. In our earlier dredgings, we attached one or two couples of 12-lb. shot to the dredge-line at a short distance from the dredge, so as

12. The weather again interfered with the prosecution of our inquiry, which had now become of most unexpected interest; but we were able on the morning of September 1st to obtain a Sounding, in lat. 60° 10′ and long. 5° 59′, which fully confirmed our previous observations. The depth was here 550 fathoms [1006 mètres], and the *minimum* temperature indicated by the mean of two thermometers* (which stood at 31°·7 and 32°·5 respectively) was 32° [0° Cent.], the surface-temperature being 53° [11°·6 Cent.]. There was, however, too much wind for dredging on that day.

13. On the following day (Sept. 2), in lat. 60° 24′ and long. 6° 38′, our Sounding gave us a depth of only 170 fathoms [311 mètres]; but even at this depth we found, with a surface-temperature of 52° [11°·1 Cent.], a *minimum* temperature, indicated by the mean of two thermometers† (which stood at 41½° and 42° respectively), of 41¾° [5°·4 Cent.],—that is, about 6° [3°·3 Cent.] lower than the minimum temperature we had found at a like depth when approaching the Faroe Banks (§ 6), and 8° [4°·4 Cent.] lower than that we subsequently encountered at the like depth when approaching the north coast of Scotland (§ 17). Our Dredgings here afforded evidence of a great abundance and variety of Animal life, Norwegian forms being mingled in a very marked manner with British. In particular we obtained a large number of specimens of *Terebratula cranium* of unusual size, a beautiful delicately moulded arenaceous triradiate Foraminifer‡, and very large examples of a coarsely arenaceous Rhizopod closely corresponding with the *Lituola Soldanii* of the Silurian Tertiaries.

14. On the following day (Sept. 3) we again found ourselves in deep water, our Sounding, taken in lat. 60° 28′ and long. 6° 55′, giving a depth of 500 fathoms [914 mètres]. The *minimum* indicated by the mean of three thermometers (which registered 31¾°, 33½°, and 34° respectively) was 33° [0°·5 Cent.], the temperature of the surface being 51° [10°·5 Cent.]. Here, again, our Dredgings gave the same general results as those of previous dredgings at the like depth and temperature (§ 11); and not only was our previous conclusion confirmed, that a pressure of 100 atmospheres is not incompatible with the existence of numerous and varied forms of Animal life, but we had the gratification of obtaining a specimen of the remarkable Echinoderm *Brisinga* (one of the Norwegian types specially mentioned in Prof. Wyville Thomson's letter), part of the arms of which

to ensure its handles being kept down upon the ground, in the position requisite for the 'biting' of its edge; but we soon became satisfied that this is effectually done by the weight of the dredge-rope itself, when it has once been deeply submerged.

* A third Thermometer had been sent down; but as it registered a *minimum* of 36°·2 [2°·3 Cent.], we thought it fair to presume that its index had not been carried down as far as the real minimum—a circumstance of frequent occurrence.

† Our third Thermometer stood on this occasion at 45° [7°·2 C.]; and its reading has not been taken into account, for the reason stated in the preceding note.

‡ This we believe to be the *Rhabdammina abyssorum* of Sars; but as no description of the type has yet (so far as we can learn) been published by him, we are unable to identify it with certainty.

came up on the dredge-rope, whilst other portions, with the body (apparently belonging to one and the same individual), were found in the dredge.

15. The weather again occasioned for two days an interruption in our dredging; and it did not even permit the use of the proper deep-sea sounding-apparatus. But a sounding was taken on Sept. 5th, in lat. 60° 30′ and long. 7° 16′, with the ordinary deep-sea lead, which showed that there was no bottom at 450 fathoms [822 mètres], and gave a *minimum* temperature, indicated by the mean of two thermometers (which marked 33° and 35½° respectively), of 33¼° [0°·7 Cent.], the surface-temperature being 50° [10°·0 Cent.].

16. It was then considered expedient to shape our course in a southerly direction; and on the morning of September 6th we found ourselves in lat. 59° 36′ and long. 7° 20′. Here a very careful Sounding gave a depth of 530 fathoms [969 mètres]; and the *minimum* temperature indicated by the mean of three thermometers (which registered 47°, 47½°, and 47½° respectively) was 47⅓° [8°·5 Cent.], the surface-temperature being 52½° [11°·4 Cent.]. This result fully confirmed that obtained by our first less satisfactory sounding in nearly the same locality (§ 5), which the low temperatures subsequently obtained with such uniformity in like depths elsewhere had led us to doubt.—We were able on this day to obtain several good casts of the Dredge, the results of which proved of extraordinary interest. The bottom consisted of a bluish-white tenacious mud, containing but a small admixture of the *Globigerinæ* so abundantly obtained by previous soundings from various parts of the sea-bottom of the North Atlantic. Imbedded in this mud there came up an extraordinary collection of *Siliceous Sponges*, of new and most remarkable forms; and with these was associated the *Hyalonema Sieboldii*, which appeared to us clearly referable to that Family. The *Rhizopods* found in this mud were scarcely less interesting; for besides numerous specimens of the typically triradiate *Rhabdammina abyssorum* (?), presenting a varied range of forms, another large group of gigantic coarsely arenaceous bodies presented themselves, of the most varied shapes, apparently referable to the *Astrorhiza limicola** as their fundamental type, together with a large and perfect living specimen of *Cristellaria*, closely resembling that common in the Sicilian Tertiaries, and a *Cornuspira* of extraordinary size. With these lower forms, our dredgings on this bottom brought up a considerable variety of higher types, *Zoophytes*, *Echinoderms*, *Mollusks*, and *Crustaceans*; among which may be mentioned, as of special interest, two specimens of *Rhizocrinus*, the small Apiocrinoid whose recent discovery by M. Sars on the coast of Norway (see Appendix) may be considered as having furnished a principal "motive" of our expedition, and a living *Oculina prolifera*, of which we had on previous occasions brought up only dead and worn specimens.—We thus obtained evidence of

* See Dr. Sandahl in 'Œfversigt af Vet. Akad. Förhandl.' 1857, p. 299.

the existence, not of a degraded or starved-out *residuum* of Animal life, but of a rich and varied Fauna, including elevated as well as humble types, at a depth of 530 fathoms [969 mètres]. This Fauna was essentially British in its general character, but included several types hitherto found only near the coast of Norway. Since it presented itself on the southern border of the deep channel intervening between the North of Scotland and the Faroe Banks, these types must henceforth be considered to appertain equally to the British province.

17. As it was necessary for us to continue our course towards Stornoway, we were not able to prosecute further inquiries in this interesting locality, as we should otherwise have been most glad to do; and on the morning of September 7th, in lat. 59° 5′ and long. 7° 29′, a Sounding gave the comparatively small depth of 189 fathoms [345 mètres]. We found the *minimum* temperature, indicated by the mean of three thermometers (respectively marking 49½°, 49¾°, and 49¾°), to be here 49⅔° [9°·8 Cent.], the surface-temperature being 52° [11°·1 Cent.]. Here our Dredge brought up almost exclusively the ordinary types of the northern shores of Scotland, the chief features of interest being the great abundance of *Cidaris papillata*, and the occurrence of *Antedon celticus* (*Comatula celtica* of Barrett), numerous specimens of which had been previously obtained off the coast of Ross-shire by Mr. J. Gwyn Jeffreys. As we approached the land, the contents of the dredge became altogether barren of animal life, probably on account of the "scour" of the strong currents and tides of this locality, and the stony character of its bottom. In the Minch (the channel between the Island of Lewis and the mainland) the dredge again brought up a considerable number of well-known North British forms; and at one of our casts it came up full of mud, sticking in which was an extraordinary number of living specimens of *Pennatula*.

18. We arrived at Stornoway on the afternoon of September 9; and here Prof. Wyville Thomson was obliged to leave us, in order to attend the Meetings of the Commission on Science and Art Instruction, of which he is a member. As, however, the weather presented an unusually settled aspect, and as the results we had already obtained led me strongly to desire an opportunity of examining both the Temperature and the Animal life of waters still deeper than any we had hitherto sounded, it was thought by Captain May and myself that, notwithstanding the lateness of the season, it would be worth while to venture another short cruise in a westerly direction, where we knew, from soundings previously taken, that a depth exceeding 1000 fathoms (1829 mètres) is to be met with.—After refitting our ship and our dredging-apparatus at Stornoway, we left that harbour for a second time on September 14, and proceeded in a N.W. course, with the view of finding, in the latitude of the region which had given us a temperature of 32° [0° Cent.] at a depth of 500 fathoms [914 mètres], but at some distance to the westward, still deeper water, and possibly a still lower temperature (the freezing-point of sea-water being

27°·4 [−2°·55 Cent.]), and of then running southwards until we should find ourselves over the deep valley between the Western Hebrides and the Rockall Bank. In this valley we hoped, from our previous success in working the Dredge at upwards of 500 fathoms, to be able, if weather should permit, to demonstrate the practicability of examining by its means the distribution of Animal life at twice that depth.

19. After a very fine run of 140 miles in a N.W. direction from the Butt of Lewis, we took a Sounding on the morning of Sept. 15 in lat. 59° 59′, long. 9° 15′, and found at 650 fathoms [1189 mètres] a bottom of bluish-white unctuous mud, very like that from which we had brought up the Siliceous Sponges (§ 16). The *minimum* temperature here indicated by the mean of three thermometers (registering 45°, 46°, and 47½° respectively) was 46° [7°·7 Cent.], the surface-temperature being 53° [11°·6 Cent.]. As it was thus evident that we were in the warm, not in the cold area of bottom-temperature, we proceeded about 60 miles still further to the N.W., and on the morning of Sept. 16 we sounded in lat. 60° 38′ and long. 11° 7′. The depth was here 570 fathoms [1043 mètres]; and the scoop of the Sounding-apparatus brought up an almost pure *Globigerina* sand. The *minimum* temperature indicated by two thermometers (registering 46½° and 47½° respectively) was 47° [8°·3 Cent.], the surface-temperature being 52°.—Still looking for deeper water and a lower temperature, we proceeded about 50 miles further in the same direction; and on the afternoon of that day took another Sounding in lat. 61° 2′ and long. 12° 4′, which gave a depth of 650 fathoms [1189 mètres]. On this occasion our Sinker and three Thermometers were unfortunately lost by the parting of the line in winding-up, so that we did not ascertain either the nature of the bottom or the *minimum* temperature; but as we had now reached a latitude far north of that of the cold depths we had previously traversed (being nearly that of the southern end of the Faroe group), we deemed it inexpedient to proceed further in this direction; and a cast of the Dredge was therefore taken at this point, the depth being greater by 120 fathoms than any at which we had previously worked it. We found no difficulty in this operation, notwithstanding that the dredge was loaded with about 2½ cwt. [127 kilog.] of whitish grey mud, of peculiar viscidity, brought up from a depth (3900 feet) nearly equal to the height of the highest mountains in Great Britain. At some 50 fathoms [92 mètres] from the dredge, two whitish tufts were seen on the dredge-rope; and these proved to consist of portions of a Siliceous Sponge, quite free from the mud with which all the specimens previously obtained had been infiltrated. As it is obvious that these specimens must have been detached by the dredge-rope in its passage over the surface of the mud (§ 11), it seems clear that these Sponges, in part at least, project above that surface, which the infiltrated condition of those previously obtained had caused us to doubt. On separating the different parts of the large mass of mud brought up by the dredge, we found it to be *everywhere* traversed by fibres, which

proved to be long siliceous Sponge-spicules; and our subsequent examination of these has shown them to be the *root-fibres* of Sponges, the *bodies* of which have a siliceous framework of very different structure. As it thus appears that these Siliceous Sponges, when growing on the surface of the mud, send root-fibres (so to speak) far and wide into its substance, the idea previously suggested by Prof. Lovén *, that the elongated flint-rope of *Hyalonema Sieboldii* is in reality the mud-imbedded stem, *supporting* the Sponge with which it is connected, instead of being *implanted* in the Sponge and supported by it (which is the commonly received opinion), seems the more likely. This idea is thought probable by Prof. Wyville Thomson, who has already paid great attention to the whole group †, and by whom all the new forms we have obtained will hereafter be fully described. —Entangled among the fibres of the Sponge were found several small *Ophiocomæ*, *Polyzoa*, *Crustacea*, and tubicolar *Annelida*, the tubes of the last being for the most part composed of *Globigerinæ* cemented together, frequently in a most regular and beautiful manner. The only living testaceous Mollusk that presented itself was a small specimen of *Terebratula cranium*. Imbedded in the mud were found a specimen of *Kophobelemnon Mülleri* (a type allied to *Pennatula*) in full life, and two headless stems of *Rhizocrinus*, the perfectly fresh aspect of which leads me to believe that they must have grown on the spot, and have been mutilated in the sifting of the mud in which they were imbedded. This mud contained a considerable proportion (about 60 per cent.) of *Globigerinæ*, together with some remarkably large *Biloculinæ* and other *Milioline* forms.— The general character of this Fauna obviously bore a close relation to that of our previous dredging in a similar bottom; and though we cannot positively affirm the Temperature of that bottom to be the same, yet we have not merely the evidence of a previous Sounding in a locality not far removed from it, but also that of a Sounding subsequently taken in another locality further to the south, but nearly in the same longitude (§ 20), to this effect.

20. Being anxious now to proceed as quickly as possible to the region in which we knew that we should find much deeper water, we steered nearly due south, and on the morning of Sept. 17 reached lat. 59° 49′ and long. 12° 36′. Here a Sounding gave us a depth of 620 fathoms [1134 mètres], with a bottom of white mud very similar to that of our last dredging. The *minimum* temperature, as shown by the mean of two ther-

* See his description of *Hyalonema boreale* in 'Œfversigt af K. Vetenskaps Akademiens Förhandlingar,' 1868, p. 105; translated in 'Annals of Natural History,' Fourth Series (1868), vol. ii. p. 81.—Dr. J. E. Gray, whilst still maintaining that the "flint-rope" is a Zoophytic product, and that the Sponge with which it is connected is parasitic, has also come to the conclusion that the brush-like termination serves as the root implanted in mud, above which the Sponge is borne. (See Ann. of Nat. Hist., Fourth Series, vol. ii. p. 272.)

† See his Paper on the Vitreous Sponges, in 'Annals of Natural History,' Fourth Series, vol. i. (1868), p. 114.

mometers (registering $45\frac{1}{2}^\circ$ and $46\frac{1}{2}^\circ$ respectively), was 46° [7°·7 Cent.], the temperature of the surface being 52° [11°·1 Cent.].

21. Still proceeding southwards, we reached in lat. $58\frac{1}{2}^\circ$ the locality in which we hoped, from soundings previously made and recorded, to be able to extend our inquiries to greater depths; but unfortunately a breeze had now set in from the N.E., which was strong enough to prevent us not only from dredging but even from sounding; and this breeze freshened on the night of Sept. 19 to a gale, which made it prudent to seek the shelter of the land by running to the eastward. Notwithstanding a partial abatement on the afternoon of the next day, it was considered by Capt. May that, having due regard to the uncertain aspect of the weather, to the state of the barometer, and to the season of the year, as well as to the fact that the time assigned by the Admiralty for our remaining at sea was on the point of expiring, it would not be prudent to hold on as we were, for the slight chance of being able to accomplish our object. Our course was therefore directed to Oban, which we reached on the afternoon of Sept. 21 *.

General Results.

Before proceeding to sum up the general results of our inquiries, and to indicate the conclusions to which these seem to point, I think it desirable to give a brief notice of the researches of those who had preceded us in the same line of inquiry.

The earliest instance I have been able to find in which living Animals were brought up from great depths in the Ocean, occurred in the Arctic Expedition (1818) of Captain (afterwards Sir John) Ross, and is mentioned in the narrative of his 'Voyage of Discovery' †. General Sabine, who was a member of that Expedition, has been kind enough to furnish me with the following more ample particulars of this occurrence:—"'The ship sounded in 1000 fathoms, mud, between one and two miles off shore (lat. 73° 37′ N., long. 75° 25′ W.); a magnificent *Asterias caput-medusæ* was entangled by the line and brought up with very little damage. The mud was soft and greenish, and contained specimens of *Lumbricus tubicola*.' So far my written journal; but I can add, from a very distinct recollection, that the heavy deep-sea weight had sunk, drawing the line with it, *several feet* into the very soft greenish mud, which still adhered to the line when brought to the surface of the water. The Starfish had been entangled in the line so little above the mud, that fragments of its arms, which had been broken off in the ascent of the line, were picked out from amongst the mud."

It hence seems indubitable that the Asterias (*Astrophyton*) and the Tubicolar Annelids were brought up *from the bottom*; and the only doubt

* This gale, being from the East, was but little felt on the West coast of Scotland; but we afterwards learned that it had done much damage on the East coast.

† Vol. i. p. 251, and Appendix, vol. ii. p. 178.

that can fairly be thrown upon the value of this observation has reference to the precise depth indicated by the Sounding, this having been made according to the old method now abandoned as unreliable. The circumstances under which this sounding was taken, however, render it probable that the actual depth was not much less than that recorded.

In another Sounding, in calm water, and with a smooth sea (lat. 72° 23′ N., long. 73° 7′ W.), a depth of 1050 fathoms was obtained with great precision; and a small Starfish was found attached to the line below the point marking 800 fathoms.

The subsequent explorations of Prof. Edward Forbes *, on which he founded the opinion that a *zero* of animal life would be found at 300 fathoms [548 mètres], did not themselves go deeper than 230 fathoms [420 mètres]; yet his high authority on questions of this nature caused his opinion to be very generally adopted, alike by Zoologists, Physical Geographers, and Geologists.

The fallacy of Prof. E. Forbes's assumption, however, was demonstrated by the results of Dredgings carried on in Sir James Ross's Antarctic Expedition, at depths of from 270 to 400 fathoms, which yielded evidence of great abundance and variety of Animal life between those depths. Dr. J. D. Hooker has kindly placed in my hands some extracts from his Journal, which give much fuller particulars of these results than are to be found in Sir James Ross's Narrative †.

On the 28th of June, 1845, the ill-fated Mr. Harry Goodsir, who was a member of Sir John Franklin's expedition, obtained in Davis's Straits, from a depth of 300 fathoms, "a capital haul,—*Mollusca, Crustacea, Asterida, Spatangi, Corallines*, &c.‡" The bottom was composed of very fine green mud, apparently corresponding to that mentioned by General Sabine.

I am not aware that between this date and that at which the researches of MM. Sars commenced, any Dredging was carried on at depths exceeding those now specified; and the additions to our knowledge of the Life of the deep sea, with one remarkable exception to be presently noticed (p. 182), were made through the instrumentality of the improved Sounding-apparatus, which brings up a specimen of the superficial deposit (of whatever nature this may be) covering the sea-bottom, with such Animals as it may meet

* "Report on the Mollusca and Radiata of the Egean Sea, and on their distribution considered as bearing on Geology;" in Report of the British Association, 1843, p. 130.

† 'Voyage of Discovery and Research in the Southern and Antarctic Regions, during the Years 1839–1843,' vol. i. p. 207, and Appendix, p. 334.—It is much to be regretted that the specimens obtained should never have been systematically catalogued, and that the many novelties which presented themselves (among them a *Pycnogonid* twelve inches across) should not have been described. The specimens, with drawings made at the ime by Dr. Hooker, were kept by Sir James Ross, with a view to their publication; but he died without carrying that intention into effect; and neither specimens nor drawings are now recoverable.

‡ See the 'Natural History of the European Seas,' by Prof. E. Forbes and R. Godwin-Austen 1859, p. 51.

with on the spot on which it drops. This method of examination must obviously be very inferior to Dredging in collecting-power; nevertheless it has yielded some very important results.

In the year 1855, Prof. Bailey (of West Point, U.S.) published a "Microscopic Examination of Deep Soundings from the Atlantic Ocean"*, between lat. 42° 4′ and 54° 17′ North, and long. 9° 8′ and 29° 0′ West, and at depths of from 1080 to 2000 fathoms. He stated that "none of these soundings contain a particle of gravel, sand, or other recognizable Mineral matter; and that they are all made up of the shells of *Globigerinæ* and *Orbulinæ*, with a fine calcareous mud derived from the disintegration of those shells, containing a few siliceous skeletons of *Polycystina* and spicules of *Sponges*." Connecting these results with those furnished by previous Soundings in the western portions of the Atlantic, Prof. Bailey inferred that with the exception of a spot near the bank of Newfoundland, in which the bottom at 175 fathoms was found to be made up of quartzose sand without any traces of organic forms, "the bottom of the North Atlantic Ocean, so far as examined, from the depth of about 60 fathoms to that of 2000 fathoms, is literally nothing but a mass of microscopic shells;" and he explicitly likened this deposit to the Chalk of England and the Calcareous Marls of the Upper Missouri. After stating that examination of samples of ocean-water, taken at different depths in situations in close proximity to the places where the soundings were made, yielded no trace of *Foraminifera*, he concludes with the following questions:—"Do they live on the bottom at the immense depths where they are found, or are they borne by submarine currents from their real habitat? Has the Gulf-stream any connexion, by means of its temperature or its current, with their distribution?" Upon these questions Prof. Bailey does not seem ever to have given a decided opinion; although he inclined to the belief that the *Globigerinæ* and *Orbulinæ* had *not* lived on the bottom where they were found, but had either been transported thither by currents, or had lived nearer the surface of the sea, and had fallen to the bottom after death. On the other hand, Prof. Ehrenberg, to whom specimens of these Soundings were forwarded, expressed his conviction (based on the condition of the organic substance contained in the cavities of the shells) that these Foraminifera *had* lived on the bottom from which they were brought up.

Similar conclusions regarding the extensive diffusion of *Globigerinæ* over the deep-sea bottom of the North Atlantic were drawn by Prof. Huxley from his examination of the Soundings brought up by Lieut.-Commander Dayman, from depths of from 1700 to 2400 fathoms†. Of the whole mass of the fine muddy sediment of which these soundings consisted, it is estimated by Prof. Huxley that 85 per cent. consisted of *Globigerinæ*; 5 per cent. of other *Foraminifera*, of, at most, not more than four or five

* Quarterly Journal of Microscopical Science, vol. iii. (1855) p. 89.

† Deep-sea Soundings in the North Atlantic Ocean, between Ireland and Newfoundland, made in H.M.S. 'Cyclops,' in June and July 1857.

species; and the remaining 10 per cent. partly of Siliceous organisms (*Diatoms* and *Polycystina*), partly of mineral fragments, and partly of the very minute granular bodies designated by Prof. Huxley *Coccoliths*. These granules he described as apparently consisting of several concentric layers surrounding a minute clear centre, and looking at first sight somewhat like single cells of the plant *Protococcus*; but as they are rapidly and completely dissolved by dilute acids, their composition cannot be organic. With reference to the question whether the *Globigerinæ* actually live at these depths, Prof. Huxley says, "The balance of probabilities seems to me to incline in that direction. And there is one circumstance which weighs strongly in my mind. It may be taken as a law that any genus of animals which is found far back in time is capable of living under a great variety of circumstances as regards light, temperature, and pressure. Now the genus *Globigerina* is abundantly represented in the Cretaceous epoch, and perhaps earlier" (*op. cit.* p. 67).

The results obtained by Prof. Bailey and Prof. Huxley, in regard to the prevalence of *Globigerinæ* over a large part of the sea-bottom in the North Atlantic Ocean, were confirmed and extended by the observations of Dr. Wallich, made during the voyage of the 'Bull-dog' in 1860; and as he was able to examine the condition of the *Globigerinæ* when freshly brought up, his testimony furnishes an important corroboration of Prof. Ehrenberg's conclusion. "The *Globigerinæ*," he says*, "have never been detected free-floating in any number in deep, or forming deposits in shallow waters; a considerable proportion of those met with in deep-sea deposits exhibit every appearance of vitality; and their maximum development is associated with the presence of the Gulf-stream, but only through the operation of collateral conditions prevailing at great depths below the current itself." But in addition, the 'Bull-dog' sounding-line brought up a cluster of *Ophiocomæ* attached to a portion of it which had lain on the bottom at a depth of 1260 fathoms; and *Globigerinæ* were found, with other matters, in their stomachs. Further, in various localities, at depths ranging from 871 to 1913 fathoms, tubes of small *Tubicolar Annelids* were brought up; and some of these were found to be composed of *Globigerina*-shells cemented together, whilst others were made up of an admixture of Sponge-spicules and minute Calcareous débris. Lastly a living *Serpula*, *Spirorbis*, and a group of *Polyzoa* were brought up from a depth of 680 fathoms, and a couple of living *Amphipod Crustacea* from a depth of 445 fathoms. "Taking into consideration the arguments adduced to prove that the conditions which prevail on the deep-sea bed are not incompatible with the maintenance of animal life, and the extreme improbability that the creatures heretofore discovered at great depths are merely exceptional or accidental examples, it will, I think, be conceded that the presence of a living Fauna in the deeper abysses of the ocean has been fully established" †.

Dr. Wallich's just conclusions have not by any means commanded the

* The North-Atlantic Sea-Bed, p. 147. † Ibid. p. 148.

universal assent of Naturalists. It is still urged* that the *Globigerinæ* lived at or near the surface, and that they only fell to the bottom after death. And it has been thought by many to be more probable that the *Ophiocomæ* had been entangled by the Sounding-line during either its descent or its ascent through the water, than that they had lived on the bottom. Our Dredge, however, having brought up, from depths of 530 and 650 fathoms, abundance of living *Globigerinæ* and *Ophiocomæ* entangled in the recesses of *Sponges*, with *Rotaliæ* attached by shell-substance to the spicules of these Sponges, the statements of Dr. Wallich with regard to these animals, which I had always myself regarded as probable, may now be considered as put beyond reasonable question †.

The general bearings of the facts thus brought to light, together with those furnished by the earlier observations of Sir John Ross and others, are fully and ably discussed by Dr. Wallich; but I must content myself with the following citation of his conclusions, referring to his Treatise for the arguments on which they rest:—

"Basing my arguments, then, on two facts which I venture to hope are unequivocally proved in the preceding pages, namely that highly organized creatures have been captured in a living condition at depths vastly exceeding those to which animal life had previously been supposed to extend, and that their presence, when captured, cannot be regarded as an accidental or exceptional phenomenon, it has been my endeavour to establish the following important propositions:—

"I. The conditions prevailing at great depths, although differing materially from those which prevail near the surface of the ocean, are not incompatible with the maintenance of animal life.

"II. Assuming the doctrine of single specific centres to be correct, the occurrence of the same species in shallow water and at great depths proves that it must have undergone the transition from one set of conditions to the other with impunity.

"III. There is nothing in the nature of the conditions prevailing at great depths to render it impossible that creatures originally, or through acclimatization, adapted to live under them should become capable of living in shallow water, provided the transition be sufficiently gradual; and hence it is possible that species now inhabiting shallow water may at some anterior period have been inhabitants of great depths.

* See Mr. Gwyn Jeffreys, in 'Annals of Natural History,' 4th series, vol. ii. (October 1868), p. 305.

† I had myself accepted Dr. Wallich's inference in regard to the *Ophiocomæ* on the following grounds:—*first*, because, having often kept *Ophiocomæ* in an aquarium for several weeks together, I never saw them swim, and do not believe that they are capable of moving in any other way than by crawling over a solid surface; and *second*, because I know it to be their habit to cluster round a rope lying along the bottom they frequent,—the first I ever saw alive having been obtained for me by the Harbour-master of Plymouth, who sank a rope in a part of the Sound which he knew to be frequented by them, and drew it up again after some hours, covered with *Ophiocomæ*.

"IV. On the one hand the conditions prevailing near the surface of the ocean render it possible for organisms to subside after death to the greatest depths, provided every portion of their structure is freely pervious to fluid. On the other hand, the conditions prevailing at great depths render it impossible for organisms still constituted to live under them to rise to the surface, or for the remains of these organisms after death to make their appearance in shallow water.

"V. The discovery of even a single species living normally at great depths warrants the inference that the deep sea has its own special fauna, and that it has always had it in ages past; and hence that many fossiliferous strata, heretofore regarded as having been deposited in comparatively shallow water, have been deposited at great depth" *.

In 1861 the very important fact was made public by M. Alphonse Milne-Edwards †, that when the Submarine Telegraph-cable between Sardinia and Algiers was taken up for repair, several living Polyparies and Mollusks were attached to portions of it which had been submerged to a depth of from 2000 to 2800 mètres, or from 1093 to 1577 fathoms. Of these, some had been previously considered very rare, or had been altogether unknown; whilst others were only known in a fossil state as belonging to the Fauna of the later Tertiaries of the Mediterranean basin.

In the Swedish Expedition to Spitzbergen in 1861, a compact mass of clay was brought up from 1400 fathoms by the "M'Clintock apparatus," the temperature of the interior of which was found to be 32°·5 [0°·3 Cent.], the temperature of the surface-water being 39°·2 [4° Cent]. "Notwithstanding this low degree of warmth, there were found several marine animals of different types and classes—amongst others a moderately large Polyparium, probably belonging to the Hydroid class, a bivalved Mussel, some Tunicata attached to the Polyparium, and one Crustacean of bright colours" ‡.

Of the very important researches which have been subsequently carried on by Prof. Sars of Christiania and his Son, we knew little more, when we proceeded on our own cruise, than is stated in Prof. Wyville Thomson's letter (Appendix). But I have since learned from the recently published Report §, which Prof. Sars has been good enough to transmit to me, that their Dredgings have ranged between 200 and 450 fathoms, and that no fewer than 427 species have been collected within this range, which he classifies as follows:—

* North-Atlantic Sea-Bed, p. 155.

† Annales des Sciences Naturelles, sér. 4, Zool. tom. xv. p. 149.

‡ See a letter from Christiania, signed M. R. B., in the 'Athenæum' for December 7, 1861.—I have not been able to meet with further information in regard to this interesting occurrence.

§ Fortsatte Bemærkninger over det dyriske Livs Udbredning i Havets Dybder, af M. Sars. (Særskilt aftrykt af Vidensk.-Selsk. Forhandlinger for 1868.)

Protozoa	Rhizopoda	68
	Spongiæ	5
Cœlenterata	Anthozoa	20
	Hydrozoa	2
Echinodermata	Crinoidea	2
	Asterida	21
	Echinida	5
	Holothurida	8
Vermes	Gephyrea	6
	Annelida	51
Mollusca	Polyzoa	35
	Tunicata	4
	Brachiopoda	4
	Conchifera	37
	Cephalophora	53
Arthropoda	Arachnida	1
	Crustacea	105
		427

Of these, 20 species of Rhizopoda, 3 of Echinodermata, 8 of Conchifera, 3 of Cephalophora, and 4 of Crustacea—in all 42—are recorded as having been found at 450 fathoms.

Shortly after our return, I learned that an exploration of the deep sea by means of the Dredge had been very successfully commenced by Count Pourtales, in connexion with the United States Coast Survey; and I have since received from Mr. Alexander Agassiz the following account of its results:—"He has dredged to 500 fathoms along quite a line of sections between Florida and Cuba; and under this pressure of nearly 100 atmospheres he has found *Echini, Starfishes, Ophiuridans, Crinoids, Corals,* many kinds of *Crustacea, Annelids, Mollusca, Molluscoids,* and, in fact, a Fauna as plentifully represented as along the most populous of our marine shore-fauna. It has been decided to send Mr. Pourtales again this winter; and with his former experience and additional equipment, we may look for grand results. The facilities placed at his disposal are very great; as his dredging-work is done in connexion with regular soundings carried on by the Survey of the Gulf-stream commenced by Mr. Bache and prosecuted by his successor Prof. Pierce"*.

Our own Dredgings, which have extended to a depth of 650 fathoms, are still the deepest of which I have any knowledge. They were accomplished without any serious difficulty, and with results fully as satisfactory as those of ordinary shore-dredging. And I have no doubt that similar dredges, worked by adequate engine-power, would answer equally well at those far greater depths, our knowledge of the living inhabitants of which has been hitherto limited (with the notable exception of the Mediterranean

* A fuller notice of these results will be found in Silliman's Journal for November 1868, and Annals of Nat. Hist. Jan. 1869.

cable, p. 182) to the few forms that have been brought up by the Sounding-apparatus*.

I. The collective results of these recent Dredgings have conclusively established the justice of the inference formerly drawn by Dr. Wallich from the more restricted data he had collected, as to the existence of a varied and abundant submarine Fauna, at depths which have been generally supposed to be either altogether *azoic*, or occupied only by Animals of very low type. And a complete disproof has thus been furnished of the doctrine, against which Dr. Wallich argued with great force, that a certain amount of bathymetric pressure must be prejudicial, if not absolutely fatal, to higher forms of Animal life.

In much that has been put forward upon this subject, two important considerations have been altogether ignored:—*first*, that pressure will not act upon an Animal whose body entirely consists of solid and liquid parts, in the same manner as it acts upon one that includes air-cavities; and *second*, that as fluids press equally in *all* directions, an Animal immersed at any depth is just as free to move one part upon another, as it would be if living near the surface. The right point from which to look at this subject has long appeared to me to be the condition of a *drop of water*, conceived as carried down from the surface to a depth (say) of 1100 fathoms [2012 mètres], at which the pressure will be about 200 atmospheres, or 3000 lbs. [1360 kilogr.] upon the square inch. Let it be conceived that this drop is inclosed in a pellicle of the thinnest possible membrane, fitted only to separate it from the surrounding medium, but having in itself no power of resistance. Now it is obvious that this drop would maintain its *form*, whatever this may have originally been, entirely unchanged, being neither flattened-out into a plane, nor reduced to a sphere, by pressure to any amount which acts upon it equally in all directions; while its *bulk* will only undergo reduction, under a pressure of 200 atmospheres, to the extent of less than one-hundredth. Next, let us suppose, instead of a drop of water contained within a pellicle, a particle of the semifluid "sarcode" of which the body of a *Rhizopod* is composed; in which the more liquid interior (*endosarc*) is contained by a more tenacious external layer (*ectosarc*), the contractility of which gives rise to continual changes of form, that are subservient to the movement of the creature from place to place, and also to the ingestion of its food. Now, it will be obvious to any one who follows out the law of fluid pressure in its application to an Animal of this simple constitution, that so long as these changes of *form* do not involve a change of *bulk*, pressure to any amount exerts no antagonizing influence; so that its movements can be performed with the same freedom on the ocean-bottom as they can be near the surface. And, further, even

* It is reported that the Swedish Expedition, which has recently returned from Spitzbergen, has brought up a considerable number and variety of animals from depths of 2000 fathoms and upwards; but whether these were obtained by the Dredge or by the 'Bulldogsmaskinen," I have not yet learned.

when the bulk of the body is augmented by the ingestion of solid or liquid particles (say the reception of a zoospore of a Protophyte as food, or the filling of the "contractile vesicle" with water from without, which seems to be a sort of respiratory process), just as much pressure will be exerted by the superincumbent liquid in forcing those particles into the body as is exerted upon the exterior of the body in resisting its distension; so that here, again, the influence of that pressure will be practically *nil*.—If the actions of any purely aquatic Animal of more complex structure be looked at from the same point of view, I am persuaded that it will be found that they are not practically interfered with by fluid pressure to any amount,—such pressure not having any tendency to alter either the general form of the body, or the shape of its softest and most delicate parts, and not interfering in the least either with the movements of these parts one upon the other, or with the circulation of fluid in their interior, or with those molecular changes which are concerned in their nutrition.

II. The results we have obtained fully justify the confident expectation we had formed and expressed (see Appendix), on the basis afforded by the observations of M. Alphonse Milne-Edwards on the Mediterranean Cable, and by the results of the dredgings of M. Sars, jun., that the systematic exploration of the Ocean-bottom, at depths much greater than are usually to be found near land, would bring to light many forms of Animal life, either altogether new to science, or hitherto supposed to be limited to particular localities, or known only as belonging to a Geological epoch supposed to have terminated. For *one and the same cast of the dredge*, in the singularly productive locality specified in § 16, brought up specimens of the highest interest belonging to each of these categories; so that if we had been able, by remaining there even for a few days, to work this ground thoroughly, a much larger addition might have been fairly expected from this one spot,—still more, therefore, if the inquiry should be extended over that much wider area in which, as will presently appear, the like conditions prevail. For it must have been a strangely fortunate accident that brought together into our dredge so remarkable a collection of *Vitreous Sponges* and gigantic *Rhizopods* (many of them altogether new, and the rest known only as inhabitants of very distant localities,—with the *Rhizocrinus* previously obtained only in one spot more than 600 miles off), if these were not diffused tolerably abundantly as well as widely; and the probability that they are so rises almost to a certainty, when it is borne in mind that the next dredgefull that was obtained from a bottom similar both in character and in temperature, though at a depth of 120 fathoms greater, and at a distance of 200 miles in a straight line, showed distinct evidence of the prevalence of similar types (§ 19).

III. Our researches have conclusively established the existence of a *minimum* Temperature* at least as low as 32° [0° Cent.] over a considerable

* It is obvious that any error in our Thermometers, arising from the pressure of

area, where the depth was 500 fathoms [914 mètres] and upwards; notwithstanding that the *surface*-temperature varied little from 52° [11°·1 Cent.], alike in this region and in neighbouring areas of similar depth, in which the *minimum* temperature was only a few degrees beneath that of the surface. The current doctrine in regard to deep-sea temperatures may be considered to be that expressed by Sir J. Herschel (Physical Geography, 1861, p. 45) in the following terms:—"In very deep water all over the globe a uniform temperature of 39° Fahr. [4° Cent.] is found to prevail, while above the level, when that temperature is first reached, the ocean may be considered as divided into three great regions or zones—an equatorial and two polar. In the former of these, warmer, in the latter colder, water is found at the surface. The lines of demarcation are of course the two isotherms of 39° mean annual temperature." This doctrine, which is more fully and explicitly set forth by Dr. Wallich ('The North-Atlantic Sea-bed,' 1862, pp. 98, 99), rests, I believe, chiefly on the temperature-observations made in Sir James Ross's Antarctic Expedition, which were not inconsistent with the prevalent belief that *sea*-water, like *fresh* water, has its maximum density at this temperature, and that consequently water at 32° or 33° cannot underlie water at 39°. Several instances, however, had been previously recorded, in which temperatures below 39° had been observed. Thus Lieut. S. P. Lee, of the United States Coast Survey, in August 1847 found 37° below the Gulf-stream, at the depth of 1000 fathoms [1829 mètres], in lat. 35° 26′ N. and long. 73° 12′ W.; and Lieut. Dayman found the temperature at 1000 fathoms [1829 mètres] in lat. 51° N. and long. 40° W. to be 32° 7′ [0°·4 Cent.], the surface-temperature being 54°·5 [12°·5 Cent.]*. "At the very bottom of the Gulf-stream," says Lieut. Maury (Physical Geography of the Sea, 1860, p. 58), "when its surface-temperature was 80° [26°·6 Cent.], the deep-sea thermometer of the Coast Survey has recorded a temperature as low as 35° [1°·6 Cent.]. These cold waters doubtless come down from the north to replace the warm waters sent through the Gulf-stream to moderate the cold of Spitzbergen; for within the Arctic Circle the temperature at corresponding depths off the shores of that island is said to be only one degree colder than in the Caribbean Sea, while on the shores of Labrador and in the Polar Sea the temperature of the water beneath the ice was invariably found by Lieut. De Haven at 28° [−2°·2 Cent.], or 4° below the melting-point of freshwater ice. Capt. Scoresby relates that on the coast of Greenland, in latitude 72°, the temperature of the air was 42° [5°·5 Cent.], of the water 34° [1°·1 Cent.], and 29° [−1°·6 Cent.] at the depth of 118 fathoms"†. That there is no Physical improbability in the

100 atmospheres to which their bulbs were subjected, would prevent them from recording a *minimum* as low as the *actual* minimum; and it seems to us not at all improbable that the actual minimum may have been from 2° to 4° *lower* than the recorded minimum.—In any renewal of the inquiry, it will be of course desirable that the Thermometric apparatus used should be specially protected from this source of error.

* See Purdy on the Northern Atlantic Ocean, 12th edit., 1865, pp. 330 and 338.

† General Sabine has been kind enough to send me the following extract from his

existence of a stratum of *sea*-water at a temperature of 32° or even 28° below a stratum at 39°, is evident from the fact (which has been experimentally established beyond question *) that Sea-water, in virtue of its saline impregnation, *contracts continuously down to its ordinary freezing-point*, which is below 28° Fahr. And the existence of such strata, even in Equatorial regions, has been regarded by high scientific authorities † as proving the existence of deep currents bringing cold water from Polar Regions to replace the warmer water that is continually flowing, as (notably) in the Gulf-stream, from the Equatorial towards the Polar Regions, as well as to make good the immense loss which is constantly taking place by evaporation from the surface of Tropical seas ‡. To such an under-current, probably proceeding from the North or North-east, the low temperatures we

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Journal of Capt. Ross's Voyage, which, if there was no error in the instrument employed, gives a lower temperature than any yet recorded :—"Having sounded, on Sept. 19, 1818, in 750 fathoms, the registering Thermometer was sent down to 680 fathoms; and on coming up, the index of greatest cold was at 25°·75. Never having known it lower than 28° in former instances (even at a depth of 1000 fathoms, and at other times when close to the bottom), I was very careful in examining the Thermometer; but could discover no other reason for it than the actual coldness of the water."

* It is stated by M. Despretz, as the result of a series of carefully conducted experiments, that the *maximum* density of Sea-water cooled down continuously without agitation is at −3°·67 Cent., or 25°·4 Fahr.; the freezing-point of Sea-water which is agitated being −2°·55 Cent., or 27°·4 Fahr. See his "Recherches sur le Maximum de Densité des Dissolutions Aqueuses," in Annales de Chimie, 1833, tom. lxx. p. 54.

† This doctrine, long since explicitly stated by Humboldt (Cosmos, vol. i. p. 296), is thus set forth by Prof. Buff in his 'Physics of the Earth' (p. 194) :—"The water of the ocean at great depths has a temperature, even under the equator, nearly approaching to the freezing-point. This low temperature cannot depend on any influence of the sea-bottom. . . . . The fact, however, is explained by a continual current of cold water flowing from the Polar regions towards the Equator. The following well-known experiment clearly illustrates the manner of this movement. A glass vessel is to be filled with water with which some powder has been mixed, and is then to be heated at bottom. It will soon be seen, from the motion of the particles of powder, that currents are set up in opposite directions through the water. Warm water rises from the bottom, up through the middle of the vessel, and spreads over the surface, while the colder and therefore heavier liquid falls down at the sides of the glass. Currents like these must arise in all water-basins, and even in the oceans, if different parts of their surface are unequally heated. The water that is cooled in the polar regions sinks and travels from the poles towards the equator, pushing away the warmer and lighter liquid from the bottom of the sea; itself to give way in turn, as it gets warm, to the colder water that follows after it. This continual flow of the water from the cold zones is replaced in a twofold manner. The warm water of the tropical seas, since it is the lightest, must spread itself north and south over the surface of the ocean, and thus gradually losing its heat, be carried to the polar regions. Between the tropics, too, evaporation goes on most vigorously, and a great part of the vapours formed fall again in rain and snow only in higher latitudes."

‡ A set of deep soundings, taken across the Arabian Sea, between Aden and Bombay, by Capt. Shortland, in H.M.S. 'Hydra,' has lately been received by the Hydrographer to the Admiralty, which give a line of bottom-temperature of 33½° [0°·8 Cent.] at depths

observed between lat. 60° 45′ and 60° 7′, as shown in the following Table and the accompanying Map (for which I am indebted to the kindness of the Hydrographer to the Admiralty), may be pretty certainly attributed.

TABLE OF PLACES, DEPTHS, AND TEMPERATURES OF SOUNDINGS.

Warm Area.

No.	Latitude, N.	Longitude, W.	Depth, in Fathoms.	Temperature	
				at surface.	at bottom.
	° ′	° ′		°	°
1	59 20	7 5	At least 500	54·5	49
2	60 32	9 10	164	54	48·5
3	60 31	9 18	229	54	48
4	60 44	8 45	72	54	49
5	61 1	7 48	62	53	50
12	59 36	7 20	530	52·5	47·3
13	59 5	7 29	189	52	49·3
14	59 59	9 15	650	53	46
15	60 38	11 7	570	52	47
16	61 2	12 4	650	—	—
17	59 49	12 36	6 0	52	46

Cold Area.

No.	Latitude, N.	Longitude, W.	Depth, in Fathoms.	Temperature	
				at surface.	at bottom.
	° ′	° ′		°	°
6	60 45	4 49	510	52	33·7
7	60 7	5 21	500	51	32·2
8	60 10	5 59	550	53	32
9	60 24	6 38	170	52	41·7
10	60 28	6 55	500	51	33
11	60 30	7 16	At least 450	50	33·2

Of its northern limit we are not able to give any account; but about 50 miles to the southward we found the temperature at the same depth to be 15° higher [8°·3 Cent.]; and since the like temperature showed itself at even greater depths to the westward, between lat. 59° 59′ and 60° 38′, and inferentially (§ 19) as far north as 61° 2′, at a distance of 175 miles from the most westerly point to which we traced this cold area, it may be presumed that this area was as limited in a *westerly* as we found it to be in a *southerly* direction. Here, therefore, within a short distance of the Northern Coast of Scotland, an opportunity is presented for determining with great precision the physical conditions of two opposing currents, having a difference of temperature of at least 15°. In such determination it

of 1800 fathoms and upwards, the surface-temperature being 75°. It seems impossible to account for this fact on any other hypothesis than that of a deep current from the Antarctic Polar region, which must have maintained this extremely low temperature throughout the vast course it has had to traverse.

would be very desirable to ascertain whether the *minimum* temperature is that of the *bottom* (a point of fundamental importance as regards the distribution of Animal life), or whether it is that of some intermediate stratum. The deep-sea Sounding-apparatus with which we were provided only allowed the attachment of the Thermometers to the extremity of the line; and it is *possible*, of course, that their *minimum* may represent, not the temperature of the sea-bottom, but that of some higher stratum. Independently, however, of the physical improbability (for the reason already stated) that Sea-water at 32° should overlie water of any higher temperature, which would be specifically lighter than itself, we have the evidence afforded by our Sounding in 170 fathoms (§ 13) within the cold area, that the temperature descends progressively with the depth; at first (as elsewhere observed) more rapidly, afterwards more slowly. And as this shallow bank is of very limited extent, and the bottom in its neighbourhood must become rapidly deeper, a careful examination of the bottom-temperature of its inclined sides at different depths would furnish satisfactory data on this point.

IV. A general comparison of the Faunæ of the different localities which we had the opportunity of examining seems to warrant the conclusion that the distribution of the Animal life of the seas beyond the Littoral zone* is more closely related to the *temperature* of the water than to its *depth*. The predominance of North British types, not merely on the southern but on the northern side of the deep valley which separates the Faroe Banks from the coast of Scotland, and in the *warm* area of the valley itself, the slight admixture of *exclusively* Scandinavian or Boreal forms even as far north as the Faroe Islands, the larger admixture of these on the shallow bank in the *cold* current, the still greater proportion of Boreal forms in the deeper and yet colder waters of that current, and (in most striking contrast with this) the presence of forms hitherto known only as inhabitants of the warmer temperate seas at the like depth in the *warm* area not many miles off,—all indicate the intimacy of the relationship between Geographical distribution and Temperature. The existence of Boreal types in the midst of an area whose surface-temperature is 52° [11°·1 Cent.], and whose bottom-temperature, even at 500 fathoms' [914 mètres] depth, is generally 47° or 48° [8°·3 or 8°·8 Cent.], is obviously a phenomenon parallel to the occurrence of Alpine plants at a high elevation on mountains within the tropics; and as every Botanist would regard such occurrence as having no relation to elevation *per se*, but only to eleva-

* The distribution of marine Animal life in the Littoral zone is affected by a great number of conditions, which place it in altogether a different category from that of the deeper seas. I am very glad to find our views on this point in harmony with those of my friend Mr. J. Gwyn Jeffreys. "The bathymetrical zones have been too much divided by Risso and subsequent authors. There are two principal zones, *littoral* and *submarine*; the nature of the habitat and the supply of food influence the residence and migration of animals, not the comparative depth of water."—Annals of Natural History, 4th ser. vol. ii. (1868) p. 303.

tion as affecting Temperature, so it is obvious that, with the evidence we are enabled to present of an abundant and varied Fauna at a depth of even 650 fathoms [1189 mètres], the Zoologist is fully justified in attributing the far different character of the Fauna we encountered at 500 fathoms [914 mètres] with a Temperature of 32° [0° Cent.] to that remarkable reduction.—Further, although the *nature of the bottom* has doubtless an important influence on the Animal life which it sustains, yet this very condition, as will presently appear, is itself dominated in great degree by Temperature.

V. The results of our Dredgings fully confirm the indications afforded by the specimens of the bottom previously brought up by the Soundings already noticed, in regard to the existence, on the sea-bottom of large areas of the North Atlantic, of a stratum of "calcareous mud," partly composed of living *Globigerinæ*, partly of the disintegrated materials of the shells of former generations, and partly of the "coccoliths" of Prof. Huxley (*loc. cit.*) and the "coccospheres" of Dr. Wallich *, with a greater or less admixture of other constituents. And they further indicate that the prevalence of this deposit is connected with a bottom-temperature of 45° and upwards, which, in latitudes above 56°, can scarcely be attributed to any other influence than that of the Gulf-stream. The examination which Prof. Huxley has been good enough to make of the peculiarly viscid mud brought up in our last dredging at the depth of 650 fathoms [1189 mètres], has afforded him a remarkable confirmation of the conclusion he announced at the recent Meeting of the British Association, that the coccoliths and coccospheres are imbedded in a living expanse of protoplasmic substance, to which they bear the same relation as the spicules of Sponges or of Radiolaria do to the soft parts of those animals. Thus it would seem that the whole mass of this mud is penetrated by a living organism of a type even lower, because less definite, than that of Sponges and Rhizopods; and to this organism Professor Huxley has given the name of *Bathybius* †. In what manner the materials for its protoplasm, as for that of the *Globigerinæ* which usually accompany it in larger or smaller proportion, are obtained, is a most perplexing problem. All the evidence we at present possess in regard to the alimentation of *Rhizopods*, leads to the belief that, in common with higher Animals, they depend upon the Organic Compounds previously elaborated by Vegetative agency under the influence of the light and heat of the Sun. But every form of Vegetable life that is visible to the naked eye seems entirely wanting at great depths in the ocean: and although this deposit is found by the Microscope to contain the siliceous *loricæ* of *Diatoms*, yet these do not present themselves in anything like the abundance that would be required for the nutrition of so large a mass of Animal life as that

* "Remarks on some novel Phases of Organic Life at great depths in the Sea," in 'Ann. of Nat. Hist.' ser. 3, vol. viii. (1861) p. 52.

† "On some Organisms living at Great Depths in the North Atlantic Ocean;" in Quart. Journ. of Microsc. Society, vol. viii. N.S. p. 203.

represented by the *Globigerina*-shells; and there appears good reason to regard them as rather representing Diatoms which have lived at or near the surface, and have only subsided to the bottom after death, than organisms which habitually live and grow in the ocean-depths. It may be that the *Bathybius* (which bears a very striking resemblance to the Rhizopod-like *mycelium* of the Myxogastric Fungi) has so far the attributes of a Vegetable, that it is able to elaborate Organic Compounds out of the materials supplied by the medium in which it lives, and thus to provide sustenance for the Animals imbedded in its midst. But to whichever of these two Kingdoms we refer it, there seems adequate reason for regarding this *Bathybius* as one of the chief instruments whereby the solid material of the Calcareous mud which it pervades is separated from its solution in the ocean-waters *.

In connexion with this subject it may be suggested, as a subject well worthy of experimental inquiry, to what depth the *Actinic* rays penetrate Sea-water in sufficient intensity to produce an appreciable effect on a highly sensitive surface. Certain it is that among the Animals brought up from great depths, bright colours are not wanting. This was noticed by Dr. Wallich in the case of the *Ophiocomæ* brought up from 1260 fathoms. And not only did the *Astropecten*, which came up on our dredge-line from 500 fathoms, at once attract attention by its bright orange-red hue, but the small *Annelids* which inhabited the Siliceous Sponge brought up from 650 fathoms were distinguished by the vividness of their red or green coloration.

VI. Our researches have brought out with remarkable force the resemblance between this Calcareous deposit and the great Chalk-formation, which had been previously pointed out by Prof. Bailey, Prof. Huxley, and Dr. Wallich, but more particularly by Mr. Sorby †, who identified the

* The discovery of this indefinite plasmodium, covering a wide area of the existing Sea-bottom, should afford a remarkable confirmation, to such (at least) as still think confirmation necessary, of the doctrine of the Organic origin of the Serpentine-Limestone of the Laurentian Formation. For if *Bathybius*, like the testaceous Rhizopods, could form for itself a shelly envelope, that envelope would closely resemble *Eozoon*. Further, as Prof. Huxley has proved the existence of *Bathybius* through a great range not merely of *depth* but of *temperature*, I cannot but think it probable that it has existed continuously in the *deep seas of all Geological Epochs*. And so far, therefore, from considering that the discovery of *Eozoonal Rock* in the Liassic or even in *Tertiary* Strata, would (as asserted by Profs. King and Rowney in a Paper recently presented to the Geological Society) be a *conclusive disproof* of its Organic origin, I am fully prepared to believe that *Eozoon*, as well as *Bathybius*, may have maintained its existence through the whole duration of Geological Time, from its first appearance to the present Epoch; and should be not in the least surprised at bringing it up from 1000 or 2000 fathoms, if I should be enabled to dredge at those depths. There must have been *deep seas* at all periods; and the considerations stated in Par. IX. show that the *continuity of Organic* types is perfectly consistent with *great local changes*. Of such continuity there is now ample evidence.

† "On the Organic Origin of the so-called Crystalloids of the Chalk," in 'Ann. of Nat. Hist.' ser. 3, vol. viii. (1861) p. 52.

"coccoliths" of Prof. Huxley and the "coccospheres" of Dr. Wallich with bodies observed in Chalk. While the *soundings*, on the nature of which this conclusion was based, could not indicate more than the existence of a mere *surface-layer* of this material, the fact that our large dredges came up completely filled with it, and the manner in which massive Siliceous Sponges had obviously been imbedded in it, clearly prove it to possess considerable thickness. The existence of this deposit over a very large area was marked out by our Dredgings at the extreme distance of 200 miles, and by several intermediate Soundings; and the variations in its character corresponded closely with those which present themselves in different parts of the same stratum of Chalk.

VII. But besides confirming the views already promulgated, as to the complete dependence of this Calcareous deposit on the enormous development of low forms of Organic Life, our researches also show that the area over which this deposit is being formed is peopled by a variety of higher types of marine Animals, many of which carry us back in a most remarkable manner to the Cretaceous epoch. Thus among Mollusca we have two *Terebratulidæ*, of which one at least (*Terebratulina caput-serpentis*) may be certainly identified with a Cretaceous species, whilst the second (*Waldheimia cranium*) may be fairly regarded as representing, if not lineally descended from, another of the types of that family so abundant in the Chalk. Among *Echinoderms* we have the little *Rhizocrinus*, that carries us back to the *Apiocrinite* tribe which flourished in the Oolitic period, and was until lately supposed to have had its last representative in the *Bourgetticrinus* of the Chalk, to which the *Rhizocrinus* presents many points of remarkable correspondence*. Among *Zoophytes*, the *Oculina* we met with in a living state seems generically allied to a Cretaceous type (*O. explanata* of Michelin). And the remarkable abundance of *Sponges*, which not improbably derive their nutriment from the protoplasmic substance that enters largely into the composition of the calcareous mud wherein they are imbedded (p. 190), is a preeminently conspicuous feature of resemblance.—We can scarcely doubt that a more systematic examination of the remarkable Formation at present in progress would place in a still stronger light the relationship of its Fauna to that of the Cretaceous period, since the specimens which our few dredgefuls contained can only be considered as a mere *sample* of the varied forms of Animal life which this part of the Ocean-bottom sustains. And if our notion of the intimacy of this relationship should be confirmed by further inquiry, it would go far to prove, what seems on general grounds highly probable, that the deposit of *Globigerina*-mud has been going on, over some part or other of the North-Atlantic sea-bed, from the Cretaceous epoch to the present time (as there is much reason to think that it did elsewhere in *anterior* Geological periods), this mud being not merely *a* Chalk-formation, but a continuation of *the* Chalk-

* See the recently published "Mémoires pour servir à la connaissance des Crinoides vivants," by Prof. Sars (Christiania, 1868).

formation; so that *we may be said to be still living in the Cretaceous Epoch* *.

VIII. It can be scarcely necessary to point out in detail those various important applications of the foregoing conclusions to Geological Science, which will at once occur to every Geologist who endeavours to interpret the past history of our globe by the light of the changes it is at present undergoing. But this Report would not be complete without some notice of these.—In the first place, it may, I think, be considered as proved that no valid inference can be drawn from either the absence or the scantiness of Organic Remains in any unmetamorphosed sedimentary rock, *as to the depth at which it was deposited.* So far from the deepest waters being *azoic*, it has been shown that they may be peculiarly rich in Animal life. On the other hand, comparatively shallow waters may be almost *azoic*, if their temperature be low or their currents be strong; and thus even littoral formations may show but few traces of the life that might be abundant on a deeper bottom at no great distance.—Again, it has been shown that two deposits may be taking place within a few miles of each other, *at the same depth and on the same geological horizon* (the area of one penetrating, so to speak, the area of the other), of which the Mineral character and the Fauna are alike different,—that difference being due on the one hand to the *direction of the current* which has furnished their materials, and on the other to the *temperature of the water* brought by that current. If our "cold area" were to be raised above the surface, so that the deposit at present in progress upon its bottom should become the subject of examination by some Geologist of the future, he would find this to consist of a barren Sandstone, including fragments of older rocks, the scanty Fauna of which would in great degree bear a Boreal character (§ 11); whilst if a portion of our "warm area" were elevated at the same time with the "cold area," the Geologist would be perplexed by the *stratigraphical continuity* of a Cretaceous formation, including not only an extraordinary abundance of Sponges, but a great variety of other Animal remains, several of them belonging to the warmer Temperate region, with the barren Sandstone whose scanty Fauna indicates a widely different climatic condition, which he would naturally suppose to have prevailed at a different period. And yet these two conditions have been shown to exist *simultaneously*, at *corresponding depths*, over *wide contiguous areas* of the sea-bottom; in virtue solely of the fact that one area is traversed by an *Equatorial* and the other by a *Polar* current †. Further, in the midst of the land formed by the elevation of the

* I think it due to my valued Colleague to state that this hypothesis (which I myself fully accept) entirely originated with him, having been foreshadowed in his first communication to me on the subject (Appendix).

† It may be said that the asserted existence of these Currents is a mere hypothesis, until an actual movement of water in opposite directions has been substantiated. But, as Prof. Buff has pointed out (p. 187, *note*), the existence of such deep currents is a

"cold area," our Geologist would find a hill some 1800 feet high, covered with a Sandstone continuous with that of the land from which it rises, but rich in remains of Animals belonging to a more temperate province (§ 13); and might easily fall into the mistake of supposing that two such different Faunæ, occurring at different levels, must indicate two distinct climates separated in time, instead of indicating, as they have been shown to do, two contemporaneous but dissimilar climates, separated only by a few miles horizontally, and by 300 fathoms vertically.—It seems scarcely possible to exaggerate the importance of these facts, in their Geological and Palæontological relations, especially in regard to those more localized Formations which are especially characteristic of the later Geological epochs. But even in regard to those older Rocks, whose wide range in space and time would seem to indicate a general prevalence of similar conditions, it may be suggested whether a difference of bottom-temperature, depending upon deep oceanic currents, was not the chief determining cause of that remarkable contrast between the Faunæ of different areas in the same Formation, which is indicated by the abundance and variety of the Fossils of one locality, and their scantiness and limitation of type in another; as is seen, for example, when the "Primordial Zone" of Barrande is compared with its equivalent in North Wales.—Further, in the case of those Calcareous deposits which owe their very existence to the vast development of Organisms that possessed the power of separating Carbonate of Lime from the ocean-waters, *temperature* may be pretty certainly assumed to be the chief condition, not merely of the character of the Animal remains which those formations may include, but of the very production of their solid material.

IX. How important a light is thrown by the facts we have brought into view on those changes in the Marine Fauna of any particular area, which cannot be referred to changes in its own geological condition, need scarcely be pointed out. As there must have been *deep seas* in all Geological epochs, so there must have been *varieties in Submarine Climate* at least as great as those we have discovered, depending upon those Equatorial and Polar Currents whose existence has been shown to be a Physical necessity. Hence it is obvious that since changes in the direction of such opposing currents must have been produced by any upward or downward movement of the sea-bottom (as in the areas of elevation and subsidence marked out by Mr. Darwin in our existing seas), a considerable modification, or even a complete reversal, of the Submarine Climates of adjacent areas might have been consequent upon alterations in the contour of the land, or in the level of the sea-bottom, *at a great distance*. The effect of such a modification of Temperature upon the respective Faunæ of these areas would probably depend upon the rate and degree of the change. If

necessary consequence of the difference of surface-temperature between Equatorial and Polar waters; and those who raise the objection are consequently bound to offer some other conceivable hypothesis on which the facts above stated can be accounted for.

rapid and considerable, it might cause the extinction over those areas of a large proportion of the species which inhabited them; whilst others would migrate in the direction of the temperature most congenial to them, and transfer to new localities those types which could no longer exist in their previous habitats,—thus establishing the *Colonies* of M. Barrande. If, on the other hand, such a change of Temperature were more gradual, the greater part of the species constituting the Faunæ of the areas over which it occurred might adapt themselves to it, undergoing such modifications in their structure and habits as might be considered sufficient to differentiate them specifically, whilst retaining so many characters of general similarity as to constitute "representative species" *.

X. The ingenious suggestion of Dr. Wallich† that the nature of the Animal life found on the sea-bottom may not unfrequently afford some clue to the history of its changes of *level*,—his discovery at great depths of a type (the *Ophiocoma granulata*) which is essentially *littoral* being indicative of slow progressive subsidence,—may be extended with some probability to changes of submarine *climate*; for where any species is found abundantly as a *littoral* form, its presence at great depths in the same region would seem to indicate that the subsidence of the bottom has not been attended with any considerable alteration of temperature, whilst its absence on neighbouring parts of the same area may be fairly taken as evidence of such a change.

The preparation of a detailed list of the Species found in each locality, with the depths from which they were brought up, furnishing the justification of the general statements made in this Report, has been kindly undertaken by Professor Wyville Thomson, who will present it at the earliest practicable date; and he will also describe the new and very remarkable forms of *Vitreous Sponges* we have obtained, this being a group to which he has already given special attention.—I shall myself lose no time in preparing an account of the *Rhizopods* we have collected, availing myself of the kind assistance of Professor Huxley, who has undertaken to examine and describe the Organic components of our various specimens of Chalk-mud, and of Professor Frankland, who will determine their Chemical composition.

We cannot but hope that when our Report shall have been thus completed, it may be found not unworthy of the Royal Society by which our inquiry was promoted in the first instance, and of the Government which provided the means for its prosecution, and that the results we have obtained may be regarded as sufficiently important to justify its extension both in range

* It will be obvious to every one who is conversant with Sir Charles Lyell's 'Principles,' that in the views above stated I have simply *extended* the doctrines long since promulgated by that great Master of the Philosophy of Geology.

† The North-Atlantic Sea-Bed, pp. 149–155.

and objects. For we cannot but believe that Physicists, Physical Geographers, Naturalists, and Geologists will alike desire such a careful and detailed exploration of the Sea-bottom between the North of Scotland and the Faroe Islands; as may determine with precision,—(1) the *depth* in every part of that area; (2) the *temperature*, not merely of every part of the bottom, but also at various depths of the water that lies upon it, say, at every 50 fathoms vertically; (3) the precise boundaries of the *cold area* of bottom-temperature which separates the northern and southern portions of the *warm area*; (4) the *direction* and *rate* of any *current* that may be detected in either or each of these areas; (5) the relative *composition* of the water in these areas respectively; (6) the relative proportions of *gases* contained in the sea-water at different *depths*, and in the same depth at different *temperatures*; (7) the *penetrating power* of the *Actinic* rays in their passage through Sea-water; (8) the nature, composition, and sources of the *deposits* in progress over the several parts of the sea-bottom, especially distinguishing those of its *warm* and those of its *cold* tracts, as well as those along the line or band of demarcation between the two; and (8) the distribution of *Animal and Vegetable Life* throughout the whole region, as complete a collection as possible being made by repeated dredgings in every part of it, so as to furnish materials for valid inferences as to the relations of its several forms to the depth, temperature, and character of the sea-bottom on which they respectively occur.

The near proximity of this area to our own shores, and the consequent facility with which a vessel may be kept at sea during the whole of the season most suitable for work of this kind, by running for supplies to Stornoway, Lerwick, or Kirkwall (as may be most convenient), renders it peculiarly fitting for such an investigation; for just as the limited area of the British Islands presents an epitome of the whole Geological series, so does this limited Oceanic area present such varieties of depth and temperature, and probably of currents, as are only likely to be met with elsewhere at a far greater distance from land, and over a much wider Geographical range.—But it is also greatly to be desired that these inquiries should be prosecuted at still greater depths; and such may be reached with no less facility by proceeding westwards from the West of Scotland or the North-west of Ireland, a depth of at least 1300 fathoms being known to exist between these Coasts and Rockall Banks.

It only remains for me to tender the grateful acknowledgments of Professor Wyville Thomson and myself to Her Majesty's Government for the readiness with which they acceded to the recommendation of the President and Council of the Royal Society, and for the liberality with which the means of prosecuting our inquiries were furnished by the Admiralty; and we would in particular express our obligations to the Hydrographer to the Admiralty for the earnestness with which he took up the idea of this Ex-

pedition in the first instance, the perseverance with which he subsequently carried through every arrangement that could promote its scientific efficiency, and the considerate kindness with which he provided all that was needful for our welfare and comfort. Our cordial thanks are also due to Staff-Commander May for the heartiness with which he threw himself into the work, and the thoughtful consideration he uniformly showed, alike for the objects of the Expedition and for our personal convenience; and to Sub-Navigating-Lieutenant Tooker, by whom Captain May's exertions in both these respects were zealously and efficiently seconded.

We would also record our sense of the friendly reception which we met with on the part of His Excellency the Governor of the Faroe Islauds, who, although we were not in any way accredited to him, did his utmost not only to promote the Scientific objects of our visit, but also (with the aid of his accomplished Lady) to render our stay at Thorshaven agreeable to us.

APPENDIX.

From the Minutes of the Council of the Royal Society, June 18, 1868.

From Dr. Carpenter, V.P.R.S., to the President of the Royal Society.

University of London, Burlington House, W.
June 18th, 1868.

Dear General Sabine,—During a recent visit to Belfast, I had the opportunity of examining some of the specimens (transmitted by Prof. Sars of Christiania to Prof. Wyville Thomson) which have been obtained by M. Sars, jun., Inspector of Fisheries to the Swedish Government, by *deep-sea* dredgings off the coast of Norway. These specimens, for reasons stated in the enclosed letter from Prof. Wyville Thomson, are of singular interest alike to the Zoologist and to the Palæontologist; and the discovery of them can scarcely fail to excite, both among Naturalists and among Geologists, a very strong desire that the zoology of the *deep sea*, especially in the Northern Atlantic region, should be more thoroughly and systematically explored than it has ever yet been. From what I know of your own early labours in this field, I cannot entertain a doubt of your full concurrence in this desire.

Such an exploration cannot be undertaken by private individuals, even when aided by grants from Scientific Societies. For dredging at great depths, a vessel of considerable size is requisite, with a trained crew, such as is only to be found in the Government service. It was by the aid of such an equipment, furnished by the Swedish Government, that the researches of M. Sars were carried on.

Now as there are understood to be at the present time an unusual number of gun-boats and other cruisers on our northern and western coasts, which will probably remain on their stations until the end of the season, it has occurred to Prof. Wyville Thomson and myself, that the Admiralty, if moved thereto by the Council of the Royal Society, might be induced to place one of these vessels at the disposal of ourselves and of any other Naturalists who might be willing to accompany us, for the purpose of carrying on a systematic course of deep-sea

dredging for a month or six weeks of the present summer, commencing early in August.

Though we desire that this inquiry should be extended both in geographical range and in depth as far as is proposed in Prof. Wyville Thomson's letter, we think it preferable to limit ourselves on the present occasion to a request which will not, we believe, involve the extra expense of sending out a coaling-vessel. We should propose to make Kirkwall or Lerwick our port of departure, to explore the sea-bottom between the Shetland and the Faroe Islands, dredging around the shores and in the fiords of the latter (which have not yet, we believe, been scientifically examined), and then to proceed as far north-west into the deep water between the Faroe Islands and Iceland as may be found practicable.

It would be desirable that the vessel provided for such a service should be one capable of making way under canvas, as well as by steam-power; but as our operations must necessarily be slow, *speed* would not be required. Considerable labour would be spared to the crew if the vessel be provided with a "donkey-engine" that could be used for pulling up the dredge.

If the Council of the Royal Society should deem it expedient to prefer this request to the Admiralty, I trust that they may further be willing to place at the disposal of Prof. Wyville Thomson and myself, either from the Donation Fund or the Government-Grant Fund, a sum of £100 for the expenses we must incur in providing an ample supply of spirit and of jars for the preservation of specimens, with other scientific appliances. We would undertake that the choicest of such specimens should be deposited in the British Museum.

I shall be obliged by your bringing this subject before the Council of the Royal Society, and remain,

Dear General Sabine, yours faithfully,

The President of the Royal Society. WILLIAM B. CARPENTER.

From Prof. Wyville Thomson, Belfast, to Dr. Carpenter, V.P.R.S.

May 30, 1868.

MY DEAR CARPENTER,—When I last saw you, I suggested how very important it would be to the advancement of science to determine with accuracy the conditions and distribution of Animal Life at great depths in the ocean; I now resume the facts and considerations which lead me to believe that researches in this direction promise valuable results.

All recent observations tend to negative Edward Forbes's opinion that a *zero* of animal life was to be reached at a depth of a few hundred fathoms. Two years ago, M. Sars, Swedish Government Inspector of Fisheries, had an opportunity in his official capacity of dredging off the Loffoden Islands at a depth of 300 fathoms. I visited Norway shortly after his return, and had an opportunity of studying with his father, Prof. Sars, some of his results. Animal forms were *abundant*; many of them were new to science; and among them was one of surpassing interest, the small Crinoid of which you have a specimen, and which we at once recognized as a degraded type of the *Apiocrinidæ*, an order hitherto regarded as extinct, which attained its maximum in the *Pear-encrinites* of the Jurassic Period, and whose latest representative hitherto known was the *Bourguetticrinus* of the Chalk. Some years previously, M. Absjornsen, dredging in 200 fathoms in the Hardangerfjord, procured several examples of a Starfish (*Brisinga*) which seems to find its nearest ally in the fossil genus *Protaster*. These observations place it beyond a doubt that animal life is abundant in the

ocean at depths varying from 200 to 300 fathoms, that the forms at these great depths differ greatly from those met with in ordinary dredgings, and that, at all events in some cases, these animals are closely allied to, and would seem to be directly descended from, the fauna of the early Tertiaries.

I think the latter result might almost have been anticipated; an probably further investigation will add largely to this class of data, and will give us an opportunity of testing our determination of the zoological position of some fossil types by an examination of the soft parts of their recent representatives. The main cause of the destruction, the migration, and the extreme modification of Animal types, appears to be change of climate, chiefly depending upon oscillations of the earth's crust. These oscillations do not appear to have ranged, in the northern portion of the Northern Hemisphere, much beyond 1000 feet since the commencement of the Tertiary epoch. The temperature of deep water seems to be constant for all latitudes at 39°; so that an immense area of the North Atlantic must have had its conditions unaffected by Tertiary or Post-tertiary oscillations.

One or two other questions of the highest scientific interest are to be solved by the proposed investigations:—

1st. The effect of *pressure* upon Animal life at great depths. There is great misapprehension on this point. Probably a perfectly equal pressure *to any amount* would have little or no effect. Air being highly compressible, and water compressible only to a very slight degree, it is probable that under a pressure of 200 atmospheres, water may be even more aërated, and in that respect more capable of supporting life, than at the surface.

2nd. The effect of the great diminution of the stimulus of Light. From the condition of the Cave Fauna, this latter agent probably affects only the development of colour and of the organs of sight.

I have little doubt that it is quite practicable, with a small heavy dredge, and a couple of miles of stout Manilla rope, to dredge at a depth of 1000 fathoms. Such an undertaking would, however, owing to the distance, and the labour involved, be quite beyond the reach of private enterprise. What I am therefore anxious for is, that the Admiralty may be induced, perhaps at the instance of the Council of the Royal Society, to send a vessel (such as one of those which accompanied the Cable Expedition to take soundings) to carry out the research. I should be ready to go any time after July; and if you would take part in the investigation, I cannot but believe that it would give good results.

I would propose to start from Aberdeen, and to go first to the Rockall fishing-banks, where the depth is moderate, and thence north-westward, towards the coast of Greenland, rather to the north of Cape Farewell. We should thus keep pretty nearly along the isotherm of 39°, shortly reaching 1000 fathoms depth, where, allowing 1000 feet for oscillations in level, and 1000 feet for influence of surface-currents, summer heat, &c., we should still have 4000 feet of water whose conditions have probably not varied greatly since the commencement of the Eocene epoch.

Yours most truly,

WYVILLE THOMSON.

These letters having been considered, it was

Resolved,—That the proposal of Drs. Carpenter and Wyville Thomson be approved, and recommended to the favourable consideration of the authorities of

the Admiralty; and that a sum, of not exceeding £100, be advanced from the Donation Fund to meet the expenses referred to in Dr. Carpenter's letter.

The following draft of a letter to be written by the Secretary to the Secretary of the Admiralty was approved:—

My Lord,—I am directed to acquaint you, for the information of the Lords Commissioners of the Admiralty, that the President and Council of the Royal Society have had under their consideration a proposal by Dr. Carpenter, Vice-President of the Royal Society, and Dr. Wyville Thomson, Professor of Natural History in Queen's College, Belfast, for conducting dredging operations at greater depths than have heretofore been attempted in the localities which they desire to explore—the main purpose of such researches being to obtain information as to the existence, mode of life, and zoological relations of marine animals living at great depths, with a view to the solution of various questions relatin to animal life, and having an important bearing on Geology and Palæontology. The objects of the operations which they wish to undertake, and the course which they would propose to follow, as well as the aid they desire to obtain from the Admiralty, are more fully set forth in the letter of Dr. Carpenter to the President, and that of Professor Thomson, copies of which I herewith inclose.

The President and Council are of opinion that important advantages may be expected to accrue to science from the proposed undertaking; accordingly they strongly recommend it to the favourable consideration of Her Majesty's Government, and earnestly hope that the Lords Commissioners of the Admiralty may be disposed to grant the aid requested. In such case the scientific appliances required would be provided for from funds at the disposal of the Royal Society.

I am, &c.,

W. Sharpey, Sec. R.S.

Lord H. Lennox, M.P., Secretary of the Admiralty.

From the Minutes of the Council of the Royal Society for October 20, 1868.

Admiralty, 14th July, 1868.

Sir,—In reply to your letter of the 22nd ultimo, submitting a proposition from Dr. Carpenter and Professor Thomson to investigate, by means of dredging, the bottom of the sea in certain localities, with a view to ascertain the existence and zoological relations of marine animals at great depths,—a research which you and the Council of the Royal Society strongly recommend in the interests of science to the favourable consideration of Her Majesty's Government, for aid in furtherance of the undertaking,—I am commanded by My Lords Commissioners of the Admiralty to acquaint you that they are pleased to meet your wishes so far as the Service will admit, and have given orders for Her Majesty's steam-vessel 'Lightning' to be prepared immediately, at Pembroke, for the purpose of carrying out such dredging operations.

I am, Sir,

Your obedient Servant,

W. G. Romaine.

To the President of the Royal Society.

The Society then adjourned over the Christmas Recess to Thursday, January 7, 1869.