NOTES

ON

THE PRESENCE OF ANIMAL LIFE

AT VAST DEPTHS IN THE SEA;

WITH OBSERVATIONS ON

THE NATURE OF THE SEA BED, AS BEARING ON SUBMARINE TELEGRAPHY.

BY

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THE following observations are extracts from a Note-book kept at sea. Should the facts recorded be deemed of scientific importance, my mind will be relieved of no trifling anxiety; for to Sir Roderick Murchison's and Professor Huxley's kind recommendation do I owe my temporary appointment on board the 'Bulldog.'

For the opportunities afforded me, during the cruise, I beg most heartily to thank Sir Leopold M'Clintock. I consider it a high privilege to have served under his orders.

H.M.S. 'Bulldog,'
Off Rockall,
8th November, 1860.

NOTES

ON THE PRESENCE OF ANIMAL LIFE

AT VAST DEPTHS IN THE SEA.

Our first clear glance at the floor of the ocean may be said to bear date from the period at which telegraphic communication between the various countries of the globe was first undertaken. Our previous knowledge of its characters was both limited and imperfect in kind. For, although the depth of the sea had been approximately ascertained over widely extended areas, no attempt had as yet been made to investigate the material of which its bed is composed. It was only during the last few years that the possibility of perfecting our information became recognized,—numerous important facts having revealed themselves, in the course of the sounding surveys conducted under the auspices of the British and United States' Governments, all of which tend to prove that the same wondrous agencies, whereby some of the sedimentary strata of the earth's crust were accumulated in ages gone by, are still in operation, and that the recesses of the deep,

hidden although they be from man's direct vision, may nevertheless be rendered subservient, in due time, to his enterprise and skill.

But whilst the history of the material obtained during the soundings referred to shed much highly interesting light on the formation of submarine deposits, it likewise showed how much still remained to be explored and accounted for. Thus, evidence was wanting to enable us to determine whether the minute shell-covered creatures, whose remains are sometimes brought up by the sounding-machine in such profusion, as to constitute a very large per-centage of the various deeper oceanic deposits, lived and died where they were discovered, or whether, having passed their existence in the superincumbent waters, their calcareous skeletons had gradually subsided to the bottom, or had been transported by currents or other agencies, to the position at which they became ultimately entombed.

Hitherto the investigation of questions of this sort had been looked upon as possessing only a scientific value. It was not believed, for a moment, that they could exercise any direct bearing on great practical enterprises, such as the Electric Telegraph; accordingly, as few inducements as opportunities were held out for their elucidation. It was extremely difficult, therefore, to arrive at any satisfactory conclusions on the subject; for the assertion that certain of the humbler forms of animal life are to be met with at vast depths in the ocean, although based on most reasonable grounds,

had only to be confronted by a bold denial, to leave the point as undecided as ever.

The deplorable fate of the Telegraphic Cable between Ireland and Newfoundland, however, accomplished what no amount of indirect evidence could achieve; for not only has it been ascertained, during the recent efforts to recover a portion of the wire, that minute animal forms, of the occurrence of which, even in comparatively speaking shallow water, we had no conception, are able to effect a lodgement within the insulating and protecting coverings of the cable, but also that the methods of scrutinizing the sea bed are utterly inadequate for the requirements of submarine telegraphy, however admirably adapted for those of navigation.

The gradual deterioration of various shorter telegraph lines, moreover, indicated the presence of disturbing and destructive influences, of the nature of which we remain more or less ignorant; whilst certain erroneous statements have, on the other hand, been so authoritatively put forth, that they commanded an almost unquestioned belief. Amongst the more prominent of these may be mentioned the assertion, that animal life cannot, by any possibility, be maintained at a depth exceeding 500 fathoms; that the process of deep-sea deposit is so universal and constant throughout its waters, that bare rock is rarely, if ever, to be met with at depths beyond 100 or 150 fathoms; and that, along the ocean floor, no current ever sweeps so as to disturb its state of perfect repose.

In the hope of being instrumental in throwing light on these and collateral topics, daily engrossing more and more of the public attention, I hailed the opportunity presented by the equipment of H.M.S. 'Bulldog' for the survey of the projected North Atlantic Telegraph route between Great Britain and America, as being singularly fitted to yield interesting results. The tender of my services was accordingly submitted to the Lords Commissioners of the Admiralty, and by them accepted with a promptitude for which I herewith beg to offer my most grateful acknowledgments.

I regret that the quantity of material collected by me falls somewhat short of what I could have wished; but, taking into consideration the uniformly tempestuous character of the period during which we have been at sea, and the attendant increase of difficulties inseparable from Natural History researches on ship-board, I venture to hope that the results may not be deemed unsatisfactory.

The main object I had in view, namely, the determination of the depths to which animal life extends in the sea, together with the limits and conditions essential to its maintenance, I rejoice to say has been in a great measure accomplished. For not only may it now be accepted as clearly proved, that life exists at depths far exceeding those heretofore supposed to circumscribe it, but, taking into consideration the high organization of the forms discovered, and how little they seem fitted to carry on their complicated functions under so enormous an amount

of pressure as that to which they are subject, we are warranted in assuming that a large class of creatures inhabit the deeper recesses of the sea, and that, by the evidence thus brought to bear on the question of oceanic deposits, our knowledge of the conditions under which many fossil forms lived and perished may be materially augmented.

The long-mooted question as to the occurrence of certain species of Foraminifera in a living state at vast depths, has been solved in like manner. A short notice of the facts which have led to these conclusions will be given immediately. Meanwhile I would mention that, as the detailed examination of the soundings obtained, of the objects collected by dredging at anchorages, or of those found on shore in the vicinity of places touched at during the cruise, must necessarily demand more time and facilities than could possibly be afforded at sea, I shall confine my observations, for the present, to a notice of the more striking forms only.

In the Appendix to Commander Dayman's Report on the Soundings taken between Ireland and Newfoundland, by H.M.S 'Cyclops,' in 1857, Professor Huxley remarks that, although far from regarding it as yet proved that the *Globigerinæ**, a genus of the Foraminifera above alluded to, live at the great depths indicated, the balance of proba-

* The *Foraminifera* are minute animals belonging to one of the most simply organized families of the Animal Kingdom, whose calcareous shells constitute a large per-centage of the "oozy" deposit so constantly brought up by the soundings in the Mid-Atlantic and elsewhere.

bilities seems to him to incline in that direction, and to be strongly supported by the fact that any genus of animals, which, like the one now spoken of, extends far back in time—that is, in a fossil state—may with certainty be regarded as capable of living under a great variety of circumstances as regards light, temperature, and pressure.

The difficulty was, how to determine the point conclusively; for it seemed legitimate to infer that, if these organisms are specially adapted to exist under conditions differing so widely from those under which shallow-water genera occur, the very circumstance of transporting them from one set of conditions to the other would inevitably destroy their vitality, if not also their organization, before it became practicable to subject them to microscopic examination. Thus we could hardly expect to find *Globigerinæ* exhibiting signs of life after the lapse of nearly an hour, during which period they had been brought from their normal medium, the pressure of which is estimated by tons, to an abnormal one in which it may be estimated by pounds.

Nor was the difficulty an imaginary or overdrawn one, as the result proved. For, whilst a number of facts tended indirectly to corroborate the view of their living where they were found, not only was positive and direct evidence wanting for its confirmation, but the further I proceeded in my inquiries the more certain did it become that such direct evidence could never be forthcoming under the circumstances. Even now, one of the most

powerful collateral proofs of the *Globigerinæ* being able to live at great depths is derived from the discovery of creatures removed far above them in the scale of organization, the vitality of which remained unimpaired for some time after they had been brought up from a depth of nearly 1300 fathoms.

But although we are fully warranted in assuming that creatures holding so low a place in the Animal Kingdom as the *Globigerinæ* are capable of existing, as asserted by Professor Huxley, under a great variety of circumstances as regards light, temperature, and pressure, according to all hitherto-received notions it would have been considered absurd to assert that animals so highly organized as the *Ophiuridæ** could by any possibility live under such conditions. They nevertheless do exist there, and were found at a point where the *Globigerinæ* constitute as much as 95 per cent. of the deposit on which they rest. From the circumstance of numbers of the latter having been detected in the digestive cavity of one of the Starfishes examined by me immediately after its capture, it is highly probable that they form their chief source of food in that locality.

This evidence, therefore, coupled with some other facts about to be noticed, is sufficient to settle the question as definitely as it can be settled, and to show, at the same time, that all preconceived views

* A family of Starfishes, some of which are very common along our own shores.

with regard to what conditions are essential to the maintenance of life in the deeper portions of the ocean, and what render life there impracticable, are utterly erroneous.

After a laborious and continued examination of Foraminifera obtained from depths varying from 50 to nearly 2000 fathoms, that is, from 300 feet to nearly two miles and a half below the surface of the sea, I have arrived at the following conclusions.

Whilst in shallow waters all, or nearly all, the specimens of *Globigerinæ* present the appearance of vitality—that is, have their chambered shells full of reddish-yellow-coloured sarcode, which, when crushed under the microscope, flows out into a granular and somewhat viscid mass, the particles of which reamalgamate here and there, and exhibit a faint vibratile action at times,—the number of specimens from deep water, in which the cells are full of sarcode, is small as compared with that in which they are wholly or partially empty. In such as present the sarcodic contents entire, its particles, on being viewed under the microscope, appear somewhat disintegrated, less viscid, and more disinclined to coalesce again after being crushed asunder. There is no vibratile tendency discernible; and the colour of the cell-contents is more dingy and inclining to brown than to yellow. When freed from the calcareous shell by the application of dilute hydrochloric acid, the contents nevertheless retain their normal size and outline; and, on

the other hand, when the entire shells are subjected to boiling in caustic potash, the sarcode matter is as readily dissolved, and leaves the calcareous walls as entire and fresh-looking as it is in recent shallow-water specimens.

I have in no single instance observed locomotion take place, or the delicate filaments extended, with which motion is said to be effected in the deep-sea forms. But this is by no means surprising, even supposing the *Rhizopods* to be always capable of exhibiting it in their natural haunts; for in the case of much more highly organized creatures, such as the *Polyzoa* or the *Actiniæ*, many days, and sometimes even weeks, have to elapse before they can be induced to protrude their ciliated arms or tentacles, under the abnormal conditions of captivity. Besides, as already stated, it is not to be expected that, if they are in reality specially constituted to exist under the conditions present at vast depths, they can carry on their varied functions when removed to a position in which every one of those conditions is changed.

Professor Huxley, in the Appendix to Commander Dayman's pamphlet already referred to, mentions having observed, in the soundings submitted for his examination, "a multitude of curious rounded bodies, to all appearance consisting of several concentric layers, surrounding a minute clear centre, and looking at first sight like cells of the plant *Protococcus*." Professor Huxley goes on to say that these cannot be organic, inasmuch as they are rapidly and

completely dissolved by dilute acids; and he applies the provisional term *Coccoliths* to them accordingly.

In almost every sample of *Globigerina*-ooze * these bodies have been detected by me. But I have also invariably found associated with them, in greater or less quantity, certain large cell-like masses, the average diameter of which is about $\frac{1}{1000}$th of an inch, on the immediate surface of which minute bodies were regularly arranged at intervals, so closely resembling the free "Coccoliths" in look and structure, as to leave little doubt that the latter are given off from the former in some way. The cell-like central portion, together with the "Coccolith"-like bodies, are imbedded in a gelatinous-looking capsule, the exact nature of which it was out of my power to determine accurately at sea. The association of the largest number of both these kinds of bodies in the soundings in which the *Globigerinæ* were in greatest quantity and in the purest condition, is worthy of notice, and is almost suggestive of their being the larval state of those organisms. The smallest *Globigerina*-shell met with by me in this material measured $\frac{1}{600}$th of an inch in diameter, and contained but two chambers,—the size of the free "Coccoliths" being $\frac{1}{3000}$th of an inch in diameter, or five times smaller. In some

* I have retained the name of "ooze" for that kind of deposit in which the *Globigerinæ* occur, in order to avoid confusion. At the same time I must mention that the samples of bottom most fruitful in *Globigerinæ* exhibited no trace of any "sticky" or "soft mealy substance," as found in some soundings by Captain Dayman.

specimens the "minute clear centre" had most distinctly divided into two portions. Much additional investigation will, however, be necessary before any reliable deductions can be arrived at, as to the nature and functions of these very remarkable structures.

In the oldest and largest *Globigerina*-shells, apertures are to be found varying in size from $\frac{1}{800}$th to $\frac{1}{1000}$th of an inch across, placed at intervals, and quite independent of the minute tubules which open out at the apices of the little conical elevations on the outer surface. Through these apertures the true organs of motion are protruded. When brought up from the bottom, they contract, in all probability, and thus form small reddish-yellow-coloured masses, closely applied to, and somewhat larger than, the apertures they emerge from. Freed from these pseudopodia, the shells present very much the appearance of the fenestrated shells of the *Polycystina*, the apertures occurring at considerable intervals, whilst between them are to be seen the stout conical tubercles of the shell itself, which, as they are prolonged into its substance, give to its section a crystalline and radiate character. In the young *Globigerina*-shell the surface is nearly smooth, and presents only a few scattered points here and there. These points gradually increase in number and size, the thickness of the shell being at the same time augmented, till at last it attains a thickness of $\frac{1}{250}$th of an inch.

It is worthy of record that the occurrence of *Glo-*

bigerina in two soundings between Cape Farewell and Rockall in 1260 and 1607 fathoms, the one containing 95 per cent., the other 98 per cent. of clean shells, with hardly a trace of any other organic or inorganic matter, affords an almost direct proof that their presence is not due to the drift or deposition by currents.

It has been observed that the number of specimens of *Globigerina* from the deep "oozy" soundings in which the mass is extremely tenacious, showing the cell-contents entire and in an apparently vital state, is, comparatively speaking, small with reference to the much larger proportion in which the cells present no such characters. The reasons for this are obvious. The extreme lightness of nearly all "oozy" deposits has been strongly dwelt on by several writers. Were these deposits to occur under the same pressure that prevails at the sea-level, they would, no doubt, be of a soft and flocculent nature. But at a depth of 2000 fathoms and upwards, where the weight of the superincumbent column of water amounts to nearly a ton and a half on the square inch of surface, all, save the immediate surface-layer of deposit, must become gradually condensed and aggregated together by molecular affinity, its permeability by the fluid particles (by means of which the state of equilibrium, as to pressure, had been hitherto maintained) is destroyed, and from that instant the weight of the entire column acts upon it. The tenacious character of some of these deposits is so

remarkable, that I see no other mode of accounting for it. On reaching the surface, the deposit presents a plastic consistence, somewhat akin to that of putty; but the adhesiveness of the particles to each other is infinitely stronger in the one case than in the other. It should, moreover, be borne in mind that, during the transit of the material from the sea-bed to the surface, the reduction of the pressure referred to must operate to an extraordinary degree, in diminishing its original solidity. Under this view the extremely tenacious and clayey character met with in most of the deep-sea soundings may be explained. There is strong evidence in support of it, moreover, inasmuch as if a portion of oozy mud be slowly rubbed down under the finger with salt water, so as to form a fluid mass, it does not regain its original consistence, although permitted to settle for four and twenty hours in a deep glass vessel, but presents the same characters that we find on mixing together any light powdery substance with water, and allowing it in like manner to subside slowly.

Of course, in the nearly pure *Globigerina*-deposits, already referred to as of rare occurrence, there is no tenacity whatever—the minute amorphous particles necessary for the production of the oozy quality being almost entirely absent; they therefore appear to the naked eye as mere aggregations of clean fine sand.

The relative proportion of living to dead individuals in the prevailing tenacious form of ooze

thus receives a ready explanation. The normal habitat of the *Globigerinæ* is on the immediate surface layer of the deposit. It is quite impossible to conceive that creatures so completely devoid of muscular energy can either move about, or imbibe the matters requisite for their sustenance, if imbedded within the dense body of such a deposit. The latter is, in short, what Lieutenant Maury describes the entire ocean-floor to be—a vast necropolis, to which are consigned the remains of countless bygone generations, mixed up with the detritus and exuviæ derived from other animal and vegetable structures.

I may here mention that, in order to find out whether *Globigerinæ* were to be met with at any distance intermediate between the bottom and sea surface, I attached a small open-mouthed bag at 200 fathoms from the lower end of the sounding line, in a locality where these organisms were abundant in the deposit, and brought it up through nearly 700 fathoms, without being able to detect a single shell.

It has been stated that *Globigerinæ* were found in the alimentary cavity of one of the Starfishes taken at 1260 fathoms. But it also appears probable that other animals, belonging to the Annelid tribe, occur along with them; and that these both subsist upon their soft parts, and build up their habitations of their shells. In one of the soundings obtained at a depth of 1913 fathoms, I detected a number of small tubes, about a line in diameter,

and varying in length from $\frac{1}{16}$th to $\frac{1}{4}$th of an inch. These, on being submitted to examination under the microscope, proved to be almost wholly built up of young empty *Globigerina*-shells cemented together side by side, as in the case of certain of the Cephalobranchiate Annelids. Intermixed with the younger shells were to be seen one or two old fully developed specimens, and, very rarely indeed, the silicious valve of a *Coscinodiscus*. In such specimens as I had time to inspect, I could detect no Annelid within the tubules; but on a renewed and more careful scrutiny of the material in which they occur, I still hope to have it in my power to determine to what creature the construction of these remarkable objects is to be attributed.

It is a most remarkable fact, that the occurrence of *Globigerina*, when in any quantity in the deep-sea deposits, is evidently associated, in an intimate manner, with the presence of the Gulf-stream or its offshoots. Thus, as has been shown by the soundings between Ireland and Newfoundland, along the greater portion of which the Gulf-stream flows in an east and somewhat northerly direction, nearly every specimen of bottom contained these organisms in greater or lesser profusion.

In the soundings taken during the cruise of the "Bulldog" between the Faroe Islands and Iceland, *Globigerina* was met with in every instance in which bottom was brought up from the deeper water, unmixed with "arming" material.

Between Iceland and Greenland they were abund-

ant in a few deposits about the central third of the channel.

Between Greenland and Labrador they were almost entirely absent.

On the return voyage, however, between Cape Farewell and Rockall, they were very plentifully found, reaching their maximum development in long. 25° W., but declining rapidly in numbers in the direction of Greenland.

The association referred to appears to be wholly irrespective of the direct drifting action of the Gulf-stream upon the Foraminiferous shells, even supposing it to extend to a very much greater depth than it does. It would rather seem to depend on the waters of the Gulf-stream being so charged with organic animal or vegetable particles, derived from the Gulfs of Mexico and Florida, or from the Sargasso fields, that circulate on its surface, as to afford food to the countless myriads of these structures, and in this way to facilitate their increase. The presence also of the minute, amorphous, yellowish particles so constant in the same deposits may thus, in like manner, be accounted for.

In the material brought up in the soundings from "the Coral Sea," spoken of by Lieutenant Maury (Physical Geography of the Sea, 1858, p. 261 *et seq.*), at a depth of 2150 fathoms, in lat. 13° S., long. 16° 2′ E., the predominant forms are not calcareous, but silicious, and consist chiefly of Sponge-spicules, with a few Polycystina and Dia-

tomaceæ; while the Foraminiferà are almost entirely absent.

Again, soundings taken in the Red Sea and Persian Gulf exhibit, if I recollect aright, a similar deficiency of Foraminiferous shells. In these the Diatomaceæ are much more abundant. Now in all three localities Coral formations occur to a vast extent. The calcareous matter which goes in the one place to build up the exquisite chambered shells of the Foraminifera, in the other goes to form the more solid but equally beautiful habitation of the Coral Polype.

Unlike the animal of the Foraminiferous shell, the Coral Polype lives, multiplies, and dies in a vast fixed Republic, towards which the particles of food must be drifted by the circulation of the medium around. The Foraminifer can move from place to place in search of its food. Of the nature of the nourishing matters demanded for the two families of creatures, we have, as yet, no evidence; but it can hardly be doubted that, on a careful analysis of the water from localities in which the calcareous and silicious-walled organisms respectively preponderate, the varying proportion of the remaining ingredients would afford a clue to the nature of the nutritive particles taken up in either case, and the source from whence they are derived.

It is deserving of notice that the *Globigerinæ*, and, indeed, the Foraminifera in general, are not abundant in deposits in which volcanic particles

form a principal element,—the abrasive character of the latter being, in all likelihood, sufficient to check, to a certain extent, the increase of such delicate organisms.

On two occasions living specimens of *Serpula* were obtained. One at a moderate depth, the other at 680 fathoms, and in conjunction with a living *Spirorbis*. Other free Annelids, and two Amphipod Crustaceans, were also taken alive at 445 fathoms.

But by far the most interesting discovery remains to be noticed. In sounding not quite midway between Cape Farewell and Rockall, in 1260 fathoms, whilst the sounding apparatus brought up an ample specimen of coarse gritty-looking matter, consisting of about 95 per cent. of clean *Globigerina*-shells, a number of Starfishes, belonging to the genus *Ophiocoma*, came up adherent to the lowest 50 fathoms of the deep-sea line employed. This quantity of line had been paid out in excess of the depth, which was determined by a separate operation; and it must therefore have rested on the bottom for a few minutes, so as to admit of the Starfishes attaching themselves to it. On reaching the surface, and for upwards of a quarter of an hour afterwards, they continued to move about energetically. One very perfect specimen, which had fixed itself close to the extreme end of the line, and was still convulsively grasping it with its long spinous arms, was secured *in situ* on the rope, and consigned to immortality in a bottle of spirits.

Here then is a fresh starting-point in the Natural History of the sea. At a depth of two miles below the surface, where the pressure must amount to at least a ton and a half on the square inch—where it is difficult to believe that the most attenuated ray of light can penetrate—we find a highly organized species of radiate animal living, and evidently flourishing,—its red and light-pink-coloured tints as clear and brilliant as seen in its congeners inhabiting the shallow waters where the sun's rays penetrate freely. Arguing from preconceived ideas, we should certainly not expect to find, in these deep-sea Starfishes, the same internal organization as is to be met with in shoal-water forms, or that the circulating fluid, no matter how simply composed, could traverse the delicate membranes possessed by them. Unlike some of the higher families of the Radiata, the *Ophiocomæ* do not boast of protrusile suckers and the complicated muscular and vascular systems associated with such organs. But it is nevertheless evident that (in defiance of the obstacles enumerated (circulation of sea-water, if of no special fluid, over the peritoneal lining of their cavities, digestion, assimilation, and reproduction are carried on unrestrictedly, in addition to the somewhat simpler, but no less essential, operations of locomotion and capture of food.

The *Ophiuridæ* are strictly carnivorous. The specimen dissected by me was found to differ in no respect, as regards internal anatomy, from the species inhabiting shallow water. In the alimentary

cavity, numerous *Globigerina*-shells occurred, more or less completely freed of their soft contents.

In Professor E. Forbes's 'Monograph on the British Starfishes,' it is stated that the Ophiuridæ do not present such a wide range as the true Starfishes, and that they are more affected by climatal causes. This only renders the occurrence of the species now under notice still more surprising. The distance of the position at which they were obtained from the nearest land of Greenland, namely Cape Farewell, is 500 miles. From the nearest point of Iceland, namely the "Blinde Skier" rocks, 250 miles. It is necessary to mention this, lest it be deemed possible that the Starfishes could have been drifted by currents or borne by any other means from either country. For the information of those who are not versed in the habits of the Starfishes generally, it may be further stated that they are essentially creeping animals, never swimming, but formed only to move along the surface of rock or bottom of any kind. In what are termed the true Starfishes, that is, in the stellate or angular forms such as *Uraster*, *Goniaster*, *Solaster*, and the like, motion is effected by the suckers already spoken of. In the Ophiuridæ, however, there are no organs of that kind, and motion is performed altogether by the spine-covered arms, from which they derive their name of "Spinigrada." The spines are all articulated to the arms, and, by means of the rowing-like motion of which they are susceptible, enable the creature

to travel along on its course,—the weight of the body and arms, chiefly made up as it is of calcareous matter, entirely precluding it from floating, or even raising itself off the bottom.

All former opinions, as to the limits of life in the deep sea, must give place under such a startling fact. Hitherto living things have not been detected, simply because due measures have neither been devised nor employed for their capture. In the present instance, the capture was as accidental as it was fortunate. But where one form so highly organized has been met with, it is only reasonable to assume that other correlated forms may also exist; and we may therefore look forward, at no very distant period, to the discovery of a new submarine fauna, frequenting the deeper fastnesses of the ocean, which, whilst furnishing a new field of research for those who are content to seek after novelty, shall also throw a gleam of light on the Geology and Palæontology of the globe.

The law will, I think, eventually be found to hold good, that any marine animal, within the cellular structure of which air or any other gaseous fluid does not necessarily occur in a free state, and every portion of whose organization is permeable by fluids, either through capillary or endosmotic and exosmotic agency, may exist under the extraordinary pressure present at great depths. Irrespectively of the pressure, temperature and light would hardly constitute any valid obstacle.

The question now remaining to be solved, is not

whether living creatures do, or do not, exist at great depths; but, as in the case of animals frequenting shallow water, what are the limits in depth within which each form is circumscribed. These limits ascertained, the question of distribution will, in all likelihood, follow as a natural sequence.

The nearly entire absence of those varied forms of animal life which present themselves almost invariably in calm weather near the surface of the sea, in northern as well as in tropical latitudes, has been so remarkable during the cruise, that it is difficult to account for it on any other hypothesis than the unusually severe character of the season. Of the extent to which the above remark applies, some idea may be formed by those conversant with the superabundance of life in Arctic waters when I state that, although constantly on the look-out for assemblages of Pteropods (such as *Clio*, for instance), on no occasion did they present themselves, —the only Pteropod captured in the North Atlantic being the common little *Spirialis*, and a small undescribed larval condition of *Pneumodermon*, or a form allied to it. It is worthy of notice, moreover, that the animalcule which occurred floating near the surface in greatest profusion, on those extremely rare occasions on which the weather could be called fine, was a *Peridinium*.

Diatomaceæ were frequently obtained. But even these vegetable structures, on which atmospheric agencies can scarcely be expected to exercise so

marked an influence as on animal life, were but scantily represented near the surface waters. Those found at great depths, associated with the matter of the various deposits, do not live there, but are either deposited from the waters above or transported thither by currents from other latitudes. Although in such as had their frustules perfect the endochrome was more or less entire, it was invariably so changed in character from recent endochrome, and so disintegrated, as to leave no doubt of vitality having been destroyed before their subsidence to the bottom. I would, however, mention having found Diatomaceæ in a healthy living condition, at a depth of nearly 400 fathoms*.

It is a remarkable circumstance, that on two occasions only, during the cruise of the expedition on the coast of Greenland, was drift-timber fallen in with. On these occasions the pieces were, moreover, so small as hardly to deserve the name. Both specimens were of pine, completely sodden by long immersion, and exhibiting no trace of epi-

* I would here suggest a method of procuring specimens of Diatomaceæ, Polycystina, &c. from sea-water, which is novel, and seems likely to prove of some service. When the boilers of the 'Bulldog' were being freed of the usual incrustations, I searched a portion of the matter scaled off, for organisms of these kinds, having, of course, previously resorted to the use of nitromuriatic acid, in order to get rid of earthy and alkaline impurities. The experiment was successful, Diatomaceæ and Polycystina being detected in considerable quantity. By procuring portions of boiler-deposits from steam-ships plying within known limits, a series of free floating Diatomaceæ might thus be secured; deficient, unfortunately, in all those interesting characters upon which our knowledge of growth and increase is based, but nevertheless affording data whereby the distribution and limits of species might, to a great extent, be ascertained.

phytic growths or parasitic animalcules, from which some clue might, possibly, have been obtained as to their source. This absence of drift-timber is the more curious, inasmuch as the immense stream of drift-ice by which the whole southern seabord of Greenland was encompassed must have been due, in great measure, to the same current that sweeps round such masses of drift-wood during ordinary seasons. It must be borne in mind that the 'Bull-dog' cruised for nearly a month, sometimes just outside the pack, sometimes in the midst of it, whilst endeavouring to effect an entrance into the harbours of "Julianshaab" and "Frederickshaab;" so that ample opportunity presented itself of seeing any drift-wood, had it been floating about. From inquiries made by me at Goodhaab, and latterly at Julianshaab, it would appear that the usual accession of drift-timber has been almost wholly suspended during the present season. It is evident that this material, commonly brought round to Greenland, must be borne along by the reflexion of the Gulf-stream coming from the shores of the countries in which it was produced. The usual course of that stream would therefore appear either to have undergone some change before meeting with the Spitzbergen current, so as to have drifted the timber to other seas or lands, or, as I think more probable, the northward range of the Arctic current must have been materially extended, so as to overpower, and even deflect, the branch of the returning Gulf-stream, without commingling with

it, in its course down the eastern shore of Greenland. Although there is not, I believe, any evidence tending to show that the actual rate per hour at which the Arctic current has swept round Cape Farewell this season is in excess of the average yearly rate, there is every reason for supposing it has extended to a much more northerly limit than is customary, and has thus been instrumental in bearing down along with it the enormous ice-fields and bergs met with so late as the beginning of October. The same cause would also be sufficient to influence the climate of Northern Europe generally. It is worthy of remark that in the Western hemisphere no such agency has been in operation. Not only was the Labrador coast almost free of berg-ice when we visited it, but the residents, at the entrance to Hamilton's Inlet, informed me that the quantity of both berg- and drift-ice had been unusually small during the present season.

Another proof of the abnormal condition of the surface waters near Cape Farewell, is derivable from the fact that in a sounding off that promontory, in nearly 1200 fathoms, there occurred such numbers of dead and empty shells of the little surface-inhabiting Pteropod *Spirialis*, as to leave no room to doubt that the animals were killed by the lowness of the temperature during the long-continued and unusually heavy ice-drift, and that the shells had gradually subsided to the bottom. This very beautiful little mollusk occurs in great abundance, at times, near the surface. That the dead shells were

not derived from the ordinary course of decay and decomposition is probable, inasmuch as I have repeatedly taken *Spirialis* at the surface where the soundings contain not a single shell. Their occurrence, therefore, in the sounding at so great a depth, indicates an exceptional destroying influence; and it is difficult to assign a more natural one under the circumstances.

It has been repeatedly laid down as a law, that, along the entire bed of the sea, wherever the depth is great, the disturbing influence of currents cannot take place. The evidence derived from some of our recent soundings proves, however, that this law, although correct in a general sense, admits of exceptions. I would more particularly mention two instances which indicate that currents do occur. In a sounding taken in lat. 59° 45′ N. and long. 46° 30′ W., at a depth of 1204 fathoms, basaltic gravel was brought up, the pieces of which were so rounded and smooth that it is difficult to assign any other agency by which they could have assumed this aspect. In another sounding, taken in lat. 61° 35′ N. and long. 24° 9′ W., at 871 fathoms, although neither stones nor gravel were brought up, another equally conclusive proof of the action of a current presented itself. It is well known that during volcanic eruptions the lava-dust is frequently transported by winds to enormous distances. At the first glance I imagined that the occurrence of this material at so great a distance from Iceland, might be attributed to this agency. But the detection of

a great number of dead shells of littoral species of Foraminifera, although it could not be said directly to negative this conclusion, could clearly not have been due to a similar cause. They must have been drifted to their position, probably from the "Blinde Skier" rocks, which were about midway between it and the mainland of Iceland. Although, therefore, it is quite possible that some of the volcanic particles may have been wafted across the sea by winds in this instance, it is reasonable to conclude that the bulk, at all events, has been transported by the current thus shown to be in operation.

In Lieutenant Maury's admirable work on the 'Physical Geography of the Sea' (1858, p. 353 *et seq.*), a letter is quoted from the late Professor Bailey of New York, to whom had been entrusted the examination of certain soundings between Ireland and Newfoundland, taken in 1849. In this letter, Professor Bailey expresses an opinion that particles of "pumice and volcanic ashes," detected by him in soundings taken between lat. 47° 50′, long. 52°, and lat. 52° 2′, and long. 24° 51′, were derived from Hecla. Lieutenant Maury, adverting to this circumstance, observes that he "cannot perceive how these cinders could have got there from Hecla or any of the extinct volcanoes of Iceland," and suggests that, "if they came from the southward, they would be found all the way across the eastern half of the Atlantic," and as far towards the Irish coast "as the deep water goes, as far north as the parallel of 25° N." On this, Professor

Bailey, having re-examined the entire series of soundings, "reports the presence of cinders in every specimen along a line more than a thousand miles in length."

I have adduced my reasons for inferring the presence of a current drifting along, at a great depth, from Iceland to the southward. The remarkable coincidence of the extreme eastern limit of the volcanic detritus mentioned, coupled with the occurrence of the same matter, almost to the very same longitude so much further to the northward, renders it highly probable, I think, that Professor Bailey's surmise with reference to Hecla is the more correct one after all.

Professor Bailey also lays stress on the pumice particles showing no evidence of abrasion, as tending against his own theory. I would observe with regard to this point, that the angularity of volcanic glass and pumice remains perfect under all circumstances. Whenever found in the deeper-water deposits, or along the wave-lashed shores of Iceland, the particles, as seen under the microscope, exhibit the same glassy, unabraded, and acute fracture.

Lieutenant Maury states (Physical Geography of the Sea, p. 265) that "the abraded appearance of these shells" (alluding to the Foraminifera), "and the almost total absence of the mixture of any detritus from the sea, or foreign matters, suggest most forcibly the idea of perfect repose at the bottom of the deep sea." The conclusion is a most natural one; but its validity appears to be shaken,

in a great measure, by the fact that along all the most stormy coasts, in every part of the world, and even under the fullest influence of the tides, are to be found living specimens of Foraminifera in abundance, the shells of which are so extremely delicate and hyaline in their structure, as to render it almost impossible to conceive how they can remain entire for an hour. Like the feeble reed which bends to the stormy blast, these exquisitely formed organisms yield to the force of the wave, and defy its rude anger.

It had long been my conviction that the methods of obtaining soundings, however admirably adapted for purposes of navigation, were wholly inadequate to meet the requirements of any telegraphic survey. Soon after the commencement of the voyage, I accordingly submitted my views on the subject to Sir Leopold M'Clintock, who not only gave them due consideration, but sanctioned the construction of various improved forms of sounding gear, by means of which it was hoped these requirements might be fulfilled. Under the joint suggestions of Sir Leopold, Mr. Roughton, Chief Engineer, Mr. Steel, Assistant Engineer, and myself, the apparatus has been gradually perfected. An account of it will, no doubt, be laid before the public in due time; it may be mentioned, however, that where

grains used to be brought up by the older forms of apparatus, pounds are now brought up.

The determination of depth, although constituting an essential element in every submarine survey, I venture to assert is by no means the only essential one. It is equally necessary to ascertain the general contour of the sea-bed; to determine whether it be uniformly level, or broken by irregularities; if covered by deposit, to trace its source and nature; and lastly, should living animal forms occur, to denote their characters and the extent of their distribution.

Taken independently of all other considerations, depth does not constitute a difficulty likely hereafter to interfere with the selection of telegraph routes. On the contrary, it is not at all improbable that the greater the depth in which a cable may be laid, the greater will be its immunity from disturbing or destructive agencies, and, however startling such a statement may at first sight appear, that the deepest route between two given points, so long as no extraordinary and sudden changes of level are involved, will eventually be found to present the fewest risks.

Although animal life has been detected, during the present survey, at depths far exceeding those hitherto assumed as its boundary (namely, at a mile and a half below the sea-level), we are justified in taking for granted, from what is known to take place as we descend from moderate to great depths,

that the number of living creatures diminishes, and that a point may be reached at which organic life ceases.

That but trifling value attaches to mere depth along any projected telegraph route, is manifest from the circumstance that in very rare instances indeed has any latitude been allowed for selection. The route has been fixed upon as the preliminary step to surveying operations; soundings have then been taken; and lastly, the wire has been consigned to its destination. A remarkable case of this kind is to be met with in the line between Aden and Kurrachee. The greatest depth encountered in that line was 2000 fathoms, being only a few hundred fathoms short of the greatest depth in the Atlantic line. From evidence adduced before the Board of Trade in May last on Oceanic Telegraphy, it will be seen that only half that depth "was expected;" and that the report on the soundings had actually not been laid before the engineers until their arrival at the scene of operations. Although soundings had previously been taken for this line, the report on them had not been received in England prior to the despatch of the cable. Its adaptation to the particular kind of bed it was destined to rest upon must therefore have been entirely disregarded.

From the same evidence it appears that the insulation of the wire improved with the increase of depth, and that at 2000 fathoms it was at its

maximum, thus affording an additional argument in favour of deep water. Beyond certain limits, the recovery of a cable for repairs must always be an operation fraught with extreme difficulty and expense. In order to make a line remunerative, the necessity for such an operation will have to be provided against in the first instance, by the employment of that form of cable, and the selection of that route, which shall be most free from risk of injury. Under any circumstances, we should hardly be justified in expecting a cable to continue in perfect working order beyond a certain number of years. It may be practicable to augment its durability by gradual improvements of various kinds; but the history of the numerous enterprises already on foot proves that many unforeseen sources of accident may spring up, and that a long period must yet elapse before the system of Submarine Telegraphy can be rendered complete. Meanwhile, during its infancy, no means should be neglected of reducing the causes of failure to a minimum; and surely the accurate survey and analysis of the sea-bed is the first step in the right direction.

The Atlantic line also affords a notable example of the imperfect manner in which the survey of the line was planned, although nothing was left undone, that could have been done under the circumstances, by the able and energetic officer who was employed to superintend it. There is no fact forthcoming to show that the rugged nature of the sea-

bed adjoining the American terminus, on which so much light has been recently thrown in the process of endeavouring to recover the wire, and also the very sudden declivity * present on the Valencia side, might not have been wholly or partially avoided by the exploration of a route to the north or south of that adopted.

This is indeed a grave question, inasmuch as a great deal of additional labour and expense is involved in the necessity for surveying, not a given line of the sea-bottom, but that line which is best fitted for the reception of the telegraphic cable. It would be far from impossible to carry out such a survey of the concealed depths of the ocean as should enable us to plot out its plains and its mountains, its precipices and its valleys, its smooth surfaces and slopes, or its serrated rock-ridges. But such a survey is neither advocated, nor is it at all necessary. It is only necessary that something more systematic than the steeplechase mode of determining a line should be resorted to—by the employment of more ships, by the patient search for the route affording the greatest facilities, and by devoting at least an equal share of time and attention to the discovery of depths and the nature of the material of which the sea-bed is composed.

The rapidity with which Submarine Telegraphy

* The sudden dip on the Valencia side gives a fall of 7200 feet in ten miles, or about 720 feet per mile. We met with a similar dip on the east coast of Greenland, in which the fall is at the rate of 1000 feet per mile, or 3468 feet in three and a half miles!

is being extended might thus receive a temporary check. Large outlay might be entailed at the outset; but security would eventually be ensured, and, to say the least of it, the public would ponder well before it again consented to drop a million sterling into the mighty sinking-fund of the ocean.

THE END.