# NOTICES OF MEMOIRS.

## On the Conditions which Determine the Presence or Absence of Animal Life on the Deep-Sea Bottom. By Dr. W. B. Carpenter, F.R.S.[1]

THE foundation of Geological Science must be based upon a study of the changes at present going on upon the surface of the earth, including the depths of the sea. This is the distinctive feature of modern Geology. Until recently nothing was really known of the depths of the ocean; but, owing to improved methods of sounding, the bottom of the sea has been reached in so many places, that we may feel tolerably sure that its depth seldom exceeds four miles. Recent statements regarding an extraordinary depth off the coast of Japan are, most probably, due to an error similar to that which formerly represented the Straits of Gibraltar as unfathomable—an error caused by the carrying-out of the sounding-line in a strong surface-current. The general depth of the Atlantic does not exceed three miles, though, as an exception, the "Challenger" has recently attained 3800 fathoms in a hole 100 miles north of St. Thomas. As an additional proof that this was a true sounding, both the protected thermometers came up crushed.

The temperature of deep water has only lately been ascertained with accuracy, the earlier attempts having been vitiated by the error arising from pressure. Of the older attempts to ascertain the temperature of the deep strata, that devised by Lenz in the second voyage of Kotzebue, though fearfully laborious, gave results that correspond most closely with the "Challenger's"; a fact in scientific annals which has been lately dug out by Prof. Prestwich, and by him brought to the notice of the lecturer, who found his own conclusions —made in entire ignorance of those of Lenz—thus singularly confirmed. The conclusions to be drawn from a study of these temperatures point towards a deep flow of polar water towards the Equator, unrestricted, as regards the Atlantic, towards the south, but limited in the direction of the North Polar area, where there are two principal channels: the one between Greenland and Iceland, the other between the Faroe Islands and the 100-fathom line of North-west Europe, on which platform the British Islands repose. This latter is the "Lightning" channel, the scene of the lecturer's first explorations, the study of which led to his view of the existence of two opposite flows in the great oceanic area, quite irrespective of any one current. In this channel it was found that there was a superficial warm stream and a deep cold stream; and that within a vertical space of 50 fathoms a most marked difference of temperature is suddenly encountered; whilst, as regards horizontal distance, temperatures of 29½° F. and 43° F. have been obtained at the same depth in places not 20 miles apart. These facts mean that there are two distinct movements of water, just as a striking difference in the temperature of the atmosphere indicates a change of wind. Hence, speaking with reference to the "Lightning" channel, it is clear that

[1] Being the substance of a Lecture delivered before the Geologists' Association, on December 4th, 1874. Henry Woodward, Esq., F.R.S., President, in the Chair.

water much colder than the mean winter temperature of the latitude must have a northerly, whilst water that is warmer must have a southerly, source. In accordance with this we find that most of the animals of the cold area, such as the beautiful *Comatula Eschrichtii*, belong to the boreal fauna; whilst British species, such as the common *Solaster papposa*, which is dwarfed from the size of a plate to that of a crown-piece, are much stunted. Yet the fauna is abundant, as no temperature seems to prevent life, so long as sea-water is liquid. Pressure, though enormous, will not affect vital functions; since an animal, whose cavities contain air in aqueous solution only, can contract and expand just as well with a pressure of three tons to the square inch as it can on the surface. Not but what change of pressure, brought on by sudden removal, might produce some derangement. Neither temperature nor pressure, then, being directly of supreme importance, it is the supply of oxygen which has most influence on Animal Life in the deep seas. This is regulated by the general flow of water near the sea-bottom,—a flow not confined to any particular passage or area, but maintained by difference of specific gravity, produced by difference of temperature. As sea-water, in this respect differing from fresh-water, continues to increase in density down to its freezing-point, which is 27° F. if agitated, and 25° F. if still, the Polar column will outweigh the Equatorial column, and there will be a lateral outflow at the bottom towards the equatorial area. This will cause a lowering of water in the polar area, and produce a surface-flow of water from the Equator towards the Poles. The two bottom-flows from either pole will thus meet near the Equator, and rising, will bring cold water nearer to the surface there than anywhere else, except where the surface itself is subjected to cold. In this way the bottom-temperature of the South Atlantic would be lower than that of the North Atlantic, by reason of the less restricted body of the polar flow in the former. The tables given in the "Challenger's" report confirm the conclusions thus arrived at. From these we find that the general temperature of the North Atlantic bottom is about 35½° or 36° F., decreasing to 34° F. near St. Thomas, and under the Equator itself to 32·4° F., the lowest temperature of all. This section proves that the South Atlantic under-flow extends north of the Equator, as had been previously surmised by the lecturer. Only one section was made in the South Atlantic, and no temperatures lower than 33½° F. were there obtained, the expedition not happening to hit upon the channel which brought in the water at 32·4° F. found under the Equator. Most remarkable of all is the line of 35° F. which can be traced across the South Atlantic and then gradually slopes down in the North Atlantic till it is lost. The temperature of the North Atlantic depths is probably about 3° F. higher than in the South Atlantic. Off the coast of Lisbon, in lat. 38° N., the line of 40° F. is found at 700 to 800 fathoms; in lat. 22° N. at 700 fathoms; and on the Equator at 300 fathoms only, descending from a surface temperature of 75° F. The reason for this has been already shown to be the continual rise of the Polar under-flow towards the surface in the Equatorial belt.

A further confirmation of these views is obtained from a comparison of specific gravities. The density (due to salinity) of surface-water increases from the poles to the tropics, while that of bottom-water in the tropics is nearly the same as in the polar area. Why then does the bottom-water of the tropics, being of lower salinity, underlie the more saline strata? Because the density it lacks from its lower salinity is more than compensated by the lowness of its temperature. Passing, however, from either tropic towards the Equator, the salinity of surface-water is found to diminish, until its specific gravity is reduced from 1027·3 to 1026·4 or 1026·3, which is that of the polar under-flow. Lenz adduced the low salinity of the surface-water under the Equator as evidence of the rise of polar water from the bottom, and showed that there is a band of water at the Equator colder than any to the north or south of it.

The Oceanic Circulation thus produced brings every drop of water in turn to the surface, enabling it to part with carbonic acid and to absorb oxygen; this, then, is its importance to Animal Life. From the analysis of gases dissolved in the water of the oceanic area, it was found that, for 45 per cent. of carbonic acid, there was usually from 16 to 20 per cent. of oxygen—this being the result of a series of observations taken off Ireland and Scotland at various depths down to 2000 fathoms. This amount of oxygen is sufficient to support a large quantity of Animal Life, in spite of the, to air-breathers, fatal proportion of carbonic acid—if indeed the carbonic acid be not in a liquefied, and thus perhaps more innocuous form.

In the Mediterranean totally different conditions prevail. It was expected that a Tertiary fauna would be found at great depths, analogous to the Cretaceous-like fauna of the ocean outside. Instead of that, only a viscid mud, almost devoid of life, was brought up. The western basin has a depth of 1600 fathoms, the eastern basin one of 2000 fathoms; the bottom temperature is nearly uniform at about 55° F., a great difference in thermal condition from the Atlantic. The reason is that the Mediterranean is cut off entirely from the polar under-flow, which, off Lisbon, produces a temperature of 40° F. at a depth of 700 fathoms, and 36½° at 1500 fathoms. In the Mediterranean, on the other hand, we have a surface temperature from 60° to 70° F., which, in the first 100 fathoms, falls to 54° or 55° F., below which to the bottom, no matter at what depth, there is no change at all, but a slight variation according to latitude, due in part to the mean winter temperature of the locality. The whole of the lower portion, therefore, below the influence of the Gibraltar current, is a mere stagnant pool; and this is the explanation of the absence of Animal Life except in the shallows. The impalpable mud, which is slowly settling to the bottom, may also not be without its effect. This is the result of the attrition of soft Tertiary shores, and of the clay brought down by the Rhone into the western basin, and by the Nile into the eastern, the finer particles pervading the entire sea. Corals and Bivalves suffer from it especially, The per-centage of carbonic acid was found to be as high as 60, whilst that of oxygen was only 5; this is believed to be due to the organic matter, brought

down by the rivers, using up the oxygen. These unfavourable conditions are primarily due to deprivation of the general oceanic circulation, which maintains life at such great depths.

There seems, however, to be a limit, in respect of depth, to the preservation of animal remains; due possibly, as conjectured by Prof. Thomson, to the solvent power of sea-water at pressures below 2200 fathoms. This may serve to explain the passage of true *Globigerina* ooze, first into grey ooze, poorer in calcareous matter, and finally at great depths into red ooze devoid of lime. Moreover, this dissolving of calcareous skeletons at great depths may serve to explain the production of Greensands, such as is now going on along the line of the Agulhas current. These consist largely of the internal casts of foraminifera, the sarcode of which has been replaced by glauconite). The importance of such facts to geologists is immense. It was the examination of a series of casts of similar bodies in a green silicate, that, years ago, formed the foundation for the lecturer's interpretation of the structure of Eozoön, where there is a replacement of its sarcodic body by a green silicate, viz. serpentine. If the sea-water, under this tremendous pressure, has dissolved away the shells of Foraminifera, after their sarcode has undergone the substitution alluded to, a beautiful application of this kind of research to geological phenomena has been brought forward.

Referring to Ed. Forbes's limitation of marine life to 300 fathoms, the lecturer observed that the statement was true of the Ægean, as of the whole of the Mediterranean, where there is abundant life in the littoral zone, diminishing rapidly towards 250 fathoms, below which Animal Life is almost at zero. Finally it is not a limit of pressure, of heat, or even of food, but the limit of oxygenation, as determined by the presence or absence of a thermal circulation, which affects the life of animals. So that deposits forming in inland seas, excepting in the shallower portions, we must expect to be destitute of fossils. This is well illustrated by the Miocene strata of Malta, where certain coarsish beds, representing shallow water conditions, are full of fossils in a fine state of preservation; whilst the very fine building stone, corresponding closely with the finest calcareous deposit of the Mediterranean, contains hardly any remains but such as would fall in from above, *e.g.* the teeth of sharks. This may explain the paucity of fossils in many strata, especially in the Red Sandstones of inland seas. Much depends upon the depth of the communication, supposing there to be one, with the oceanic circulation; and the level of this may be often inferred from a knowledge of the line of permanent temperature of such inland sea. To the general paucity of animal life under such conditions the Red Sea appears to be an exception, notwithstanding the shallowness of the Straits of Babelmandel. This is probably due to the absence of the sediment and oxidating matter of large rivers, and to the rocky nature of its shores, conditions which insure a clear water; whilst a certain circulation, producing oxygenation, is kept up to supply the enormous evaporation, which, if the Straits were closed, would desiccate the basin in three or four hundred years.