I would observe, in conclusion, that, although much has been written on the geology of Arran, comparatively little is accurately known, especially as regards the rocks in the southern half of the island. A few rambles along the shore and among the hills should surely teach a geologist that there are igneous rocks of different ages, presenting various modes of occurrence; yet such important distinctions as those between interbedded sheets and intrusive dykes have been generally overlooked or completely misunderstood. What is now wanted is a good geological map and memoir, a work which could not be in better hands than in those of Prof. Geikie and his staff, and with which it is to be hoped geologists may soon be favoured.

V.—ON THE TEMPERATURE AND OTHER PHYSICAL CONDITIONS OF INLAND SEAS, IN THEIR RELATION TO GEOLOGICAL INQUIRY.¹

By WILLIAM B. CARPENTER, M.D., LL.D., F.R.S., F.G.S.

THE researches in which the Author has been personally engaged during the last four years into the Temperature and other Physical conditions of the Deep Sea, combined with the information he has obtained from other sources, have led him to the knowledge of certain remarkable differences in regard to these conditions, which prevail between Inland Seas and the open Ocean. As these differences have a most direct and important bearing upon the distribution of Animal life, and as it would seem highly probable that similar differences have existed in all Geological periods, he thinks it important that Geologists, by being made aware of them, should be in possession of a key that seems likely to open the way to a rational interpretation of many Palæontological phenomena which are at present obscure.

The *general facts* in regard to Ocean Temperature, which have been determined by recent observations, are briefly as follows:—

1. In high Northern latitudes, the Temperature of the *surface* of the sea, near the border of the ice barrier, is but little above 32°; and at small depths below the surface, according to the recent observations of Payer and Weyprecht, it falls below 32°. Making allowance for the known influence of pressure upon the thermometers with which temperature-observations at great depths have been made in these regions, there is every reason to believe that—save in cases in which the temperature of the upper stratum may be modified by local causes—there is a progressive descent from 32° to 29°, or even lower; so that the average temperature of the *entire column* of *Polar water* may be considered to be not above 30°.

2. In lower latitudes, the Temperature of the surface of the sea is greatly influenced by solar radiation; but the *superheating* thus produced does not generally extend in a marked degree much below 100 fathoms. Beneath this, in the Atlantic, is a stratum of which the temperature may be said to range from about 52° to 45°, in all but the highest latitudes; but the depth of this stratum varies considerably, extending downwards to about 500 fathoms near the Faroe Banks, to about 700 fathoms off the coast of Portugal, and to 1,000 or 1,200 fathoms nearer the Equator.

3. Beneath this stratum is a “stratum of intermixture” in which the thermometer falls rapidly, sometimes as much as 10° in 200 fathoms; and below this the temperature again becomes more uniform, sinking very gradually from 39° or 38°, to 36° or 35°, at depths of 2,000 fathoms or more, near the Eastern border of the North Atlantic. It is probable that Temperatures yet lower than these will be found to prevail over the deep bottom of the Mid-Atlantic; the recent Temperature-soundings of Captain Chisholm in the Eastern Seas, made with ‘protected’ Thermometers, having now fully demonstrated that, *even under the Equator*, the bottom-temperature at great depths of the Ocean may be as low as 32°.

4. Thus the Intertropical column may be considered as consisting of (1) a *superheated stratum*, of which the temperature ranges from 84° at the surface to 52° at

¹ Extracted from *The English Mechanic and World of Science*, for September 20-27, 1872, with additions and corrections by the Author.

200 fathoms; (2) an *upper warm stratum* of (say) 1,000 fathoms' depth, of which the temperature ranges from 52° to 45° ; (3) a *stratum of intermixture* of about 200 fathoms' depth, in which the thermometer falls from 45° to 39° ; and (4) of a *cold stratum* occupying the whole of the deeper portion of the great Oceanic basins beneath 1,400 fathoms, its temperature falling with increase of depth, so that in its deepest portion the thermometer has been seen as low as 32° . The *average* of the entire column may thus be about 45° .

Now, as *Sea* water progressively diminishes in bulk and increases in Specific Gravity down to its freezing point, it is maintained by the Author that supposing the Polar and Intertropical columns to be equal in height, the excess of weight in the former will produce a lateral pressure at its lower portion, which will occasion an outflow of Polar water along the floor of the ocean, towards the Equator; this deep outflow, by lowering the surface, will produce an indraught of water into the Polar area, which, in its turn, will acquire by cooling the same excess of Specific Gravity, thus producing a continual *downward* movement; while on the other hand the deep outflow, being subject to the heating influence of the crust of the earth beneath, and of the warmer water above, will be gradually thinned as it passes towards the Equator, so as to lie at a greater and greater depth beneath the surface. As the continual indraught into the Polar area must ultimately be supplied from the surface of the Intertropical sea, there will be a continual movement of the *upper stratum* from the Intertropical towards the Polar area; while as the last-arrived Polar water will always be colder than that which preceded it, the former will take its place beneath the latter, so that there will be a continual *upward* movement of the water in the Intertropical area.—Of this upward movement of colder water from below, a very curious indication has lately been obtained in the fact that off the west coast of Africa the temperature of the sea at 200 fathoms is about 5° lower over a bottom deep enough to be covered by the Polar overflow, than it is over a bottom of only 700 or 800 fathoms' depth.

The doctrine of a *vertical circulation* advocated by the Author was long since suggested by Pouillet as the best explanation of the facts then known in regard to Ocean-temperature; but it was put aside through the general acceptance of the doctrine of a uniform deep-sea temperature of $39\frac{1}{2}^{\circ}$, which was supposed to have been established by Sir James Ross's observations, and which was adopted and promulgated by Sir John Herschel. The corrections supplied by more recent and trustworthy observations have afforded a new set of data; on the basis of which it has been argued by the Author, that such a Circulation *must* necessarily take place under the conditions above specified, and that it gives an adequate scientific *rationale* for the facts determined by observation. And his views on this subject have been accepted by Sir John Herschel and Sir William Thomson.

Now, it is obvious that if this doctrine of a Vertical Oceanic Circulation, sustained by antagonism of Temperature, be admitted, the thermal condition of any Inland Sea that is cut off from any but a superficial communication with the great Oceanic basins, and at the same time corresponds with them in depth, must be very different. Of such a sea, the Mediterranean is a typical example. It consists of two very deep basins: the Western, which extends from the Strait of Gibraltar to the Adventure and Skerki Banks that connect Sicily with the coast of Tunis, having a depth which ranges, over a large part of its area, to 1,000—1,600 fathoms; whilst the Eastern, which extends from Malta and the eastern coast of Sicily to the Levant, is yet deeper, its bottom having in some parts a depth of nearly 2,000 fathoms. The Strait of Gibraltar, which constitutes the sole channel of communication between the Mediterranean basin and the outside Atlantic, and which has a depth of about 500 fathoms between Gibraltar and Ceuta, gradually shallows, as it widens, towards its western *embouchure* between Capes Trafalgar and Spartel; where there is a "ridge," or "submarine watershed," of which the average depth is about 120 fathoms, certain passages across it approaching 200 fathoms in depth. Through this Strait there is a double current, modified in force and direction by Tidal action, as the researches which the Author carried on last August in conjunction with Captain Nares have shown: the *predominant* movement of the *upper stratum* being *inwards*, while that of the *lower stratum* is *outwards*; and the quantity of water which thus *enters* the Mediterranean from the Atlantic being considerably greater than that which *flows out* of the Mediterranean into the Atlantic. The surplus of the upper current goes, as was maintained nearly 200 years ago by Dr. Halley, to make up for the loss sustained by the water of the Mediterranean, in consequence of the excess of evaporation from its surface over the whole quantity restored to it by rain and rivers; whilst the outward

under-current serves, by continually carrying back a portion of the denser Mediterranean water, to prevent the accumulation of salt in the Mediterranean basin, which would otherwise result from the continual inflow of sea water in place of the fresh water that has passed off by evaporation. This outflow the author believes (with Captain Maury) to depend upon the excess of weight of the Mediterranean column above the Atlantic column; its immediate physical cause, therefore, being exactly the same as that of the outflow of bottom-water from the Polar area.¹

It will be obvious from what has preceded, that the Gibraltar in-current will produce very little change in the temperature of the Mediterranean; since, as its depth on the "ridge" is little more than 100 fathoms, the water which it brings-in will entirely belong to that superficial stratum whose temperature depends upon solar radiation. The summer temperature of that stratum in the Atlantic is a few degrees below that of the superficial stratum of the Mediterranean; and the winter temperatures of the two are about the same. We may, therefore, throw the thermal influence of the Gibraltar in-current out of consideration, except as regards its influence in slightly lowering the surface-temperature of the westernmost portion of the Mediterranean. The temperature of the deeper stratum will never be affected by it, since it is always below that of the water entering by the Strait, which will float upon it in virtue alike of its lower salinity and of its higher temperature.

The Summer temperature of the surface of the Mediterranean, where not depressed by the entrance of Atlantic water, generally ranges between 70° and 80°. But this temperature rapidly falls in passing from the surface downwards; as much as 20° being sometimes lost in the first 30 fathoms. In the Western basin, the thermometer generally sinks at 50 fathoms to 55° or 56°; and below this we observe very little change down to 100 fathoms, at which it usually stands at 54°. From this to the bottom, however deep that bottom may be, the temperature continues uniform, the water between 100 and 1,600 fathoms having absolutely the same temperature of 54° throughout. In the Eastern basin, of which the axis lies about 2° further to the south, the heat of the superficial stratum extends somewhat further down; but the uniform temperature is always reached at less than 200 fathoms; and from that depth to the bottom at (it may be) 2,000 fathoms, the temperature of 56° degrees is found everywhere to prevail.

Now, it is obvious from these facts (1) that Depth *per se* has no effect in reducing temperature; (2) that the uniform temperature of the Mediterranean from 100 or 200 fathoms to the bottom must be determined by some local condition; whilst (3) as this condition might be expected to have the same effect on the water of the outside Atlantic under the same parallel of latitude, the coldness of its lower stratum, ranging, from 900 fathoms downwards, between 39° and 36·5°, must be due to the importation of water from a Polar source. What, then, is the determining condition of the uniform temperature of 54° in the Western basin of the Mediterranean, and of 56° in the Eastern?

In the Report (for 1870) of his first researches in the Mediterranean, the Author attributed it to the subjacent influence of the warm crust of the earth, the temperature of which in the Mediterranean area, as indicated by the uniform temperature of a deep cave in the Island of Pantellaria, and by that of the deepest tanks in Malta, seems to be 54°. But he is now inclined to believe that this coincidence is accidental only, and that, no colder water being admitted from without, the uniform temperature of the mass of Mediterranean water in each basin really corresponds to its lowest winter mean, or *isothermal* temperature. According to the best information he has been able to obtain, the Winter temperature of the Western basin is 54° from the surface to the bottom, while that of the Eastern basin is 56° throughout; the slight excess in the latter being due to the small difference in latitude, with the effect of the hot winds from Central Africa. As the sun gains power, its radiation raises the temperature of the superficial stratum, but does not penetrate far downwards; and thus the great mass of the water beneath remains unaffected by it. If, on the other hand, the Winter temperature of the surface were to be reduced, that reduction would affect the entire mass; because, as the surface-water is cooled, it sinks, and diffuses its cold through the water beneath.

Thus the bottom-temperature of a deep Inland Sea may be expected to depend

¹ So in the case of the Black Sea, it was maintained by the Author that the excess of Specific Gravity of the *Ægean* water must produce an inward under-current through the Dardanelles and the Bosphorus; and this prediction, which was affirmed by Captain Spratt to have been disproved by his own previous researches, has recently been verified by the "Shearwater" investigations.

upon one or the other of two conditions; *first*, the mean Winter temperature or *isothermal* of the surface; and *second*, the temperature of the coldest water that is admitted into it from the Ocean outside. If its communication with that ocean be so shallow that the temperature of the water admitted through it is never lower than the *isothermal*, then the latter will be the uniform temperature of the entire mass beneath the variable surface-stratum; but if the communication be deep enough to admit the water of a colder stratum of the Ocean, the bottom-temperature of the Inland Sea will be the temperature of this stratum.

Let us see how this view applies to two other cases. The Red Sea, like the Mediterranean, is almost entirely cut off from communication with the deeper and colder stratum of the Arabian Gulf, with which its surface-layer communicates through the shallow Strait of Babelmandeb; for whilst the lowest temperature observed in that surface-layer, even in the northernmost extension of the Red Sea known as the Gulf of Suez, is 71° (as I learn from Captain Nares, who has been recently engaged in its survey), that temperature is there uniformly carried down to the bottom at 450 fathoms; and it may hence be pretty certainly affirmed that no lower temperature than this will be found in the southern portion of the Red Sea, even on a bottom exceeding 1000 fathoms in depth, since the *lowest* surface-temperature of that portion is probably never less than 75° , the *highest* being nearly 90° . Yet, in the Arabian Gulf, the temperature at a depth of 2,000 fathoms is certainly not *above*, and is very probably *below*, $36\frac{1}{2}^{\circ}$. Here, therefore, the uniform temperature which will probably be found to prevail throughout, beneath the surface-stratum, will be the *isothermal*.

Now it seems to be the universal opinion of those who have most carefully studied the existing Coral Formations, that the reef-building corals do not live and grow at a greater depth than 20 fathoms; and since it is affirmed by Mr. Dana as a deduction from the distribution of coral formations, that the existence of the reef-builders is geographically limited by the isothermal line of 68° , the Author cannot but suspect that the *bathymetrical* limit may be essentially a *thermal* one.² For all we know of the relation of Temperature to Depth would indicate that even within the Inter-tropical area of the open Ocean, the temperature at 20 fathoms may not be above 68° , and that in the next 10 fathoms it suffers considerable reduction. Now if the temperature of the Red Sea nowhere falls below 71° , it is obviously a most interesting question to determine whether the reef-building Corals are or are not to be found in that sea at a greater depth than in the Oceanic area; and if so, what is the greatest depth at which they exist there. For since the Author's previous inquiries have shown that Stony Corals, similar in all essential particulars to the reef-building types, can live and grow at the depth of many hundred fathoms, there seems no *a priori* reason why the latter should not thrive at like depths, if the Temperature be congenial to them.

A similar contrast is shown by the Temperature-soundings of Commander Chimmo (which have been kindly communicated to the Author by the Hydrographer) between the deep temperature of the Sulu Sea, a small area between the north-eastern portion of Borneo and Mindanao, and that of the China Sea. The former, though not ostensibly an Inland Sea (being but very partially surrounded by land), is so shut in by reefs and shoals, as to have only a very superficial and limited communication either with the China Sea or with the Celebes Sea. Notwithstanding this inclosure, its depth is very great, ranging to 1,603 fathoms; and its Temperature-phenomena present *exactly the same contrast* with those of the China Sea,³ that the Temperature-

¹ "On Corals and Coral Formations," p. 108.

² It is a very significant fact that the cold current which comes up from the south on the eastern coast of South America, and which the Author regards as the indraught of the Pacific Equatorial current (as the similar current on the eastern coast of South Africa is of the Atlantic Equatorial current), pushes the southern isothermal of 68° , the Coral Sea boundary, to the north of the Equator, between the South American coast and the Galapagos, which, though under the Equator, lie outside of that boundary.

³ The Temperatures here given are those of the *bottom* at different depths in the line of the telegraph cable between Singapore and Hong-Kong. Why the fall of temperature from 51° to 37° should seem to take place in the China Sea at so much smaller a depth than it does in the Atlantic, cannot be positively affirmed until we have *serial* soundings which shall give the Temperatures of successive strata in the deepest part of that sea. But as the temperatures given above are those of the *bottom* at various depths, *on the sides of a valley*, and as the careful researches of the United States Coast Survey have placed it beyond all doubt that the colder

phenomena of the Mediterranean present when compared with those of the Eastern Atlantic, as will be seen in the following table:—

SULU SEA.				CHINA SEA.			
deg.				deg.			
83	...	...	surface	...	...	84	
—	...	...	30 fathoms	...	...	77	
—	...	...	40 "	...	...	74	
—	...	...	50-80 "	...	...	71	
64.5	...	...	100 "	...	...	—	
—	...	...	120 "	...	...	62	
—	...	...	150 "	...	...	56	
—	...	...	200 "	...	...	51	
—	...	...	250 "	...	...	49	
51.5	...	...	308 "	...	...	—	
—	...	...	416 "	...	...	41	
50	...	...	500-1603 "	...	...	—	
—	...	...	673-1546 "	...	...	37	

Thus it appears that with a Surface-temperature almost exactly identical, and with a rate of descent through the Sub-surface stratum which seems nearly the same, there is a most marked difference beneath. For whilst, in the Sulu Sea, the thermometer only falls from $51\frac{1}{2}^{\circ}$ at 308 fathoms to 50° at 500 fathoms, and the temperature is uniform from that point down to the bottom at 1,603 fathoms, the thermometer undergoes a rapid descent in the China Sea from 49° at 250 fathoms to 41° at 416 fathoms, and thence to 37° at 673 fathoms, at which point it remains stationary down to the bottom at 1,546 fathoms. This difference is attributed by Capt. Chimmó, in the Author's opinion with adequate reason, to the exclusion from the Sulu Sea of the deep Polar (Antarctic) current, which lowers the temperature of the China Sea. That the uniform temperature of its deep water from 500 fathoms downwards is lower by 4° or 5° than that of the Mediterranean, notwithstanding that it is so much nearer the Equator than the temperature of its superficial stratum is considerably higher, can be easily accounted-for on the very probable supposition that there are passages between its bounding reefs and islands, which admit water of a temperature below 50° from the outside sea. In fact, we might fix the probable depth of such passages at about 250 fathoms.

The influence of a still less complete seclusion from the Polar under-flow is shown in the Celebes Sea, which has lately been found by Capt. Chimmó to have the extraordinary depth of 2667 fathoms, with a bottom-temperature of $38\frac{1}{2}^{\circ}$; whilst at nearly the same depth in the Indian Ocean a little to the west of Sumatra, the bottom-temperature was 32° . And the land-locked condition of the Gulf of Mexico seems to furnish the explanation of that extension of a high temperature to a much greater depth than in ordinary Atlantic water, which is the distinguishing attribute of the Gulf Stream; as the Author has shown in his Report of the 'Shearwater' Scientific Researches (Proceedings of the Royal Society, vol. xx. pp. 615-619).

In his Report for 1870,¹ in which year the Author's researches were confined to the Western basin of the Mediterranean, he described the fine muddy deposit which is being formed over the whole of its deeper portion; this probably consists mainly of the minuter particles brought down by the Rhone, which appear to be diffused through the entire mass of the water of the basin, and to be gravitating very slowly to the bottom—the lowest stratum of water being everywhere rendered turbid by their accumulation. Last year he found the same condition to prevail over the bottom of the Eastern basin, the sediment having been there obviously brought down, for the most part, by the Nile. This turbidity of the bottom-water appeared to him to afford a rational explanation of the *extreme scantiness of animal life* on the deep bottom of the Mediterranean,² which presented a most unexpected contrast to its abundance, even at temperatures more than 20° lower, on the deep bottom of the and heavier stratum underlying the Gulf Stream comes nearer the surface with every rise of the bottom over which it flows, I think it may fairly be presumed that the same cause is in operation here also; as it seems to be likewise in the "Lightning Channel" between the north of Scotland and the Faroe Islands.

¹ Proceedings of the Royal Society, vol. xix. pp. 199-202.

² His results on this point have been confirmed by the results of Oscar Schmidt's dredgings in the Adriatic.

Atlantic. In fact the almost azoic condition of the abyssal depths of the Mediterranean, whilst its shallower portions teem with life, shows that Edward Forbes's doctrine (based on his researches in the *Ægean*) as to the limitation of animal life to a depth of 300 fathoms, seems to be generally true of the Mediterranean, although quite inapplicable to Oceanic basins.

Whilst not abandoning the belief that the Turbidity of the bottom-water unfavourably affects its suitability as a residence for most marine animals, the Author is now disposed to attribute more influence to the other condition which he suggested in his Report for 1870 (p. 203), as likely to operate prejudicially to Animal life—namely, *the stagnation produced by the almost entire absence of vertical circulation*. In the great Oceanic system, if the doctrine previously advocated be correct, every drop of water is, in its turn, brought to the surface, and exposed to the purifying influence of prolonged exposure to Atmospheric air; whereby a large proportion of its Carbonic Acid and other products of the decomposition of Organic matter will be removed, and Oxygen will be absorbed in their place. But from this movement the water of the Mediterranean may be said to be virtually excluded. Now, as the Nile and the Rhone, to say nothing of other rivers, are constantly bringing down a very large quantity of Organic matter, the finer particles of which seem to be diffused through the whole mass of the water in the two basins, and to be slowly gravitating to their bottom, it might be anticipated that in their gradual decomposition they would generate Carbonic Acid at the expense of the Oxygen dissolved in the water; so that the abyssal water, being separated from the atmosphere by an intervening stratum of many hundred fathoms, and being never brought up to the surface, would come to be unfit for the maintenance of animal life.

Now in the *Porcupine* Expedition of 1869 it was found that the presence of a very large proportion of Carbonic acid in the bottom-water of the Ocean was not incompatible with the existence of Animal Life in great abundance. In fact, there was reason to believe that there was a general relation of conformity between the proportion of Carbonic acid and the amount of Animal life on the bottom as indicated by the dredge-results; the effect of the respiratory and other changes produced by the latter being to increase the proportion of carbonic acid at the expense of the oxygen. Thus, whilst the per-centage of Oxygen in surface-water averaged about 25 per cent., and that of Carbonic Acid averaged something less than 21 per cent., the Oxygen in bottom-water did not average above 19·5 per cent., while the Carbonic acid had increased to nearly 28, the per-centage of Nitrogen being reduced, at the same time, from 54 to 52·5. The per-centage of Carbonic acid in bottom-water often rose much higher than this, being frequently between 30 and 40, and in one instance more than 48; but the per-centage of Oxygen did not show a corresponding reduction, being never less than 16, while that of Nitrogen came down from 54 to 34·5. Thus it appeared that *so long as Oxygen was present in sufficient proportion*, the increase of Carbonic acid to nearly half the total amount of gases removable by boiling, did not exert any unfavourable influence on Animal life; from which it might be surmised that the Carbonic acid dissolved in water under great pressure is in a condition altogether different from that of *gaseous* Carbonic acid, as regards its relation to Animal respiration.¹

In the Author's second visit to the Mediterranean, in the summer of 1871, each of the samples of bottom-water taken in two deep Mediterranean soundings was boiled until no more gas came over; and the total quantity given off, which corresponded very closely with the average obtained in former Expeditions, was divided in each case into two parts, so that there were four specimens in all. The composition of these specimens agreed very closely, the per-centages being approximately (for the Author does not pretend to minute accuracy) as follows:—Oxygen, 5; Nitrogen, 35; and Carbonic acid, 60. Thus it appeared that very nearly the whole available Oxygen had been converted into Carbonic acid, so that while the proportion of Oxygen to Carbonic acid was never, in the open sea, less than *one-third*, it was here no more than *one-twelfth*,—a difference fully adequate to account for the paucity of Animal life on the deep bottom of the Mediterranean.

That this condition does not extend to those moderate depths in which the water is subjected to the disturbing action of winds, tides, and currents, may be fairly presumed; but whether it prevails through the whole stratum beneath 250 or 300

¹ It is by no means improbable that such sluggish animals as Mollusks and Echinoderms may be able to bear a much larger proportion of Carbonic acid in the water they breathe, than Fishes and Crustacea. Experimental inquiries upon this point, which might be readily carried out in connexion with any large Aquarium, would give results of great Physiological interest.

fathoms, so as to constitute the essential condition by which Animal life is limited to these depths, it would obviously be premature to assert. The Author ventures to think, however, that he has shown that the Physical conditions of any Inland sea, which, like the Mediterranean, is cut off from the general Oceanic circulation, must be such as greatly to modify its relation to Animal life; and that it is a matter of great scientific importance, especially in relation to Geological inquiry, that these conditions should be carefully inquired into.

The Red Sea would probably be found to present in many particulars a striking contrast both to the Mediterranean and to the open Ocean. Its Thermal condition, as has been already shown, is altogether peculiar; for while its surface-temperature rises as high as that of any Intertropical portion of the Ocean, that temperature seems to be maintained with very little reduction, even to its greatest depths. But the Red Sea further differs essentially from the Mediterranean, in not being the recipient of any great Rivers bringing down *detritus* from the land. This, of course, will affect the condition of the bottom, on which we should not expect to find the abundant sedimentary deposit that is everywhere settling down in the abyssal depths of the Mediterranean. It will also leave the bottom-water clear; and in this respect the condition of the bed of the Red Sea will be more favourable to Animal life than that of the Mediterranean. But the absence of Organic sediment, if the views previously adduced be correct, will constitute a still more important difference between the conditions of the two seas in relation to Animal life; for while its progressive decomposition in the abyssal water of the Mediterranean consumes its Oxygen and imparts to it Carbonic acid, at a greater rate than "diffusion" can counterbalance without any vertical circulation in the water itself, and thus tends to render the depths of that sea uninhabitable, the absence of the like source of impurity in the water of the Red Sea may be expected to leave its abyssal water in a condition fit to support a moderate amount of Animal life: since the process of diffusion, even without vertical circulation, will maintain a certain amount of interchange of gases between the superficial and the deep strata.

These views are suggested merely as fair inferences from our present very limited knowledge, to be confirmed or set aside by the result of future inquiries.

NOTICES OF MEMOIRS.

GEOLOGICAL SURVEY OF ENGLAND.

I.—EXPLANATION OF QUARTER-SHEET 98 S.E.; ILLUSTRATING THE GEOLOGY OF THE NEIGHBOURHOOD OF KIRKBY LONSDALE AND KENDAL. By W. T. AVELINE, F.G.S.; T. McK. HUGHES, M.A., F.G.S.; and R. H. TIDDEMAN, B.A., F.G.S.

THIS is a description of part of the Lake District, the greatest portion of the area being in Westmoreland, the remaining parts being in Lancashire and the West Riding of Yorkshire. The rocks described include the Lower Silurian, Coniston Limestone=Caradoc or Bala Beds; Upper Silurian, Coniston Flags and Grits, Bannisdale Slates, and Kirkby Moor Flags=Wenlock and Ludlow Rocks; the Upper Old Red Conglomerate, the Carboniferous series, and the Permian beds. The physical geography of the area is described, and Mr. Hughes points out that all the great valleys in the neighbourhood of Kirkby Lonsdale coincide with lines of fault: these he describes in some detail; he makes a few remarks also on the formation of swallow-holes. The Silurian rocks and their fossils are described by Messrs. Aveline and Hughes, chiefly by the latter. Mr. Hughes gives the account of the Old Red Conglomerate, which is regarded as the basement bed of the Carboniferous series. The Carboniferous rocks are described by Messrs. Aveline, Hughes, and Tiddeman, and the Permian rocks by Mr. Hughes.