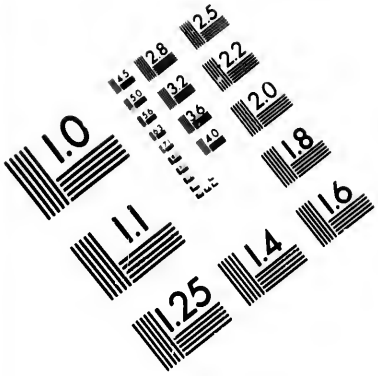

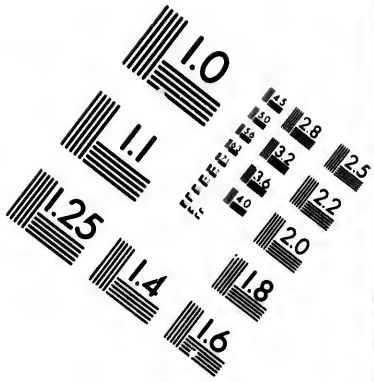

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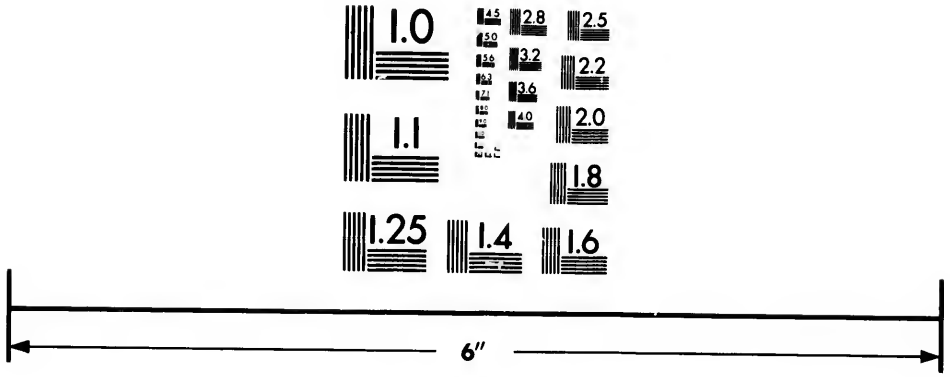

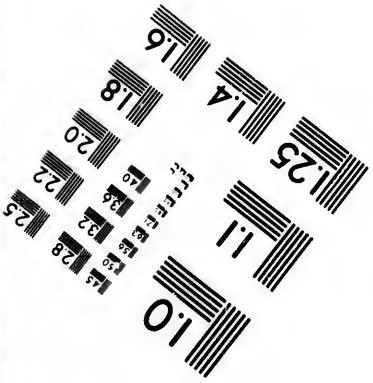

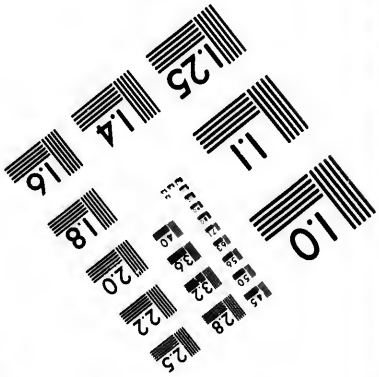

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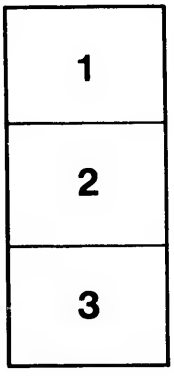

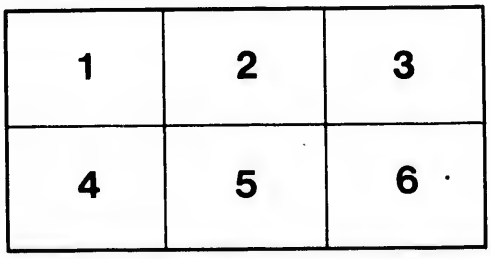

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ON

THE OBJECT

OF THE

SALT CONDITION OF THE SEA.

BY E. J. CHAPMAN,

PROFESSOR OF MINERALOGY AND GEOLOGY IN UNIVERSITY COLLEGE, TORONTO, CANADA WEST:

LATE PROFESSOR IN UNIVERSITY COLLEGE, LONDON.

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NOTE

ON THE OBJECT

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SALT CONDITION OF THE SEA.

BY PROF. CHAPMAN, UNIVERSITY COLLEGE, TORONTO.

[*Communicated to the Canadian Institute, January* 20, 1855.]

For what beneficent purpose has the great Creator of all things ordained that the sea shall be salt? To this often mooted question, no satisfactory answer has hitherto been returned. So far as I can ascertain * the following suggestions are all that have been proposed as yet in elucidation of the subject: First, that the sea is salt, in order to preserve it in a state of purity. Secondly, in order to render the water of greater density, and consequently to impart a greater buoyancy to bodies floating in it. And thirdly, in order to cause its freezing point to be lower than that of fresh water, and hence to preserve it from congelation to within a shorter distance of the poles than would otherwise be the case.

The first suggestion is scarcely tenable, because, without the intervention of other conditions, the amount of saline matter present in the sea is not sufficient to prevent the putrefaction or decomposition of organic bodies. In many salt marshes and

* See the Appendix.

on sheltered coasts, for instance, it is well known that after heavy gales, accumulations of sea-weed frequently collect to such an extent as to occasion by their decomposition the most injurious exhalations. During calms, again, on low tropical coasts, gaseous emanations arising from the decomposition of animal matter in the sea, have often been remarked. In these and other similar cases, it is to be borne in mind, however, that the decomposing matters are present in unusual quantities under the influence of peculiar or temporary causes. Under ordinary conditions, it has now been satisfactorily shewn, that organic impurities—and these only can effect the present question—diffused through a vast body of moving water, whether fresh or salt, become altogether lost, and with extreme rapidity: so much so, indeed, as apparently to have called forth a special agency to arrest the total destruction of organised matter in its final oscillation between the organic and inorganic worlds. I allude to the myriads of microscopic creatures which inhabit all waters, and whose primary function is ably surmised by Professor Owen, to be that of feeding upon, and thus restoring to the living chain, the almost unorganised matters diffused through their various zones of habitation. Not only do we find these creatures in every stagnant pool, but the sea itself teems with them in all their varied types. "The application of the microscope," says Humboldt, "increases in the most striking manner our impression of the rich luxuriance of animal life in the ocean, and reveals to the astonished senses a consciousness of the universality of life. In the oceanic depths, far exceeding the height of our loftiest mountain chains, every stratum of water is animated with polygastric sea-worms, Cyclidiæ and Ophrydinæ. The waters swarm with countless hosts of small luminiferous animalcules, Mammaria (of the order Acalephae), Crustacea, Pteridinia, and circling Nereides, which when attracted to the surface by peculiar meteorological conditions, convert every wave into a band of flashing light."* These creatures preying upon one another, and being preyed upon by

* Cosmos, vol. I.

others in their turn, the circulation of organic matter is kept up, and carried through its appointed rounds. If we do not adopt this view, we must at least look upon the animal infusoria, the foraminifera, and indeed on many other forms belonging to far higher types of organization, as scavenger agents appointed to prevent an undue accumulation of decaying matter; and in either case, so far as regards the object under discussion, the oceanic waters might have been indifferently either fresh or salt.

According to the second suggestion, the sea holds saline matter in solution, in order that its density may be increased thereby. The superior density of sea-water, as compared to fresh, undoubtedly plays an important part in many of the physical phenomena of which the ocean is the stage. A greater counterpoise is perhaps thus offered to lunar and other cosmical attractions; and the effects produced by winds and atmospheric disturbances must be modified also by this principle to no slight extent; but causes such as these, when considered even in their fullest relations, can scarcely be considered adequate to meet the entire solution of so vast and grand a problem as that which is manifestly involved in the salt condition of the sea. Neither can the third supposition, as given below, be considered of greater value in this respect, because the difference between the freezing points of fresh and sea-water is under 4° Fah.; and hence, with the present distribution of land and water, and still less probably with that of former geological epochs, no very important effects would have resulted from this cause, if the ocean had been fresh instead of salt. So far as regards the habitable portions of the world for instance, the present difference would be next to nothing. I do not mean to imply, nevertheless, that this principle may not be without some secondary bearings on the phenomenon in question; but I do not consider it sufficient for the complete elucidation of the same.

The suggestion which I have now to lay before the Institute, as an attempt to explain the object in view—although confessedly

not free from certain difficulties—will be found, I think, of a far more satisfactory character than those hitherto advanced. As already mentioned, I am not aware of any previous application of the principle which it embodies, to the solution of the present question. Without further preface, then, I may state that I regard the salt condition of the sea *as mainly intended to regulate evaporation*, and to prevent within certain limits, an undue excess of that phenomenon under the influence of any disturbing causes that might from time to time arise. It has been long known that different liquids boil at the same atmospheric pressure, under very different degrees of temperature; and that the stronger the solution of a given salt, the higher will be the temperature required to raise it to the boiling-point. In like manner, evaporation at natural temperatures, other conditions being equal, proceeds far more slowly from saturated than from weak solutions; and, necessarily, more slowly also from these latter, than from ordinary water. In sea-water we have, as a mean, about three and a half per cent. of solid matters : 2.6 of this, on an average, consisting of chloride of sodium.

In order to observe the effects produced in retarding evaporation by so small a quantity of solid matter in solution, but without attempting to imitate the complex composition of sea-water, I placed a weighed quantity of ordinary rain-water, and the same holding in solution 2.6 per cent. of Na Cl, in porcelain vessels of equal diameter; and exposed the two, side by side, to spontaneous evaporation; re-weighing them every twenty-four hours for six days. The experiment was then repeated, but with an exchange of vessels, so as to eliminate any errors that might arise from a slight difference in the diameters of the capsules employed. The results of each set of experiments were strikingly in accordance. The mean results of the two weighings, reduced to their per centage quantities, are given in the annexed table. Column A shews the evaporation loss resulting from the water. Column B, the same from the water of the salt solution; the amount of salt being deducted through-

out as a constant quantity, and its weight confirmed by evaporation and re-weighing at the close of the experiment. Column C exhibits the excess of evaporation of A over B.

Hours.	A Loss from the Rain Water.	B Loss of Water from the Salt Solution.	C Excess of loss of A over B.
24	8.83	8.29	.54
48	19.12	18.08	1.04
72	26.63	25.17	1.46
96	30.82	29.05	1.77
120	39.00	36.76	2.24
144	44.99	42.43	2.56

An excess of 0.54 per cent. in twenty-four hours, in the evaporation of fresh water over water containing 2.6 per cent. of Na Cl, may seem at first sight of little moment; but when applied to even the present surface of the ocean—a surface so exposed over wide areas to evaporation-tending influences far higher than those brought into play in the above experiments—we may easily conceive that an exeess of this kind would be of enormous magnitude. Besides which, it must be remembered that the salt solution of the above table, contained at the commencement of the experiment, one per cent. less of solid matter than that present in the waters of the sea. As the salt solution becomes more and more concentrated, the excess of evaporation of A over B necessarily becomes higher and higher, according to the law announced above.

Here then we have a self-adjusting phenomenon; one of those admirable contrivances in the balance of forces, which an attentive study of nature reveals to us in every direction. If, other conditions being the same, any temporary cause render the amount of saline matter in the sea above its normal value, evaporation goes on the more and more slowly; and, on the other hand, if this value be depreciated by the addition of fresh water in undue excess, the evaporating power is the more and

more increased; thus aiding time, in either instance, to restore the balance.

In conclusion I would observe, that the consideration of this principle may shed some further light on the geographical distribution of fresh and salt-water lakes on the present surface of the globe.

APPENDIX.

Since the publication of the above memoir, my attention has been called by Lieutenant Maury, of the United States Navy,—Superintendent of the National Observatory at Washington,—to a chapter on the "Saltness of the Sea" in his "Sailing Directions," to accompany his admirable Wind and Current Charts. In this work, Lieutenant Maury has developed a new and highly ingenious theory in relation to the salt condition of the sea. When I first opened the volume, I thought that I had been anticipated in my views, but this, as shewn by the subjoined letter, containing a general exposition of the subject, is not the case. According to Lieut. Maury's hypothesis, the sea is salt in order to *produce circulation;* according to mine, in order to *regulate evaporation.* The two, however, may not be irreconcilable. To a phenomenon indeed, of so complicated a character, more than one object is undoubtedly attached.—E. C.—April 4, 1855.

TO LIEUTENANT MAURY, LL.D.,

Superintendent of the National Observatory, Washington, &c. &c. &c.

DEAR SIR,—

I beg to return you my best thanks for your kind present of a copy of the sixth edition of the "Wind and Current Charts."

When I sent to the Canadian Institute my note "On the Object of the Salt Condition of the Sea," believe me, I was altogether unaware of your previous publications on that sub-

ject. My paper was read and discussed some weeks before it appeared in the Journal of the Institute; but no notice of your highly important work was elicited from any of our members. As it is, I shall remedy the omission, so far as it lies in my power to do so, by calling attention to your views in an additional note on the subject, to appear, if possible, in the May number of the *Journal*.

Will you allow me, however, with all due deference to one so deservedly distinguished in this branch of inquiry as yourself, to call in question the justness of some of your inferences?

If I understand the matter rightly, your hypothesis is to the following effect, viz :—That the salt condition of the sea has for its object the production of a system of circulation: this circulation being effected, first, by the surface water becoming salter (and hence heavier) by evaporation, and so, sinking downwards, and giving place to the lighter water from below; and, secondly, by the labours of coral animals, and by vital agencies generally, in removing from the water the lime and other salts.

To the correctness of the latter view, I most willingly concede, although I can scarcely look upon the cause in question, as sufficiently intense to produce the phenomena of oceanic currents, according, if I mistake not, to your suggestion at page 188 of the above mentioned work. This, however, in the present state of our knowledge, is a mere matter of opinion. The merit of the enunciation belongs entirely to you; for, although writer after writer has instanced the compensating power of the marine Mollusks and Radiata,* in withdrawing from the sea the various salts brought into it by rivers, no one appears to have hinted, even, at the further effects due to this action.

But these organic agencies are mainly referrible to the abstraction of the lime salts from the sea water: the object of the presence of the chloride of sodium—the principal saline constituent of the sea—being sought to be explained on the

* And we may add that of marine vegetation also. Dr. Lyon Playfair was, I believe, the first to suggest the action of Algæ in abstracting carbonic acid from the water, and thus setting free the carbonate of lime.—E. C.

first hypothesis,* and it is here that I venture to differ from you, and to prefer my own explanation, as published in the March number of the *Canadian Journal.*

The surface water of the sea would necessarily be rendered salter and consequently heavier than the underlying strata, were no antagonistic influences at work; but I think we have sufficient experimental evidence to shew that the effects of evaporation are counteracted by the constant additions of fresh water which the ocean receives at its surface, and by the comparatively high temperature of this latter (the surface) in those regions where evaporation is the most active. Comte d'Archiac in his compendium of the Physics of the Globe (vol. I. of his Histoire des Progrès de la Géologie) has the following observations:—"Les recherches faites sur la composition des eaux recueillies en mer pendant le voyage de la corvette *la Bonite*, ont démontré que dans l'Océan Pacifique, le Golfe du Bengale, l'Océan Indien et l'Océan Atlantique meridional, la densité generale de l'eau prise à la surface était moindre que celle de l'eau prise à une certaine profondeur. Une seule exception à cette règle a été reconnue. A une seule exception près aussi, le degré de salure est plus prononcé au fond [I

* "The vapor is taken from the surface water; the surface water thereby becomes more salt, and consequently heavier; it therefore sinks; and hence we have due to the salts of the sea, a vertical circulation, viz: a descent of heavier—because salter and cooler—water from the surface, and an ascent of water that is lighter—because it is not so salt—from the depths below." —Lieut. Maury: *Wind and Current Charts*, 6th ed., p. 182.

This view has been entertained, however, by other observers. Thus, in reference to the Mediterranean, Sir Charles Lyell, in his "Principles of Geology," has the following remarks:—"After evaporation, the surface water becomes impregnated with a slight excess of salt, and its specific gravity being thus increased, it instantly falls to the bottom, while lighter water rises to the top, &c." But here we have to consider, how far this surface water could sink without yielding a portion of its extra salt to the surrounding water, and so rendering the whole uniform. I question altogether the probability of a vertical descent of this kind taking place in ordinary seas, at least, to any depth. Over broad areas, moreover, it would necessarily be subject to frequent and long-continued interruptions.—E. C.

suppose he means at considerable depths, not absolutely at the bottom] qu'à la surface.* This view is in accordance, I believe, with the usually received opinion.† From all that I have read and thought upon the subject, it appears to me, that in the phenomenon of the, so to say, reversed inequalities of temperature between the surface and deep waters in the inter-tropical and polar regions, we have the main cause of oceanic movements. With all this, however, I do not mean to infer that the principle announced by you, is to be wholly disregarded in our attempts to frame a satisfactory hypothesis respecting the object of the saltness of the sea. In striving to uphold my own theory, I have done so perhaps in too exclusive a spirit.

With regard to the origin of the saline components of sea-water, you adopt, I perceive, the views of the elder Darwin, and others, to the effect that these components have been entirely despoiled from the land, by springs and rivers, and so carried into the deep, the action continually going on. But here, again, you must allow me to differ from you. My reasons for this dissent, are the following:—First, the striking preponderance of chloride of sodium over the other salts in the sea-water; whereas, amongst the saline matters generally present in river-water, it by no means occupies a very conspicuous place. But even if the sea were fed by brine-springs instead of rivers, my argument would still hold good; for in nine cases certainly out of every ten, these brine-springs would be but returning to the ocean, what, in former geological epochs,

* "The results of the chemical examination of samples of sea-water collected during the voyage of the corvette *la Bonite*, have shewn, that, in the Pacific Ocean, the Gulf of Bengal, the Indian Ocean, and the South Atlantic, the general density of water taken from the surface was *less* than that taken from a certain depth. Only a single exception to this law was noticed. With little more than a single exception also, the degree of saltness was greater at great depths than at the surface." See also *Comp. rend.* vol. vi. p. 616, from which the above is quoted.—E. C.

† Theoretically, the surface water, owing to evaporation, should be slightly cooler than the stratum of water immediately below it. I allude, of course, to warm and temperate seas.—E. C.

the ocean had rendered to the land. Fownes's assertion, quoted in your note at page 179,* appears to me to be altogether untenable, or at least without true bearings on the point at issue. Lakes, so peculiarly-conditioned as those of which he speaks, have evidently not been rendered salt (in the common acceptation of the term) by the rivers which flow into them, but have been salt from the beginning—as portions of ancient seas cut off from the main ocean by geological changes. Secondly, according to this view, the sea must at one time have been far less salt than at present, and have gradually become salter and salter; an inference, the assumption of which is scarcely warranted on palæontological data.† This objection might be met, however, by assuming that marine life was created, as a compensating agent, so soon as the sea attained to its

* "The case of the sea," says Fownes, "is what occurs in every lake into which rivers flow, but from which there is no outlet except by evaporation. Such a lake is invariably a salt lake. It is impossible that it can be otherwise; and it is curious to observe that this condition disappears when an artificial outlet is produced for the waters."—Lieut. Maury.

To this, I reply, that, owing to the comparatively small amount of chloride of sodium in ordinary river-waters, a lake of this kind, if originally fresh, would become silted up by deposition of carbonate of lime, &c., long before it could possibly exhibit the composition of the ocean. An originally salt lake would necessarily become fresh in course of time, if river-waters were constantly poured into it, and an outlet also provided by lower levels to the sea. If we place at three different levels, an empty vessel, a vessel containing a salt solution, and one filled with ordinary water, this latter occupying the highest level, and connect the three by strips of filtering paper or a few cotton threads to act as siphons, the contents of the middle vessel (here representing the salt lake) will be gradually replaced by the water from above, and transferred to the under vessel. Where no outlet is provided, local conditions, on the other hand, as in the case of the Dead Sea, may modify to a marked extent the original composition of the water.—E. C.

† I am quite aware that the study of Fossil Ichthyology offers some slight support to the view mentioned in the text; but this, at the best of doubtful acceptation, is, on the other hand, completely outbalanced, if we take into consideration the immense numbers of radiated animals, brachiopods, cephalopods, and other types, which preceded fish-life, and which were undoubtedly marine.—E. C.

present saltness, and not before. I place, therefore, no great stress upon it.

Finally, may we not legitimately seek to ascertain, why chloride of sodium should have been chosen by Divine Wisdom, in preference to other salts, as the chief constituent of the solid matter of the sea. Apart from its manifold economic applications, I feel assured that some abstract principle is involved in its selection. I have been trying to devise some experiments to elucidate this, but hitherto, without success. May not, however, the primary cause of its selection, lie in the extremely slight variation which it exhibits in regard to its solubility in water of very different temperatures?

Trusting that you will look upon these observations, as they are meant, in the light of a friendly interchange of opinion,

I am, dear Sir,

Most truly yours,

EDWARD J. CHAPMAN.

University College,
Toronto, Canada West, April 3, 1855.

ADDITIONAL NOTE.

Since the above was in type, I have obtained, somewhat accidentally, a sight of the English edition of Gustav Bischof's Chemical Geology, published by the Cavendish Society of London. From this able work, which differs very materially, as stated by its author, from the original German edition, I have extracted the following remarks in further illustration of my subject. With regard to the origin of the saline ingredients of sea-water, it will be seen, that Professor Bischof's opinion coincides entirely with my observations as expressed at page 12; and although partly agreeing, in reference to vertical circulation, with Lieutenant Maury, his views are still, in the main, even here, essentially in accord with mine.—E. C., April 17, 1855.

I.

Origin of the saline constituents of the Sea.

"The origin of the large amount of saline ingredients contained in sea-water, has long been an object of attention. More than a century ago, Halley (Philos. Transact. No. 344) endeavoured to shew that it is due to the water which the sea receives from rivers being always more or less impregnated with salts, while in that which it loses by evaporation there are none of these present. In the German edition of my 'Geology' I also adopted this view. At that time only two analyses of river water existed; there was consequently no sufficient data from which the amount of salts which are conveyed into the sea by rivers could be estimated. Misled by the large amount of chloride of sodium contained in mineral springs, I over estimated the proportion in which it exists in rivers. Sulphates are carried into the sea in much greater quantities than chlorides.

"From the salts contained in stratified formations we cannot derive any explanation as to the salts contained in the water of the sea, inasmuch as the former have merely been deposited from the sea.

"Throughout the whole sedimentary period, from the transition rocks to the tertiary formations, rock-salt has been deposited, though not certainly everywhere. Since it can only be supposed that such deposition took place from the sea, immense quantities of salt must have been withdrawn from it in this way.

"From beds consisting of pure rock-salt, very little is carried back to the sea by rivers. The chloride of sodium which is conveyed to the sea, can therefore only be derived from that which is contained in small quantities in rocks, and which is dissolved out by the water percolating through them. It is impossible, however, that this can be an equivalent for the important beds of rock-salt which have separated from the sea throughout the whole sedimentary period. During this period, therefore, the quantity of chloride of sodium in the sea cannot have increased, but must have decreased, in the same proportion as its deposition in the form of rock salt, inaccessible to the percolating water, exceeds the quantity derived from crystalline rocks.

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"From the foregoing considerations it follows that the solid constituents of sea-water have, since the Creation, undergone a constant circulation, which still continues and always will continue. We can, however, come to no other conclusion than that the fixed constituents, which are at present held in sea-water, were always present, although perhaps in different proportions."—*Dr. Gustav Bischof.*

II.

"By evaporation the water at the surface of a sea must become concentrated. Were a sea a column of water in a state of rest, it would present a progressive increase of its saline constituents from the surface downwards.

So far downwards, however, as the movements of the waves extend, the particles of water are mingled together; thus far, therefore, the proportion of saline constituents is equal. If, however, that should be increased ever so little, in consequence of evaporation, the water which has become specifically heavier, will sink beneath the specifically lighter water of the tranquil sea. This is sufficient to explain the greater proportion of saline constituents in the lower strata of the waters of the Mediterranean.

"This phenomenon is, however, intimately connected with the circumstance, that the sea in question receives less water through the medium of rivers and rain than it loses by evaporation. * * * In the ocean the relations are different. If the particles of water at its surface become concentrated and sink, such water, rich in saline constituents, must still, by means of currents, be constantly mingling with water containing a small quantity of them, and, in this way, cannot collect in any one place. Moreover, the ocean, taken in its whole extent, is always receiving as much water from rivers, as well as by means of rain and snow, as it loses by evaporation. Only in inland seas, or at least in such as merely communicate with the ocean by narrow channels, and which, therefore, take no part in the great currents affecting the latter, can an increase in the saline constituents in proportion to the depth take place, in consequence of the causes above-mentioned.

"By the continuance of evaporation in the Mediterranean, Lyell remarks, additional supplies of brine are annually carried to deep repositories, until the lower strata of water are fully saturated, and precipitation of continuous masses of pure rock-salt, extending perhaps for hundreds of miles in length, might eventually take place. In reference to this, it must be observed, that even if by evaporation the surface water should become quite saturated with salt, this saturated fluid cannot reach the deeper parts, quite unmixed with water poorer in salt. Even if no wave motion took place, such an intermixing would still result, and more so if the sea be in violent agitation. At present, therefore, certainly no rock salt is deposited on the bottom of the Mediterranean, nor does this seem to be Lyell's opinion."—*Dr. Gustav Bischof.*

*** It is due to Lieutenant Maury, to state, that in a letter received from him at this last moment (April 20th), he mentions the abandonment of his views respecting the origin of the salt in sea water, some time after the publication of the last edition of his work.—*E. C.*