SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

THE LAW OF DEPOSIT OF THE FLOOD TIDE:

ITS DYNAMICAL ACTION AND OFFICE.

BY

CHARLES HENRY DAVIS, A.M., A.A.S. M.A.P.S.

LIEUTENANT U. S. NAVY.

ACCEPTED FOR PUBLICATION

BY THE SMITHSONIAN INSTITUTION,

DECEMBER, 1851.

COMMISSION

TO WHICH THIS PAPER HAS BEEN REFERRED.

PROF. L. AGASSIZ.
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In a "Memoir upon the Geological Action of the Tidal and other Currents of the Ocean," published in the fourth volume (New Series) of the Memoirs of the American Academy of Arts and Sciences, I endeavored to trace a permanent and intelligible connection between the currents of the sea and the alluvial deposits on its borders, and in its depths; to show in what manner the structure, position, and amount of these deposits depended on this connection; and, finally, to assign to it the character of a law, subordinate to the higher law of universal gravitation, which had, by a consistent and uniform operation, combined with other laws to give to the great masses of land, called continents, their actual form and body.

The views contained in this Memoir were founded upon observation. An examination of the various parts of the alluvial coast of the United States, through a series of years, had led to the discovery that the shape, extent, and distribution, of the loose material of which they are composed,—quartzose sand,—were chiefly determined by the action of the tides. It was seen that the same forms of deposit were constantly repeated under similar circumstances; and the conclusion was therefore drawn, that the forms and circumstances were mutually dependent.

This being the case, we are enabled to explain the character of the present formations on alluvial coasts; to account for their peculiar shape, and their comparative size; to understand the law of their accumulation, or growth, and to foresee the future results of certain combinations of circumstances, by a study of similar instances elsewhere.

One of the first steps in the Memoir referred to, was to specify the different kinds of deposit that are found below and above the surface of the sea. They were classified under the name of shoals, hooks, bay deposits, bars, beaches, &c.; and their characteristic features being described, the precise and distinct mode of operation of the current, by means of which these features were decided, was stated and illustrated by numerous examples.

The next inquiry was concerning the geographical distribution of these alluvial deposits in all parts of the world. The cases of ocean deposits hitherto adduced, were those of the American shores, and principally of the shores of New England. They were accessible; they exhibited in minute detail all the different results of constructive action, and had been maturely examined and collated. They furnished also the examples for illustration, as they had first suggested the principles to be elucidated. But leaving these districts, the generalization of the views presented, was extended so as to become applicable to the sandy coast of the United States, from Florida to Maine, regarded as a whole; to the gigantic subaqueous accumulations to the North and East, as George's Bank, Newfoundland Bank, &c., to the Bay of Campeachy, and the shores of the Gulf of Mexico on the West and the North, to the belt of sand on the west coast of Peru, which on the North terminates in the Desert of Pachira; and passing from America to Europe, to that most interesting of all similar formations, the countries of the Netherlands, which owe their national peculiarities to the character of their territory, to the sandy region on the southern border of Norway; and, finally, to the well-known Landes of France.

In that part of the investigation which relates to our own coast, and which comprised the introduction of the elementary principles of this theory, the tidal currents referred to owed their origin to purely local causes, and were restricted to limited areas. But in the section devoted to the subject of "Geographical Distribution," the general course of the tidal wave, and the points of divergence and convergence were treated; currents, the influence of which was felt through large spaces, were considered; peculiar systems of waves, the resulting motions of the water occasioned by the conflict and mutual interference of waves approaching each other in different directions, as in the English Channel, and round the Island of Great Britain in the North Sea, or round Ireland in St. George's Channel and the Irish Sea, were mentioned; and lastly, two conspicuous examples were brought forward of the similar action of permanent ocean currents, where they impinged with one continuous direction on a long line of coast on the sea border of Peru, and on the shores of the Gulf of Mexico.

The concluding section of this Memoir was reserved for an inquiry into the geological action of the tides in the past ages of the earth's history. The instances were taken from the tertiary and subsequent periods; and in the cases cited there was no difficulty in determining how the transmission of the tide wave, and consequently the character of the currents during the accumulation of the aqueous deposits in question, had been affected and controlled by the earlier formations.

The geographical distribution of the Dune, or alluvial Flora, on the shores of the United States, and of Nova Scotia, was employed, at the suggestion of Professor A. Gray, of Harvard University, to throw additional light upon this theory; a striking and instructive resemblance was noticed between the bottoms of our principal bays in their present state, and the formation and condition of the valleys in the Swiss Canton Soleure, as described by M. Gressly; and, by means of a somewhat minute description of Nantucket Shoals, and the intervening channels, with their inhabitants, it was attempted to show that, throughout all periods of geology, one of the grand results of the operation of the tidal laws had been to prepare the place suitable to marine animal life.

The preceding is a very brief and general sketch of the theory and its applications, contained in the Memoir mentioned at the beginning of this paper. It is introduced here to give interest to what follows, and to exhibit its connection.

In the section relating to geographical distribution, it was laid down as a fundamental principle, that the deposits on the *ocean border* are only made by the current of the *flood tide*. It was added, by way of explanation, that, "in the *sounds* and *bays*, the *ebb* tide may also leave its burden; since, in its retreat, it may not only meet with obstructions, but must press upon the land, in some parts, precisely as the advancing flood does upon the exterior coast. In a group like the Nantucket Shoals, the ebb, carrying with it the sand that has been loosened on the shore, and, being hindered in its course by the inequalities of the bottom, must also contribute to build up the deposits. These cases are not alleged as exceptions to a law, but are stated as modifications merely, through which the action of the ebb is brought to resemble that of the flood. In general, as the deposit of the flood is made on the shore in the direction of its progress, so the deposit of the ebb is buried in the bosom of the ocean. The former furnishes the material for the alluvial deposit above water; the latter supplies the substances found in the depths of the sea.

"It is not meant to say by this, that the action of the flood and ebb tides is reciprocal. On the contrary, the mode of operation of the flood is essentially accumulative. Its tendency, also, is continually to carry onward the deposit, in the course of its current, so that it performs the double office of increasing the collection at every successive tide, and of advancing from place to place the matter at its disposal." This process, and the law by which it is produced, were proved by the manner in which the materials of wrecks are conveyed along the shore, and the direction (always that of the flood) in which the various forms of deposit are increased. Many well-authenticated instances of the transportation of wrecked matter were adduced.

Since writing that Memoir, I have endeavored to add to the number of these facts and instances, and to extend the inquiries to other parts of the coast of the United States. It is difficult, if not impossible, to make these inquiries through another person, with a perfectly intelligible and satisfactory result. It is safe to rely upon such information only as is collected in personal communication with the wreck-masters themselves. It has not, therefore, been possible to add many facts to those already collected. The following statements, which are well attested, appear to be satisfactory, and to accord with the general law as it has been stated.

I learned from Mr. Joseph H. Skillman, Inspector of the Port, at Greenport, Long Island, that in the month of October, in the year 1842, the whale ship *Plato*, of New Bedford, was wrecked on Neapeaque beach, on the south side of Long Island, and was sold to the wreck-masters. He took part in the purchase. After removing the oil, the upper frame separated from the lower timbers, and drifted to the westward. The wreck-masters built a house on the beach, in which they lived two weeks, employed in rescuing the cargo and materials of the vessel. During this time bricks (spare ones for the "try-works") and wood drifted to the westward, and were collected on the beach in that direction only. Nothing was carried to the eastward. The top frame that had separated was heavy, water-logged, and weighed down with iron fastenings, it floated deep; and, at the time of its drifting to the westward, the wind was blowing from the west. The bricks and firewood constantly advanced in a westerly direction. During three of the fourteen days, passed by the wreckers on the beach, the wind was from the north-west, and one day very strong; at no time did it blow from the east. Before the top timbers broke off, the decks were burnt out to lighten the hull, and get out the copper fastenings; after this was done, the lightened hull began to work to the westward, so that it was necessary to secure it by ropes made fast to stakes driven into the sand.

Mr. Hiram Bishop, a highly reputable ship-carpenter, at Greenport, formerly a resident on the Atlantic side, informed me that the British sloop-of-war *Sylph* was lost on the south side of Long Island, near Southampton, in the winter of 1814–15. The materials of this wreck also were taken up to the westward, some of them beyond Fire Island beach, during the three weeks following her destruction. And, curious to relate, her rudder was found, seven years afterwards, twenty miles to the westward of the place of her loss; it was known by its size, and the king's arrow on the copper. Mr. Bishop also added that the French brig *Le Bon Père de Marseilles*, went to pieces about the year 1838, on the south side of Long Island, opposite Moriches, Brookhaven; that most of her cargo came up near where she struck, but that one piece of her top hamper went one mile and a half to the west.

The above cases are sustained by such reliable testimony, that it seems worth while to preserve them; it is only requisite to add, that the current of the flood tide, on that part of the Long Island shore referred to, runs to the westward.

Proofs of the principle in question, derived from the form and mode of increase of certain deposits were introduced into the Memoir. They were of so decisive a character, that it would be superfluous to multiply them. But there is one statement, made on the authority of Lieutenant-commanding J. N. Maffitt, Hydrographical Assistant in the coast survey of the United States, which is too important to be omitted. Cape Hatteras is a point of divergence of the tide wave; or, in other words, a split of the tides takes place there; in consequence of which, the advancing flood that supplies the harbor of Charleston flows along the coast from the north to the south. Lieutenant Maffitt says that the water, while it runs *flood*, is loaded with sand; but that, when it runs *ebb*, it contains little or none of this matter.

Thus the law of deposit of the flood tide has been already distinctly enunciated, and the facts and observations, by means of which it was inductively inferred, have been fully offered.

The object of the present paper is to search into the mechanical operation of this law, and the uses that it may be thought to have served in the general economy of the globe; to investigate its mode of action, and to assign to it, if admissible, a place among the subordinate fundamental laws that direct the distribution of the loose materials of the earth's crust.

And first, as to how it acts. The law of deposit of the flood tide exhibits itself in the gradual transportation of the matter held in suspension by the water from place to place, along the line of its direction, and in the gradual accumulation of this matter at its terminus, which terminus is the limit of progress, or transmission, of the tide in one course, created by the land or by conflicting streams of the tide, from opposite directions. The mode of immediate supply of the material has been treated elsewhere. It is sufficient to say here that it exists. If the rise of the tide, and its progress from one point to another distant point upon a line of coast, be followed, it will be observed that the water begins to move forwards first at the lower point A, towards B, ascending in height upon the shore, and that this progress and ascent continue during the state of flood. Now if a floating body, a piece of wood for example, be thrown into the water at the first point, but at a distance from the shore, the action of the flood will tend to make it approach the shore, carrying it forwards at the same time in the direction of its course. It will finally reach the shore, upon which it will rise with the surface of the water, and there it will ultimately be left. When the flood tide changes to ebb, and runs in the opposite direction from B to A, preserving apparently an opposite course, and seeming to adhere not less closely to the shore, this piece of wood will not be disturbed, but will remain in the place at which it was left by the flood tide; and if the flood of the next day should rise higher upon the shore than its predecessor, the piece of wood will be lifted still farther up, and again left. And if the floating object should be immersed, so that a part of it will be under the surface, or should be suspended under the water by means of a float, the result will be the same.

And again, if a strong wind should arise from such a quarter as to cause a heavy sea upon the beach, to create a surf, the floating body will be thrown up still farther on the shore; if it be light, to the farthest line to which the surf reaches; if heavy, not so far, perhaps, but that the inner edge of the waves may still break over it. These are the general facts, of which I will directly cite some examples that have fallen under the notice of the most casual observer.

And to these may be added one other, that is, if during the ebb tide a floating object be placed upon the water, outside of the line at which the sea breaks, it will be taken off, but if inside the breakers, it will be cast upon the shore, and there left.

From these facts it appears that there is a mechanical action by means of which the water, when in contact with the shore, ejects the substances either floating upon its surface, or held by it in suspension, and that the effect of the flood current is to transport these substances and place them within the reach of this action, and that of the ebb is to transport these substances beyond the reach of this action. That is to say, what is called the law of deposit of the flood tide may be divided into two distinct phenomena; one of which is the transporting power of the flood current towards, and on to, the shore, the other the dynamical action of the water at the shore.

Concerning the first of these, the transporting power of the flood current towards the shore, which acts equally upon objects on, and below the surface, it is important to bear in mind the service it performs in bringing all suspended matter within reach of the latter power, particularly on an alluvial coast where, in consequence of the destructive agency of storms, great quantities of sand, &c., are continually placed at its disposal. It will be observed that I make here an entire distinction between tidal waves and tidal currents. What the effect, or *modus operandi,* of the oceanic tidal wave might be, if it were permitted to approach a coast without interruption or interference, until it actually impinged upon the continent, will appear hereafter. This, however, is a case not found in nature. Owing to the rapid decrease of depth near the land, and to the broken and indented forms of coasts, the water, the surface of which is raised by the transmitted wave, accumulates, and overflows in every direction, giving rise to currents which, more or less rapid, constitute one of the general features and characteristic conditions of the tides. These currents, though generally appearing to run along the land on the external sea border, do actually press in towards the shore. When running round sharply-turning headlands, they may be deflected for a moment; but the inward pressure from the sea soon carries them back to the coast. In like manner, the ebb tide falls off *from* the shore.

This inward tendency of the flood tide carries all floating objects, or matter held in suspension, either into the harbors, bays, and other recesses of the coast, or upon the outer sea-coast, where it comes under the influence of the wave action. In the first case, the water comes to a state of repose in the interior of the bay, which is very favorable to deposit. But it is the second case which we are to consider, and with regard to which this general statement is correct. It is, if I may so say, the prevailing law or result.

Now, having brought the suspended matter within the reach of the wave action, we are to investigate the nature of that action, by means of which this matter is cast upon the shore, and forced to remain there. To ascertain this, I have had recourse to the experiments of John Scott Russell, Esq., detailed in his Report on Waves, in the proceedings of the British Association for 1844.

In order to discover the motion of water particles during wave transmission, Mr. Russell made an experiment, or series of experiments, which exactly resemble the case we are considering. He studied the motion of small particles visible in the water, of the same or nearly the same specific gravity as water; and of small globules of wax connected by very slender stems, so as to float at required depths. (P. 340.) "The motions of these were observed from above on a minutely divided surface on the bottom of the channel, and from the side through glass windows, themselves accurately graduated, the side of the channel opposite to the window being covered with lines precisely equal to those on the window, and similarly situated." He calls the visible motion of the wave form, along the surface, the *motion of transmission*, the actual motion of the particles themselves, the *motion of translation*.[1]

The wave form is caused by the successive displacement of given masses of water, by a mass preceding them, which has been set in motion by some active force. The moving mass presses upon that before it dislodges it, and occupies its place. "The water particles crowd upon one another in the act of going out of their old places into the new; the crowd forms a temporary heap, visible upon the surface of the fluid; and, as each successive mass is displacing its successor, there is always one such heap, and this heap travels apparently along the channel at that point where the process of displacement is going on; and, although there may be only one crowd, yet it consists successively of always another and another set of migrating particles. The *visible moving heap of crowding particles is the true wave*." (P. 314.)

"Let us select from the crowd of water particles an individual particle, and watch its behavior during its migration. The progressive agitation first reaches it while in a state of perfect repose; the crowd behind it pushes it forward, and new particles take its place. One particle is urged forward on that before it, and being still urged on from behind, by the crowd still swelling and increasing, it is raised

[1] An apparatus similar to that described by Mr. Russell has been constructed for the purpose of repeating his experiments on waves of the first order.

out of its place and carried forward with the velocity of the surrounding particles; it is urged still on, until the particles which have displaced it have made room for themselves behind it, and then the power diminishes." It finally settles down quietly in its new place. This is the *motion of migration of an individual particle* of water. (P. 315.)

This is the migratory motion, or *motion of translation* of the water particles in the wave of the first order of Mr. Russell's classification; and I shall aim to show, directly, that this is the only wave action to be considered, the only one the process of which applies to the present investigation.

This motion of the water particle is resolved into two components, a vertical motion and a longitudinal motion. "First, the particles begin to rise, scarcely advancing; they next advance as well as rise; they cease to rise but continue advancing; they are retarded and come to rest, descending to their original level." (P. 342.) This is the course of the water particle, as observed by Mr. Russell, by means, as I said before, of visible particles suspended in the water, a mode of investigation precisely analogous to the case of nature, where matter held in suspension, as sand, is transported by the moving water, and brought under the influence of the wave action. "The wave is thus a receptacle of moving power," (p. 347,) "a vehicle for the transmission of mechanical force." (P. 361.) During the translation of the particle, the greatest height accompanied by the progressive motion is at the top of the wave, or in the middle, corresponding to the greatest height, or crest, of the wave. Now when, in travelling along a gradually shoaling channel, approaching a sloping coast, the depth of the water diminishes to an equality with the height of the wave, the wave breaks, or falls to pieces, "the particles in the ridge of the wave pass forward out of it, fall over, and the wave becomes a surge or broken foam, a disintegrated heap of particles, having lost all continuity." (P. 352.) The velocity with which the particles pass forward out of the wave, or are trajected, in other words the velocity of translation, is in proportion to the height of the wave. The mechanical power exerted is, therefore, in proportion to the height of the wave. This is so apparent to every one who has watched the surf, in different stages of violence, that it is hardly worth while to state it.

The wave I have described here is the positive wave of the first order; that is, the wave which makes its appearance in a form wholly raised above the general level of the fluid. And it is this form of wave that is to be seen at all times breaking upon an alluvial coast, and there only; it is the final wave which, inside of, and beyond, all others, comes into actual contact with the beach, and defines the inner limit of the water. This form of wave follows upon the destruction of the waves of the sea, as they break upon the shore, as may be observed at any time on the sea-shore, and to the greatest advantage upon the long, gently sloping, and shallow beaches. "One of the common *sea waves* approaches the shore, consisting of a negative or hollow part, and of a positive part raised above the level." As the water becomes more shallow the positive part increases in height, this increase goes on with the diminution of depth, until at length the wave breaks, and its crest falls forward into the hollow in front. (P. 373.) But it does not cease to travel, though it takes a new form. The water inside of the breaker presents the appearance of a plane, more or less inclined, the surface of which is broken by small raised waves, without any companion hollows, that is, waves of the first order, which are everywhere breaking, and everywhere, therefore, exerting the projectile force, by virtue of which any matter held in suspension is thrown out and forward, while any substances upon which they impinge receive a shock that tends to force them still farther up on the beach.[1]

There are two or three characteristic features of the sea-beaches, which exemplify this action, and which fall under the most cursory observation. I referred to them in the beginning. One is sea-weed, the others shingles, or stones and wrecks. Every one must have noticed how the light sea-weed, which is easily moved, shows by an exact and well-defined line the limit of height of the water at the preceding flood tide. Indeed, there will be several such lines seen on most beaches where the weed is abundant, each one corresponding to different heights, and these lines vary from time to time. The heavier material, however, of the stones and wrecks, is found farther up on the beach, and shows the extent to which the mechanical action of the water has reached in great storms. They are only moved by the violent impulses belonging to the action of waves generated by violent tempests.

Such then I conceive to be the mode of mechanical action, by which the law of deposit of the flood tide operates. The inward tendency of the wave action on the shore, ejects, or repels, as it were, the matters brought under its influence, and the transporting power of the flood current bears them from place to place, bringing them finally under this influence. And further, as the mechanical force of the flood current gives to the breaking wave an inclination in the direction of its course, the projected particle will not strike the beach perpendicularly to its length, but obliquely, so that it will advance, as it rises on the shore; and in this manner, also, the combined action of the two forces leads to the accumulation of deposits in the direction of the flood tide.

Herein is contained an explanation of the connection between the manner in which waves approach sea-beaches, and the local direction of the flood current; which was recorded in the Memoir, p. 140. And lastly, the action of the great oceanic tide wave, if, as was before observed, it approached a sea-coast without interruption, would be similar; that being regarded by Mr. Russell as a wave of the first order.

If this mode of deposit of the flood tide be regarded as a fundamental and permanent law, and it would seem to be so, then it becomes of interest to inquire into its design, and into the results it has effected in the long lapse of time, the *secula seculorum*, during which our earth has been undergoing modification and transformation. And in order to do this briefly, I will select for an example a period in

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[1] This change from the sea wave, or wave of the second order, to the wave of the first order, in the course of which the motion of oscillation of the water particle is transformed into a motion of translation, may be compared to Mr. Russell's case of "Genesis by a column of fluid," acting, to use his language, as a "mechanical prime mover," by means of which that wave is generated which exhibits throughout its action, the "transmission of mechanical force."

the world's history which was most fruitful in producing the present form, and filling up, of our globe, the most active, so to speak, in preparing it for its most perfect development of life; and will apply to it some of the views which readily suggest themselves.

It may be premised, however, that the same views might also be applied to earlier periods of geology. During the first period of organic life, the indications are, I believe, that there were numerous and widely extended seas of little depth, and long shallow beaches, over which the wave of translation would have had free play. But whatever may have been the temporary prevalence of the laws of aqueous deposit during any particular period, as the old red sandstone, or the cretaceous, it is certain that the present *form* of the earth's crust is due to other causes, to mighty revolutions "which elevated entire mountain districts and depressed others." (Agassiz, *Edin. New Phil. Journ.*, No. 35, 1843, p. 4.) A period which produced faults, dislocations, and protrusions, that remain the lasting evidences of the violence that reigned at that epoch.

But the period to which the views that have occurred to me seem particularly to apply, is that subsequent to the tertiary, and preceding the drift, which is supposed to have supplied, or must have supplied the drift material, and over which, on several accounts, the tides and currents of the ocean must have exercised a great and permanent influence. A greater influence than now; because, the matter subjected to their action was much more abundant, and the field over which it was exerted was much more extensive, owing to the greater portions of the European and American continents being under the sea. The epoch of the retreat of the glacial period, as it is called by Agassiz, is the one referred to. The movement of the masses of loaded ice, and the numerous floods formed from the melting ice and snow, both carried with them that immense quantity of diluvium and sand, the detritus of older periods, either made by the ice, and the atmospheric changes accompanying it, or collected by the flood from older degradations, which form the superficial covering of the earth over all its vast plains and slopes. A large portion of this material was carried to the sea; a portion of it was dropped in the progress thither. That which has come in contact with the water, and has been subject to its action, is distinguished by stratification. It is worthy of remark here, that these two characters of the materials, the stratified and unstratified, are found in close connection with each other, owing to the different changes in the level of the sea. Mr. Agassiz has pointed out an interesting example of this in Cambridge, Massachusetts, near Mount Auburn, in the valley of the Charles River, where there is a superficial deposit of stratified sand, overlying the unstratified drift. Every excavation in similarly constituted regions, and the constant recurrence of the valley formations, particularly on the eastern slope of this continent, taken in connection with the materials with which these valleys are filled up, abundantly show that the surface deposit has been carried down to the sea in and by aqueous forces operating on the surface of the elevated lands. At the period referred to, these forces were most active; the streams, as appears from the examination of their ancient beds, were great and impetuous; the amount of material transported was immense. If, when this material was brought down to the sea border, and subjected to the power of the waves and currents of the sea, either by floods or by the subsidence of the land, it had been removed by their action, and distributed over the great depths of the ocean, the form and size of the continents would have been very different from the present. It would have been lost in space, instead of serving, as it does now, to fill up the cavities between the olden strata, to level off plains, and to create the comparatively uniform platform which is the actual stage of human existence.

To prevent this waste and diffusion, and to secure the actually existing state of things, we may conceive to be the office of the law of deposit of the flood tide.

By virtue of this law, which, as I have said before, may be resolved into two modes of action, one the transporting power of the flood, the other the mechanical force of the wave of translation; the sedimentary matter, especially of the coarse sort, is repelled by the sea, returned again to the base of the mountains from which it was originally taken, and distributed with something like equality over the vast spaces that divide them. And the admitted state of gradual elevation of the continents must have been particularly favorable to the operation of this law, on account of the long, shallow, and sloping basins and beaches which it created.

And this view finds some confirmation in the character of the sea bottom. Wherever soundings of great depth have been obtained, the bottom has been found to be of the finest mud, such as, when dry, becomes almost an impalpable powder. And this is the lighter sedimentary matter, which, approaching somewhat to the specific gravity of water, is removed by the river currents penetrating far into the sea, and subsides in the ocean beyond the influence of the tidal currents; the latter being most rapid and most influential nearer the coast. But at a limited distance from the shore, along the sea border of the Atlantic States, and to a limited depth, the bottom is sand, the sand of the beaches. Here, then, is exhibited the outer terminus of this aggregation of the coarser matter around the nuclei of its origin, the skeletons, of which it constitutes, as it were, the flesh and muscles. It has for this purpose been sifted out by the water.

In this paper, reference has been made to the probable effects of the atmospheric fluctuations, which there is every reason to suppose must have been much more violent and very different from those of our time. But it readily suggests itself, that these must have exerted great influence in producing the present state of things, as far as it has been brought about by oceanic forces, (through their control of these forces,) when we consider that the great waves of the sea, which are waves of the second order, after breaking upon a shore, are changed into waves of the first order, in which the particles have the motion of translation, or the projectile force, and that this form of wave continues to the very edge of the water, and ends its life on the dry land, its mechanical force being in proportion to its height.

The effect of general oceanic currents having one constant direction, would be the same as that of the flood current, both in the power of conveying matter, and in that of modifying the manner in which the waves break on the shore, where, of course, this current came in contact with the land.

And finally it will be observed again, that although I have selected the latest period of great organic change, and the one that has been the most fruitful in the creation and supply of loose materials, suited to conform to the aqueous action, as it has been described for the illustration of these views, yet there seems to be no reason to doubt that this law, which operates so actively and beneficially now, was equally efficient in earlier periods of the earth's changes.

The earlier deposits are those of the sea in its depths, and along its shores, and (as it has been said) " our examination of the structure of the existing land is nothing more than the examination of the successive deposits in the ancient ocean, varied by the effects of subterranean movements." (Phillips.)

But these views of the aqueous forces, and their action, assume a special interest from the beginning of the tertiary period, on account of the marked geographical relation of the marine tertiary strata to the present basins and arms of the ocean, and the analogy of the tertiary sediments to the daily production of the existing seas and rivers. The distinct separation of the tertiary from the cretaceous deposits, the difference of the organic remains constituting distinct groups of life, and the similarity or identity of the organic remains of that period, to those of the existing races in the sea and on the land, together with the reasons before mentioned, have led to the opinion that the tertiary commences a new condition of the globe, intimately related to the present state. (Phillips.)

And another reason for this opinion may be added to the above, which seems to me to possess hardly inferior weight; and that is, the general conformity of the tidal motions, both wave and current motions, of the tertiary period to those now existing, and the adaptation of those motions, under the laws of action as here understood, to produce those results which are apparent in the present form and distribution of the tertiary deposits.