CHAPTER XIII.

Reproductive effects of running water—Division of deltas into lacustrine, mediterranean, and oceanic—Lake deltas—Growth of the delta of the Rhone in the Lake of Geneva—Chronological computations of the age of deltas—Recent deposits in Lake Superior—Deltas of inland seas—Rapid shallowing of the Baltic—Arguments for and against the hypothesis of Celsius—Elevated beaches on the coast of Sweden—Marine delta of the Rhone—Various proofs of its increase—Stony nature of its deposits—Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic—Rapid conversion of that gulf into land—Mineral characters of the new deposits—Delta of the Nile—Its increase since the time of Homer—Its growth why checked at present.

We have hitherto considered the destroying agency of running water, as exhibited in the disintegration of rocks and transportation of matter from higher to lower levels. It remains for us to examine the reproductive effects of the same cause. The aggregate amount of matter accumulated in a given time at the mouths of rivers, where they enter lakes or seas, affords clearer data for estimating the energy of the excavating power of running water on the land, than the separate study of the operations of the same cause in the countless ramifications into which every great system of valleys is divided. We shall proceed to select some of the leading facts at present ascertained respecting the growth of deltas, and shall then offer some general observations on the quantity of subaqueous sediment transported by rivers, and on the manner of its distribution. Deltas may be divided into, first, those which are formed in lakes; secondly, those formed in inland seas; and thirdly, those formed on the borders of the ocean. The most characteristic distinction between the lacustrine and marine deltas consists in the nature of the organic remains, which become imbedded in their deposits; for, in the case of a lake, it is obvious that these must consist exclusively of such genera of animals as inhabit the land or the waters of a river or lake; whereas, in the other case, there will be an admixture and most frequently a predominance of animals which inhabit salt water. In regard, however, to the distribution of inorganic matter, the

deposits of lakes and inland seas are formed under very analogous circumstances, and may be contra-distinguished from those on the shores of the great ocean, where the tides co-operating with currents give rise to a distinct class of phenomena. In lakes and inland seas, even of the largest dimensions, the tides are almost insensible, and the currents are, for the most part, inconsiderable, although some striking exceptions to this rule will be mentioned when we treat of tides and currents.

DELTAS IN LAKES.

Lake of Geneva.—It is natural to begin our examination with an inquiry into the new deposits in lakes, as they exemplify the first reproductive operations in which rivers are engaged when they convey the detritus of rocks and the ingredients of mineral springs from mountainous regions. The accession of new land at the mouth of the Rhone, at the upper end of the Lake of Geneva, or the Leman Lake, presents us with an example of a considerable thickness of strata, which have accumulated since the historical era. This sheet of water is about thirty-seven miles long, and its breadth is from two to eight miles. The shape of the bottom is very irregular, the depth having been found, by late measurements, to vary from twenty to one hundred and sixty fathoms *. The Rhone, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vallais, (Portus Valesiæ of the Romans,) once situated at the water's edge, at the upper end, is now more than a mile and a half inland,—this intervening alluvial tract having been acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river, and full of marshes.

Mr. De la Beche found, after numerous soundings in all parts of the lake, that there was a pretty uniform depth of from one hundred and twenty to one hundred and sixty fathoms throughout the central region, and, on approaching the delta,

* De la Beche, Ed. Phil. Journ., vol. ii., p. 107, Jan. 1820

the shallowing of the bottom began to be very sensible at a distance of about a mile and three-quarters from the mouth of the Rhone; for a line drawn from St. Gingoulph to Vevey, gives a mean depth of somewhat less than six hundred feet, and from that part to the Rhone, the fluviatile mud is always found along the bottom *. We may state, therefore, that the strata annually produced are about two miles in length: so that, notwithstanding the great depth of the lake, the new deposits are not inclined at a high angle; the dip of the beds, indeed, is so slight, that they would be termed, in ordinary geological language, horizontal. The strata probably consists of alternations of finer and coarser particles, for during the hotter months from April to August, when the snows melt, the volume and velocity of the river are greatest, and large quantities of sand, mud, vegetable matter, and drift wood are introduced; but, during the rest of the year, the influx is comparatively feeble, so much so, that the whole lake, according to Saussure, stands six feet lower. If then, we could obtain a section of the accumulation formed in the last eight centuries, we should see a great series of strata, probably from six to nine hundred feet thick, and nearly two miles in length, inclined at a very slight angle. In the mean time, a great number of smaller deltas are growing around the borders of the lake, at the mouths of rapid torrents, which pour in large masses of sand and pebbles. The body of water in these torrents is too small to enable them to spread out the transported matter over so extensive an area as the Rhone. Thus, for example, there is a depth of eighty fathoms within half a mile of the shore, immediately opposite the great torrent which enters east of Ripaille, so that the dip of the strata in that delta is about four times as great as those deposited by the main river at the upper extremity of the lake †.

The capacity of this basin being now ascertained, it would be an interesting subject of inquiry, to determine in what number of years the Leman Lake will be converted into dry land. It would not be very difficult to obtain the elements for such a calculation, so as to approximate at least to the quantity of time required for the accomplishment of this result. The number of cubic feet of

* De la Beche, M.S. † Ibid.

water annually discharged by the river into the lake being estimated, experiments might be made in the winter and summer months, to determine the proportion of matter held in suspension or in chemical solution by the Rhone. It would be also necessary to allow for the heavier matter drifted along at the bottom, which might be estimated on hydrostatical principles, when the average size of the gravel and the volume and velocity of the stream at different seasons were known. Supposing all these observations to have been made, it would be more easy to calculate the future than the former progress of the delta, because it would be a laborious task to ascertain, with any degree of precision, the original depth and extent of that part of the lake which is already filled up. Even if this information were accurately obtained by borings, it would only enable us to approximate within a certain number of centuries to the time when the Rhone began to form its present delta; but this would not give us the date of the origin of the Leman Lake in its present form, because the river may have flowed into it for thousands of years, without importing any sediment whatever. Such would have been the case, if the waters had first passed through a chain of upper lakes; and that this was actually the fact, is indicated both by the course of the Rhone between Martigny and the Lake of Geneva, and still more decidedly, by the channels of many of its principal feeders.

If we ascend, for example, the valley through which the Dranse flows, we find that it consists of a succession of basins, one above the other, in each of which there is a wide expanse of flat alluvial lands, separated from the next basin by a rocky gorge, once evidently the barrier of a lake. The river has filled the lake, and partially cut through the barrier, which it is still gradually eroding to a greater depth. The examination of almost all valleys in mountainous districts affords abundant proofs of the obliteration of a series of lakes, by the filling up of hollows and the cutting through of rocky barriers—a process by which running water ever labours to produce a more uniform declivity. Before, therefore, we can pretend even to hazard a conjecture as to the era at which any particular delta commenced, we must be thoroughly acquainted with the geological history of the whole system of higher valleys which communicate with the main stream, and all

the changes which they have undergone since the last series of convulsions which agitated and altered the face of the country. The probability, therefore, of error in our chronological computations, where we omit to pay due attention to these circumstances, increases in proportion to the time that may have elapsed since the last disturbance of the country by subterranean movements, and in proportion to the extent of the hydrographical basin on which we may happen to speculate. The Alpine rivers of Vallais are prevented at present from contributing their sedimentary contingent to the delta of the Rhone in the Mediterranean, because they are intercepted by the Leman Lake; but when this is filled, they will transport as much, or nearly as much, matter to the sea as they now pour into that lake. They will then flow through a long, flat, alluvial plain, between Villeneuve and Geneva, from two to eight miles in breadth, which will present no superficial marks of the existence of a thickness of more than one thousand feet of recent sediment below. Many hundred alluvial tracts of equal, and some of much greater area, may be seen if we follow up the Rhone from its mouth, or explore the valleys of many of its principal tributaries.

What, then, shall we think of the presumption of De Luc, Kirwan, and their followers, who confidently deduced from the phenomena of modern deltas the recent origin of the present form of our continents, without pretending to have collected any one of the numerous data by which so complicated a problem can be solved? Had they, after making all the necessary investigations, succeeded in proving, as they desired, that the delta of the Rhone, and the new deposits at the mouths of all other rivers, whether in lakes or seas, had required about four thousand years to attain their present dimensions, the conclusion would have been fatal to the chronological theories, which they were anxious to confirm. The popular reception of these, and similar sophisms, respecting the effects of causes in diurnal action, has hitherto thrown stumbling-blocks in the way of those geologists who desire to pursue the science according to the rules of inductive philosophy. If speculations so vague and visionary can be proposed concerning natural operations now passing before our eyes—if authors may thus dogmatize, with impunity,

on subjects capable of being determined with considerable degree of precision, can we be surprised that they who reason on the more obscure phenomena of remote ages, should wander in a maze of error and inconsistency * ?

The Leman Lake fills a great cavity in rocky strata, composed of a tertiary conglomerate and sand, which constitutes its bottom, almost all its northern banks, and a great part of its southern or Alpine side. It has often been asked, why this cavity has not been filled up by the detritus of rocks, removed from the numerous valleys now drained by the waters which enter the lake? In order to remove this difficulty, it would be necessary to enter into a description of the strata of different ages composing the Alps and the Subalpine districts; to point out the distinct periods of their elevation above the sea, and the pre-existence of many mountain valleys, even to the formation of those deposits wherein the Lake of Geneva is contained. It would be premature, therefore, to enter upon this subject at present, to which we shall revert when we have described the phenomena of some of the ancient strata.

Lake Superior.—Lake Superior is the largest body of fresh water in the world, being about one thousand five hundred geographical miles in circumference, if we follow the sinuosities of its coasts, its length, on a curved line through its centre, being about three hundred and sixty, and its extreme breadth one hundred and forty geographical miles. Its average depth varies from eighty to one hundred and fifty fathoms; but, according to Captain Bayfield, there is reason to think that its greatest depth would not be overrated at two hundred fathoms†, so that its bottom is, in some parts, nearly six hundred feet below the level of the Atlantic, as its surface is about as much above it. There are appearances in different parts of this, as of the

* It is an encouraging circumstance, that the cultivators of the science in our own country have begun to appreciate the true value of the principles of reasoning most usually applied to geological questions. While writing this chapter (April, 1830), I happened to attend a meeting of the Geological Society of London, where the president, in his address, made use of the expression, *a geological logician.* A smile was seen on the countenances of some of the audience, while many of the members, like Cicero's augurs, could not resist laughing; so ludicrous appeared the association of Geology and Logic.

† Trans. of Lit. and Hist. Soc. of Quebec, vol. i., p. 5, 1829.

other Canadian lakes, leading us to infer that its waters have formerly occupied a much higher level than they reach at present; for at a considerable distance from the present shores, parallel lines of rolled stones and shells are seen rising one above the other, like the seats of an amphitheatre. These ancient lines of shingle are exactly similar to the present beaches in most bays, and they often attain an elevation of forty or fifty feet above the present level. As the heaviest gales of wind do not raise the waters more than three or four feet *, the elevated beaches must either be referred to the subsidence of the lake at former periods, in consequence of the wearing down of its barrier, or to the upraising of the shores by earthquakes, like those which have produced similar phenomena on the coast of Chili. But there seem to be no facts which lend countenance to the latter hypothesis, in reference to the North American lakes. The streams which discharge their waters into Lake Superior are several hundred in number, without reckoning those of smaller size; and the quantity of water supplied by them is many times greater than that discharged at the Falls of St. Mary, the only outlet. The evaporation, therefore, is very great, and such as might be expected from so vast an extent of surface.

On the northern side, which is encircled by primary mountains, the rivers sweep in many large boulders with smaller gravel and sand, chiefly composed of granitic and trap rocks. There are also currents in the lake, in various directions, caused by the continued prevalence of strong winds, and to their influence we may attribute the diffusion of finer mud far and wide over great areas; for, by numerous soundings made during the late survey, it was ascertained that the bottom consists generally of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree, as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third

* Captain Bayfield remarks, that Dr. Bigsby, to whom we are indebted for several communications respecting the geology of the Canadian lakes, was misinformed by the fur traders in regard to the extraordinary height (twenty or thirty feet) to which he asserts that the autumnal gales will raise the water of Lake Superior. Trans. of Lit. and Hist. Soc. of Quebec, vol. i., p. 7, 1829.

white, hardening into a substance resembling pipe-clay *. From these statements, the geologist will not fail to remark how closely these recent lacustrine formations in America resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France. In both cases, many of the genera of shells most abundant, as Lymnea and Planorbis, are the same; and in regard to other classes of organic remains, there must be the closest analogy, as we shall endeavour more fully to explain when speaking of the imbedding of plants and animals in recent deposits.

DELTAS OF INLAND SEAS.

Deltas of the Baltic.—Having offered these few remarks on lacustrine deltas now in progress, we may next turn our attention to those of inland seas.

The shallowing and conversion into land of many parts of the Baltic, especially the Gulfs of Bothnia and Finland, have been demonstrated by a series of accurate observations, for which we are in a great measure indebted to the animated controversy which has been kept up, since the middle of the last century, concerning the gradual lowering of the level of the Baltic. Celsius, the Swedish astronomer, first originated the idea that from the earliest times there had been a progressive fall of about forty-five inches in a century, in the mean level of the waters of that sea. He contended that this change rested not only on modern observations, but on the authority of the ancient geographers, who stated that Scandinavia was formerly an island. By the gradual depression of the sea, he said, that great island became connected with the continent; and that this event happened after the time of Pliny, and before the ninth century of our era. To the arguments urged in support of these positions, his opponents objected that the ancients were so ignorant of the geography of the most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked that if the land which connected Scandinavia with the main continent

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i., p. 5, 1829.

was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have risen above the sea at the latter period, the rate of depression could not have been uniform, as was pretended, for it ought to have fallen much more rapidly between the ninth and eighteenth century.

Many of the physical proofs relied on by Celsius and his followers, show clearly that they did not distinguish between the shallowing of the water by deposition of fresh sediment, and the diminution of depth caused by subsidence of the sea. By their own statements, it appeared that the accessions of new land, and the loss of depth, were at the mouths of rivers, or in certain deep bays, into which it is well known that sand and mud are carried by currents. As illustrating, however, the gradual conversion of the Gulf of Bothnia into land, their observations deserve great attention. Thus, for example, they pointed out the fact, that at Pitea half a mile was gained in forty-five years, and at Lulea no less than a mile in twenty-eight years. Ancient ports, on the same coast, had become inland cities. Considerable tracts of the gulf were rendered three feet shallower in the course of fifty years—many old fishing-grounds had been changed into dry land—small islands had been joined to the continent. According to Linnæus, the increase of land on the eastern side of Gothland near Hoburg, was about two or three toises annually for ninety years*. Besides these changes, it was asserted that along the southern shore, also, of the Baltic, particularly in West Prussia and Pomerania, anchors and sunk ships had been discovered far inland; and although these occurrences were partly accounted for by the silting up of river-beds, yet the tradition seems worthy of credit, that a bay of the sea penetrated, at a remote period, much farther to the south in that direction. These, and many other facts, are of geological interest, although they afford no confirmation to the theory of Celsius.

His most plausible arguments were derived from the alleged exposure of certain insular rocks in the Bothnian and other bays, which were declared to have been once entirely covered with water, but which had gradually protruded themselves more and more above the waves, until, in the course of about

* Linn. de tell. habit. increm.

a century and a half, they grew to be eight feet high. Of this phenomenon, the following explanation was offered by his opponents. The islands in question consisted of sand and drift-stones, and the waves, during great tempests, threw up new matter upon them, or converted shoals into islands. Sometimes, also, icebergs, heavily laden with rock, were stranded on a shoal or driven up on a low island; and when they melted away, they left a mass of debris, many feet in height. Browallius, and other Swedish naturalists, pointed out that some of these islands were lower than formerly; so that, by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious and very conclusive proof of the permanency of the water-level for many centuries. On the Finland coast were some large pines, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that they had stood there for four hundred years. Now, according to the Celsian hypothesis, the sea had sunk fifteen feet during that period, so that the germination and early growth of these pines must have been for many seasons below the level of the water. In like manner it was shewn, that the lower walls of many ancient castles, such as those of Sonderburg and Abo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea. Another unanswerable argument in proof of the stability of the level of the Baltic, was drawn from the island of Saltholm, not far from Copenhagen. This isle is so low that, in autumn and winter, it is permanently overflowed; and is only dry in summer, when it serves for pasturing cattle. It appears, from documents of the year 1280, that this island was then also in the same state, and exactly on a level with the mean height of the sea, instead of being twenty feet under water, as it ought to have been according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after six and even eight hundred years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level

of the sea in the year 1000; and after eight centuries, its relative position remains exactly the same *.

Notwithstanding these convincing proofs that the supposed change in the relative level of land and sea arose from some local appearances, there are still many who contend for a lowering of the Baltic; and many Swedish officers of the pilotage establishment declared, in the year 1821, in favour of this opinion, after measuring the height of landmarks placed at certain heights above the sea, half a century before, as objects of comparison for the express purpose of settling the point at issue. Before we attach any weight to these assertions, which only relate to slight differences of elevation, we ought to be assured that the observers were on their guard against every imaginable cause of deception arising from local circumstances. Thus, for example, if the height of an alluvial plain was taken during the last century, it might have been subsequently raised by fresh deposits, and thus the sea would appear to have sunk; or, if a mark was cut in the rocks, the sea may have been several inches or even feet higher at one period than another, in consequence of the setting in of a current urged by particular winds into a long narrow gulf, which cause is well known to raise the Baltic, at some seasons, two feet above its ordinary level.

Von Buch, in his travels, discovered in Norway, and at Uddevalla, in Sweden, beds of shells of existing species at considerable heights above the level of the water. Since that time, several other naturalists have confirmed his observation; and, according to Ström, some deposits occur at an elevation of more than four hundred feet above the sea in the northern part of Norway. M. Alex. Brongniart, who has lately visited Uddevalla in Gotheborg, a port at the entrance of the Baltic, informs us that the principal mass of shells in the creek of Uddevalla rises about two hundred feet above the level of the sea, resting on rocks of gneiss. All the species are identical with those now inhabiting the contiguous sea, and are for the most part entire, although some of them are broken, as happens on a sea-beach. They are nearly free from any admixture of earthy matter. The reader need scarcely be reminded that, at the height of a

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, Geschichte, &c., vol. i., p. 439.

few feet above the beach, on our coasts, the rocks, where they are alternately submerged and laid dry by the ebbing and flowing tide, are frequently covered with barnacles or balani, which are firmly attached. On examining, with care, the smooth surface of the gneiss, immediately above the ancient shelly beach at Uddevalla, M. Brongniart found, in a similar manner, balani adhering to the rocks, so that there can be no doubt that the sea had for a long period sojourned on the spot *. Now, this interesting fact is precisely analogous to one well known to all who are acquainted with the geology of the borders of the Mediterranean. Perforating shells (Venus lithophaga, Lam.) excavate funnel-shaped hollows in the hardest limestone and marble, along the present sea-shores; and lines of these perforations, sometimes containing the same species of shells, have been discovered at various heights above the sea near Naples, in Calabria, at Monte Pelegrino, in the Bay of Palermo, and other localities. As many of these districts have been violently shaken by earthquakes within the historical era, and as the land has been sometimes raised and sometimes depressed, as we shall afterwards show by examples, there is no difficulty in explaining the phenomena, provided time be allowed. But no argument can be derived, from such observations, in support of great upheavings of the coast, whether by slow or sudden operations in modern times, unless we use the term *modern* in a geological sense. On the contrary, we know that the physical outline of the coast and heights in the bay of Palermo, when it was a Greek port more than two thousand years ago, was so nearly the same as it is at present, that the beds of recent shells, and the perforations in the rocks, must have stood nearly in the same relation to the level of the Mediterranean as they stand now. The high beaches on the Norwegian and Swedish coast establish the important and certainly very unexpected fact, that those parts of Europe have been the theatres of considerable subterranean movements within the present zoological era, or since the seas were inhabited by species now our contemporaries. But the phenomena do not lend the slightest support to the Celsian hypothesis, nor to that extraordinary notion proposed in our own times by Von Buch, who imagines that the whole of the land

* Tableau des Terrains, &c., p. 89. 1829.

along the northern and western shores of the Baltic is slowly and insensibly rising! No countries have been more entirely free from earthquakes since the times of authentic history than Norway, Sweden, and Denmark. In common with our own island, and, indeed with almost every spot on the globe, they have experienced some slight shocks at certain periods, as during the earthquake of Lisbon, and on a few other occasions, but these may rather be considered as prolonged vibrations in the crust of the earth, extending in the manner of sounds through the air to almost indefinite distances, than as those violent movements which in the great regions of active volcanos change, from time to time, the relative level of land and sea.

Delta of the Rhone.—We may now turn our attention to some of the principal deltas of the Mediterranean, for no other inland sea affords so many examples of accessions of new lands at the mouths of rivers within the records of authentic history. We have already considered the lacustrine delta of the Rhone in Switzerland, and we shall now describe its contemporaneous marine delta. Scarcely has the river passed out of the Leman Lake, before its pure waters are again filled with sand and sediment by the impetuous Arve descending from the highest Alps, and bearing along in its current the granitic detritus annually carried down by the glaciers of Mont Blanc. The Rhone afterwards receives vast contributions of transported matter from the Alps of Dauphiny, and the primary and volcanic mountains of Central France; and when at length it enters the Mediterranean, it discolours its blue waters with a whitish sediment for the distance of between six and seven miles from its mouth, throughout which space the current of fresh-water is perceptible. Strabo's description of the delta is so inapplicable to its present configuration, as to attest a complete alteration in the physical features of the country since the Augustan age. It appears, however, that the head of the delta, or the point at which it begins to ramify, has remained unaltered since the time of Pliny, for he states that the Rhone divided itself at Arles into two arms. This is the case at present; one of the branches being now called Le petit Rhône, which is again subdivided before entering the Mediterranean. The advance of the base of the delta, in the last eighteen centuries, is demonstrated by

many curious antiquarian monuments. The most striking of these is the great detour made by the old Roman road from Ugernum to Beziers (part of the high road between Aix, Aquæ Sextiæ, and Nismes, Nemausus). It is clear that, when this was first constructed, it was impossible to pass in a direct line, as now, across the delta, and that either the sea or marshes intervened in a tract now consisting of terra firma *. Astruc also remarks, that all the places on the low lands, lying to the north of the old Roman road between Nismes and Beziers, have names of Celtic origin evidently given to them by the first inhabitants of the country; whereas the places lying south of that road, towards the sea, have names of Latin derivation, and were clearly founded after the Roman language had been introduced. Another proof, also, of the great extent of land which has come into existence since the Romans conquered and colonized Gaul, is derived from the fact, that the Roman writers never mention the thermal waters of Balaruc in the delta, although they were well acquainted with those of Aix and others, still more distant, and attached great importance to them, as they invariably did to all hot springs. The waters of Balaruc, therefore, must have formerly issued under the sea—a common phenomenon on the borders of the Mediterranean; and on the advance of the delta they continued to flow out through the new deposits. Among the more direct proofs of the increase of land, we find that Mese, described under the appellation of Mesua Collis by Pomponius Mela †, and stated by him to be nearly an island, is now far inland. Notre Dame des Ports, also, was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, and is now two leagues from the sea. Several old lines of towers and sea-marks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners, which may well be conceived when we state that the tower of Tignaux, erected on the shore so late as the year 1737, is already a French mile remote from it ‡.

By the confluence of the Rhone and the currents of the

* Mem. d'Astruc, cited by Von Hoff, vol. i., p. 228.

† Lib. II., c. v.

‡ Bouche, Chorographie et Hist. de Provence, vol. i., p. 23, cited by Hoff, vol. i., p. 290.

Mediterranean driven by winds from the south, sand-bars are often formed across the mouths of the river: by these means considerable spaces become divided off from the sea, and subsequently from the river also, when it shifts its channels of efflux. As some of these etangs, as they are called, are subject to the occasional ingress of the river when flooded, and of the sea during storms, they are alternately salt and fresh. Others, after being filled with salt-water, are often lowered by evaporation till they become more salt than the sea; and it has happened, occasionally, that a considerable precipitate of muriate of soda has taken place in these natural salterns. During the latter part of Napoleon's career, when the excise-laws were enforced with extreme rigour, the police was employed to prevent such salt from being used. The fluviatile and marine shells enclosed in these small lakes, often live together in brackish water; but the uncongenial nature of the fluid usually produces a dwarfish size, and sometimes gives rise to strange varieties in form and colour.

Captain Smyth, in the late survey of the coast of the Mediterranean, found the sea, opposite the mouth of the Rhone, to deepen gradually from four to forty fathoms, within a distance of six or seven miles, over which the discoloured fresh-water extends; so that the inclination of the new deposits must be too slight to be appreciable in such an extent of section as a geologist usually obtains in examining ancient formations. When the wind blew from the south-west, the ships employed in the survey were obliged to quit their moorings; and when they returned, the new sand-banks in the delta were found covered over with a great abundance of marine shells. By this means, we learn how occasional beds of drifted marine shells may become interstratified with fresh-water strata at the mouths of rivers.

That a great proportion, at least, of the new deposit in the delta of the Rhone consists of *rock*, and not of loose incoherent matter, is perfectly ascertained. In the museum at Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter, including multitudes of broken shells of recent species. The observations recently made on this

subject corroborate the former statement of Marsilli *, that the earthy deposits of the coast of Languedoc form a stony substance, for which reason he ascribed a certain bituminous, saline, and glutinous nature, to the substances brought down with sand by the Rhone. If the number of mineral springs charged with carbonate of lime which fall into the Rhone and its feeders in different parts of France be considered, we shall feel no surprise at the lapidification of the newly-deposited sediment in this delta. It should be remembered, that the fresh-water introduced by rivers, being lighter than the water of the sea, floats over the latter, and remains upon the surface for a considerable distance. Consequently, it is exposed to as much evaporation as the waters of a lake; and the area over which the river-water is spread, at the junction of great rivers and the sea, may well be compared, in point of extent, to that of considerable lakes. Now, it is well known, that so great is the quantity of water carried off by evaporation in some lakes, that it is nearly equal to the water flowing in; and in some inland seas, as the Caspian, it is quite equal. We may, therefore, well suppose that, in cases where a strong current does not interfere, the greater portion not only of the matter held mechanically in suspension, but of that also which is in chemical solution, must be precipitated within the limits of the delta. When these finer ingredients are extremely small in quantity, they may only suffice to supply crustaceous animals, corals, and marine plants, with the earthy particles necessary for their secretions; but whenever it is in excess (as generally happens if the basin of a river lie partly in a district of active or extinct volcanos), then will solid deposits be formed, and the shells will at once be included in a rocky mass.

Delta of the Po.—The Adriatic presents a great combination of circumstances favourable to the rapid formation of deltas—a gulf receding far into the land,—a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adige, besides numerous minor streams draining on the one side a great crescent of the Alps, and on the other

* Hist. Phys. de la Mer.

some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste, where the Isonzo enters, down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than one hundred miles in length, which, within the last two thousand years, have increased from *two to twenty miles in breadth*. The Isonzo, Tagliamento, Piave, Brenta, Adige, and Po, besides many other inferior rivers, contribute to the advance of the coast-line, and to the shallowing of the gulf. The Po and the Adige may now be considered as entering by one common delta, for two branches of the Adige are connected with arms of the Po. In consequence of the great concentration of the flooded waters of these streams, since the system of embankment became general, the rate of encroachment of the new land upon the Adriatic, especially at that point where the Po and Adige enter, is said to have been greatly accelerated. Adria was a seaport in the time of Augustus, and had, in ancient times, given its name to the gulf; it is now about twenty Italian miles inland. Ravenna was also a seaport, and is now about four Italian miles from the main sea. Yet even before the practice of embankment was introduced, the alluvium of the Po advanced with rapidity on the Adriatic; for Spina, a very ancient city, originally built in the district of Ravenna, at the mouth of a great arm of the Po, was, so early as the commencement of our era, eleven Italian miles distant from the sea *.

The greatest depth of the Adriatic, between Dalmatia and the mouths of the Po, is twenty-two fathoms; but a large part of the gulf of Trieste and the Adriatic, opposite Venice, is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist partly of mud and partly of rock, the latter formed of calcareous matter, encrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or calcareous precipitates †. Olivi, also,

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. i., p. 118.

† Ibid., vol. i., p. 39.

found some deposits of sand, and others of mud, extending half way across the gulf; and he states that their distribution along the bottom was evidently determined by the prevailing current *. It is probable, therefore, that the finer sediment of all the rivers at the head of the Adriatic may be intermingled by the influence of the current; and all the central parts of the gulf may be considered as slowly filling up with horizontal deposits, precisely similar to those of the Subapennine hills, and containing many of the same species of shells. The Po merely introduces at present fine sand and mud, for it carries no pebbles farther than the spot where it joins the Trebia, west of Piacenza. Near the northern borders of the basin, the Isonzo, Tagliamento, and many other streams, are forming immense beds of sand and some conglomerate, for there some high mountains of Alpine limestone approach within a few miles of the sea. In the time of the Romans, the hot baths of Monfalcone were on one of several islands of Alpine limestone, between which and the main land, on the north, was a channel of the sea, about a mile broad. This channel is now converted into a grassy plain, which surrounds the islands on all sides. Among the numerous changes on this coast, we find that the present channel of the Isonzo is several miles to the west of its ancient bed, in part of which at Ronchi, the old Roman bridge which crossed the Via Appia was lately found buried in fluviatile silt.

Notwithstanding the present shallowness of the Adriatic, it is highly probable that its original depth was very great; for if all the low alluvial tracts were taken away from its borders and replaced by sea, the high land would terminate in that abrupt manner which generally indicates, in the Mediterranean, a great depth of water near the shore, except in those spots where sediment imported by rivers and currents has diminished the depth. Many parts of the Mediterranean are now ascertained to be above two thousand feet deep, close to the shore, as between Nice and Genoa; and even sometimes six thousand feet, as near Gibraltar. When, therefore, we find near Parma, and in other districts in the interior of the peninsula, beds of horizontal tertiary marl, attaining a thickness of about two

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. ii., p. 94.

thousand feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above a thousand feet in thickness, and extending seven or eight miles in length, we behold nothing which the analogy of the deltas in the Adriatic might not lead us to anticipate.

Delta of the Nile.—That Egypt was the gift of the Nile, was the opinion of her priests before the time of Herodotus; but we have no authentic memorials for determining, with accuracy, the additions made to the habitable surface of that country since the earliest historical period. We know that the base of the delta has been considerably modified since the days of Homer. The ancient geographers mention seven principal mouths of the Nile, of which the most eastern, the Pelusian, has been entirely silted up, and the Mendesian, or Tanitic, has disappeared. On the other hand, the Bucolic has, in modern times, been greatly enlarged, and has caused the coast to advance; so that the city of Damietta, which, in the year 1243, was on the sea, and possessed a good harbour, is now one mile inland. The Phatnitic mouth, and the Sebenitic, have been so altered, that the country immediately about them has little resemblance to that described by the ancients. The Bolbitine mouth has increased in its dimensions, so as to cause the city of Rosetta to be at some distance from the sea. But the alterations produced round the Canopic mouth are the most important. The city Foah, which, so late as the beginning of the fifteenth century, was on this embouchure, is now more than a mile inland. Canopus, which, in the time of Scylax, was a desolate insular rock, has been connected with the firm land; and Pharos, an island in the times of old, now belongs to the continent. Homer says, its distance from Egypt was one day's voyage by sea*. That this should have been the case in Homer's time, Larcher and others have, with reason, affirmed to be in the highest degree improbable; but Strabo has judiciously anticipated their objections, observing, that Homer was probably acquainted with the gradual advance of the land on this coast, and availed himself of this phenomenon to give an air of higher antiquity to the

* Ody., B. iv., 355.

remote period in which he laid the scene of his poem *. The Lake Mareotis, also, together with the canal which connected it with the Canopic arm of the Nile, has been filled with mud, and is become dry. Herodotus observes, that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams, had formed deltas. "Egypt, therefore," he says, "like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile," he adds, "should by any means have an issue into the Arabian Gulf, it might choke it up with earth in twenty thousand, or even perhaps in ten thousand years; and why may not the Nile have filled with mud a still greater gulf, in the space of time which has passed before our age †?"

The depth of the Mediterranean is about twelve fathoms at a small distance from the shore of the delta; it afterwards increases gradually to fifty, and then suddenly descends to three hundred and eighty fathoms, which is, perhaps, the original depth of the sea where it has not been rendered shallower by fluviatile matter. The progress of the delta, in the last two thousand years, affords, perhaps, no measure for estimating its rate of growth when it was an inland bay, and had not yet protruded itself beyond the coast-line of the Mediterranean. A powerful current now sweeps along the shores of Africa, from the Straits of Gibraltar to the prominent convexity of Egypt, the western side of which is continually the prey of the waves; so that not only are fresh accessions of land checked, but ancient parts of the delta are carried away. By this cause Canopus, and some other towns, have been overwhelmed; but to this subject we shall again refer when speaking of tides and currents.

* Lib. I., Part i., pp. 80 and 98. Consult Von Hoff, vol. i., p. 244.

† Euterpe, XI.