CHAPTER XIV.

Oceanic deltas—Delta of the Ganges and Burrampooter—Its size, rate of advance, and nature of its deposits—Formation and destruction of islands—Abundance of crocodiles—Inundations—Delta of the Mississippi—Deposits of drift wood—Gradual filling up of the Yellow Sea—Rennell's estimate of the mud carried down by the Ganges—Formation of valleys illustrated by the growth of deltas—Grouping of new strata in general—Convergence of deltas—Conglomerates—Various causes of stratification—Direction of laminæ—Remarks on the interchange of land and sea.

OCEANIC DELTAS.

THE remaining class of deltas are those in which rivers, on entering the sea, are exposed to the influence of the tides. In this case it frequently happens that an estuary is produced, or negative delta, as it has been termed by Rennell, where, instead of any encroachment of the land upon the sea, the ocean enters the river's mouth, and penetrates into the land beyond the general coast-line. Where this happens, the tides and currents are the predominating agents in the distribution of transported sediment. The phenomena, therefore, of such estuaries, will come under our examination when we treat of the movements of the ocean. But whenever the volume of fresh-water is so great as to counteract and almost neutralize the force of tides and currents, and in all cases where the latter agents have not sufficient power to remove to a distance the whole of the sediment periodically brought down by rivers, oceanic deltas are produced. Of these, we shall now select a few illustrative examples.

Delta of the Ganges.—The Ganges and the Burrampooter descend, from the highest mountains in the world, into a gulf which runs two hundred and twenty-five miles into the continent. The Burrampooter is somewhat the larger river of the two, but it first takes the name of the Megna, when joined by a smaller stream so called, and afterwards loses this again on its union with the Ganges, at the distance of about forty miles from the sea. The area of the delta of the Ganges (without including that of the Burrampooter, which has now become conterminous) is considerably more than double that of the Nile; and its head commences at a distance of two hundred and twenty miles, in a direct line from the sea. That part of the delta bordering on the sea is composed of a labyrinth of rivers and creeks, all of which are salt, except those immediately communicating with the principal arm of the Ganges. This tract, known by the name of the Woods, or Sunderbunds, a wilderness infested by tigers and alligators, is, according to Rennell, equal in extent to the whole principality of Wales *. The base of this magnificent delta is two hundred miles in length, including the space occupied by the two great arms of the Ganges which bound it on either side. On the sea-coast there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge. Although the flux and reflux of the tide extend even to the head of the delta, when the river is low, yet, when it is periodically swollen by tropical rains, the velocity of the stream counteracts the tidal current, so that, except very near the sea, the ebb and flow become insensible. During the flood-season, therefore, the Ganges almost assumes the character of a river entering a lake or inland sea; the movements of the ocean being then subordinate to the force of the river, and only slightly disturbing its operations. The great gain of the delta in height and area takes place during the inundations; and during other seasons of the year, the ocean makes reprisals, scouring out the channels, and sometimes devouring rich alluvial plains.

So great is the quantity of mud and sand poured by the Ganges into the gulf in the flood-season, that the sea only recovers its transparency at the distance of sixty miles from the coast. The general slope, therefore, of the new strata must be extremely gradual. By the charts recently published, it appears that there is a gradual deepening from four to about sixty fathoms, as we proceed from the base of the delta to the distance of about one hundred miles into the Bay of Bengal. At some few points seventy, or even one hundred fathoms are obtained at that

* Account of the Ganges and Burrampooter Rivers, by Major Rennell, Phil. Trans. 1781.

distance. One remarkable exception, however, occurs to the regularity of the shape of the bottom; for opposite the middle of the delta, at the distance of thirty or forty miles from the coast, is a nearly circular space called the "swatch of no ground," about fifteen miles in diameter, where soundings of one hundred, and even one hundred and thirty fathoms, fail to reach the bottom. This phenomenon is the more extraordinary, since the depression occurs within five miles of the line of shoals; and not only do the waters charged with Gangetic sediment pass over it continually, but, during the monsoons, the sea, loaded with mud and sand, is beaten back in that direction towards the delta. As the mud is known to extend for eighty miles farther into the gulf, we may be assured that, in the course of ages, the accumulation of strata in "the swatch" has been of enormous thickness; and we seem entitled to deduce, from the present depth at the spot, that the original inequalities of the bottom of the Bay of Bengal were on as grand a scale as are those of the main ocean. Opposite the mouth of the Hoogly river, and immediately south of Sager Island, four miles from the nearest land of the delta, a new isle was formed about thirty years ago, called Edmonston Island, where there is a lighthouse, and the surface of which is now covered with vegetation and shrubs. But while there is evidence of rapid gain at some points, the general progress of the coast is very slow, for the tides, which rise from thirteen to sixteen feet, are actively employed in removing the alluvial matter, and diffusing it over a wide area.* The new strata consist entirely of sand and fine mud; such, at least, are the only materials which are exposed to view in regular beds on the banks of the numerous creeks. No substance so coarse as gravel occurs in any part of the delta, nor nearer the sea than four hundred miles. It should be observed, however, that the superficial alluvial beds, which are thrown down rapidly from turbid

* It is stated in the chart published in the year 1825, by Captain Hosburgh, that the sands opposite the whole delta stretched between four and five miles farther south than they had done forty years previously; and this was taken as the measure of the progress of the delta itself, during the same period. But that gentleman informs me that a more careful comparison of the ancient charts, during a recent survey, has proved that they were extremely incorrect in their latitudes, so that the advance of the new sands and delta was greatly exaggerated.

waters during the floods, may be very distinct from those deposited at a greater distance from the shore, where crystalline precipitates, perhaps, are forming, on the evaporation of so great a surface, exposed to the rays of a tropical sun. The separation of sand and other matter, held in mechanical suspension, may take place where the waters are in motion; but mineral ingredients, held in chemical solution, would naturally be carried to a greater distance, where they aid in the formation of corals and shells, and, in part, perhaps, become the cementing principle of rocky masses.

Among the remarkable proofs of the immense transportation of earthy matter by the Ganges and Megna, may be mentioned the great magnitude of the islands formed in their channels during a period far short of that of a man's life. Some of these, many miles in extent, have originated in large sand-banks thrown up round the points at the angular turning of the river, and afterwards insulated by breaches of the stream. Others, formed in the main channel, are caused by some obstruction at the bottom. A large tree, or a sunken boat, is sometimes sufficient to check the current, and cause a deposit of sand, which accumulates till it usurps a considerable portion of the channel. The river then borrows on each side to supply the deficiency in its bed, and the island is afterwards raised by fresh deposits during every flood. In the great gulf below Luckipour, formed by the united waters of the Ganges and Burrampooter (or Megna), some of the islands, says Rennell, rival in size and fertility the Isle of Wight. While the river is forming new islands in one part, it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the Tamarix Indica, and other shrubs, forming impenetrable thickets, where tigers, buffaloes, deer, and other wild animals, take shelter. It is easy, therefore, to perceive, that both animal and vegetable remains must continually be precipitated into the flood, and sometimes become imbedded in the sediment which subsides in the delta.

Two species of crocodiles, of distinct genera, abound in the Ganges and its tributary and contiguous waters; and Mr. H. T. Colebrooke informs me, that he has seen both kinds in places far inland, many hundred miles from the sea. The Gangetic crocodile, or Gavial (in correct orthography, Garial), is confined to the fresh-water, but the common crocodile frequents both fresh and salt; being much larger and fiercer in salt and brackish water. These animals swarm in the brackish water along the line of sand-banks where the advance of the delta is most rapid. Hundreds of them are seen together in the creeks of the delta, or basking in the sun on the shoals without. They will attack men and cattle, destroying the natives when bathing, and tame and wild animals which come to drink. "I have not unfrequently," says Mr. Colebrooke, "been witness to the horrid spectacle of seeing a floating corpse seized by a crocodile with such avidity, that he half emerged above the water with his prey in his mouth." The geologist will not fail to observe how peculiarly the habits and distribution of these saurians expose them to become imbedded in those horizontal strata of fine mud which are annually deposited over many hundred square miles in the Bay of Bengal. The inhabitants of the land, when they happen to be submerged, are usually destroyed by these voracious reptiles; but we may suppose the remains of the saurians themselves to be continually entombed in the new formations.

It sometimes happens, at the season when the periodical flood is at its height, that a strong gale of wind, conspiring with a high spring-tide, checks the descending current of the river, and gives rise to most destructive inundations. From this cause, in the year 1763, the waters at Luckipour rose six feet above their ordinary level, and the inhabitants of a considerable district, with their houses and cattle, were totally swept away.

The population of all oceanic deltas are particularly exposed to suffer by such catastrophes, recurring at considerable intervals of time; and we may safely assume, that such tragical events have happened again and again since the Gangetic delta was inhabited by man. If human experience and forethought cannot always guard against these calamities, still less can the inferior animals avoid them; and the monuments of such disastrous inundations must be looked for in great abundance in strata of all ages, if the surface of our planet has always been governed by the same laws. When we reflect on the general order and tranquillity that reigns in the rich and populous delta of Bengal, notwithstanding the havoc occasionally committed by the depredations of the ocean, we perceive how unnecessary it is to attribute the imbedding of successive races of animals in older strata to extraordinary energy in the causes of decay and reproduction in the infancy of our planet, or to those general catastrophes and sudden revolutions resorted to by cosmogonists.

As the delta of the Ganges may be considered a type of those formed on the borders of the ocean, it will be unnecessary to accumulate examples of others on a no less magnificent scale, as at the mouths of the Orinoco and Amazon, for example. To these, indeed, it will be necessary to revert when we treat of the agency of currents. The tides in the Mexican Gulf are so feeble, that the delta of the Mississippi has somewhat of an intermediate character between an oceanic and mediterranean delta. A long narrow tongue of land is protruded, consisting simply of the banks of the river, and having precisely the same appearance as in the inland plains during the periodical inundations, when nothing appears above water but the higher part of that sloping glacis which we before described. This tongue of land has advanced many leagues since New Orleans was built. Great submarine deposits are also in progress, stretching far and wide over the bottom of the sea, which has become throughout a considerable area extremely shallow, not exceeding ten fathoms in depth. Opposite the mouth of the Mississippi large rafts of drift trees, brought down every spring, are matted together into a net-work many yards in thickness, and stretching over hundreds of square leagues *. They afterwards become covered over with a fine mud, on which other layers of trees are deposited the year following, until numerous alternations of earthy and vegetable matter are accumulated. An observation of Darby, in regard to the strata composing part of this delta, deserves attention. In the steep banks of the Atchafalaya, that arm of the Mississippi which we before alluded to when describing "the raft," the following section is observable at low water:—first, an upper stratum, consisting invariably of blueish clay, common to the banks of the Mississippi; below this a stratum of red ochreous earth peculiar to Red River, under which the blue clay of the Mississippi again appears †; and this arrange-

* Captain Hall's Travels in North America, vol. iii., p. 338.

† Darby's Louisiana, p. 103.

ment is constant, proving, as that geographer remarks, that the waters of the Mississippi and the Red River once occupied alternately considerable tracts below their present point of union. Such alternations are probably common in submarine spaces situated between two converging deltas. For before the two rivers unite, there must almost always be a certain period when an intermediate tract will be alternately occupied and abandoned by the waters of each stream; since it can rarely happen, that the season of highest flood will precisely correspond in each. In the case of the Red River, for example, and Mississippi, which carry off the waters from countries placed under widely distant latitudes, an exact coincidence in the time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of Sediment in River Water.—Very few satisfactory experiments have as yet been made, to enable us to determine, with any degree of accuracy, the mean quantity of earthy matter discharged annually into the sea by some one of the principal rivers of the earth. Hartsoeker computed the Rhine to contain, when most flooded, one part in a hundred of mud in suspension*. By several observations of Sir George Staunton, it appeared that the water of the Yellow River in China contained earthy matter in the proportion of one part to two hundred, and he calculated that it brought down, in a single hour, two million feet of earth, or forty-eight million daily; so that, if the Yellow Sea be taken to be one hundred and twenty feet deep, it would require seventy days for the river to convert an English square mile into firm land, and twenty-four thousand years to turn the whole sea into terra firma, assuming it to be one hundred and twenty-five thousand square miles in extent †. Manfredi, the celebrated Italian hydrographer, conceived the average proportion of sediment in all the running water on the globe, which reached the sea, to be $\frac{1}{175}$, and he imagined that it would require a thousand years for the sediment carried down to raise the general level of the sea about one foot. Some writers, on the contrary,

* Comment, Bonon., vol. ii., part i., p. 237.

† Staunton's Embassy to China. London, 1797, 4to. vol. ii., p. 408.

as De Maillet, have declared the most turbid waters to contain far less sediment than any of the above estimates would import; and there is so much contradiction and inconsistency in the facts and speculations hitherto promulgated on the subject, that we must wait for additional experiments before we can form any opinion on the question.

One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the Delta of the Ganges. "A glass of water," he says, "taken out of this river when at its height, yields about one part in four of mud. No wonder, then, that the subsiding waters should quickly form a stratum of earth, or that the delta should encroach on the sea * !" The same hydrographer computed with much care the number of cubic feet of water discharged by the Ganges into the sea, and estimated the mean quantity through the whole year to be eighty thousand cubic feet in a second. When the river is most swollen, and its velocity much accelerated, the quantity is four hundred and five thousand cubic feet in a second. Other writers agree that the violence of the tropical rains, and the fineness of the alluvial particles in the plains of Bengal, cause the waters of the Ganges to be charged with foreign matter to an extent wholly unequalled by any large European river during the greatest floods. We have already alluded to the frequent sweeping down of large islands by the Ganges; and Major R. H. Colebrooke, in his account of the course of the Ganges, relates examples of the rapid filling up of some branches of the river, and the excavation of new channels, where the number of square miles of soil removed in a short time (the column of earth being one hundred and fourteen feet high) was truly astonishing. Forty square miles, or 25,600 acres, are mentioned as having been carried away, in one locality, in the course of a few years †. But although we can readily believe the proportion of sediment in the waters of the Ganges to exceed that of any river in northern latitudes, we are somewhat staggered by the results to which we must arrive if we compare the proportion of mud, as given by Rennell, with his computation of the quantity of water discharged, which latter is probably very correct. If it

* Phil. Trans., 1781.

† Trans. of the Asiatic Society, vol. vii., p. 14.

were true that the Ganges, in the flood-season, contained one part in four of mud, we should then be obliged to suppose that there passes down, every four days, a quantity of mud equal in volume to the water which is discharged in the course of twenty-four hours. If the mud be assumed to be equal to one-half the specific gravity of granite (it would, however, be more), the weight of matter *daily* carried down in the flood-season, would be about equal to seventy-four times the weight of the Great Pyramid of Egypt *. Even if it could be proved that the turbid waters of the Ganges contain one part *in a hundred* of mud, which is affirmed to be the case in regard to the Rhine, we should be brought to the extraordinary conclusion, that there passes down, every two days, into the Bay of Bengal, a mass about equal in weight and bulk to the Great Pyramid.

The most voluminous current of lava which has flowed from Etna within historical times, was that of 1669. Ferrara, after correcting Borrelli's estimate, calculated the quantity of cubic yards of lava in this current, at one hundred and forty millions. Now this would only equal in bulk one-seventh of the sedimentary matter which is carried down in a single year by the Ganges, assuming the average proportion of mud to water to be no more than one part in one hundred, so that, allowing seven grand eruptions in a century, it would require an hundred Etnas to transfer a mass of lava from the subterranean regions to the surface, equal in volume to the mud carried down in the same time from the Himalaya mountains into the Bay of Bengal †. As considerable labour has been bestowed

* According to Rennell, the Ganges discharges, in the flood-season, 405,000 cubic feet of water per second, which gives, in round numbers, 100,000 cubic feet of mud per second, which × 86,400, the number of seconds in twenty-four hours, = 8,641,100,000, the quantity of cubic feet of mud going down the Ganges per diem. Assuming the specific gravity of mud to be half that of granite, the matter would equal 4,320,550,000 feet of granite. Now about twelve and a half cubic feet of granite weigh one ton; and it is computed, that the Great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 of tons.

† According to Ferrara's calculation, about 140,000,000 of cubic yards of lava were poured from the crater of Etna in 1669. This × 27, will give 3,780,000,000 of cubic feet, which would be about one-seventh of the amount of mud carried down by the Ganges in a year; for, assuming the average proportion of mud to be one part in a hundred, this would give on an average 800 cubic feet per second: 800 × 31,557,600, (the number of seconds in a Julian year,) gives 25,246,080,000.

in computing the volume of lava-streams in Sicily, Campania, and Auvergne, it is somewhat extraordinary that so few observations have been made on the quantity of matter transported by aqueous agents from one part of the earth to another. It would certainly not be difficult to approximate to the amount of sediment carried down annually by some of the largest rivers, such as the Amazon, Mississippi, Ganges, and others, because the earthy particles conveyed by them to their deltas are fine, and somewhat uniformly spread throughout the stream, and the principal efflux takes place within a limited period during the season of inundation. Arguments have been expended in vain for half a century, in controverting the opinion of those who imagine the agency of running water in the existing state of things, even if continued through an indefinite lapse of ages, to be insignificant, or at least wholly incompetent to produce considerable inequalities on the earth's surface. Some matter-of-fact data should now be accumulated, and we may confidently affirm, that when the aggregate amount of solid matter transported by rivers in a given number of centuries from a large continent, shall be reduced to arithmetical computation, the result will appear most astonishing to those who are not in the habit of reflecting how many of the mightiest operations in nature are effected insensibly, without noise or disorder. The volume of matter carried into the sea in a given time being once ascertained, every geologist will admit that the whole, with some slight exceptions, is subtracted from *valleys*, not from the tops of intervening ridges or the summits of hills; in other words, that ancient valleys have been widened and deepened, or new ones formed, to the extent of the space which the new deposits, when consolidated, would occupy.

Grouping of Strata in Deltas.—The changes which have taken place in deltas, even since the times of history, may suggest many important considerations in regard to the manner of distribution of sediment in subaqueous deposits. Notwithstanding frequent exceptions arising from the interference of a variety of causes, there are some general laws of arrangement which must evidently hold good in almost all the lakes and seas now filling up. If a lake, for example, be encircled on two sides by lofty mountains, receiving from them many rivers and torrents of different sizes, and if it be bounded on the other sides, where the surplus waters issue, by a comparatively low country, it is not difficult to define some of the leading geological features which will characterize the lacustrine formation when this basin shall have been gradually converted into dry land by influx of fluviatile sediment. The strata would be divisible into two principal groups; the *older* comprising those deposits which originated on the side adjoining the mountains, where numerous deltas first began to form; and the *newer* group consisting of beds deposited in the more central parts of the basin, and towards the side farthest from the mountains. The following characters would form the principal marks of distinction between the strata in each series. The more ancient system would be composed, for the most part, of coarser materials, containing many beds of pebbles and sand often of great thickness, and sometimes dipping at a considerable angle. These, with associated beds of finer ingredients, would, if traced round the borders of the basin, be seen to vary greatly in colour and mineral composition, and would also be very irregular in thickness. The beds, on the contrary, in the newer group, would consist of finer particles, and would be horizontal, or very slightly inclined. Their colour and mineral composition would be very homogeneous throughout large areas, and would differ from almost all the separate beds in the older series.

The following are the causes of the diversity here alluded to between the two great members of the lacustrine formation. When the rivers and torrents first reach the edge of the lake, the detritus washed down by them from the adjoining heights sinks at once into deep water, all the heavier pebbles and sand subsiding near the shore. The finer mud is carried somewhat farther out, but not to the distance of many miles, for the greater part may be seen, where the Rhone enters the Lake of Geneva, to fall down in clouds to the bottom not far from the river's mouth. Certain alluvial tracts are soon formed at the mouths of every torrent and river, and many of these, in the course of ages, become several miles in length. Pebbles and sand are then transported farther from the mountains, but in their passage they decrease in size by attrition, and are in part converted into mud and sand. At length some of the numerous deltas, which are all directed towards a common centre, approach near to each other—those of adjoining torrents become united, and are merged, in their turn, in the delta of the largest river, which advances most rapidly into the lake, and renders all the minor streams, one after the other, its tributaries. The various mineral ingredients of each are thus blended together into one homogeneous mixture, and the sediment is poured out from a common channel into the lake. As the average size of the transported particles decreases continually, so also the force and volume of the current augments, and thus the newer deposits are diffused over a wider area, and are consequently more horizontal than the older. When there were many independent deltas near the borders of the basin, their separate deposits differed entirely from each other. We may suppose that one was charged, like the Arve where it joins the Rhone, with white sand and sediment, chiefly derived from decomposed granite—that another was black, like many streams in the Tyrol, flowing from incoherent rocks of dark slate—that a third was coloured by ochreous sediment, like the Red River in Louisiana—and that a fourth, like the Elsa in Tuscany, held much carbonate of lime in solution. At first, they would each form distinct deposits of sand, gravel, limestone, marl, or other materials; but after their junction, new chemical combinations and distinct colours would be the result, and the particles, having been conveyed ten, twenty, or a greater number of miles over alluvial plains, would become finer.

In deltas where the causes are more complicated, and where tides and currents partially interfere, the above description would only be applicable, with certain modifications; but if a series of earthquakes accompany the growth of a delta, and change the levels of the land from time to time, as in the region where the Indus now enters the sea, and others hereafter to be mentioned, the phenomena will then depart widely from the ordinary type. If we possessed an accurate series of maps of the Adriatic for many thousand years, our retrospect would, without doubt, carry us gradually back to the time when the number of rivers descending from the mountains into that gulf by independent deltas, was far greater in number. The deltas of the Po and the Adige, for instance, would separate themselves within the *human* era, as, in all probability, would those of the Isonzo and the Torre. If, on the other hand, we speculate on future changes, we may anticipate the period when the number of deltas will greatly diminish; for the Po cannot continue to encroach at the rate of a mile in a century, and other rivers to gain as much in six or seven centuries upon the shallow gulf, without new junctions occurring from time to time, so that Eridanus, "the king of rivers," will continually boast a greater number of tributaries. The Ganges and Burrampooter have probably become confluent within the historical era; and the date of the junction of the Red River and the Mississippi would, in all likelihood, have been known, if America had not been so recently discovered. The union of the Tigris and the Euphrates must undoubtedly have been one of the modern geographical changes on our earth, and similar remarks might be extended to many other regions.

Along the base of the Maritime Alps, between Toulon and Genoa, the rivers, with few exceptions, are now forming strata of conglomerate and sand. Their channels are often several miles in breadth, some of them being dry, and the rest easily forded for nearly eight months in the year; whereas during the melting of the snow they are swollen, and a great transportation of mud and pebbles takes place. In order to keep open the main road from France to Italy, now carried along the sea-coast, it is necessary to remove annually great masses of shingle, brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made by the deltas of minor rivers on this coast need not surprise us, when we recollect that there is sometimes a depth of two thousand feet at a few hundred yards from the beach, as near Nice. Similar observations might be made respecting a large proportion of the rivers in Sicily, and, among others, respecting that which, immediately north of the port of Messina, hurries annually vast masses of granitic pebbles into the sea.

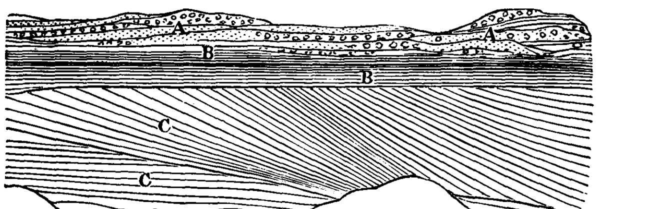
When the deltas of rivers having many mouths converge, a partial union at first takes place by the confluence of some one or more of their arms; but it is not until the main trunks are connected above the head of the common delta, that a complete intermixture of their joint waters and sediment takes place.

The union, therefore, of the Po and Adige, and of the Ganges and Burrampooter, is still incomplete. If we reflect on the geographical extent of surface drained by rivers such as now enter the Bay of Bengal, and then consider how complete the blending together of the greater part of their transported matter has already become, and throughout how vast a delta it is spread by numerous arms, we no longer feel so much surprise at the area occupied by some ancient formations of homogeneous mineral composition. But our surprise will be still farther lessened when we afterwards inquire into the action of tides and currents, in disseminating the matter accumulated in various deltas.

Stratification of Deposits in Deltas.—That the matter carried by rivers into seas and lakes is not thrown in confused and promiscuous heaps, but is spread out far and wide along the bottom, is well ascertained; and that it must for the most part be divided into distinct strata, may in part be inferred where it cannot be proved by observation. The horizontal arrangement of the strata, when laid open to the depth of twenty or thirty feet in the delta of the Ganges and in that of the Mississippi, is alluded to by many writers; and the same disposition is well known to obtain in all modern deposits of lakes and estuaries. Natural divisions are often occasioned by the interval of time which separates annually the deposition of matter during the periodical rains, or melting of the snow upon the mountains. The deposit of each year acquires some degree of consistency before that of the succeeding year is superimposed. A variety of circumstances also give rise annually to slight variations in colour, fineness of the particles, and other characters. Alternations of strata distinct in texture, mineral ingredients, or organic contents, are produced by numerous causes. Thus, for example, at one period of the year, drift wood may be carried down, and at another mud, as was before stated to be the case in the delta of the Mississippi; or at one time when the volume and velocity of the stream are greatest, pebbles and sand may be spread over a certain area, over which, when the waters are low, fine matter or chemical precipitates are formed. During inundations the current of fresh-water often repels the sea for many miles; but when the river is low, salt-water again occupies the same space. When two deltas are converging, the intermediate space is often, for reasons before explained, alternately the receptacle of different sediment derived from the converging streams. The one is, perhaps, charged with calcareous, the other with argillaceous matter; or one may sweep down sand and pebbles, the other impalpable mud. These differences may be repeated with considerable regularity, until a thickness of hundreds of feet of alternating beds is accumulated.

An examination of the strata of shell-marl now forming in the Scotch lakes, or of the sediment termed "warp," which subsides from the muddy water of the Humber, and other rivers, shows that recent deposits are often composed of a great number of extremely thin layers, either even or slightly undulating, and parallel to the planes of stratification. Sometimes, however, the laminæ in modern strata are disposed diagonally at a considerable angle, which appears to take place where there are conflicting movements in the waters. In January, 1829, I visited, in company with Professor L. A. Necker, of Geneva, the confluence of the Rhone and Arve, when those rivers were very low, and were cutting channels through the vast heaps of debris thrown down from the waters of the Arve, in the preceding spring. One of the sand-banks which had formed, in the spring of 1828, where the opposing currents of the two rivers neutralized each other, and caused a retardation in the motion, had been undermined; and the following is an exact representation of the arrangement of laminæ exposed in a vertical section. The length of the portion here seen is about twelve feet, and

No. 6.



the height five. The strata A A consist of irregular alternations of pebbles and sand in undulating beds: below these are seams of very fine sand, B B, some as thin as paper, others about a quarter of an inch thick. The strata c c are composed of layers of fine greenish-grey sand, as thin as paper. Some of the inclined beds will be seen to be thicker at their upper, others at their lower extremity, the inclination of some being very considerable. These layers must have accumulated one on the other by lateral apposition, probably when one of the rivers was very gradually increasing or diminishing in velocity, so that the point of greatest retardation caused by their conflicting currents shifted slowly, allowing the sediment to be thrown down in successive layers on a sloping bank. The same phenomenon is exhibited in older strata of all ages; and when we treat of them, we shall endeavour more fully to illustrate the origin of such a structure.

We may now conclude our remarks on deltas, observing that, imperfect as is our information of the changes which they have undergone within the last three thousand years, they are sufficient to show how constant an interchange of sea and land is taking place on the face of our globe. In the Mediterranean alone, many flourishing inland towns, and a still greater number of ports, now stand where the sea rolled its waves since the era when civilized nations first grew up in Europe. If we could compare with equal accuracy the ancient and actual state of all the islands and continents, we should probably discover that millions of our race are now supported by lands situated where deep seas prevailed in earlier ages. In many districts not yet occupied by man, land animals and forests now abound where the anchor once sank into the oozy bottom. We shall find, on inquiry, that inroads of the ocean have been no less considerable; and when to these revolutions produced by aqueous causes, we add analogous changes wrought by igneous agency, we shall, perhaps, acknowledge the justice of the conclusion of a great philosopher of antiquity, when he declared that the whole land and sea on our globe periodically changed places *.

* See an account of the Aristotelian system, p. 16, *ante*.