CHAPTER XVI.

Action of Tides and Currents, *continued*—Inroads of the sea upon the delta of the Rhine in Holland—Changes in the arms of the Rhine—Estuary of the Bies Bosch, formed in 1421—Formation of the Zuyder Zee, in the 13th century—Islands destroyed—Delta of the Ems converted into a bay—Estuary of the Dollart formed—Encroachment of the sea on the coast of Sleswick—Inroads on the eastern shores of North America—Tidal wave, called the Bore—Influence of tides and currents on the mean level of seas—Action of currents on inland lakes and seas—Baltic—Cimbrian deluge—Straits of Gibraltar—Under-currents—Shores of Mediterranean—Rocks transported on floating icebergs—Dunes of blown sand—Sands of the Libyan Desert—De Luc's natural chronometers.

THE line of British coast considered in the preceding chapter offered no example of the conflict of two antagonist forces; the entrance, on the one hand, of a river draining a large continent, and on the other, the flux and reflux of the tide, aided by a strong current setting across a river's mouth. But when we pass over by the Straits of Dover to the continent, and proceed northwards, we find an admirable illustration of such a contest, where the Rhine and the ocean are opposed to each other, each disputing the ground now occupied by Holland; the one striving to shape out an estuary, the other to form a delta. There was evidently a period when the river obtained the ascendency, but for the last two thousand years, during which man has witnessed and actively participated in the struggle, the result has been in favour of the ocean, the area of the whole territory having become more and more circumscribed; natural and artificial barriers having given way, one after another, and many hundred thousand human beings having perished in the waves.

The Rhine, after flowing from the Grison Alps, copiously charged with sediment, first purges itself in the Lake of Constance, where a large delta is formed: then, swelled by the Aar and numerous other tributaries, it flows for more than six hundred miles towards the north; when, entering a low tract, it divides into two arms, not far north of Cleves—a point which

must therefore be considered the head of its delta. The left arm takes the name of the Waal, and the right, retaining that of the Rhine, sends off another branch to the left, called the Leck, and still lower down, another named the Yssel. After this last division, the smallest stream, still called the Rhine, passes by Utrecht, and loses itself in the sands before reaching the German Sea, a few miles below Leyden. It is common, in all great deltas, that the principal channels of discharge should shift from time to time; but in Holland so many magnificent canals have been constructed, and have diverted, from time to time, the course of the waters, that the geographical changes in this delta are endless; and their history, since the Roman era, forms a complicated topic of antiquarian research. The present head of the delta is about forty geographical miles from the nearest part of the gulf called the Zuyder Zee, and more than twice that distance from the general coast-line. The present head of the Nilotic delta is about eighty or ninety geographical miles from the sea; that of the Ganges, as we before stated, two hundred and twenty; and that of the Mississippi about one hundred and eighty, reckoning from the point where the Atchafalaya branches off, to the extremity of the new tongue of land in the Gulf of Mexico. But the comparative distance between the heads of deltas and the sea affords scarcely any data for estimating the relative magnitude of the alluvial tracts formed by their respective rivers. For the ramifications depend on many varying and temporary circumstances, and the area over which they extend does not hold any constant proportion to the volume of water in the river.

We may consider the Rhine, at present, as having three mouths; the southernmost or left arm being the Waal; the Leck, the largest of the three, being in the centre; and the Yssel forming the right or northern arm. As the whole coast to the south, as far as Calais, and on the north, to the entrance of the Baltic, has, from time immemorial, yielded to the force of the waves, it is evident that the delta of the Rhine, if it had advanced, would have become extremely prominent, and even if it had remained stationary, would long ere this have projected, like that strip of land already described, at the mouth of the Mississippi, beyond the rounded outline of the coast. But we find, on the contrary, that a line of islands which skirts

the coast have not only lessened in size, but in number also, while great bays in the interior have been formed by incursions of the sea. We shall confine ourselves to the enumeration of some of the leading facts, in confirmation of these views, and begin with the southernmost part of the delta where the Waal enters, which is at present united with the Meuse, in the same manner as an arm of the Po, before mentioned, has become confluent with the Adige. The Meuse itself had once a common embouchure with the Schelde, by Sluys and Ostburg, but this channel was afterwards sanded up, as were many others between Walcheren, Beveland, and other isles at the mouths of these rivers. The new accessions were almost all within the coast-line, and were far more than counterbalanced by inroads of the sea, whereby large tracts of land, and dunes of blown sand, together with towns and villages, were swept away between the fourteenth and eighteenth centuries. Besides the destruction of parts of Walcheren, Beveland, and populous districts in Kadzand, the island Orisant was in the year 1658 annihilated.

One of the most memorable eruptions occurred in 1421, where the tide, pouring into the mouth of the united Meuse and Waal, burst through a dam in the district named Bergse-Veld, and overflowed twenty-two villages, forming that large sheet of water called the Bies Bosch. No vestige even of the ruins of these places could ever afterwards be seen, but a small portion of the new bay became afterwards silted up, and formed an island. The Leck, or central arm of the Rhine, which enters the sea a little to the north of this new estuary, has, at present, a communication with it. The island Grunewert, which in the year 1228 existed not far from Houten, has been entirely destroyed. Farther to the north is a long line of shore, covered with sand dunes, where great depredations have been made from time to time. The church of Scheveningen, not far from the Hague, was once in the middle of the village, and now stands on the shore; half the place having been overwhelmed by the waves in 1570. Catwyck, once far from the sea, is now upon the shore; two of its streets having been overflowed, and land torn away to the extent of two hundred yards in 1719. It is only by aid of embankments, that Petten, and several other places farther north, have been defended against the sea.

We may next examine the still more important changes which have taken place on the coast opposite the right arm of the Rhine or the Yssel, where the ocean has burst through a large isthmus, and entered the inland lake Flevo, which, in ancient times, was, according to Pomponius Mela, formed by the overflowing of the Rhine over certain low lands. It appears, that in the time of Tacitus, there were several lakes in the present site of the Zuyder Zee, between Friesland and Holland. The successive inroads by which these, and a great part of the adjoining territory, were transformed into a great gulf, began about the beginning of the thirteenth century, and were completed about the end of the same. Alting gives the following relation of the occurrence, drawn from manuscript documents of contemporary inhabitants of the neighbouring provinces. In the year 1205, the island now called Wieringen, to the south of the Texel, was still a part of the main land, but during several high floods, of which the dates are given, ending in December, 1251, it was separated from the continent. By subsequent incursions, the sea consumed great parts of the rich and populous isthmus, a low tract which stretched on the north of Lake Flevo, between Staveren in Friesland, and Medemblick in Holland, till at length a breach was completed about the year 1282, and afterwards widened. Great destruction of land took place when the sea first broke in, and many towns were destroyed; but there was afterwards a reaction to a certain extent, large tracts at first submerged having been gradually redeemed. The new straits south of Staveren are more than half the width of those of Dover, but are very shallow, the greatest depth not exceeding two or three fathoms. The new bay is of a somewhat circular form, and between *thirty* and *forty* miles in diameter. How much of this space may formerly have been occupied by Lake Flevo, is unknown.

A series of isles, stretching from the Texel to the mouths of the Weser and Elbe, are evidently the last relics of a tract once continuous. They have greatly diminished in size, and have lost about a third of their number, since the time of Pliny*. While the delta of the Rhine has suffered so mate-

* Some few of them have extended their bounds, or become connected with others, by the sanding up of channels; but even these, like Juist, have generally

rially from the action of tides and currents, it cannot be supposed that minor rivers should have been permitted to extend their deltas. It appears, that in the time of the Romans there was an alluvial plain of great fertility, where the Ems entered the sea by three arms. This low country stretched between Groningen and East Friesland, and sent out a peninsula to the north-east towards Emden. A flood, in 1277, first destroyed part of the peninsula. Other inundations followed at different periods throughout the fifteenth century. In 1507, a part only of Torum, a considerable town, remained standing; and in spite of the erection of dams, the remainder of that place, together with market-towns, villages, and monasteries, to the number of fifty, were finally overwhelmed. The new gulf, called the Dollart, although small in comparison to the Zuyder Zee, occupied no less than six square miles at first; but part of this space was, in the course of the two following centuries, again redeemed from the sea. The small bay of Leybucht, farther north, was formed in a similar manner in the thirteenth century, and the bay of Harlbucht in the middle of the sixteenth. Both of these have since been partially reconverted into dry land. Another new estuary, called the Gulf of Jahde, near the mouth of the Weser, scarcely inferior in size to the Dollart, has been gradually hollowed out since the year 1016, between which era and 1651 a space of about four square miles has been added to the sea. The rivulet which now enters this inlet is very small; but Arens conjectures, that an arm of the Weser had once an outlet in that direction.

Farther north we find so many records of waste on the western coast of Sleswick, as to lead us to anticipate, that, at no distant period in the history of the physical geography of Europe,

given way as much on the north towards the sea, as they have gained on the south, or land side. Osterdun, Borkun, and several others, have been continually wasting away. Buissen is reduced to a sand-bank. Langeroog has been divided into three parts, and Wangeroog cut in two, many buildings having been carried away. Pliny counted twenty-three islands between the Texel and Eider, whereas there are now only sixteen, including Heligoland and Neuwerk.—Hoff, vol. i., p. 364. Heligoland at the mouth of the Elbe began in the year 800 to be much consumed by the waves. In the years 1300, 1500, and 1649, other parts were swept away, till at last only a rock and some low ground remained. Since 1770, a current has cut a passage sufficiently deep to admit large ships through this remaining portion, and has formed two islands.—Hoff, vol. i., p. 57.

Jutland will become an island, and the ocean will obtain a more direct entrance into the Baltic.

Northstrand, up to the year 1240, was, with the islands Sylt and Föhr, so nearly connected with the main land as to appear a peninsula, and was called North Friesland, a highly cultivated and populous district. It measured from nine to eleven geographical miles from north to south, and six to eight from east to west. In the above-mentioned year it was torn asunder from the continent, and in part overwhelmed. The Isle of Northstrand, thus formed, was, towards the end of the sixteenth century, only four geographical miles in circumference, and was still celebrated for its cultivation and numerous population. After many losses, it still contained nine thousand inhabitants. At last, in the year 1634, on the evening of the 11th of October, a flood passed over the whole island, whereby one thousand three hundred houses, with many churches, were lost; fifty thousand head of cattle perished, and above six thousand men. Three small isles, one of them still called Northstrand, alone remained, which are now continually wasting.

A review of the ravages committed during the last two thousand years on the French, Dutch, and Danish coasts, naturally leads us to inquire how it happened that the Rhine was enabled, at some former period, to accumulate so large a delta. We might, perhaps, in reply to this question, repeat our former observation, that the set of tides and currents necessarily varies from time to time; and that different coasts become, each in their turn, exposed to their fury, and then again restored to a state of quiescence. Islands and promontories, moreover, may have disappeared, which once protected the present site of Holland; and that region may afterwards have been laid open, as the Baltic would be, if the ocean, by renewing its attacks, should finally breach the isthmus by Sleswick. It may also be suggested that if, in former times, the Straits of Dover were closed, the Rhine must have entered at the bottom of a deep bay, on the one side of which was Great Britain, and on the other the coasts of Norway, Denmark, the Netherlands, and France. The transporting power of the current might then have been much inferior to that afterwards exerted, when the tide ran freely through the channel. Pliny expressed his wonder that

the new lands at the mouths of the Tigris and Euphrates grew so rapidly, and "that the fluviatile matter was not swept away by the tide, which penetrated far above the tracts where great accessions were made*." The remark proves that he had considered the different condition of rivers in inland seas, and those discharging their waters into the ocean; but he did not reflect, that at the bottom of a deep bay where there is no current setting across the river's mouth, the ebbing and flowing of the waters cannot remove the sedimentary matter to a great distance.

After so many authentic details respecting the destruction of the coast in parts of Europe best known, it will be unnecessary to multiply examples of analogous changes in more distant regions of the world. It must not, however, be imagined that our own seas form any exception to the general rule. Thus, for example, if we pass over to the Eastern coast of North America, where the tides rise to a great elevation, we find many facts attesting the incessant demolition of land. At Cape May, for example, on the north side of Delaware Bay, in the United States, the encroachment of the sea was shown by observations made consecutively for sixteen years, from 1804 to 1820, to average above nine feet a year†; and at Sullivan's Island, which lies on the north side of the entrance of the harbour of Charlestown, in South Carolina, the sea carried away a quarter of a mile of land in three years, ending in 1786‡.

Of oceanic deltas in general, it may be said that, even where they advance, a large portion of the sediment is carried away by the movements of the sea. In the case of the great river of Amazons, the effects of the tides are still sensible at the Straits of Pauxis, five hundred miles from the sea, after an interval of several days spent in their passage up. The ponding back, therefore, of this great body of fresh-water, and the resistance opposed by the spring-tides to its descent, cause a rapid acceleration during the ebb, whereby the sediment is

* "Nec ullâ in parte plus aut celerius profecere terræ fluminibus invectæ. Magis id mirum est, æstu longè ultra id accedente non repercussas."—Hist. Nat., lib. vi., c. 27.

† New Monthly Mag., vol. vi., p. 69. ‡ Hoff, vol. i., p. 96.

carried far from the mouth of the river, and then borne by a current towards the north. Captain Sabine * found that the sea was discoloured by the waters of the Amazon, at the distance of not less than three hundred miles from its mouth, where they were still running, with considerable rapidity, in a direction inclined to that of the equatorial current of the ocean. The deposits derived from this source appear to have formed a large portion of the maritime districts of Guiana, and are said to extend even to the mouths of the Orinoco, ten degrees of latitude farther north, where that river also is pouring an annual tribute of earthy matter into the sea.

Before we conclude our remarks on the action of the tides, we must not omit to mention the wave called "the Bore," which is a sudden and abrupt influx of the tide into a river or narrow strait. Those rivers are most subject to this wave which have the greatest embouchures in proportion to the size of their channels; because, in that case, a larger proportion of tide is forced through a passage comparatively smaller. For this reason, the Bristol Channel is very subject to the Bore, where it is of almost daily occurrence, and at spring-tides rushes up the estuary with extraordinary rapidity. The same phenomena is frequently witnessed in the principal branches of the Ganges, and in the Megna. "In the Hoogly, or Calcutta river," says Rennell, "the Bore commences at Hoogly Point, the place where the river first contracts itself, and is perceptible above Hoogly Town; and so quick is its motion, that it hardly employs four hours in travelling from one to the other, though the distance is near seventy miles. At Calcutta it sometimes occasions an instantaneous rise of five feet; and both here, and in every other part of its track, the boats, on its approach, immediately quit the shore, and make for safety to the middle of the river. In the channels, between the islands in the mouth of the Megna, the height of the Bore is said to exceed twelve feet; and is so terrific in its appearance, and dangerous in its consequences, that no boat will venture to pass at spring-tide †." These waves may sometimes cause inundations, undermine cliffs, and still more frequently sweep away trees and

* Account of Experiments to determine the Figure of the Earth, &c., p. 446.

† Rennell, Phil. Trans., 1781.

land animals from low shores, whereby they may be carried down, and ultimately imbedded in submarine deposits.

There is another question, in regard to the effects of tides and currents, not yet fully determined—how far they may cause the mean level of the ocean to vary at particular parts of the coast. It has been supposed, that the waters of the Red Sea maintain a constant elevation of between four and five fathoms above the neighbouring waters of the Mediterranean, at all times of the tide; and that there is an equal, if not greater diversity, in the relative levels of the Atlantic and Pacific, on the opposite sides of the isthmus of Panama. But the levellings recently carried across that isthmus by Mr. Lloyd, to ascertain the relative height of the Pacific Ocean at Panama, and of the Atlantic at the mouth of the river Chagres, have shown, that the difference of mean level between those oceans is not considerable. According to the result of this survey, on which great dependence may be placed *, the mean height of the Pacific is three feet and a half, or 3.52 above the Atlantic, if we assume the mean level of the sea to coincide with the mean between the extremes of the elevation and depression of the tides. For between the extremes of elevation and depression of the greatest tides in the Pacific, at Panama, there is a difference of 27.44 feet; but the mean difference at the usual spring-tides is 21.22 feet: whereas at Chagres this difference is only 1.16 feet, and is the same at all seasons of the year. The tides, in short, in the Caribbean Sea are scarcely perceptible, not exceeding those in some parts of the Mediterranean; whereas the rise is very high in the bay of Panama. But astronomers are agreed, that, on mathematical principles, the rise of the tidal wave above the mean level of a particular sea must be greater than the fall below it; and although the difference has been hitherto supposed insufficient to cause an appreciable error, it is, nevertheless, worthy of observation, that the error, such as it may be, would tend to reduce the difference now inferred, from the observations of Mr. Lloyd,

* Mr. Lloyd received from General Bolivar a special commission to survey the isthmus of Panama, with the view of ascertaining the most eligible line of communication between the two seas. He was assisted by Capt. Falmarck, a Swedish officer of engineers; and the result of their labours will appear in the Philosophical Transactions.

to exist between the levels of the two oceans. It is scarcely necessary to remark how much all points relating to the permanence of the mean level of the sea must affect our reasoning on the phenomena of estuary deposits; and it is to be hoped, that further experiments will be made to ascertain the amount of irregularity, if any exist.

ACTION OF CURRENTS IN INLAND LAKES AND SEAS.

Coast of the Baltic.—In such large bodies of water as the North American lakes, the continuance of a strong wind in one direction often causes the elevation of the water and its accumulation on the leeward side; and while the equilibrium is being restored, powerful currents are occasioned. By this means the finer sedimentary particles, as we before mentioned, are borne far out from the deltas, and argillaceous and calcareous marls are formed far from the shores. In the Euxine, also, although free from tides, we learn from Pallas, that there is a sufficiently strong current to undermine the cliffs in many parts, and particularly in the Crimea. But the force of currents is exerted in a much more powerful degree in seas like the Mediterranean and the Baltic, where strong currents set in from the ocean, whether driven in during tempests or from other more constant causes. The current which runs through the Cattegat, or channel of communication between the German Ocean and the Baltic, not only commits dreadful devastations on the isles of the Danish Archipelago, but acts, though with less energy, on the coasts far in the interior, as, for example, in the vicinity of Dantzic *. The continuance of north-westerly gales and storms in the Atlantic, during the height of the spring-tides, has often been attended with the most fatal disasters on the Danish coast, where, during the last ten centuries, we find authentic accounts of the wearing down of promontories, the deepening of gulfs, the conversion of peninsulas into

* Thus, in the year 1800, near the village of Jershoft a great mass was projected by a landslip into the sea. Hela, a point of land running out before Dantzic, was formerly much broader than at present; and farther north, in Samland, woods and territories have been torn away by the sea.—Hoff, vol. i., p. 73, who cites Pisansky.

islands, and the waste of isles; while in several cases marsh land, defended for centuries by dikes, has at last been overflowed, and thousands of the inhabitants whelmed in the waves *.

We have before enumerated the ravages of the ocean on the eastern shores of Sleswick; and as we find memorials of a series of like catastrophes on the western coast of that peninsula, we can scarcely doubt that a large opening will, at some future period, connect the Baltic with the North Sea. Jutland was the Cimbrica Chersonesus of the ancients, and was then evidently the theatre of similar calamities; for Florus says, "Cimbri, Theutoni, atque Tigurini, ab extremis Galliæ profugi, cum terras eorum inundasset Oceanus, novas sedes toto orbe quærebant†." Some have wished to connect this "Cimbrian deluge" with the bursting of the isthmus between England and France, and with other supposed convulsions; but when we consider the annihilation of Heligoland and Northstrand, and the other terrific inundations in Jutland and Holstein since the Christian era, wherein thousands have perished, we need not resort to hypothetical agents to account for the historical relation. The wave which, in 1634, devastated the whole coast of Jutland, committed such havoc, that we must be cautious how we reject hastily the traditions of like catastrophes on the coasts of Kent, Cornwall, Pembrokeshire, and Cardigan; for, however sceptical we may be as to the amount of territory destroyed, it is very possible that former inroads of the sea may have been greater on those shores than any witnessed in modern times.

* Thus the island Barsoe, on the coast of Sleswick, has lost year after year an acre at a time. The island Alsen suffers in like manner. The peninsula Zingst was converted into an island in 1625. There is a tradition, that the isle of Rugen (which is composed of tertiary limestone) was originally torn by a storm from the main land of Pomerania; and it is known, in later times, to have lost ground, as in the year 1625, when a tract of land was carried away. Some of the islands which have wasted away consist of ancient alluvial accumulations, containing blocks of granite, which are also spread over the neighbouring main land. The Marsh Islands are mere banks, like the lands formed of the "warp" in the Humber, protected by dikes. Some of them, after having been inhabited with security for more than ten centuries, have been suddenly overwhelmed. In this manner, in 1216, no less than ten thousand of the inhabitants of Eyderstede and Ditmarsch perished; and on the 11th of October, 1634, the islands and the whole coast as far as Jutland suffered by a dreadful deluge.

† Lib. iii., cap. 3.

Straits of Gibraltar.—It is well known that a powerful current sets constantly from the Atlantic into the Mediterranean, and its influence extends along the whole southern borders of that sea, and even to the shores of Asia Minor. Captain Smyth found, during his survey, that the central current ran constantly at the rate of from three to six miles an hour eastward into the Mediterranean, the body of water being three miles and a half wide. But there are also two lateral currents—one on the European, and one on the African side; each of them about two miles and a half broad, and flowing at about the same rate as the central stream. These lateral currents ebb and flow with the tide, setting alternately into the Mediterranean and into the Atlantic. The escape of the great body of water, which is constantly flowing in, has usually been accounted for by evaporation, which must be very rapid and copious in the Mediterranean; for the winds blowing from the shores of Africa are hot and dry, and hygrometrical experiments recently made in Malta and other places show that the mean quantity of moisture in the air investing the Mediterranean is equal only to one half of that in the atmosphere of England. It is, however, objected that evaporation carries away only fresh-water, and that the current is continually bringing in salt-water: why, then, do not the component parts of the waters of the Mediterranean vary? or, why do they remain apparently the same as those of the ocean? Some have imagined that the excess of salt might be carried away by an under-current running in a contrary direction to the superior; and this hypothesis appeared to receive confirmation from a late discovery that the water taken up about fifty miles within the Straits, from a depth of six hundred and seventy fathoms, contained a quantity of salt *four times greater* than the water of the surface. Dr. Wollaston*, who analysed this water obtained by Captain Smyth, truly inferred that an under-current of such denser water, flowing outward, if of equal breadth and depth with the current near the surface, would carry out as much salt below as is brought in above, although it moved with less than one-fourth part of the velocity, and would thus prevent a perpetual increase of saltness in the Mediterranean beyond that

* On the Water of the Mediterranean, by W. H. Wollaston, M.D., F.R.S., Phil. Trans. 1829, part I., p. 29.

existing in the Atlantic. It was also remarked by others, that the result would be the same if, the swiftness being equal, the inferior current had only a fourth of the volume of the superior. At the same time there appeared reason to conclude that this great specific gravity was only acquired by water at immense depths; for two specimens of the water taken at the distance of some hundred miles from the Straits, and at depths of four hundred, and even four hundred and fifty fathoms, were found by Dr. Wollaston not to exceed in density that of many ordinary samples of sea-water. Such being the case, we can now prove that the vast amount of salt brought into the Mediterranean *does not* pass out again by the Straits. For it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the Capes of Trafalgar and Spartel, which are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on the side of Cape Spartel, is only *two hundred and twenty fathoms*. It is therefore evident that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than two hundred and twenty fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar.

What, then, becomes of the excess of salt?—for this is an inquiry of the highest geological interest. The Rhone, the Po, and many hundred minor streams and springs, pour annually into the Mediterranean large quantities of carbonate of lime, together with iron, magnesia, silica, alumina, sulphur, and other mineral ingredients, in a state of chemical solution. To explain why the influx of this matter does not alter the composition of this sea has never been thought to present a great difficulty; for it is known that calcareous rocks are forming in the delta of the Rhone, in the Adriatic, on the coast of Asia Minor, and in other localities. Precipitation is acknowledged to be the means whereby the surplus mineral matter is disposed of, after the consumption of a certain portion in the secretions of testacea and zoophytes. But some have imagined that, before muriate of soda can, in like manner, be precipitated, the whole Mediterranean ought to become as much saturated with salt as the brine-springs of Cheshire, or Lake Aral, or the

Dead Sea. There is, however, an essential difference between these cases; for the Mediterranean is not only incomparably greater in extent than the two last-mentioned basins, but its depth is enormous. In the narrowest part of the Straits of Gibraltar, where they are about nine miles broad, between the Isle of Tariffa and Alcanzar Point, the depth varies from one hundred and sixty to five hundred fathoms; but between Gibraltar and Ceuta, Captain Smyth sounded to the extraordinary depth of *nine hundred and fifty fathoms!* where he found a gravelly bottom, with fragments of broken shells. Saussure sounded to the depth of two thousand feet, within a few yards of the shore, at Nice. What profundity, then, may we not expect some of the central abysses of this sea to reach! The evaporation being, as we before stated, very rapid, the surface water becomes impregnated with a slight excess of salt; and its specific gravity being thus increased, it instantly falls to the bottom, while lighter water rises to the top, or that introduced by rivers, and by the current from the Atlantic, flows over it. But the heavier fluid does not merely fall to the bottom, but flows on till it reaches the lowest part of one of those submarine basins into which we must suppose the bottom of this inland sea to be divided. By the continuance of this process, additional supplies of brine are annually carried to deep repositories, until the lower strata of water are fully saturated, and precipitation takes place—not in thin films, such as are said to cover the alluvial marshes along the western shores of the Euxine, nor in minute layers, like those of the salt "étangs" of the Rhone, but on the grandest scale—continuous masses of pure rock-salt, extending, perhaps, for hundreds of miles in length, like those in the mountains of Poland, Hungary, Transylvania, and Spain*.

* As to the existence of an inferior current flowing westward, none of the experiments made in the late survey give any countenance whatever to this popular notion; and it seems most unnecessary to resort to it, not only because the expenditure of the Mediterranean, by evaporation, must be immense, but because it is not yet proved that the two lateral currents, which conjointly exceed in breadth that of the centre, do not restore the equilibrium, if occasionally disturbed. They ebb and flow with the tide, but they may carry more water to the west than to the east. The opinion, that in the middle of the Straits the water returned into the

The Straits of Gibraltar are said to become gradually wider by the wearing down of the cliffs on each side at many points; and the current sets along the coast of Africa so as to cause considerable inroads in various parts, particularly near Carthage. Near the Canopic mouth of the Nile, at Aboukir, the coast was greatly devastated in the year 1784, when a small island was nearly consumed. By a series of similar operations, the old site of the cities of Nicopolis, Taposiris, Parva, and Canopus, have become a sandbank*.

Floating Icebergs.—Marine currents are sometimes instrumental in the transportation of rock and soil, by floating large masses of ice to great distances from the shore. When glaciers in northern latitudes descend the valleys burdened with alluvial debris, and arrive at the shore, they are frequently detached, and float off. Scoresby† counted five hundred icebergs in latitude 69° and 70° north, rising above the surface from the height of one to two hundred feet, and measuring from a few hundred yards to a mile in circumference. Many of these contained strata of earth and stones, or were loaded with beds of rock of great thickness, of which the weight was conjectured to be from fifty thousand to one hundred thousand tons. As the mass of ice below the level of the water is between seven and eight times greater than that above, these masses may sometimes take the ground in great numbers, in particular parts of the sea, and may, as they dissolve, deposit such masses of matter on particular parts of the bottom of the deep, or on the shores of some isles, as may offer perplexing problems to future geologists. Some ice islands have been known to drift from Baffin's

Atlantic by a submarine counter-current, first originated in the following circumstance. M. Du l'Aigle, commander of a privateer called the Phœnix, of Marseilles, gave chase to a Dutch merchant ship, near Ceuta Point, and came up with her in the middle of the gut, between Tariffa and Tangier, and there gave her one broadside, which directly sunk her. A few days after, the sunk ship, with her cargo of brandy and oil, arose on the shore near Tangier, which is at least four leagues to the westward of the place where she sunk, and directly against the strength of the *central* current.—Phil. Trans., 1724. It seems obvious that the ship in this case was brought back by one of the *lateral* currents, not by an *under* current.

* Clarke's Travels in Europe, Asia, and Africa, vol. iii., pp. 340 and 363, 4th edition. † Voyage in 1822, p. 233.

Bay to the Azores, as we before stated, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope.

Sand Hills.—It frequently happens, where the sea is encroaching on a coast, that perpendicular cliffs of considerable height, composed of loose sand, supply, as they crumble away, large quantities of fine sand, which, being in mid-air when detached, are carried by the winds to great distances, covering the land or barring up the mouths of estuaries. This is exemplified in Poole Bay, in Hampshire, and in many points of the coast of Norfolk and Suffolk. But a violent wind will sometimes drift the sand of a sea-beach, and carry it up with fragments of shells to great heights, as in the case of the sands of Barry, at the northern side of the estuary of the Tay, where hills of this origin attain the extraordinary height of from two hundred and fifty to three hundred feet. On the coast of France and Holland long chains of these dunes have been formed in many parts, and often give rise to very important geological changes, by barring up the mouths of estuaries, and preventing the free ingress of the tides, or free efflux of river water. The Bay of Findhorn, in Morayshire, has been blocked up in this manner since the beginning of the seventeenth century, so that large vessels can no longer enter; and we have already mentioned changes of a similar kind at Great Yarmouth, in Norfolk. Chains of sand-hills have also accumulated on the shores of the delta of the Nile, especially opposite the Lakes of Brulos and Menzala, forming mounds whereby the waters of these lakes are retained*. By the alternate formation and destruction of such barriers, fresh-water and marine deposits may sometimes be formed in succession on the same spots, and afterwards be laid dry by the exclusion of the tides, and be again submerged when high tides break into the estuary again. Many of the phenomena of submarine forests may, perhaps, admit of explanation, when the effects of such barriers of sand have been more carefully studied. The loose sand often forms a firm mass when bound together by the roots of plants fitted for such a soil, particularly the Arundo arenaria, and Elymus arenarius.

* Rennell's Herodotus.

A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift-sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells. By the shifting of the sands, the ruins of ancient buildings have been discovered; and, in some cases where they have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some localities, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand *. Terrestrial shells are found enclosed entire in this rock.

The moving sands of the African deserts have been driven by the west winds over all the lands capable of tillage on the western banks of the Nile, except such as are sheltered by mountains †. The ruins of ancient cities are buried under these sands between the Temple of Jupiter Ammon and Nubia. De Luc attempted to infer the recent origin of our continents, from the fact that the sands of the desert have only arrived in modern times at the fertile plains of the Nile. This scourge, he said, would have afflicted Egypt for ages anterior to the times of history, if the continents had risen above the level of the sea several hundred centuries before our era ‡. But the author proceeded in this, as in all his other chronological computations, on a multitude of gratuitous assumptions, not one of which he had the candour to state explicitly. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period; for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand-flood might have been long posterior to the formation of the greater portion of that continent. That the different parts of Europe were not all elevated at one time, is now generally admitted. De Luc should also have pointed out the depth of

* Boase on the Submersion of part of the Mount's Bay, &c. Trans. Roy. Geol. Society of Cornwall, vol. ii., p. 140.

† De Luc, Mercure de France, Sept. 1809. ‡ Ibid.

drift sand in various parts of the great Libyan deserts, and have shown whether any valleys of large dimensions had been filled up,—how long these arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history. If, in the absence of all these necessary elements of the computation, the doctrines of this author, respecting "natural chronometers," were extremely popular, and that, too, in an age when close reasoning and rigorous investigation were applied to other branches of physical science, it only proves how strong were the prepossessions in regard to time which impeded the progress of geology.

There is not one great question relating to the former changes of the earth and its inhabitants into which considerations of time do not enter; and so long as the public mind was violently prejudiced in regard to this important topic, men of superior talent alone, who thought for themselves, and were not blinded by authority, could deduce any just conclusions from geological evidence. It ought not, therefore, to be matter either of surprise or discouragement to us, that at the commencement of the present century, when for three hundred years much labour had been devoted to these investigations, so few sound and enlightened views had met with general reception.