Notes on the Formation of extensive Conglomerate and Gravel Deposits. By Henry T. de la Beche, Esq. F.R.S. &c.

(Extracted from the Philosophical Magazine of March, 1830.*)*

At the present time, when actual causes are by some geologists considered adequate to the production of nearly all the phænomena which we observe in the structure of the earth's crust, it becomes important to ascertain, as far as our knowledge will permit, the value of such causes, and thence judging how far the whole, or any part of them, may have been capable of forming rocky masses of which the surface of our planet is composed.

It has been imagined that extensive conglomerate and gravel deposits are owing to causes similar to those now existing; in some cases to the joint action of rivers on their beds and seas on their shores, and in others solely to the action of the former. To ascertain if such causes could have produced such effects, we should examine the present action of seas on their coasts and rivers on their beds, so far as regards the production of rounded gravels.

I. *Action on Tidal Seas on their Coasts.*

It has long been known, and often remarked, that seas gain on some coasts and lose on others; in other words, that seas cut away and destroy rocks, even the hardest, in some places, and pile up the detritus, acquired either from this destruction, or from rivers, in others. Playfair has well observed, that rounded gravel "can only be found in the beds of rivers, or on the shores of the sea; for in the depths of the ocean, though currents are known to exist, yet there can be no motion of the water sufficiently rapid to produce the attrition required to give a round figure and smooth surface to hard and irregular pieces of stone."* Although it is acknowledged that no trituration of rock fragments into rounded gravel is now effected in the bottom of the ocean, it has been supposed that gravels formed or collected on the shores of continents or islands are conveyed there, to be consolidated, and converted into beds of conglomerate. An attention to the effects of seas on their coasts will, however, show us that these gravels do not travel outwards into great depths, but that the ocean exerts its power to throw them back upon the dry land whence they were derived. Attention to a sea coast with a shingle beach during

* Illustrations of the Huttonian Theory, p. 7.

a gale of wind will show this. Every breaker is more or less charged with shingles, which are forced forward as far as the broken wave can reach, and in their shock against the beach drive others before them, that were not held in momentary mechanical suspension by the breaker. By these means, and particularly at the top of high-water, the shingles are projected on the land beyond the reach of retiring waves. Heavy gales and high tides combined seem to produce the highest beaches; they do indeed sometimes cause breaches in the ramparts they have raised against themselves, but they quickly repair it. The great accumulation of beach upon the land being effected at the height of the tide, when the tide ebbs, it is quite clear the sea cannot deprive the land of what it has thrown upon it. In moderate weather and during neap tides various little lines of beach are formed, which are swept away by a heavy gale; and when these little beaches are so obliterated, it might be supposed by a casual observer that the shingles of the lines, so apparently swept away, are but accumulated elsewhere. These remarks of course only apply to such situations where the sea, during gales, has no access to cliffs or piers, from whence there might be a back-wave carrying all before it? but to such situations, and they are abundant, where the breakers meet with no resistance, and strike nothing but the more or less inclined plane of a shingle beach. Even in cases where the waves in heavy gales and high tides do reach cliffs, and for the time remove shingle beaches, it is curious to see how soon these latter are restored when the weather moderates, and when the breakers, in consequence of a diminished projecting force, cease to recoil from the cliff behind.

Shingle beaches travel in the direction of the prevalent winds, or those which produce the greatest breakers; of this excellent examples are seen on our southern coast, where the prevalent winds being W. or S.W. the beaches travel eastwards. If rocky projections or points of land occur on the east of any shingle beach so travelling, the sea soon forms a considerable barrier against itself, more particularly when the mouths of valleys or flat lands back the shingles; such flat lands or mouths of valleys thus obtaining protection from the ravages of the sea (Plate II. fig. 2). If the streams which discharge themselves into the sea from such valleys or flat lands are small, their mouths are barred by the beach, and the water percolates through the shingles. Such streams, in cases of flood, cut through the shingle a passage again to be dammed up by the effects of a gale of wind.

It would appear that though shingle or pebble beaches travel coastways, in consequence of the general direction of the breakers, there is no evidence of their being transported outwards or into the depths of the ocean. The seaward front of most shingle beaches, particularly when they defend tracts of flat country, is bounded by a line along the edge of the beach; above this line the beach generally makes a considerable angle with the sands, in cases of sandy flats.

In cases where shingle beaches are not entirely quitted by the tide, sandy, shelly, or very fine gravel soundings are commonly obtained a short distance from the shore, unless the bottom be rocky, in which latter case it is generally a mixture of sand, rock, or fine gravel* and shells. In fact, if the present continents or islands were elevated above, or the sea depressed beneath, the present ocean level, shingle beaches would be found to fringe the land, but not to extend far seaward.

It is but rarely that the pebbles on shingle beaches are found to have travelled considerable distances, even along shore; in the Chesil Bank indeed,—that extraordinary ridge of pebbles about sixteen miles long, which connects the Isle of Portland with the main land,—the shingles seem to have travelled twenty or thirty miles from the westward. This bank is remarkable on many accounts, and among others for the power the sea has exhibited of heaping up a barrier against itself, even when not backed by land, provided it has two solid resting places for each end of the bank. It also appears that the shingles do not travel from the bank; for Portland Roads have a bottom of clay, the continuation of the Kimmeridge clay of the base of Portland and the Ferry Point, affording one of the best holding grounds for vessels in the Channel; and the bottom to the S.W. of the bank is sand, fine gravel with shells, or rock.†

Single beaches are generally formed on the sea shores under consideration, from the harder parts of the neighbouring coasts being destroyed by the joint action of atmospheric agency, land springs, and the sea. The softer portions are soon washed away, and even the harder, first forming the shingles, are eventually ground down into sand. It is, however, by no means un-

* These gravels are generally fine, very different in size from the common shingles of beaches. It might be supposed by persons unaccustomed to take soundings, that the gravels marked on charts were coarse, resembling shingles; but in general such gravels do not exceed the size of a nut, and are most commonly smaller. Such fine gravels are very frequently mixed with shells; and no soundings are more common on coasts, particularly our own coasts, than gravel with shells, sand and gravel, and sand and shells.

† This bank also possesses considerable interest in another point of view. The hills behind the bank are composed of clay and loose rubbly or slaty limestones (Forest marble, Cornbrash, Oxford clay, Oxford oolite, and Kimmeridge clay,) which, if not protected by this mass of shingles, would soon be swept away before the heavy seas rolling in from the Atlantic, and breaking with so much fury on this coast. That they have not been thus attacked is evident, for the large rounded forms of the hills and dales are only here and there marked by little cliffs, cut by the water intervening between the bank and main-land; it therefore seems fair to conclude, that since the existing order of things in the Chesil Bank has existed, and that the main-land behind it has not, since it acquired its gentle undulatory form, been attacked by the furious waves from the Atlantic.

common to find, in coasts composed of both hard and soft materials, taluses of blocks or large indurated concretions, detached from the cliffs, and defending them from that quick destruction that would otherwise ensue.

The effect of the joint action of the sea and air upon hard rocks is well seen in the Scilly Islands. There the granite decomposes into its usual blocky forms, the angles gradually disappear, and eventually the masses fall on the beach, where the tremendous breakers of that coast grind them against each other into balls, and often hurl them high up on the shore.

I know not how Playfair could have imagined that following waves were merely confined to the shore*; for the destruction of coasts of equal hardness almost always bears a proportion to the extent of open sea to which they are exposed, allowance being always made for the force and duration of prevalent winds.

The power of the sea to erect barriers against itself, under other circumstances than those previously noticed, is very ably illustrated by Mr. R. C. Taylor, in his Geology of East Norfolk. After observing that the land encroachment at Lowestoft Ness had been effected at distinct and distant intervals; that its form had been influenced by the direction of the currents in the channel, and the position of the adjacent shoals, and that the lines of growth are indicated by a series of concentric ridges or embankments, inclosing certain areas, he observes "a rampart of heavy materials is first thrown up to an unusual altitude, by some extraordinary tide, attended with a violent gale. Subsequent tides extends the base, and heap up lighter substances on its summit. Sand is blown from the beach and fills the interstices. The *Arundo arenaria* and other plants, by degrees obtain a footing; creep along the ridge, give solidity to the mass, and in some cases forms a matted covering of turf: meanwhile another mound is forming externally, and by the like process rises and gives protection to the first. Occasionally the sea forces its way through one of the external and incomplete mounds, but it is singular to observe how soon the breach is repaired†."

In tropical countries the advance of the Mangrove trees outwards from sheltered situations at the bottom of creeks, bays, or the mouths of rivers, has a great tendency to increase land at the expense of the sea. So long as the sea continues sheltered, it throws up no barrier against the Mangroves; but when their strange stilt-like roots have advanced the mass of

* Illustrations of the Huttonian Theory, p. 432,—Had it been the Professor's fate to have lain in the trough of a heavy following sea in the middle of the Atlantic, or to have rejoiced in the dexterity of the helmsman in avoiding the shock of a far seen heavy wave, he would hardly have supposed that following waves were confined to the shore.

† On the Geology of East Norfolk, p. 52, and the highly instructive plate 6.

these trees to places exposed to the waves, the sea accumulates a beach against them, forming lagoons or lakes*.

I have observed off Jamaica, that the coral reefs and islands are protected on the side of the prevalent winds and breakers by shingle beaches composed of rounded pieces, and, occasionally, large fragments of coral†.

From what has been above stated, it will be seen that the sea endeavours to throw back upon the land the detritus it has received from it, and even, as in the case of corals and shells, of hard substances that have been formed in it, and that the pebbles or shingles are not likely to quit the coast under ordinary circumstances‡; indeed the common velocity of tides seems inadequate to transport them in moderate depths, where the power of the waves on the surface of the sea ceases.

II. *Action of Tideless Seas on their Coasts.*

The principal difference between these and those above noticed, consists in the phænomena attendant on the discharge of rivers into them, which will be noticed under the head of rivers. Shingle beaches are accumulated, and protect lands behind them, but from the want of tide we do not see their bases, and they appear of inferior dimensions to those on tidal seas. From the want of tide, which should successively present different portions of a cliff to the greatest action of the breakers, the destruction of coasts is not so great, and the spaces of open sea being more or less limited, and the battering power of the breakers is greatly inferior to that of the great ocean swell, discharged on a tidal coast. Still the same rejection of detritus derived from the land will be observed when it does not fall into deep water, beyond the reach of the moving power of such seas; and we know of no current sufficiently strong in tideless seas to distribute the gravel that has been thrown into their deep waters.

Large lakes present nearly the same phænomena as to shin-

---

* Lakes of this description at Albion, south side of Jamaica, contain numerous alligators (Crocodilus actus, *Cuv.*) and marine fish. The zoology of some of these lakes would be interesting to geologists, as they become brackish from the heavy rains that drain into them from the mountain sides, and may thus contain marine and fresh-water animals.

† I remarked one or two curious instances of the growth of land behind such beaches at Old Harbour. There are many islands, some covered by Mangrove trees; one in particular struck me: on its windward side there was a beach of coral shingles, evidently on the increase, the older or back part bound together by tropical sea-coast creepers; behind these were the Mangroves, mixed, if my recollection does not fail me, with some other tropical sea-shore trees near the beach, but alone and advancing into the sea on the leeward side of the island, where, not being exposed to breakers, they accumulated silt and mud about their roots, and thus extended the island in that direction.

‡ Even in the case of sands, which do not enter within the scope of this memoir, there is a tendency in the sea to throw them upon the land. Witness the sandy Dunes, so common on various coasts.

gle beaches as tideless seas; and as most of them are lower at one time than another, we may observe the shingle beaches better; and it is by no means uncommon to see a skirting of shingle round them when their waters are low.

III. *Action of Rivers on their Beds.*

Rivers most frequently, though not always, take their rise among hills and mountains, and are supplied either by the melting of snows or glaciers, the draining of rain waters, or by springs. The two former particularly bring down fragments formed by discomposition from the neighbouring rocks, into the bed of the river. In mountainous regions fragments of rocks of greater or less dimensions fall into the river from the mountain sides. The river also undermines its banks, and the loose decomposed surface of the rocks tumbles into it. From these sources the river obtains the materials for its gravel. The greater the velocity of the water, the sooner will the angular fragments be ground by attrition into pebbles. Rivers are most rapid in high mountain ranges, having to find their way from a high to a much lower level in comparatively short distances. Now as the decomposition and the fall of rocks is greatest amid high mountains, and as the rivers are most rapid in the same situations, the greatest quantity of river gravel is there produced.

In low situations, where rivers lose their rapidity, gravels are rarely formed, but sands or mud are common. In times of flood, gravels formed in their beds, in the high lands, are brought down into their beds in the plains; but even these do not appear to travel far. It is asserted, but has not been proved, that rivers carry their gravels to considerable distances; but I cannot avoid suspecting that pebbles derived from great gravel plains, or from cliffs of loosely aggregated conglomerate, such as the Nagelfluhe of Switzerland, cut away by the rivers, and thus carried into their beds, have been sometimes mistaken for gravels transported from great distances by the rivers. There is no want of gravel, composed of pebbles from the high Alps, in the bed of the Rhone, where that river quits the lake of Geneva, or in the bed of the Ticino, where it quits the Lago Maggiore; and I presume no person would imagine that the gravels have been brought down by either river from the Alps, as all such pebbles must have been quickly deposited in the bottoms of the respective lakes. In both instances the gravels have been derived from conglomerates formed by more general causes, cut through by the rivers after they have quitted the lakes. Innumerable other instances might be produced. The same observation applies to rivers cutting great gravel plains, where they obtain pebbles, derived originally from distant rocks, from their banks, but to transport which, by the rivers, physical obstacles oppose themselves. Such obstacles commonly present themselves in the shape of lakes, the beds of which it is impossible the rivers could have cut. Into these the rapid and detritus-bearing rivers deposit their gravel and sand, so that such rivers constantly tend to fill up lakes so situated. The detritus, thus driven into a lake, will always be deposited in a peculiar form, variously modified according to the depth of the lake, and the pebble or sandy nature of the detritus.

In cases where rivers discharge pebbles into lakes, that of the Drance torrent for instance, which deposits its pebbles in the lake of Geneva, the advance is gradual and local. It is obvious that the stratification resulting from these causes must have a peculiar figure; and supposing a lake, nearly filled by these means, to be examined after drainage, the beds of gravel, sand or clay, would be very irregular, and not be disposed horizontally.

To take examples from the Alps; the present transport of river-formed pebbles from a large part of these mountains is prevented by numerous lakes on their north and south sides. On the north the Rhone deposits its mountain detritus in the lake of Constance, and the Rhone its transported pebbles and sands in the lake of Geneva. Between these the lakes of Zurich, Lucerne, &c. receive the gravels of other alpine rivers. On the south the Lago Maggiore receives the alpine detritus of the Ticino, the lake of Como that of the Adda, and the lakes of Garda, &c. perform the same office to other rivers. From these circumstances it will be evident that the river-formed pebbles of a large portion of the Alps cannot travel by the rivers into either the ocean or the Mediterranean: it might at first sight be supposed that the Po could transport the river-formed pebbles of a large portion of the Alps into the Adriatic; but the Po becomes a sandy-bended river before it receives the Ticino.

It may also be supposed that though the Rhone can transport no alpine detritus beyond the spot where it enters the lake of Geneva, yet that, after it has quitted that lake, it can carry all the pebbles borne down by the Arve from the district of Mont Blanc. I have often stood at the junction of the two rivers, and could not perceive that there were marks of any great transport of pebbles by the Arve, though it held, as is common to most alpine glacier waters, a considerable quantity of sand in mechanical suspension. The banks of both the Arve and the Rhone afford abundance of rounded alpine pebbles, and it would be no easy matter to say, how much of the pebble bed of the Arve was derived directly from the Alps, and how much from its banks near Geneva. But supposing the Arve did bring down abundantly pebbles from the Alps, their progress would seem to be checked at the gulf known as the Perte du Rhone.

As a general fact, it may be fairly stated that rivers, where their courses are short and rapid, bear down pebbles into the seas near them, as is the case with the torrents in the Maritime Alps; but that when their courses are long, and changed from rapid to slow, they deposit the pebbles where the force of the stream diminishes, and finally transport mere sand or mud to their mouths, as is the case with the Rhine, Rhone, Po, Danube, &c.

IV. *Discharge of Rivers into Tidal Seas.*

Tidal rivers, when large, most frequently keep their mouths open, though their is always a tendency to form bars and sandbanks; as for example, the Thames, the Severn, the Seine, the Loire, the Tagus, the St. Lawrence. In such situations, the ditritus, if any, is small enough to be held in mechanical suspension.

Some tidal rivers, or rivers which discharge themselves into tidal seas, form deltas when the force of the current is considerable, the tides small, or the seas not much subject to storms setting in shore, but merely to land and sea breezes. Of the mouths of such rivers, the Mississippi, the Oronoco, the Ganges, and the Yellow River of China, are examples. The detritus brought down by such rivers to their mouths is either sand or mud; therefore they do not contribute towards the formation of gravels at the bottom of the ocean.

Tidal rivers, when small, have a tendency to be blocked up by the sea, which often increases the bars into long banks of pebbles or sand, and it is with difficulty that the rivers deliver their waters into the sea; if the line of coast keeps the direction of the prevalent winds, the difficulty is increased, and the river generally gains a cliff or some hard ground, for one of its banks, before it can effect its escape into the sea. Good examples of these embouchures are seen on our southern coast. The Teign has a tendency to be blocked up by the bank upon which part of Teignmouth is built, named the Den, which the easterly winds, producing the greatest breakers on this beach, drives across the mouth of the river from E. to W., and the Teign escapes by the side of the Ness Point, which affords it support. The Axe is also deflected from its course by the pebble bank thrown up from W. to E. by the prevalent W. and S.W. winds, which here afford the heaviest breakers, and it escapes into the sea by supporting itself against Axmouth cliff; the sea, however, is constantly endeavouring to bar up its passage.

The harbour at Shoreham is a good example of a river deflected from its straight course by banks thrown up by the sea.

The river in this case escapes through a gap which it has formed in the bank itself.

It is obvious that in these cases the sea rejects the detritus it receives from the rivers, and forces it back, with the cliff detritus, upon the land.

The great flats on the western coast of South America are excellent examples of mud and sandy detritus forced back upon the land.

V. *Discharge of Rivers into Tideless Seas.*

These discharges are more or less modified, according to the open waters and prevalent winds to which they are exposed; and in general they tend to push forward deltas before them, which more or less protrude according to the depth of water into which the rivers deliver themselves, the greater or less shelter of the coasts, the quantity and nature of the detritus held in mechanical suspension, and the force of the current. Those rivers which push forward great deltas, such as the Nile, Rhone, Po, Danube, and Volga, bear mud and silt before them, and of these materials the deltas are almost wholly composed. The rivers which bear down pebbles into tideless seas are short, rapid, and of the torrent kind. Most frequently, from the high mountainous nature of the coasts, the gravel is deposited in deep water, and therefore, being out of the influence of breakers and waves, remains quietly at the bottom, unless carried by currents sufficiently strong to remove it: of currents so strong we have not any known examples in a tideless sea. Nice will afford a good examples of such deposits. The Var and the Paglion bring down pebbles into the Mediterranean, which are almost immediately conveyed into deep water and remain undisturbed, extending but a short distance seaward; for the gravel soundings obtained further from the coast must not be confounded with the river detritus, such soundings being upon the prolongation of the tertiary conglomerates beneath the level of the sea*.

If tideless seas, such as the Mediterranean, Black and Caspian seas, were to become dry, these deltas and gravel deposits would be very apparent, both more or less presenting the advance noticed in the case of lakes, and we should not have beds of detritus parallel to the coasts, but a series of projections with a stratification peculiar to each, but not common to the whole.

Upon a review of the phænomena productive of gravels on sea beaches and in river beds, it will, I think, appear probable

* It should always be recollected that in gravel soundings the probabilities are as great of finding rounded pebbles beneath the sea as on the surface of the land.

that in neither case could pebbles be furnished in such a way as to afford materials for those great deposits of gravel and conglomerate, which we observe in rocks that must have been formed at various epochs; the coasts present lines of shingle or sand, more advanced in cases of the embouchures of rivers into tideless, generally calm, or nearly tideless seas, and the rivers afford mere lines of pebbles. To make these materials available in the formation of extensively deposited gravels and conglomerates, some greater and more general force than the action of seas on their coasts, or rivers on their beds, must collect them together. This force it seems natural to seek in masses of water more or less voluminous according to circumstances. To produce these at various times and in greater or less abundance, the various dislocations of strata everywhere so observable, seems adequate. It is now known that mountains have been raised at different epochs, and that horizontal strata, even those deposited at comparatively recent geological epochs, have been shattered and broken into faults, a large proportion of which are duly covered by the gravels that have been termed diluvium. Can we imagine that such great convulsions and disruptions of our planet's crust could have been unaccompanied by violent movements in the mass of waters, and that debacles, as they are called, have not been frequent and great? It seems but rational to infer that such debacles or deluges must have more or less resulted from every great convulsion, and have been more or less extensive according to the power of the disrupting force. Such causes could easily form the extensive gravel and conglomerate deposits; we now observe, not only by their own destructive power, but also by amassing all the river and sea-shore gravel within their influence.

According to this theory, the extent of gravels would correspond with the extent of the disturbing forces, and would be general where these forces were applied generally, and partial where these forces were applied partially.

Substance of the Journal of two Trading Travellers, and of the Communications of a Missionary, regarding their recent visits to the Countries in the rear of the Portuguese Settlement at De la Goa Bay. By Mr. John Centlivres Chase.

[*Read at the South African Institution.*]

While Messrs. Cowie and Green, part of whose notes I have already submitted to the public, were remaining at De la Goa, another expedition, under the management of two trading travellers, named Scoon and Luckie, had penetrated through