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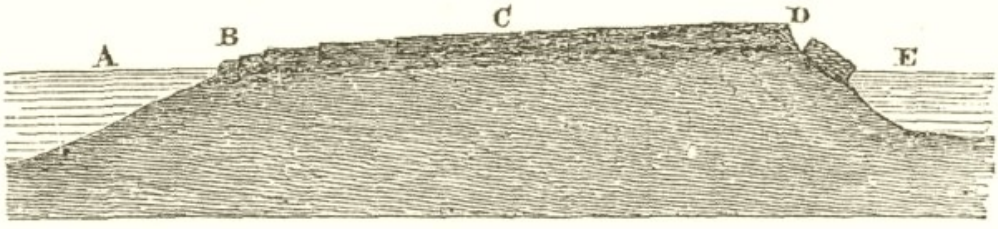
XXXVII. *On a remarkable Bar of Sandstone off Pernambuco, on the Coast of Brazil.* By C. DARWIN, *Esq., M.A., F.R. & G.S.**

IN entering the harbour of Pernambuco, a vessel passes close round the point of a long reef, which, viewed at high water when the waves break heavily over it, would naturally be thought to be of coral-formation, but when beheld at low water it might be mistaken for an artificial breakwater, erected by cyclopean workmen. At low tide it shows itself as a smooth level-topped ridge, from thirty to sixty yards in width, with even sides, and extending in a *perfectly* straight line, for several miles, parallel to the shore. Off the town it includes a shallow lagoon or channel about half a mile in width, which further south decreases to scarcely more than a hundred yards. Close within the northern point ships lie moored alongside the reef to old guns let into it.



Transverse section: vertical heights considerably exaggerated.

A. Level of the sea at low water.
B. Subsided masses, thickly coated with Serpulæ, &c.
C. Summit of the bar, which generally slopes a little seaward; but the slope in the woodcut has been unintentionally somewhat increased.
D. Subsided masses of bare sandstone.
E. Surface of the harbour or lagoon.

* Communicated by the Author.

The accompanying woodcut represents, at low water spring tides, a transverse section of the northern part of the bar, where a section of about seven feet in height is exhibited on the inner side. It consists of a hard pale-coloured sandstone, breaking with a very smooth fracture, and formed of siliceous grains, cemented by calcareous matter. Well-rounded quartz pebbles, from the size of a bean, rarely to that of an apple, are imbedded in it, together with a very few fragments of shells. Traces of stratification are obscure, but there was an included layer in one spot of stalactitic limestone, an eighth of an inch in thickness. In another place some false strata, dipping landwards at an angle of 45°, were capped by a horizontal mass. On each side of the ridge quadrangular fragments have subsided, as shown in the woodcut; and the whole mass is in some places fissured, apparently from the washing out of some soft underlying bed. One day, at low water, I walked a full mile along this singular, smooth, and narrow causeway, with water on both sides of me, and could see that for nearly a mile further its form remained unaltered. In Baron Roussin's beautiful chart of Pernambuco (*Le Pilote du Brésil*) it is represented as stretching on, in an absolutely straight line, for several leagues; how far its composition remains the same, I know not; but from the accounts I received from intelligent native pilots, it seems to be replaced on some parts of the coast by true coral reefs.

The upper surface, though on a large scale it must be called smooth, yet presents, from unequal disintegration, numerous small irregularities. The larger imbedded pebbles stand out supported on short pedestals of sandstone. There are, also, many sinuous cavities, two or three inches in width and depth, and from six inches to two feet in length. The upper edges of these furrows sometimes slightly overhang their sides; they end abruptly, but in a rounded form. One of the furrows occasionally branches into two arms, but generally they are nearly parallel to each other, and placed in lines transverse to the sandstone ridge. I know not how to account for their origin, without they be formed by the surf, as it daily breaks over the bar, washing to and fro pebbles in depressions, originally only slight. Opposed to this notion is the fact, that some of them were lined with numerous small living *Actineæ*. I have copied this passage, as I at the time wrote it, because furrows of a somewhat similar nature on the surface of rocks have lately received much attention, and are supposed invariably to indicate the former action of a waterfall, over the edge of a moving glacier.

The exterior part of the bar is coated with a thin layer of

calcareous matter; this, on the outer subsided masses, which can only be reached between the successively breaking waves at low water, is so thick, that I could seldom expose the sandstone with a heavy hammer. I procured, however, some fragments where the layer was between three and four inches in thickness; it consists chiefly of small *Serpulæ*, including some *Balani*, and a few very thin paper-like layers of a *Nullipora*. The surface alone is alive, and all within consists of the above organic bodies filled up with dirty white calcareous matter. The layer, though not hard, is tough, and from its rounded surface resists the breakers. Along the whole external margin of the bar, I only saw one very small point of sandstone which was exposed to the surf. In the Pacific and Indian Oceans the outer and upper margin of the coral reefs are protected, as will be described in a forthcoming work, by a very similar coating; but there it is almost exclusively formed of several species of *Nulliporæ*. Lieut. Nelson, in his excellent memoir on the Bermudas (Geol. Trans., vol. v. part 1. p. 117), has described reefs, formed, as he states, but I cannot avoid suspecting only coated, by similar masses of *Serpulæ*. I inquired from some old pilots, whether there was any tradition of change in the form and dimensions of this sandstone bar; but they were unanimous in answering me in the negative. It is astonishing to reflect, that although waves of turbid water, charged with sediment, are driven night and day, by the ceaseless trade-wind, against the abrupt edges of this natural breakwater, yet that it has lasted in its present perfect state for centuries, or more probably thousands of years. Seeing that the surface on the inner side does gradually wear away, as shown by the pebbles on the sandstone pedestals, this durability must be entirely owing to the protection afforded by the thin coating of *Serpulæ* and other organic beings: it is a fine example, how apparently inefficient, yet how effectual, are the means of preservation, like those of destruction, which nature employs.

I believe similar bars of rock occur in front of some of the other bays and rivers on the coast of Brazil: Baron Roussin states that at Porto Seguro there is a "*quay*" similar to that of Pernambuco. Spaces of several hundred miles in length on the shores of the Gulf of Mexico, the United States, and southern Brazil are formed by long narrow islands and spits of sand, including very extensive shallow lagoons, some of which are several leagues in width. The origin of these linear islets is rather obscure: Prof. Rogers (Report to British Association, vol. iii. p. 13.) gives some reasons for suspecting

that they have been formed by the upheaval of shoals, deposited where currents met. These phænomena, it is very probable, are connected in their origin with the same causes which have produced the remarkable bar of sandstone off Pernambuco. The town of Pernambuco stands on a low narrow islet and on a long spit of sand, in front of a very low shore, which is bounded in the distance by a semicircle of hills. By digging at low water near the town the sand is found consolidated into a sandstone, similar to that of the breakwater, but containing many more shells. If, then, the interior of a long sandy beach in one part, and in another the nucleus of a bar or spit extending in front of a bay became consolidated, a small change, probably of level, but perhaps simply in the direction of the currents, might give rise, by washing away the loose sand, to a structure like that in front of the town of Pernambuco, and along the coast southward of it; but without the protection afforded by the successive growth of organic beings, its duration would be short, if indeed it were not destroyed before being completely exhibited.

XXXVIII. *On the Heat evolved by Metallic Conductors of Electricity, and in the Cells of a Battery during Electrolysis.* By James Prescott Joule, *Esq.**

1. THERE are few facts in science more interesting than those which establish a connexion between heat and electricity. Their value, indeed, cannot be estimated rightly, until we obtain a complete knowledge of the grand agents upon which they shed so much light. I have hoped, therefore, that the results of my careful investigation on the heat produced by voltaic action, are of sufficient interest to justify me in laying them before the Royal Society.

Chap. I.—*Heat evolved by Metallic Conductors.*

2. It is well known that the facility with which a metallic wire is heated by the voltaic current is in inverse proportion to its conducting power, and it is generally believed that this proportion is exact; nevertheless I wished to ascertain the fact for my own satisfaction, and especially as it was of the utmost importance to know whether resistance to conduction is the *sole* cause of the heating effects. The detail, therefore, of some experiments confirmatory of the law, in addition to those already recorded in the pages of science, will not, I hope, be deemed superfluous.

* Communicated by the Author.