III.—ON THE EVIDENCES OF RECENT CHANGES OF LEVEL IN THE MEDITERRANEAN COAST-LINE.¹

By GEORGE MAW, F.L.S., F.G.S., etc.

THERE is, perhaps, no question of greater interest in the whole range of physical geography than the circumstances that have determined the existence on the earth's surface of large and comparatively unbroken areas of land and water, involving as it does the debateable subject of marine and sub-aerial denudation, and the careful weighing of evidence on the just apportionment of these operations and of oscillations of level that have brought about the existing boundaries of sea and land.

No observer, who has given the subject the least consideration, can pass in review new scenes of coast-line without having his attention directed to the evidences bearing on it; and having recently visited the Mediterranean, I beg to submit some remarks on a few of the many indications of change of level which its coast presents.

These may be considered under the following heads:—

- 1st. The Coast Structure, and the form of the land on the sea-board.
- 2nd. The Inset Current from the Atlantic.
- 3rd. The Limestone Caverns and Submarine Springs on the Coast-Line.
- 4th. The Lagoons on the Coast.
- 5th. The Coast Deposits of Post-Tertiary Age.

EVIDENCES OF DEPRESSION.

1st. *Coast Structure.*—On entering the Straits of Gibraltar from the Atlantic a notable change takes place in the aspect of the coast. Cape St. Vincent, on the Atlantic coast, presents a bold line of cliffs to the sea, and bluff cliffs extend many miles towards the Straits; but as soon as these are passed a change of coast-form takes place, which must be noticeable to every observer. Cliffs on the sea-board become the exception, and the general line of the coast is merely a shelving under the sea of the general hill-and-valley-system of the land, the sea running up all the depressions, and the land elevations spreading out into the sea with scarcely any abrupt cliff-line of demarcation.² The uneven sea bottom of the Straits seems to be a continuation of the contour of the adjacent land, consisting of rolling alternations of hill and valley which must have received its conformation by sub-aerial agencies.

¹ Read at the Liverpool Meeting of the British Association, 1870.

² It is true that both Gibraltar on its eastern face and Apes Hill on the African coast facing the north present cliff-like contours, but in neither case are these on the present sea-board: most of the Gibraltar escarpment is separated by an intervening deposit of sand, and is not washed by the sea, and the face of Apes Hill is set back from the sea by an intervening undercliff; and I am inclined to attribute to both escarpments an earlier origin than the existing coast-line of the Straits. The Gibraltar escarpment appears to be on a line of fault which is visible in the Limestone at the southern extremity of the peninsula near Europa Point.

Corsica, and the adjacent islands of Elba, Capriera, and Monte-Christo, are also remarkable for the absence of cliffs, and are wanting in those abrupt escarpments separating land and water which are so abundant on our own coasts. Their aspect is that of mountain tops rising out of the sea, suggesting to the eye the seaward prolongation of their sub-aerial contour of sloping hill-sides and river-cut valleys, as though the sea had not stood sufficiently long at its present level to excavate an escarpment. The deep intersecting bays that occur along the coast from Marseilles to the Riviera, suggest the same conclusion, the undulating land surface spreading down to the water's edge, and the deep bays running up the intervening valleys, which must have had an origin common with that of their landward prolongations.

One of the most noticeable of these inlets, is the Etang de Berre, skirted by the railway between Arles and Marseilles. It has a superficial area of about 90 square miles. It is entirely land-locked, shut in by high ground of Jurassic limestone, and connected with the sea by only a very narrow outlet. There is an absence of cliff structure on its border, to which the surrounding land slopes down in gentle undulations. The sea cannot have effected its excavation through the existing narrow channel, and its basin must be a valley of sub-aerial denudation, into which the salt water has recently entered from the Mediterranean on the subsidence of the land. It is altogether different in character from the Stagnos or salt-water lakes on the low coasts. The almost complete isolation of this curious sheet of water suggests an affinity with the salt lakes of Algeria and other parts bordering on the Mediterranean coast, including perhaps the Dead Sea; all of which, probably, owe their saline character to connexion at some time with the Mediterranean. The various heights at which they occur both above and below the sea-level, and the various degrees of concentration of saline ingredients, in relation to the surrounding areas of drainage, involve intricate questions bearing on the changes of level and relative antiquity of the movements, which it would be of the greatest interest to carefully work out.

2nd. *The Inset Current from the Atlantic*—Several theories have been offered in explanation of the causes inducing the current that sets in towards the Mediterranean through the Straits of Gibraltar. Receiving as it does the sub-aerial drainage of more than a third of Europe and a large area of Africa, the natural inference is, that its accumulation would pass outwards through the Straits, and it has been suggested that a deeper return current towards the Atlantic compensates for the influx on the surface.¹

Another theory is, that evaporation reduces the water of the Mediterranean at a greater rate than the supply from river drainage. This, however, would only be tenable supposing the area of evapo-

¹ Sir C. Lyell stated in the discussion that the existence of a reverse current at a greater depth had been disproved.

ration bore a larger proportion to the land area of supply than does the open ocean to its sources of accession from land drainage, which is not the case. The evidences of repeated recent changes of level in the Mediterranean basin seem to suggest a more satisfactory explanation, viz.: That the influx through the Straits may be due to a gradual depression of the bottom *now going on*. The area of the Mediterranean is so great compared with the width of the Straits, that an amount of submergence, too slight to be perceptible on the boundary of the area subject to it, might produce such a current as exists, through the connecting channel with the Atlantic.

3rd. *Limestone Caverns and Submarine Springs on the Coast-line*.—To the east of Mentone the Oolitic Limestone is extensively honey-combed with cavernous channels, some of which are filled up with loamy earth; others are open; and some serve as channels for subterranean streams. These caverns, which without doubt had a sub-aerial origin, are now, in one place at least, prolonged to a considerable distance below the present sea-margin. At about a mile to the east of Mentone, just opposite the point where the limestone is seen to be perforated with caves and channels, a fresh-water spring bursts up to the surface with sufficient strength to produce in calm weather a little oasis in the salt water. This spring probably at one time debouched on and flowed over dry land, since which the coast must have been considerably submerged.

EVIDENCES OF UPHEAVAL.

4th. *Lagoons on the Coast*.—The brackish water lakes which extend from the Spanish frontier on the west to the delta of the Rhone, and also along the east coast of Corsica, present some features indicating an upheaval of the coast. They are entirely distinct in character from the Etang de Berre, the salt-water lake near Marseilles before referred to. They are bounded by narrow spits of low land running parallel with the general direction of the coast, and these, cutting off, as it were, the indentations of the higher ground, give to the coast on the map between Perpignan and Marseilles a more direct line than the higher ground actually follows. These indentations are occupied by low marshy ground of an average height of eight or ten feet above the sea-level, and the shallow lagoons are shut off from the sea by bar-like ridges of shingle, blown sand, and marshy meadows. There is little in the character of these flats on the French continental coast to distinguish them from the seaward extension of low ground seen at the mouths of many rivers, and which accumulate independently of oscillations of level; but the lagoons and flats on the east coast of Corsica of precisely similar character and height afford evidence of a rise of the coast of at least 25 feet since the neighbouring low ground was deposited.

The most northerly of these is the Stagno di Biguglia, $3\frac{1}{2}$ miles south of Bastia. It is a long narrow pool of brackish water, several thousand acres in extent, on the sea-margin of a great level tract of

gravelly marsh land, and shut off from the sea by a narrow tongue of similar land.

Fig. 1. Plan of the Stagno di Biguglia, near Bastia.

The main road from Bastia to Corte skirts for several miles this level tract on the inner side of the Stagno, and follows, with one exception, a perfectly dead level. At about five miles south of Bastia, a sudden and abrupt rise takes place, and the road again descends to the general level of the marsh. The ridge (R), extending to the edge of the lagoon, can be traced inland up to the rising ground of the older formations. At first sight the existence of this long ridge of drift resting on the flat, evidently levelled by the sea, was difficult to account for; but on descending to its southern side, a

Fig. 2. Ideal Section of the Stagno di Biguglia, near Bastia.

small stream running parallel with its course suggested an explanation. The long ridge of drift is evidently connected with the

stream, as it leads up to where the stream leaves the hill-side on the edge of the plain, and evidently consists of matter it has deposited. The stream, however, under existing conditions, could not have maintained its course along the top of the ridge; but if we suppose the level marsh-land to have been at one time 20 or 25 feet lower, and covered by the sea, the accumulation resting upon it is accounted for, as the matter carried seaward by the stream at the point where it now enters the marsh on the hill-side; and on the rise of the land and the appearance of the delta-like ridge above the sea, the stream was naturally diverted to the lower level where it now flows.

5th. *The Coast Deposits of Post-Tertiary Age.*—As my observations on these beds have been limited to the neighbourhood of Gibraltar, I shall confine myself to noticing a few examples implying an elevation of the coast-line at the eastern extremity of the Mediterranean. One of the most remarkable is the great mass of sand flanking the eastern face of Gibraltar. As already noticed, most of the escarpment is not now washed by the sea, being covered to a height of nearly 700 feet by a huge deposit of sand in Catalan Bay.

Fig. 3. Eastern Face of Gibraltar. S, Sand deposit of Catalan Bay.

It has been referred to by several geologists; and by some it has, I think, been incorrectly described as *blown sand*: it has somewhat the aspect of a sub-aerial talus, and from weathering and washing down, the beds of loose sand on its sloping surface range with its inclined contour; beneath this, however, it is found to be regularly stratified, and in places is consolidated into level courses of rock from Calcareous infiltration.¹

Fig. 4. Section of Gibraltar.
S, Sand deposit of Catalan Bay.

Further to the west, at about the middle of the Straits, near Tarifa, another mass of sand is seen extending up the land to a height of nearly 200 feet. I had not an opportunity of examining it except at a distance, and it may be merely blown sand; but from its height above the sea-level, I am inclined to attribute to it a similar origin to that of the stratified sands of Catalan Bay.

¹ Mr. James Smith, of Jordan Hill, in his description of the geology of the rock (Quart. Journ. Geol. Soc., vol. ii., page 41), records the occurrence of *Patella ferruginea*, a recent Mediterranean species, at a height of 700 feet, and notices the evidences of old sea.

Still further westward, outside the Straits in the neighbourhood of Cadiz, long ranges of low cliffs occur closely resembling the raised beaches of Devon, and, like them, composed of a hard concrete of sand and shells.¹ The shells are, I believe, of recent species. This raised beach would imply an elevation of the coast of 40 or 50 feet.

Crossing to the African side of the Straits, further evidence of recent upheaval is to be seen in level strata of sand and clay resting on the edges of nearly vertical strata of older rocks. At Tangier

Fig. 5. Low Cliff. Tangier Bay.

these occur at about 40 feet above the sea-level. They are probably of Post-Tertiary age (though I was unable to verify this by the detection of organic remains), and perhaps may be incidental to the same upheaval that elevated the raised beaches of Cadiz.

General Observations.—These observations, which apply to only a very limited area of the great Mediterranean basin, are scarcely sufficient to place in proper sequence the various oscillations of level it has undergone, but may be brought into comparison with the abundant evidences of recent changes of level on the Mediterranean coast which have already been put on record.

The well-known case of the Temple of Serapis, recorded by Lyell, giving evidence of submergence and re-elevation within known heights and certain limitations of historic time, suggests a comparison with other evidences of similar elevation; and I would remark that Lyell's estimate of the amount of emergence of the shell-bored columns on the Italian coast agrees almost exactly with the amount of elevation in other distant parts, implied by the raised gravel ridge on the Corsican marshes, the great plain of shingle at the Rhone delta and the lagoons of the south-western Mediterranean French coast. Furthermore, Mr. Gwyn Jeffreys informs me that a recent marine deposit, containing *Galeomma Turtoni* and other shells of

margins at various heights extending nearly to its summit. I cannot, however, admit that these recent oscillations of level can, as Mr. Smith supposes, be correlated with the various dislocations the limestone formation has undergone. On the upper part of the western face there is a general sloping sub-aerial contour which has superseded all surface evidences of structural dislocations, and both the denudation producing this western slope, and the occasional evidences of higher shore-lines superimposed on it, must have been infinitely more recent than the great dislocations of the limestone strata.

¹ It is sufficiently compact to be extensively quarried for building purposes. The city of Cadiz is almost exclusively built of it.

species now living in the adjacent parts of the Mediterranean, occurs at Antibes at a similar height, viz. 25 feet, above the sea-level; and Mr. James Smith, in the paper before referred to, attributes the sandy plain immediately to the north of Gibraltar to a period of stationary level with a littoral zone exactly 24 feet above the present level of the sea. The close coincidence in height is remarkable, and if these elevations at such distant points were contemporary, it implies a uniform amount of oscillation over a very large proportion of the Mediterranean area. The raised coast deposits at Tangier and Cadiz may have been connected with an independent oscillation of greater antiquity than the 25 feet rise, but yet more recent than that which submerged and re-elevated Gibraltar at least 700 feet.

The great basin appears to have been subject to repeated changes of level down to the historic period, and, judging from the distribution of deposits of such varied character close to the coast, the area subject to the oscillations must have been approximately limited to the present Mediterranean boundary.

IV.—CONTRIBUTIONS TO BRITISH FOSSIL CRUSTACEA.

By HENRY WOODWARD, F.G.S., F.Z.S., etc.,
of the British Museum.

(PLATE XXIII.)

IN my fourth Report to the British Association,¹ I described, among other Crustacea, two species belonging to the genus *Cyclus*, one of which still remains unique. Since that date, I have, by the kindness of Professor T. Rupert Jones, F.G.S., received a number of specimens of this genus, collected by Prof. Harkness, F.R.S.; Mr. Joseph Wright, of Belfast; and Mr. J. H. Burrow, of Settle, Yorkshire; from the Carboniferous Limestone, which I now propose to describe,

1. *Cyclus bilobatus*, H. Woodw., sp. nov., Pl. XXIII., Fig. 3, 3a,

This specimen is from Settle, in Yorkshire, and was collected by Mr. J. H. Burrow. Its greatest length is three lines, its greatest breadth three lines. Viewed in profile, it is nearly hemispherical (see Fig. 3a), its greatest elevation being one line and a half. In general form it reminds us strongly of the dorsal aspect of certain Coleopterous Insects of the genus *Coccinella* or *Cassida*; the elytra being represented by the two large smooth posterior lobes of the shield, with their dividing ridge, and the head and thorax by the anterior third. The border is not flattened and curved outwards in this species, as in *C. radialis* and some others, but is bent downwards and terminates abruptly at the same angle as the rest of the carapace (see Fig. 3a). The frontal margin was probably divided into six parts, but it is only imperfectly preserved.

The anterior part of the carapace or buckler is divided transversely from the posterior and larger portion by, what, for convenience, we may call "the cervical furrow"; whilst a median, or "dorsal

¹ Continued from page 497.

² 38th Report, Norwich Meeting, 1868, p. 72, Plate ii.