BRACKISH-WATER FOSSILS OF CRETE.

Being Illustrations of the Characters of Fluviatile, Lacustrine, and Estuarine Formations.

By H. M. JENKINS, F.G.S., Assistant-Secretary of the Geological Society.

THE Grecian Archipelago and the surrounding mainland have a truly classic interest for the Geologist, not so much on account of their geographical position and ancient fame, as because they were the scenes of some of the most famous labours of the late Professor Edward Forbes, a naturalist who, in his brief but brilliant career, was enabled, chiefly through his investigations in these regions, to throw the bright light of genius over some of the most intricate paths of palæontological research, and who thus invested the eastern portion of the Mediterranean with a far greater interest to the geologist than it otherwise ever would have possessed. Still it must not be supposed that the region is barren of facts outside the common course of geological phenomena, for, as was shown by Professor Forbes, the fresh-water and estuarine strata which occur there contain fossils exhibiting remarkable modifications of form caused by the more or less adverse influences of the conditions under which they lived.

The fossil shells which have given rise to this paper, and which are figured in the Plate, and described in the Appendix, were submitted to my examination by Capt. T. Spratt, R.N., C.B., F.G.S., who was the companion of Professor Edward Forbes in a great portion of his travels in Asia Minor and the regions round about, and conjoint-author with him of the 'Travels in Lycia;' and he is now busily engaged in bringing out a work on the Island of Crete, which will doubtless add to his already high reputation as a geologist.

Of the other observers who have travelled in these regions, and have contributed to our knowledge of their geology, I may mention Mr. Hamilton, F.R.S., now President of the Geological Society, and his fellow-traveller, the late Hugh Strickland, who were the first to explore geologically these classic countries. We are also much indebted to M. Tchihatcheff and M. Raulin, whose papers have been published in the 'Bulletin de la Société Géologique de France.'

The ancient Lake of the Eastern Mediterranean.—One of the principal points brought forward by Captain Spratt, in his several papers, is that the Eastern portion of the Mediterranean, including Greece, parts of Asia Minor, and probably the north-eastern extremity of Africa, was at some distant epoch in the Tertiary period, the site of a huge fresh-water lake; but the precise geological date at which it existed has not yet been satisfactorily made out, though it probably coincided with that of the deposition of the estuarine strata about to be noticed.

Many years ago, Messrs. Hamilton and Strickland described a series of lacustrine beds in various parts of Asia Minor, where it appears

to be the formation most commonly met with in the low grounds; while Captain Spratt has given descriptions of similar strata occurring near Smyrna, and in Lycia, as well as in the Islands of Samos, Rhodes, Cos, Cerigo, &c.; but there is some confusion as to their probable age. Captain Spratt originally considered all of them to be of Eocene date, it being borne in mind, however, that when that opinion was published, the term 'Eocene' included what is now known as Lower Miocene, and referred to under that name in these pages. With the assistance of Professor Forbes, this opinion was afterwards somewhat modified, the Smyrna beds being still retained as Eocene (=Lower Miocene), but the Lycian strata, as well as those of Cos and Rhodes, being considered newer. To the supposed age of these newer fresh-water beds I shall have occasion to refer presently at some length, as it bears very importantly upon the age of some of the fossils under consideration.

Geology of the Eastern Mediterranean Region.—The Tertiary beds of Greece, of the Islands of the Archipelago, and of Asia Minor, are generally found reposing on the Apennine Limestone, or Scaglia, which is of Cretaceous age, or else abutting against it, the Scaglia in such cases forming the high land of the interior, and the Tertiary beds skirting it and facing the sea, and often extending to the coast. Some of these Tertiary strata contain marine remains, others include fresh-water (probably lacustrine) organisms, and the fossils figured in the Plate were probably from a brackish-water lake or estuary.

For the better understanding of the subject it will, first of all, be necessary to give a synopsis of the argument which has been supposed to prove that the fresh-water beds of the Valley of the Xanthus, of Cos, and of Rhodes, are of Pliocene age, and for this purpose I must call in the aid of Professor Forbes and Captain Spratt.*

Relative Age of the Marine and Fresh-water Strata of Lycia.—In the Valleys of Xanthus and Kassabar there is a fresh-water formation supposed to be more recent than certain marine sandy strata, containing shells which also occur in the Upper Miocene beds of Bordeaux, Touraine, &c.; and the manner in which this is apparently proved may be thus stated. The valley of Xanthus is bounded on each side by hills of highly-inclined Scaglia, upon which rests conformably a slightly newer deposit termed 'Macigno.' The floor of the valley consists of horizontal beds of marl, capped by conglomerate, and containing fresh-water fossils. High up on the hill-sides are patches of the marine formation in question, dipping west at a high angle, and it has been assumed to be the older, entirely on account of its being inclined, while the fresh-water beds are horizontal; the order of events being—(1) its deposition horizontally over where the valley now is, (2) its tilting-up and entire denudation, and (3) the deposition of fresh-water beds in its place. Granting the assumed basis of the argument, the reasoning is perfectly correct.

Furthermore, the Xanthus fossils are some of them identical with those occurring in the island of Cos, in a fresh-water formation forming

* 'Travels in Lycia,' vol. ii. p. 175.

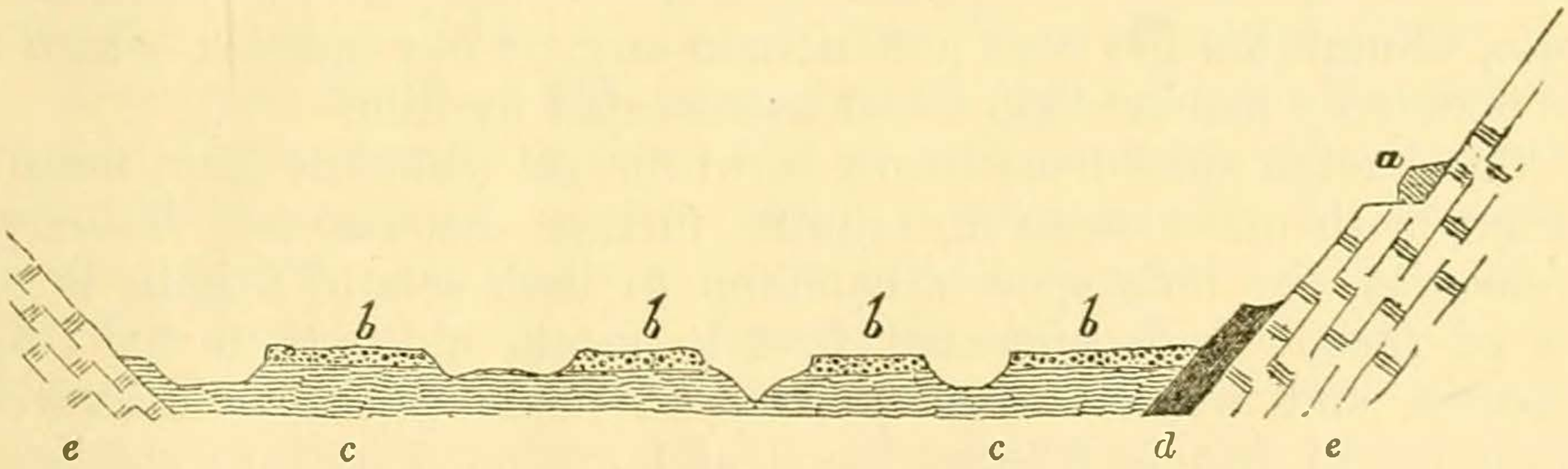
the wall of a series of marine beds containing newer Pliocene fossils; so that the fresh-water beds must be the older, and as, granting the correctness of the former argument, they have been proved to be newer than the Upper Miocene, they must, in that case, hold an intermediate position, and on these grounds they have been termed Older Pliocene.

Thus far, excluding the scepticism, I have followed Professor Forbes and Captain Spratt, who enunciated the above (apparently) convincing proof of the age of the Cos and Xanthus fresh-water beds in the 'Travels in Lycia' already referred to. From a very brief consideration of the argument, the principle on which it is based will make itself apparent to everyone. The object is to fix a limit in both directions to the age of the strata, or, to use the original terms, to find an 'ante-date' and an 'after-date,'—a process often resorted to by the inquisitive in their efforts to discover the ages of their friends!

If we inquire a little more closely into the basis of the argument, namely, that the inclined position of the marine strata is suggestive of their greater age (which is altogether assumed), we shall find, on reference to the section given below, that they *dip the wrong way!*—and thus a doubt is cast upon the whole of the reasoning. The following explanation will make my meaning clear: suppose the Scaglia and Macigno to be more or less horizontal, and the marine formation to be deposited conformably on it, then suppose the valley to be formed by the elevation of the Scaglia on each side, and to be rendered deeper by the erosion of the marine strata, it is evident that the remaining patches of the marine formation would dip conformably with the Scaglia, not at nearly right angles to it, as in the following section:—

Section across the Valley of Xanthus.—(After Forbes and Spratt.)

E. W.



a Marine sandy strata (Miocene), dipping *from* the centre of the valley.
b. Conglomerate. *c*. Marl (freshwater). *d*. Macigno.
e. Scaglia (Cretaceous) dipping *towards* the centre of the valley.

On the other hand, if the Scaglia were upheaved, as it evidently was, before the deposition of the marine beds, it is quite impossible that the latter could have been deposited horizontally and afterwards tilted up, because the Scaglia must have been affected at the same time; and if we assume that its dip was lower when the marine beds were formed, the latter must have been deposited almost vertical, which cannot be credited for a moment; and if the marine Tertiaries were deposited in a horizontal position, the Scaglia must formerly have been nearly vertical. Indeed, it is evident that the apparent dip of the marine

beds is due to false-bedding, and not to elevation at all; consequently it is no indication of their being older than the horizontal fresh-water strata.

Again, supposing that the marine beds were the older, they must once have filled up the valley. By what manner of water-action could they have been so completely washed away that no trace of them exists anywhere beneath the fresh-water formation, and only small patches are left high up on the hill-sides, where they could least of all be expected?

Considering all the difficulties in the way of the marine beds being the older, and that there is no physical reason why they should not be the newer (granting the apparent dip to be due to the false-bedding), we may legitimately compare the fossils of the Cos and Xanthus fresh-water beds, with the shells figured in the Plate, without taking into account their supposed Pliocene age, to which view, it will be found, their evidence is entirely antagonistic. It may be remarked, however, that if the fresh-water strata are the older, the lowest bed, in which occur the same genera as Captain Spratt has obtained from Crete, must, according to its fossils, either be very low down in the Upper Miocene, or must belong to the Lower Miocene: perhaps it does not matter which we consider it; but the point I shall now attempt to establish is that our Cretan fossils are of the same age.

Geological Age of the Fossils under consideration.—A glance at the following lists will show that of those from Cerigo, all, with the exception of *Cerithium Cytherorum* (a new species), occur in the Upper Miocene of Europe, while two began life earlier. The balance of evidence is therefore strongly in favour of the Cerigo fossils being Upper Miocene; that is to say, of the age of the Vienna and Bordeaux Basins. The marine formation in Crete, described by M. Raulin, and said to be of Miocene age, may possibly belong to the same set of strata, though his list does not include any of our species, which are less decidedly marine than those enumerated by him.

The Cretan specimens being, however, all different from those of Cerigo, with one exception, require further discussion. *Melanopsis buccinoidea*, the only species common to both sets of fossils, is also one of those which appeared first in strata older than the Upper Miocene, and with it is associated in Crete *Cerithium Lamarckii*, which began life in Eocene times and extended up into the Lower Miocene, but which has not been found in newer strata. On the other hand, we have *Melanopsis Bouei*, representing the Upper Miocene period, and a species of *Unio*, allied to *Unio litoralis*, which tells us very little concerning its age. The remaining species, three in number, are new, and one of them presents some remarkable modifications of form, so that it is rather difficult to form a correct idea of their geological date.

The genus *Unio* contains very many species, resembling one another so closely as to render it very difficult to distinguish them, especially in the fossil state, so that very little reliance can be placed on them as indicative of the age of Tertiary strata. *Melanopsis buccinoidea*, as we have seen, furnishes no clue to the age of beds

in which it occurs, its range being so extended. *Cerithium Lamarckii*, on the contrary, is a well-known shell, which occurs abundantly in Lower Miocene strata, and is found also in the Eocene "Sables de Beauchamp," so that its occurrence would appear to stamp the age of the deposit as Lower Miocene or older, and to the period named I am inclined to refer it, though it is not impossible that a larger collection of shells may prove it to be somewhat newer. But the great difference between these shells and recent species renders it impossible that the deposit should be Pliocene, as has been supposed.

It by no means follows, however, that there is no more recent formation in Crete; on the contrary, M. Raulin, in a paper on the geology of Crete,* speaks of a lacustrine limestone above a marine formation; and a late lacustrine deposit occurring in the plains in the interior of the island furnished him with the lower jaw of a *Hippopotamus*.

The so-called lacustrine formation of Rhodes contains species of *Neritina* and *Melanopsis*, the latter being *M. Bouei*; with it occurs *Cerithium plicatum*, an associate of *C. Lamarckii* in the Paris and Mayence basins. Although the occurrence of *Cerithium plicatum* is, of itself, not antagonistic to the Upper Miocene age of the strata, yet, when associated with *C. Lamarckii*, it seems reasonable to consider them, for the present at least, as Lower Miocene, especially as the only true Upper Miocene species occurring with them is *Melanopsis Bouei*, and the only recent species is *M. buccinoidea*, which occurs in great numbers in Lower Miocene strata also. The only obstacle to the Upper Miocene age of the beds is, in fact, the occurrence of *Cerithium Lamarckii*; and, although there is no reason why that species may not occur higher in the series, yet as it has not been found in that position hitherto, and as the evidence is at present strongly in favour of its Lower Miocene age in Crete, we must consider it for the present limited to Eocene and Lower Miocene strata.

Malformed Shells.—The fresh-water beds of Rhodes are admitted to be of the same age as those of Cos and Xanthus, some species of shells being common to the three localities, and the remarkable *Neritina abnormis* (Figs. 7*a* to 7*e* of the Plate) from Crete being very near the *Neritina* from Cos figured by Professor Forbes,† if not identical with it. The specimens from both islands exhibit the same kind of malformation, showing that the faunæ of both series of strata lived under similar conditions, which appear to have been unfavourable to some of the species

On examination, it will be seen that the older the specimen, the more distorted does it appear, and the larger are the keels on the whorls, and that, at last, tubercles and even spines spring from them. So in Figs. 8*a* to 8*c*, representing a *Unio*, the same kind of result is seen in the great thickness of the shell, and the small size of one of the specimens, and in Figs. 4*a* to 4*c* in the comparative coarseness of the ribs of *Melanopsis Bouei*. The *Neritina* represented in Figs. 6*a*

* Bull. Soc. Géol. de France. Deuxième Série, vol. xiii.
† 'Travels in Lycia,' vol. ii. p. 203.

to 6*d* has escaped this malformation, to a great extent, but still it is not always quite free from distortion.

But the most remarkable shell "cheated of feature by dissembling nature" is shown in Figs. 3*a* and 3*b*; it is turned the wrong way, and this circumstance, with its peculiar ornament, gives it such a singular appearance, that out of twenty shells spread out on a table, a conchologist would certainly take up this one first, as I have verified by experiment. It seems to defy determination. There are two specimens in Captain Spratt's collection, so that its reversal is not accidental, but, with its thickness and coarse ornament, is apparently due to its having lived under unfavourable circumstances. The species is certainly new, and I have called it *Melania* (*?*) *anomala*, though I am by no means sure of its genus.

These monstrous kinds of growth are interesting on many grounds, and especially so in relation to the mode of formation of the deposit in which they occur. Professor Forbes and Captain Spratt described such malformed shells from Cos several years ago in the 'Travels in Lycia;' but some of them belonged to the genus *Paludina*, and others, as in this case, to the genera *Neritina* and *Melanopsis*. The Cretan specimens that exhibit abnormal characters belong to the two last-named genera, and to the bivalve genus *Unio*; but the *Cerithia*, which cannot live in fresh water, are quite normal in appearance.

Malformation as a Test of Habitat.—It is easy to see that malformations of this kind may furnish an important clue to the origin of a formation; for instance, in this case, the most truly marine genus is represented by species exhibiting normal characters, while the more fresh-water genera are distorted; thus it appears impossible to assign a purely fresh-water origin to the deposit, and we shall presently see that this conclusion is borne out by independent arguments.

Nearly fifty years ago, M. Beudant proved by experiment, that of the mollusks which inhabit fresh water, those only which had the power of shutting off all communication between themselves and the water they lived in could resist the action of brackish or salt water; that is to say, only bivalves and operculated univalves could exist at all under such circumstances. Upon *à priori* grounds it is allowable to extend this law, for certain pulmoniferous gasteropods are operculated; but, as they cannot breathe without rising to the surface, and as that process entails repeated contact with the noxiously salt water, it is but reasonable to conclude that they could not long survive such a disagreeable necessity. We may therefore say that all pulmoniferous gasteropods and all non-operculated fresh-water gasteropods are unable to live in salt or brackish water.

But although these bivalve and operculated univalve mollusks could resist the action of salt water for a time, M. Beudant found that even the latter could only live permanently if the water contained not more than 4 *per cent.* of saline matter, and that even this small quantity was sufficient to kill the bivalves after a short time; hence arises the paucity of shells of the genera *Unio*, *Cyclas*, &c., in brackish water deposits.

It will now be possible to discuss fairly the probability of the

fossils in question having been deposited in a lake or an estuary, and this discussion is the more desirable, because the more or less fresh-water formations of Asia Minor, &c., have often been treated of as necessarily lacustrine. The only circumstances necessary to remember are: (1) that the following remarks do not refer to Cerigo, the fossils from thence being normally estuarine; and (2) that in Crete the most essentially salt-water genera are represented by species normal in character, while the fluviatile genera are represented by distorted species.

But to enable us to decide whether we have been dealing with a marine, an estuarine, a fluviatile, or a lacustrine formation, it is now necessary to discuss the distinctive characters of these classes of deposits, chiefly from a palæontological point of view.

Distinctive Characters of Lacustrine, Fluviatile and Estuarine Deposits.—Purely fresh-water strata are nearly always lake-deposits, because a river seldom deposits in its own bed, and when it does, the deposit is so insignificant, that it is rarely preserved; while, on the other hand, the deposit of a river at its mouth, that is, a delta, contains brackish-water shells, generally mixed with those of fluviatile and terrestrial origin. Again, a lake may be more or less brackish, or even absolutely salt; and a lagoon, which is but another name for a lake connected with a larger body of water, may be subject to periodical irruptions of salt water. Thus there are many contingencies to be guarded against in deciding as to the lacustrine or estuarine origin of a series of beds, supposing the fossils contained in them to exhibit characters not antagonistic to the presence of a certain quantity of salt water, especially in the region under consideration, where lagoons are so abundant; but very little difficulty exists if the shells happen to be purely freshwater and normal in character. Of course, there is this difference between a lake and a river, that whereas the water in the former is more or less stagnant, that in the latter is in motion; but a deposit from a river into a lake would yield evidence of both running and stagnant water, and, unfortunately, shells afford but little evidence as to their fluviatile or lacustrine origin. It would, however, be strange indeed if the fossils of a true lacustrine deposit did not consist, to a certain extent, of the shells of pulmoniferous mollusks; and inasmuch as there is not a single shell belonging to that group amongst the fossils under consideration, the theory of a fresh-water lake cannot well be accepted.

Nature of the Crete Deposit.—All the fossil genera under notice from Crete, excepting the genus *Unio*, have existing species which live in brackish water, or even in the sea, so that they are not antagonistic to the estuarine nature of the deposit, though they are equally favourable to its being a salt-lake formation; but as some of the genera cannot exist in fresh water, the beds cannot have been deposited in a fresh-water lake. Again, *Neritina* and *Melanopsis* are essentially the inhabitants of running water, and the genus *Unio* is just as essentially fresh water, therefore if the fossils presented no abnormal characters, the only rational conclusion would be that the Crete formation is a deposit from a river in an estuary.

But we have seen that one species of *Neritina* is keeled and tuberculated, while another presents ordinary characters, that the *Unio* is unnaturally thick, and, except one specimen, very much stunted, while the most abundant species of *Melanopsis* is represented both by small specimens normal in character, and by large examples unnaturally coarse and ribbed, to say nothing of the wonderful *Melania*. How, therefore, can we account for the entombment of species which lived under normal conditions in association with specimens of the same and other species that evidently lived under circumstances not quite suited to them? Bearing in mind that the normal specimens belong both to fresh-water and estuarine genera, and that the abnormal ones are wholly fresh-water, as well as the fact that all of them could exist in brackish water, being either operculated gasteropods or bivalves, and not belonging to purely fresh-water genera, it appears to me that the only way of accounting for the association is by supposing that the deposit was formed in a lagoon, which was subject to occasional irruptions of salt water, and into which a river flowed.

This conclusion is very similar to that arrived at by Professor Forbes and Captain Spratt respecting the Cos fossils, only that they assumed the lagoon to be at first quite fresh, and to have become gradually saline, and they did not call in the aid of a river; but the occurrence of the *Unio* and of normal and abnormal specimens of *Neritina*, &c., appears to render the latter device necessary in this case. In the lagoon, all the species could exist for a time, after having been carried down by the river, and thus the abnormalities described may have been produced.

APPENDIX.

I.—Descriptions of New Species from Crete.

1. *Neritina abnormis*, mihi. Figs. 7*a* to 7*e*.

Shell broadly ovate, trochiform, ornamented with brownish zig-zag longitudinal lines or bands; whorls three, crowned by a broad cord-like keel, and with a thinner and sharper ridge in the middle, often corded or crenate, and sometimes tuberculated or irregularly spiniferous, separated from the upper keel by the concave upper portion of the whorl. Mouth in a plane nearly at right angles to the axis, more or less semilunate in form; inner lip concave, smooth, with a broad callosity covering the base of the shell, and becoming very thick and encroaching on the mouth in old specimens.

2. *Neritina Spratti*, mihi. Figs. 6*a* to 6*d*.

Shell ovate, smooth, ornamented with many blackish spots, more or less regularly arranged; whorls three or four, declining above, sometimes compressed in the middle, convex at the base. Spire depressed, blunt. Mouth oblique, irregularly semilunate in form; inner lip concave, callous, minutely dentate.

3. *Melania? anomala*, mihi. Figs. 3*a*, 3*b*.

Shell thick, reversed, turreted, ovate, somewhat obtuse at the apex; whorls about seven, slightly convex, transversely and longitudinally ridged; transverse ridges coarse and blunt, obsolete on the uppermost whorls, and gradually increasing in number, from two on the third whorl to four on the body-whorl; longitudinal ridges obsolete on the upper whorls and becoming gradually more apparent on the lower; they are the same distance apart as the transverse ridges, which they

cross at right angles, forming a tubercle at the point of intersection. Base of the shell similarly ornamented and slightly umbilicate. Mouth oval; columella thickened; inner lip callous above; callosity flat, thin, spreading over part of the base of the shell above the small umbilicus.

4. *Cerithium recticostatum*, mihi. Figs. 2*a*, 2*b*.

Shell turreted, acute; whorls numerous, slightly convex, ornamented with three sharp transverse ridges, crossed at right angles by about ten straight, sharp, very prominent, and almost lamelliform varices, which are slightly tuberculated at the point of crossing, and also just below the suture, where they are crossed by a fourth and very small longitudinal ridge. Mouth oval, effuse at the base, where the peristome is prolonged into a pointed spout.

5. *Unio Cretensis* mihi. Figs. 8*a to* 8*c*.

Shell very thick and coarse, sub-rhomboidal, with the upper margin convex, and the lower almost straight; anterior extremity rounded, scarcely projecting beyond the umbo; posterior extremity obliquely projecting, very convex, almost pointed, ending above in a sharp angular ear; umbo prominent, scarcely eroded. Hinge-teeth and lamellæ very thick and projecting; anterior muscular impression very deep, much deeper than the posterior.

II.—DESCRIPTION OF A NEW SPECIES FROM CERIGO.

Cerithium Cytherorum, mihi. Fig. 11.

Shell turreted, acute; whorls numerous, convex, ornamented with two convex transverse bands, which are separated by a sharply-defined shallow groove, and are tuberculated where crossed by the varices; varices curved, broad, not very distinct; suture neatly impressed, slightly undulated. Mouth small, nearly round; columella callous, twisted, and somewhat produced, oblique. Base of the shell ornamented with about five parallel ridges crossed by distinct lines of growth.

EXPLANATION OF PLATE.

FOSSILS FROM CRETE.

FIGS. 1*a*, 1*b*.—*Cerithium Lamarckii*. Magnified 2 diameters. From the plain of Arkadia.
„ 2*a*.—*C. recticostatum*. Natural size. From Kherisoniso.
„ 2*b*.—*C. recticostatum*, var. Natural size. From Kherisoniso.
„ 3*a*, 3*b*.—*Melania? anomala*. Magnified 2 diameters. From Kherisoniso.
„ 4*a to* 4*c*.—*Melanopsis Bouei*. Magnified 2 diameters. From Kherisoniso.
„ 5*a*, 5*b*.—*Melanopsis buccinoidea*. Natural size. From the Plain of Arkadia. This species also occurs in Cerigo.
„ 6*a to* 6*d*.—*Neritina Spratti*. Magnified 2 diameters. From Kherisoniso.
„ 7*a to* 7*e*.—*N. abnormis*. Magnified 2 diameters. From Kherisoniso.
„ 8*a to* 8*c*.—*Unio Cretensis*. Natural size. From Kherisoniso.

FOSSILS FROM CERIGO.

FIGS. 9*a*, 9*b*.—*Cerithium plicatum*. Natural size.
„ 10.—*C. doliolum*. Magnified 2 diameters.
„ 11.—*C. Cytherorum*. Magnified 2 diameters.
„ 12*a*, 12*b*.—*Neritina fluviatilis*. Magnified 2 diameters.

1.b.

1.a.

2.a.

3.a.

3.b

2.b.

4.d

5.a.

4.a.

4.b.

4.c.

5.b.

6.a.

6.b.

6.c.

6.d.

8.a.

9.

7.d.

8.b.

7.a.

7.b.

7.c.

7.e.

10.a.

10.b.

11.

12

13.a.

13.b.

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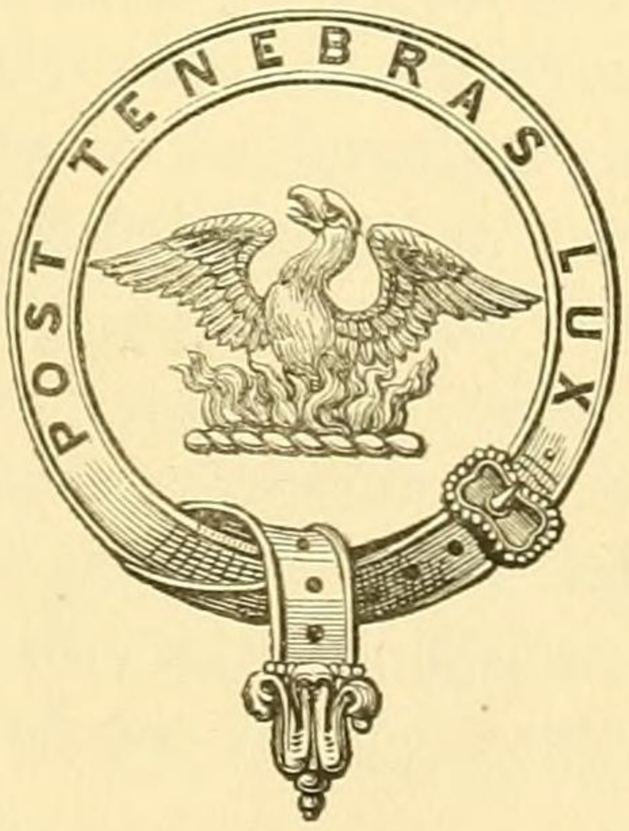

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