

16. *On the PLIOCENE BEDS of ST. ERTH.* By PERCY F. KENDALL, Esq., Berkeley Fellow of the Owens College, and ROBERT GEORGE BELL, Esq., F.G.S. *With an APPENDIX by Dr. G. J. HINDE, F.G.S.* (Read February 24, 1886.)

IN presenting this paper for the consideration of the Geological Society, we desire to state at the outset that it is intended only as a report upon reaching a stage in the investigation of this interesting deposit, and that any speculative remarks which we may venture to offer are intended rather as indicating certain directions to which inquiry may be turned with a prospect of useful result, than as well-matured conclusions to which we are prepared rigidly to adhere.

The materials at present available do not warrant us in taking a less guarded attitude, the list of fossils which we bring forward, though very large, being, we are convinced, capable of considerable increase by a more extended examination of the beds than we have hitherto been able to make.

The attention of the Society was first directed to the St. Erth deposits by a communication from the late Mr. S. V. Wood, which was read at an early meeting last session. That paper was considered by Mr. Wood to be of a tentative character, nothing very accurate being known of the physical conditions of the deposit, nor was there anything like a good knowledge of its contents, and it was his hope that the attention of competent geologists might be drawn to its occurrence, so that it might be worked out and surveyed in a better manner than, in his invalid condition, he was able to perform. Shortly afterwards Mr. Wood died, and by his desire the whole of the material and correspondence was placed in the hands of one of the authors of this communication, with the wish that the subject might be still further worked out, especially with regard to the Mollusca.

In the course of the last summer St. Erth was visited by Mr. Henry Keeping, who collected, in the interest of the Woodwardian Museum, a large series of Mollusca, with a few other remains, with one or two exceptions all invertebrates, these exceptions being two or three small vertebræ and two otoliths of fishes. Mr. Clement Reid, of H.M. Geological Survey, also visited the section, making observations and collecting a few shells (among which were three or four species which had not been found previously) from the spoil-heaps that had been left; but the sides had subsequently fallen in and he was unable to collect very extensively. Later on it was examined by one of us, having the kind permission of the Vicar of St. Erth, on whose glebe-land the deposit is exposed, and the result of these several visits has been to materially increase the list of species above that which was known at the time Mr. Wood's paper was read.

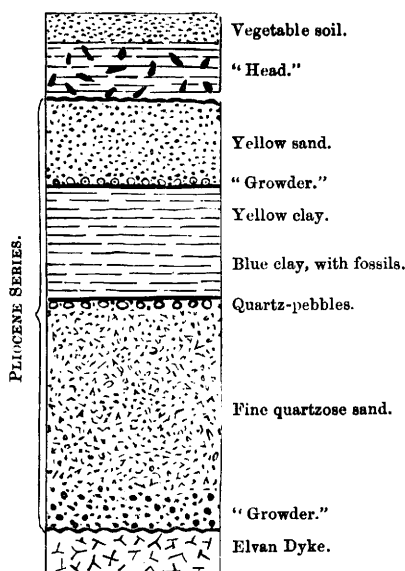
At present the number of known and described or named species amounts to seventy-two, while there are about twenty more which

do not seem to be known, either in a fossil or recent state; of these, some few were named by the late Mr. Wood in MS., and, as such, have been included in the synoptical list of Mollusca appended; but the authors have thought it better to postpone the naming and description of any other new species until further specimens have been collected.

The various deposits are to be seen in a sand and clay pit excavated upon the N.W. slope of the hill upon which stands the vicarage of St. Erth, and at an altitude of 100 feet above O. D. Other exposures will be mentioned in the sequel.

The succession of the beds is shown in the section subjoined (fig. 1).

Fig. 1.—Section at St. Erth.



The Bed 1, or “Head,” is an argillaceous deposit containing many angular fragments of killas and other local rocks, and is probably of glacial origin. Mr. S. V. Wood identifies it with the “warp” of his memoir on the “Newer Pliocene Formation”; below this comes the series of beds with which we purpose dealing.

Bed 2 is composed of fine yellow sand, which is well exposed upon the N.E. face of the pit.

Bed 3, yellow clay without fossils, separated from “2” by a thin layer of very coarse ferruginous quartzose sand (“Growder”).

Bed 4. Blue Clay, with many fossils.

Bed 5. Layer of scattered quartzose pebbles.

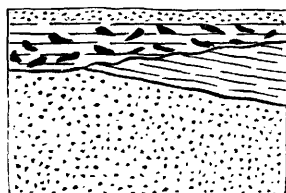
Bed 6. Fine quartzose sand, yellow above and purplish below.

Bed 7. Very coarse highly ferruginous sand (“Growder”).

One observed dip gave about  $3\frac{1}{2}^{\circ}$  to  $4^{\circ}$  to N.N.W.; but the true dip is probably  $5^{\circ}$ .

Mr. Wood states, on the authority of Mr. Cornish, that the clay occurs as a lenticular patch in the midst of the sand; but though the section was much obscured when our examination was made, all the appearances then presented led to the conclusion that the bedding was quite regular (see fig. 2).

Fig. 2.—Section in West Corner of Sand-pit, St. Earth.



At a slightly less elevation to the N.N.E. a thick bed of "Growder" (probably No. 7) occurs, and about three hundred yards to the west, in a deep quarry beside the road leading from the St. Earth Post-Office to Hayle, and excavated in an elvan dyke, the "Growder" is seen resting directly upon an irregular surface of the felsite, fragments of which, in a greatly decomposed state, are imbedded in the sand. The same "Growder" is to be seen along the roadside at various points nearly as far as the village of St. Earth.

A short distance along the road in the opposite direction, in the corner of a field called "Moor Meadow," a small pond was excavated, as we are informed, in the Blue Clay, but no fossils were observed. At the present time it is filled in by surface mould, but some traces of clay could be seen.

In a lane to the south of St. Earth, a roadside-cutting is said to have exposed the Blue Clay, but only obscure traces of it can now be seen.

The extent of the lines of outcrop is not traceable on account of the covering layer of "Head," which is in many places of considerable thickness, and the cuttings necessary to confirm the statements made to us could not be made, owing to the short time available and to the inclement weather; for the same reason, dips and levels could not be taken. The area embraced by these alleged exposures is about one hundred and twenty acres.

The lithology of these beds cannot be treated exhaustively in this communication, owing to the difficulty of obtaining clean and un-mixed specimens, consequent upon the falling in of the side of the pit.

The sands are of well-rounded quartzose grains, primarily derived from some Plutonic rocks. Black grains occur, which are probably hornblende.

The difference in colour of the two clays is, no doubt, attributable

to the oxidation of the upper part, though it should be noticed in this connexion that the yellow clay is almost destitute of fossils, only fragments being found. The washings yield, according to Mr. Wood, about 1 per cent. of angular rock-fragments, mostly killas, and some vein-quartz; the finer washings also show abundance of fine angular quartz grains, and some mica.

The clay-bed, No. 4, seems to be the deposit in which nearly all the shells and other remains are found; but this does not seem to be uniformly fossiliferous, as a large quantity obtained for examination by Mr. Wood was very barren, while careful washing and sifting of about thirty pounds weight from another part yielded nearly the whole of the smaller species of *Mollusca* recorded, and brought to light many species of *Rissoa*, *Odostomia*, and other genera, with a quantity of the fry of the larger species.

The fossils are in general very strong and in good condition, the finer striæ and ornamentation even of the Foraminifera being well preserved, probably owing to the tenacious character of the matrix. It is remarkable, however, that the larger bivalves are almost all fragmentary, the oysters alone being generally found in a tolerably perfect condition: this may probably have been owing to the presence in the St. Erth sea of a large number of predatory fishes, such as the Wolf-fish (*Anarrhichas lupus*), which breaks up the strong shells of *Nucula* and *Pectunculus* with its solid pavement of teeth.

So far as investigation has been carried out in this deposit, nearly all the palæontological evidence obtained has been confined to the Invertebrata; the only remains of a higher class consist of a few undeterminable fish-vertebræ and otoliths.

Several species of Polyzoa occur, all of which have a wide geographical range, mainly southern; the encrusting forms were attached to the interior of Gastropods, and single detached cells are found in the fine washings; but it is a remarkable fact that we have not found a single example upon an oyster, *Pecten*, or any other bivalve which usually forms their habitat. The following species have been determined:—

<i>Melicerita Charlesworthii</i> , <i>M.-Edw.</i>		<i>Lepralia Pallasiana</i> , <i>Moll.</i>
<i>Salicornaria (Cellaria) sinuosa</i> , <i>Hassall.</i>		— ( <i>Microporella</i> ) <i>violacea</i> , <i>Johnston.</i>

All these occur in the Coralline Crag and the Italian Pliocenes. No characteristic northern species has been found. Fragments of *Balanus* occur, and several species of swimming Crabs are represented by chelæ and fragments of the carapace. Detached plates of *Echini* and portions of the test of an irregular Echinid abound; also the spines of both groups. We have also found three or four species of Annelida and a Nullipore (*Melobesia*, sp.), and in the fine siftings spicules of calcareous sponges, upon which Dr. Hinde has appended a note. Shells bored by *Cliona* are also found.

An interesting discovery is that of an Alcyonarian.

Plates referable to the Holothurians (*Cucumaria*, sp.) are fairly common.

But perhaps the most remarkable of the fossils of this deposit

are some minute stellate spicules of calcareous composition which, with the kind assistance of Mr. Ridley, of the British Museum of Natural History, we determined to belong to an order of the Invertebrata which has never before been found in a fossil state, viz. the Tunicata; but in order to make quite sure of its affinities, we submitted specimens to the judgment of Professor W. A. Herdman, of University College, Liverpool, who confirmed our determination, and pronounces it closely allied to *Leptoclinum tenue*, a species to be mentioned in the second part of his report on the 'Challenger' Tunicates, which is now in the press.

The Foraminifera and Ostracoda are present in large numbers; of the former Mr. F. J. Millet, of Marazion, found about one hundred and twenty species and varieties; and the Ostracoda, which are in the hands of Messrs. Brady and Robertson, seem individually quite as numerous, every part of the clay from bed No. 4 yielding multitudes of examples of both these groups.

With regard to the Mollusca, which, as in nearly all other deposits, present the best means of determination respecting age, climate, and other conditions, much, in our opinion, remains to be learned; but enough is known to enable us, with some degree of certainty, to confirm the view expressed by the late Mr. Wood as to the date of the Blue Clay; we think there is little doubt of its being of Pliocene age and contemporary with the middle or lower portion of the Red Crag. Several remarkable shells, which have always been regarded as characteristic of that deposit, occur here, such as *Littorina subaperta*, *Conovulus pyramidalis*, *Nassa granulata*, and *Columbella sulcata*; the first two occur only in the Red Crag and one of the Belgian upper Crag, the last not earlier than the Coralline Crag, where it is very rare, and certainly not the same form as the single St. Erth shell, which is large, and resembles the coarser varieties of the Middle Red Crag. The large numbers of *Nassa serrata* or *reticosa* (these species are undistinguishable), *Turritella incrassata*, and *Natica millepunctata*, which similarly occur in plenty in both deposits, tend to the same conclusion as to the identity in time of the St. Erth deposits and the Red Crag. At the same time it must not be overlooked that a small number of important and prominent species occur at St. Erth which have no representatives in the Crag of Suffolk, and are entirely of a southern character, such as *Fusus corneus* or *lignarius*, *Nassa mutabilis*, *Cardium papillosum*, and *Cardita aculeata*. Three of these species have never been found in Great Britain, either fossil or recent, and, excepting in the Italian Pliocenes and French Miocenes, have never before been noticed north of the Mediterranean and Cadiz; and it will be observed, on reference to the synoptical list at the end of this paper that, with the exception of three species of small size, nearly the whole of the shells which have a living-range into the seas of Norway, also extend in a southerly direction into the Mediterranean.

It may be as well to call attention to the large size of these St. Erth examples of peculiarly Mediterranean Mollusca, such as *Nassa mutabilis*, *Turritella incrassata*, &c.; these far exceed any examples in the seas or formations of Southern Europe, and although

we cannot offer any adequate explanation of such extreme size, it is worthy of note.

The remarkable character of the fauna appears to point to certain conclusions of great moment, and, with the reservations stated at the outset, we venture to bring them forward in the hope that the criticism to which they will doubtless be subjected will, whether favourable or otherwise, give us a secure standpoint from which to view the great mass of additional evidence which will assuredly be brought to light when the deposit is submitted to a closer and more exhaustive examination.

Taken as a piece of negative evidence, the southern facies of the fauna may be inferred from the total absence of the boreal or arctic forms of predatory Mollusca.

Of such shells as *Fusus antiquus*, *F. gracilis*, *Buccinum Dalei*, and *B. undatum*, which are so common in the Red Crag, no trace has been found. *Turritellæ* and other shells have been found to be bored by carnivorous Gastropods, but the abundance of the large *Nassa serrata* will account satisfactorily for this circumstance.

We think, however, that this absence indicates the prevalence of physical conditions in the British area and Western Europe generally very different from those now obtaining.

If a comparison be made between the fauna of those few Upper Tertiary beds which have been noticed in the Channel and the West of England, and is further carried onward to include the Pliocene beds of the Cotentin in France, it will be found that the Mediterranean element is a conspicuous feature, the whole having a southern character with a manifest exclusion of Red Crag and strictly boreal shells. The beds of the Cotentin have been worked by MM. Gustave Dollfus and Vasseur, and through the kindness of the former gentleman we have received a more complete list of the fossils of that region than is usually obtainable; and though they appear to us to be of an earlier date than the St. Erth clay (probably being of Coralline-Crag age), they approximate sufficiently closely to admit of their inclusion in the same statement.

Even in the most recent of the deposits mentioned, viz. that at Selsey, the *Fusi* before alluded to are entirely absent, and even in recent times they are rare at the western end of the Channel.

The Mediterranean aspect of the fauna down the western seaboard of France in Mio-Pliocene times has long been noticed; but no special significance was attached to it in consequence of the proximity of the Spanish province, which has no really distinctive fauna, but merely a blending of northern and southern forms, and during a warmer period the former element might easily have been excluded by climatal unsuitability.

We have shown, however, that the St. Erth deposit was probably accumulated during the earlier portion of the Red Crag period, when the premonitory refrigeration of the Glacial epoch had gone on so far as to permit of a great descent of *Boreal* or even Arctic Mollusca; and in the oldest Red-Crag deposit, that of Walton-on-the-Naze, 30 species occur which have an exclusively northern range in

Recent seas. Several of these may be called prevailing shells, for example *Buccinum Dalei*. The absence of such shells in a locality only 100 miles further south is to us quite inexplicable on any hypothesis which takes the physical features and distribution of land and water in Western Europe as they now are. Mr. Wood, in his paper, alluded to the difference observable between the Eastern and Western Pliocene faunas, and considered that the existence of a land-barrier which stretched across the eastern end of the English Channel would explain this, as the communication between the St. Erth Sea and that portion of the North Sea in which our Crag beds were deposited would then be round the north of Scotland, which is  $9^{\circ}$  of latitude from St. Erth.

This explanation would be satisfactory as accounting for an absence of southern species in the East Anglian area, which, however, we do not observe, while it wholly fails to account for the arrest of the south-westerly migration of shells of northern habitat.

We think that the facts at present before us point to the conclusion that, at the period of which we are writing, no channel of direct communication existed between the North Sea and the Atlantic Ocean, the Straits of Dover in the south being closed, while on the north-west the Tertiary Volcanic chain threw a barrier across from the north of Scotland to Greenland by way of the Shetland and Farøe Islands and Iceland.

The study of the present configuration of the North Atlantic seabottom is strongly confirmatory of this opinion. The 100-fathom line encloses the Orkneys and Shetlands, while a long submerged ridge with deep water upon each side extends from the Hebrides to the Farøes and, as has been so fully explained by the late Dr. Jeffreys, has had a great influence in preventing the intermingling of the marine faunas upon each side of it.

The component islets of the Farøe group are separated by deep narrow straits with very precipitous sides, which might almost be called fiords, and are clear indications of considerable subsidence.

From the Farøes to Iceland an undulating bottom exists, reaching a depth of 368 fathoms, whence a plunge takes place to 686 fathoms, and within 30 miles recovers to 350 fathoms.

Across the Denmark Straits, between Iceland and Egede's Land (Eastern Greenland), the depth nowhere reaches 500 fathoms, though both N. and S. much more profound depths are recorded.

From the south-western angle of Iceland a great submarine promontory runs down far into the Atlantic, carrying the 500 and 1000 fathom lines in a great sweep many degrees to the south, and upon this is situated the spot marked on the old charts as the "Sunken land of Buss." This region is mentioned by some Venetian navigators of the 14th century, who state that they found there a well-populated land, which they called West Friesland. In later records mention is made of the "Sunken land of Buss;" and even so late as 1777, charts indicated the existence of a dangerous shoal in the vicinity. Sir John Ross sounded over the spot in 1818, but found no bottom with 180 fathoms of line. To the S.W. of this point, in



lat.  $56^{\circ} 1' N.$ , long.  $34^{\circ} 42' W.$ , H.M.S. 'Valorous' found a depth of only 690 fathoms, and 100 miles to the west 1450 fathoms.

Thus it will be seen that a submarine ridge, the crest of which is nowhere 500 fathoms beneath the surface, extends from Scotland to Greenland, while deep water occurs on each side. The inequalities of the bottom we hold to be quite incompatible with the idea of the permanence of marine conditions over the area from times as remote as the Miocene period.

Apart from the rather doubtful "Land of Buss," evidence is not lacking on the coast of Greenland of considerable subsidence during the historic period; and this movement may be a continuation of the great subsidence which depressed the great N.W. barrier.

The former existence of such a barrier has been suggested by several previous observers, who based their opinions upon widely different grounds.

The late Prof. Forbes believed that it did not extend to Scotland during the Crag period, but to Norway; we think, however, that the presence of a great number of Arctic forms in the Craggs entirely negatives that supposition.

Prof. Boyd Dawkins has argued in favour of a western closure of the North Sea from the distribution of the Upper Tertiary Mammalia.

There are in our list only four shells which offer any obstacle to the acceptance of the theory which we have put forward.

One of these, *Cardium elegantulum*, Müll., = *C. strigilliferum*, Wood, is found in the Coralline Crag and the Cotentin Marnes à Nassa, and its known recent range is strictly northern, the southernmost extension being to Norway. It must be borne in mind that it is a very small shell, and that our knowledge of the distribution of small Mollusca, both recent and fossil, is very imperfect.

*Columbella sulcata* is only known from the English and Belgian Pliocenes; but so many allied species are found in the Italian Tertiaries that it is very questionable if it be not identical with one or other of the forms described by Bellardi.

*Littorina subaperta* is a very doubtful species, having a range of variation which carries it even beyond generic limits.

A much more important argument against our position is furnished by the occurrence of *Conovulus pyramidalis*, inasmuch as it is only found in the East Anglian and Belgian Upper Craggs, the St. Erth Pliocene, and the Wexford gravels and clays (Glacial). Regarding this shell, it should be noticed that there is a singular paucity of evidence respecting the marine members of the genus.

The southern connexions of the St. Erth Sea appear to have been much more direct with the Mediterranean than at present. The Cotentin deposits, and those on the Loire Inférieure and in the Bordeaux region, are in obvious relation to the Perpignan beds, and indicate a gulf extending from the Mediterranean across S.W. France and along the northern side, then cutting off the Finisterre district, throwing an arm across to the Cotentin, and thence running in a westerly direction to St. Erth.



The tract of land between the mouth of the Garonne and Perpignan attains a maximum elevation of 600 feet, according to Prof. Prestwich\*, who quotes M. Virlet d'Aoust, to the effect that Pliocene beds occur on the Mediterranean slope at an elevation of 540 feet.

Dr. Gwyn Jeffreys remarked†:—"I, however, fully agree . . . that at some former period . . . there was an open communication between the Atlantic and the Mediterranean by which the fauna became diffused. I should be inclined to place the Atlantic point of communication at Bordeaux, and that of the Mediterranean at Narbonne, in the line of the Languedoc Canal, which extends from one coast to the other, and is very little above the present level of the sea. This communication must have been very wide, and it remained open during the Glacial epoch, which affected not only the N. of Europe, but also Naples, Sicily, and probably Rhodes." The Straits of Gibraltar appear to have been closed during the late Pliocene times.

Many recondite problems concerning the present and past distribution of life will, we think, be elucidated by the application of these hypotheses; and to one or two of these we may perhaps be permitted to refer, while others must be reserved for consideration in a future paper.

The speculations of the late Edward Forbes regarding a former great western extension of the continent should, we think, be carefully examined in connexion with the subject of which we are treating; but it would be foreign to our present purpose to do more than draw attention to them and suggest the propriety of such an inquiry.

His (Forbes's) theory was that a continuous or only slightly interrupted land-surface extended from Ireland to Spain in late Tertiary times, permitting of the free migration of Spanish plants to Ireland, where about 20 species still survive.

The western shores of this land he placed along the line of the Sargasso Weed.

Much additional evidence in favour of this view is to be obtained from the study of the distribution of Recent Mollusca, both marine and terrestrial, in the Azores, Canaries, and on the western shores of the Spanish Peninsula.

The position of the beds at St. Erth shows that some considerable movements have taken place subsequently to their accumulation; thus the beds occur at an altitude at least 200 feet above their original position of deposition, and dip about 5° to the N.N.W.

The movement which raised them was clearly not one of equal elevation, otherwise they would have no dip; so that it seems safe to assume that it was an undulatory or tilting movement, like in kind, though in less degree, to that now affecting the Scandinavian peninsula.

Reversing this movement to restore the beds to their original position, we should have a broad gulf at St. Erth and to some distance eastward. The fulcrum would be about 1 mile to the W.; and

\* Quart. Journ. Geol. Soc. vol. xxvii.

† Shetland Report, Brit. Assoc. 1868.

### Table of Mollusca.

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TABLE (continued).

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## THE PLIOCENE BEDS OF ST. ERTH.

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