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June 16. 1880. —

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[*From the* Quarterly Journal *of the* Geological Society *for* *May* 1880.]

On the Oligocene Strata *of the* Hampshire Basin.

By Prof. John W. Judd, F.R.S., Sec. G.S.

[Plate VII.]

Contents.

I. Introduction.

There are perhaps few portions of the series of British strata which have attracted so large a share of the attention of geologists, both in this country and abroad, as the fluvio-marine formation which constitutes the highest member of the Tertiaries of the Hampshire basin. When we remember the numerous memoirs which, since the commencement of the present century, have been devoted to a description of these strata and of their fossils, it might well be supposed that little can remain to be done, either in working out the order of succession of the beds, or in determining their relations to the deposits of other areas. That such is not the case, however, I shall have occasion to show in the memoir which I now submit to this Society; and it may be well that, at the outset of this inquiry, I should briefly indicate the difficulties which beset the study of this particular formation, and the causes which have led to the serious discrepancies of opinion concerning the mutual relations and the geological age of the strata which compose it.

Among the difficulties which confront the investigator of the order of succession in these fluvo-marine strata of the Hampshire basin, the most serious is found in the tendency shown by the various members of the formation to undergo rapid variations in mineral characters within short distances. As in the Wealden and other similar deposits formed in deltas, so here, we find the whole mass of strata made up of lenticular patches of sediment dovetailing into one another in the most complicated manner; so much, indeed, is this the case, that we seldom discover any bed in the whole formation exhibiting such persistency of character as to allow of its being traced over any considerable area. Hence the art of the geological surveyor and map-maker—which, in dealing with the more uniformly deposited marine strata, often affords such valuable aid in making out the order of succession of beds—is here comparatively useless. And the perplexities of the geological surveyor are greatly increased by the fact that all over the northern half of the Isle of Wight and the New Forest, where these strata are developed, thick superficial

deposits of sand and gravel almost everywhere conceal the underlying Tertiaries from our view.

Although additions to our knowledge of the fauna and flora of these beds have been made by the examination of such isolated exposures as are to be found in railway-cuttings, brick-pits, quarries, and wells, yet, in seeking to determine the relations of the several beds to one another, we are obliged to fall back upon the more extensive and continuous sections exhibited in the sea-cliffs; and it is a fortunate circumstance that these coast-sections are both numerous and well exposed.

It may be readily believed, too, that the frequent repetition of beds deposited under similar conditions, and therefore presenting identical mineral characters, will be a fruitful source of error, unless the aid of the palæontologist be constantly invoked to enable us to identify the several members of the formation by their organic remains. And the geologist must be prepared to avail himself to the fullest extent of the researches of investigators of strata of equivalent age in other areas, where important light may be thrown upon the order of appearance of the forms of organic life which occur in our own district.

In my study of these strata, which has occupied me during many years, I have endeavoured to avail myself, as far as possible, of these different kinds of assistance. Moreover, in my examination of the positions and relations of the strata, I have been greatly aided by the publication of the admirable 6-inch and 25-inch maps of the Ordnance Survey, which supply us with the means of plotting the cliff-sections in a manner which was not possible at the time when the geological survey of the island was made, when no Ordnance map existed, except the obsolete and incorrect 1-inch map of 1810. I will now briefly enumerate the conclusions to which I have been led by these studies.

The strata exposed at the base of Headon Hill, at the western extremity of the Isle of Wight, are not, as supposed by previous observers, a mere repetition, through an anticlinal fold, of the beds seen in Colwell and Totland Bays, but are on a distinct and lower horizon than the latter. These Headon-Hill beds are also found to contain a different assemblage of fossils from that which characterizes the Colwell- and Totland-Bay beds. I shall show that this new reading of the succession of strata in the Hampshire basin harmonizes much better with the order established by foreign geologists and palæontologists than does the one usually accepted. Indeed it will be made apparent, as the result of this investigation, that the sequence of beds in this country agrees most closely with that of the equivalent Middle Tertiary strata in France, Belgium, and Northern Germany. Finally, it will be proved that the thickness and importance of this series of strata is much greater than has hitherto been supposed, attaining to not less than 800 or 900 feet; and it will be shown to belong to the lower division of a great system of strata, which is represented, both in Europe and North America, by deposits of enormous thickness, everywhere characterized by large and distinctive faunas and floras.

II. History of Previous Opinion.

The foundation of our knowledge of the succession of the Tertiary strata in Western Europe was laid by the publication, in the year 1808, of Cuvier and Brongniart's 'Essai sur la Géographie Minéralogique des Environs de Paris.' It was through the study of this work that Webster, who had already collected much valuable topographical information concerning the beds exposed on the coasts of the Isle of Wight, Hampshire, and Dorsetshire, was enabled to classify those fluvio-marine beds, with which we are now particularly concerned, and to point out their equivalents among the strata of the Paris basin. It would appear that Webster found in the Museum of this Society a collection of fossils procured from the neighbourhood of Paris by Count de Bournon; and on a comparison of these with the series of organic remains which he had himself obtained from the several divisions of the Isle-of-Wight strata, he was greatly impressed with their general resemblance. So interested was he, indeed, by this discovery, that, without waiting for the advent of more favourable weather, he set out in midwinter to re-examine the Isle-of-Wight sections, with the aid of the new clue which he had obtained. The result of this investigation he gave to the world in his twelfth and concluding letter addressed to Sir Henry Englefield on February 11th, 1813*.

Cuvier and Brongniart had divided the Tertiary strata of the Paris basin into five groups; and it was with the upper three of these that Webster correlated the fluvio-marine beds of the Hampshire basin. Hence arose the division of the Isle-of-Wight fluvio-marine beds into a "Lower Freshwater Formation:" a "Middle Marine Formation," and an "Upper Freshwater Formation:" and this classification long held its ground; for it seemed to find support in the fact that at many points marine strata might be observed with freshwater beds lying both above and below them.

But subsequent observations, especially those of M. Constant Prévost, demonstrated that the simple classification of Cuvier and Brongniart did not hold good, even for all parts of the Paris basin; while Mr. Prestwich's researches in this country proved that Webster and those who followed his views, in seeking to bring into exact agreement the succession of beds in the Paris and Hampshire basins respectively, had confounded together deposits as distinct from one another as the London, Bracklesham, and Barton Clays.

With respect to the fluvio-marine beds, however, Webster's threefold division long held its ground, and was unhesitatingly accepted by all geologists. The researches of Sedgwick, Lyell, Bowerbank, Mantell, and others added many new facts to the stock of information acquired concerning these beds; while the important discovery that they contain a mammalian fauna similar to that of the gypsum of Montmartre (which discovery was made by Dr. Buckland

* 'A Description of the Principal Picturesque Beauties, Antiquities, and Geological Phenomena of the Isle of Wight,' by Sir Henry Englefield, Bart. (London, 1816), p. 226.

in 1825*, and fully confirmed by Mr. S. P. Pratt in 1835†, and by Prof. Owen in 1841‡), established the fact of their general parallelism with the upper portion of the series seen in the Paris basin.

The first step towards the rectification of the classification of the fluvio-marine strata was made by Mr. Prestwich in the year 1846. In a short but very suggestive and valuable paper§, he showed that at Hamstead and Bouldnor Cliffs, in the Isle of Wight, there occurs a series of estuarine and freshwater deposits, which he regarded as overlying the whole fluvio-marine series, and which contains, as he pointed out, a fauna of distinct character from that of the underlying beds.

Although many details concerning the several strata were observed and described in succeeding years by Mr. Searles V. Wood, Dr. Wright, and the Marchioness of Hastings, both in the Isle of Wight and on the opposite coast of Hampshire, while great additions were made to our knowledge of the reptilian and mammalian fauna by these and other authors, yet no new step in advance was made in the classification of these beds till Edward Forbes turned his attention to the subject in the year 1852. In the meanwhile the difficulty of harmonizing the accepted classification of the Hampshire beds with the divisions established by accurate observers in various parts of the Continent was strikingly illustrated by the discordant results arrived at by such able students of Tertiary geology as Constant Prévost‖, d'Archiac¶, Dumont**, and Hébert††.

Forbes's careful study of the relations of the beds exposed in the cliff-sections of the Isle of Wight, combined with his thorough and critical examination of the fossils collected at different horizons, enabled him to establish two very important points. In the first place, he confirmed Mr. Prestwich's determination that the strata exposed at Hamstead and Bouldnor Cliffs overlie and are of younger age than all the other strata of the fluvio-marine series. For this upper series of strata, which he showed to contain a very distinct and characteristic assemblage of fossils, Forbes proposed the name

* "On the Discovery of *Anoplotherium commune* in the Isle of Wight. By the Rev. Prof. W. Buckland," Ann. of Phil. ser. 2, vol. x. p. 360.

† "Remarks on the Existence of the *Anoplotherium* and *Palæotherium* in the Lower Freshwater Formation at Binstead, near Ryde, in the Isle of Wight. By S. P. Pratt," Trans. Geol. Soc. ser. 2, vol. iii. p. 451.

‡ "Description of some Fossil Remains of *Chœropotamus*, *Palæotherium*, *Anoplotherium*, and *Dichobune* from the Eocene Formation, Isle of Wight. By Prof. R. Owen," Trans. Geol. Soc. ser. 2, vol. vi. p. 41.

§ "On the Occurrence of *Cypris* in a part of the Tertiary Freshwater Strata of the Isle of Wight," Rep. Brit. Assoc. for 1846, Trans. of Sections, p. 56.

‖ "Coupe d'Alum Bay et d'Headen-Hill, dans l'île de Wight," Bull. Soc. Géol. France, t. viii. p. 76.

¶ "Note sur les Sables et Grès Moyens Tertiaires," Bull. Soc. Géol. France, t. ix. p. 54.

** "Essai sur la co-ordination des terrains tertiaires du Nord de la France, de la Belgique, et de l'Angleterre," Bull. Soc. Géol. France, t. x. pp. 158, 168.

†† "Comparaison des Couches tertiaires inférieures de la France et de l'Angleterre," Bull. Soc. Géol. France, sér. 2, t. ix. p. 350.

of the "Hempstead Series"*. In the second place Forbes demonstrated, by both stratigraphical and palæontological evidence, that the thick freshwater limestones seen at Bembridge Ledge and in Headon Hill respectively, are not, as had been supposed by all previous writers on the subject, on the same horizon, but that the former of these belongs to a much more recent period than the latter.

As the result of his observations of the strata and study of their fossils in 1853, Edward Forbes proposed the total abandonment of Webster's classification, and the division of the fluvio-marine strata of the Isle of Wight into four series—the Headon, the Osborne and St. Helens, the Bembridge, and the Hempstead†. This is the classification which was adopted in the publications of the Geological Survey, and is now generally received among geologists.

Unfortunately, Edward Forbes's life was not spared sufficiently long to enable him to complete his study of this important formation. While his observations on the three higher divisions of the formation are very full and detailed, it is evident, from an examination of Forbes's posthumous work, that he had been able to devote far less attention to the study of the succession of beds and the fossils of the lowest or Headon series. With regard to these strata Forbes maintained, as almost all previous observers had done, that the beds of Colwell and Totland Bays are on the same horizon as those at the base of Headon Hill and at Hordwell Cliff.

It will be seen that Webster made the mistake of placing all marine bands in the fluvio-marine formation upon one horizon. Prestwich made the first rectification of this error by proving that the Hamstead strata are superior to all the other fluvio-marine strata; and Forbes followed in the same direction, by showing that the oyster-beds of Bembridge are on a distinct and much higher horizon than those of either Colwell Bay or Headon Hill. I shall now demonstrate that the Colwell-Bay marine beds are not, as has hitherto been supposed, the equivalent of those of Headon Hill and Hordwell Cliff, but that they occupy a distinct and much higher horizon.

Since Edward Forbes's premature removal from our midst, very great and important additions have been made to our knowledge of the fauna and flora of the fluvio-marine beds of the Hampshire basin. To no one do we owe more for valuable additions to our knowledge of the palæontology of this formation than to the late Mr. Frederick E. Edwards and Mr. S. V. Wood‡, who have collected and described

* In the choice of this name Forbes was singularly unfortunate. The name of the farm near which the beds are exposed is "Hamstead," though it is misprinted "Hempstead" on the old 1-inch map of 1810. This name, as it now stands, is not only quite unknown in the Isle of Wight, but runs the risk of being confounded with localities in Essex and Hertfordshire.

† "On the Fluvio-marine Tertiaries of the Isle of Wight," Quart. Journ. Geol. Soc. vol. ix. p. 259; "On some new Points in British Geology," Edin. New Phil. Journ. vol. lv. p. 263.

‡ 'A Monograph of the Eocene Mollusca, Cephalopoda and Gasteropoda,' by F. E. Edwards, supplemented by S. V. Wood; 'Bivalves,' by S. V. Wood. Palæontographical Society, 1848–1877.

so many of the fossils of the Lower Tertiary formations. Owing to their labours and those of other indefatigable collectors, the number of known fossil forms from the fluvio-marine beds is at least four times as great as was recognized by Edward Forbes.

At the same time the remarkable fauna of Brockenhurst, in the New Forest, which was discovered by Mr. Edwards, has been carefully studied by Von Könen* and Dr. Duncan†, who have shown the exact agreement of this fauna with that of the Lower Oligocene in Northern Germany; while the Rev. Osmond Fisher‡ and Mr. H. M. Jenkins§ have recognized its identity with that of certain strata in the Isle of Wight.

Last, but not least, must be mentioned the great advances which have been made in our knowledge of the faunas of equivalent strata upon the continent of Europe, especially those which we owe to the researches of Deshayes in the Paris basin, of Sandberger in the Mayence basin, and of Hörnes in the Vienna basin, which have supplied valuable means of comparison between the English and foreign strata, such as were almost wholly wanting when Forbes was engaged in the study of the Isle-of-Wight beds. Furthermore, many able geologists, among whom may especially be mentioned M. Hébert in France, MM. Charles Mayer and Renevier in Switzerland, MM. Sandberger and Beyrich in North Germany, and M. T. Fuchs in Austria, have occupied themselves with the question of the correlation of the various European Tertiary deposits with great success.

Under these circumstances we are now supplied with the means for making a much more exact and rigid comparison of the strata of the Hampshire basin with those of the other European areas than was possible twenty-five years ago. Foreign geologists, who have endeavoured to correlate the British deposits of this age with their equivalents on the continent, have experienced the greatest difficulties, owing, as I believe, to the succession of beds in this country having been hitherto misunderstood. It is on these grounds that I venture to offer a new classification of these strata as the result of researches which I have carried on for some time past.

III. Stratigraphical Evidence.

We have stated that hitherto a serious error has been made in reading the succession of strata exposed in the cliff-sections at the western extremity of the Isle of Wight. The beds seen at Colwell and Totland Bays have been regarded by nearly all observers as being upon the same geological horizon as those exposed at the base of Headon Hill, whereas, as I shall now proceed to show, the latter altogether underlie the former. The primary cause of this mistake concerning the succession of these beds is not difficult to discover.

* "On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England," Quart. Journ. Geol. Soc. vol. xx. p. 97.

† 'A Monograph of British Fossil Corals,' 2nd series, Palæontographical Society, 1866.

‡ Quart. Journ. Geol. Soc. vol. xviii. p. 67, footnote.

§ Quart. Journ. Geol. Soc. vol. xxiv. p. 519.

Almost every geologist who has studied the section in question has assumed the existence of a great anticlinal fold, of which the summit is supposed to be seen in Totland Bay; and as the effect of this great flexure, the strata seen at the base of Headon Hill are supposed to be repeated, with an opposite dip, in Colwell and Totland Bays. The manner in which this supposed anticlinal is regarded as having affected the strata is illustrated in Prof. Edward Forbes's memoir (see Pl. VII. fig. 1), and also in Sheet 47 of the Horizontal Sections published by the Geological Survey.

The circumstance which seems to have given rise to this correlation in the first instance was the occurrence, both at Colwell Bay and at the base of Headon Hill, of a band containing numerous oysters and other marine shells, and especially characterized by abundant and well-preserved specimens of *Cytherea incrassata*, Sow. Now the "Venus-bed," as it was called by collectors, so well seen in Colwell Bay, soon came to be identified with that at the base of Headon Hill; and the term "Middle Headon" was applied to both. At the same time the freshwater beds, lying respectively above and below these marine bands, were correlated with one another and termed "Upper" and "Lower Headon."

But *Cytherea incrassata*, Sow., is not by any means to be regarded as an eminently characteristic shell marking a particular geological horizon. According to the Geological Survey, it makes its first appearance in the Barton Clay, and ranges up certainly as high as the Bembridge Marls. As I shall show hereafter, the "Venus-bed" of Colwell Bay contains a very different fauna from that at the base of Headon Hill. A third "Venus-bed" is found in the midst of the Bembridge series; and the failure of geologists, prior to the work of Edward Forbes, to discriminate between this and the other "Venus-beds" led to the Headon strata being placed on the same horizon as the Bembridge.

This correlation of the "Venus-beds" of Colwell Bay and Headon Hill has been productive of a great amount of confusion, as will soon be made apparent when we critically examine the conclusions of different authors who have written upon the subject. As early as the year 1821 Mr. G. B. Sowerby pointed out that the so-called marine bed of Headon Hill had little claim to be so regarded; for the number of freshwater forms found in it is so great that it can only be considered as having been deposited under estuarine conditions. Sedgwick, who reexamined the sections in the following year, seems to have clearly perceived the points of difference between the beds in Colwell Bay and in Headon Hill.

Both Edward Forbes and Mr. Bristow appear to have experienced the greatest difficulties in their attempt to correlate with one another the beds above and below the "Venus-beds" of Colwell Bay and Headon Hill respectively. Thus they found it necessary to assume that the beds called "Upper Headon" at Colwell Bay have suddenly expanded within a distance of less than two miles from 49 feet to 85 feet; while the thick beds of limestone which are so conspicuous in the latter locality are entirely wanting in the former. The diffi-

culties felt by the geological surveyors are brought out very prominently if we carefully compare the several publications which they have issued at successive dates. Thus, in the sections prepared to illustrate the memoir published in 1856*, 48 feet of strata, which in the text of the memoir are described as belonging to the "Osborne and St. Helen's Series," are placed in the "Upper Headon;" but in the sheet of 'Vertical Sections,' issued in 1858†, the first reading is adopted, while in the general memoir on the Isle of Wight, which appeared in 1862‡, a return is made to the second reading. A comparison of these several publications of the Geological Survey must lead every one to the conclusion that, by the assumption of the identity of the marine beds at Colwell Bay and Headon Hill, the authors of these works had been led into inextricable difficulties and confusion. All these difficulties are removed when we recognize the fact that the Colwell- and Totland-Bay beds altogether overlie those exposed at the base of Headon Hill.

There are not wanting indications, however, that several authors were almost upon the point of recognizing the true succession of beds at the western extremity of the Isle of Wight. Thus Dr. Wright, in his admirable section of the strata between Cliff End and Headon Hill §, clearly points out that the Limnæan limestone of How Ledge, and the sandy rock of Warden Point, are distinctly recognizable high up in the north-eastern face of Headon Hill. This being the case, it is clear that the "Venus-bed" and Oyster-bands of Colwell Bay, which are undoubtedly *above* the Limnæan limestone and sandy rock, cannot possibly be represented by the brackish-water beds which occur just above the sea-level in the same part of Headon Hill. Unfortunately, however, Dr. Wright did not follow up this important clue to the true succession of beds which he had discovered, but permitted himself to be carried away by the usually accepted opinion that there exists only one marine stratum with freshwater deposits above and below it.

Dr. Wright's valuable observations were published in 1851; and in the year following Prof. Hébert declared his conviction, as the result of a personal examination of the Isle-of-Wight sections, that the Colwell-Bay beds are upon an altogether higher horizon than those of Headon Hill. Prof. Hébert, whose exact acquaintance with the Lower Tertiaries of the Paris basin lends the greatest weight to his opinions, pointed out that the marine beds of Headon Hill and Hordwell Cliff contain precisely the same fauna as "the upper fossiliferous zone of Mortefontaine, Monneville," &c., while the Colwell-Bay beds agree in their fossils with the lower part of the Fontaine-

* Mem. Geol. Surv. 'On the Tertiary Fluvio-marine Formation of the Isle of Wight,' by Prof. Edward Forbes, F.R.S. Compare plate 10 and p. 81.

† Vertical Sections, Geol. Survey, sheet 25.

‡ Mem. Geol. Surv. 'The Geology of the Isle of Wight' (sheet 10), by H. W. Bristow, F.G.S., plate 4.

§ "A Stratigraphical Account of the Section from Round-Tower Point to Alum Bay, on the North-west Coast of the Isle of Wight," by Dr. T. Wright, Ann. and Mag. Nat. Hist. ser. 2, vol. vii. p. 14, and Proc. Cotteswold Nat. Club, vol. i. p. 87.

bleau Sands. Hence the distinguished French geologist argued that Colwell-Bay beds are of younger age, and must overlie those of the Headon Hill and Hordwell*. Unfortunately some of the points of correlation insisted upon by M. Hébert in the same paper, were such as could not be accepted by English geologists (and this was forcibly pointed out by Lyell and Forbes); thus the really valuable suggestions made by the French geologist came to be altogether neglected by later writers upon the subject in this country.

Although I was led to the recognition of the true succession of beds in the Isle-of-Wight section quite independently of these observations of Dr. Wright and M. Hébert, it is right to point out how near these geologists were to the true solution of the problem. I may add that I am convinced that although Prof. Edward Forbes argued so strongly against the views of M. Hébert, yet before his death he had begun to perceive the difficulties which beset the accepted classification of the Headon beds, and that, had his life been spared to complete that rigid palæontological examination of the lower beds of the fluvio-marine series which he so successfully accomplished with respect to the higher parts of the same series, he would have so modified his classification as to have rendered the publication of the present memoir unnecessary. In Forbes's posthumous memoir the account of the Headon beds occupies only three pages, which are reprinted, almost without alteration, from the memoir read before this Society by the author on the 4th of May, 1853†.

If we now proceed to examine the supposed proofs of the existence of a great anticlinal by which the strata at the base of Headon Hill are folded over so as to reappear in Colwell Bay, we shall find that they do not stand the test of careful scrutiny and exact measurement. Webster and other authors following him have well shown how the Tertiary and underlying strata of the Isle of Wight have been subjected to disturbances producing a series of flexures, the axes of which lie in an east-and-west direction, and which attain their maximum development in the great anticlinal curve stretching from Whitecliff Bay to Alum Bay and thence on to Studland Bay on the Dorsetshire coast. But, in addition to these east-and-west folds, the Isle-of-Wight strata exhibit evidence of having been subjected to another set of flexures, at right angles to the former, and having their axes striking north and south. The positions and effects of this second series of flexures were well illustrated by Prof. Edward Forbes in his memoir read before this Society ‡.

Now, from Cliff End to Headon Hill, the coast of the Isle of Wight trends nearly north and south, and we have presented to us in the cliffs a section nearly at right angles to the first-mentioned series of folds. From Cliff End to Warden Point the beds have a steady dip of from 2° to 3° to the north, interrupted only by several

* "Comparaison des couches tertiaires inférieures de la France et de l'Angleterre," Bull. Soc. Géol. France, 2e ser. t. ix. p. 191.

† Quart. Journ. Geol. Soc. vol. ix. p. 259.

‡ Quart. Journ. Geol. Soc. vol. ix. p. 260, fig. 1.

slight dislocations and a small series of contortions. At Totland Bay there is undoubted evidence of the presence of a slight anticlinal fold, having its summit near Widdick Chine, to the westward of which the beds for a short distance have a slight dip to the south. The great mural face of Headon Hill, however, has a trend almost at right angles to that of the cliffs of Colwell and Totland Bays; and the section exposed on the face of the hill is nearly at right angles to the *second* series of flexures which have been indicated as affecting the Isle-of-Wight beds. These strata seen in Headon Hill have a slight dip to the west. Passing round Heatherwood Point we again find the cliffs assuming a northerly and southerly trend, and the beds are found dipping to the north, at an angle which increases very rapidly, till at Alum Bay the strata assume a vertical position, and near the Chalk are for a short distance actually inverted.

Now, when these Isle-of-Wight cliffs are viewed from the sea, the great changes which take place in the trend of the coast may be easily overlooked; and undoubtedly the first impression which is made upon the mind of an observer is, that there exists a great anticlinal flexure, the summit of which is seen in Totland Bay, and that the Colwell-Bay and Headon-Hill beds respectively lie in equivalent positions on either side of this axis, and are therefore representatives the one of the other.

If, however, instead of trusting to the general impression which is produced by viewing these beds from a distance, we carefully plot the section to scale by the aid of the admirable 25-inch maps of the Ordnance Survey, allowing carefully for the changes in direction of the cliffs, we shall find that the effect produced by the Totland-Bay anticlinal has been very greatly overrated, and that, in consequence of this, the true order of succession of the beds has been altogether misunderstood. The strata of How Ledge and Warden Point are seen in such a true-scale section (Pl. VII. figs. 1, 2, & 3) to be clearly continued in precisely similar beds appearing underneath the gravel of Headon Hill; the clays beneath are found to be a continuation of those seen in Totland Bay; while all the underlying strata are recognized as distinct from and on a lower horizon than those exposed in the bays to the north of Headon Hill.

When we come to compare the succession and thickness of the several strata exposed in Headon Hill and in the bays to the northwards, the correctness of this new reading of the section will become strikingly apparent. The two series of beds can only be correlated with one another, as has been attempted by previous observers, by supposing that in the distance of a mile or two the most remarkable changes have taken place, both in the mineral character and the fossil contents of the several beds. But if, on the other hand, we admit that the lowest beds in Totland Bay are represented in the higher part of the Headon-Hill section, while the main part of the strata at that locality are on a different and lower horizon, the difficulties and discrepancies will at once disappear.

Fortunately, however, I am able to adduce proofs of the most

convincing kind of the correctness of the reading of these sections which I now offer. If, as is supposed by the earlier interpretation, the strata of Colwell and Totland Bays be only a repetition of those of Headon Hill, resulting from the presence of a great anticlinal flexure, then the well-marked white sands of Headon Hill ought to be found near the summit of the anticlinal in Totland Bay. In this position they are actually represented as occurring, in both the longitudinal and vertical sections of the Geological Survey*, it being supposed that they are concealed by heavy masses of talus which cover that portion of the cliffs. Now within the last few years excavations have been made at this locality for the purpose of erecting the new reading-rooms; and it is found that the Headon-Hill Sands do not occur in the position indicated by the Geological Survey, but that beds are found which have their exact counterpart in the Headon-Hill section, not at the base, but at a much higher part of the series. I looked forward with great interest to the opening of these sections in Totland Bay, as enabling me to apply a crucial test to the two interpretations of the section; and the results are such as to remove any possibility of doubt upon the subject.

Again, the position of the Bembridge Limestone at Headon Hill quite agrees with the interpretation of the section which I now offer, but is altogether irreconcilable with that which has hitherto been adopted. It is admitted on all hands that at the north-east angle of Headon Hill the marine band ("Middle Headon beds") makes its appearance just above the sea-level. Now the excellent maps of the Ordnance Survey enable us to fix with the greatest precision the height above the sea-level of the Bembridge Limestone, which is so well exposed with all its characteristic fossils near the cottage on the Warren. We thus learn that 250 feet of strata must intervene between the Bembridge Limestone and the marine band of Headon Hill; but the Geological-Survey section shows less than one half of that thickness of beds, and in Colwell Bay the distance between the Bembridge Limestone and the marine band is 120 feet. Hence, if we believe that the marine bed at Headon Hill is identical with that at Colwell Bay, we must suppose that in a distance of little more than one mile a mass of beds 120 feet thick has expanded to 250 feet, and, further, that the beds have been entirely changed in their mineral characters. But 250 feet of strata is precisely the thickness required by my interpretation. It may be objected that the marine beds of Colwell Bay have never been detected in the upper part of the Headon-Hill section, where they must exist according to my view. But those who know the manner in which the succession of beds is obscured in the upper part of Headon Hill, through land-slips and the great capping of gravel, will feel little surprise that this particular bed has never been seen there.

In the two diagrammatic sections on Plate VII. the two readings of the succession of strata, as seen at the western end of the Isle of Wight, are illustrated. Fig. 1 is exactly copied from the diagram

* Horizontal Sections, sheet 47; Vertical Sections, sheet 25.

given by Prof. Edward Forbes in his memoir on the Tertiary Fluvio-marine Formation of the Isle of Wight (p. 89). In fig. 2 the relative heights are given in accordance with the measurements of the Ordnance Survey; but the vertical scale is different from the horizontal; and the section illustrates diagrammatically the view of the succession of beds which I now put forward. The section fig. 3 on the same Plate is drawn upon the true scale, both vertical and horizontal, the heights and distances being taken from the new maps of the Ordnance Survey.

IV. Palæontological Evidence.

I shall now proceed to show that the palæontological evidence in favour of the correlation which I propose is not less complete and satisfactory than the stratigraphical. According to the usually received interpretation, a series of marine strata 100 feet thick in Whitecliff Bay, the well-known and distinctly marked marine beds of Colwell Bay, and the marine beds of the New Forest exposed at Brockenhurst, Roydon, and Lyndhurst are represented at Headon Hill by the brackish-water Middle Headon beds, and at Hordwell Cliff by a band a few inches thick, containing both marine and fresh-water forms.

But against this correlation several very serious objections may be urged. In the first place, it must be noticed that at Whitecliff Bay, at Colwell Bay, and in the several New-Forest localities, the strata are of *purely marine* origin, and contain no admixture of fresh-water shells, while in the last-mentioned reef-building corals abound*, and to the existence of these an influx of fresh water is known to be highly inimical. The so-called "Middle Marine" beds of Headon Hill and Hordwell Cliff are of totally different character, exhibiting clear evidence of the prevalence of estuarine or brackish-water conditions only. At both localities we find some shells belonging to marine genera, such as *Ancillaria*, *Area*, *Bulla*, *Cancellaria*, *Chemnitzia*, *Corbula*, *Cytherea*, *Fusus*, *Lucina*, *Murex*, *Natica*, *Nucula*, *Ostrea*, *Pleurotoma*, *Psammobia*, *Scalaria*, and *Voluta*, with Balani and Serpulæ. But these marine forms are almost always dwarfed in size, and exhibit clear evidence of having lived under unfavourable conditions: while mingled with them we find shells belonging to genera which usually frequent brackish water, such as *Cerithium*, *Cyrena*, *Hydrobia*, and *Odostomia*, with other purely freshwater forms, such as *Limnæa*, *Melania*, *Melanopsis*, *Potamomya*, and *Planorbis*.

The marine beds of Whitecliff Bay attain a thickness of 100 feet; at Colwell Bay they are about 25 feet; while in the New Forest their entire thickness, although it has never been determined, is probably very considerable. These beds contain a very large and

* See the important memoir by Dr. Duncan "on the Physical Geography of Western Europe during the Mesozoic and Cainozoic Periods, elucidated by their Coral Faunas," Quart. Journ. Geol. Soc. vol. xxvi. (1870), p. 51.

varied marine fauna, which, as I shall hereafter show, characterizes a higher horizon in the geological series as displayed upon the Continent than is represented by the brackish-water fauna of Headon Hill and Hordwell Cliff.

Now, although in such series of strata as those of the Isle of Wight we might be prepared to find marine beds passing at certain points into others exhibiting evidence of brackish-water conditions, yet it is impossible to believe that a thick mass of marine strata, maintaining such a uniformity of character and of fossils at points so distant as Whitecliff Bay, Colwell Bay, and Brockenhurst, could lose all their distinctive characters and pass into brackish-water strata at intermediate points like Headon Hill and Hordwell Cliff. Moreover, as I shall proceed to show, the marine fossils of these two sets of beds are not identical in character, as has been supposed, but very distinct, the faunas being such as, at many points upon the Continent, characterize two perfectly distinct horizons.

This distinction between the fauna of the Colwell-Bay beds and that of the Headon-Hill and Hordwell-Cliff beds is rendered strikingly apparent if we direct our attention to the species and varieties by which certain genera are represented in these two deposits. The genus *Cerithium* especially affords very interesting and valuable evidence bearing on this point; and it was, indeed, while engaged in a series of researches, commenced many years ago, with a view to the determination of the genealogy and lines of descent of the forms of this group, that I first detected the serious errors which have crept into our classification and correlation of the strata we are now considering. While the form now known as *Cerithium pseudocinctum*, d'Orb. (with its variety *C. trizonatum*, Morris) occurs in great abundance both in the marine beds of Colwell Bay and all through the Headon series, two well-marked forms, *Cerithium ventricosum*, Sow., and *C. concavum*, Sow. (with its varieties *C. pleurotomoides*, Lam., and *C. rusticum*, Desh.), are entirely confined to the Headon beds, occurring similarly at Hordwell Cliff. At both these latter localities these two forms of *Cerithium* are found in such prodigious abundance as to constitute the most characteristic fossils of the beds; and their total absence from the Whitecliff-Bay, the Colwell-Bay, and the New-Forest beds is a most significant circumstance.

Now, as long ago shown by M. Hébert, the form of *Cerithium* known in this country as *C. concavum*, Sow., and in France as *C. rusticum*, Desh., and *C. pleurotomoides*, Lam., is found at a very definite horizon in the Paris basin—"the Upper fossiliferous zone of Mortefontaine and Monneville &c."—the beds there, like those of Headon Hill, being characterized by the extreme abundance of that fossil. More recently Dr. C. Mayer, of Zurich, whose researches have contributed greatly to our knowledge of the exact correlation of the various Tertiary deposits, has insisted upon the importance of this palæontological horizon, which he has distinguished by the name of "the Zone of *Cerithium concavum*"*. Dr. Sandberger, too, fully

* C. Mayer, 'Table des Terrains Tertiaires Inférieurs,' Zürich, 1875.

indorses the opinion of Hébert and Mayer as to the distinctness and importance of this division of the Lower Tertiary series.*

When we come to study the whole of the marine forms of Headon Hill and Hordwell, and to compare them with those of the Brockenhurst, Colwell-Bay, and Whitecliff-Bay beds, the distinction of the two faunas becomes strikingly apparent. Nearly one hundred marine forms are known from Headon Hill and Hordwell, while almost twice that number have been obtained from the New-Forest localities, Colwell Bay, and Whitecliff Bay. Of the forms found at Headon Hill and Hordwell Cliff, less than one half occur at the three other places. Again, if we compare both of the marine faunas with that of the Barton series, we find that while nearly *one third* of the Hordwell and Headon-Hill marine shells are Barton forms, not more than *one fifth* of those occurring at Brockenhurst, Colwell Bay, and Whitecliff Bay are found at Barton. On the other hand the latter fauna has more species in common with that of the Hempstead beds than has the former.

Summing up the results of this palæontological examination of the beds, we find that the fossils in the Headon-Hill and Hordwell-Cliff beds are almost identical, while those of Colwell Bay, Whitecliff Bay, and of the New Forest localities also present the very closest agreement with one another. But when we come to compare the fauna of the two first-mentioned places with that of the other three, we are struck by remarkable points of difference. In the first place, the conditions indicated by the former are estuarine, of the latter purely marine; secondly, more than one half of the forms found in the former are different from those in the latter; thirdly, the former exhibits a much closer approximation to the Barton fauna than does the latter; and, fourthly (and most important of all), the fauna of the former agrees with that of a series of beds occurring both in France and Germany, which unquestionably underlie and are of older date than beds containing the fauna of the latter. We thus see that the palæontological evidence fully supports the conclusion derived from a study of the physical evidence—namely, that the Hordwell-Cliff and Headon-Hill strata are not, as has previously been supposed, on the same horizon with those of Brockenhurst, Colwell Bay, and Whitecliff Bay, but occupy a distinct and lower place in the geological series.

V. Correlation of the Strata with Foreign Deposits.

Since the date of the appearance of Edward Forbes's posthumous monograph 'On the Tertiary Fluvio-marine Formation of the Isle of Wight,' so much has been done in the investigation of the faunas and floras† of the several divisions of the series, and at the same

* Sandberger, 'Land- u. Süsswasser-Conchylien der Vorwelt,' p. 198.

† The valuable collection of Lower Tertiary fossils made with such untiring industry by the late Mr. F. E. Edwards, and in part described by himself, Mr. S. V. Wood, and Dr. Duncan in the publications of the Palæontographical Society, have fortunately been acquired for the nation, and are now in

time so vast a fund of new information has been accumulated concerning the age and relations of the equivalent beds upon the Continent, that geologists are now in a very different, and far more favourable, position for estimating the evidence concerning the correlation of the various beds than was the case at the time of Edward Forbes's death in 1854. This circumstance, taken in connexion with the fact which I have now established, viz. the error hitherto made in the determination of the order of succession of the beds, affords sufficient warrant for that revision of the classification and nomenclature of the beds in question which I now propose to make.

As Professor Huxley has well pointed out, the time is approaching when geologists will have to establish two distinct and parallel systems of classification, for the formations of marine and freshwater origin respectively. In the series of beds which we are now considering, we have such remarkable alternations of marine and freshwater conditions that it will be of advantage to consider the evidence afforded by the study of the marine fauna, and by the freshwater and terrestrial fauna and flora respectively. The earliest classification of the Tertiary strata—that of Lyell—was based entirely upon the study of the marine Mollusca; and these forms still constitute the safest guides in correlating the beds over different areas; but, at the same time, so much attention has of late years been devoted to the study of the freshwater and terrestrial shells (the results of which have been admirably embodied in Dr. Sandberger's 'Die Land- und Süsswasser-Conchylien der Vorwelt'), that great assistance may be obtained from these forms in the comparison of the strata in different areas. Lastly, the flora and vertebrate fauna occupying the land of the period afford the means of a third series of comparisons. We shall proceed to the study of each of these three kinds of evidence, in the order in which we have enumerated them, which is the order of their respective importance.

Confining our attention in the first instance to the forms of marine life, we find that we have three well-marked horizons in the English series which enable us to bring our strata into exact correlation with those of France, Belgium, and Northern Germany, and, less directly, with the deposits of the Alps, the Italian peninsula, and Eastern Europe.

At the base of the Fluvio-marine series lies the richly fossiliferous marine deposit of the Barton Clay. So long ago as 1857, Professor Prestwich was able to enumerate no less than three hundred species of Mollusca from this formation; and when all the known forms contained in the numerous collections in this country come to be described, the number of species from this deposit will probably be found to exceed a thousand.

Now all palæontologists are agreed that the Barton Clay is repre-

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the British Museum. This splendid collection is so admirably arranged that the work of the palæontologist who shall deal with these species is greatly simplified; and it is to be hoped geological literature will soon be enriched by the publication of the as yet undescribed forms by the Palæontographical Society, or, failing this, by the keepers of the national collection.

sented in the Paris basin by the "Sables Moyennes" or "Sables de Beauchamp," and in Belgium by the "Système Lackénien" of Dumont. Most geologists, too, regard this well-marked fossiliferous zone as constituting the highest member of the Eocene or Nummulitic formation. This being admitted, we have an admirable and safely established base-line from which to start in our comparison of the English and foreign representatives of the succeeding geological periods.

Lying upon the Barton Clay we find a great series of estuarine strata, which in places attains a thickness of nearly 400 feet; and this is succeeded by the beds containing the second marine fauna. At Whitecliff Bay these marine beds are 100 feet in thickness; at Colwell Bay they are reduced to 25 feet, while in the New Forest we have evidence that their thickness is considerable, though it has never been exactly determined. Our knowledge of these marine beds in the New-Forest area is derived entirely from an examination of exposures in artificial openings—brickyards, wells, and railway-cuttings. Some of the peculiar fossils of this horizon were obtained so long ago as 1823 by Sir C. Lyell, and by him submitted to Mr. Sowerby for description. Mr. F. E. Edwards made many interesting collections from beds on this horizon at Brockenhurst, Roydon, Whitley Ridge, and Lyndhurst, especially during the period when railway-cuttings were being opened at the first-mentioned of these localities. From information communicated to him by Mr. Edwards, supplemented by his own studies, Von Könen, who was well acquainted with the equivalent beds on the Continent, was enabled to give the account of these beds which was published by this Society in 1864*. Professor P. M. Duncan about the same time described the important coral-fauna of these beds, the distinctive character of which he was the first to recognize.

Now the marine fauna of these beds is a very rich and highly interesting one. Von Könen was able in 1864 to enumerate 56 species of Mollusca as occurring at Brockenhurst; but we are now acquainted with nearly 200 marine forms from the several localities at which the beds representing this horizon occur.

The first point which claims our attention in connexion with this second marine fauna is its striking distinctness from that of the Barton beds. Of the 200 forms which it contains, not more than 20 per cent. are found in the Barton beds. Now this second fauna is found to occur at many points upon the Continent, and always in strata which distinctly overlie the Bartonian deposits. In the Paris basin, it is true, this second marine fauna is not represented; for there the gypsum of Montmartre and other freshwater deposits occur at this horizon, to the exclusion of marine beds; but in Belgium, Northern Germany, and Switzerland we find the exact equivalent of our English strata everywhere containing the same well-characterized fauna. The fossils of the "Tongrien inférieur" of Dumont (the Lower Limburg of Lyell), those of the strata which

* "On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England," Quart. Journ. Geol. Soc. vol. xx. p. 97.

over so large a part of North Germany overlie the Brown Coal, and those of the "étage Ligurien" of C. Mayer agree so closely with the forms found in the Isle-of-Wight and New-Forest beds as to put their contemporaneity beyond question. The number of molluscan forms obtained from this horizon at various points on the Continent now greatly exceeds 1000; and everywhere the distinctness of this fauna from that of the Bartonian is not less clearly marked than it is in this country.

Up to the present time, however, the beds which in this country contain this important marine fauna have not received a distinctive local appellation; and as their position in the geological series and their relations to foreign deposits are now fully established, I propose to call them them the "Brockenhurst Series," from the locality in the New Forest at which they have yielded the greatest number of fossils.

The appended list will serve to illustrate the richness and variety of this second marine fauna. I have included in it a number of MS. names given by the late Mr. F. Edwards; for although the forms thus designated have not been described and figured, yet they are so carefully arranged and so accessible for purposes of reference in the British Museum, that I think I am justified in so doing. As to the question whether these forms should be regarded as species or varieties, I hold it to be one of very little importance; enough for us if they can be recognized as presenting constant and distinctive characters, and are found characterizing definite geological horizons.

Fossils of the Brockenhurst Series.

W, found at Whitecliff Bay; C, at Colwell Bay; B, Brockenhurst and neighbourhood; L, Lyndhurst; *x*, pass down into Barton Series; *a*, pass up into Hempstead Series.

x Marginella simplex, *Edw.* C.
x —— æstuarina, *Edw.* B, L.
Voluta tereticosta, *Edw.* MS. W, C.
—— geminata, *Sow.* B, L.
—— spinosa, *Lam.* C, B, L.
x —— decora, *Beyr.* (V. maja, *Edw.*). B, L.
—— suturalis, *Nyst* (V. contabulata, *Edw.*). B.
x —— depauperata, *Sow.* C.
Mitra gracilenta, *Edw.* MS. B.
—— abbreviata, *Edw.* MS. B.
—— polygyra, *Edw.* MS. B.
Conorbis (Conus) dormitor, *Sol.*, var. seminuda, *Edw.* B, L.
—— procerus, *Beyr.* (C. alatus, var. hemilissa, *Edw.*). B, L.
Pleurotoma transversaria, *Lam.* B.
—— ——, var. cymæa, *Edw.* B.
—— ——, var. nana, *Edw.* C.
—— pyrgota, *Edw.* B.
—— bellula, *Phill.* B.
x —— headonensis, *Edw.* C, L.
x —— denticulata, *Bast.* L.
—— ——, var. odontella, *Edw.* C, L.
—— læviuscula, *Edw.* B.
—— subdenticulata, *Goldf.* (P. hantoniensis, *Edw.*). B, L.
Borsonia sulcata, *Rouault.* C.

a Aporrhais (Chenopus) Margerini, *de Kon.*, var. speciosa, *Schloth.* B.
x Rimella rimosa, *Sol.* W, C, B, L.
x Hippocrenes (Rostellaria) ampla, *Sow.* (R. macroptera, *Lam.*). L.
Murex hantoniensis, *Edw.* MS. B, L.
—— sexdentatus, *Sow.* C.
—— ——, var. cinctus, *Edw.* MS. C.
x —— minax, *Sol.* B.
—— obtusus, *Desh.* B.
x Typhis pungens, *Sol.* B, L.
Cantharus subcostulatus, *Edw.* L.
a Pisania (Fusus) labiata, *Sow.* C, B, L.
—— ——, var. concinna, *Edw.* MS. C.
—— nodicosta, *Edw.* MS. B.
—— acuticosta, *Edw.* MS. C.
x Clavella (Fusus) longæva, *Sol.* B, L.
—— ——, var. egregia, *Beyr.* B.
Chrysodomus (Fusus) Sandbergeri, *Beyr.* B.
Leiostoma (Fusus) ovatum, *Beyr.* B.
x Strepsidura (Buccinum) armata, *Sow.* (B. bullatum, *Phill.*). W, B, L.
—— semicostata, *Edw.* MS. C.
x Cominella (Buccinum) deserta, *Sol.* (B. excavatum, *Beyr.*). B.
—— flexuosa, *Edw.* MS. C, B.
—— ventricosa, *Edw.* MS. C.
x Ancillaria buccinoides, *Lam.* C, B, L.
x Cassis ambigua, *Sol.* (C. affinis, *Phill.*). B.
x Natica hantoniensis, *Sow.* B.
—— ——, var. obovata, *Sow.* B.
a —— conulus, *Edw.* MS. B.
—— grossiuscula, *Edw.* MS. B.
—— dubia, *Edw.* MS. B.
—— Studeri, *Bronn.* C, B.
a, x —— labellata, *Lam.* B, L.
Cancellaria pyrgota, *Edw.* MS. (C. sex-muricata, *S. V. Wood*). C, B, L.
—— elongata, *Nyst.* C, B, L.
—— roydonensis, *Edw.* MS. B.
—— scrobicula, *Edw.* MS. B.
x —— evulsa, *Sol.* B.
Pyramidella (Turbonilla?) obscura, *Edw.* MS. B.
Turbonilla plicatella, *Edw.* MS. C, B.
—— semilævis, *Edw.* MS. B.
Odostomia loxodonta, *Edw.* MS. C.
—— subumbilicata, *Edw.* MS. C.
—— geminata, *Edw.* MS. C.
—— multispirata, *Edw.* MS. C.
—— gracilis, *Edw.* MS. C.
—— angustata, *Edw.* MS. B.
Eulima gracillima, *Edw.* MS. C.
Scalaria lævis, *Morr.* C.
—— tessellata, *Edw.* MS. C, B.
Cerithium pseudocinctum, *d'Orb.* W, C, B, L.
—— pyrgotum, *Edw.* MS. C, B.
—— varians, *Edw.* MS. C.
—— subconoideum, *Edw.* MS. C.
—— pliciferum, *Edw.* MS. C.
—— subventricosum, *Edw.* MS. C.
a Nematura parvula, *Desh.* C.
a —— pygmæa, *Forbes.* C.
Trochita (Infundibulum) obliqua, *Sow.* B.
Phorus cretifer, *Edw.* B.
Teinostoma minutissimum, *Edw.* MS. C.
—— micans, *Edw.* MS. C.

Nerita aperta, *Sow.* C.
—— æstuarina, *Edw.* MS. C.
Neritina concava, *Sow.* C.
Tornatella (Actæon) hinnæformis, *Sandb.* B.
—— altera, *Desh.* B.
Orthostoma crenata, *Sow.* B.
—— retiarium, *Edw.* MS. B.
x Ringicula parva, *Edw.* MS. B.
Bulla æstuarina, *Edw.* MS. C, L.
—— Lamarckii, *Desh.* B.
—— curta, *Edw.* MS. L.
—— simillima, *Edw.* MS. L.
—— navella, *Edw.* MS. C.
Cylichna globulus, *Edw.* MS. B.
—— ovalis, *Edw.* MS. C.
Anomia Alcestiana, *Nyst.* B.
Ostrea velata, *S. Wood.* C.
—— ventilabrum, *Goldf.* (O. prona, *S. Wood*). W, C, B, L.
Pecten bellicostatus, *S. Wood.* B.
x Avicula media, *Sow.* B.
Dreissena unguiculus, *Sandb.* B.
Mytilus strigillatus, *S. Wood.* C.
Modiola Nystii, *Kickl.* MS. B.
—— ignota, *Edw.* MS. B.
x Arca biangula, *Lam.* B.
—— appendiculata, *Sow.* W, B.
—— lævigata, *Caill.* C, L.
x —— duplicata, *Sow.* (A. sulcicostata, *Nyst*). B.
Trigonocœlia deltoidea, *Lam.* C, B, L.
Nucula headonensis, *Forbes.* C.
—— nudata, *S. Wood.* B. C.
x —— similis, *Sow.*, var. B.
Leda propinqua, *S. Wood.* C.
—— minima, *Sow.* B.
Cardita simplex, *Edw.* MS. B.
—— paucicostata, *Sandb.* B.
—— deltoidea, *Sow.* W, B, C, L.
—— orbicularis, *Goldf.* B.
x —— oblonga, *Sow.*, var. transversa, *Edw.* MS. B.
Crassatella hantoniensis, *Edw.* B.
Luciua obesa, *Edw.* MS. C.
—— concava, *Defr.* B, C.
—— pulvinata, *Edw.* MS. C.
x —— bartoniensis, *Edw.* MS. B.
x —— Menardii, *Desh.*, var. B.
Strigilla colvellensis, *Edw.* MS. C.
Diplodonta suborbicularis, *Edw.* MS. B.
—— obsca, *Edw.* MS. B.
—— planiuscula, *Edw.* MS. B.
x —— dilatata, *Sow.* B.
x Cardium porulosum, *Lam.* B.
—— obliquum, *Lam.* B.
—— Edwardsii, *Desh.* B.
Protocardium hantoniensis, *Edw.* B.
x Cypricardia pectinifera, *Sow.* B.
Isocardia transversa, *Nyst.* B.
Scintilla angusta, *S. Wood.* C.
Lepton tumidum, *Edw.* MS. C.
Cyprina scutellaria, *Desh.* (*Nyst*). B.
—— Nystii, *Héb.* B.
a, *x* Cytherea incrassata, *Sow.* sp. W, B, C, L.

Cytherea turgescens, *Edw.* MS. B, L.
—— tumida, *Edw.* MS. B.
—— suborbicularis, *Edw.* MS. B.
—— subelliptica, *Edw.* MS. B.
—— hantoniensis, *Edw.* MS. B.
x —— Solandri, *Sow.* B.
x —— elegans, *Lam.*, var. B.
x Psammobia compressa, *Sow.* (P. stampinensis, *Desh.*). B, C.
—— ——, var. æstuariua, *Edw.* MS. B, C.
—— rudis, *Lam.* (P. solida, *Sow.*). C.
x Sanguinolaria Hollowaysii, *Sow.* L.
a Tellina corbuloides, *Edw.* C.
Syndosmya colwellensis, *Edw.* MS. C.
Mactra filosa, *Edw.* MS. C.
a, *x* —— fastigiata, *Edw.* MS. C.
Mya producta, *Edw.* MS. C.
x Corbula cuspidata, *Sow.* W, C, L.
x —— pisum, *Sow.* L.
Panopæa subeffusa, *Edw.* MS. C.
—— sulculosa, *Edw.* MS. B.
—— corrugata, *Sow.* B.
Clavigella coronata, *Desh.* B.
—— Goldfussi, *Phill.* B.
Fistulana Heyseana, *Phill.* B.
Saxicava, sp. B.
Pholas, sp. B.
Teredo antenautæ? *Sow.* B.
x Balanus unguiformis, *Sow.* B.
Solenastræa cellulosa, *Dunc.* B.
—— Kœneni, *Dunc.* B.
—— Reussi, *Dunc.* B.
—— gemmans, *Dunc.* B.
—— Beyrichi, *Dunc.* B.
—— granulata, *Dunc.* B.
Balanophyllia granulata, *Dunc.* B.
Lobopsammia cariosa, *Goldf.* sp. B.
Litharæa brockenhurstii, *Dunc.* B.
Axopora Michelini, *Dunc.* B.
Madrepora Solanderi, *Defr.* B.
—— Rœmeri, *Dunc.* B.
—— anglica, *Dunc.* B.

Of the 13 species of corals, 4 (namely *Lobopsammia cariosa*, Goldf., *Madrepora Solanderi*, Defr., *Solenastræa Kœneni*, Dunc., and *S. gemmans*, Dunc.) are found in the Oligocene strata of the Continent. I am indebted to Dr. Duncan for valuable information upon this point. It is only right to point out that the study of these corals led Dr. Duncan to the conclusion that the Brockenhurst strata are the representatives of the Oligocene of North Germany, and that this conclusion was arrived at by him quite independently of the work of Von Könen upon the molluscan forms in the same beds.

Separated from the Brockenhurst series by about 300 feet of estuarine and freshwater beds, we find the strata containing our third marine fauna. This fauna is not represented, it is true, by so large a number of species as either the Barton or the Brockenhurst fauna; but we have, nevertheless, sufficient evidence of its distinctness from both of them, and data by which we can correlate the

deposits containing this third fauna with beds of the same age upon the Continent. In the upper part of Hamstead (or "Hempstead") and Bouldnor Cliffs in the Isle of Wight, the only point at which the beds of this age are clearly displayed, about 100 species of marine Mollusca have been obtained. The distinction between this fauna and that of the Barton and Brockenhurst series respectively is shown by the fact that at Hamstead only five Barton and twelve Brockenhurst forms occur. Indeed, as was clearly perceived by Lyell, the nearest analogues to the Hempstead fauna are to be found, not in the Eocene deposits, but in the Miocene.

The annexed list of Hempstead fossils sufficiently indicates the character of this fauna; and there cannot be the smallest doubt as to the foreign deposits which must be correlated with the beds containing it. In the Paris basin we have the Lower Fontainebleau Sandstone, in Belgium the Upper Tongrian or Kleyn-Spawen beds, in the Mayence basin and Northern Germany the Marine Sands and Septarian Clay, and in Switzerland the Lower Marine Molasse—each of which contains a fauna presenting so many forms in common with the fauna of the Hempstead beds as to leave no room for doubt as to the approximate contemporaneity of all these deposits.

Fossils of the Hempstead Series.

Voluta Rathieri, *Héb.* (V. Forbesii, *Edw.*).
—— detrita, *Edw.* MS.
Aporrhais (Chenopus) Margerini, *de Kon.*, var. speciosa, *Schloth.*
Cantharus crebricostatus, *Edw.* MS.
Pisania (Fusus) labiata, *Sow.*
—— tricincta, *Edw.* MS.
—— parviuscula, *Edw.* MS.
Chrysodomus (Fusus) Edwardsii, *Mor.*
Cuma (Purpura) monoplex, *Desh.* (C. Charlesworthii, *Edw.*).
Natica conulus, *Edw.* MS.
—— hempsteadensis, *Edw.* MS.
—— labellata, *Lam.*
Turbonilla (Pyramidella) subconvexa, *Edw.* MS.
—— micans, *Edw.* MS.
—— spiculoides, *Edw.* MS.
—— pseudospina, *Edw.* MS.
—— scalaris, *Edw.* MS.
Cerithium plicatum, *Lam.*
—— ——, var. ryssum, *Edw.* MS.
—— ——, var. muticum, *Edw.* MS.
—— ——, var. lineatum, *Edw.* MS.
—— ——, var. immeritum, *Edw.* MS.
—— ——, var. Galeotti, *Nyst.*
—— ——, var. intermedium, *Sandb.*
—— ——, var. papillatum, *Sandb.*
—— subcostellatum, *Forbes.*
—— inornatum, *Mor.* (C. acutum, *Sow.*?).
—— Lamarckii, *Brong.* (C. Sedgwickii, *Mor.*).
—— elegans, *Desh.*
—— ——, var. Austenii, *Forbes.*
—— margaritaceum, *Sow.*
—— submargaritaceum, *A. Braun.*
—— conoidale, *Lam.*
—— venustum, *Edw.* MS.

Cerithium acuminatum, *Edw.* MS.
—— odontolon, *Edw.* MS.
—— asperulum, *Edw.* MS.
—— ligatum, *Edw.* MS.
—— triseriale, *Edw.* MS.
—— asperum, *Edw.* MS.
—— tropis, *Edw.* MS.
—— ornatissimum, *Edw.* MS.
—— cinctum, *Brug.*, var. vectensis, *Edw.* MS.
—— ——, var. conjunctum, *Forbes.*
Rissoa turbinata, *Lam.*
—— diversa, *Edw.* MS.
—— paucicostata, *Edw.* MS.
—— obliquecostata, *Edw.* MS.
Odostomia lineolata, *Sandb.*
—— sulcifera, *Edw.* MS.
—— nitens, *Edw.* MS.
—— micans, *Edw.* MS.
Nematura pupa, *Nyst.*
—— parvula, *Desh.*
—— pygmæa, *Forbes.*
Teinostoma (Adeorbis) decussatum, *Sandb.* sp.
—— subumbilicare, *Edw.* sp.
—— nitidum, *Edw.* MS.
—— affine, *Edw.* MS.
Collonia trigonostoma, *Edw.* MS.
Neritina tristis, *Forbes.*
—— striatula, *Edw.* MS.
—— fulminifera, *Sandb.*
—— marginata, *Edw.* MS.
—— denticulata, *Edw.* MS.
—— planulata, *Edw.* MS.
Tornatella (Actæon) limnæiformis, *Sandb.*
—— fasciolata, *Edw.* MS.
Bulla cælata, *Desh.*
—— Sandbergeri, *Edw.* MS. (B. conoidea, *Sandb.*, non *Desh.*)
—— conoidea, *Desh.*
Ostrea cyathula, *Lam.*
—— callifera, *Lam.*
—— longirostris, *Lam.*
Mytilus affinis, *Sow.*
—— strigillatus, *S. Wood.*
Modiola Prestwichii, *Mor.*
—— flabellula, *S. Wood.*
—— Deshayesii, *Sow.*, var. hempsteadensis, *S. Wood.*
Lithodomus delicatulus, *Desh.*
Arca Websteri, *Forbes.*
Nucula sphenoides, *Edw.*
Lutetia trigonula, *Edw.*
Lucina Thierensi, *Heb.*
Cardium hempsteadianum, *Edw.* MS.
—— nanum, *Edw.* MS.
—— Etheridgii, *Edw.* MS.
Cytherea Lyelli, *Forbes.*
Venus vectensis, *Edw.* MS.
—— Forbesii, *Edw.* MS.
Tellina Nysii, *Desh.*
—— vectensis, *Edw.*
—— hempsteadiensis, *Edw.*
—— corbuloides, *Edw.*
Mya minor, *Forbes.*
—— hempsteadiensis, *Edw.* MS.

Mya donacialis, *Edw.* MS.
Corbula vectensis, *Forbes.*
—— subpisum, *d'Orb.*
Panopæa Heberti, *Bosq.* (P. minor, *Forbes*).
Pholas, sp.

If we now turn our attention to the forms of life contained in the two groups of freshwater and estuarine strata alternating with the three marine series which we have indicated, the views at which we have arrived concerning the age and foreign equivalents of the latter are supported and strengthened. The lowest of these groups of freshwater and estuarine beds is more than 400 feet in thickness, and exhibits many indications of the prevalence from time to time of brackish-water and marine conditions. Hence there have been collected from these beds a considerable number of marine forms, in all about 100 species. Now if we examine their distribution, we arrive at some interesting results. About one half of them occur in the Brockenhurst series above, one third in the Barton below, while one third are peculiar, and one sixth common to all three formations.

If we compare the British with foreign deposits, we find that the marine fossils of this lower group of estuarine strata agree very closely indeed with those of the series of beds developed at many points of the Paris basin, as at Mortefontaine, Senlis, and Monneville, and now well known to geologists under the name of the "Zone of *Cerithium concavum*," Sow. ("Sous-étage de Mortefontaine" of C. Mayer).

Marine Fossils from the Brackish-water Bands of Headon Hill and Hordwell Cliffs.

[*a* Pass up into the Brockenhurst series. *x* Pass down to the Barton clay.]

a Marginella simplex, *Edw.*
—— vittata, *Edw.*
a Pleurotoma headonensis, *Edw.*
a —— denticulata, *Bast.*, var. odontella, *Edw.*
—— Woodi, *Edw.*
a, x Borsonia sulcata, *Rouault.*
a, x Rimella rimosa, *Sol.*
a, x Hippocrenes (Rostellaria) ampla, *Sow.*
a Murex sexdentatus, *Sow.*
Fasciolaria crebrilinea, *Edw.* MS.
Pisania (Fusus) scalaroides, *Lam.*
a Natica grossiuscula, *Edw.*, MS.
—— Studeri, *Bronn*, var. clausa, *Edw.*
a, x —— labellata, *Lam.*
x Odostomia hordeola, *Lam.*
a —— loxodonta, *Edw.* MS.
a —— subumbilicata, *Edw.* MS.
a —— geminata, *Edw.* MS.
a —— multispirata, *Edw.* MS.
a —— gracilis, *Edw.* MS.
x Turbonilla obliquecostata, *Edw.* MS.
—— sorella, *Edw.* MS.
a Scalaria lævis, *Morr.*
Cerithium concavum, *Sow.*
—— gyrostoma, *Edw.*

a Cerithium duplex, *Sow.*
—— ventricosum, *Sow.*
—— contiguum, *Desh.*?
—— multispiratum, *Desh.*
—— parvulum, *Edw.* MS.
—— cavatum, *Edw.* MS.
—— speculatum, *Edw.* MS.
Cæcum Morrisii, *Edw.* MS.
Lacuna clausa, *Edw.* MS.
Rissoa carinata, *Edw.* MS.
a —— ——, var. denticulata, *Edw.* MS.
—— ditropis, *Edw.* MS.
Hydrobia polita, *Edw.* MS.
a, *x* —— anceps, *S. Wood.*
—— Dubinsoni, *Bouillot*, var. rimata, *Edw.*
—— subangulata, *Edw.* MS.
a, *x* Nematura parvula, *Desh.*
—— lubricella, *A. Braun.*
Trochus pictus, *Edw.* MS.
Adeorbis æstuarina, *Edw.* MS.
—— aperta, *Edw.* MS.
a Nerita aperta, *Sow.*
a —— æstuarina, *Edw.* MS.
a Neritina concava, *Sow.*
—— neritopsidea, *Edw.* MS.
a Actæon limneiformis, *Sandb.*
Ringicula ringens, *Lam.*
a Bulla æstuarina, *Edw.* MS.
a —— Lamarckii, *Desh.*
—— tenuicula, *Edw.* MS.
x Anomia tenuistriata, *Desh.*
a Ostrea velata, *S. Wood.*
a Avicula media, *Sow.*
a Dreissena unguiculus, *Sandb.*
a, *x* Mytilus affinis, *Sow.*
a, *x* —— strigillatus, *S. Wood.*
x Modiola elegans, *Sow.*
—— ——, var. elegantior, *S. Wood.*
a Arca lævigata, *Caill.*
a, *x* Trigonocœlia deltoidea, *Lam.*
a Nucula headonensis, *Forbes.*
—— tumescens, *Edw.* MS.
—— ampla, *Edw.* MS.
x —— lissa, *Edw.* MS.
a —— nudata, *S. Wood.*
a Cardita oblonga, *Sow.*, var. transversa, *Edw.* MS.
—— ——, var. serratina, *Edw.* MS.
x Lucina inflata, *Edw.* MS.
a, *x* —— obesa, *Edw.* MS.
x —— concava, *Defr.*
a —— pulvinata, *Edw.* MS.
x —— gibbosula, *Lam.*
—— pratensis, *Edw.* MS.
a Strigilla colvellensis, *Edw.* MS.
—— pulchella, *Agass.*
a, *x* Cardium obliquum, *Lam.*
a, *x* Scintilla angusta, *S. Wood.*
—— nitidulum, *S. Wood.*
a, *x* Cytherea incrassata, *Sow.*
—— partimsulcata, *Edw.* MS.
a —— suborbicularis, *Edw.* MS.

a Psammobia æstuarina, *Edw.* MS.
a, x —— rudis, *Lam.* (P. solida, *Sow.*).
x Tellina ambigua, *Sow.*
—— reflexa, *Edw.*
a, x Mya angustata, *Sow.*
a —— producta, *Edw.* MS.
a Corbula nitida, *Sow.*
a —— cuspidata, *Sow.*
a, x —— pisum, *Sow.*
—— fortisulcata, *Edw.* MS.
a, x Panopæa subeffusa, *Edw.* MS.

The comparison of the terrestrial and freshwater Mollusca of these two groups with one another, and with the forms contained in strata of equivalent age upon the Continent, is now greatly facilitated by the publication of Prof. Sandberger's "Land- und Süsswasser-Conchylien der Vorwelt." The conclusions to which we are led are in perfect agreement with those which result from the study of the marine faunas. About 120 forms of freshwater and terrestrial Mollusca have been described as occurring in these strata. Of these more than one half are peculiar to the Headon beds, about one quarter are peculiar to the Bembridge, while the remainder are common to the two groups of strata. The distribution of these forms is illustrated in the following Table:—

Freshwater and Terrestrial Mollusca of the Oligocene of the Isle of Wight.

	Bembridge group.	Headon group.
Helix globosa, *Sow.*	*	
—— Morrisii, *Edw.*	*	
—— tropifera, *Edw.*	...	*
Fruticola (Helix) vectensis, *Edw.*	*	*
Hyalina (Helix) d'Urbani, *Edw.*	*	*
Nanina (Helix) occlusa, *Edw.*	*	*
Patula (Helix) omphalus, *Edw.*	*	*
Strobilus (Helix) sublabyrinthicus, *Edw.*	...	*
—— (Helix) pseudolabyrinthicus, *Sandb.* (= H. labyrinthica, *S. V. Wood*, non *Say*)	...	*
Gastrodonta (Helix) headonensis, *Edw.*	...	*
Bulimus convexus, *Edw.*	*	
Glandina (Bulimus) costellata, *Sow.*	*	
Amphidromus (Bulimus) ellipticus, *Sow.*	*	
Nystia (Bulimus) polita, *Edw.*	...	*
Pomatias (Bulimus) heterostomus, *Edw.*	*	*
—— (Bulimus?) vectiensis, *Edw.*	*	
Cyclostoma (Pomatias) lamellosum, *Edw.*	...	*
Pupa oryza, *Edw.*	...	*
Torquilla (Pupa) perdentata, *Edw.*	*	
Clausilia striatula, *Edw.*	*	
Magalomastoma (Cyclostoma) mumia, *Lam.*	*	
Callia? (Pupina?) lævis, *Edw.*	*	
Cyclotus cinctus, *Edw.*	*	
—— (?) nudus, *Edw.*	*	

Freshwater and Terrestrial Mollusca (continued).

	Bembridge group.	Headon group.
Assiminea conica, *C. Prévost*	...	*
Succinea sparnacensis, *Desh.*	...	*
Tapada (Succinea) imperspicua, *S. Wood*	...	*
Limnæa longiscata, *Brong.*	*	*
—— ——, var.	*	
—— fusiformis, *Sow.*	*	*
—— pyramidalis, *Desh.*	...	*
—— columellaris, *Sow.*	...	*
—— fabulum, *Brong.*	...	*
—— ovum ?, *Brong.*	...	*
—— arenularia, *Brard*	...	*
—— elongata, *Marcel de Serres*	...	*
—— minima, *Sow.*	...	*
—— caudata, *Edw.*	...	*
—— sulcata, *Edw.*	...	*
—— gibbosula, *Edw.*	...	*
—— mixta, *Edw.*	...	*
—— tumida, *Edw.*	...	*
—— convexa, *Edw.*	...	*
—— subquadrata, *Edw.*	...	*
—— costellata, *Edw.*	...	*
—— cincta, *Edw.*	...	*
—— angusta, *Edw.*	...	*
—— recta, *Edw.*	...	*
—— tenuis, *Edw.*	...	*
—— sublata, *Edw.*	...	*
Ancylus (?) latus, *Edw.*	*	
Velletia elegans, *Sow.*	...	*
Nematura (?) pupa, *Nyst*	...	*
—— parvula, *Desh.*	*	*
Planorbis discus, *Edw.*	*	
—— Sowerbyi, *Brong.*	*	
—— rotundatus, *Brard*	*	*
—— obtusus, *Sow.*	*	*
—— platystoma, *S. Wood*	*	*
—— lens, *Brong.*	...	*
—— tropis, *Edw.*	...	*
—— hemistoma, *Sow.*	...	*
—— elegans, *Edw.* (P. Baudoni ?, *Desh.*)	...	*
—— biangularis ?, *Edw.*	...	*
Menetus (Planorbis) euomphalus, *Sow.*	...	*
—— (Planorbis) goniobasis, *Sandb.*	*	*
Helisoma (Planorbis) oligyratum, *Sow.*	*	
Paludina (Bythinia) globuloides, *E. Forbes*	*	
—— lenta, *Sow.*	*	*
—— concinna, *Sow.*	*	*
—— orbicularis, *Sow.*	*	*
—— lenta, var.	*	
—— minuta, *Sow.*	*	
—— angulosa, *Sow.*	...	*
Mitrula (Neritina) aperta, *Sow.*	*	*
Neritina concava, *Sow.*	*	*
—— tristis, *Forbes*	*	

Freshwater and Terrestrial Mollusca (continued).

	Bembridge group.	Headon group.
Neritina Forbesii, *S. Wood*	...	*
—— zonula, *S. Wood*	...	*
—— planulata, *Edw.*	...	*
Euchilus Chastelii, *Nyst*, sp.	*	
Potamaclis (Melania) turritissima, *Forbes*	*	*
Melania muricata, *Sow.*	*	*
—— fasciata, *Sow.*	*	*
—— costata, *Sow.*	*	*
—— Nystii, *Duchastel*	*	
—— angulata	...	*
—— conica	...	*
—— polygyra	...	*
—— minima, *Sow.*	...	*
—— interrupta, *Edw.*	*	
—— inflata, *Morr.*	*	
—— Forbesii, *Morr.*	*	
—— excavata, *Morr.*	*	
Melanopsis subulata, *Sow.*	*	
—— subfusiformis, *Morr.*	*	*
—— fusiformis, *Sow.*	*	*
—— ancillaroides, *Desh.*	...	*
—— subcarinata, *Morr.*	...	*
—— subulata, *Sow.*	...	*
Hemisinus (Melanopsis) brevis, *Sow.*	*	*
Macrospina (Melanopsis) carinata, *Sow.*	*	*
Unio Austenii, *Forbes & Morr.*	*	
—— Gibbsii, *Forbes & Morr.*	*	
—— Solandri, *Sow.*	...	*
—— tumescens, *Edw.* MS.	...	*
—— vectensis, *Edw.* MS.	...	*
Corbicula (Cyrena) obovata, *Sow.*	*	*
Batissa (Cyrena) obtusa, *Forbes.*	*	
Cyrena semistriata, *Desh.*	*	
—— pulchra, *Sow.*	*	
—— transversa, *Forbes*	*	
—— britannica, *Desh.*	...	*
—— pisum, *Desh.*	...	*
—— cycladiformis, *Desh.*	...	*
—— pulchra, *Sow.*, var. Wrightii, *Forbes*	...	*
—— arenaria, *S. Wood*	...	*
—— tenera, *S. Wood*	...	*
—— gibbosula, *Morr.*	...	*
Cyclas Bristovii, *Forbes*	*	
—— tumidula, *S. Wood*	...	*
Sphenia angustata, *Sow.*	...	*
—— minor, *Forbes*	*	
Potamomya plana, *Sow.*	*	*
—— gregaria, *Sow.*	...	*
—— angulata, *Sow.*	...	*

The freshwater and terrestrial Mollusca of the strata above the Brockenhurst series in many cases belong to species which occur likewise in the Calcaire de St. Ouen and the gypseous series of Montmartre in the Paris basin, in the Palæotherium-Limestone of

the South of France, and in strata of the same age in Belgium and Northern Germany. The forms which occur in the beds below the Brockenhurst series are many of them common to the Tongrian of Belgium and the Lower Oligocene of Northern Germany.

A very considerable number of vertebrate forms has been obtained from this great estuarine series of beds. Teeth of *Squalus* and *Myliobates*, and scales and teeth of *Lepidosteus*, abound in the lower group. Of reptiles we have the remarkable *Crocodilus Hastingsiæ*, Owen (of which the fine *Alligator hantoniensis* of S. Wood is believed by both Owen and Huxley to be only a variety). With this Crocodilian we have also in the lower series of estuarine strata a number of remarkable Chelonians, including *Trionyx Henrici*, Owen, *T. Barbaræ*, Owen, *T. marginatus*, Owen, *T. rivosus*, Owen, *T. planus*, Owen, *T. circumsulcatus*, Owen, with *Emys crassa*, Owen, and *E. hordwellensis*, Seeley. There have also been found at the same horizon some Ophidian and Lacertilian remains that as yet remain undescribed. In the Upper series of estuarine beds lying above the Brockenhurst series, the only recorded reptilian form is the *Trionyx incrassatus*, Owen.

The study of the Mammalian fauna of these beds yields some facts of considerable interest. The beds above the Brockenhurst series have yielded four species of *Palæotherium*, two of *Anoplotherium*, one of *Chœropotamus*, two of *Hyopotamus*, and one of *Dichobune*. The beds below the Brockenhurst series have yielded three species of *Palæotherium*, all distinct from those of the beds above, with representatives of the genera *Palaplotherium*, *Dichobune*, *Microchœrus*, *Spalacodon*, *Hyænodon*, and *Dichodon*. There also exist in the British and Woodwardian Museums, and in some private collections, undescribed vertebrate remains, which, when carefully studied, will probably throw much new light on the terrestrial life of this period.

In 1862 Prof. Heer described the following ten species of plants as derived from the black band of Hamstead in the upper of the two estuarine series. These are *Sequoia Couttsiæ*, Heer, *Cyperites Forbesi*, Heer, *Sabal major*, Ung., *Andromeda reticulata*, Ett., *Nymphæa Doris*, Heer, *Nelumbium Buchii*, Ett., *Carpolites Websteri*, Brong., *Carpolites globulus*, Heer, *Chara Escheri*, A. Brong., and *Chara tuberculata*, Lyell, var. Of these no less than six, as pointed out by Prof. Heer, are well-known species, found in Switzerland and elsewhere in the Aquitanian and Tongrian divisions of the Tertiary series, or in strata which are now classed with the Oligocene.

In the lower series of estuarine strata, or Headon group, Gyrogonites are the only common plant-remains. One of the forms, *Chara Wrightii*, Forbes, is peculiar to the Headon group; and another, *C. tuberculata*, Lyell, is common to both the Bembridge and Headon groups. Mr. J. Starkie Gardner records a feather-palm from these beds*.

* Monograph of the British Eocene Flora, Pal. Soc. 1879, p. 20.

VI. Subdivisions and Nomenclature of the Series.

According to the classification of the Tertiary strata usually followed in this country, it is necessary to divide the fluvio-marine series into two portions, placing one in the Eocene and the other in the Miocene. This is the grouping of the strata followed by the late Sir Charles Lyell; and no one who has studied the faunas of the Hempstead beds, and of their equivalents the Fontainebleau Sandstone of the Paris basin, and the Rupelian of Belgium, can for one moment doubt that this classification is well founded. The fauna of the Fontainebleau Sandstone and of the Rupelian being unquestionably more closely related to the Miocene than to the Eocene, it is quite impossible to accept the grouping adopted by the Geological Survey, and followed in most English text-books of geology, and to extend the Eocene or Nummulitic series upwards so as to embrace beds containing such faunas as those of the Brockenhurst and Hempstead series.

On the other hand the inconvenience of breaking up so natural a group of strata as that which the fluvio-marine beds of the Hampshire basin manifestly constitute is apparent to every one; and it is doubtless this conviction which has operated in preventing the general acceptance of the Lyellian classification. It has been felt, and rightly too, that no such break in continuity exists between the Hempstead and Bembridge strata as would warrant their being placed in distinct divisions of the geological series.

Fortunately a method of classification is open to us which, while it does not break up this natural group of the Fluvio-marine of the Hampshire basin, yet enables us to refer its members to divisions of the geological series which have been based on the careful and exact study of the faunas of the Tertiary strata all over Europe. This classification completely satisfies the apparently opposing requirements of the physical geologist and the palæontologist.

In the year 1854 Prof. Beyrich, in describing the nature and affinities of the fauna which was yielded by the Tertiary beds of Northern Germany, pointed out that the same difficulty is found in defining whether they should be regarded as Eocene or Miocene as is the case with the English strata which we are now considering. He further showed how recent discoveries had added greatly to the importance which must be attached to the beds on this horizon, beds which he has demonstrated to be represented by deposits of great thickness, not only in Hampshire but in the Paris basin, Belgium, the Mayence basin, and Northern Germany; and he suggested that these strata form a division of such consequence, and containing a fauna so distinct, that they deserve to be erected into a new grand division of the Tertiary series. For this division of the geological series Prof. Beyrich proposed the name of "Oligocene," a term formed on the same principle as was adopted by Lyell in devising names for the other divisions of the Tertiary strata.

This division of the Tertiary series, to which Beyrich applied the name of Oligocene, has now come to be very generally recog-

nized on the Continent. It has been shown that, not only in the districts in which its existence was first made known, but also in Switzerland, Italy, and Hungary, deposits are found, sometimes attaining a thickness of several thousands of feet, which contain the same well-characterized fauna, and must be referred to the same division of the geological series. And by the labours of Beyrich, Von Könen, Sandberger, Mayer, Von Hantken, and many other palæontologists our knowledge of the extent and peculiarities of the fauna has been greatly enlarged.

The marine fauna of the Hempstead beds unquestionably agrees in the closest manner with that of the Fontainebleau Sandstone, the Rupelian of Belgium, the marine sand of the Mayence basin, and the clays of Hermsdorf, Cassel, &c. in Northern Germany. All of these strata are now recognized as belonging to the Middle Oligocene.

The Brockenhurst beds contain a rich fauna, the analogues of which, as we have seen, are not found in the Paris basin (where the strata of this horizon are of freshwater origin), but which find their exact representatives in the Lower Tongrian of Belgium and the Clays of Lattorf, Egeln, and Helmstadt in Northern Germany. These constitute the Lower division of the Oligocene.

With regard to the beds which underlie the Brockenhurst series, those, namely, of Headon Hill and Hordwell Cliff, there is equally little room for doubt. They unquestionably represent the "Zone of *Cerithium concavum*," which was long ago recognized as existing in the Paris basin by Prof. Hébert, and of which the importance has been more recently demonstrated by Dr. C. Mayer and Prof. Sandberger. On one point some little difference of opinion may still exist—namely, as to whether the strata of the Zone of *Cerithium concavum* should be placed in the Eocene or Oligocene. As we have already pointed out, a study of the marine forms which they contain proves that the fauna is intermediate between those of the Barton and Brockenhurst series. Both Dr. Mayer and Prof. Sandberger incline to the view that they should be grouped with the Bartonian, and regarded as an upper member of that division. In this country, on the other hand, as also in the Paris basin, the evidence appears to me to point in the other direction, and I cannot but regard this Zone of *Cerithium concavum* as the base of the Oligocene—a view which is shared by Prof. Beyrich himself. As a matter of fact, the fauna of the beds in question is so strictly intermediate in character between the Barton and the Brockenhurst faunas, that it may be regarded as a question of convenience whether they should be grouped with one or the other. In this country there can be no doubt that convenience demands that they should be grouped with the other fluvio-marine beds.

In dealing with the classification of the Oligocene strata of the Hampshire basin it is desirable to retain as far as possible the local groupings which are already familiar to geologists, only making such corrections as the new facts discovered concerning the succession of the strata prove to be absolutely indispensable.

Table of the Oligocene Strata of Western Europe.

	Hampshire basin.	Paris basin.	Netherlands.	North Germany and Mayence basin.	Switzerland.
Upper Oligocene.	Absent.	Freshwater limestone of Beauce. Millstones of Montmorency &c.	Beds of Maestricht.	Strata of Osnabruck, Bünde, Cassel, Wiepke, &c. Lower Rhenish Brown Coal. Cyrena Marl of the Mayence basin.	Brown Coal formation (Aquitanian).
Middle Oligocene.	Hempstead series. Bembridge group.	Upper Fontainebleau Sandstone. Lower Fontainebleau Sandstone. Green Marls of Montmartre. Millstones and Marls of Brie.	Rupélien. Tongrien supérieur.	Septarian Clay. Marine Sand of the Mayence basin.	Lower Marine Molasse (Tongrian).
Lower Oligocene.	Brockenhurst series. Headon group.	Gypsum of Montmartre. Marine Marls. *Cerithium-concavum* beds of Mortefontaine &c. Freshwater Limestone of St. Ouen.	Tongrien inférieur.	Clay of Egeln, and shell-beds overlying the Brown Coal.	Upper Flysch and top of Nummulitic series.
Upper Eocene.	Barton Clay.	Sands of Beauchamp.	Laekénien.	Brown Coal.	Nummulitic.

First in importance we have the strata containing the three marine faunas, which, as we have seen, are so well characterized and are so distinct from one another. The name of Bartonian is now accepted everywhere for the strata containing the *first* and lowest marine fauna and their continental equivalents. For the beds which contain the *second* marine fauna, I have proposed the name of the *Brockenhurst series*.

For the beds containing the *third* and highest marine fauna, I propose to retain the name of the Hempstead series. It is a very unfortunate circumstance that, in selecting this name, Prof. Edward Forbes was labouring under a mistake. As I have already pointed out, Hamstead, in the Isle of Wight, is spelt in a different manner from that of the well-known London suburb; while the name of Hempstead is not only quite unknown in the Isle of Wight, but belongs to localities in Essex and Hertfordshire. Nevertheless the inconvenience of changing a name which has been so generally adopted both in this country and abroad is so manifest that I do not propose to interfere with it. It is desirable, however, to restrict its application to the more purely *marine* strata constituting the upper 100 feet of the section in the Isle of Wight. The grounds on which Prof. Forbes separated the estuarine marls below the marine strata of Hamstead from the Bembridge marls below can now be shown to be very unsubstantial. The occurrence of a lignite seam like the "Black band" of the Hempstead series is too common a circumstance in the case of these fluvio-marine beds to warrant us in making it the limit between two series of strata; while the first appearance of *Hydrobia* (or *Rissoa*) *Chastelii*, to which Prof. Forbes attaches so much importance, loses its significance now that, as is shown by Prof. Sandberger, the shell in question is recognized as a freshwater form belonging to the genus *Euchilus*.

In dealing with the estuarine strata which separate these three marine groups, the Barton, the Brockenhurst and the Hempstead, I am impressed with the desirability of avoiding the multiplication of names for small and local groups of these strata, where no good palæontological grounds can be shown for such divisions. The strata are so inconstant in their mineral characters, and it is so manifestly impossible to trace them at the surface by the methods at the command of the geological surveyor, that such minute subdivision of the beds can tend only to the confusion rather than to the elucidation of their relations.

I therefore propose to extend the name of the Headon series so as to cover all the beds between the Barton and the Brockenhurst series, and to call all those strata which, as we have seen, belong to the palæontological Zone of *Cerithium concavum*, the Headon group. The divisions of Upper, Middle, and Lower Headon cannot, as I shall show, be traced to any distance; and we therefore regard the abandonment of these smaller subdivisions as an actual advantage. The Headon group, as now constituted, will embrace the whole of the true Headon series, with certain others both above and below it.

To all the beds between the Brockenhurst and Hempstead series I propose to apply the name of the "Bembridge group," which also

includes strata both above and below the "Bembridge series" of Edward Forbes. It includes not only the Bembridge limestone and marls of that author, but also beds referred by him to the base of the Hempstead, the Osborne and St. Helens, and to the Upper Headon. These great changes in the classification and nomenclature of the strata are rendered absolutely necessary by the discovery that has been made of the error in the existing views of the succession of the strata.

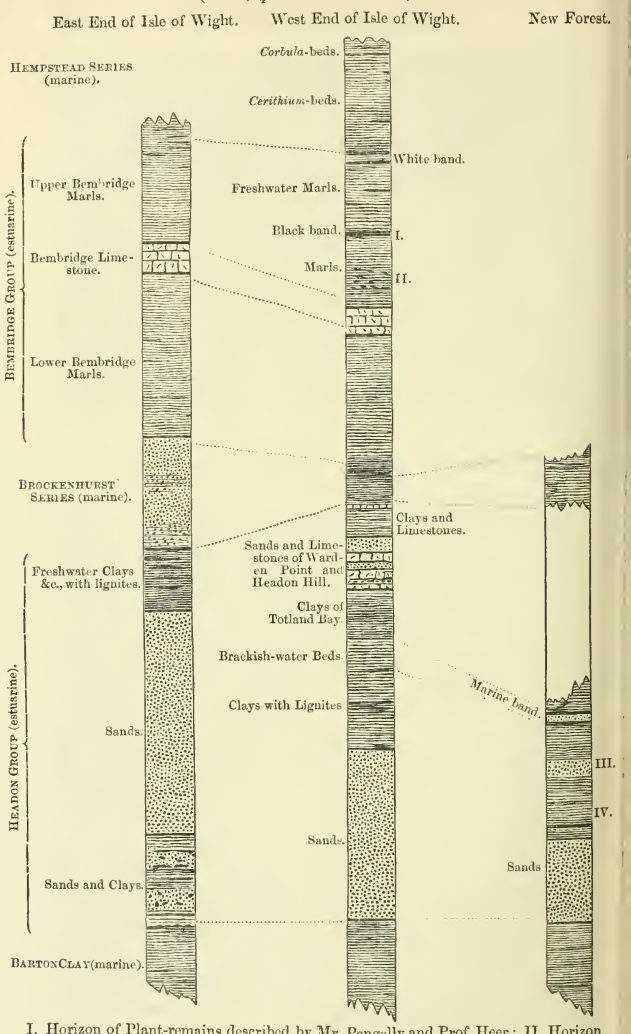
With respect to Forbes's division of the "Osborne and St. Helen's series," I think that it had better be given up altogether, and on the following grounds:—*First*, there are no good characters, either physical or palæontological, by which this division can be defined. *Secondly*, the separation of this division from those above and below it has been found so difficult, that even in the different publications of the Geological Survey very serious discrepancies exist as to the limits of the series; and *thirdly*, under this name beds lying below the Brockenhurst series, as at Headon Hill, have been confounded with others on a totally different horizon, above the Brockenhurst series.

VII. Thickness of the Strata and their Development in different Areas.

Immediately above the richly fossiliferous Barton Clay we find a series of sandy strata with subordinate argillaceous beds. At Alum Bay these strata attain a very considerable thickness, which has been variously estimated at from 100 feet to 200 feet; it is probably not less than 150 feet. These Headon-Hill sands are usually called the Upper Bagshot beds; but it appears to me that it cannot but be a source of confusion to base our classification of the Upper Eocene strata on the poorly fossiliferous deposits of the London basin rather than on the richly fossiliferous deposits of the Hampshire basin. It is true that at Alum Bay the Headon-Hill sands have not yielded any fossils; but the equivalent beds at Hordwell Cliff contain a by no means scanty fauna, in which we find the same admixture of marine and freshwater forms which characterizes the overlying Headon strata. As, moreover, we detect in these beds the eminently characteristic fossil *Cerithium concavum*, it seems clear that we must regard them as constituting the lowest member of the Headon group.

The Headon group, as exhibited at the western extremity of the Isle of Wight, is about 400 feet in thickness. It consists in the upper part of freshwater and terrestrial beds,—beds of limestone containing *Limnæa*, *Paludina*, *Planorbis*, and other pulmoniferous Gasteropods, alternating with sands and clays containing freshwater fossils, while beds of lignite, sometimes a foot or two in thickness, indicate old terrestrial surfaces. But in all the lower part of the series we find a tendency to the recurrence of brackish-water conditions; and in these intercalated fluvio-marine bands we find numerous *Cerithia*, *Cyrenæ*, and dwarfed *Ostreæ*.

Comparative Vertical Sections of the Oligocene Strata of the Hampshire Basin.
(Scale, $\frac{3}{4}$ inch to 100 feet.)



I. Horizon of Plant-remains described by Mr. Pengelly and Prof. Heer; II. Horizon of bed containing Insect and Crustacean remains discovered by Mr. A'Court Smith; III. Horizon of bed containing Crocodilian and other Reptilian remains at Hordwell; IV. Horizon of bed with Mammalian remains at Hordwell.

When the beds of the Headon group are traced over to the opposite coast of Hampshire, they are found at Hordwell, apparently diminished in thickness; and here we have evidence of the existence of numerous reptilian and mammalian forms of life which do not occur in the Isle-of-Wight strata. Unfortunately, however, the exposure is incomplete, only the lowest 100 feet of the group being seen in the cliff section. The correspondence both of the freshwater and brackish forms of the Mollusca at Headon Hill and Hordwell is perfect, and leaves no room for doubt that the two series of strata are upon the same geological horizon.

When we pass to the eastern extremity of the Isle of Wight, we find at Whitecliff Bay a very different series of strata from that exposed at Headon Hill. Immediately below the well-marked Brockenhurst series at Whitecliff Bay we have a series of clays and lignites with some bands of ironstone, which appear to be entirely of freshwater origin. These are estimated by Mr. Prestwich at 92 feet in thickness; but the officers of the Survey make them only 40 feet. My own measurements indicate a thickness intermediate between these two amounts, namely about 60 feet. Below these we have 200 feet of sands usually identified with the Headon-Hill sands, but which I cannot but regard as representing all the lower part of the Headon group. Unfortunately they do not contain any fossils, with the exception of the casts of a few undeterminable bivalves. As is well known, the Barton series is very imperfectly represented at Whitecliff Bay, and it is difficult to draw a boundary either between the Bracklesham and the Barton beds or between the latter and the overlying fluvio-marine strata.

The Brockenhurst series is represented at Whitecliff Bay by 100 feet of purely marine strata. The identity of these with the beds of the New Forest, so well worked out by Mr. Edwards and Herr Von Könen, has already been recognized by Mr. Fisher* and by Messrs. Jenkins and Codrington†. At Colwell Bay this marine series is reduced to a thickness of 25 feet; but the number of its fossils is so great as to render its correlation with the Brockenhurst beds unquestionable. In the New Forest, unfortunately, we have no clear sections showing the thickness and succession of the Brockenhurst series. A well-section, observed by Mr. Henry Keeping and recorded by Mr. Wise in his work on the New Forest, shows that the thickness of this marine series is certainly not less than at Colwell Bay. Considering the wide area over which the fossils of this horizon have been found, the thickness of the Brockenhurst series in the New Forest is probably very considerable.

The Bembridge group consists of a series of beds which at the western end of the Isle of Wight attain a thickness of more than 250 feet. In the midst of the series occurs the well-known limestone of Bembridge, having a thickness of about 25 feet. We may distinguish the beds above and below the Bembridge Limestone respectively as the Upper and Lower Bembridge Marls. The Lower

* Quart. Journ. Geol. Soc. vol. xviii. (1862) p. 67.
† *Ibid.* vol. xxiv. (1868) p. 519.

Bembridge Marls separate the Bembridge Limestone from the Brockenhurst series, and are about 100 feet in thickness. Their fossils are entirely such as lived in fresh water. The Upper Bembridge Marls are about 130 feet in thickness (including the lower parts of the beds formerly referred to the Hempstead series), and are much more richly fossiliferous than the Lower Bembridge Marls. Near their base and at a little distance above the Bembridge Limestone occurs the band of fine-grained limestone which has yielded to Mr. A'Court Smith such a large number of crustacean and insect remains, some of which have been described by Dr. Woodward* and the Rev. P. B. Brodie†. In the higher part of the Upper Bembridge Marls there occurs a lignite bed (Black Band) which has yielded a considerable number of plant-remains‡. At the eastern extremity of the Isle of Wight the Bembridge group is nowhere exhibited in its entirety, but the thickness of strata above the Brockenhurst series is found to be 220 feet.

The Lower Bembridge Marls are here about 140 feet in thickness, and, as at the western extremity of the Isle of Wight, contain but few fossils, and these entirely of freshwater species. But at one point at the east end of the Isle of Wight (namely, between Ryde and St. Helens) these lower beds of the Bembridge group assume a totally distinct character, and are seen as strata of sand and sandstone, occasionally passing into conglomerates. To the upper part of this arenaceous representative of the Lower Bembridge Marls, Prof. Forbes gave the name of the "St. Helen's Sands;" and the lower part he called the "Nettlestone Grits." The Bembridge Limestone is very constant in character and thickness wherever it is seen in the Isle of Wight. The Upper Bembridge Marls at the eastern part of the Isle of Wight are generally similar to the beds on the same horizon at the west end of the island; but about 5 feet above the top of the Bembridge Limestone there occurs a band containing *Ostreæ*, *Cytherea incrassata*, and other marine forms mingled with freshwater shells. This band was long confounded with the "Venus-beds" of Colwell Bay and Headon Hill, its distinctness from these being first established by Prof. Edward Forbes. Only about 80 feet of the lower part of the Upper Bembridge Marls are exposed at the east end of the Isle of Wight.

Although the Bembridge Limestone is found at Sconce, stretching beneath the sea in the direction of the Hurst-Castle promontory, and isolated exposures of Bembridge beds are seen in Hampshire, yet no continuous sections of the Bembridge group are found in the New-Forest area.

The Hempstead series is only clearly exposed at the Hamstead and Bouldnor Cliffs; but, as pointed out by Mr. Godwin-Austen, there are proofs of the existence of these beds on the high ground covered by Parkhurst Forest§, while Dr. Wilkins has found them

* Quart. Journ. Geol. Soc. vol. xxxv. p. 343.

† Proc. Warwickshire Nat. & Archæol. Field-Club, 1878.

‡ Quart. Journ. Geol. Soc. vol. xviii. p. 369.

§ 'On the Tertiary Fluvio-marine Formation of the Isle of Wight' (1856), p. 37.

on the Osborne estate on the east side of the Medina*. It is not improbable that under the extensive beds of gravel that almost everywhere conceal the Oligocene strata in the northern part of the Isle of Wight, the Hempstead beds may be present at many points. They have not, however, been detected on the north side of the Solent.

The portion of the Hempstead series, as now limited by me, which is exposed at Hamstead Cliff, is about 100 feet in thickness. The incoming of brackish-water conditions at the base of the series is marked by the appearance of numerous forms of *Cerithium* and marine Mollusca. At the top of the series the marine forms become much more numerous. The Hempstead beds represent, as we have pointed out, the lower part of the Middle Oligocene; whether the representatives of the remainder of the Middle Oligocene and of the Upper Oligocene were ever deposited in the Hampshire basin we have unfortunately no means of determining. It is interesting, however, to notice that the Lower Oligocene and the inferior portion of the Middle Oligocene deposits are in this country more than 900 feet in thickness.

VIII. Conclusion.

Whether we regard the enormous thickness of the beds deposited during this portion of the Tertiary epoch, the marked and distinctive characters of both the marine and terrestrial faunas, or the vast changes in the distribution of land and water, of which we have such clear proofs in the deposits of this period, it must be admitted that the Oligocene is worthy to rank among the great divisions of the Cainozoic epoch, and must be regarded as of equal value with the Eocene, the Miocene, or the Pliocene.

It is clear that at the commencement of the Oligocene period great changes must have taken place in the physical geography of Europe and Asia. Large areas, in which marine deposits had been slowly accumulating during the Nummulitic period, were now upheaved and formed dry land; and though the sea from time to time re-invaded these areas, the deposits formed in Europe during the Oligocene period were to a great extent of terrestrial and lacustrine origin, while the marine strata were, for the most part, quite subordinate to these. During Eocene times marine conditions, due to continued subsidence, prevailed; and during Miocene times terrestrial conditions, resulting from elevation, existed: the Oligocene was deposited in a period of oscillation (one of enormous duration) which separated these two epochs.

The reason why the importance of the marine fauna representing the Oligocene was so long overlooked, is to be sought for in the circumstance that marine strata of this age are usually thin and subordinate to intercalated freshwater or estuarine beds; and the fact that the strata of this age are very frequently covered by thick superficial accumulations long prevented the collection and study of the fossils of the period.

It was during the Oligocene period that those great movements commenced which resulted in that folding and crumpling of strata,

* Proc. Geol. Assoc. vol. i. p. 194.

so strikingly exhibited in the Alps and Himalayas and the other great ranges which constitute the axis of the eastern continent. At the same time, too, began those volcanic outbursts along lines parallel to this axis, which attained their climax in the Miocene period, and have not yet died out at the present day.

The Oligocene was a period at which, as we have seen, many oscillations in the level of the land and sea took place in this part of the globe, elevation and subsidence alternating with one another again and again. Hence we find the thickness of the several deposits exhibiting great variations within very short distances. In eastern Europe (Hungary and Transylvania) the Oligocene strata attain a thickness of from 2000 to 3000 feet, and contain numerous beds of coal, one of which, in the Tsilthal, measures no less than 90 feet. But in Northern and Western Europe the Oligocene is represented by a series of delta deposits of much less considerable thickness. As, however, we approach the great mountain axis, where the maximum amount of movement has taken place, we find that deposits of enormous thickness have been accumulated, as in Bavaria, Switzerland, and Northern Italy, where beds of this age attain a thickness of from 10,000 to 12,000 feet.

That the Oligocene must represent a period of enormous duration we cannot, after what has been stated concerning the thickness of the deposits, for one moment doubt. And this conclusion is fully sustained when we come to study the marine and terrestrial forms of life which flourished while these strata were being accumulated. The labours of Beyrich, Von Könen, Sandberger, and others have now made known to us a marine fauna consisting of several thousands of species; and this fauna is found to be clearly distinguished alike from that of the Eocene below and that of the Miocene above. The reasons why Lyell failed to recognize this great fauna and to include it in his scheme of classification of the Tertiary strata, we have already pointed out. The terrestrial fauna and flora of the Oligocene is also as distinct from those of the Eocene and Miocene respectively, as is the marine fauna; and the characteristic Oligocene terrestrial fauna and flora have been recognized, not only in the Eastern continent, but in North America.

That which has been asserted of the Oligocene formation generally, may be maintained with equal truth concerning its representatives in these islands, the fluvio-marine strata of the Hampshire basin. These strata, although they unfortunately furnish only a fragmentary record of the earlier portions of the Oligocene period, are nevertheless between 800 and 900 feet in thickness. They contain a marine fauna and a terrestrial fauna and flora agreeing in the most perfect manner with those of the continental Oligocene; and, moreover, the great zones of life determined in the latter can, as we have pointed out, be clearly recognized in the former. Like the continental Oligocene strata, our fluvio-marine beds were evidently deposited during a period of oscillation which followed the long-continued submergence of the Eocene or Nummulitic, and preceded the final and most violent of those movements to which the plication and metamorphism of the Alpine rocks bear such striking

testimony, movements which brought about those terrestrial conditions that prevailed over so large an area in Miocene times. Of these great movements we are not without illustrations in this country; for striking evidences of them are afforded in the folded, uptilted, and occasionally inverted strata of the Hampshire basin.

When it is further remembered that the classification of the fluvio-marine strata in our Hampshire basin has always presented peculiar difficulties to geologists, and that for a long time no course seemed open to them between unnaturally extending the bounds of the Eocene so as to embrace them, or else of breaking up this homogeneous mass of deposits and placing one part in the Eocene and the other part in the Miocene, I think we may assert of any method which avoids both of these inconvenient arrangements that it is worthy of the most serious attention; and if I have not been altogether unsuccessful in the manner in which I have presented the subject, the exact agreement of our Hampshire fluvio-marine strata with the lower divisions of the continental Oligocene must be clearly apparent to everyone.

It is of course a matter of comparative indifference to geologists whether they classify the Cainozoic deposits in three or four great groups; but I maintain that the thickness of the strata and the distinctness of the fauna and flora of the Oligocene are such as to entitle it to take rank as a great system by itself, and that this is a more natural arrangement than to group it either with the Eocene or Miocene, or to divide it between those two systems of strata.

It is no answer to this argument to assert that beds are found forming a complete transition from the Eocene to the Oligocene, and others which bridge over the gap between the latter and the Miocene. As our acquaintance with the geological series grows over widening areas, such transition deposits will constantly be discovered. Few will be bold enough to assert that because we find in the Vienna basin a continuous series through the Miocene into the Pliocene, therefore these two great divisions ought to be given up: for on such grounds every possible classification and terminology of geological deposits would have to be abandoned. I argue for the use of the term Oligocene in this country because its convenience has been felt and demonstrated over a large part of the continent, and because it enables us to get rid of serious difficulties connected with the classification of a very important part of our British series of strata.

EXPLANATION OF PLATE VII.

In fig. 1 is given a *facsimile* of the diagram published in Forbes's 'Tertiary Fluvio-marine Formation of the Isle of Wight,' p. 89. In this section no attempt has been made to maintain the relative proportions between the heights of the several cliffs; and hence several serious errors are committed in joining the different strata by means of dotted lines. The Headon-Hill sands are represented as occupying not only the whole base of Headon Hill itself, but as being largely developed in Totland Bay. Yet a careful examination of the section will show that this view is quite erroneous. As the Headon-Hill sands are 70 feet beneath the marine band (Middle Headon), we ought, if Forbes's view of the identity of the Colwell-Bay and the Headon-Hill marine beds be the correct one, to find them in Totland Bay; for there are 120 feet of strata

between the Colwell-Bay marine band and the shore at Totland Bay. Hence Forbes was fully justified, taking his interpretation of the section, in placing the Headon-Hill sands where he did; and the fact of their absence at this point is clear proof that he was mistaken in his interpretation.

In fig. 2 the vertical and horizontal scales are different, but the relations between the several heights, as fixed by the new Ordnance Survey maps, are carefully maintained. Now the position of the Bembridge Limestone on Headon Hill is found to be 250 feet above the sea-level, at the point where the brackish-water strata of Headon Hill crop out on the shore. The vertical sections of the Geological Survey give the distance between the Bembridge Limestone and the Headon-Hill brackish-water bed as 125 feet. The discrepancy is so great that it is impossible to account for it by supposing a sudden thickening and change in character of the whole of the beds. But the new interpretation, illustrated by the dotted lines in this figure, removes all difficulties, and the strata of Headon Hill are brought into exact correlation with those of Totland Bay. Unfortunately that part of the section in which the Brockenhurst series would be found is entirely concealed by a talus from the beds above and the gravel which caps the hill.

In fig. 3 the same section is drawn upon the same vertical and horizontal scale, so that the exact relations of the several beds are clearly shown.

Discussion.

The President, in proposing a vote of thanks, expressed his sense of the value of Prof. Judd's communication.

Prof. Prestwich said that, notwithstanding the ability displayed in the paper, he was not yet prepared to accept all the conclusions, more especially as regards the correlation of the Headon-Hill beds. It was his impression that the Headon-Hill sands just reappeared in Totland Bay, and that the variation noticed by Prof. Judd in the marine beds at Headon Hill and Colwell Bay might be due to the more freshwater conditions which prevailed at the former place. He doubted also if the beds at Brockenhurst quite bore out Prof. Judd's opinion. It must be remembered that these beds varied much in thickness and in character. As to the importance of the Oligocene formation, he quite agreed with the author.

Prof. Duncan referred to the contests on the subject of the term Oligocene in the year 1863. He had studied the classification of these beds from the point of view of their coral fauna. That showed the existence of a formation intermediate between Eocene and Miocene. Beds in Scinde bore similar testimony to those of Europe. This was represented in Britain by the Brockenhurst fauna, which he had considered the equivalent of the "Tongrien Inférieur." He welcomed therefore Prof. Judd's classification and acceptance of the Oligocene.

Mr. Etheridge said Von Könen had identified the Oligocene in England in 1863. He thought Prof. Judd had gone far to clear up the difficulty which every student must have felt about the Colwell-Bay beds. After reading the details given by Prof. Judd in his paper, it might be possible to form an opinion as to the reason of the remarkable oscillations shown in the south of England and in Germany by this series. To clear up some of these difficulties would be a great boon to the Tertiary geologist.

Prof. Seeley thought that Von Könen had identified the Colwell-Bay bed with the Brockenhurst [Prof. Judd explained it was so; but he had identified them with the Headon-Hill beds also]. There

was certainly some parallelism between the Middle Headon and the Brockenhurst, though less than between the Colwell-Bay beds and the Brockenhurst. He had therefore thought the marine series might be one whole group representing the Brockenhurst. He inquired where Prof. Judd proposed to class the Upper-Bagshot sands. He asked what number of fossils were common to the above beds. He objected to the classification of the Tertiary strata into Miocene, Oligocene, Eocene, &c., as laying down laws before the evidence for them was in existence, and thought it was better, seeing that the fossils changed with the localities, to give local names to the formations.

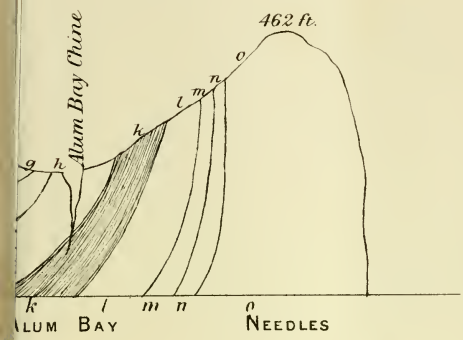
Mr. Tawney stated Mr. H. Keeping's objections to the identification of the Colwell and Headon beds. He explained the greater number of species in Colwell Bay by the imperfection of the collection from Headon Hill.

Rev. J. F. Blake thought that the assemblage of fossils seen in the field was more important than the regarding of rare fossils; adding that he thought the Colwell-Bay bed was distinct from the Headon-Hill bed.

Mr. Gardner said that the marine conditions seem to recede to the east in going upwards in the Hampshire Basin. Examination of the plants would lead him to draw the base-line for the Oligocene below the Bournemouth beds. He thought also the evidence of the Mollusca was not entirely opposed to this.

Mr. Whitaker, after speaking of the advantages of the large-scale maps, criticised two of the sections on the wall as difficult to compare. If the introduction of the term Oligocene would save debates about whether a set of beds should be called Lower Miocene or Upper Eocene, it would be a boon, as such debates were profitless.

Prof. Judd said some of the objections now raised reminded him of those brought against Forbes's classification, when he proposed to separate the Headon from the Bembridge series. He was, however, convinced of the accuracy of his views. To Prof. Prestwich he said the amount of the anticlinal had been exaggerated, the distance of the Bembridge limestone from the marine band on Headon Hill did not correspond with the distance at Cliff-end. Just where the Colwell-Bay beds should appear on Headon Hill the ground is wholly masked. In his paper he had referred at length to Dr. Duncan's and Von Könen's work. He agreed that there was not much importance in a name; but the term Oligocene was established on the continent, and it was very desirable to use it. He thought the Upper Bagshot sands which contain *Cerithium concavum* should be grouped with the Headon. He thought it was too late in the day to get rid of the terms Eocene &c. He did not agree with the identification which Mr. H. Keeping had made of the shells he had collected for Mr. Edwards. In reply to Mr. Blake, he said he had paid special attention to the representatives of the same genus in the different beds. As regards Mr. Gardner's remarks, he said the position of the land in Eocene and Oligocene times was quite different; and the line could not be drawn where he placed it, as the limits of the groups were founded, not on terrestrial, but on marine faunas.



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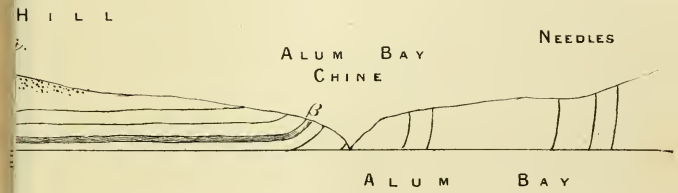

Dangerfield Lith 22. Bedford St. Covent Garden