CHAPTER VII.

THE OXFORD AND BANBURY DISTRICT.

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INTRODUCTION.

THIS district is bounded on the south by the River Thames, or that portion of it known as the Isis, which, with the single exception of a small branch of the Stour, north of Hook Norton, receives the drainage of the whole area.

The general surface of the country slopes gradually downwards to the south-east. The highest ground, over 700 ft., lies along the north-west boundary of the county, between Chipping Norton and the Edge Hill escarpment, six miles to the north-west of Banbury, forming the watershed between the Thames and Severn river systems, whilst a low-lying district, below 200 ft., is met with in the Thames Valley in the immediate neighbourhood of Oxford and in the plain of Ot Moor, a few miles to the north-east.

This slope is, however, somewhat obscured by the tributary valleys of the Isis, of which the most important are the Cherwell, the Evenlode, and the Windrush.

The Cherwell enters the county near Chipping Warden, and, forming its eastern boundary between Banbury and Aynho, flows thence in a winding course nearly due south to its junction with the main river at Oxford.

The Evenlode, rising in the Vale of Moreton, enters near Chipping Norton Junction, and runs through Charlbury to the Thames, north of Wytham Hill.

The Windrush enters west of Burford, and runs through Witney to the Thames at Newbridge.

In the south-east of the district a series of outlying hills—Brill, Shotover, Cumnor, Wytham, etc.—rise out of the Oxford plain, forming, as it were, ramparts to the Chilterns, which constitute a natural boundary to the south.

The geological structure of the country has an intimate connection with its main topographical features. The district comprises beds representative of the whole Jurassic system, which have an almost constant strike from north-east to south-west, and dip gently to the south-east; thus, approaching Oxford from the north-west, we pass successively from older to newer formations. The Edge Hill escarpment, on the north-west, forms the limit of a great Middle Lias marlstone plateau, which rises above the softer ground of the Shipston and Moreton district, composed

of Lower Lias clays, and slopes gradually downwards to the south-east. The latter formation is exposed, however, along the valleys of the Evenlode and Cherwell, which have cut down to it through the Marlstone plateau.

The Upper Lias in this district is very thin, and has only a minor effect on the landscape; several outliers, however, occur scattered over the marlstone, and patches of Great Oolite, let down by faults, are also met with.

The Marlstone plateau is bounded on the south by a bold escarpment of Great Oolite, running from Chipping Norton through Duns Tew to Aynho; this escarpment forms the edge of a second great plateau, on which outlying patches of Forest Marble, capped by Cornbrash and Oxford Clay, are met with in the neighbourhood of Wychwood Forest. The top of the Great Oolite series is formed by a constant band of Cornbrash, which forms a belt of rather flat country running through Witney, Woodstock, and Bicester.

This is succeeded to the south by the low-lying country of the Thames Valley, formed by a thick band of Oxford Clay; it is continued to the north-east through the plain of Ot Moor along the valley of the Ray, a tributary of the Cherwell.

Along a line drawn from Islip to Marsh Gibbon appear a series of inliers rising out of the Oxford Clay; these are formed mainly of Cornbrash, which is brought to the surface along an anticlinal flexure. In the Islip inlier Great Oolite appears brought in along a line of fault which strikes to the south-east.

The isolated hills which stand out to the east and west of Oxford are formed mainly by the Upper Oolites, the Calcareous Grit, Coral Rag, Kimeridge Clay, and Portland Oolite; finally capping Shotover Hill, we find iron sands containing fresh-water fossils, which have been assigned to the Wealden.

The Thames, flowing as it does in this district along the strike of the Oxford Clay, furnishes a good example of a subsequent stream, as does also the Ray.

The Cherwell, Evenlode, and, in a lesser degree, the Windrush, on the other hand, flow with the general slope of the country across the strike of the beds, and are thus consequent. The extensive river gravels of the district, which have recently been so admirably worked out by Mr. T. I. Pocock, form the site of Oxford and of many surrounding villages, and will be referred to later.

The successive geological formations will now be dealt with in ascending order.

THE LIAS.*

Lower Lias.—The dark-blue clays and shales of this formation, which form the foot of the Marlstone plateau to the north-

* See *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. iii, pp. 161, 220, 268.

west, are continued for some distance down the valleys of the Evenlode and Cherwell; in the former case occurring nearly as far south as Charlbury, in the latter extending to King's Sutton. They are also met with in the neighbourhood of Deddington along a tributary valley of the Cherwell. Sections are seldom visible, the presence of the Lower Lias often being assumed merely from the clayey nature of the soil and the appearance of springs along the base of the Marlstone. As, however, clays occur in the zone of *A. margaritatus*, the boundary line between Lower and Middle Lias must, in the absence of sections, remain somewhat hypothetical.

During the construction of the Oxford and Worcester railway several good sections were exposed in the neighbourhood of Ship-ton-under-Wychwood; the fossils obtained indicated the top-most beds of the Lower Lias—zones of *A. capricornus* and *A. henleyi*. Similar beds were found during the cutting of the railway tunnel at Chipping Norton, consisting of blue shales weathering brown and grey, with nodules of earthy limestone and iron concretions. Dr. F. A. Bather has also furnished evidence of the same zone near Fawler.

The thickness of the Lower Lias in this neighbourhood has been proved by boring to be about 450 ft.

The upper beds appear again in the Banbury district, where they contain a hard, shelly limestone band known as the Banbury Marble. At the waterworks of Grimsbury great numbers of *Montlivaltia victoria* were obtained by T. Beesley.

Among the commoner fossils from this neighbourhood may be mentioned *Modiola scalprum*, *Hippopodium ponderosum*, *Pholadomya ambigua*, *Unicardium cardioides*, *Gryphæa arcuata*, *Plicatula spinosa*, and *Inoceramus ventricosus*.

Middle Lias.—This division here consists of a lower series of marls and clays and an upper Marlstone group, indicating a gradual shallowing of the Lower Lias sea.

The Marlstone consists of a very variable sandy and ferruginous limestone, brown in colour, but appearing greenish when unweathered. It is perhaps nowhere better developed than in the country around Banbury; it covers a wide area to the north-west, rising gradually upwards to the steep scarp of Edge Hill, and by its disintegration has been formed the rich red wheat-growing soil of Oxfordshire.

At Horton and Edgehill it forms an excellent building stone. Sections in this neighbourhood were examined during a visit of the Geologists' Association at Whitsuntide, 1895, under the directorship of Mr. Edwin A. Walford, and the maximum thickness of the rock bed was estimated to be about 30 ft.; at its base was found a nodular bed, containing mollusca and corals.

Fossiliferous sections were also found at Bloxham, $3\frac{1}{2}$ miles south-west of Banbury, and at Constitution Hill, the whole of

the *A. spinatus*-zone being exposed, with a few feet of marl below; it is interesting to note that the Hornton stone furnished Sowerby's type of *Terebratulina punctata*. In 1873 a visit was paid by the Association under John Morris and Thomas Beesley to Twyford Wharf, near King's Sutton, on the Oxford Canal; here lower beds, representing the *A. margaritatus*-zone, were observed resting on the Lower Lias, and many fossils were obtained, including *Cardium truncatum*, *Cypricardia cucullata*, and *Plicatula spinosa*, the latter in a fine state of preservation.

Similar beds in this zone were again visited five years later near Chipping Norton, under the guidance of Thomas Beesley and W. H. Hudleston.

Middle Lias Beds can also be traced outcropping down the valleys of the Windrush, Evenlode, and Cherwell.

In the Taynton brook, west of Burford, the higher beds are represented by 20 ft. of ferruginous sandstone, containing Belemnites.

The Marlstone becomes a valuable iron-ore over a considerable part of this district, corresponding in level to the Cleveland Ironstone of Yorkshire. In the Evenlode Valley, at Fawler, the old ironstone workings afford a good section from the Marlstone to the Inferior Oolite. In September, 1907, during the visit of the foreign geologists for the celebration of the Geological Society's Centenary, Professor Sollas caused the quarry to be dug out, and an excellent exposure was then visible. This classical quarry has been visited by members of the Geologists' Association on several occasions—in April, 1874, under the directorship of Professor John Phillips and Mr. James Parker; in May, 1890, under Professor A. H. Green; and recently, in May, 1908, under Professor W. J. Sollas.

The quarry had been dug out the day before this last visit, and some excellent fossils were obtained. The upper part of the Marlstone series, about 16 ft., was visible, containing *Terebratulina punctata* and *Rhynchonella tetrahedra* in abundance; beneath this were formerly exposed about 11 ft. of sands, below which was found blue clay with *Am. margaritatus*. The Fawler section will be again referred to under Upper Lias.

A similar iron-ore crops out at Enstone, five miles to the north, and in the Cherwell Valley at Steeple Aston and Lower Heyford, whilst it has been extensively worked at Adderbury, King's Sutton, and, more recently, at Hook Norton. It appears to die out to the north-east in the direction of Northamptonshire.

Upper Lias.—This formation consists of blue shales and clays, with concretionary bands of limestone, often containing a profusion of Ammonites, though the zones of the latter are not well marked in this district. The Upper Lias is met with as outliers scattered over the Marlstone plateau, and as narrow belts running down the river valleys.

North-east of Banbury, at Chipping Warden, the base of the Upper Lias is formed by a bed a few inches thick, consisting of grey friable marl and marly limestone, forming a transition between the Middle and Upper Lias; it is characterised by an abundance of *Am. acutus*.

During Whitsuntide, 1895, Mr. Edwin A. Walford conducted a party of the Geologists' Association to Constitution Hill, three-quarters of a mile west of Banbury. Here was presented an excellent section of Middle and Upper Lias, and above the topmost rock bed of the Marlstone was observed a band about half-an-inch thick, composed entirely of Pentacrinus joints. This development of the Transition Bed, thin as it is, has been traced by Mr. Walford ten miles to the north of Banbury; he has shown that it may be due to the decomposition of the underlying rock or to a pause in the deposition of sediment, during which an abundance of organic remains was accumulated. The Transition Bed has not been definitely noted south of Banbury.

An interesting section was exposed at Thorpe Mandeville in 1900, during the cutting of the Great Central railway, from which the following fossils were obtained: *Am. serpentinus*, *Am. acutus*, *Am. communis*, *Rhynchonella tetrahedra*, and *Am. margaritatus*, thus indicating the passage from Middle to Upper Lias.

The Upper Lias borders the Cherwell valley at Steeple Aston and Heyford, and appears along the Windrush to a point east of Burford. The most instructive section, however, is that at Fawler, on the Evenlode, the visits of the Association to which have been already mentioned.

Here can be seen about 12 ft. of unfossiliferous blue clay with occasional small ironstone concretions lying beneath the rag-stones of the Inferior Oolite. Below the clay occurs a thin band of earthy ferruginous limestone, containing a number of Upper Lias fossils and resting directly on the Marlstone. The following Ammonites were obtained from this band during the last visit of the Association: *Am. serpentinus*, *Am. communis*, *Am. holandrei*, and *Am. bifrons*. It is clear then that the 350 ft. of Middle and Upper Lias in Gloucestershire are here represented by only 50 ft.

This great thinning out of the Lias towards Oxford is further shown by the following borings taken from the Survey Memoir:

	BURFORD.		WYTHAM.		OXFORD CITY BREWERY.
	ft. in.		ft. in.		ft. in.
Upper Lias	81 6		14 6		absent
Middle Lias	98 1		170 6+		absent
Lower Lias.....	447 4				17 0+

THE OOLITIC ROCKS.

The Inferior Oolite.*—The district of Chipping Norton, Banbury, and Charlbury is one in which the relations of all the subdivisions of the Inferior Oolite are very difficult to determine, for the Cotteswold type is here passing into that of Northamptonshire. The Great Oolite appears to lie irregularly on different members of the series, and faulting has added further complications. The work of Messrs. T. Beesley, E. A. Walford, J. Windoes, and W. H. Hudleston, however, has done much to elucidate the structure of the district.

The beds overlap one another towards the east, until the topmost or Ragstone beds are found, as at Fawler and Burford, lying directly on the Upper Lias clays. Thus beds which, at Cheltenham, have a total thickness of 264 ft., at Charlbury are represented by only 30 ft., and in the Cherwell valley have entirely disappeared or are represented by a few feet of brown sandstone. Some confusion formerly arose from the fact that the term Northampton Sand was applied to varied sandy limestones occurring between the Upper Lias and Great Oolite series. That these were not the true equivalents of the Northamptonshire sands is shown by the fact that in many localities they included the zone of *Am. parkinsoni*. The true Northampton Sands appear to extend as far west as Dasset Hill, near Fenny Compton, where they were seen by the Association on Whit Monday, 1895, under the directorship of Mr. Edwin A. Walford. The general succession in the neighbourhood of Chipping Norton is as follows:

- (i.) Chipping Norton Limestone.—A variable oolitic and sandy limestone, often made up of broken shells and rolled oolitic pebbles. This limestone, never more than 30 ft. in thickness, presents many Bathonian characters, but, as it is found below the Stonesfield slate, is classed as the top of the Bajocian.
- (ii.) The Clypeus Grit.—A loose, friable oolitic limestone containing *Clypeus Plotii* and *Parkinsonia parkinsoni*. This is underlain by coarse pisolitic ironshot ragstone beds.
- (iii.) Oolitic Marl.—Pale marly limestones, very local in extent.
- (iv.) Northampton Beds.—Calcareous sands and sandstones with *Am. opalinus*.

The Inferior Oolite forms a narrow band on each side of the Evenlode valley from Ashford mills upwards, and winds round by Chipping Norton till it abuts against a fault at Colls Combe Barn.

The classical exposure at Fawler, already mentioned, affords the following section:

	ft.
Chipping Norton Limestone, oolitic limestone	12 to 15
Clypeus Grit. rubbly and marly oolites	8 to 12
Trigonia Grit { Marly Limestones	5 to 6
{ Hard oolitic limestones, with pebble bed	
{ at base	4

These lower beds furnish evidence of contemporaneous local erosion.

* See *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. iv, p. 146.

In a pit on the east side of the Charlbury road only a few feet of *Trigonia* and *Clypeus* Grit cap the Upper Lias clay. The following fossils were obtained from these beds, when visited by the Association under Professor Sollas on May 9th of this year (1908):

Terebratula globata, *Am. parkinsoni*, *Rhynchonella concinna*, *Clypeus plotii*, *Echinobrissus*, *Myacites*, *Holcypus depressus*, etc.

The Inferior Oolite is also met with along the river Swere, a tributary of the Cherwell, where it is let down by two parallel faults half a mile apart. (A visit of the Association was made to this locality under John Morris and Thomas Beesley, on April 15th, 1873.) Similar beds have been quarried at Blackingrove, on the other side of the river, ever since Roman times.

The Great Oolite Series occupies a tract of country extending from Burford to Brackley and Buckingham, and attaining its greatest width between Chipping Norton and Woodstock. It forms the southern limit of the great Marlstone plateau and dips beneath the Oxford Clay to the south-east.

Certain members of the series are again brought to the surface as a group of inliers in the Oxford Clay country, by an anticlinal flexure referred to below. Outlying patches are also met with, let down by faults into the Marlstone plateau, as at Tadmorton and Hook Norton.

Great Oolite.—The subdivisions of this formation are very inconstant; the upper beds are frequently overlapped by the Forest Marble, and *remanié* beds, indicating contemporaneous local erosion, are often met with.

At Chipping Norton, Langton Bridge, and on Chadlington Down the base of the Great Oolite is formed by a peculiar layer of clay and marl containing *Ostrea acuminata*. Similar clays containing fresh-water as well as marine fossils have been proved in the Oxford City Brewery boring, and are also found underlying the Stonesfield Slate.

These beds indicate the transition from the Fullonian of the south-west into the Upper Estuarine series of the north-east. In the neighbourhood of Chipping Norton, Tadmorton, Banbury, etc., this basement-clay forms a *remanié* bed containing rolled limestone pebbles, resting irregularly on different members of the Inferior Oolite group, and filling rifts and pipes in the underlying beds. It has locally been termed the "rift bed" by Mr. E. A. Walford. At Chipping Norton it has yielded remains of *Cetiosaurus*. This remarkable physical break and apparent unconformity must in part be due to disintegration of the underlying limestone.

In the Windrush valley and Burford district, the Great Oolite consists of a lower division of white false-bedded freestone,

the celebrated Taynton building-stone, now quarried at Milton-under-Wychwood, and an upper division of white rubbly limestone, and yellow and white marls with thin limestone partings.

In the Evenlode valley and district of Stonesfield the upper and lower divisions of the Great Oolite shade into one another. The upper division consists of white limestones and marls yielding *Nerinea eudesii*, *Ostrea sowerbyi*, *Terebratulula maxillata*, etc.

The lower division consists of a variable series of strata, shelly oolite, sandy limestones, and laminated sandstones, splitting readily along the bedding planes and producing the celebrated Stonesfield Slates. These beds form the high ground between Fawler and Stonesfield, but thin away towards the east.

The slates, which are now chiefly used for ornamental purposes, are obtained from levels driven from the bottom of deep shafts, but the great heaps of waste material furnish all the characteristic fossils, and many of the better specimens are obtainable from the workmen.

The following section gives some idea of the nature of the slate beds:

	ft. in.
"Rag."—Oolitic Limestone and coarse, soft calcareous stone forming roof of the levels.	
"Soft-stuff."—Yellowish sandy clay with fibrous gypsum	6
"Upper Head."—Sand containing large flat spheroidal concretions (called "Pot-lids") of calcareous grit pervaded by oolitic particles. It includes oolitic pebbles. These pot-lids furnish the best stone to	1 6
"Manure or Race."—Slaty, friable calcareous and micaceous sand rock	1 0
"Cap" and "Lower Head."—The upper portion contains concretionary pot-lids. The rock varies from a very compact, fine-grained grit, effervescing strongly with acids, to a stone of which the larger portion is made up of oolitic particles to	2 0
Here are obtained the mammalian remains and all the common fossils, <i>Trigonia impressa</i> , <i>Gervillia acuta</i> , <i>Pecten vagans</i> , <i>Rhynchonella obsoleta</i> , etc.	
"Bottom stuff."—Coarser calcareous grit with oolitic particles (base not seen)	1 0

The fauna of the Stonesfield Slate, a complete list of which is given in the Geological Survey memoir on "The Jurassic Rocks of Britain," vol. iv, by Mr. H. B. Woodward, furnishes abundant evidence of the immediate neighbourhood of land composed of Inferior Oolite rocks, the detritus from which was deposited in a relatively shallow sea or lagoon, thus forming a transition to the more thoroughly estuarine conditions which prevailed to the north. Oolitic pebbles and rolled fossils from the Inferior Oolite are of common occurrence, and the remains of land animals, insects and plants are found commingled with a rich marine fauna.

The celebrated Stonesfield mammalia, *Amphilestes*, *Amphitherium*, *Amphitylus*, *Phascolotherium*, and *Stereognathus*, are all too well known to need description.

The remains of Coleoptera and Neuroptera, plant remains (Carpolithes), Chelonian scutes, Fish teeth (*Acrodus*, *Hybodus*, *Strophodus*, etc.), Saurian bones, Crustacea, and other marine forms, may be obtained whenever the pits are being worked. The occurrence of *Ceratodus*, the mudfish of the Queensland rivers, is also of remarkable interest.*

The lower division of the Great Oolite thins out towards Woodstock, and the character of the upper beds becomes so variable that it is difficult to correlate the beds in the numerous exposures. The upper division is well exposed on the right bank of the Evenlode below Ashford Mill and in the cuttings of the Worcester branch of the Great Western Railway; it covers a large area to the north-west of Woodstock, forming the plateau cut through by the Glyme and Dorne, the thickness of the beds being here about 30 ft.

About 12 ft. of false-bedded oolite with clay partings, and blue-hearted limestones, yielding fish teeth, are visible in the quarry north-east of Hanborough station, which are coloured on the new Survey Map of the Oxford district as Forest Marble, but which may partly belong to the Great Oolite. Similar beds also appear in the railway cuttings of the Woodstock branch line, and beneath the Forest Marble in the Bladon Quarry, to mention a few of the more important exposures.

In the Cherwell valley the Great Oolite is well exposed at Enslow Bridge, in the scarp on the west of the river, and in the celebrated *Cetiosaurus* quarries. These were visited by the Association under John Phillips and Mr. J. P. Earwaker on May 12th, 1871, on which occasion a fine head and skeleton of *Teleosaurus* was exposed to view.

In these quarries about 30 ft. of Great Oolite are visible beneath the Forest Marble, and from this locality Phillips obtained the remains of his huge *Cetiosaurus*, now preserved in the Oxford Museum. A bed crowded with *Terebratulæ maxillata* is a noticeable feature about half-way up the succession.

Farther to the east in the Ray valley, the Great Oolite is exposed in the faulted area of the Islip, Noke, and Woodeaton inlier; it is visible on the top of Noke Hill, in the quarry south-west of Islip railway station, and in the railway cutting. These top beds are again seen in a new cutting for the Great Western Railway to Bicester, on Blackthorn Hill.

In the complex region of Chipping Norton and Hook Norton

* The following visits have been made by the Association to the Stonesfield workings:—April 7th, 1874, under Mr. James Parker; May 27th, 1890, under A. H. Green; May 9th, 1908, under Prof. W. J. Sollas. See also *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. iv, p. 310.

in the north-west of this district, it appears that the basement-beds are not everywhere on the same horizon, and that some beds are impersistent and overlapped by higher stages.

The railway sections between the above places have opened up a number of interesting sections, many of which were visited by the Association under the guidance of Thomas Beesley and W. H. Hudleston, on April 22nd and 23rd, 1878.

These beds are described at some length in the Survey Memoir on the Lower Oolitic Rocks, their thickness being given as: Great Oolite 56 ft. 7 ins., Stonesfield Slate series with rift bed at base 17 ft. 5 ins.

Great Oolite beds have also been observed in the Tadmarton Forest Marble pit, on Constitution Hill Banbury, and at North Aston, south of Deddington.

The Forest Marble derives its name from Wychwood Forest, south-west of Charlbury, where the beds occur as outlying patches on the Great Oolite plateau separated from the main outcrop; the latter runs from Witney, through Hanborough, Bladon, and Woodstock to Bucknell, north-west of Bicester, where it is cut off by a fault.

Beyond this point only a few traces of Forest Marble have been observed, and these only of extreme thinness.

Outliers are also met with in Blenheim Park, at Dornton, and near Tadmarton. It also appears beneath the Cornbrash along the stream courses north of Bicester, in the inliers of Ishp, Wood-eaton, and Oddington, and again in the Blackthorn Hill railway cutting.

The beds consist of thin shelly oolitic false-bedded limestones, usually associated with bands of clay and shale.

No true Bradford Clay is recognised in this district, although a specimen of *Apiocrinus* has been recorded from Kirtlington.

The boundary line between Great Oolite and Forest Marble is usually merely conjectural, but occasionally an intermediate *remanié* bed furnishes a definite physical break; examples of such being visible at Holly Court farm in the Wilcote valley and in the Hanborough railway cutting. Although 100 ft. thick in Gloucestershire, in the neighbourhood of Witney the Forest Marble has thinned to about 34 ft., whilst at Woodstock it is only half this thickness, and in the direction of Bucknell it is represented by clays overlying 5 or 6 ft. of shelly Limestone with clay bands.

The section at the Hanborough quarry has been previously referred to. At Bladon 12 ft. of Forest Marble underlie the Cornbrash, consisting of blue oolitic limestones at the base, quarried for building purposes, overlain by shelly limestones with intervening clay bands.

These beds are again seen in the Woodstock railway cutting and in the Enslow Bridge quarries. In the Ray valley inliers

the thickness is only about 5 ft. and the beds consist chiefly of clay.

Clays again predominate in the Blackthorn Hill cutting south-east of Bicester, which yielded the following fossils :

Gervillia acuta, *Modiola imbricata*, *Astarte* sp., *Cyprina loweana*, *Waldheimia obovata*, *Rhynchonella concinna*, etc.

In the north of the district the Tadmorton outlier exposes about 11 ft. of Forest Marble, consisting of alternating clays and shelly limestones with a nodule bed at the base.

From this locality John Phillips obtained a fine series of bones of *Teleosaurus brevidens* and *T. subulidens*.

A visit of the Association was made here on April 15th, 1873, and to the Forest Marble of the Pest House cutting on the Chipping Norton and Banbury line five years later.

The Cornbrash, or topmost division of the Great Oolite series is remarkably constant in its lithological characters.

In this district it has an average thickness of about 6 ft., and consists of irregular layers of earthy and shelly limestone, never false bedded and seldom oolitic ; when protected by a capping of Oxford clay the stone is of a bluish-grey colour, and sufficiently compact to be used for building purposes, elsewhere the beds are very rubbly, and weather to a deep reddish-brown colour.

The absence of current-bedding and of any pebble beds would appear to indicate that the Cornbrash was deposited in a sea of somewhat greater depth than that of the Great Oolite.

The main outcrop of Cornbrash runs from Norton Brize by Witney, Woodstock, and Bicester to Buckingham, spreading out in places into a broad inclined plateau.

It is frequently exposed in quarries opened in the Forest Marble and Great Oolite, forming a few feet of rubbly limestone beneath the surface soil.

The commonest fossils are *Avicula echinata*, *Waldheimia obovata* and *Terebratula intermedia*; the zone ammonite *Macrocephalites macrocephalus* has also been obtained from several localities.

Among the best known sections are those at Hanborough, Bladon and Enslow Bridge, whilst exposures are numerous over the plateau north of Bicester.

In the north-west of this area Cornbrash has been detected in the Pest House cutting between Hook Norton and Chipping Norton by John Morris and W. H. Hudleston, whilst typical fossils of this formation were obtained near the Tadmorton Forest Marble pit during a visit of the Association previously referred to. The Cornbrash also occurs in several outliers on Wychwood Forest, and in the succession of inliers running from Islip to Marsh Gibbon brought up by an anticlinal fold running north-east to south-west and crossed by minor folds at right angles to it. The Islip inlier was visited by the

Association on May 26th, 1890, under the directorship of A. H. Green, when the formation was observed to have its typical development, and many characteristic fossils were obtained.

The Blackthorn Railway cutting exhibits a fine section of Cornbrash cut through by a fault with a downthrow on the north-west. To the south of the fault the rock presents its typical rubbly facies, but on the downthrow side it has been protected by a thin layer of Kellaways Rock or Oxford clay, and forms a compact blue-hearted limestone, yielding: *Avicula echinata*, *Pecten annulatus*, *Pholadomya lyrata*, *Lima duplicata*, *Waldheimia obovata*, *Anabacia orbulites*, and many other forms.

The Oxford Clay,* so called from its extensive development in the neighbourhood of Oxford, rises in somewhat rounded hills above the Cornbrash, and covers a wide area south-east of a line drawn through Witney, Bicester, and Buckingham, forming the valleys of the Thames, the Cherwell from Kidlington to Oxford, and the Ray, including the plain of Ot Moor, whence it is continued to the south-east between Stanton St. John and Boarstall nearly to the valley of the Thame.

The thickness in this district has been estimated at about 400 ft., consisting throughout chiefly of bluish and grey clays weathering yellow at the surface and showing traces of bedding only in the lower stages, where the formation becomes more shaly.

The beds contain much iron pyrites and selenite, and lignite is occasionally met with. Bands of septarian nodules, often of large size, are of common occurrence.

Hard sandstones near the base, containing *Kepplerites calloviensis*, are referred to the Kellaways Rock, to which beds the somewhat abrupt rise of the formation above the underlying beds is due. Beds of this nature have been exposed near Bicester and on the Woodstock railway.

Two main zones of the Oxford Clay have been recognised in this district; the lower, that of *Cosmoceras ornatum*, being usually found north of the Thames, whilst the upper, that of *Cardioceras cordatum*, forms the slopes leading up to the Corallian escarpments. A few feet of unfossiliferous clay near the base of the succession are visible beneath drift gravel on the heath between Long Hanborough and North Leigh; these beds are again seen on Combe Hill and in Eynsham Park.

Several fine sections are visible in the brick pits opened in the immediate neighbourhood of Oxford. That at Wolvercote, exposing about 40 ft. of clay, lying beneath river gravels of the third terrace, is especially rich in fossils, of which the most abundant are: *Cosmoceras jason*, *Peltoceras annulare*, *P. athleta*, *Belemnites sulcatus*, *Gryphæa dilatata*, *Aulacothyris impressa*, *Nucula elliptica*, and *N. ornata*; the zone fossil *Cosmoceras*

* See *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. v, pp. 40, 45.

ornatum is also far from rare. Similar beds again appear half a mile to the north at Peartree Hill, containing *Gryphaea dilatata* and *Peltoceras athleta*. About the same thickness of clay is also visible at Summertown beneath river gravels of the second terrace. *Cardioceras cordatum* has been obtained from the upper beds, which would indicate a somewhat higher level than that at Wolvercote. *Cosmoceras jason*, *C. duncani*, *Belemnites sulcatus*, *B. oweni*, *B. hastatus*, and *Gryphaea dilatata* occur here in some abundance. These sections were recently visited by the Association under Professor Sollas.

Higher beds are to be seen in the St. Clements brick-pits and in a pit on the east of the road between Magdalen Bridge and Marston.

*The Corallian** in the neighbourhood of Oxford is divisible into a lower group of Calcareous Grits and Sands from 20 to 60 ft. in thickness, the zone of *Aspidoceras perarmatum*, and an upper Coral Rag and Coralline Oolite group about 30 ft. thick, the zone of *Perisphinctes plicatilis*, consisting for the most part of rubbly yellow limestone made up of broken shells, corals, and other organisms, with here and there large reef-like masses of coral, and occasionally hard blue limestone beds suitable for building purposes. Many of these coral bands are so perfect that it is only possible to imagine they have been preserved on the spot upon which they grew, and do not represent drifted reefs as some observers have held; their association with rolled corals and other organic débris is only to be expected as the result of the sea breaking on a coral shore. The Coral Rag forms a well-marked plateau to the east of Oxford, on which are built the villages of Elsfield, Beckley, Stanton St. John, and Headington. A brief description of the time-honoured section through Headington Hill and Shotover will perhaps give the best idea of its typical development in this district.

The somewhat steep rise from Oxford is made at first over Oxford Clay, but near the point where the road over Shotover branches off the main road Calcareous Grit is first met with. Following the former road for a mile, about 6 ft. of yellow sand belonging to this division are visible in the Windmill quarries, beneath 10 ft. or more of rubbly Coral Rag containing *Isastræa explanata*, *Thecosmilia annularis*, *Lima rigida*, *Pecten fibrosus*, *Exogyra nana*, *Serpula tricarinata*, *Lithodomus inclusus*, and spines of *Cidaris florigemma*.

The corals often form well-defined reefs, especially in the pit south-east of the cross-roads.

A quarter of a mile farther on, a road branches to the north on the right of which a quarry exposes the sharp junction of the Coralline Oolite with Kimeridge Clay; a well sunk here passed through about 30 ft. of rock before penetrating the Cal-

* See *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. v, p. 128.

careous Grit. A more complete section is, however, seen in the large quarry opposite the vicarage. Nearly 30 ft. of the formation are visible, the loose Coral Rag near the surface passing down into a compact blue limestone, below which are seen a few feet of Calcareous Grit. The limestone yields the following fossils: *Belemnites abbreviatus*, *Lima laeviuscula*, *Chemnitzia heddingtonensis*, *Goniomya V-scripta*, *Pecten lens*, etc., etc. The once famous "Headington" quarries are now for the most part disused and overgrown.

During Corallian times, then, the sea over this district supported a luxuriant coral fauna and was comparatively free from terrigenous sediment; a few miles to the east, however, thick deposits of argillaceous material were being formed, and the conditions remained more or less unchanged from the time of the Oxford Clay to that of the Lower Portland, beds referred to the Corallian being known as Amphill Clay. As the typical development of the latter occurs outside Oxfordshire it will not be discussed here.

The only well-marked Corallian rock in this eastern area occurs near Studley, at the base of the Amphill Clay. It forms a peculiar band of argillaceous chert, containing spicules of the Tetractinellid sponge, *Rhaxella perforata*, which have also been described by Dr. G. J. Hinde from cherts in the Calcareous Grit of Yorkshire. This rock has been fully described by Dr. A. Morley Davies,* who has termed it the "Arngrove Stone."

The Kimeridge Clay is of a dark blue or black colour, due partly to the presence of carbonaceous matter, partly to iron bisulphide; it is much more shaly than the Oxford Clay and contains layers of large septarian nodules. Lenticular selenite formed by the decomposition of pyrites is often met with.

The sudden transition from corallian limestone to dark clay is one of the most striking features of the Shotover section, and this marked break no doubt indicates a certain amount of erosion of the topmost Corallian Beds previous to the deposition of the Kimeridge. The thickness of the latter is here probably about 70 ft., and the brick pits on the west of Shotover Hill afford excellent sections of both the passage from Corallian to Kimeridge, and Kimeridge to Portland. The clay here is not very fossiliferous, though Saurian bones are of common occurrence. *Ostrea deltoidea* has been recorded above the junction with the Corallian, and a shallow pit on the south of the road exposes the subzone of *Exogyra virgula*, the remains of this fossil being very abundant. *Am. bplex*, the zone-fossil of the Upper Kimeridge, is found in the pit of the Brick and Tile works.

* *Quart. Journ. Geol. Soc.*, vol. lxiii (1907), p. 37

The Portland Beds, which form a long outlier extending from Shotover Hill to Garsington and Cuddesdon, show the incoming once more of shallow-water conditions in this neighbourhood. The distinction between Upper and Lower Portland is not well marked, but the following section taken from the Survey Memoir gives the general sequence :

		ft.
UPPER PORTLAND.	Ferruginous sands, <i>Trigonia</i>	20 to 30
	Whitish limestones, <i>Cardium dissimile</i>	
	Clays, loam and Greenish sands	4
	Rubbly glauconitic limestone	
	Lydites.	
LOWER PORTLAND.	Blue and brown clay with lydites and phosphates in base of clay and top of sands	3 to 5
	Yellow and Greenish sands, glauconitic with so-called "Portland crackers," huge spheroidal doggers of calciferous sandstone, blue-hearted, with small lydites ; many fossils	
		20

The full thickness of the beds has been estimated as over 100 ft. The clay band with lydites runs diagonally up the face of the section and its true stratigraphical position is not at all clear. Professor Sollas is inclined to the view that it is of Kimeridge age, and has attained its present position by squeezing or an overthrust. The base of the section is, however, obscured by *débris*, and its supposed junction with the Kimeridge is therefore only a matter of conjecture. If this view is not correct a tremendous amount of slipping must have taken place on the surface of the underlying clay for the beds to have reached their present position.*

Among the most abundant fossils from this locality may be mentioned : *Am. boloniensis* cf. *giganteus*, *Am. pectinatus*, *Trigonia gibbosa*, *Ostrea expansa*, *Pholadomya rustica*, *Cardium dissimile* (internal casts), *Perna mytiloides*, and *Lucina portlandicum*.

The action of percolating water on the Portland Stone, resulting in the partial or complete silicification of the original oolitic grains, has been fully described by Mr. H. H. Thomas in the recent Survey Memoir on the Oxford district. He has shown that the calcite may be replaced by amorphous silica or by the growth of quartz in crystalline continuity with a minute nucleus of that mineral, and that the outline of the original oolitic grain may be traced in the silicified matrix by the ferruginous inclusions.

THE CRETACEOUS ROCKS.

Shotover Sands.—At the close of Portland times this district rose above sea-level, and, capping Shotover Hill, we next

* During a recent visit a number of Kimeridge fossils, including the species usually termed *Am. biplex*, were obtained from this clay-band, and there is consequently now no doubt as to its age.

find about 50 ft. of ironsand with fresh-water fossils, the so-called Shotover Sands which from their stratigraphical relations have been assigned to the Wealden. These beds, which are arranged in elongated lenticles, consist of a varied succession of yellow and brown sands with tabular concretionary ironstone, grey and white clay resembling fuller's earth, very pure fine white sand used in the manufacture of soap, ochre, and coarse sands and loam with purple ironstone concretions. The latter often contain hollow casts of *Paludina*, *Unio*, and *Cyrena*.

The ferruginous matrix with marine fossils, mentioned as forming the top of the Portland, is due to subsequent infiltration of mineral waters through these overlying ironsands. Similar fresh-water ironsands are found on the Brill and Muswell Hill outliers to the east of this area, resting on Purbeck beds.

Traces of Purbeck beds have also been noted south of Wheatley, overlain by the Shotover Sands; they consisted of oolitic limestones and marls, about 4 ft. in thickness, containing remains of *Cypris*, *Mytilus*, *Modiola*, *Paludina*, and *Planorbis*.

The fault-line of the Islip and Woodeaton inliers, previously mentioned, is continued in a south-easterly direction and affects the upper Jurassic rocks to the north-east of Shotover Hill. The Corallian is faulted between Wheatley and Holton, and at Forest Hill the Portland and Shotover Sands are let down by a trough-fault between the Corallian and Kimeridge.*

THE DRIFT.

It would be impossible within the limits of this chapter to give more than a passing reference to the extensive river gravels of the district, and the reader is referred to the excellent description of them given by Mr. T. I. Pocock in the recent Survey Memoir on the district around Oxford.

That author has divided the Pleistocene and recent deposits of the Thames valley into:

1. *Alluvium*.—Recent deposits of fine silt, forming flat meadows slightly above the ordinary water-level, which during the season of floods appear as lake-like expansions of the river above the narrower parts of its valley. Extensive tracts of alluvium form the flat country east of Stanton Harcourt, Port Meadow, and the district of Ot Moor.

* The following is a list of excursions made by the Geologists' Association to Shotover Hill and the neighbourhood of Wheatley: April 6th, 1874, under Mr. James Parker; May 17th, 1880, under Prestwich and Mr. James Parker; May 28th, 1890, under A. H. Green; June 7th, 1902, under J. H. Blake.

2. *River Gravels*.—Stratified deposits occurring as terraces on the valley slopes, consisting of oolitic limestone pebbles, quartzose and flinty material, with subordinate layers of sand and loam.

Mr. Pocock has mapped four terraces in this district, of which the three youngest constitute a low-level group, not rising more than 50 ft. above the present river and containing bones and teeth of the mammoth, *Elephas antiquus*, woolly rhinoceros, etc. The first terrace, five or ten feet above flood-level, forms the site of the low-lying quarters of Oxford near Folly Bridge and the suburb of New Hinksey.

The second terrace, 20 to 30 ft. above the present river, is far the most extensive. On this terrace Oxford and most of the villages of the upper Thames valley are built.

It forms the long spread of gravel from Summertown to Oxford, between the Cherwell and Thames, and a good section is seen overlying the Oxford Clay in the Summertown brick pit. During the epoch of the second terrace the Cherwell flowed into the Thames at Yarnton, and the Ray was a tributary of the main river, entering it near Summertown.

The third terrace is very limited in extent, and occurs about 40 to 50 ft. above the present river.

The following section is exposed in the Wolvercote clay pit :*

*Finely laminated clay	...	15 ft.	0 ins.
Lenticle of peat and sand	...		2 ins.
Gravel and sand (resting on			
Oxford Clay)	...	2 ft.	6 ins.

The lowest bed is rich in Palæolithic implements, which Prof. Sollas has compared with those of the Chel-léen stage of culture.

This terrace is also seen at Peartree Hill.

The fourth terrace, the sole representative of the high-level group, varies in height from 70 to 100 ft. above the present river, and is principally developed as a series of promontories projecting from the oolitic up-lands on to the lower slopes of the valleys.

Gravels belonging to this terrace are exposed in several pits in the Hanborough district, that at "the Row," Long Hanborough, showing the effect of solution in "organ pipes"; in others the solution has been carried a stage farther and the gravels are thrown into a state of great confusion.

(Most of the above sections in the four terraces were

* A. M. Bell. *Quart. Journ. Geol. Soc.*, 1x. (1904), p. 120.