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INTRODUCTION.

THE Cambridgeshire area is full of interest to the geologist not only on account of the variety of the strata which range from the Oxford Clay to recent fluviatile deposits, but also because of the peculiar local development and relations of some of the formations. We may mention for instance the argillaceous representative of the Corallian limestones of other districts, the Upware coral reef, the Cambridge Greensand, and the river-terraces.

Physical features. There are four natural regions depending on geological structure into which the County of Cambridgeshire may be divided. These are (1) the chalk hills and plateau in the south and east; (2) the high ground in the west; (3) the median valley of the Rhee, and the Cam, and (4) the Fenland in the north. There is no definite line of demarcation between the last two regions, for the river-valley widens out gradually and passes imperceptibly into the Fenland.

The first region comprises the whole range of chalk hills from Royston in the south-west to Newmarket in the north-east, and from it flow down the main tributaries of the Cam and Ouse, cutting their way through the face of the escarpment. In many parts the typical scenery of a chalk country is displayed, as for instance round Royston, where the well-known rolling outlines of chalk downs

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covered with short smooth turf present a marked contrast to the level plain in the northern part of the county. Over a large area, however, post-tertiary deposits cover the solid rock and the characteristic features are obscured. The highest ground occurs in the eastern region. Thus at Tharfield the escarpment is 500 feet high, whereas its average height is about 300 feet in the Gog Magog Hills.

The second region is an irregular hilly district composed partly of outliers of Lower Chalk with long promontories projecting eastwards, the whole capped by an extensive layer of Boulder Clay. In the south-west the Lower Greensand rises into picturesque hills of some importance, as near Sandy. The Jurassic clays lie still further to the west and form a plain except where patches of drift or gravel cause gentle elevations or ridges. This is particularly the case in the northern part where the plain merges into the Fenland.

The third region comprises the valley and alluvial plain of the Cam, the Rhee, and their tributary streams. It is composed chiefly of Gault and Chalk Marl with a covering of gravel along the present and ancient river-courses. The town of Cambridge is situated on the Gault in the middle of this valley. The portion of this region composed of Chalk Marl is gently undulating but the Gault areas are mostly very flat. The lines of gravel give rise to ridges and slightly elevated ground, and the three river-terraces are well developed.

The fourth region consists of peat-land in the south and silt-land in the north. The flat open treeless character of the landscape where peat prevails is well known. A long tongue of the Fenland projects southward to include Burwell Fen. To the west of the Cam the Ouse forms

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the southern boundary of this region between St Ives and Thetford. A few scattered 'islands' rise above the general dead level, the most important of which are the Isle of Ely formed of Kimeridge Clay capped by Lower Greensand and Boulder Clay; the raised ground round March which consists of Boulder Clay and marine gravel; and the inlier of Jurassic rocks and Lower Greensand composing the Upware ridge.

A great expanse of level ground stretches from Cambridge in the south to the Wash in the north—a distance of about forty-five miles, and the whole Fenland forms the largest plain in England, having an area of about 1300 square miles. The Wash was once coextensive with the Fenland and the whole silting up of this vast area has taken place within recent geological times[1]. In fact the Fenland is an enormous complex delta formed by several rivers, flowing chiefly from the south-west into a large shallow bay. At the landward end they deposited their loads of detrital material which stretched out as muddy flats for miles into the sea. The tides brought in fine silt which was thrown down against the outward face of the delta and gradually formed banks which rose above high-water mark. Over these low-lying lands forests and peat-bogs ultimately spread. The process by which the land encroaches in this way on the sea and by which the sea itself is silted up is still going on in the Wash though at a slower rate than in past times, and the growth of the marshes along the present coast of the Wash may still be observed. Occasional incursions of the sea over these low-lying tracts have taken place in historical times, but much land has been reclaimed by artificial banks in the course of the last few centuries. The Fenland is indeed

[1] Miller and Skertchly, *The Fenland* (1878), p. 5.

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the Holland of England, for that country is but the delta of the Rhine: the surface features of the two areas are strikingly similar, as might be expected from their similar origin and history.

The rivers of Cambridgeshire belong to one main drainage-system—that of the Cam and Ouse. The principal waterway runs in a general N.N.E. direction through the county along the median valley, and all the lateral streams ultimately find their way into it. This Rhee-Cam-Ouse river occupies a longitudinal valley running along the strike of the beds and following very nearly the main outcrop of the Chalk Marl to a point as far north as Waterbeach. Thus it forms a 'subsequent[1]' river, for it does not flow down or against the dip-slope of the strata but along the line of strike.

The Rhee rises at Ashwell in Hertfordshire. The springs which give rise to it are thrown out by the Chalk Marl. It flows along the longitudinal valley in the Gault in a general north-easterly direction, and at Hauxton is joined by the united waters of the Granta and Lin rivers, forming the river Cam. The branch of the Cam known as the Granta rises near Quendon in Essex and flows across the strike of the Cretaceous beds and against their dip. Streams with such a course have been called 'obsequent[2]' streams and must be later in date than the formation of the escarpment through which they cut. The Granta in fact was once a short stream which ran westwards from the face of the escarpment into the longitudinal valley. It has cut its way back through the whole Chalk plateau to its present source at Quendon, and, since the existence of this 'obsequent' valley has

[1] W. M. Davis, *Geogr. Journ.* vol. v. (1895), p. 127.
[2] W. M. Davis, *loc. cit.*

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been proved to be even in Essex previous to the deposition of the Chalky Boulder Clay (see p. 161), we can form some idea of the great antiquity of the drainage system now represented by the Cam.

The valley of the Lin is also occupied by an 'obsequent' stream which flowed along the same course before glacial times (see p. 161).

The Granta flows from Quendon, past Newport, Wenden, Chesterford, and Whittlesford to Shelford, where it is joined by the Lin which also rises on the Chalk and makes its way past Linton, Abington, and Babraham to Shelford.

The united rivers then flow west-north-west to Hauxton, there to join the Rhee.

From this point the river is known as the Cam and flows as a 'subsequent' stream along its north-easterly longitudinal valley, through the town of Cambridge, past Fen Ditton, Horningsea, Waterbeach, and Upware to Thetford, where it joins the Ouse.

The most important tributary of the Cam from the west is the river Bourn, which rises on the high ground near the village of Bourn as the overflow of the water in the Lower Greensand and finds its way over a low place in the rim of Gault bounding it on the east. It flows past Bourn in an easterly direction to join the Cam just below Grantchester. The Bourn is what is known as a 'consequent' stream because it flows down the dip-slope of the beds. The ridge of Chalk Marl that stretches with considerable interruptions between Madingley, Coton, and Castle Hill, forms a low watershed, the drainage from its north side falling into the Ouse while that from its south side finds its way to the Cam.

There is an 'obsequent' stream on the east which rises

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near Fulbourn, but becomes a 'subsequent' stream east of Teversham owing to abstraction. Its ancient course which is marked by patches of gravel would bring it directly westward to Fen Ditton. The 'subsequent' stream is in its turn captured by a small 'obsequent' stream near Swaffham which flows westward into the Cam. From Little Wilbraham another 'obsequent' stream flows N.W. to the Cam; and after the junction of the Ouse and Cam at Thetford we meet with a succession of 'obsequent' rivers draining the high ground in the east and running against the dip of the beds to fall into the Ouse. Such are the Ousel, Ivel, Lark, Little Ouse, and Stoke.

The river Ouse itself between Bluntisham and Thetford is a true 'consequent' stream, and is abstracted at Thetford by the 'subsequent' river occupying the longitudinal valley.

According to Prof. W. M. Davis the elaboration of the rivers is the result of two cycles of denudation. At the close of the first cycle, when the land had been reduced to a 'peneplain' or lowland of faint relief, an uplift took place which started the second cycle of denudation by renewing the activities of the rivers, and this has led to the high degree of perfection in the adjustment of the streams to structures. This drainage-system was however determined in pre-glacial times, and after the departure of the ice the land was left swathed in a covering of clay of variable thickness and possibly of somewhat irregular and patchy distribution. The country however stood then and stands now at a lower level than it did before the incoming of glacial conditions, for the buried channels filled with Boulder Clay, silt, etc. are sometimes below the present sea-level (see p. 156). The water running off the clay-covered surface which the ice

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had left flowed mainly into its ancient channels or at any rate along the lines of their depressions, and the general coincidence of direction in the pre- and post-glacial stream-courses shows that the mantle of drift was not sufficiently thick to obliterate the main features of the landscape. Thus the principal rivers are the revived successors of the pre-glacial streams, though in a minor degree they have been "superimposed by sedimentation[1]."

The great antiquity of our river-system is shown by the prevalence of 'subsequent' streams, for all young river-systems have their 'consequent' streams more strongly developed. In pre-glacial times the 'consequent' streams had all been 'beheaded' owing to their upper portions being diverted by the strong 'subsequent' streams; and the 'obsequent' rivers had likewise cut back long and important valleys.

Since the glacial period subærial denudation has proceeded apace, for we find that the steepest slope of the chalk scarp over which the Boulder Clay was spread is distant $1\frac{1}{4}$ miles west of the present face of the escarpment (see p. 159).

In the northern region of Cambridgeshire the flat Fenland is only at a very slight altitude above the sea. At Upware, for instance, the level of the Cam is only about 12 feet above low-water level at Lynn Deeps, so that artificial drainage by dykes is general. A few sluggish meandering streams traverse the plain to empty themselves into the Wash, amongst which may be mentioned the Old Croft river which marks the former course of the Great Ouse before it was artificially diverted into its present northerly direction.

[1] G. K. Gilbert, "Geology of the Henry Mountains," *U. S. Geol. Surv.* (1877), p. 143.

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THE JURASSIC BEDS.

General remarks. The members of the Jurassic System which are found in this area occupy only its northern and north-western portion, with the exception of the Upware inlier. In the immediately adjoining counties of Bedford and Huntingdon there are, however, several sections of interest which are readily accessible; and in order to give a clear idea of the relations, etc. of the beds it will be necessary briefly to refer to them.

The only portions of the Jurassic System which occur in Cambridgeshire belong to the Middle and Upper Oolites, from the Oxford Clay to the Kimeridge Clay inclusive.

One of the features of the series in this part of England is the absence of the typical calcareous development of the Corallian to which we are accustomed in the south-western counties and in Yorkshire. In Bedfordshire, Cambridgeshire, and Lincolnshire there is an almost unbroken succession of clays from the Oxford Clay to the Kimeridge Clay. Some subsidiary and thin limestone bands are indeed intercalated, and the Upware Corallian limestone reef has long been famous, but practically the Jurassic deposits of this region consist of argillaceous material. It used even to be held by

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some authors that with the exception of the Upware limestone the Corallian beds were here entirely absent. But Prof. Seeley[1] in 1861 showed that they were palæontologically represented by part of the clay formation which had been included in the Oxford Clay; and more recently Mr T. Roberts[2] has brought forward considerable evidence in favour of this view not only for Cambridgeshire but also for Lincolnshire[3].

The Oxford and Kimeridge Clays which are fairly persistent in their characters from Dorsetshire to Yorkshire, show no peculiar lithological features in this district.

The Portland and Purbeck beds are wholly wanting and perhaps never existed in this part of England.

The general succession of the Jurassic rocks of Cambridgeshire is as follows:—

Upper Oolites { Kimeridge Clay.

Middle Oolites { Corallian { Ampthill Clay = { Coral Rag. / Coralline Oolite. / Lower Calcareous Grit. / Oxford Clay.

THE OXFORD CLAY.

General remarks. The lowermost beds of the Oxford Clay do not occur in the Cambridge district but are met with near Peterborough and in Northamptonshire where the Kellaways Rock is quarried[4].

The western limit of the Oxford Clay runs in an irregular line from Bedford to Peterborough, being marked

[1] *Geologist*, vol. IV. (1861), p. 552.
[2] T. Roberts, *The Jurassic Rocks of Cambridge* (Sedgwick Essay, 1886).
[3] T. Roberts, *Q. J. G. S.* vol. XLV. (1889), p. 545.
[4] T. Roberts, *Jur. Rocks of Cambs.* p. 10. Judd, *Geol. of Rutland* (*Mem. Geol. Surv.*), 1875, p. 232.

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by the outcrop of the Lower Oolites of east Northamptonshire. It forms the broad valley of the Ouse in the neighbourhood of Bedford and the low-lying flat country or plain to the north, as may be well seen from the Lower Greensand escarpment at Sandy.

Its whole outcrop in Cambridgeshire is considerably obscured by drift, but its eastern limit must lie somewhere to the east of the River Ouse, between Bedford and Huntingdon.

The unconformable junction of the Cretaceous with the Jurassic beds is well exposed in the railway cutting west of Sandy Station, where the Lower Greensand is seen resting on the denuded edges of the Oxford Clay.

Characters and thickness. The Oxford Clay consists of dark blue or bluish grey tenacious clays with thin bands of sandy argillaceous limestones or lines of septaria. The clays are occasionally crowded with crystals of selenite (sulphate of lime), and nodules of pyrites (sulphide of iron) are not uncommon.

The Oxford Clay has not been pierced in the Cambridge district. At Bluntisham a well 300 feet deep did not reach its base, but its thickness is not as much as 700 feet, as stated in the Survey Memoir[1], for most of the Ampthill Clay is there included with the Oxford Clay. According to Mr T. Roberts the thickness is probably about 500 feet.

Occurrences and exposures. Near Sandy in Bedfordshire there is a good exposure of Oxford Clay with septarian nodules and thin calcareous bands in the brick pits at the foot of the Lower Greensand cliff on the north side of the Great Northern Railway. Fossils are fairly

[1] *Mem. Geol. Surv. Explan. Quart. Sheet* 51, S.W. p. 5.

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