CHAPTER IX.

NORTH KENT AND ADJOINING PARTS OF
SURREY.

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INTRODUCTION.

NORTH KENT, as a geological area, forms with part of Surrey the northern limb of the Wealden anticline. It is therefore naturally limited on the south by the edge of the Chalk escarpment of the North Downs, and on the north by the Lower Thames and its estuary. Broadly speaking, this area comprises a range of Chalk uplands, largely overlain by ancient "drifts" of various kinds and ages, and flanked on the north by a broken belt of Eocene strata which stretch eastward from the main mass to the borders of the Isle of Thanet. The Eocene beds are partly masked by Pleistocene Drifts and fringed on the north by the alluvial deposits of the Thames and its tributaries. Near Guildford, where the Eocene border lies near the Chalk scarp, the Chalk forms a ridge barely half-a-mile in width, but, eastward, the Tertiary beds have been swept back by denudation to an irregular escarpment several miles north of the crest of the North Downs. The Chalk outcrop thus becomes 6 or 8 miles broad and so continues many miles in its eastward range towards Canterbury and Dover, where it increases to fully 10 miles. Except in the neighbourhood of the deep transverse valleys of the Darent and Medway, where the Tertiaries and Drifts have been much eroded, there are few large areas of bare Chalk, since much of the upland Chalk is covered by red Clay-with-flints and the associated brick-earths. The North Downs, ranging east-north-east from the Wey to the Medway and thence nearly south-east towards Dover, form the southern margin of the shallow synclinal trough known as the London Basin, within which lie the Eocene formations. A special feature of North Kent, as contrasted with north-east Surrey, is the great development of the older Eocene group of Lower London Tertiaries. In Surrey, west and north of Croydon, this group, even where present, is hidden by the London Clay, but in North Kent it is admirably exposed and exhibits its most characteristic structural variations. The full development of the Lower London Tertiary group distinguishes North Kent, geologically, from the adjoining area of Surrey. That the London Clay once spread uninterruptedly over all the Lower London Tertiaries

and also over part, if not the whole, of the Wealden area, is generally accepted; but, being more susceptible to denudation than the lower group, it has disappeared from a great part of North Kent except in the form of outliers. Between Croydon and the Cray lies the main outcrop of the Lower London Tertiaries; farther east the enormous erosion around the Darent and the Medway has reduced even this group to the condition of a series of outliers varying from square miles to square yards in area. Subaerial denudation, continuing probably marine erosion, has also removed the Eocene beds from the higher parts of the Chalk dip-slope, leaving only a few scattered outliers high upon the North Downs, to indicate the former southerly extension of the Lower Tertiaries.

A consideration of the "solid" geology alone would suggest erroneous ideas of the surface features of North Kent, and particularly of the Chalk area. Much of the upland Chalk is covered by Clay-with-flints, which not only checks the development of the rounded hills and flowing contours of true Chalk areas, but supports thick woods and forms good pastures and fruit lands, thus imparting to the northern slope of the Downs much of the aspect of the Tertiary clay-lands. The striking change witnessed in passing from the pastures and woodlands of the clay-covered dip-slope to the dry, open, often treeless scarp overhanging the Vale of Holmesdale speaks eloquently of the scenic influence of a thin superficial deposit.

The feature formed by the higher clay-covered levels of the Chalk upland (rising south of the Tertiary escarpment) is conveniently termed the Kentish Plateau. It is deeply trenched by the Darent, the Medway, and the Stour, and grooved by many dry chalk valleys which run mainly in nearly parallel courses down the dip-slope, leaving a set of roughly parallel ridges still capped by Clay-with-flints. Between the Darent and the Medway, where the "plateau" is most characteristically developed, it rises to nearly 800 ft. O.D. Its deposits include not only Clay-with-flints and various Eocene and probably Pliocene outliers, but certain ancient Drifts—the Plateau-gravels, which form another special feature of the geology of North Kent. The far-reaching conclusions as to the antiquity of man, drawn from the discovery of palæolithic and eolithic implements in these gravels, which now cap the highest hills, but probably were originally deposited in river valleys, impart to the geology of North Kent an interest altogether unique.

A district so rich in geological interest has offered to the Geologists' Association abundant opportunities for field work. Soon after its foundation the Association visited the great Tertiary sections at Charlton and Lewisham, and during the half-century (1858-1908) more than 100 excursions have been arranged for the demonstration of the main geological features

of the area. The Eocene sections at Charlton, Lewisham, Erith, Herne Bay, etc., have frequently been visited, but the Chalk, until recently, received somewhat scant attention. In the last few years the zonal features of the Surrey Chalk have been demonstrated,* but in Kent the inland Chalk, apart from the exposures in the Charlton, Gravesend, and Medway districts, still awaits zonal examination. The Pleistocene deposits of Erith, Crayford, Swanscombe, etc., occur in association with excellent Tertiary sections, and have frequently been examined, but few of the Plateau gravels have formed the object of an excursion, and this remark holds equally true with regard to more problematic deposits, such as Clay-with-flints, dry-valley gravels, and the infillings of "pipes" in the Chalk. Yet these superficial deposits of vast age and doubtful stratigraphical significance suggest some of the most interesting questions in the geology of the present day.

In geological literature North Kent has been almost exhaustively treated. Concerning the Tertiaries, for instance, Mr. Whitaker† remarks, "Our knowledge is comparatively perfect," and, it may be added, our knowledge of the composition and physical relations of the Drifts has now reached an equally advanced stage. The presentation of details of sections and lists of fossils, in this paper, seems therefore unnecessary, as these have been so often printed. A more useful purpose will, perhaps, be served by showing how the features of the various stratigraphical divisions have been demonstrated during the excursions, and then dealing a little more fully with some points of special interest. The deep-seated Cretaceous and Wealden rocks and the "underground plain of palæozoic rocks," which afford no opportunity for field-work,‡ and moreover demand for their discussion an area much greater than the North Kent "dip-slope," are omitted from consideration.

GEOLOGICAL FORMATIONS.

SUPERFICIAL DEPOSITS	.	.	.	{	HOLOCENE alluvium.	
BEDS OF DOUBTFUL AGE	.	.	.		PLEISTOCENE sands and gravels.	
				.	Sands, Gravels.	
PLIOCENE. LENHAM BEDS	.	.	.	{	Sands.	
					Fossiliferous Ironstones.	
EOCENE.	{	BAGSHOT BEDS	.	.	Sands.	
		LONDON CLAY	.	.	Clay.	
	{	LOWER LONDON	.	.	TER-	Blackheath and Oldhaven Beds.
		TIARIES	.	.		Woolwich and Reading Beds.
CHALK.					Thanet Beds.	

* "Excursion to Ashted and Headley," *Proc. Geol. Assoc.*, vol. xix (1906), p. 347; "Excursion to Guildford," *ibid.*, vol. xx (1907), p. 174.

† "A Dozen Years of London Geology," *Proc. Geol. Assoc.*, vol. xvii (1902), p. 347.

‡ "Excursion to Plumstead and Crossness," *Proc. Geol. Assoc.*, vol. iii (1873), p. 268.

THE CHALK.

In recent years the chief interest of the Chalk has been in the recognition of the *Marsupites*-zone in the North Downs. The accidental discovery of fragments of *Marsupites* at Russell Hill, near Purley, in 1904, by two members of the Association,* gave a fresh impetus to the study of the zones of the Surrey chalk. Russell Hill lies $1\frac{1}{2}$ miles south of the Tertiary escarpment. Since the *Marsupites*-zone had here escaped denudation, it became evident that it had not been swept away before the deposition of the Tertiaries,† and therefore it might reasonably be sought in pits nearer and within the Tertiary border. Mr. G. W. Young,‡ by systematic examination, demonstrated the presence of the *Marsupites*-zone, not only in outliers on the older Chalk, but also at many points along the Tertiary escarpment, proving conclusively that "the *Marsupites*-zone in its strictest sense does extend throughout the whole length of Surrey."

In North Kent the zones have been determined in the Charlton, East Wickham, Swanscombe, Gravesend, Rochester, and Medway districts.§ Along the Medway Valley all the zones have been determined from the *Micraster cor-anguinum*-zone to that of *Holaster planus*, but the Darent Valley still awaits complete examination. The tracing of the *Marsupites*-zone through Kent would link the Surrey with the Thanet exposures of this zone; it has been found at Keston and Farningham by Mr. G. E. Dibley, but the conditions favourable to its preservation farther east are not quite so good as in Surrey, and the great erosion of the Chalk in the vicinity of the Darent and Medway gaps will probably be found to make its recognition, as a continuous exposure, very difficult.

Chalk Mines.—The Geologists' Association has thrice visited the great galleries in the Chalk at Chislehurst,|| by means of which, instead of open quarries, Chalk has been extensively worked. The subject is hardly geological, but it has acquired a fictitious importance from the extraordinary theories recently advanced in connection with these old Chalk workings. It may be admitted that definite evidence of the first opening of the Chislehurst galleries is wanting, but that is equally the case with hundreds of open quarries on the chalk hills. The galleries, "driven underground for quarrying pur-

* *Proc. Geol. Assoc.*, vol. xix (1905), p. 196.

† *Mem. Geol. Survey*, "The Cretaceous Rocks of Britain," vol. iii, p. 179.

‡ *Proc. Geol. Assoc.*, vol. xix (1905), p. 188; *ibid.*, vol. xx (1906), p. 422.

§ "Excursion to East Wickham," *Proc. Geol. Assoc.*, vol. xix (1906), p. 341; "Excursion to Gravesend," *ibid.*, vol. xv (1898), p. 463; "Excursion to Northfleet," *ibid.*, vol. xiii (1894), p. 368; "Excursion to Rochester," *ibid.*, vol. xx (1907), p. 178. See also "Zonal features of the Chalk Pits in Rochester, Gravesend, and Croydon Areas," G. E. Dibley, *Proc. Geol. Assoc.*, vol. xvi (1900), p. 484.

|| "Camden Park Galleries," *Proc. Geol. Assoc.*, vol. iii (1872), p. 114; "Camden Park Galleries," *ibid.*, vol. iv (1876), p. 498; "Excursion to . . . the Chislehurst Caves," *ibid.*, vol. xvii (1902), p. 369. (Caves at the Bickley Arms).

poses, consist of longitudinal and transverse workings, leaving great masses as pillars for the support of the roof" (*Report*, 1876). The chalk was used for lime-making, brick-making, and manure: the flints for building and for knapping into gun-flints. The reasons for driving galleries here instead of making open quarries are admirably stated in the *PROCEEDINGS* (*Report*, 1902). At the present time similar galleries are worked in the Chalk below the Tertiaries and Drift in the East Wickham valley.* There are at least three sets of workings, entered by vertical shafts about 90 ft. deep, and the total length of the galleries probably runs to at least 3 miles. All have been opened within the past fifty years, and the whole of the chalk has been used in brick-making. Somewhat similar galleries exist at Guildford and Northfleet.

Dene-holes.—These excavations, like the Chiselhurst galleries, but with greater justification, have aroused much curiosity, and their age and purpose have evoked much speculation. The Association has visited dene-holes at Hangman's Wood in Essex (see chapter ii, page 59), also at Bexley† and Stone, near Dartford. At Stone and at Abbey Wood‡ the cone of *débris* on the floor of the dene-hole was carefully searched, but no bones other than those of common domestic animals were found, and nothing indicative of great age or of any other purpose for the excavations than the quarrying of chalk for industrial uses. Amongst the many investigators of dene-holes opinion inclines more and more to the conclusion that dene-holes were not made for any other purpose than to obtain chalk.

Eocene.

[A date, in brackets, in the text, indicates the year in which a particular feature was specially noted. Reports of excursions between 1860 and 1885 are summarised in the *Record of Excursions*. References, in full, to later Excursions are given in the footnotes.]

The Eocene sections of North Kent fall readily into four groups:

- I.—The Herne Bay and Sheppey group.
- II.—The Upnor and Higham group.
- III.—Those of the main Lower London Tertiary outcrop, *e.g.*, Erith, Charlton, Chiselhurst.
- IV.—The outliers high on the North Downs.

* "Excursion to East Wickham" (1906), *Proc. Geol. Assoc.*, vol. xix, p. 341. In this report the depths assigned to the shafts are too great.

† "Excursion to the Dene-holes of Bexley" (1882), *Proc. Geol. Assoc.*, vol. vii, p. 400; "Excursion to Dartford and Stone" (1908), *ibid.*, vol. xx, p. 458.

‡ A dene-hole was thoroughly examined here in the summer of 1908, by the Woolwich Antiquarian Society.

I.—The bed of green-coated, unworn flints at the base of the Thanet Beds is not exposed at Reculvers, but it occurs at Pegwell Bay (1885) and in many sections throughout North Kent.

Near Herne Bay* and Reculvers the very fossiliferous clayey and marly marine sands of the *Thanet Beds* are not clearly separable from the *Woolwich Beds*, which they resemble structurally and palæontologically (1905). West of Oldhaven Gap false-bedded sands and sandstones 18 to 20 ft. thick constitute the *Oldhaven Beds*, the equivalents in this district of the Blackheath Pebble-beds. Towards Herne Bay the *London Clay* comes on, with a sandy and pebbly base resting irregularly on,

FIG. 39.—IDEAL SECTION OF THE LONDON CLAY.—After Prestwich.

and without passage into, the Oldhaven Beds, but the junction is marked better by "the sudden contrast of light buff sands and dark masses of clay" (1885). At Herne Bay the London Clay yields few fossils except pyritised wood. The scarcity of the fossil fruits, which abound in Sheppey, has been regarded as "evidence of the easterly flow of the Eocene river, by which these remains of vegetation were carried into the London Clay sea, the fruits becoming waterlogged and sinking nearer the estuary than the twigs and fragments of wood, which occur almost alone at Herne Bay" (1894).

In Sheppey† the *London Clay* is similar lithologically to the formation in the London area, but it differs palæontologically. The occurrence of the remains of turtles indicates the proximity of land, and the extraordinary abundance of plant remains "affords ground for concluding that near here a river

* *Record of Excursions*, 1863, 1870, 1875. "Excursion to Canterbury, Reculvers, etc." (1885), *Proc. Geol. Assoc.*, vol. ix, p. 168; "Excursion to Herne Bay" (1894), *ibid.*, vol. xiii, p. 375; "Excursion to the Isle of Thanet" (1905), *ibid.*, vol. xix, p. 149. See also *post* chapter x, p. 256.

† *Record*, 1861, 1868, 1875, 1881. "Excursion to Sheppey" (1887), *Proc. Geol. Assoc.*, vol. x, p. 194; "Excursion to Sheppey" (1898), *ibid.*, vol. xv, p. 459.

emptied itself into the London Clay sea" (1875). Fossils are chiefly obtained from the nodules and masses of iron pyrites strewn along the beach by the waves. The large septarian nodules often contain beautiful crystals (1887) of Heavy Spar (BaSO_4).

Mr. W. H. Shrubsole's remarkable discoveries of mineralised diatoms, pyritised radiolaria, reptilian and avian skulls, etc., are briefly described in the 1898 Report.

In Sheppey the London Clay approaches 480 ft. in thickness, but to the west it decreases, and a similar thinning is shown by the lower Eocene beds. This is indicated in the annexed diagram.

Near Eastchurch sands of *Lower Bagshot* age occur. In the cliff section between Hensbrook Gap and East End Lane

FIG. 40.—DIAGRAM SECTION ALONG THE LEFT BANK OF THE MEDWAY, NEAR UPNOR.—W. Whitaker.

they increase from a thin line to a thickness of 25 ft. of sands and loams (1887). Although a passage from the London Clay is seen in the sections in the London area, "a sharp line of demarcation has been observed in these cliff sections" (1898).

II.—Near Rochester* the *Thanet Beds* become almost unfossiliferous, and moreover are distinctly separated from the Woolwich series by a thin pebble bed (1891), thus differing from the Herne Bay type. An unusual feature occurred near Cliffe, where "the middle of the Thanet Sand showed signs of slight erosion or gentle current bedding" (1881). North of Upnor, pits near the church exhibit the complete Lower Tertiary sequence. In the *Oldhaven* and *Woolwich Beds* a curious seleniferous sand sometimes makes casts of shells. Selenite occurs abundantly in the *London Clay* in thin sheets along joint planes and in single crystals (1880, 1902).

* *Record of Excursions*, "Upnor" (1880), "Higham" (1881); "Excursion to Higham" (1889), *Proc. Geol. Assoc.*, vol. xi, p. lxxii (Thames embankments); "Excursion to Upnor" (1891), *ibid.*, vol. xii, p. 150; "Excursion to Frindsbury and Upnor" (1902), *ibid.*, vol. xvii p. 397.

III.—In the London district,* the Lower London Tertiaries differ from the East Kent type in the following respects:

- (a) The *Blackheath Pebble-beds* replace the Oldhaven Beds.
- (b) The *Woolwich Beds* become estuarine, not marine, in character, and are clearly divided from the Thanet Sand by a thin bed of pebbles.
- (c) The *Thanet Sand* is almost unfossiliferous, and belongs, probably, to a lower division of the Thanet Beds than part of those of East Kent.

At Charlton, East Wickham, and Erith very fine sections still display the whole group, revealing their general *similarity* of structure, and also the variable nature of the middle member (Woolwich Beds). At Erith, in the Woolwich Beds, "traces of mottled clay and variegated strata occur among the higher members of the series, so that the Erith type forms a connecting link between the marine type of these strata seen around Canterbury and the more purely fluvatile strata represented by the beds at Reading" (1885).

In the East Wickham Valley (Fig. 41), between Plumstead Common and Bostal Heath, the fossiliferous estuarine clays and the thinly-bedded loams of the Woolwich Series are well exposed (1906), and evidence of an important change in physical conditions after their deposition is afforded by the deep "scoops" in which the Blackheath Pebble-beds lie. Opposite Hope Cottage the base of the Pebble-beds is only 12 feet above the top of the Thanet Sand, while, close by, in the Cemetery brickfield, nearly 50 feet of Woolwich Beds remain beneath the Blackheath Pebble-beds (1906). Scoops equally deep at Erith "seem to cut out locally nearly the whole of the Woolwich Series" (1885).

Charlton, with its fossiliferous Blackheath and Woolwich Beds, still remains a type-section of the Lower London Tertiaries. The pit now worked (Gilbert's, in Hanging Wood) was not the scene of the early excursions of the Association, but some of the old pits remain open, although the sections are much obscured.

From the Thanet Sand, fragile internal casts of two species of *Pholadomya* are occasionally obtained. Charlton thus presents the only general Lower London Tertiary section where all the members are fossiliferous. A "leaf-bed" in the Woolwich series has been noted here (1881), but it was formerly better

* *Record of Excursions*; Charlton, Lewisham, Blackheath, Greenwich, Westcombe Park, Plumstead, Erith, Crayford, Bromley, Chislehurst Sundridge, St. Mary Cray have most of them been visited many times, and the Reports deal with both the Tertiary and the "Drift" geology. "Excursion to Loampit Hill, etc." (1888), *Proc. Geol. Assoc.*, vol. x, p. 501; "Excursion to Loampit Hill, etc." (1903) *ibid.*, vol. xviii, p. 161; "Excursion to Charlton" (1895), *ibid.*, vol. xiv, p. 111; "Excursion to Charlton" (1901), *ibid.*, vol. xvii, p. 182; "Excursion to Charlton and Erith" (1908), *ibid.*, vol. xx, p. 505; "Excursion to Plumstead" (1887), *ibid.*, vol. x, p. 191; "Excursion to East Wickham" (1906), *ibid.*, vol. xix, p. 341; "Excursion to Shooters Hill, etc." (1905), *ibid.*, vol. xix, p. 103; "Excursion to Erith and Crayford" (1885), *ibid.*, vol. ix, p. 213; "Excursion to Chislehurst 1897" *ibid.*, vol. xv, p. 108.

FIG. 41.—SECTION IN THE "CEMETERY" BRICKFIELD, NEAR EAST WICKHAM, APRIL, 1906.—A. L. Leach.

developed at Loam-pit Hill. East of Elmstead (Chiselhurst) the conglomerates of the Blackheath Beds in Sundridge Rock-pit (1897) are very fossiliferous. A few quartzite pebbles have been found here (1897), and at Croydon by Dr. Hinde; they occur, also, at Worms Heath, Knockmill (1908), and Belvedere, and their derivation is one of the minor problems of the Blackheath Beds.

Good sections showing the junction of the Blackheath Beds and the London Clay are not often seen in north-west Kent. The London Clay being very uniform in structure and usually unfossiliferous, is of much less interest in the field than the variable Lower London Tertiaries. *Modiola* and *Nucula* were obtained at Shooters Hill (1905), and near Lewisham (1903) the Basement Bed of the London Clay yielded *Ditrupea*.

The prominence of the Lower London Tertiaries in north-west Kent arises from slight modifications of the general dip of the Chalk northwards from the escarpment. Although not usually exceeding 5° or 6°, this dip, if steadily maintained, would carry the Chalk far below O.D. along the line of the Lower Thames, and the river would run wholly in London Clay. But in the neighbourhood of Woolwich the base of the London Clay rises to about 200 O.D., and between Greenhithe and Tilbury the Thames cuts through a high ridge of Chalk. Lines of slight disturbance in the Chalk have been traced near Orpington,* Bromley, Chiselhurst, and Crayford; they indicate the existence of "a set of gentle and roughly-parallel waves running nearly east and west, by means of which the lower beds are kept at the surface to a greater extent than would otherwise be the case."†

One of the most interesting points brought out in reviewing the Tertiary sections is the presence of "planes of erosion" at various levels in the Eocene beds. The long sections in railway cuttings‡ have afforded excellent opportunities for the examination of these irregularities. Usually between the Woolwich and Blackheath Beds an uneven junction appears. At Charlton there is but slight irregularity, but at Plumstead Common (1906) and Erith (1885) the Blackheath Beds rest in large "scoops" in the Woolwich clays and loams, which evidently were deeply trenched before the deposition of the Pebble-beds. The scouring action of estuarine currents, aided, perhaps, by slight tectonic move-

* "Excursion to Orpington" (1900), *Proc. Geol. Assoc.*, vol. xvi, p. 533.

† *Mem. Geol. Survey*, "Geology of London," vol. i, p. 483.

‡ "Excursion to the cutting near Shortlands, etc." (1891), *Proc. Geol. Assoc.*, vol. xii, p. 92; "Excursion along the new railway from Blackheath to Bexley Heath" (1893), *ibid.*, vol. xiii, p. 152; "Excursion to the railway cutting south of Grove Park Station, S.E.R." (1900), *ibid.*, vol. xvi, p. 522; "Excursion to Grove Park, etc." (2nd visit), (1901), *ibid.*, vol. xvii, p. 136; "Excursion to S.E.R. Main line widening at Elmstead cutting." (3rd visit), (1902), *ibid.*, vol. xvii, p. 368; "Excursion to S.E.R. Main line widening, etc." (4th visit), (1902), *ibid.*, vol. xvii, p. 489; "Excursion to Orpington" (1900), *ibid.*, vol. xvi, p. 533; "Excursion to Orpington" (1901), *ibid.*, vol. xvii, p. 169.

ments, such as the initiation of the "rolls" in the underlying Chalk, may account for these "scoops." At Elmstead, towards the Chiselhurst end of the tunnel, more than 40 ft. of Blackheath Beds rest directly on the bottom-bed of the Woolwich Series, but towards the north, Woolwich Beds remain in considerable thickness at Grove Park, and also at Orpington on the south. The Woolwich clays and shell-beds are therefore completely cut out in less than half a mile.

A higher plane of erosion appeared at the base of the London Clay in the cutting for the Bexley Heath Railway (1893). Near Blackheath Park the London Clay rested unconformably not only upon Blackheath Beds, but also on an eroded surface of Woolwich Beds. This unusual feature is brought out in the diagram (Fig. 42), which shows, also, the irregular junction between the Blackheath and Woolwich Beds.

These "scoops" of Blackheath Pebbles into Woolwich Beds are of considerable interest in connection with the Tertiary outliers of the North Downs.

IV.—Along the north-western escarpment of the Eocene Tertiaries from Reading to Hertford, Woolwich Beds (Reading type) or London Clay rest directly on the Chalk, both Thanet and Blackheath Beds having thinned out farther east. This state of things occurs in numerous outliers in Berkshire and Hertfordshire, but the outliers of the North Downs present a different type. At Knockmill (727 ft. O.D.), Worms Heath (800 ft. O.D.), and Woldingham, patches of pebble-gravel, having the lithological character of Blackheath Pebble-beds, rest directly on the Chalk or on thin irregular layers of sand. Since they are unfossiliferous, their age is a matter of inference from their lithology. In explanation of the absence of the lower members of the Lower London Tertiary group, an overlap* of the Blackheath Beds has been suggested—an overlap which Mr. Jukes-Browne remarks "was probably a general southward overlap and overstep along a wide tract or front caused by a contemporary uplift of the Chalk over the Wealden area."† This overlap has been indicated more particularly in reference to the Addington and Shirley district, where Blackheath Beds rest on Thanet Sand. But at Sanderstead and Well Hill, to the south of the line of the Addington "overlap," Woolwich outliers remain, and at Punish, east of Knockmill, an outlier of Woolwich Beds rests on Thanet Sand near the edge of the escarpment. It is therefore by no means clear that any "overlap" along a wide front actually occurs. What is here seen appears to be due to "scooping" on a large scale, rather than to a gradual and regular advance of the Blackheath Beds beyond the edges of the

* *Mem. Geol. Survey*, "Geology of London," vol. i, p. 215.

† *Proc. Geol. Assoc.*, vol. xix, p. 287.

FIG. 42.—SECTION FROM RAILWAY JUNCTION ABOUT $\frac{1}{4}$ MILE EAST OF BLACKHEATH STATION TO A POINT S.W. OF LOWER KIDBROOKE FARM.—*T. V. Holmes.*

Figures 100, 118 show the height of the surface. L.C. London Clay. B.P. Blackheath Pebble Beds. W.B. Woolwich Beds.
W.S.B. Woolwich Shell Bed. T.S. Thanet Sand.

Scales: Horizontal, 6 inches = $\frac{1}{2}$ a mile; Vertical, $\frac{1}{4}$ of an inch = 20 feet.

lower members of the same group (*i.e.*, overstep). Considered in connection with the large "scoops" previously mentioned, it seems probable that the Blackheath outliers of the North Downs were originally deposited in "scoops" which reached to some depth into the Chalk.

Both at Worms Heath* and Knockmill† the pebble-gravels have undergone disturbance, and their identification as Blackheath Beds has been questioned. But the irregularities appear to be due to movements brought about by the slow subsidence of the gravels into "pipes," which are readily formed beneath such porous beds. At Worms Heath the "pipes" are clearly shown in the gravel-pits; there is good evidence of their existence also at Knockmill. A few ovoid quartzite pebbles found at Worms Heath and Knockmill form an interesting lithological link with the Blackheath Beds of the main mass.

PLIOCENE.

Another set of outliers, consisting of sands and clays with layers of ironstone, occurs on the North Downs. The ironstone is sometimes fossiliferous and yields casts of Pliocene mollusca, but in the absence of fossils the Eocene or Pliocene age of some of these scattered deposits must remain in doubt. The well-known Pliocene Lenham Beds consist of patches of sand, clay, and fossiliferous iron-sandstones,‡ underlying the red clay-with-flints, and also filling deep "pipes" in the Chalk. Prestwich first claimed these as Pliocene sands and ironstones, but his views failed at first to meet with general acceptance. The Lenham Beds are now regarded as representatives of the continental Diestian sands, probably of the age of the Coralline Crag, or perhaps older.§ They are of great interest as indications of marine conditions over the northern part of the Wealden area in late Tertiary times; neither the Vale of Holmesdale, the Chalk escarpment, nor the valley of the Lower Thames can therefore antedate the Lenham Beds. At Lenham the sands and ironstones have been traced to a depth of 80 ft. in some of the "pipes." Farther east, at Paddlesworth, the deposits of this age are more extensive but less fossiliferous. Going westward, patches of light-coloured clayey sands and ironstones are met with on the Downs near Vigo, Otford, Merstham, etc., as far as Netley Heath, where they yielded fossils (1900). At Lenham the deposits range from 500 to 620 ft. O.D.; the sands on Headley Heath occur at 628 ft. O.D.; the level of these patches is therefore *below* that of the highest

* "Excursion to Woldingham" (1905), *Proc. Geol. Assoc.*, vol. xix, p. 133.

† "Excursion to Knockmill and Cotman's Ash" (1908), *Proc. Geol. Assoc.*, vol. xx,

p. 532.

‡ "Excursion to Lenham" (1892), *Proc. Geol. Assoc.*, vol. xii, p. 385.

§ F. W. Harmer, *Quart. Journ. Geol. Soc.*, vol. liv, p. 308, and *ante*, chap. iii, p. 87.

Eocene outliers. This has been explained as "due to their porous nature, which allows water to pass through and dissolve the Chalk,"* but as the Eocene outliers are equally porous, some additional explanation must be sought. During the denudation subsequent to the Miocene Wealden uplift, the waste of the Eocene beds must have been enormous, especially along the flank of the anticline, where sub-aerial agencies could operate with most effect. The general result was probably the formation of a deeply grooved surface with areas of bare Chalk, and upstanding ridges of Eocene beds. When, by subsidence, this surface was covered by the Pliocene Sea, Crag beds would be deposited here and there on bare Chalk below the level of some of the Eocene masses, and during a later period of uplift, "pipes" would most readily be formed beneath the porous pebbly Eocene outliers and the Pliocene beds which *rested directly on the Chalk*, with the result that these beds would subside irregularly into the "pipe" cavities and thus be, to some extent, protected during the severe post-Pliocene denudation which stripped the bulk of the Crag and Eocene beds from the higher levels of the North Downs.

BEDS OF DOUBTFUL AGE.

That mixed Eocene and Pliocene deposits occur in some of the "pipes" is very probable. The larger Eocene outliers—Worms Heath and Knockmill—are recognisable by their lithology; the larger Pliocene outliers yield characteristic fossils, but a number of small patches of sands and gravels† and "pipe" deposits occur which, in the absence of fossils, cannot be correlated strictly with either Eocene or Pliocene beds.

SUPERFICIAL DEPOSITS.

The deposits overlying the Chalk and Tertiaries may conveniently be grouped as (a) Residual, (b) Glacial, (c) Fluvial, according to their probable mode of origin; (b) and (c) are essentially Drifts containing transported material foreign to the locality; (a) (of which Clay-with-flints affords the best example), while doubtless mainly residual deposits, generally contain notable proportions of drifted Tertiary and pre-Tertiary material. Probably no purely residual deposit remains on the Plateau where the superficial deposits have been much disturbed by movements resulting from sub-aërial denudation.

* "Excursion to Netley Heath" (1900), *Proc. Geol. Assoc.*, vol. xvi, p. 524.

† Otford, Knockholt, Fair Seat, Ridley, Chipstead, etc. Many of the smaller patches are not marked on the Geological Survey maps, but they are recorded in "Geology of London Basin," *Mem. Geol. Survey*, vol. iv, pp. 336-342.

(a) *Residual deposits*.—Clay-with-flints, a stiff red clay containing abundant unworn Chalk-flints and, occasionally, Tertiary flint pebbles and fragments of older rocks, forms the "Plateau" above 400 ft. O.D. in the Medway and Darent areas, and descends to about 200 ft. O.D. near Sittingbourne. It lies very irregularly on the Chalk, and varies in thickness from a mere trace to 12 ft. or more. At Lenham it overlies part of the Pliocene deposits. Except by the presence of derivative pebbles and loams, it affords no evidence of transport, and, therefore, has been regarded as the residuum of the slow solution of the Chalk. Commenting upon its occurrence at Down, Darwin wrote, "During the dissolution of the Chalk a vast number of unrolled flints of all sizes has been left on the surface, and forms a bed of stiff red clay full of flints. . . ." But the very small percentage of clay in chalk, and the occurrence of Tertiary pebbles and loamy material suggest that to the residue of the Chalk there have been added "the clayey and loamy wash from the Tertiary lands, and the remains of beds of that age left in pipes and hollows of the Chalk. The irregular-shaped flints would help in catching and holding the earthy matters, the iron would give a brownish-red colour to the whole, and the irregular decomposition of the Chalk would cause the resultant deposit of these actions to have a varying thickness and an irregular position."† This seems to provide an adequate explanation of the features shown by the Clay-with-flints on the Kentish "plateau." Its age remains doubtful; it sometimes underlies the Plateau-gravels, and must represent a long period of severe sub-aërial denudation, probably in part contemporary with glacial conditions north of the Thames Valley.

A residual Drift of pelley chalk occurs locally along the foot of the Chalk escarpment near Wrotham and elsewhere. It has been mapped as "Scarp Drift" by Mr. F. J. Bennett,‡ who regards it as the waste of the escarpment.

An equally problematic set of deposits, the "dry valley gravels," has been included by some observers, amongst the residual deposits. Mr. G. W. Young§ discusses the formation of "dry chalk valleys," and concludes that "these dry valleys are not valleys of corrasion|| at all, but are due to the simple dissolution of the chalk by surface water." He further remarks, "As might be expected on this theory the floor of these valleys is thickly covered with unrolled flints," and in some valleys thick masses of residual chalk drift ("Scarp drift") are found consisting of "small rounded grains of pure soft chalk, the evident

* Quoted in Report of "Excursion to Down" (1892), *Proc. Geol. Assoc.*, vol. xii, p. 393.

† *Mem. Geol. Survey*, "Geology of London," vol. i, p. 282.

‡ "Excursion to Borough Green and Igham" (1906), *Proc. Geol. Assoc.*, vol. xix, p. 462.

§ "On the Chalk area of North East Surrey" *Proc. Geol. Assoc.*, vol. xix, p. 191.

|| "Corrasion," a term introduced by Prof. J. W. Powell to denote the excavation or deepening of a river-channel as contrasted with the widening due to erosion of the banks.

result of this mode of weathering." The subject of dry valleys has been fully discussed in reference to other areas by Mr. Clement Reid* and Mr. Jukes-Browne;† it can only be treated very briefly here. In North Kent, whatever may be the case in other districts, the dry valleys are obviously connected with the present drainage system. In the Darent, Cray and Ravensbourne areas particularly, the upper dry valleys, trending in general to the north-north-east, open as tributaries into larger valleys,‡ also now dry, which contain thick deposits of valley gravel and stratified brick-earths, and in these gravels rolled flints, Tertiary pebbles, and Lower Greensand chert and ironstone often are present in notable proportions. Since these upper dry valleys do not trench the chalk escarpment (except perhaps in the case of the Maplescombe Valley), this Lower Greensand material has probably been derived from the Southern Drift of the Plateau-gravels, and not directly from the former Wealden highlands; in either case, it indicates *transport* down the valleys. It is not easy, therefore, to see why *solution* should be regarded as the sole, or even the main, cause of these valleys. The transporting agency that moved and abraded the masses of chalk flints in the Cray Valley must have had a powerful *corrasive* action on the valley floor. Under present conditions the dry valleys are probably being slowly extended by the solvent action of rain-water and drainage from the clay-with-flints, and the unworn flints may represent the residue of this action, but the main lines of the valleys were probably sketched out, and their principal excavation took place, under conditions which no longer hold. The main objection to stream action in the formation of these valleys is based on the porosity of the chalk. Under present conditions the plateau and its dry valleys lie considerably above the saturation-level of the chalk, but any condition which would raise the level of the underground water, or make the chalk impermeable to rain-water, would permit the valleys to be eroded in a normal manner. Two conditions have been suggested:

1. An increase in the rainfall sufficient to keep the chalk permanently saturated.
2. A decrease in mean temperature sufficient usually to retain the interstitial moisture of the Chalk in a frozen state.

Probably during the glaciation of Central and Northern England these two conditions were from time to time alternately effective in North Kent, and the chalk uplands suffered "torrential denudation." Under such conditions the chalk would support only a scanty vegetation, its exposed surface would become deeply weathered, worn into ruts and broken into rubble by rain

* *Quart. Journ. Geol. Soc.*, vol. xliii (1887), p. 364.

† *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. iii, p. 418.

‡ Hartley, Longfield, Fawkham, Maplescombe, Halstead (Upper Cray Valley).

and frost, and from time to time the chalk and flint *débris* would drift down into the deepening valleys, and become mixed with the flints torn from the chalk by the corrosive action of the streams. With the post-glacial amelioration of the climate marked by decreased rainfall and increased temperature, the saturation-level would gradually sink below the valley floors, and the streams would cease to flow. During any temporary return of the first condition indicated above, stream-action in the valleys is renewed by the intermittent streams, called bournes, whenever the saturation-level rises to intersect the valley-floor. The rising-point of the bourne "gradually gets farther and farther up the valley as the underground water-level rises, until the greatest flow occurs, and then, as the flow decreases, the rise of the stream gets lower again with the decrease of the underground water-level, until at last the outflow ceases and the valley returns to its usual dry state."*

(b) *Glacial Drift*.—Several observers have strongly upheld the existence of evidence of severe ice action in North Kent, but no deposits are yet generally accepted as the direct products of glacial action. A "white rubble," or "chalk-and-flint rubble," on the plateau above Otford was regarded by Prestwich† as "glacial waste" associated with that stage of valley erosion which preceded the formation of the low-level drifts in the valleys. Near Sepham Farm, where it underlies Clay-with-flints and extends into the dry valleys, it contains crushed chalk and sharply angular flints, with a few Tertiary pebbles and fragments of Lower Greensand chert. Its position *under* the Clay-with-flints is probably due to local slipping of the clay. Near Dartford, in a pit near the "Orange Tree," a similar drift lies beneath the Pleistocene gravels of the Darent.

Certain scratched flint flakes found in the Plateau Drifts were regarded by Prestwich and others as glacially striated, and a "striated drift" has recently been described in the PROCEEDINGS.‡

(c) *Fluviatile Drifts*.—That the Kentish plateau is deeply sculptured by rivers and that these rivers have left, at various base-levels of erosion, gravels which contain flint implements washed in from the contemporaneous land surfaces, are now generally accepted views, and the existence of man during the deposition of the highest valley-gravels is also generally admitted. Controversy arose when flint tools were stated to occur in a set of much older drifts—the Plateau gravels—not connected with the present drainage system, and which, if they are truly fluviatile drifts, must have been deposited by rivers with a gathering ground to the south over and beyond the area

* "Excursion to the Croydon Bourne" (1904), *Proc. Geol. Assoc.*, vol. xviii, p. 388.

† "On the Age, Formation and Drift-stages of the Valley of the Darent," *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), pp. 126-163.

‡ "Excursion to Well Hill," *Proc. Geol. Assoc.*, vol. xix, p. 235.

now occupied by the Vale of Holmesdale. Man must therefore have lived in Kent before the formation of the present Chalk escarpment, and before the excavation of the valley, 300 ft. deep, by which the Darent breaks through the North Downs. The position and composition of these gravels are now well known. They rest at various levels from 500 ft. O.D. up to nearly 900 ft. O.D. on the Clay-with-flints or on Tertiary outliers, and are composed mainly of (1) unstained angular flints, (2) much worn, very sub-angular, deep brown-stained flints, (3) Tertiary pebbles, (4) Oldbury stone, Lower Greensand chert and other detritus, and rare quartzite-pebbles.

Neolithic and Palæolithic implements occur *on* the gravel patches, and with them and at various depths *in* the Drifts, where palæoliths do not occur, certain much-worn, deeply-stained, rudely-worked flint implements are found. Prestwich, accepting the view of Mr. B. Harrison, that these rudely-chipped flints were shaped by man, carried this view to its logical conclusion and maintained that these implements (subsequently termed "eoliths") were deposited with and in the Drifts by streams flowing from the Wealden anticline, and that their mineral condition, identical with that of the unworked flints with which they are associated, indicated a derivation from still older Drifts. Since these Plateau gravels rest on Clay-with-flints—a deposit of great but doubtful age—their age can be fixed only in terms of denudation. They belong to the "Southern Drift," of Prestwich, and contain material (as above) which must have been derived from the Lower Greensand and Wealden areas by transport down a slope or river-valley from the outcrop of those formations. Between the Chalk and the Lower Greensand a great longitudinal valley, 300 ft. deep (Holmesdale, in part), now extends many miles east and west; the gravels must therefore have been deposited, and man must have lived in Kent, before the excavation of Holmesdale. The antiquity of man, as indicated by this enormous denudation, is undoubtedly very great; that he is pre-glacial is freely admitted, many even claim that he is older than the late-Pliocene. Whether the contemporaneous implements of the plateau gravels are termed "eoliths" or simply "older palæoliths" is of less importance than the recognition of their equality in age with the Drift from the ancient "Wealden Highlands."

In the controversy which centred about these plateau implements, it was urged that :

1. The chipping had been produced by purely natural agencies.
2. The "eoliths" did not occur *in* but *on* the gravels, and therefore might have been dropped by man long after

the deposition of the plateau gravels containing southern material.

The second objection could not be sustained after the discovery of "eoliths" at depths of 6 ft. to 8 ft. in undisturbed Plateau Drifts.

The question of the artificial origin of *some* eoliths is now practically settled in the affirmative, but, unfortunately, "eolithic chipping" is recognised by many collectors on flints which, to more critical eyes, show only the results of natural battering and pressure agencies. The use of such a term as "characteristic eolithic chipping" is to be deprecated, since it appears to be frequently impossible to distinguish between "eolithic" and natural chipping. Mr. Harrison remarks: "The chipping, although perhaps sufficiently regular to excite curiosity, does not warrant the inference that it is necessarily due to artificial causes."* There can be little doubt that "eolithic chipping" is only of value as a test of human handiwork when the chipped flints show "a tendency to approximate to certain defined types."

The eolithic implements of the plateau gravels are said to fall into groups of definite type, and, moreover, are distinguished from the palæoliths by their deep staining, which colours the natural and the artificial surfaces, and by their much-worn and rolled state. They are now very generally accepted as human implements deposited contemporaneously with the gravels by rivers flowing from the denuded dome of the Wealden anticline.†

At various levels below the plateau deposits lie the Pleistocene gravels of the present river-system. These have been very fully described in geological literature‡ and at present are chiefly of interest from the attempts made to trace a progressive development in their implements. Messrs. Kennard and Hinton§ divide the implements of the Lower Thames Valley into ten groups, but the absence of illustrations makes it difficult to judge how far the implements, considered individually or in groups, present features of progressive development which may be regarded as indications of man's corresponding advances in mechanical skill and intellectual development. If this omission

* "An outline of the History of the Eolithic Implements" (1904), p. 9.

† "Excursion to St. Mary Cray, Well Hill, etc." (1874), *Proc. Geol. Assoc.*, vol. iv, p. 155; "Excursion to the Kentish Plateau" (1895), *ibid.*, vol. xiv, p. 196; "Excursion to Chelsfield and Well Hill" (1905), *ibid.*, vol. xix, p. 234; "Excursion to Borough Green and Igham" (1906), *ibid.*, vol. xix, p. 460; for Excursions to Pleistocene gravels, see references to Tertiaries; also "Excursion to Crayford" (1890), *Proc. Geol. Assoc.*, vol. xi, p. cxliv; "Excursion to Swanscombe" (1890), *ibid.*, vol. xi, p. cxlv; "Excursion to Dartford" (1893), *ibid.*, vol. xiii, p. 70; "Excursion to Galley Hill" (1896), *ibid.*, vol. xiv, p. 305; "Excursion to Crayford" (1903), *ibid.*, vol. xviii, p. 165; "Excursion to Erith and Crayford" (1905), *ibid.*, vol. xix, p. 137; "Excursion to East Wickham, etc." (1906), *ibid.*, vol. xix, p. 341; "Excursion to Crayford and Dartford Heath" (1907), *ibid.*, vol. xx, p. 122; "Excursion to Knockmill," etc. (1908), *ibid.*, vol. xx, p. 532.

‡ See "Superficial Deposits of Central and parts of Southern England," by Dr. A. E. Salter. *Proc. Geol. Assoc.*, vol. xix, pp. 1-56, where numerous references are given.

§ "The Relative Ages of the Stone Implements of the Lower Thames Valley," *Proc. Geol. Assoc.*, vol. xix, p. 76.

could be remedied the value of the paper as a basis for future work in the Thames Valley, and as an aid to the correlation of its deposits with those of other rivers, would be greatly increased.

In the "90 ft. Terrace" (Dartford Heath and Swanscombe) the gravels undergo a marked change in composition by the incoming of Jurassic, Triassic, and Carboniferous rocks and fossils. This foreign material associated with the rocks carried down from the "Southern Drift" of the North Downs is found in all the lower drifts of the Thames Valley.

A pebble of Lower Greensand chert lying side by side with a Carboniferous Limestone coral in the gravels of the Lower Thames, may epitomise the geological history of the gravels of North Kent. The one began its travels when the North Downs were part of the Wealden dome and rivers flowed over the Kentish plateau; the other entered the Upper Thames Valley, probably beneath the forefoot of a glacier, and gradually drifted down the stream during a period which, although almost inconceivably remote, is but as yesterday in comparison with the age of the pebble from the ancient Wealden uplands.

NOTE.—A general section of the Weald is given on page 435, chapter XIX, and two sections illustrating the formation of the Kentish Plateau will be found in vol. xix of our PROCEEDINGS, Plate I, illustrating a paper by Messrs. Kennard and M. Hinton.