

to be an old bed of the Hogg's Mill, corresponding to the 90—100 ft. terrace of the Thames.

This gives us some conception of the age of the Kingston Hill gravels, the gravels of St. George's Hill, and of the ridges seen at Oxshott. It would appear that the change in base level which set in after these gravels were deposited continued till the 90—100 ft. level was reached; that this was followed by a period during which deposition was renewed; and this again by a period during which the Thames cut down its channel by at least 110 ft., widened its valley towards the south, and deposited upon the floor of it the material of the lower terraces. This last period must have been a very long one, for obviously the lower terraces could not have been laid down till downward corrasion had been checked. That the lower terraces are associated with the climatic conditions of the ice age we know from the mammalian remains found in them.

The party returned to Waterloo by the 6.52 p.m. train. Miss E. Cadmore acted as excursion secretary.

REFERENCES.

- Geological Map, 1-inch London (Drift Edition). No. 3.
 Ordnance Survey, 1-inch, Large Sheet Series, Sheet 115.
 1909. WOODWARD, H. B.—"The Geology of the London District." *Mem. Geol. Survey*.
 1912. DEWEY, H.—"Excursion to Claygate and Oxshott." *Proc. Geol. Assoc.*, vol. xxiii, p. 237.

GEOLOGICAL AND GEOGRAPHICAL NOTES ON THE RAVENSBOURNE VALLEY.

BY ARTHUR L. LEACH, F.G.S., *Director of an Excursion to the District on July 8th, 1916.*

THE programme for this Excursion included geological and geographical features of the Ravensbourne Valley, West Wickham, Hayes and Keston Commons, and, especially, the West Wickham winterbourne then in flow.

Assembling at Hayes Station at 2.30 p.m., the party, numbering thirty, walked to the flooded gravel-pits south-west of Hayes Station, thence along the valley to see the bourne overflowing the road near the Rectory, and farther southwards towards Sparrows Den, where the highest outflow of the bourne occurred in a waterlogged meadow. The route then led to West Wickham Church on an outlier of Thanet Sand, through the fields to Coney Hall, and amidst the ancient oak trees on the Lower Tertiaries escarp-

ment (Thanet, Woolwich, and Blackheath Beds) to an earthwork, probably prehistoric, on West Wickham Common. Tea was taken at Keston. Afterwards the Keston ponds, Cæsar's Well, and a good section of Blackheath Beds above the well were examined. The party then walked into Holwood Park to see the historic Wilberforce Oak, noting on the way two trees—oak and yew—very curiously intergrown, and returned over the Commons to Hayes Station for the 7.45 p.m. train for London.

The following notes include the Director's remarks upon the geology and geography. Mr. Whitaker kindly supplied much information about the bourne, and its course south of Hawes Farm, as shown in the accompanying map (Fig. 15), has partly been drawn from his field-sketch. An account of the bourne-flow, with gaugings and detailed water-analysis, is being prepared by him for the Croydon Natural History Society.

THE RAVENSBOURNE.

The stream named "Ravensbourne" on topographical maps and shown flowing from Keston ponds cannot geographically represent the head of the river which under that name passes through Lewisham to the Thames at Deptford. The true Ravensbourne Valley, a well-developed transverse feature with thick valley gravels, extends several miles southward above the incoming of the stream from the ponds and, as a valley-form, without gravels, continues almost to the crest of the North Downs. Although it has unfortunately acquired the name of the main stream the flow from Keston enters the valley merely as a tributary. To avoid confusion between topographical and geographical uses, the name Ravensbourne Valley will apply in these notes to that well-marked physical feature which extends from near Worm's Heath on the North Downs, past Addington and Hayes to the Thames at Deptford Creek.

The Ravensbourne Valley, with its branches, resembles a letter Y, with somewhat incurved branches upon the Chalk and Clay-with-flints and a long north-pointing stem entrenched in the Lower London Tertiaries. These formations give rise to a steep escarpment heavily wooded, bordering the northern side of each branch, and in the angle a remnant of Thanet Sand forms a conspicuously wooded outlier. Many confluent and shallow dry valleys at the head of each branch appear on geological maps as V-shaped inlets in the northern margin of the Clay-with-flints. In the field the wooded borders of this plateau deposit frequently outline and emphasise the valley-forms by contrast with the comparatively treeless slopes of chalk below.

The eastern arm comes down from near Tatsfield on the North Downs, passes beside the Lower Tertiary escarpment to Coney Hall, and in a broad area of valley-gravel north of West

Wickham Church, joins the western or Addington branch, which has its origin near Worm's Heath. This western branch in which gravels may be traced up to about 450 O.D., and where also at intervals a bourne breaks out, may be justly regarded as the true line of the Ravensbourne Valley, to which the Coney Hall branch is a side-valley or tributary.

No "windgap" can be traced at the head of either the streamless main or tributary valleys. The crest of the North Downs forms their southern limit, and all active tributaries of the river are further restricted within the district bounded by the escarpment of the Lower London Tertiaries.

The Ravensbourne Valley comprises three sections. (a.) Streamless head-valleys on the flanks of the North Downs. (b.) The section traversed by an intermittent stream or winterbourne. (c.) The course of the permanent stream north of Hayes.

(a.) In common with many dry valleys in the North Downs the streamless head-valleys of the Ravensbourne exhibit winding courses, steep sides and rapidly falling floor-gradients, but they present no features of special interest to throw light on the parts played in their formation by rivers, solution, frost and other factors of subaerial erosion.

(b.) Winterbournes or nailbournes, controlled by conditions too well known to need more than a passing reference, depend on variations in the height of the water-table or saturation-level in the chalk. In position and volume their outflow is directly influenced by the precipitation during preceding winter-months. Above Croydon, in the adjoining valley of the Wandle, the rise of the underground water leads to frequent bourne-flows. Here in the Ravensbourne Valley outbursts are less frequent and very irregular in the times of their occurrence. Formerly bourne-flows appear to have been more frequent, if not almost continuous, also of greater volume, and to have issued higher up the valleys. They temporarily restore conditions which once were normal rather than exceptional. In a later section some particulars are given of the winterbourne, which in May of this year broke out in the Ravensbourne Valley, about one mile north-east of Addington.

(c.) A small permanent stream. "The Bourn,"* begins normally in the Ravensbourne valley at about 190 O.D., beside New Road, near Hayes Station, in a pool which probably receives slight outflows from Woolwich Beds on the sides of the valley.

All the tributaries of the Ravensbourne enter below this point. Moreover, they all rise in the Tertiaries bordering the

* This spelling, taken from the 6-inch Ordnance Map, should undoubtedly be "Bourne." The stream is directly in line with the channel of the winterbourne.

valley, at higher levels than "The Bourn," and even considerably above the winterbourne source in the Chalk. From Keston ponds, fed by Caesar's Well, a spring thrown out by Woolwich Beds at about 420 O.D., flows the "Ravensbourne" of topographical maps. Farther east the Quaggy, gathering supplies from Blackheath Beds at about 350 O.D. above Farnborough, passes below Chislehurst to Lee, where a small feeder comes in from springs at about 350 O.D. below the gravel-cap on Shooter's Hill. On its west bank the Ravensbourne receives the Beck and the Pool from West Wickham and Elmer's End, where many small ponds and springs occur between 200 and 400 O.D.

Thus, under ordinary circumstances (no bourne flowing), the river which enters the Thames at Deptford Creek draws no supply directly from the chalk, but depends wholly on permanent springs issuing from the Tertiary Beds at constant levels determined only by the positions of impermeable layers in these beds.

These sources differ essentially from the bourne supply, which is not constant in position, and fluctuates greatly in volume. The present condition of the Ravensbourne as a whole may not inaptly be compared to that of a tree in which the upper part of the trunk and the head branches are dry and lifeless while the lower stem and main branches remain alive and active.

RAVENSBOURNE GRAVELS.

Gravels occur all along the valley and in the streamless head-valleys up to nearly 470 O.D. above Addington, and to nearly 300 O.D. in the Coney Hall dry side-valley. Sections in excavations near Hayes Station show large chalk-flints, subangular, battered and broken, intermingled with pebbles from the Tertiaries, all embedded in coarse, gritty loam, not clearly stratified nor water-sorted.

Materials from the Lower Cretaceous rocks (*e.g.*, Hythe Beds chert, and carstone) if present are rare. Animal remains, recorded by Mr. Griffin, include *Elephas primigenius*, *Rhinoceros antiquitatis*, and *Equus caballus*, and Dr. Male has obtained fragments of reindeer antler. A pit above Coney Hall has coarse gravel of battered chalk-flints, with scarcely any intermixture of pebbles, although Blackheath Beds cap the slope immediately above.

In four small patches on the left bank west of Bromley, at about 200 O.D., Mr. Whitaker recognised traces of a higher terrace (*Geology of London*, vol. i, p. 445). Spurrell noted a drift above Rowes Farm, between 300 and 400 O.D., in the Coney Hall side-valley, and another patch lies below Layham's Farm at about 457 O.D. These drifts are clearly connected with the valley, but the absence of sections, and the highly cultivated and wooded character of the ground, make their interpretation uncertain.

GEOGRAPHICAL FEATURES.

As a whole the district drained by the Ravensbourne resembles the geographical unit termed a "cuesta" by Prof. W. M. Davies. In the alluvial flats of the Thames may be recognised an outer lowland, backed by the gentle rise of the Tertiaries towards a dissected upland (North Downs); beyond lies the steep Chalk escarpment above an inner (Gault) lowland, which in turn abuts against an older upland of ancient rocks, Lower Cretaceous and Wealden, upon which the cuesta has developed.

Several transverse or consequent rivers divide the northern dip-slope of the Wealden anticlinal upland into similar geographical units. From these rivers—the Medway, Darent, Wandle, Mole—the Ravensbourne differs, not in origin, but in its peculiar stage of arrested development. Certain conditions favoured the development of master-streams, such as the Darent and Mole, with strong longitudinal tributaries along the strike of the Gault. The upland became thus broken up into well-defined blocks, limited laterally by consequent streams and bounded on the south by strike-streams. These longitudinal streams, by their continued extension in both directions, brought into being the Chalk escarpment with these further results, (*a*) reduction of the gathering grounds, and in some cases beheading of the younger consequent streams, (*b*) lowering of the water-table in the Chalk. Finally, these factors in combination retarded and arrested the southward growth of minor or younger streams like the Ravensbourne and reduced them to their present insignificant volume.

The Ravensbourne may be briefly compared with a few neighbouring rivers. In its geographical stage the Beverley brook is less advanced; the Wandle, unlike the Ravensbourne, has a pronounced windgap in the North Downs, which may be interpreted as evidence of a former southerly extension of the river previous to its reduction or capture by the longitudinal tributaries of the Darent and Mole. The Darent, with its wide water-gap in the Chalk hills, has been cut off from the area south of the Lower Greensand range, while the Medway, with water-gaps in the North Downs and in the Lower Greensand hills, drains the true Weald, and, in continuing the capture of the head-waters of the Darent, is applying the process by which that river had previously affected the gathering grounds of the Wandle and other small streams. Admitting the application of these geographical principles, the atrophied condition of the Ravensbourne finds an explanation in harmony with the growth of the large neighbouring streams, which flow from the old Wealden Upland, and its dry head-valleys, bourne-flows and diminished volume are seen to be phenomena connected with the geographical development of the rivers.

WEST WICKHAM BOURNE

PLAN SHEWING SPRINGS. X
AND GAUGE POINTS A.B.

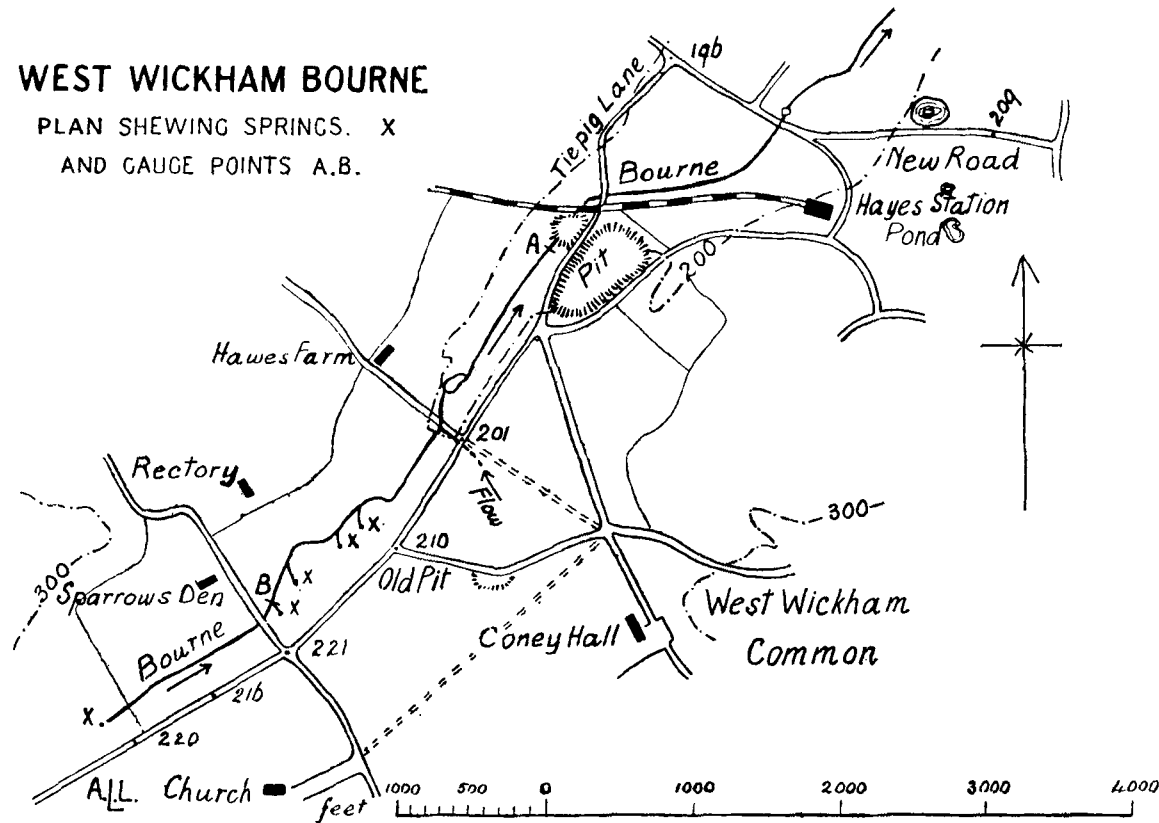


FIG. 15.

WEST WICKHAM WINTERBOURNE.

In May, 1916, the highest springs of this bourne were about $\frac{1}{4}$ mile W.N.W. of West Wickham Church, and approximately at 215 O.D., in a field then under hay. Although much of the field had become water-logged, and shallow pools had gathered in slight depressions, the ground remained dry a few yards above the source. The water rose along the lower part of the swampy field through the gravel on the valley-floor of Chalk, became concentrated into an old channel, probably artificially straightened to accommodate earlier outflows, and a clear rapid stream ran through the meadow to a conduit under the road below Sparrows' Den. In an adjoining field several small springs further augmented its flow.

Below Hawes Farm the old channel had become choked. Here the bourne overflowed the road, which had not been raised above the valley-floor, and a temporary foot-bridge had been improvised. Near this point a slight flow came in from the Coney Hall side-valley, but no definite stream appeared on the east of the road.

Onwards towards Hayes the bourne flowed along an old grass-grown channel (Plate 26.A), which led to the small pit west of Tiepig Lane. Into this pit (Plate 26.B) now brimful, the bourne ran merrily. The overflow, escaping by a conduit to the north side of the railway, passed under Tiepig Lane (which was overflowed in May), and through an adjoining meadow to a small pool beside New Road, where, under ordinary circumstances, the highest permanent stream in the main valley has its source. The 6-inch Ordnance Map shows the "Bourn" flowing from this pool, but no stream course is indicated in the fields to the south. On the 1-inch map a channel is marked from the railway-bridge over Tiepig Lane to the head of the "Bourn."

Previous flows of the West Wickham Winterbourne were observed in 1877, 1879, 1881, and 1883.* Gaugings taken in the last of these years show a much greater flow than the present outburst. According to figures supplied by Mr. Whitaker from gaugings taken by Mr. Baldwin Latham, the flow in March, 1881, amounted to 3,742,200 gallons per day at a point below Sparrows' Den. In the present year Mr. Latham noted :

May 28th.—Point A, 1,628,550 gallons per day ; Point B, 892,440 gallons per day.

July 12th.—Point A, 538,740 gallons per day ; Point B, 53,910 gallons per day.

The effects of the rise of the underground water-level were very evident in the gravel-pits adjoining Tiepig Lane. The large excavation, although not in the course of the bourne, had become

* Baldwin Latham, "Croydon Bourne Flows," 1904, p. 21.

flooded by soakage through the saturated valley-gravels. A slight further rise would have brought the water over the road and into direct connection with the small pit west of Tiepig Lane, where the water was from 12 ft. to 15 ft. deep (Plate 26.B). In a normal summer this pit is quite dry, and the fact that it has been excavated in the line of the bourne shows that the earlier bourne flows had apparently been locally forgotten.

THE COMMONS.

The beautiful commons of Hayes, West Wickham, and Keston admirably exemplify the plateau-forming tendency of the Blackheath Beds, and retain almost undisturbed many of the characteristic surface-features and the vegetation naturally associated with these pebble-deposits.

The mineralogy and botany of the commons have been described in papers issued by the Croydon Natural History Society. Mr. G. M. Davies gives the following list of heavy minerals from Hayes Common: heavy minerals, 0.42% including staurolite, tourmaline, ilmanite, kyanite, zircon, rutile, garnet, magnetite, epidote, hornblende, apatite, and detrital andalusite.

This Common is also one of the numerous localities where quartzites occur in the pebble-beds. Five specimens, of the usual smooth, ellipsoidal form, have been obtained by the Director and by Mr. R. H. Chandler.

REFERENCES.

- Geological Survey Map. London (Drift Edition). Sheet 4.
 1906. GRIFFIN, W. H.—“Geology of the Upper Ravensbourne Valley, with Notes on the Flora.” *The South-Eastern Naturalist*
 1916. DAVIES, G. M.—“The Rocks and Minerals of the Croydon Regional Survey Area.” *Proc. Croydon Nat. Hist. Society*.
 1908. DIBLEY, G. E., and KENNARD, A. S.—“Excursion to Hayes and Keston.” *Proc. Geol. Assoc.*, vol. 21 (1910), p. 34.



A.—THE WEST WICKHAM BOURNE, SOUTH OF HAWES FARM
[Photo by T. W. Reader.]



B.—THE WEST WICKHAM BOURNE FLOWING INTO A FLOODED GRAVEL-
PIT WEST OF TIEPIG LANE.
[Photo by T. W. Reader.]