33. NOTE on the PLATEAU-GRAVELS of EAST BERKS and WEST SURREY ;
their AGE, COMPOSITION, and STRUCTURE. By the Rev. A. IRVING,
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(Abridged.)

IN the year 1883 my first paper on Tertiary geology * was published by the Geologists' Association. In dealing with the gravels of the Bagshot district I pointed out that my observations up to that date had led me to regard the Plateau-gravels as Pre-glacial and contemporaneous with the Crag. This view has been worked out in fuller detail by Prof. Prestwich in Part III. of his recent paper "On the Mundesley and Westleton Beds and their extension inland." † It was a gratification to find myself in accord with him as to their pre-glacial age. For several years past it has been in my mind to give the results of further studies in this subject to the Society ; he has happily forestalled me, and brought to the consideration of the subject a much wider range of data than I could command. Still it seems that the argument by which he arrives at the conclusion that these Plateau-gravels are of *later* Pliocene age is not a very strong one ; for, when the Diestian age of the Lenham deposits is admitted (and Mr. Clement Reid's conclusion ‡ that they both are of older Pliocene age is also admitted), the assumption (which forms the cardinal point of the whole argument) that certain outlying sands high up on the slope of the North Downs are contemporaneous with the Lenham deposits has no other support than their being at approximately the same height ; while the lithological evidence points to their Eocene age §. This might very well be, if—as seems probable from various considerations—the north-western portions of the Weald partook in later Eocene time of the movement which is recorded in the upheaval of the axis of Kingsclere and Inkpen ||. Again, there is the absence of all marine deposits of Miocene age in the South of England, indicating (in addition to many other collateral considerations) a high degree of probability that the Miocene was the period of maximum elevation of this part of Europe, rather than one of depression beneath the sea. To this long period of Miocene (and Pliocene) elevation of the Weald we must look, I think, mainly for the supply of the vast amount of flinty subangular detritus under notice. From long exposure on the surface of the Chalk, as chemical erosion proceeded,

* See Proc. Geol. Assoc. vol. viii., "On the Bagshot Beds of the London Basin, and their associated Gravels."

† Quart. Journ. Geol. Soc. vol. xlv. pp. 155 *et seq.*

‡ See *Nature* (1886), vol. xxxiv. pp. 341, 342. I have discussed this matter with Mr. Reid, and have examined the Lenham fossils in the Museum of Practical Geology.

§ See some remarks by the author in the Geol. Mag. 1888, pp. 123, 124 ; and 1890, p. 406.

|| In Topley's memoir "On the Geology of the Weald" there are many facts which point to this conclusion.

it suffered that amount and kind of lithological change* which, with subsequent fluvial transport for distances of 10 to 15 miles, would give such materials the character and the subangular form which they for the most part are found to present in the Plateau-gravels. The flint pebbles, with which they are now intermingled, were probably preserved from the action of those atmospheric agencies which induced the lithological changes in the subangular flints, by having been sealed up in the Eocene strata, after having been formed by shore-action†. These two chief constituents of the Plateau-gravels, together with the subangular fragments of Neocomian chert, were intermingled, no doubt, in the rivers which flowed from the Wealden Hill-range, as the denudation of the Eocene beds in their formerly southerly extension proceeded, with the increased accentuation of the anticline, *pari passu* with the transport of the angular-flint material by rivers from the Weald across the northward-sloping plateau of Eocene land.

These Plateau-gravels seem to have no necessary connexion in time or otherwise with the "Mundesley and Westleton shingle" of Prestwich, since the flinty materials found in that might very well have been derived from an elevated Chalk region of Mercia and East Anglia.

Even the high-level gravels of the country north of the Thames may have had to a large extent a subaërial origin; for the fact that so many of them are covered up by boulder-clay (and so protected from the solvent action of carbonated atmospheric waters) renders it extremely difficult to account for their non-fossiliferous character by the hypothesis of "decalcification"‡. The above explanation of the intermingling of such different forms of the flinty material was put forward in 1883; and was, as then pointed out, suggested to me by my previous observations of the vast accumulations of angular flint material (mere insoluble residue) found to-day on the top of Saint-Boniface Downs in the Isle of Wight§. The quartz-pebbles mentioned by Prof. Prestwich in his recent paper, and by Prof. Rupert Jones||, are in my experience rare in the Plateau-gravels; nor do I believe, after sifting the evidence, that Mr. Monckton's large rolled block of vein-quartz came out of them¶.

Observation in the field tells us that as we work south the presumably older gravels become, as we should expect, more angular, and acquire a more massive development, most fully seen in the vast

* See Appendix i. Note e, in my "Chemical and Physical Studies in the Metamorphism of Rocks," p. 103 (1889).

† See Proc. Geol. Assoc. vol. viii. 1883, pp. 167, 168; also the Quart. Journ. Geol. Soc. vol. xlv. p. 184.

‡ Prestwich, *op. cit.* p. 146. The predominance of land and freshwater remains in the list of organic remains given in Quart. Journ. Geol. Soc. vol. xlv. pp. 115, 116, seems to point to an estuarine origin for the beds at Westleton and Mundesley, suggesting a terrestrial origin for the higher beds inland.

§ See also the new edition of the Geol. Survey's 'Memoir on the Geology of the Isle of Wight,' 1890, p. 210.

|| See Proc. Geol. Assoc. vol. vi. p. 439.

¶ See Quart. Journ. Geol. Soc. vol. xlv. p. 154.

accumulations of coarse flint detritus which cap the highest ground remaining of the Bagshot *terrain*, on Cæsar's Camp (600', ordn. datum) and Hungry Hills (550', o. d.) above Aldershot*. These vast accumulations (in places cemented into a conglomerate) of almost unworn flints, with scarcely a trace of even the rudest stratification, impress the mind more than anything I have seen in this part of England with a vivid idea of the enormous extent of the destroyed Upper-Chalk strata, which once arched over the region lying directly to the south. They may be the remains of the insoluble *débris* which accumulated under subaërial conditions along the base of the northern slope of the old Miocene Wealden mountain-range; materials, which, by their assortment and transport in part across the sloping plateau of the old Tertiary district immediately to the north, furnished the chief constituent, in a more rolled and worn condition, of the Plateau-gravels of the "Southern Drift." I know of nothing with which they compare so well as the old (pre-glacial) "Schotter" (unstratified *débris* often conglomeratic) of the lower Alpine valleys, which Von Hauer † and other authors have described under the name "Terrassen-Diluvium."

Such materials, however, as were carried away northwards and deposited in the lines of river-drainage or spread out on flats, where the declivity of the plateau diminished ‡, assumed a more or less *stratified arrangement*. This structural character is of great importance in recognizing the ancient Plateau-gravels in the sections furnished by the numerous gravel-pits opened of late years on the hill-tops, as the demand for road-material has increased with the opening-up of this ancient forest-country. The structural facies they most commonly present is that of interstratified masses of sand § (often loamy) and shingle, the sand-layers being generally coarse and ferruginous, with pronounced oblique lamination or current-bedding. Even where there are not distinct layers of sand in the sections, the stratification is generally manifest from the horizontal position of the longer axis of the pebbles and of the flint and chert fragments, allowance being made for the occasional local disturbance of these by the roots of pine-trees, by "soil-cap" movements on a small scale, and by the formation of talus at the expense of the plateau-gravels, owing to the removal of the sandy materials of the subjacent hill-flanks by ordinary agencies of erosion ||.

Further field-work since 1883 has shown me that the plateau-gravels must be recognized down to levels (as we work northwards) as low as 300 ft. (o.d.) and even lower. These are, of course, the

* I cannot recollect ever meeting with rolled flint pebbles in these gravels.

† See 'Die Geologie,' 1878, p. 704.

‡ Somewhat, as I conceive, after the fashion in which the broad expanses of gravelly detritus are formed by the Alpine rivers as they debouch upon the Plain of Bavaria.

§ These are sometimes cemented by ferric oxide into the hard "pan" occasionally used for building, and which defies the action of the atmosphere, as in the Roman Wall of Silchester.

|| Often resulting from the high-level springs which frequently issue from the base of the gravels; Rupert Jones, Proc. Geol. Assoc. vol. vi. p. 434.

youngest deposits of the series; for I conceive that the series as a whole covers a very large interval of geologic time, perhaps the whole of the Pliocene Period, the oldest of them (on Cæsar's Camp and Hungry Hill, Aldershot) being possibly of very early Pliocene age. On the other hand, the patches of unstratified and angular gravel found on the higher slopes and minor bluffs of the present valleys are probably mere "run-of-the-hill" of the later denudation of the country, and do not necessitate the idea of glacial action.

Localities furnishing Sections of the Plateau-gravels.

Locality.	County.	Above o.d. feet.
Cæsar's Camp and Hungry Hill (Aldershot)	Hants.	500 to 600
Hook Wood (north of Netley Heath) *	Surrey.	500 to 600
Fox Hills.....	"	350 to 400
Frimley Ridges	"	400
Bagshot Orphan-Asylum †	"	400
Obelisk Hill (Camberley)	"	370
Crawley Hill (Camberley)	"	350
Long Down (Sandhurst)	Berks.	350
Edgeburrow (Sandhurst)	"	370
Broadmoor	"	400
Cæsar's Camp ‡ (Easthampstead).....	"	400
Wagbullock Hill (Easthampstead) ‡	"	400
Gravel Hill (Swinley) ‡	"	400
Finchampstead Ridges §.....	"	330
Tower Hill (Swinley)	"	350
Race-Course Hill (Ascot)	"	300+
Long Hill (Ascot)	"	300+
Chevy Down (Ascot)	"	300+
Goathurst Hill (Ascot)	"	320
Buckhurst Hill 	"	300+
Farley Hill (S. of Reading)	"	280
Bearwood ¶.....	"	280

The whole of Easthampstead Plain and Chobham Ridges is probably capped with the same sort of gravels as are exposed at the localities mentioned.

In nearly all the sections the stratification is clear, and in most cases as pronounced as it is in the Low-level Gravels of the present Valley of the Thames, at Reading, at Ealing, and at Kensington; a fact which seems to point clearly to their river-origin. They are totally destitute of organic remains, except such as have been brought in the flints from the Chalk (impressions of fragments, spines, and occasionally complete casts, of *Micraster*, *Galerites*, *Ananchytes*, *Pecten*, *Inoceramus*, &c.), or as Sponge-spicules from the

* Flint pebbles and coarse unworn flint debris, interstratified with a stiff loam.

† Nine feet of gravel proved in the well-section (see 'Mem. of the Geol. Survey,' vol. iv. p. 537).

‡ Three great spurs at the north end of Easthampstead Plain. Open gravel-pits may be seen on each of these hills.

§ Three extensive pits worked for gravel.

|| This gravel extends some distance to the north in the direction of Binfield.

¶ See Geol. Mag. dec. iii. vol. iv. pp. 112, 115.

Neocomian. On comparing their altitudes some allowance has to be made for slight Post-Pliocene movements producing some changes of the relative levels. They remain as indexes of the ancient Pliocene lines of drainage northwards, having preserved the present hills from degradation; while the originally higher ground has been scored with the present valley-system.

Evidence of Glaciation.

With one apparent exception * I know of no distinct evidence of glaciation in the part of England referred to in this paper, nor in the Thames Valley above 240 ft. (o.d.), though many examples of it have been described at lower altitudes. If we assume, therefore, that these mark the period of the maximum glaciation of the old Thames Straits, we have to allow for a very considerable amount of excavation of the present valley-system of this part of England prior to the Glacial Period.

§ 1. In a new pit † at the Brickyards of Messrs. T. Lawrence and Sons, close to the Nine-mile Ride, between the Wokingham and Binfield roads, a fine section has been recently opened, exposing the laminated basal clays of the Middle Bagshot, with the underlying Lower Sands. The clays here are splendidly contorted, and overfolded by great masses of gravel, in some cases weighing several tons apiece, having been driven, probably in a solid (frozen) condition, into them. The lamination of the clays is distinctly traceable in the contortions, and leaves no doubt as to the nature of the agency which has here been at work. Altitude, 230 to 240 ft. (o.d.).

The gravel is one of the secondary or terrace-gravels of the country, derived from the older Plateau-gravels, with an increased proportion of flint pebbles, furnished by the destruction (prior to the glacial action) of the pebble-beds of the Bagshot terrain to the south.

§ 2. In the Tangley cutting of the South-Western Railway near Wokingham, on the other side of the valley, very distinct glaciation of the same laminated clays is seen at the top of the cutting above the Lower Sands at about 220 ft. (o.d.).

§ 3. At Sunninghill the same succession is seen in the railway-cutting, with similar folding, puckering, and included pockets of gravel, at about 220 ft. (o.d.).

* The case here referred to is that of a completely unstratified gravel, with scarcely any pebbles in it, which occurs on Lodge Hill, Broadmoor, at 400 ft. (o.d.). The angular fragments stand in all positions in it. May it not, from its exceptional character and altitude, be a glacial deposit of the cold Pliocene age (Etheridge, 'Manual of Geology,' p. 652; and Lyell's 'Student's Elements,' p. 181). The pit has been recently re-opened. It reminds me of nothing so exactly as of the moist masses of loose, incoherent, subangular stuff, which every observer of higher Alpine phenomena is familiar with in the trail of the minor snowfields as they retreat up the smaller valleys during the summer. A repetition of such deposits of trail for a number of seasons would give just what we see in the pit on Lodge Hill.

† This pit has been considerably extended since the note referring to it at the foot of p. 164 of vol. xlv. of the Society's 'Journal' was written.

§ 4. Other evidences of glaciation may be seen (*a*) in an unstratified clay with pebbles standing erect in it, upon an older angular and sandy gravel, which lies upon an eroded surface of London Clay in the Brick-and-Tile Company's Brickyard north of Bracknell; (*b*) in what appears to be a lacustrine deposit, as if in an extra-morainic lake, above the Bagshot beds in the brick-pits at Warfield *, wrongly described (as I venture to think) as a part of the Bagshot formation; (*c*) in the California clay-pits at Finchampstead †, where a similar lacustrine deposit probably occurs above the Middle Bagshot Clay, at about 230 ft. (o.d.).

The phenomena described in §§ 1, 2, 3, I take to be due to the mechanical work of floating ice, as pack-ice was formed from time to time in the old Thames Straits under the influence of high winds ‡.

Conclusions.

(1) Looking at the distribution of the Plateau-gravels of the district under consideration, their roughly-stratified structure, their constituent materials, the entire absence in them of contemporaneous organic remains, the frequent occurrence in them (especially near their base) of blocks of concretionary sandstone § (in many cases unworn, in others smoothed on the upper surface by the scouring action of sand and water), the frequent reconstruction and rough stratification of the immediately subjacent Upper Bagshot Sands (on which for the most part these gravels rest), and the marked erosion of these sands in many places beneath the gravels,—it is difficult to resist the conclusion that they had a fluvatile origin, the materials having been derived from the south.

(2) The only conception I can form which harmonizes with all the evidence available, is that of an elevated district of the older Tertiaries, subjected to subaërial waste, and having a general slope to the north towards what may have been an estuarine arm of the ancient Anglo-Germanic Sea, on the western margin of which the Crag was being deposited at levels not very different from those at which it is found to-day; the present gravels marking the drainage-courses of the later Tertiary valleys, while the present valley-system of the district occupies those portions which then formed higher ground, and has been initiated owing to the absence of the gravel-capping to which the present hills owe their preservation.

* Compare Section F, p. 386, vol. xliii. Quart. Journ. Geol. Soc. 1887.

† *Ibid.* vol. xliv. p. 172, Section Q.

‡ In all such cases the piling up of the ice takes place too quickly for deformation of the ice-masses to proceed *pari passu* with the increase of pressure. We thus get a mechanical agency brought into play quite different from anything which we can rationally postulate from the slow movement of a glacier. See my paper on the "Mechanics of Glaciers," Quart. Journ. Geol. Soc. vol. xxxix.; also the published work of Prof. Spencer, Geol. Mag. April 1887, and 'American Naturalist,' vol. xxii. 1888.

§ In the Proc. Geol. Assoc. 1883, I gave reasons for rejecting the Sarsens as evidence of a glacial origin of the gravels, in and near the base of which they usually occur.

(3) The more ancient arterial line of drainage of southern Eocene England * having been obliterated by the silting up of the Eocene estuary † by the Bagshot Beds, and subsequent regional movements of the Mesozoic strata to the south, the modern Thames Basin began to be outlined, although probably its main line of drainage did not coincide exactly with the modern valley of the Thames.

(4) Distinct evidence of glaciation at much lower levels than the plateau-gravels (210 to 240 ft., o.d.) being now to hand in the district, and this being presumably the work of floating ice in the old Thames Straits, we may (in the absence of distinct traces of glaciation at higher levels) assign something like 200 feet (vertical ‡) of the excavation of the present valley-system of this part of England to a period intervening between the deposition of the plateau-gravels of the Southern Drift and the Glacial Epoch at its maximum.

(5) The deposition of these Plateau-gravels appears to have occupied a considerable portion (perhaps the whole) of the Pliocene Period ; the only data available for fixing the time of the initiatory stage of their deposition being the inconclusive evidence furnished by the well-known Lenham deposits. The results of my own work and of the independent researches of Prof. Prestwich are thus seen to confirm the suggestions of Sir A. C. Ramsay §, made years ago, as to the pre-glacial age of these Plateau-gravels, and of the present valley-system of Southern England.

DISCUSSION.

Mr. MONCKTON had no doubt that the block of quartz referred to in the paper came from the Plateau-gravel. Everybody was agreed as to the materials of the Plateau-gravels having come from the south-east. Such contortions as described were generally accepted as evidence of snow or ice. The age of the Plateau-gravels was admittedly doubtful ; and, if possible, the Author had rendered their age more unsettled than ever. He (the speaker) inquired as to whether the Author used the term Boulder-clay with chronological significance, and what evidence was brought forward as proof of the marine or fluvial origin of the Plateau-gravels.

Prof. RUPERT JONES said that Mr. Godwin-Austen referred the Plateau-gravel to an early Tertiary age. He had lately seen, at Cuckmere, conditions of the shingle analogous to those which Dr. Irving had suggested for the Plateau-gravel. He believed that this, as well as the lower gravel, exhibited the effects of ice-action.

* See "The Stratigraphy of the Bagshot Beds, &c." *Quart. Journ. Geol. Soc.* vol. xlv. pp. 181, 182.

† This question has been discussed in my papers on the Bagshot Beds in the *Quart. Journ. Geol. Soc.* vols. xliii. & xlv.

‡ To this it would be easy to attach an exaggerated importance, if we overlooked the easily-destructible nature of the Bagshot strata.

§ 'Physical Geography and Geology of Great Britain' (5th ed.), p. 533.

THE AUTHOR, in reply, stated, with reference to the contortions, that the cases cited by Mr. Monckton hardly bore on the question, as they occurred much lower down the Thames valley, and at lower altitudes. The main point on which he differed from Prof. Prestwich was that he could not accept his later Pliocene date as fixing the minimum time. The term "Boulder-clay" was used only in a descriptive sense. He thought that one of the speakers had not given attention to all the facts brought forward.