VII. *Theoretical Considerations on the Conditions under which the (Drift)* Deposits containing the Remains of Extinct Mammalia and Flint Implements were accumulated, and on their Geological Age.* *By* Joseph Prestwich, *Esq.*, *F.R.S.*, *F.G.S.*

Received March 20,—Read March 27, 1862.

On the Loess of the Valleys of the South of England, and of the Somme and the Seine. *By* Joseph Prestwich, *Esq.*, *F.R.S.*, *F.G.S.*

Received May 15,—Read June 19, 1862.

[Note.—By permission of the Council of the Royal Society these two papers have been incorporated. At the time of reading the first paper, the author felt difficulties respecting the origin of the Loess, which led him to defer the consideration of the subject. When he afterwards brought forward the second paper, it proved so clearly complemental to the first, that the rearrangement of the two became desirable and almost necessary. This has also enabled the author to shorten both papers. The main portion of the second now appears in § 4. The bracketed remarks in the Introduction are inserted in consequence of a suggestion made to the author that it would be desirable to state in what respect the views advocated by him differ from those previously brought forward. Returned May 21, 1863.]

§ 1. INTRODUCTORY REMARKS.

In the paper I had the honour to lay before the Royal Society in May 1859†, on the occurrence of Flint Implements in France and in England associated with the remains of extinct mammalia, I postponed the consideration of the theoretical questions involved, to allow time for a more complete investigation of the physical phenomena. The facts I sought on that occasion to establish were,—1, the artificial nature of the Flint-implements; 2, their occurrence in undisturbed ground; 3, their contemporaneity with the extinct animals; and 4, their postglacial origin. Subsequent researches by myself‡ and other geologists have confirmed my views upon these several points§.

When I first visited Amiens in 1859, the opinion I formed was that the St. Acheul gravel-beds were deposited before those of St. Roch, and that the excavation of the

* The term "Drift" has been hitherto used as a convenient expression for the superficial beds generally; but as the relative positions of these beds are becoming better determined, we shall now be able to drop this term and introduce others of greater precision.

† Philosophical Transactions, vol. cl. p. 277. See also Mr. Evans's paper, Archæologia, vol. xxxviii. p. 280.

‡ Journ. Geol. Soc. vol. xvii. p. 362, where the various localities are mentioned.

§ Flower, Quart. Journ. Geol. Soc. vol. xvi. p. 190, June 1859. Gaudry, Comptes Rendus, Oct. 1859, p. 465. G. Pouchet, Actes du Mus. d'Hist. Nat. de Rouen, 1860, p. 33. L'Abbé Cochet, Mém. de la Soc. d'Emulation d'Abbeville, 1858–61, p. 607. Evans, Archæologia, vol. xxxix. p. 5, 1861. See also Sir Charles Lyell's Address at the Aberdeen Meeting of the British Association, Sept. 1859; Mr. Leonard Horner's Anniversary Address to the Geol. Soc. Feb. 1861; Sir Roderick Murchison's Address, Brit. Assoc. Sept. 1861.

Somme valley was of intermediate date; but I hesitated to adopt this view until facts could be obtained for a surer decision. The upper section at Montiers, however, which I discovered in 1861, was conclusive as to the relative ages of the two gravels. I had further considered that, supposing even this relation to be established, it was possible for the excavation of the valley to have been partly the result of some exceptional agencies, by which the interval of time between the formation of the beds of St. Acheul and those of St. Roch might have been shortened. But after repeated visits to the several districts during the last three years, and looking at the question from every point of view, I find myself unable to discover a sufficient explanation in the direction in which I first sought for one, and have been led to form conclusions respecting the causes in operation differing considerably on some points from those I at one time thought to be the more probable.

[A few very brief remarks on the opinions hitherto held respecting the position and age of the deposits of this class may here not be out of place. In my former paper I showed that the flint-implement-bearing beds were of later date than the Boulder Clay, and that at Abbeville the latest of them passed directly under the recent alluvium of the valley of the Somme. They thus occupy a definite geological period, which yet remained to be studied as a whole. The quaternary deposits in general, of which these beds form part, had long been the subject of my special investigation. The various drift-gravels had been regarded,—1, as being of marine origin; 2, as due to cataclysmic action; and 3, as of fluviatile origin. In one place we had marine shells, at others freshwater shells. But as the greater number of the gravel-beds were without fossils and occurred at very different levels, it was a long-debated question how they should be correlated. Palæontologists too were of opinion that the fossils indicated different ages, so that the freshwater deposits in a single valley, like that of the Thames, were held to be of independent and not synchronous formation*. On the palæontological evidence, the beds of Grays were generally supposed to be pliocene or preglacial, a view maintained by Sir CHARLES LYELL† until 1857, when he expressed uncertainty as to their age. Other beds in the same valley, as those at Brentford, were considered by Sir CHARLES to be newer than those of Grays. On physical grounds I had long been satisfied of the contemporaneity of these deposits, and contended for their posteriority to the Boulder Clay. Professor MORRIS and Mr. TRIMMER had also arrived at very similar conclusions, and were both in advance of me in attributing the phenomena to old river-action, but neither they, nor, as far as I am aware, any other geologists had attempted to make the rule general; nor had they taken in the high-level gravels, or the Loess, as belonging to the same series and as part of the same phenomena. When, further, I found similar land and freshwater shells at Hurley Bottom and other places in the Thames valley, the different deposits, showing the same conditions, became readily correlated.

* FORBES, Mem. Geol. Survey, vol. i. pp. 393, 395; SEARLES WOOD, Trans. Palæont. Soc. for 1848, p. vi. and 1856, p. 304; WOODWARD, Manual of the Mollusca, p. 298; and others.

† Manual of Elementary Geology, 5th edit. 1855, pp. 153, 154, and Supplement, 1857, p. 5.

But although it was evident that there were old land surfaces and possibly old rivers, there was no evidence that any supply of water could have existed to fill such large valleys; and the present streams seemed totally inadequate to have spread out such vast beds of gravel and sand, by far the greater part of which are also without organic remains to indicate their origin. Sir CHARLES LYELL, who advocated the fluviatile origin of these lower valley-gravels, considered that it would be "a rash inference" to conclude "that rivers in general have grown smaller, or become less liable to be flooded than formerly"*. This view, more or less modified, was held also by many other distinguished geologists. I could not accept it, because it seemed to me that to form such beds of gravel some greater water force must have been in operation than that which now obtains; at the same time, the hydrographical basins and the watersheds being the same as they were at that Quaternary period, I did not see whence the larger supply of water, which seemed to me indispensable, could have been obtained.

That valleys have been excavated by rivers was the hypothesis brought forward by HUTTON and PLAYFAIR†. It has been frequently advocated since; but the opinion has made little progress, owing to the absence of proof of how such an operation could have been effected, and to the insufficient physical and palæontological evidence. The subject, as far as regards Auvergne, was ably touched upon by Mr. POULETT SCROPE‡ in 1827, and discussed and argued more fully by CROIZET and JOBERT§ in 1828. Some remarkable cases were described by these geologists, to show, from the position of old shingle-beds preserved under masses of basalt, high above the present rivers, that the rivers in that part of France had excavated the valleys in which they now flow; but the cause of such phenomena remained unexplained, and the date undetermined.

Mr. GODWIN-AUSTEN showed, so early as 1837‖, that in Devonshire there were terraces of gravel fringing the valleys; and in 1851 and 1855¶, in correlating these and other quaternary deposits, he considered that the ancient low-level alluvia of the Thames and Seine valleys, and the old beach and the Elephant-beds of Brighton, were anterior to the Boulder Clay, and he was further of opinion that river- and ice-action had played an important part in producing these valley deposits. Sir CHARLES LYELL also discussed with his usual ability the question of the origin of valleys, and of ancient river-alluvia and river-terraces, both in his 'Principles' and in his 'Elements'**, but without attaching to the phenomena the importance I would show them to possess in such valleys as those of the Thames and the Seine. He was rather disposed to attribute the erosion of some lower parts of the valley of the Seine to sea-action††. Mr. TRIMMER‡‡

* *Op. cit.* pp. 70 & 84.

† Theory of the Earth, vol. ii. p. 401.

‡ Memoir on the Geology of Central France, 1st edit. pp. 163–4.

§ Ossemens Fossiles du dépt. du Puy-de-Dome, pp. 66–88.

‖ Trans. Geol. Soc. 2nd series, vol. vi. p. 439.

¶ Q. Journ. Geol. Soc. vol. vii. p. 136, and vol. xiii. p. 40.

** *Op. cit.* p. 85, and Principles of Geology, 9th edit. pp. 219 & 484.

†† *Op. cit.* p. 269 & 271.

‡‡ Quart. Journ. Geol. Soc. vol. ix. p. 286.

noticed the existence of terrace-gravels in the Thames valley, but explained them by alternate movements of depression and elevation*.

Sir R. MURCHISON also described at length some of the Drift phenomena of the South-east of England, more especially of the Wealden area. This distinguished geologist arrived at the conclusion that the heaps of detritus and angular débris following certain lines on the borders of the Wealden area, and found also in the Thames valley, result from the action of waves of translation passing from west to east†, and that the fossil mammalia (at Folkestone) were destroyed "by violent oscillations of the land, and were swept by currents of water from their feeding-places into the hollows where we now find them"‡. Mr. HOPKINS, in reviewing the question of the Drift, agreed with Sir RODERICK in supposing that the Wealden area has been traversed by waves of translation§, and in attributing to such agencies much of the Drift phenomena.

The observations of the distinguished naturalist the late Professor E. FORBES, recorded in his Anniversary Address, in 1854, to the Geological Society, express the then unsettled state of the question relating to the Drift ||; whilst the opinion hitherto commonly held with regard to the range in time of the large mammalia is manifested by Professor PHILLIPS ¶ and so many other eminent writers on the subject having restricted them to the preglacial period.

In France similar differences of opinion have prevailed respecting these particular quaternary deposits. The views generally adopted, however, with regard to the valley-gravels have been that they are the result of diluvial action, caused by waves of translation, or by cataclysms arising from the bursting of lakes, or by the sudden melting of the snow on mountain-chains. The deposits of this age in the valley of the Seine and other rivers in the North of France are usually classed under four divisions, viz. *Loess*, *Diluvium rouge* (part), *Sables lacustres*, and *Diluvium gris*, each being regarded as of separate and distinct origin, and the two diluviums referred to cataclysmic origin**.

Thus there were two extremes; I have been led to adopt an intermediate course. I could not admit the possibility of river-action, as it now exists, having in any length of time excavated the present valleys and spread out the old alluvia; neither was it possible to admit purely cataclysmic action in cases where the evidences of contemporaneous old land-surfaces and of fluviatile beds were so common. But with river-action of greater intensity, and periodical floods imparting a torrential character to the rivers, the consequences of the joint operation are obtained, and the phenomena admit of

* The occurrence of old river-terraces along narrow valleys is one of the features earliest noticed by geologists, but these are quite distinct from the great and isolated beds of gravel capping the adjacent hills.

† Quart. Journ. Geol. Soc. vol. vii. p. 361. ‡ Ibid. p. 386. § Ibid. vol. viii. p. li. || Ibid. vol. x. p. xliii.

¶ Manual of Geology, edit. 1855, p. 408. This opinion held good till 1859 and 1860.

** An excellent résumé of this subject is given in M. D'ARCHIAC's 'Progrès de la Géologie,' vol. ii. pp. 1–4, 154–221, 421–433. See also ANSTED's 'Elem. Course of Geol.' 2nd edit. 1856, p. 416 *et seq.*; D'OMALIUS D'HALLOY's 'Abrégé de Géol.' 7th edit. 1862, pp. 228–38, 449, 478; and a paper by M. CH. D'ORBIGNY (followed by one by M. LEYMERIE) in Bull. Soc. Géol. 2e sér. vol. xii. p. 1297–1304, with observations by M. HEBERT and others; and another by M. BUTEUX in vol. xvii. p. 72.

more ready explanation. I long since had proposed the separation of the gravels into the high-level gravels and low-level gravels, and shown that the former were older than the latter. I was, however, at one time disposed to adopt in part some of the views of M. ELIE DE BEAUMONT with respect to the operation of cataclysmic action in preference to the slower action of rivers; but further research, and the discovery of land and freshwater shells in so great a number of low-level gravels, and in some of the high-level gravels, and especially the striking evidence eventually afforded by the beds of St. Acheul, and by the higher-level gravels around Paris*, satisfied me that river-action peculiar to each valley commenced with the high-level gravels, while the mass of débris and the large blocks present in the beds indicate the action of a large volume of water and of ice-transport. Further, I was ultimately led to connect the Loess with both series of valley-gravels, and the frequent independence of the former, which at first seemed an irreconcileable difficulty, finally proved an important auxiliary fact; for the separate range of this deposit now serves as a measure of the old flood waters, and of the extent of the river inundations during this quaternary period.

I conceive that the hypothesis brought forward in this paper gives consistency to the whole subject. It brings down the large mammalia to a period subsequent to that when the extreme glacial conditions prevailed, and closer to our own times; it places all the old river alluvia in the same period, and groups together the previously isolated fluviatile beds of Grays, Brentford, and other places in England, together with the Loess and various "Sables lacustres" and "diluviums" (part) of the French authors; it connects the great platform terraces of gravel skirting so many of our river-valleys with the same period, and makes the connexion between these, and the excavation of the valleys themselves and the formation of the Loess, dependent upon one prolonged and uniform set of operations, in accordance with the climatal conditions and necessarily resulting from them.—May 1863.]

§ 2. GEOLOGICAL POSITION OF THE FLINT-IMPLEMENT-BEARING BEDS.

In almost every instance the flint implements have been found in beds of sand and gravel along the line of existing river-valleys,—in some cases but little above the level of the rivers, in others on adjacent hills at heights of from 30 to 100 feet above the river. In these valleys one series of gravel-beds is spread over more or less of their breadth, rising occasionally on their flanks to a height of 10 to 30 feet, and ranging throughout their length, though constantly obscured and hidden by recent alluvial deposits. The lower ranges of hills which flank these valleys on either side are occasionally capped by other similar gravels, but which, so far from being continuous like the lower-level beds, occur only at intervals, and there are long tracts without any such drift. The higher gravels are also generally separated from the lower gravels by a bare sloping surface, whilst they rarely extend far from the valley and never reach the tops

* This evidence is, with a few rare exceptions, wanting in the high-level gravels of England.

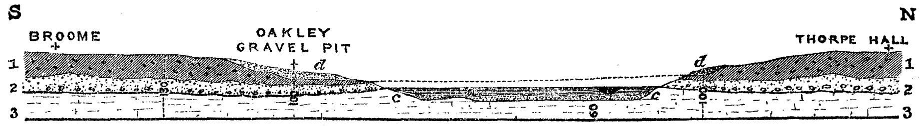
of the higher hills. The two series bear nevertheless a definite relation one to the other. They both consist of débris derived from rocks in the valleys through which the present rivers or their tributaries flow, and they both occasionally contain organic remains, of which the greater number of species are common to the two. Both series may be considered as "valley-gravels;" but for the sake of distinction I purpose calling that which occupies the bottom of the valleys, and reaches to a comparatively small height above the river-level, the "low-level valley-gravels," whilst to that found on the adjacent hills, I would apply the term "high-level valley-gravels." The height of the latter above the valley is variable; and though generally limited to one main platform, it is not always on the same level, and there are cases of minor intermediate terraces between the extreme levels. The heights are of course relative one to the other, and not directly to the sea-level.

Valley of the Waveney.—The levels recorded in my former paper establish the fact that the flint-implement-bearing deposit of Hoxne is at a height of 40 feet above the Gold Stream, and 50 feet above the Waveney, of which the Gold Stream is a tributary. Mr. EVANS and I found a very similar deposit, also overlying the Boulder Clay, at Athelington, a few miles higher up the valley of the former stream. In following the course of the Waveney, from above Diss to the sea at Lowestoft, terraces of gravel are found at distant intervals on the adjacent hills. They never extend far from the valley, and the intermediate higher but flat ground between the river-valleys invariably presents bare tracts of Boulder Clay. It is particularly between Diss and Harleston that these terrace-gravels are best exposed, and where I have determined with some care their extent and development (Plate V. fig. 3). I have found them on the right bank of the Waveney, at Stutston Common, Oakley, and Shotford Heath, lying upon the Boulder Clay; and on the left bank at Scole, Billingford, Thorpe Abbots, and Needham. Thence to the sea they may be traced at intervals on both sides of the valley; but they seem gradually to fall to a lower relative level. At the places above mentioned, on the contrary, they occupy a tolerably regular level of from 40 to 60 feet above the valley, are from 5 to 12 feet thick, and rarely exceed a quarter of a mile in length, or more than 200 to 400 feet in width. They consist chiefly of a mass of subangular flints, with pebbles of siliceous sandstones and of the older rocks, in a matrix of ochreous sand and clay. No organic remains have been found in them. The low-level gravel is not often exposed, being generally covered by alluvial deposits. It may, however, be seen at Oakley and at Needham, and has been reached at various places under the recent alluvium of silt and peat. Care must be taken to distinguish these gravels from those which underlie the Boulder Clay in this district. The latter are more sandy and far more distinctly stratified*. They may be seen in superposition in a pit on the hill above Oakley Street; in contact with the high-level gravel at Needham near Harleston, and at Moor Bridge near Hoxne; and lying on the Boulder Clay at Thorpe Abbots. The following section, taken across the valley

* The great number of pebbles of white quartz is one of the chief features which serves to distinguish the gravel under the Boulder Clay from the valley-gravels.

of the Waveney between Scole and Hoxne, shows the relation of these gravels to each other, to the Boulder Clay, and to the surrounding district*.

Fig. 1.—*Section across the Valley of the Waveney, near Hoxne.*

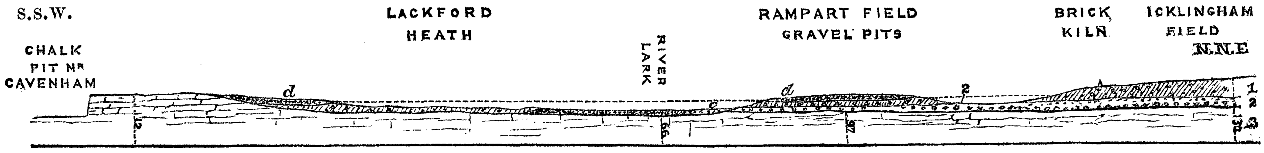


a. Alluvial deposits. *c*. Low-level valley-gravel. *d*. High-level valley-gravel.
Traces, but somewhat indistinct, of Loess exist on the gravel *d*, and on the slopes of the valley.
1. Boulder Clay. 2. Sands and gravels under the Boulder Clay. 3. Chalk.
The dotted lines here and in the other sections show the presumed old surfaces.

The higher valley deposits assume in the tributary valley of the Gold Stream at Hoxne a more lacustrine character. The lower-level gravels may be seen in the field opposite the Swan Inn, overlying the sand and gravel of the Boulder Clay series.

Valleys of the Ouse and Lark†.—In the main valley of the Ouse at Bedford eight flint implements have been found under circumstances which admit of no doubt of their geological position; and at Icklingham in the valley of the Lark, a tributary of the same river, two specimens have been met with, which, although not discovered *in situ*, there is good reason to believe came from the high-level gravel‡. In descending the valley of the Lark, from Bury St. Edmunds to Icklingham, Mr. Evans and I found it flanked by low ridges of gravel rising from 20 to 30 feet above the valley, and these again commanded by higher ground formed of the Boulder Clay. In a pit at Flempton I found in the gravel a fragment of bone, and remains of the Elephant have been met with at various places near Bury St. Edmunds; but we saw no traces of shells in any of the drift-gravels or sands of this district. The section of the valley is as follows:—

Fig. 2.—*Section across the Valley of the Lark, near Icklingham.*



a. Recent alluvial deposits. *c*. Low-level gravel. *d*. High-level gravel. (Only traces of Loess.)
1. Boulder Clay. 2. Sands and gravel under the Boulder Clay. 3. Chalk.

In the valley of the Ouse at Bedford (see fig. 3) I have been unable to detect at

* The scale of height in these and all the following river-valley sections is 1 inch to 400 feet. In the horizontal scale 1 inch equals about ½ a mile (except figs. 4 & 5). The base-line gives the sea-level approximately.

† I originally made a section of the valley of the Ouse at Bedford in 1854, and then determined the relation which the well-known mammaliferous gravel of this valley bore to the adjacent Boulder Clay. The number of fossil bones subsequently discovered in the cutting of the Great Northern Railway, led Mr. Evans and myself at once to direct our attention to this valley on our return from the valley of the Somme in 1859. The discovery, by Mr. Evans, of fluviatile shells in the Biddenham gravel confirmed the analogy we suspected, and we directed Mr. Wyatt's attention to it and to the probable occurrence of flint implements, in the search for which this gentleman has since been so successful. 27 specimens are now recorded by Mr. Wyatt.—Feb. 1864.

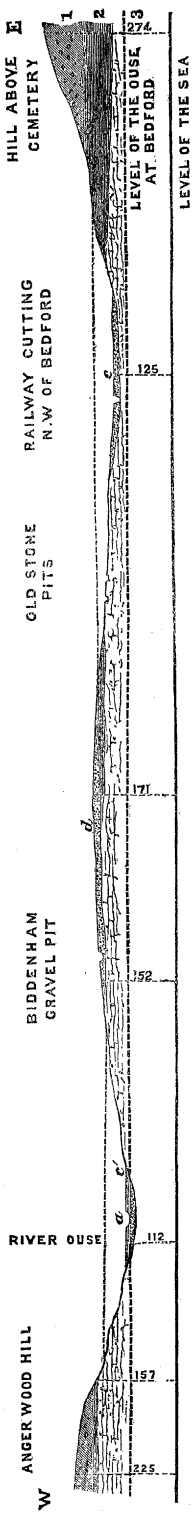
‡ The author in Quart. Journ. Geol. Soc. vol. xvii. p. 363. A number more have been since found (1864).

present any distinct high-level gravel. I am rather disposed, however, to consider it possible that the gravel at the Biddenham pit, where flint implements have been discovered, may belong to that series, although not to the highest level; for although the ground slopes very gently towards Bedford, and I could not mark any break in the continuity or much change in the character of the gravel, still, in the distance of 1½ mile, there is a difference of level of some 20 to 30 feet between the Biddenham pit and the gravel adjoining the railway and under the town*. There are also apparently certain slight differences in the fauna. At Biddenham the remains of the *Hippopotamus* have not yet been met with, whereas in the railway-cutting near the town they were very abundant. The profusion also of the other mammalian remains at the latter place is in marked contrast to their rarity at the former.

I have traced the gravels with similar conditions of structure above Bedford, as far as Olney and Wolverton, and in descending the river I have followed them at intervals as far as Lynn. At Offord, 3 miles S. of Huntingdon, there is a well-marked low terrace of gravel, in which a large number of mammalian remains were found during the making of the Great Northern Railway; and at Hemingford, 2½ miles E. of Huntingdon, a freshwater deposit with mammalian remains has been described by the Rev. Mr. De la Condamine†, which I consider belongs to the low-level valley series.

Herne Bay.—I am unable to offer a sufficiently satisfactory account and explanation of the position of the flint implements found on the shore near Herne Bay. Whether derived from a clay drift or from the gravel which caps the cliffs is uncertain. With respect to that at Swalecliffe, between Herne Bay and Whitstable, it would seem to have been derived from a freshwater and mammaliferous clay and gravelly sand, belonging to a low-level valley deposit and abutting against a cliff 54 feet high, on the top of which is a bed of high-level gravel. The same gravel may be traced on the other side of the valley at

Fig. 3.—*Section across the Valley of the Ouse near Bedford.*



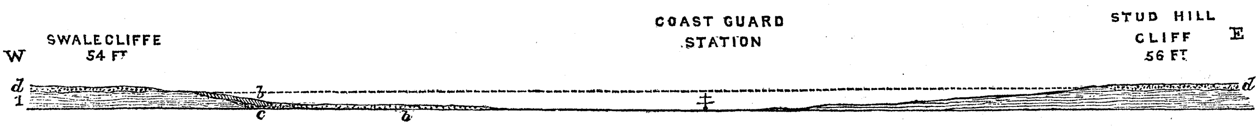
a. Recent alluvium. *c*. Low-level valley-gravel. *d*. High-level valley-gravel. 1. Boulder Clay. 2. Oxford Clay. 3. Oolitic series. (*Cornbrash*).
Traces of Loess, in the form of a thin bed of brown sandy clay with angular fragments of flint, overlie both the gravels.

* A recent visit to Bedford, and fresh levels taken with the aneroid barometer, have confirmed this distinction. By taking another line of section, I traced the Biddenham gravel to a height of 60 feet above the river, and found it separated from the gravel at Bedford by a bare tract of oolitic strata. The section given above (fig. 3) embodies these last observations. Mr. Wyatt and Mr. Evans have lately found two flint implements of the ovoid or Menchecourt type in the low-level gravel of Summerhouse Hill.—Feb. 1864.

† Quart. Journ. Geol. Soc. vol. ix. p. 271 (1853).

Studhill, and in it Mr. Evans found part of an Elephant's tooth. I am inclined to believe that the features observable at Swalecliffe are partly dependent upon the small lateral valley which runs a few miles up the country, and are only indirectly connected with the more general phenomena of the main valley of the Thames (fig. 4).

Fig. 4.—*Section along the coast east of Whitstable*—$1\frac{1}{2}$ *mile in length.*



b. Loess with shells and bones. *c.* Low-level gravel. *d.* High-level gravel.

With regard to the valley of the Thames* the structure is far more complicated, from the circumstance of there being in this district, in addition to the high- and low-level valley-gravels, a wide-spread set of higher or hill-gravels, of marine origin, presenting a very close similarity to some of the valley-gravels, and covering large tracts of country. As this district will form the subject of a separate communication from me elsewhere, I here merely allude to it for the purpose of remarking that, after eliminating the foreign element, there remains a set of valley- and terrace-gravels which, though not so marked or well characterized as in the Seine valley, are nevertheless of nearly similar order and age. The same remarks apply to most of the valleys of the South of England, including the valley of the Severn. In the latter there are fossiliferous terrace-gravels skirting the Severn and the tributary Avon†, with valley deposits corresponding to those at Grays and Menchecourt, whilst, as in the Thames district, there is a set of higher-level hill-gravels more wide-spread, and probably of marine formation.

These cases all point to some common origin, and concur in showing that the flint implements hitherto met with have been found in beds holding like positions. The only exceptions are the discovery by Mr. Evans of a flint implement of the Amiens type upon the chalk hills of Hertfordshire, 200 feet above the valley, and of one of the Abbeville type on the chalk hills three miles from Dartford in Kent, by Mr. Whitaker. Both these are considerably above the valley and the valley-gravels, and the conditions are such as do not admit of exact correlation with any of the other cases.

The confusion just alluded to arising from the occurrence, on levels often not far apart, of gravels and drifts of different ages and different origin, is common through a great part of England, while also questions connected with the direction of the transporting currents are obscured in consequence of the materials of the high- and low-level gravels having been formed in large part out of higher-level hill- and marine gravels. Owing to the

* The flint implement found so many years since in the Gray's Inn Road still remains, with respect to the London district, a unique and remarkable case. Several specimens, however, have been found by Mr. Hughes near Sittingbourne and Faversham, lower down the Thames valley and its tributaries.—Feb. 1864.

† There are also in the valley of the Severn low-level gravels of marine origin. See Strickland's paper in Geol. Trans. 2nd ser. vol. vi. p. 552–5, and various papers by the Rev. W. S. Symonds.

absence of the marine pliocene and post-pliocene beds in the North of France, we there obtain clearer evidence relating to the valley-gravels, as they are free from rock-fragments and boulders foreign to their own origin and area. From causes to which we shall presently allude, the whole class of these phenomena is also more marked and on a larger scale in France than in England, and has attracted more attention and been more fully investigated. It is sometimes not easy to determine the high-level gravels in our valleys, whereas in France they are generally on a scale of height and extent which prevents any doubtful interpretation of their relative position.

Valley of the Somme.—M. BUTEUX * gives a number of localities at which the beds he terms Diluvium occur in the valley of the Somme, between Amiens and St. Quentin, but without going into structural details and levels. On my first visit to St. Acheul and St. Roch I suggested the possibility of the beds at the former place † being a stage older than the latter. The distance between them being 1½ mile, it seemed quite possible that the difference of level might have arisen from other causes than a further excavation of the valley subsequent to the deposition of the St. Acheul beds, and anterior to that of the St. Roch beds, but the difficulty of proof was considerable; the existence of faults, the slope of the ground, or an unequal extent of elevation might have been the cause of the difference. The point being one of importance in its bearing on the question of the age and antiquity of the St. Acheul beds ‡, I reserved my opinion in the hope of finding better evidence elsewhere in this valley.

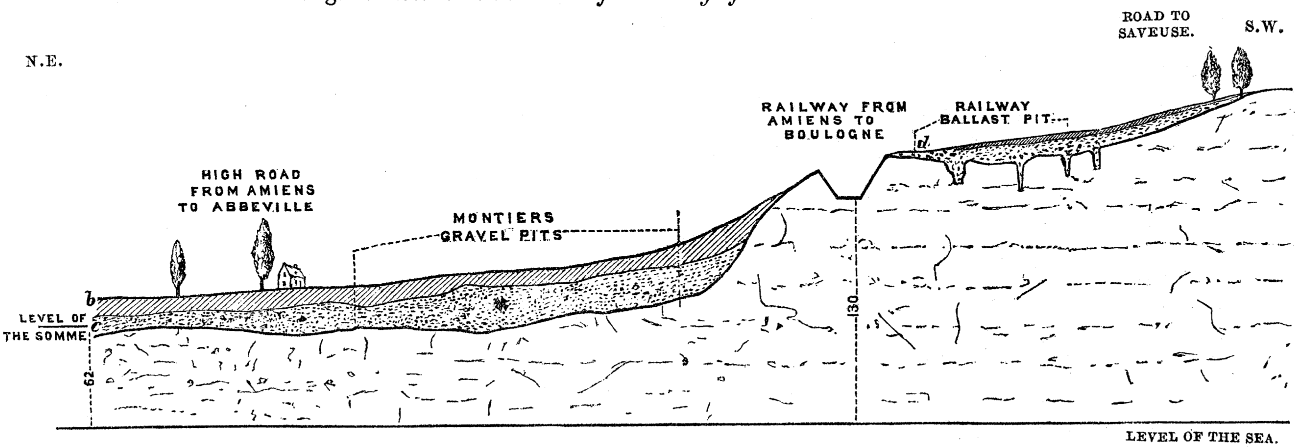
At a distance of from one to two miles N.W. from Amiens, and parallel with the river, is a series of large pits extending past Montiers along the road to Abbeville. The gravel is on the same level and of the same character as that of St. Roch. Few mammalian remains, and no shells or flint implements, had been found there up to the period of my first visit in 1859. As at St. Roch, the gravel abuts against a low chalk hill, and no fossiliferous gravel had been met with on the hill above. The railway runs just at the back of the pits, and at a height of some 30 feet above them. In the spring of 1860 I found a pit just opened immediately above the slope of chalk through which the line passed, and in such a position that the gravel could be wheeled on a level from this new pit into the railway trucks in the cutting. In position and level this last deposit is related to the beds of St. Acheul as the beds in the old pits are to that of St. Roch; but here the two beds were in close and determinable proximity. The section from one to the other is fortunately perfectly clear, and I could detect no fault in the separating chalk ledge cut through by the railway.

* Esquisse Géologique du département de la Somme, Paris, 1849, and two supplements; and 1862; also a paper by the same author in Mém. de la Soc. d'Emul. d'Abbeville for 1857, p. 561.

† Phil. Trans. 1860, p. 303.

‡ I have since been enabled to trace, by means of some trial pits near the Amiens railway station, the low-level gravel with remains of *Rhinoceros tichorhinus* close up to the base of the hill on the top of which the St. Acheul gravels extend, forming a section therefore very analogous to that at Montiers, and establishing directly the relation of the St. Acheul beds to the lower-level gravels, which continue uninterruptedly from the railway station to St. Roch.—Feb. 1864.

Fig. 5.—*Section on the side of the valley of the Somme at Montiers.*



b. Brick-earth (*Loess*) ...... 3 to 12 feet

c. Irregularly stratified sands and gravels (low-level valley-gravel). Remains of Horse, Ox, Elephant, &c. Flint implements of the flake type not rare; one discovered at ✠ ...... 20 to 25 feet.

d. Rude mass of coarse gravel (high-level valley-gravel). A few fossil bones; numerous shells 10 to 12 feet.

1. Chalk. (The height at the railway cutting is only approximate.)

The gravel at the new ballast-pit is much mixed with chalk débris, and is less regular in its structure than the gravel at St. Acheul. It contains similar boulders of sandstone, and the identity of the two deposits was further confirmed by the discovery in the upper and more sandy part of the gravel bed of an abundance of land and freshwater shells, more numerous as to individuals than at St. Acheul, but of fewer species.

Shells from the new ballast-pit south of the railway at Montiers.

Helix concinna.	*Pupa marginata.*	*Ancylus fluviatilis.*	*Pisidium fontinale.*
—— *pulchella.*	*Succinea elegans.*	*Limnæa palustris.*	*Planorbis spirorbis.*
—— *hispida.*	—— *putris.*	—— *truncatula.*	*Valvata piscinalis.*

I also found a few fragments of bone, but not determinable. Of flint implements I could discover none, nor have any been yet found by the men. In the lower pits on the other side of the line the gravel is spread out in great horizontal beds, or rather lenticular masses, and is interstratified with some very sandy beds; the beds vary more in colour, and no shells have been found. Their thickness amounts to about 25 feet, whereas the higher gravel (*d*) is only about 12 to 15 feet thick. In all respects the lower gravel (*c*) resembles that of St. Roch. On the occasion of a former visit I had shown the men a flint implement from St. Acheul, and requested them to look for and keep any specimens. On my second visit, accompanied by Sir Charles Lyell, to whom I had mentioned the interest of the section, the men showed us a flint implement which they had just discovered at a depth of 17 feet from the surface, and at a point marked ✠ in the section*. This specimen is quite white, has dendritic markings, and is of the simple broad flake type common in the low-level gravel at Mautort†. On my last visit I obtained five more specimens, all of the narrow flake type known as flint knives, except

* Whilst in the pit we employed a man to work at a heap of the weathered gravel. A small flint knife was the result of an hour's search.

† See fig. 2, Plate XII. Phil. Trans. 1860.

one, which more resembles the St. Acheul spear-head type. The deep discoloration and curious dendritic markings on these flints, their form (not upon the neighbouring St. Acheul type, but upon one before unknown to the men), and their small number preclude the idea of any collusion or deception, and substantiates the statement of Dr. RIGOLLOT, that such implements have been found in the like gravel at St. Roch*. On the hill rather higher than the new ballast-pit is another pit, where the gravel is shallower, contains no organic remains, and is probably of rather older date.

The more general examination I have made of the Somme valley, from about six miles above Amiens, to the sea at St. Valery, a distance of forty-seven miles, has been sufficient to show the persistence of the same structural features. (Pl. V. fig. 2.) In descending the valley below Amiens, after passing the gravel-pits of Montiers and Breilly, the chalk hills rise abruptly from the valley, covered only with more or less loam or brick-earth, except near Picquigny, where a few gravel pipes in the escarpment attest the former presence of a high-level gravel apparently 60 or 80 feet above the valley. On the hill which projects into the valley between Le Gard and Crouy is a capping of flint gravel.

At Condé the valley-gravel again occurs, but thence by Fontaine and Liercourt the hills present a bare surface of chalk, or else a capping and skirting of brick-earth only. At Mareuil, three miles south from Abbeville, and still on the left bank of the river, we find the gravel, capping, to a thickness of 6 to 8 feet, the hills which rise behind the village to a height of 110 to 130 feet. I could not discover any organic remains or flint implements†. From this spot to Mautort the chalk hills rise abruptly from the valley, either bare or more or less covered by brick-earth, but still showing here and there traces of gravel pipes, indicating the former existence of gravel beds at about the level of 80 to 100 feet above the river. Here also, as at other spots where the hills advance upon the valley, the depth of the latter seems to be greater, so that all the valley-gravel and Loess is covered up and hidden by the recent alluvial deposits which come close to the foot of the chalk escarpment. (Pl. V. fig. 1.)

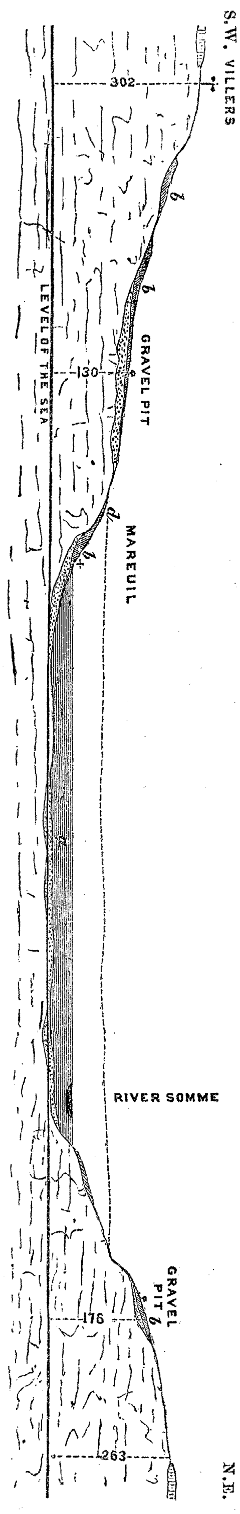


Fig. 6.—*Section across the Valley of the Somme near Abbeville.*

a. Recent alluvium. *b.* Loess. *c.* Low-level valley-gravels. *d.* High-level valley-gravels. 1. Chalk.

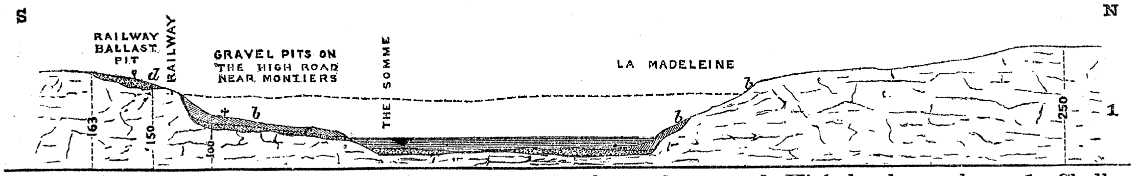
* I have since had the opportunity of confirming the statement of Dr. RIGOLLOT, the men having found four rude but undoubted flint-flakes at this spot (April 1863).

† M. BOUCHER DE PERTHES has two specimens in his collection labelled as from this locality.

Four miles lower down, and immediately opposite Menchecourt, are the pits of Mautort, described in my former paper. A bed of gravel there occurs on the slope of the hill at a height of 80 feet* above the river, and lower down another bed forms a bank on which the village stands. At a pit belonging to M. Ducastel, these lower gravels are very sandy and distinctly bedded, and there is good evidence for believing that marine shells (*Cardium edule* and *Littorina littorea*) occur at their base. I found no flint implements, but Sir Charles Lyell obtained, in the gravel-pit at the further end of the village, two indisputable specimens of the low-level ovoid form. There is a patch of high-level gravel near Saigneville, whilst at the mouth of the Somme a considerable width of ochreous flint gravel caps the hills near St. Valery, at a height of about 100 feet above the sea. I could discover no organic remains in any of the pits†.

The right bank of the Somme, between Amiens and Abbeville, shows a much greater amount of denudation. The hills are steeper and present generally bare surfaces of chalk, with more or less brick-earth on their summits and flanks.

Fig. 7.—*Section across the valley of the Somme near Amiens.*



a. Recent alluvium. *b.* Loess. *c.* Low-level gravel. *d.* High-level gravel. 1. Chalk.

Near Amiens I found nothing to correspond with the opposite St. Acheul high-level valley-gravel, except some scattered sandstone boulders at Longpré. From this point to Pont Remy‡, the ground requires further examination. Thence to Abbeville the hills, at a height of from 100 to 150 feet, are capped occasionally by flint gravel, in which no remains of any sort are met with until we reach the gravel-pits of St. Gilles and Moulin Quignon, described in my former paper.

In all the foregoing cases the sandy and ochreous subangular flint gravel nowhere occurs on hills higher than about 150 feet above the level of the Somme, and flint implements have not been found in beds more than 100 feet above that level; these gravel beds range parallel to the Somme, and in no case, except at the embouchure of the river, extend more than half a mile from the side of the valley.

* There was a discrepancy between my estimated height of the upper pits on the road to Moyenville, near Mautort, and the measurement obtained for me by M. Boucher de Perthes, for which I could not account in 1860. A well has been since sunk adjoining the old pit (now filled up), and the water-level in the chalk reached at a depth of 81 feet. Allowing 5 feet for the fall to the river, the height of the ground at that spot would be 86 feet.

† A raised beach containing *Cardium edule* has been stated to occur at the top of the hill near the old castle; but after a careful search I could not find a trace of any such bed. Sir Charles Lyell came independently to the same conclusion. On a more recent visit there with Mr. Evans and Mr. Lubbock, we merely found numbers of weathered valves of recent *Cardium edule* &c., and fragments of pottery in a black soil—a sort of Kjökkenmödding.

‡ M. de Perthes has a tooth of the *Elephas primigenius* from this place, but the exact position is not recorded.

The same features are repeated on a smaller scale in some of the lateral valleys. Near Amiens, for example, in the tributary valley of the Arve at Boves, four miles from its junction with the Somme, are large beds of gravel like those of St. Roch, abutting against the side of the chalk hills on the right bank of the stream. Remains of the *Elephas primigenius*, *Rhinoceros tichorhinus*, Horse, and Deer have been found there, together, it is reported, with a few flint implements.

At Abbeville the Escardon joins the Somme. At Oneux, eight miles up the valley of this tributary, a bed of flint gravel was formerly worked, in which, it is said, mammalian remains and flint implements were met with; whilst at Drucat, on another branch of this stream, a singular isolated patch of gravel has been found high up on the hills, at an elevation of about 100 feet above the valley, and 150 feet above the Somme at Abbeville. The sand and gravel are of great thickness, owing to their being in a depression of the chalk, from which they further descend in huge cylindrical holes or pipes to a depth of more than 100 feet. On the top of the light-coloured sands and gravels are other beds of reddish gravel and thin brick-earth. In M. BOUCHER DE PERTHES's collection there are two flint implements which are said to have come from these upper beds.

The Valley of the Seine.—Another important discovery of flint implements was made early in 1860, in the valley of the Seine at Paris, by M. GOSSE*. The specimens are ruder and less abundant than those of the Somme valley. They were found in the pits of the Allée de la Motte Piquet†, near the Ecole Militaire, at a depth of 16 feet in a gravel composed chiefly of subangular tertiary and cretaceous débris about 20 feet thick, roughly bedded, and containing remains of extinct mammalia. No shells are recorded. Large blocks of *Meulière*, little worn, are dispersed through the gravel. At this spot, the height of which above the Seine is 36 feet, the relation of the beds to any of the "higher-level" quaternary deposits of the neighbourhood of Paris is not seen, but at the Gare d'Ivry, on the other side of Paris, and at a similar level with regard to the river, the same bed of gravel, only more sandy and containing more large granite boulders, is again largely worked. It here abuts against the calcaire grossier, which forms, immediately behind, the heights of Gentilly, where these tertiary strata come to the surface and are extensively quarried. Following the plain in a direction at right angles to the river, some coarse gravels of moderate thickness set in, and are worked near the Barrière de Vitry, at a height of about 130 feet above the Seine. Further on a cutting, on the side of the road leading from the Barrière d'Italie to Gentilly, exposes a section described in 1840 by M. DUVAL‡ and singularly like that at St. Acheul§. The lower bed is a white sandy gravel of subangular chalk flints

* Comptes Rendus, 1860, vol. l. p. 812.

† M. BOUCHER DE PERTHES had in 1847 expressed an opinion that flint implements would be found in these pits: 'Antiquités Celtiques et Antédiluviennes,' vol. ii. pp. 123, 494, and 501.

‡ Bull. de la Soc. Géol. vol. xi. p. 302, and vol. xiii. p. 297.

§ It is, however, not improbable that the deposits both of Gentilly and Charonne may be older than that of St. Acheul, although belonging to the series of the high-level valley-gravels.

mixed with much-worn tertiary débris with a few older rock pebbles, and above which is a sandy marl. In these beds a considerable number of land and freshwater shells and mammalian remains were found. The whole is capped by a variable thickness of Loess. The slopes of the adjoining higher ground of Bicêtre are bare, with the exception of occasional patches of Loess.

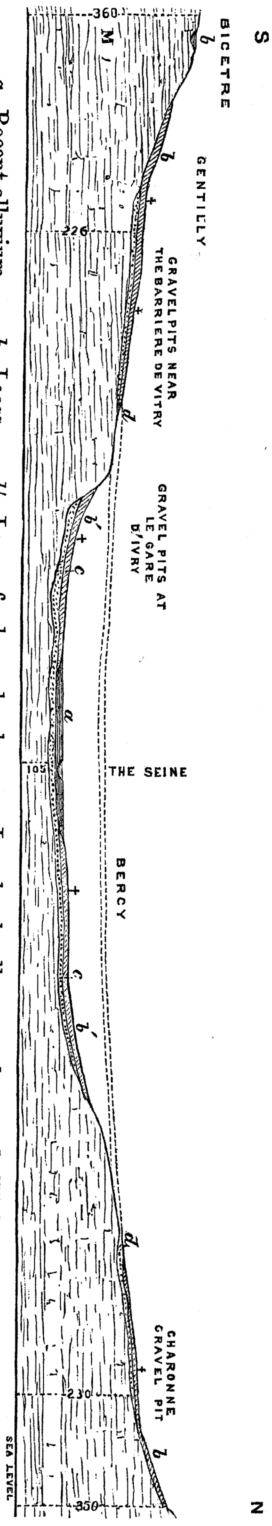


Fig. 8.—*Section across the Valley of the Seine East of Paris.*

a. Recent alluvium. *b.* Loess. *b'.* Loess of a lower level. *c.* Low-level valley-gravels. *d.* High-level valley-gravels.
M. Freshwater marls and limestones (gypseous series), overlying the Calcaire grossier and Lower tertiary strata.

No freshwater shells have hitherto been recorded from the low-level valley-gravels of the Seine; but in April 1862 I found at Sotteville* near Rouen, intercalated in the middle of thick beds of gravel, about 10 to 20 feet above the river-level, a seam of marly sand, in which I obtained a few specimens of the *Limnœa peregra* and opercula of the *Bythinia tentaculata*; and at Paris I discovered in the hard concreted gravel of the Petite Rue de Reuilly, and about 30 to 40 feet above the Seine,

Limnœa peregra, *L. truncatula*, *Valvata piscinalis*, *Zua lubrica*;

whilst at Clichy I found, low down in the gravel containing, I am informed by M. Lartet, the *Elephas primigenius* and *E. antiquus*, three specimens of the *Limnœa peregra*. All these specimens are entire and uninjured. In this latter locality M. Lartet had also recently found a very perfect ovoid flint implement of the Abbeville type.

In the high-level gravel of Gentilly have been found†—

Pisidium amnicum.	*Bulimus.*	*Hydrobia.*
Valvata piscinalis.	*Limnœa.*	*Helix.*

On the north side of the Seine, thick gravel-beds extend from the river to the base of the hills, and some distance up their slopes, as shown at the canal de l'Ourcq and in the pit in the Petite Rue de Reuilly. As the tertiary strata again come to the surface a short distance further on, it is probable that this bed of gravel, like that on the south of the Seine, abuts or slopes rapidly up against their escarped edges. At Charonne, about a mile beyond the last-named pit, and near the Barrière du Trône, there are several pits of sand and gravel, containing numerous land

* M. l'Abbé Cochet states that there are in the Museum at Rouen two flint implements of the St Acheul type said to have been found in these pits, *op. cit.* p. 8.

† *Op. cit.* p. 297. M. Duval does not give the specific names in his list. Few specimens are now to be found.

and freshwater shells together with the remains of mammalia. This deposit is identical with that at Gentilly*. The section of this part of the valley of the Seine may therefore be represented as in fig. 8†.

M. Charles d'Orbigny has traced the high-level gravel of Charonne, with few interruptions, as far as Joinville five miles east of Paris. It there caps a hill rising abruptly 80 to 100 feet above the river, and contains a large and interesting series of land and freshwater shells‡, associated with the remains of the *Elephas primigenius* and *Rhinoceros tichorhinus*. No flint implements are recorded from these gravels.

The same features hold good throughout the course of the Seine and its tributaries. Brongniart, in his description of the Paris basin, observes that the drift (Terrain de transport) occupies two positions—one in the valleys, and another on plains considerably raised above the actual rivers. He seems to suggest for them different origins §.

Higher up the course of the Seine this structure has been more specially noticed. M. Leymerie, in describing the country traversed by the upper part of this river and its tributaries, remarks that at the commencement of the valleys there is but little drift (Diluvium), but that some way down them "the beds of drift (Terrain diluvien) exhibit a great extension, both horizontally (maximum four leagues), and also in a vertical direction (maximum sixty metres) above the ordinary level of the valley-waters"||. In the neighbourhood of Troyes they form a plain eight miles in length and of five miles average breadth, and attain in places a height of from 120 to 180 feet or even more above the river, with a thickness of 10 to 12 feet, and contain teeth of Elephant, Deer, Horse, &c. At Nogent there is another expanse of gravel 10 feet thick, and 200 feet above the river. In the tributary valley of the Aube, M. Leymerie describes at Brienne a similar expanse of gravel five leagues long by three broad, and 130 feet above the river¶.

Of the lower part of the valley of the Seine we possess but few details**. The plain through which the river winds is covered irregularly with a coarse sandy gravel, abounding especially in large blocks of Meulière, Calcaire grossier, and of other tertiary rocks;

* M. Charles d'Orbigny in Bull. de la Soc. Géol. 2e sér. vol. xii. p. 1295 (1855). The pit he described is now filled up, but several others are open beyond the outer Boulevards. My sections are taken from these.

† One of the best plans of valley-gravels, well and carefully worked out, that I have seen, is the one executed by M. Triger for the Department of the Sarthe. The river Sarthe, which flows through palæozoic rocks, has a gravel abounding with blocks of granite &c., whilst the Huisne, which joins the former river at Le Mans, contains nothing but tertiary débris. The extent of these old alluvia are well shown on this fine map.

‡ For a list of these and a description of the section, see Bull. de la Soc. Géol. 2e sér. vol. xvii. p. 66 (1859). (I have recently had reason to believe that these fossils may be from old pits on a lower level than those now worked. Owing to this uncertainty I omit the list of fossils I had at first given.—March 1864.)

§ Déscription Géol. des Environs de Paris, édit. 1835, pp. 118 & 569.

|| Statistique Géol. et Minér. du dép. de l'Aube, p. 99 (1846). M. Clément Mullet had also remarked that at Fresnoy a gravel from 22 to 26 feet thick occurred at a height of 100 to 130 feet above the river; and a like arrangement exists at Pougy in the valley of the Aube. Bull. de la Soc. Géol. de France, vol. xii. p. 116.

¶ Ibid. pp. 88, 90 to 92, 94.

** See De Senarmont's 'Déscrip. Géol. du dépt. de Seine et Oise.'

and I found gravel rising to a height of about 100 feet at Mantes, of 140 feet at Pont de l'Arche, and of above 100 feet near Rouen.

In the valley of the Yonne the gravel attains a height of 66 feet at Pontaubert*; but exact particulars are wanting of the terrace-gravels in this valley. Of the valley of the Marne, M. MICHELIN† observes that "on the heights around St.-Menehould there is a gravel containing the remains of the Elephant, Horse, and some other mammalia." M. CORNUEL states that the same valley higher up and that of the Blaise are covered with an oolitic gravel containing some remains of the Elephant, and names two small hills (buttes) near St. Dizier, and two near Vassy, which are capped by a similar gravel‡.

Valley of the Oise.—In this large tributary valley of the Seine, M. DE VERNEUIL§ has reported the discovery, at Précy near Creil, of a flint implement in beds of gravel containing the remains of the Elephant, Deer, &c. In this instance the specimen was not found *in situ*, but was picked up amongst the gravel thrown on the adjacent line of railway. In April 1861 Sir CHARLES LYELL and I visited the ballast-pit whence the gravel was extracted. It is situated half a mile north from the Précy station, is about 25 feet above the river, and presents a fine section of light-coloured subangular gravel, roughly stratified, 12 to 15 feet thick, and overlain by 5 to 10 feet of Loess. Some beds of the gravel are very coarse, and amongst the flint and tertiary débris are fragments from the oolitic strata and older rocks. The valley at this spot is about half a mile wide, and the hills on either side rise to a height of from 150 to 250 feet above the valley. In going over this ground some years since with the deeply lamented EDWARD FORBES, we found the rocks almost everywhere bare of drift, but I have a recollection of having met with traces of gravel with old-rock pebbles on a hill about 80 feet high on the right bank of the river between Auvers and Beaumont. M. GRAVES, in speaking of the drift (Diluvium des vallées) of the Oise, observes that "it ascends the slope of the hills to some height" .... "some incontestable traces of it are sometimes found on surfaces of high platforms" ‖, but he gives no exact position or levels.

M. D'ARCHIAC, in describing the valley of the Aisne, the upper portions of the valley of the Oise, and their tributaries, states that the gravel (dépôt de cailloux roulés, avec des blocs erratiques et des ossements nombreux des grands mammifères) "occupies the floor of the principal valleys, rises sometimes up their sides to a certain height, but very rarely extends over the adjacent high-ground plateau"¶. Further on he mentions that between Menneville and Neufchatel (valley of the Aisne) the gravel rises 65 feet above the river, and is about 16 feet thick, that between Voyenne and Marle (valley of the Serre) it is more than 130 feet** above the river—whilst at Guise (valley of the Oise) it rises 184 feet above the river, is 16 feet thick, and extends $1\frac{1}{4}$ mile

* Bull. de la Soc. Géol. 2e sér. vol. ii. p. 683 (1845).

† Ibid. vol. vii. p. 83 (1836).

‡ Mém. de la Soc. Géol. de France, vol. iv. p. 270 (1841).

§ Bull. de la Soc. Géol. de France, 2e sér. vol. xvii. p. 555.

‖ Topographie Géognostique du dépt. de l'Oise, pp. 529, 530 (1847).

¶ Mém. de la Soc. Géol. de France, vol. v. p. 188 (1842).

** English feet are always given.

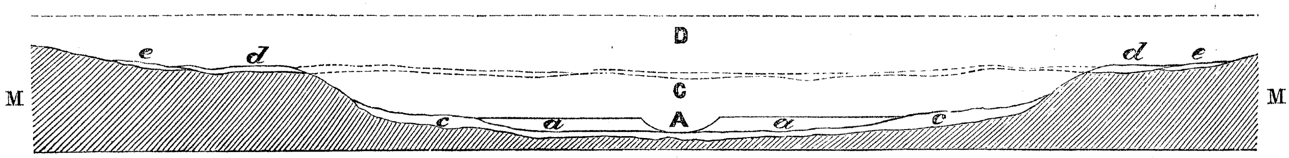
from the river*. Respecting the upper part of these valleys, MM. SAUVAGE and BUVIGNIER remark that beds of sand and gravel cover the hills which border the valleys, at levels far above the present rivers†; and M. BUVIGNIER has described beds of gravel 4 to 6 feet thick, with remains of Elephants and other animals, at heights of from 100 to 130 feet above the Aire, and 160 to 200 feet above the Chée, the Ornain, and the Saulx‡.

It is therefore certain that at points more or less distant along the course of all the rivers in the South of England and the North of France§, detached and isolated beds of sand and gravel occur on terraces, or on the top or shoulders of the low hills or platforms bordering the valleys, at various and often considerable heights above the present river-levels. Another and more continuous stream of gravel stretches along the bottom of the valleys. Beds of Loess cover both gravels irrespectively, and extend beyond them. It is in these deposits only (caves excepted) that the flint implements have hitherto been found.

§ 3. HIGH- AND LOW-LEVEL VALLEY-GRAVELS.

From the constancy of the phenomena described, we may arrive at a general proposition which can be expressed by the following diagram (fig. 9) and terms:—

Fig. 9.



M. General section of the ground.
D. Major valley of denudation anterior to the excavation of the valley C.
C. Minor valley of river-excavation.
A. Present river-channel.
e. Non-fossiliferous drift on the slopes and base of the major valley D.
d. High-level valley deposits } with or without fossils.
c. Low-level valley deposits } with or without fossils.
a. Recent alluvium.

This diagram represents the conditions of the case on the supposition that all the parts are complete. But this rarely happens. The gravel along the base of the major valley (D) is spread out or contracted according to the width, depth, and shape of its channel. If the secondary valley C should extend on either side beyond the limit of the beds *e* or *d* deposited along that first depression, the section would be represented by diagram fig. 10, where, as at Amiens, the hills on one side are completely denuded, whilst on the other side a portion of *d* remains. Or it might happen, as is the case in many parts of the valley between Amiens and Abbeville, also in the valley of the Oise near Creil, again in the valley of the Seine near Paris, and commonly elsewhere, that the width of C exceeds that of the first-formed channel characterized by the drift *e* and *d*, in which case the river-valley would pass through bare hills denuded of all traces of *e* and *d*, as in the

* Mém. de la Soc. Géol. de France, vol. v. pp. 190, 193 (1842).
† Statistique Minér. et Géol. du dépt. des Ardennes, p. 58 (1842).
‡ Géologie du dépt. de la Meuse, pp. 95, 96 (1852).
§ I restrict my remarks to this area; but the fact has a much wider application.

Fig. 10.

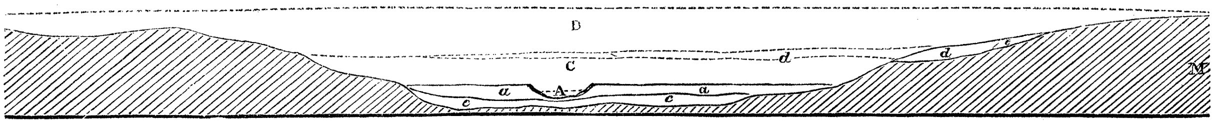
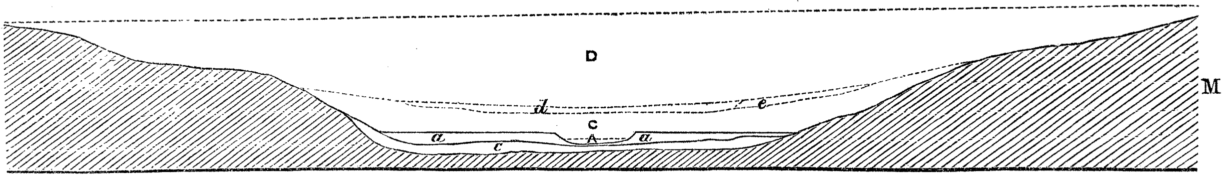


diagram fig. 11. Or the various gravels may also have been wanting originally, as there must have been parts of the old river-bed always left bare.

Fig. 11.



It is therefore not essential to the case that the high-level valley-gravels *d* should be permanent or continuous in the direction of their length. We have seen that they are generally found at heights above the river of from 50 to 150 feet, though occasionally more or less. The low-level gravels, on the contrary, often have even their upper terraces so little above the level of present inundations that they might be attributed to such recent causes. The coincidence, however, arises from merely local conditions, and we can hardly apply to them a different rule, the more especially as, although the level of the terraces may be at places so low as to merge in the gravel at the bottom of the valley, still they even then form a breadth and mass of deposit which indicate a very different power to that now in operation in the existing rivers.

That the formation of the higher terraces can be owing to the action of the present rivers is clearly impossible under existing conditions; for they are far above the level reached by the rivers at the highest floods.

Taking the mean depth of the Waveney near Hoxne at 3 feet and its width at 33 feet, whilst the depth of the valley between the two gravel terraces is about 40 feet and the width 2000 feet, the sectional area of the former will be 100 square feet nearly, whereas the latter will be represented by about 80,000 feet—in round numbers as 1 : 800. The Ouse at Bedford has an average depth of 5 feet and a width of 200 feet, or a sectional area of 1000 feet. The valley at the same point gives us about 12,000 feet—or as 1 : 600. The rise of these rivers above their ordinary level never exceeds a few feet. Very little is known of the discharge of either river during floods*.

If we take the Somme at Amiens at 4×200, the sectional area is 800 feet, whereas the valley at the level of the St. Acheul gravel gives 80×5000, equal to a sectional area of 400,000, or as 1 : 500. The floods of the Somme rarely exceed 5 feet above its mean level. Taking the Seine at Paris at a mean width of 600 feet and a depth of 4 feet, the sectional area is 2400 feet. The valley between the heights of Gentilly and of Charonne

* The numbers in this and the next paragraph are only approximately correct; exact data are wanting.

2 O 2

has a depth of 120 feet; and taking as a mean a width of 8000 feet, we have a sectional area of 960,000 feet, or as 1 : 400. The greatest flood of the Seine on record is that of the year 1658, when it rose to a height of 29 feet. Even in this case a flood of nearly 60 times that magnitude would be required merely to fill the valley to the level of the high-level gravels, without taking into consideration the more rapid discharge. But neither in this nor in the other cases of modern times, are we aware of an increase in the volume of water, during floods in these regions, to many times the ordinary mean average, whereas we see that in a case such as is presented at Amiens a flood having a volume five hundred times that mean would be required to reach the beds of St. Acheul.

This I conceive is sufficient to prove that the high-level valley gravels cannot be ascribed to floods of the present rivers, as has been, even of late, suggested. The only means adequate to fill, under existing conditions, the river-valleys of the Waveney, the Ouse, the Somme, and still more of the Seine, would be the ingress of the sea; but such a supposition is at once refuted by the fact of the prevalence of land and freshwater shells in both the high- and low-level gravels, and the absence of marine remains unless immediately adjacent to the present coast. If therefore neither the supposition of river-floods, nor of a different relative level of land and sea allowing the latter to penetrate up the valleys, be admissible, how far are the facts in accordance with the hypothesis of these deposits being the alluvia of old rivers, and the valleys their excavated channels?

Let us in the first instance trace the direction whence the materials have come.

The valley of the Waveney traverses a district formed of Boulder Clay, with underlying sands and shingle, reposing on Chalk, which latter comes to the surface in the upper part of the river's course, and is just visible at Scole. There is little in the valley-gravels to indicate a distant origin, as most of the débris composing them might generally have been derived from the surrounding hills. The only material in excess is the mass of subangular flint-fragments, derived probably in part from the more distant chalk area. Although not quite conclusive, still the evidence affords fair presumptive proof of the transport of the gravel from the watershed of the Waveney to the sea along the breadth of surface indicated by the valley-gravels (see Map, Plate IV.).

A nearly similar uniformity exists in the case of the valley of the Ouse, which traverses a district of Boulder Clay overlying various members of the oolitic series. It is not, however, easy to determine in what proportion and to what distances the different materials composing the gravel of the valley of the Ouse have been transported from their parent rocks. They exhibit, as in the case of the Waveney, a local origin in connexion with the existing valley. All the materials found in the gravels can be referred to rocks or to older drift deposits traversed by these valleys and their tributaries, and in no instance do we find the introduction directly of any foreign element. Thus, besides the flint débris derived from the chalk in the valley of the Waveney, and the oolitic limestone and sandstone débris derived from the Oolitic series in the valley of the Ouse, all the superadded pebbles and boulders of the older rocks, as well as a

certain proportion of the chalk-flints found in the gravels of both valleys, can be traced to the adjacent Boulder Clay.

I have noticed the same facts in almost all the river-valleys of the South-east of England where the valley passes through belts of different formations, as, for example, the occurrence of Wealden and Greensand débris on the chalk hills in the valley of the Medway, between Maidstone and Rochester; and in the same manner the occurrence of Purbeck and Greensand débris on terraces in the valley of the Wiley between Wilton and Salisbury. Traces of Greensand and Oolitic débris are to be detected in the valley of the Thames, also mixed with débris of the Boulder Clay.

With reference to the French area, the phenomena have been well studied by many French geologists*, to whose works, before cited, I beg leave to refer for fuller particulars than I can here introduce. I will say a few words, however, of the valleys of the Somme, the Oise, and the Seine,—more especially of such parts as I have myself visited.

The Somme flows through a chalk district with a few tertiary outliers, while the tributary valley of the Arve penetrates to the main body of the tertiaries. At St. Acheul the quantity of sandstone blocks and pebbles, and of flint pebbles, derived from tertiary strata, is very considerable, and the presence of specimens of *Nummularia lævigata* and of the *Venericardia planicosta* shows the upland direction of their origin, as no beds containing these fossils exist below Amiens. In the several patches of high-level gravels (chiefly of subangular chalk-flints) between Amiens and Abbeville, tertiary débris continue to be found, and at Moulin Quignon sandstone-fragments of a large size are still numerous, although they are fewer and smaller than at St. Acheul†.

The occurrence of rolled fragments and boulders of granite and other old rocks in the valley of the Seine at Paris, is a fact which has long been well known. The presence of similar materials of distant origin has also been proved to hold good in the higher-level gravels of Gentilly and Charonne. M. Duval described the section at the first-named place (which applies to the other), as consisting of sands passing downwards into a gravel composed of pebbles and fragments of cretaceous and tertiary rocks, together with others of porphyry, and "a prodigious quantity of grains and pebbles of red granite"‡, some of which weighed from eleven to thirty-four pounds. Land and freshwater shells and small reptilian bones were common, with some bones of the large mammalia.

The valley-gravels at Frénoy, Nogent-sur-Seine, and Troyes consist chiefly of oolitic

* The case is very clearly put by M. d'Archiac in his admirable work the 'Histoire du Progrès de la Géologie,' vol. ii. p. 139, where he observes, "On reconnaîtra que les matériaux des dépôts meubles sont distribués ou répartis exclusivement soit sur les flancs de certaines gibbosités principales et dans les vallées qui y prennent naissance, soit dans de larges dépressions ou bassins hydrographiques qui ne sont limités à leur pourtour par aucun relief bien prononcé. Dans l'un ni dans l'autre cas il n'y a mélange des matériaux transportés." . . . . . . "Cette distribution nous démontrera que l'orographie générale était au commencement de la période diluvienne à très peu près ce qu'elle est aujourd'hui, et nous reconnaîtrons que les lignes de partage entre certains bassins hydrographiques et dont l'élévation devait être bien faible alors ont pu cependant restreindre les effets du phénomène erratique aux mêmes limites que les eaux qui se rendent actuellement dans chacun d'eux." He excepts Great Britain and the North of Europe from the exhibition of these conditions.

† See sect. figs. 3, 5, 6 in Phil. Trans. for 1860, pp. 287–290.

‡ *Op. cit.* p. 304.

pebbles*. At none of these places is there any admixture of old-rock pebbles. These latter all come into the valley of the Seine through its tributary valley of the Yonne, which, with that of the Cure, originate in the Morvan—a district consisting of granitic, porphyritic, and slate rocks, forming ranges of hills from 800 to 1200 feet high.

The valley of the Aube, which joins that of the Seine between Nogent and Troyes, contains only oolitic and cretaceous débris; so also, judging from the incidental notices of M. CORNUEL, the upper parts of the valley of the Marne and its tributaries. These valleys traverse Cretaceous and Jurassic formations only (see Map, Plate IV.).

Speaking of the gravel of the valley of the Oise, M. D'ARCHIAC remarks that it "is composed of the débris of tertiary, secondary, and transition rocks, always rolled, and that the characters of the deposit vary according to the region from which its constituent elements have been brought, and consequently according to the valleys where these are found"†. The slate rocks of the Ardennes, from which the Oise flows, form a range of hills on the frontiers of Belgium, from 1400 to 1600 feet high.

The next feature we have to notice in the high-level valley-gravels is the presence of large boulders, and the irregularity, confusion, and general want of stratification of the beds, which are, further, frequently contorted.

In the valley of the Waveney there are no hard rocks to furnish boulders; the few therefore that are found are derived from the Boulder Clay; but very large masses of flint with sharp and intact angles are common. In the valley of the Lark the features are precisely analogous. At Flempton we found, mixed up in the flint gravel, large blocks of half a ton weight of basalt and hard sandstones derived from the Boulder Clay. At Biddenham in the valley of the Ouse the lower part of the gravel is full of small blocks of oolitic limestones and sandstones very little worn, and there are none of a large size. In the valley of the Thames, boulders of large size are rare; I have not met with ten in the course of as many years.

In the valley of the Aire, M. SAUVAGE and BUVIGNIER remark that the gravel capping the hills has an irregular surface and is waved (ondulé). In the valleys of the Seine and Aube, M. LEYMERIE describes the base of the gravel capping the hills at Frénoy as irregular, and at Troyes as containing blocks and angular pieces of shelly neocomian strata, together with a few unworn flints. At Brienne the gravel also wants regularity. In the valley of the Oise at Guise, M. D'ARCHIAC states that this gravel contains some fragments of quartz "the size of the fist," and that it is "without distinct stratification"‡. In the valley of the Seine, M. CHARLES D'ORBIGNY, in speaking of the lower bed of the gravel at Joinville, remarks that it forms "a tumultuous deposit, at the base of which are found large erratic blocks§. One mass of tertiary sandstone (B, fig. 12) measured by us was $8\frac{1}{2}$ feet long by 3 feet 4 inches thick, and was on the top of the light-coloured lower gravel (diluvium gris), or rather at the base of the red gravel (diluvium rouge).

* LEYMERIE, *op. cit.* p. 92.

† Mém. de la Soc. Géol. de France, vol. v. p. 188; and GRAVES, *op. cit.* pp. 535, 542.

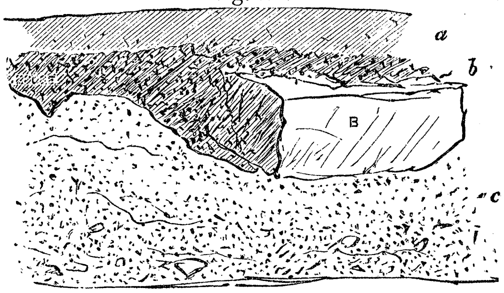
‡ Ibid. p. 193.

§ *Op. cit.* p. 68.

A pit near the Barrière de Vincennes (fig. 13) afforded me an excellent example of contorted bedding.

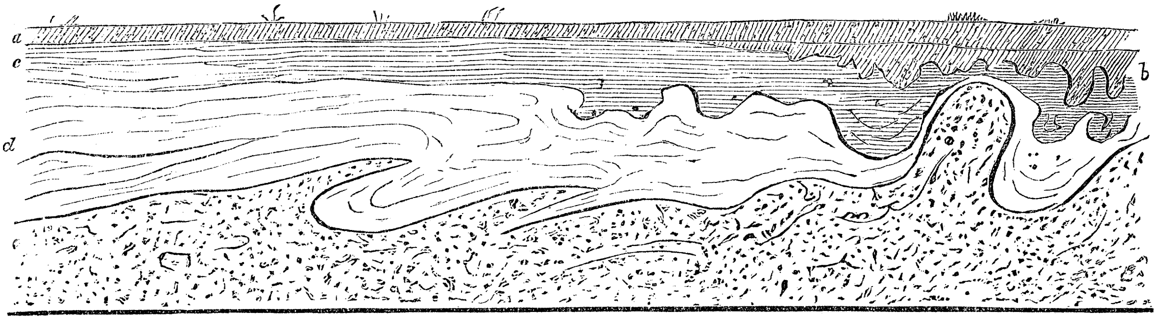
In the valley of the Somme this class of phenomena is particularly well marked and decisive. I know of no place where they are better shown than in the pits at St. Acheul (figs. 14, 15). The two following sections taken from my former paper will illustrate these peculiarities. There are two points to be noted,—the one the pre-

Fig. 12.



a. Surface soil and reddish loam.
b. Red argillaceous gravel (diluvium rouge).
c. Light-coloured sandy fossiliferous gravel.

Fig. 13.



a. Surface soil and made ground. *d*. Sand and fine gravel with a few shells, 3 to 4 feet.
b, *c*. Loam and red gravel, 2½ feet. *e*. Coarse light-coloured gravel, with mammalian remains, 5 to 8 feet.

Sections in the gravel-pits of St. Acheul.

Fig. 14.

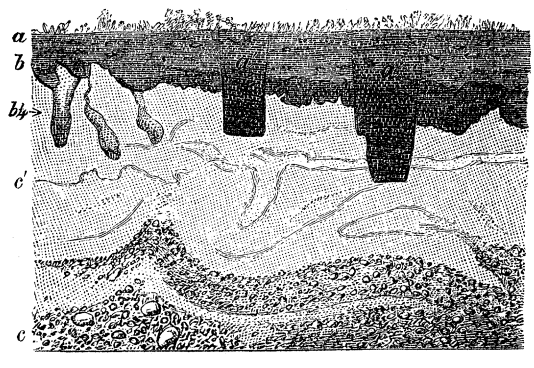
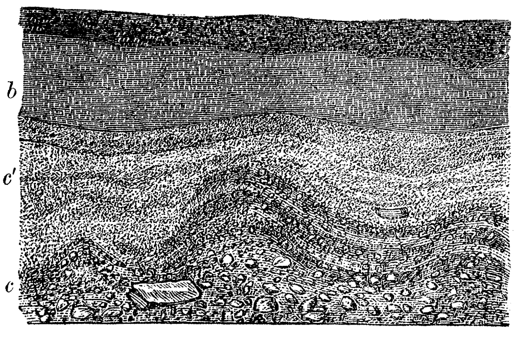


Fig. 15.



a, *b*. Soil and brick-earth and subordinate beds of gravel—with Gallo-Roman graves, *a'*.

c'. Whitish marly sands with land and freshwater shells, containing here and there a few patches of gravel and blocks of sandstone, and showing in places fine lamination.

c. Subangular gravel, in places level, and in other places disturbed, containing numerous blocks of sandstone, and large flints not worn: *flint implements*, *mammalian remains*, and a few *shells*.

sence of large blocks of sandstone, some weighing as much as four to five tons, dispersed irregularly through the lower bed of gravel,—and the other the disturbed and contorted condition of the surface of that gravel, and of the bed of sand overlying it. These two features are perfectly independent. It is not the presence of the blocks which

gives rise to the heaping of the gravel, nor are the depressions in its surface marked by the presence of any such interfering masses; yet the disturbance has been from above, and sometimes before the deposition of the brick-earth; for the upper part of the gravel (*c*) and the overlying sand-bed (*c'*) are often affected independently, without there being any corresponding disturbances in the lower gravel or overlying brick-earth. The irregularities in the bedding of the gravel do not depend upon the presence of blocks, which occur in all levels through it; and the lamination of the marly sand (*c'*) is continued through the curved planes of contortion in a manner and at angles which such a sedimentary bed could never have assumed in process of deposition by the mere action of water. The tertiary blocks come from a distance of twenty to forty miles above Amiens.

Low-level Valley-Gravels.—It may not be possible to draw an exact line of demarcation between those gravels which I have designated as the high-level valley-gravels and these low-level gravels. They are the extremes of a series, marking a long period of time and probably formed under analogous but not identical conditions. The higher-level terraces are generally, however, so distinct, so broad, and so clearly separated from the low-level gravels, by bare slopes of the underlying rock formations, that, although they may differ amongst themselves to the extent of several feet, the space between the two groups is usually sufficiently distinct to make it not difficult to refer each bed to its right relative position. In places there are passage beds following the more gentle slopes, and at other places there are intermediate terraces, though commonly of little importance and trifling width. The broad distinction consists in the one being on hills of various heights flanking the valley, while the other occupies the immediate river-valley, always following its main channel and constantly rising on its sides to the height of several feet, and, where the valley is broad, forming low terrace platforms on its sides. Unlike the high-level gravels, of which the interrupted and local occurrence, comparative isolation, and unequal levels render the course and connexion indistinct, these low-level gravels, from their general continuity and their slight difference in level, leave us in no doubt as to their relation to the existing valleys.

The main points of difference to note are the greater thickness of the low-level gravels, their more uniform bedding, the more common presence of beds of sand and fine gravel with oblique lamination, and the absence generally of contorted strata. When we speak of bedding or stratification in these deposits, it is not continuous and persistent seams that we refer to, but to the greater or lesser extension of lenticular masses of sands and gravel of various thickness, which gives to a small section the appearance of bedding; but none of the beds are persistent. Large blocks are often common in these lower gravels. They are generally more worn than in the upper gravels, and the question arises to what extent they may be derived from the former. A great number occur in the lower gravels of the valley of the Somme, though they are not so numerous as in the upper gravels. In the valley of the Seine, on the contrary, they are extremely numerous in the lower gravels at the Gare d'Ivry, at Grenelle, and in various pits between Paris and Rouen. In the valley of the Thames I know of but very few. On the whole these

lower gravels have a more washed, sorted, and worn character than the upper gravels, although there is in these also a certain proportion of angular materials.

As the various Eocene, Miocene, or Pliocene strata spread over the South of England and North of France prove that, at some comparatively late geological period, the sea or large lakes extended over that area, it follows as an almost necessary consequence, that, when the land rose from beneath those seas or those lakes, a mass of débris, in quantity and length of transport proportionate to the greater or less rate of elevation and the depth of the superincumbent waters, must have been spread over the bottom of the channels along which the water flowed off; and assuming the rise to have been tolerably uniform over considerable districts, the course of the currents would be influenced by the form the land assumed during its emergence, or in fact by the present watersheds, which either result from or else bore part in that operation. In either case the ultimate effect, so far as our position is concerned, would be the same. That this must have been a *vera causa* to a certain extent is manifest, inasmuch as that which was sea or lake is now dry land; and although it will not explain the origin of all the high-level gravels, there is a certain proportion of these beds which may nevertheless have this older and independent origin*: it is to be distinguished by rising higher up the hills, and not being restricted to so definite a level as some of the other beds. I have reason to believe that some of the gravels in the South of England and the higher levels of the Somme valley may be of this age,—such as those above Epagnette, and the higher levels of those above Breilly and Montiers. In proof of the existence of some gravels older than those of St. Acheul and yet belonging to the Somme valley, I would mention the not uncommon occurrence at that place of subangular flints, with a deep brown staining, imbedded in layers of perfectly white gravel. As this discoloration can only arise from the flint having been imbedded at some time in an ochreous or ferruginous matrix, I infer that such specimens are derived from beds of gravel of that character, and older at all events than the St. Acheul gravels. As a proof of their staining being clearly unconnected with any colouring-matter of the existing matrix and being of older origin, I noticed that they have all had a second rolling, and that where their first angles have been worn off and the outer brown coat removed, the eroded surfaces often show, first an original white crust, and then the black core of the flint, without any change of colour on these fresher surfaces due to their present position.

The theories that have been formed to account for the entire series of these valley-gravels by the bursting of lakes, by the sudden melting of the glaciers and snow of mountain-regions, or by the transitory passage of any body of water over the land, are open to objection, because the débris would have been swept along in fewer and more definite directions, or would have held its course more irrespective of the existing water-sheds, and would have shown an amount of wear in all cases proportionate to the distance travelled. Not only is this not the case, but the condition of the fragile shells

* Another portion of the high-level gravels must have been formed before the country became inhabited, and would therefore also be unfossiliferous.

shows the Testacea to have generally lived on the spot; and the sharp and entire state of the greater part of the fossil bones shows that they have rarely been rolled far or subjected to much violence*. The deposits we have noticed might be, it is true, lake deposits so far as these organic remains are concerned; but the continuity and the distant transport of the gravel, and its uniform relative wear, point to water with a course, in each case, in one direction of commensurate length; while the absence of the remains of any independent basins, depressions, or barriers in the high-level valley, referable to old lakes, indicate that even the oldest beds are due rather to early river-action—the rivers, however, having been necessarily broader at some places than at others.

§ 4. THE BRICK-EARTH OR LOESS.

All the valleys of the South-east of England contain brick-earth forming banks on their sides and often beds at various heights on their slopes. This is particularly apparent in the valleys of the Stour, the Medway, and the Thames. In France it is seen on a larger scale in the valleys of the Somme and the Seine and of their tributaries. This deposit contains occasionally some land-, and rarely a few freshwater shells, and it is in almost every respect identical with the Loess of the valley of the Rhine. This well-known formation has been described as an independent deposit by various geologists, amongst others by Sir CHARLES LYELL†, who concluded that it was a fluviatile silt deposited by that river after its hydrographical basin had acquired very nearly its present outline of hill and valley; and he explained the height (near Basle 1200 feet above the sea) to which it rises above the valley by supposing a filling up of the main and lateral valleys by river silt during a period of subsidence, and a re-excavation in part during a subsequent upheaval. In many respects the analogy established by this distinguished authority between this ancient river-deposit and that of the plain of the Mississippi, and his argument in favour of its fluviatile character, are satisfactory and conclusive.

The difficulty I have felt in applying this hypothesis in its entirety to certain valleys in the South of England, and more especially to the valleys of the Somme and the Seine, has been the great height to which the Loess rises above the levels of these rivers, and the impossibility, for reasons assigned at p. 265, of admitting such a deposition of silt to have taken place since their present basins had been formed; nor would it be easy to conceive pre-existing depressions, of the depth we shall have to speak of, to have been filled up without an influx of the sea further inland than at present, and a conversion of the river-valleys into narrow estuaries far beyond existing tidal influences. But the evidence is rather in a contrary direction. The quaternary deposits adjoining the estuary of the Thames show conditions more purely freshwater than those which now obtain in the adjoining waters. The Loess at Menchecourt contains no trace of marine organisms; and in the valley of the Seine we have recently found freshwater shells in the low-level valley-gravels of Rouen. At the same time a subsidence so regulated as to be

* There are, however, a sufficient number of rolled fragments to show wear in river-shingle.

† Manual of Elem. Geol., 5th edit. p. 122–5. By some it has been considered a glacier mud.

exactly proportioned to the accumulation of river sediment and to keep out the sea is very difficult to imagine, and is certainly not supported by the facts.

What I propose to show is, on the contrary, that the brick-earth is intimately associated with all the valley-gravels and is contemporaneous with and dependent upon them from the beginning to the end of the series, the higher deposits having been formed before the excavation of the valleys, and those on the lower terraces being of later date.

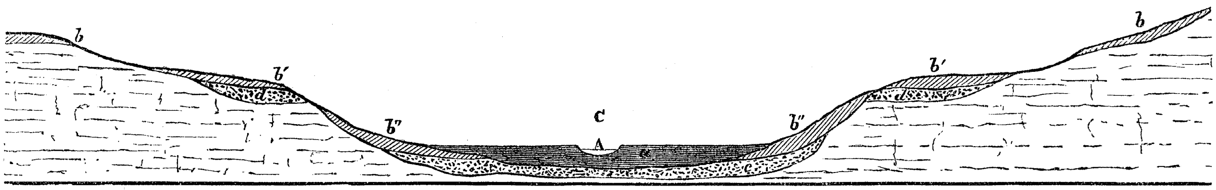
I have said that in the valley of the Somme the high-level gravels rise to the height of 100 feet above the river; and from some recent observations I conclude that there are some beds which attain a height of 150 feet. Now, if we take this latter level as having been the floor of the valley through which the river flowed at the period when these gravels were deposited, we shall find the Loess still extending to about 60 or 80 feet above such a plane. At the same time we know that the greater portion of it is accumulated in irregular masses on the slopes of the hills at a still lower level, where it either reposes immediately upon the chalk substratum or else covers the low-level gravels. In the adjoining valley of La Bresle I found traces of the higher gravels 40 feet above the river, and the Loess, with *Pupa* &c., rising to 110 feet above this level. In the valley of the Oise, near Creil, I noticed traces of gravel on hills 65 feet above the river, whilst the Loess rises to a height of 115 feet. In the valley of the Seine I observed the high-level gravel at the Pont de l'Arche rising 140 feet above that river, and again the Loess 50 feet higher. In the neighbourhood of Mantes and of Rouen we found analogous phenomena. The great height to which the Loess rises in the neighbourhood of Paris has often been remarked upon by the French geologists, and its occurrence on the hills above Meudon has long presented a difficulty*. Its height there is about 320 feet measured by an aneroid barometer. It is perfectly well developed, is several feet thick, contains a few land shells, and presents all the characters of the same material on the lower levels. M. Charles d'Orbigny has shown me the Loess rising up to the top of the hill above Ivry, and between the fort and Villejuif. It there attains a height of 305 feet above the river. These levels give a height above the high-level gravels of 150 to 200 feet, for at the Butte-aux-Cailles these are not more than 130 feet above the river; but some gravels I observed on a hill-terrace near Mont Valérien may be as much as 150 to 160 feet above the Seine. Further search may also show the existence of higher beds; or such beds may have been denuded.

However much, in fact, the Loess may extend beyond the limits of the present river-valleys, it is always bounded by higher hills flanking the plains and the lower ranges. Thus, though it spreads over the low plains and hills of Belgium, it does not rise more than two-thirds up the flanks of Mont St. Pierre at Maestricht. In Kent it extends far up the slopes of the hills flanking the river-valleys, but it is in all cases bounded

* This outlier of Loess has been represented as capping those hills. This would greatly increase the difficulty of connecting it with any old river-action, as it would extend the river boundaries to a comparatively indefinite distance. Such, however, is not the case. High as it is, it is still at least 100 feet below the summit of the hill.

by the higher chalk hills*. So again in the valley of the Somme, both the flanks of the valleys and the lower hills adjoining the valley are covered, but the higher watersheds between the different valleys are free from it. A general section across the Somme valley may be represented thus (fig. 16).

Fig. 16.—*Theoretical section across the valley of the Somme.*



A. River. *a.* Recent alluvium. *b, b′, b″.* Loess on different levels and of different ages. *c.* Low-level gravels. *d.* High-level gravels.

The Loess is therefore, like the high- and low-level valley-gravels, connected with existing river-valleys, although the connexion is, owing to its irregularity and wider extension, not so apparent; and it becomes a question whether they may be related to the same common cause, presenting two phases connected with temporary changed conditions. In the first place, such organic remains as are found in the Loess are all common to the fluviatile gravels; but in the latter they are coordinate with a fauna of a more freshwater character. Thus there exists in the lower marl, gravels, and sands at Menchecourt the same species of *Helix*, *Pupa*, and *Clausilia* as occur in the overlying Loess. In the former, however, they are intermingled with *Limnæa*, *Bythinia*, *Planorbis*, and other freshwater shells, whereas in the Loess these shells are the exception (see p. 285). With the shells in the Loess are also associated the remains of the same species of Elephant, Horse, Deer, &c. as are found in the underlying series.

It is well known that in all rivers subject to floods and carrying down much sediment, as, for example, the Severn in its lower course, three forms of sediment will be deposited: 1st, coarse gravel and shingle in the more direct channel through which the waters flow with the greatest velocity; 2nd, sand and fine gravel in those portions of the more direct channel where the velocity of the stream is checked from any cause; and 3rd, fine silt and sediment in those parts where the flood-waters out of the direct channel remain for a time in a state of comparative repose; such places are the lee-side of the hills, lateral valleys, and plains, and any local depressions or hollows: none or little would accumulate in the main channel, as the scour of the retiring waters would there prevent its deposition.

In like manner I conceive the Loess to be the result of river-floods commencing at the period of the highest valley-gravels†, and continued down to the end of that

* In the valley of the Thames the Loess covers the low-level gravels in thick masses, but is very scantily spread over any part of the high-level gravels, and is rarely to be traced much above them.—March 1864.

† The Loess may have begun to form even before the fossiliferous high-level gravels, and therefore probably when the floor of the original valley was yet higher than these beds indicate.

of the lowest valley-gravel; that the higher beds (*b*) were formed at the time the higher-level gravels were being accumulated in the bed of the old river; the beds (*b'*) after the gravel (*d*) was left dry; whilst the lower beds (*b''*) result from inundations of the river after the excavation of the valley C, and when the higher levels were beyond the reach of floods. The same characters prevail throughout all the levels, except that the lower masses usually contain more shells, and show more distinct traces of bedding and lamination. That the deposit of Loess was out of the reach of the ordinary current of the river is evident from the circumstance of its containing no rolled pebbles or fluviatile shells—except a few of either sometimes swept in from the ordinary river-channel, and serving to show the connexion of the two deposits,—from the uniformity of its composition, and from the local nature and angularity of its débris. It presents precisely those characters which would result from fine deposition from turbid waters, with the occasional presence of a few angular fragments of the adjacent rocks. As the waters subsided, this silt would be left in sheltered positions, would be added to from year to year, until, as the river wore a deeper channel, the first-formed sediment would be left permanently dry, only to be disturbed by meteorological agencies, which would from time to time carry down portions of it into the river, now at a lower level, there to be re-deposited at such lower levels.

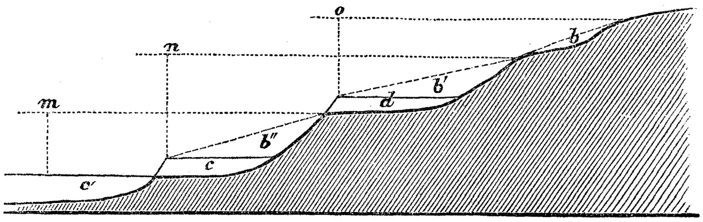
Another proof of its limited extent and of its not having at any time filled the valleys, is that in the lower levels, when it abuts against the hill-sides, it always slopes up towards the hill, following in fact nearly the present shape of the ground, and does not form horizontal beds cut off and truncated in the way which so generally occurs with the higher-level gravels, or when sedimentary strata have been excavated.

On this view of the subject the difficulty otherwise experienced in conceiving floods of a magnitude such that the waters would rise to the brim of these deep valleys, or in supposing these valleys to be filled up with silt and afterwards re-excavated, is avoided, for it would reduce the rise to be accounted for to limits more compatible with our experience of certain existing rivers. It is possible also that variations in the extent of elevation of the land may even cause the difference often to appear greater than it is.

There is one seeming difficulty to this hypothesis, which must occur to every field geologist: it is, the apparently distinct separation of the Loess and the underlying gravels wherever they occur in association. But a close examination will sometimes show thin seams of loam, not to be distinguished from the Loess, intercalated in the gravels, especially in the higher levels, though as a rule the masses of this material invariably overlie the gravels. The explanation of this fact is, I apprehend, to be found in the circumstance that it is only when the shingle or gravel ceased to be deposited, owing to the changes in the level or course of the river, that the Loess could accumulate. So long as the place was in the direct line and on the level of the stream, and subject to its scouring action, no such deposit could take place. Consequently, so long as the bed of the old river was on the level of *d*, diag. fig. 17, so long would the accumulation of the Loess from the rise of the flood-waters to *o* be restricted to *b*. When the valley

became deepened to *c*, the gravels *d*, though raised above the river-channel, would still be subject to be covered on the occasion of the flood-waters rising to *n*, and the Loess would accumulate at *b'*, covering the gravel *d* and sloping up against the side of the hill to the level of the line *n*. So again when further deepened to *c'*, the Loess would be deposited at *b''* so long as the flood-waters rose to *m*, or to any point between *c* and *m*.

Fig. 17.—*Diagram representing one side of a valley with a series of gravel and Loess beds.*



The Loess occasionally contains thin seams of gravel, derived sometimes from the underlying gravels *d* and *c*, but more frequently from the adjacent land-surface. The extreme sharpness, as a rule, of the débris from the latter, leads me to believe that the transport of such angular fragments, and the common irregularity of their bedding, arose from drifting shore-ice. The usually small size of the fragments and the general absence of subangular gravel is also compatible only with the thin ice that might be formed at night during the spring floods, and away from the shingle-strewed river-channel.

The valley-gravels by themselves give no direct evidence of the extent of the floods. They merely show, in the quantity of débris, the coarse shingle, and the worn blocks, the results of torrential action. If, however, we admit the flood-water origin of the Loess, it necessarily follows that, as we find this deposit on ground 50 (if not 100) feet above the highest beds of the valley-gravels (which fix approximately the position of the main channels of the old rivers), it gives a measure of the floods of that period, and shows them to have exceeded even those of arctic rivers at the present day, for the waters of these rivers rarely rise more than 40 to 50 feet above their low summer level. This fact furnishes, therefore, strong corroborative evidence of the scouring and erosive energy of these old rivers, and tends to strengthen the opinion, before expressed, of their power to excavate, when taken in conjunction with the other agencies before described, the large valleys through which the rivers now flow in such dwarfed volumes. I would observe that in each valley the height to which the Loess rises above the high-level valley-gravels is proportionate to the length of the valley and the area drained, showing therefore its dependence upon them, and that it is not referable to any uniform level or to any general cause.

Another character common to the Loess, and pointing, I conceive, to the same flood-water origin, is the presence of numerous small worm-like cavities penetrating the mass. These appear to me to be likely to have arisen in most instances from the presence of the vegetable and animal matter with which flood-waters are always more or less charged, and which, deposited with the mud, decomposed and gave rise to gases that, as they

escaped through the soft and pasty silt, leavened, as it were, the mass, and produced these innumerable tubular cavities.

Sometimes the Loess puts on a local character, derived from either adjacent chalk, sand, or clay beds. It then becomes so modified as to render its true character not easily distinguishable. In some cases it becomes very argillaceous, in others very sandy or very chalky. Occasionally it is so full of angular rock- or flint-fragments as to pass into an angular gravel. It is the presence of a local bed of this nature, made up in part of the angular fragments so peculiar to the Loess, and partly from the subangular gravel taken up from the underlying white gravel (Diluvium gris), and generally deeply coloured, which has given rise, in a number of cases, to the Diluvium rouge (part) of the French geologists, as exhibited in the sections at Charonne, Gentilly and Joinville, as well as at Abbeville and Amiens. Therefore, so far from being a separate deposit, this bed at these places is, I consider, merely an accident of the Loess, which again is merely a condition of a river-deposit of the period of the valley-gravels; so that, instead of the four separate deposits of 'Loess,' 'Diluvium rouge,' 'Sable lacustre,' and 'Diluvium gris,' into which some able French geologists would divide the deposits at Gentilly, Joinville, St. Acheul, &c. *, I would divide them, on lithological characters alone, into two groups—the Loess and the Valley-gravels; whilst so far as age is concerned I should consider them as one, representing phases of like causes under different conditions.

§ 5. ORGANIC REMAINS OF THE VALLEY-GRAVELS.

As it is very desirable to determine whether any changes in the fauna occurred during the period which elapsed between our earliest fossiliferous high-level valley-gravels and the latest low-level gravels, I have attempted to form separate lists of the organic remains of each series. I feel, however, that we are not yet in a position to do so with certainty or completeness. The difficulties in the way are, 1st, the uncertainty as to which series the beds may in some cases belong to; 2nd, the frequent absence of record as to the level at which the organic remains have been found; 3rd, the incompleteness of the search. I therefore submit these results merely as an approximation and a commencement. I am indebted to Dr. FALCONER and M. LARTET for much valuable information respecting the mammalian remains, and to Mr. GWYN JEFFREYS for the correction of my former lists of the Mollusca, and for his kind assistance in determining additional species. As a term of comparison for the Mollusca, I have taken the group of land- and freshwater shells now inhabiting the districts† where the fossil species are found, adopting, generally, Mr. GWYN JEFFREYS's nomenclature and distribution for England, and taking for their range in France M. PICARD's "shells of the department of the Somme"‡, M. BOUCHARD-CHANTEROUX for those of the "Pas de Calais," and M. BAUDON §

* Bull. de la Soc. Géol. de France, 2e sér. vol. xii. pp. 1277, 1297, 1298; vol. xvii. pp. 18, 19, 67–78, 103. (With reference to M. HÉBERT's observations, 2e sér. vol. xvii. p. 18, see his "rectification," vol. xii. p. 255.) It was not until towards the end of 1859 that this able geologist expressed belief in the discoveries at St. Acheul.

† FORBES and HANLEY's 'British Mollusca,' and Mr. GWYN JEFFREYS's 'British Conchology,' vol. i.

‡ Journ. de la Soc. Linnéenne du Nord de la France, vol. i. p. 149.

§ Soc. Acad. de l'Oise, 1855.

for those of the Oise. I have given in the Appendix the results of this examination of the range of the quaternary species of the beds under review.

HIGH LEVELS.—The high-level gravel of St. Acheul has furnished a distinct and tolerably complete list of Mollusca; but in England the evidence is more imperfect. Hoxne supplies but few species, and some uncertainty attaches to the level of Biddenham*.

Out of a total of 109 land- and freshwater shells now inhabiting the South of England and North of France, 36 species have been found in the flint-implement-bearing high-level gravels; and of the 12 freshwater genera 8 are represented in these old alluvia.

There is a singular scarcity of Unionidæ and Paludinidæ. The Neritinidæ are not present at all. The Limnæadæ, of species inhabiting marshes and pools, on the contrary, abound, together with, in places, the fluviatile species of *Ancylus*; the Helicidæ are, *Succinea* excepted, poorly represented, compared to their numbers in the low-level gravels. A variety of species are common at St. Acheul, while at Montiers one species of *Pupa* (*P. marginata*) occurs in thousands with but few other shells, and in the various other isolated patches of high-level gravels between Amiens and Abbeville, including the beds at Moulin Quignon, I have not been able to discover any traces of shells. They are equally rare in the high-level gravels of other valleys, except at a very few places. Combined with this scarcity, there is also an absence of such shells as would mark full deep rivers or lakes, whilst such as might be found in broad and shallow rivers, that, like many of those of Northern America at the present day, are flooded at one period of the year and nearly dry at others, occur at long intervals. In most of these northern rivers shells are also extremely scarce. Mr. BELL mentions an instance where he travelled along the banks of the river Magdalen for four weeks, during which the only shell he met with was a species of *Limnæa*†. This scarcity of shells is common in most of the rivers in these high latitudes. Along such rivers, however, there are often quiet pools, where shells are more numerous. If to the limited fauna found under these circumstances we add the land-testacea carried down by freshets and by small tributary streams, the shells so brought together would form a collection very similar in character to that which we find in these post-pliocene deposits.

At St. Acheul Mr. GODWIN-AUSTEN called my attention to a large sandstone block having on its surface numerous rudely worm-shaped lines of concreted sand, bearing a very close resemblance to those made by the sand-covered gelatinous attached polyzoa so common in our clear stony-bedded streams, as a proof that it had lain in a running stream. Such specimens are not rare, and taken with the absence of mud or clay beds in these gravels, and the general character of the shells, lead also to the inference that the old rivers were usually clear and limpid.

With respect to the species of Mollusca, they show, with few exceptions, a near

* I give the list of shells I have found at Biddenham, together with the list of those found by Mr. WYATT at Summer-house Hill in beds which certainly belong to the low-level series. I do not, however, feel sure that both Biddenham and Joinville, though distinctly above the low-levels, should not be placed on an intermediate level.—Feb. 1864.

† Geological Survey of Canada, 1857 & 1858.

identity with those now living in the same area. There are rarely sufficient modifications in size or form to lead us *à priori* to infer any material differences in the conditions under which they lived. Certain species of *Pisidium*, *Cyclas*, *Limnæa*, *Succinea*, *Planorbis*, *Helix*, &c., were then, as now, among the most abundant shells. Some varieties, such as one of *Pisidium fontinale*, and that of *Helix pulchella*, are, I am informed by Mr. JEFFREYS, forms more peculiar to the north of Europe. The *Hydrobia marginata*, though not known in northern Europe, ranges high in the subalpine tracts of the Jura and Alps.

But though there is nothing sufficiently specific in the individual species to indicate a climate different from that of the present day, there is at the same time nothing to require restriction to an identical climate. If, further, we look at the group as a whole, we shall find it to have not only a very wide range, but one more in a northern than in a southern direction. Of the 36 species found in these high-level gravels, 29 are found in the plains or on the hills of Lombardy*, whereas 34 of them range to Sweden and 31 to Finland; amongst these are the common *Succinea putris*, *S. elegans*, *Helix hispida*, *H. nemoralis*, *H. pulchella*, *Zonites radiatulus*, *Pupa marginata*, *Limnæa peregra*, *L. palustris*, *L. truncatula*, *Planorbis vortex*, *P. complanatus*, *P. albus*, *P. spirorbis*, *Bythinia tentaculata*, *Ancylus fluviatilis*, *Valvata piscinalis*, *Cyclas cornea*, *Pisidium amnicum*, and *P. fontinale*. Many range further north in Europe, but there is no list of the land and freshwater shells of any more northern district so complete as that of Finland†. It is known, however, that a great number of these same species are found in Siberia. The annual freezing of the rivers, even in less northern latitudes, proves at all events the power of these mollusks to endure a great winter cold‡. This capability of enduring severe cold, and their northern range, show that they could readily have adapted themselves to great changes of climate in the region where they are now found. The general absence of southern species is also not without its significance; for while out of a total of 77 Finland species 31 have been found at the few places named in our list (see Appendix), only 29 out of the 193 Lombardy species have been met with in these beds.

Our knowledge of the fossil Mammalia of the high-level gravel-beds is very incomplete. I might, it is true, include those I have reason to believe are of the same age and which would furnish us with more complete and positive data—such, for instance, as a great number of the cave-deposits; but, from the circumstances I have before alluded to, I deem it best to confine myself to these particular beds and to the localities where flint implements have been found. Few of our own high-level gravels contain any organic remains at all: in the greater part they are entirely absent.

* Catalogo dei Molluschi della Lombardia, by A. & G. B. VILLA. Milan, 1844 & 1853.

† Finland Mollusker, af Nordenskiöld och Hylander, Helsingfors, 1856.

‡ PICARD mentions an instance where some specimens of *Limnæa auricularia* he had placed in a vase, froze in the ice, which was exposed to a temperature of $-2°$ Fahr. When the thaw came and they were released they soon recovered and became as active as ever.—*Op. cit.* p. 278.

The mammalian remains at present recorded from the High-level Flint-implement-bearing Gravels are:—

	Hoxne.	Bedford. *Biddenham.*	Amiens. *St. Acheul.*
Elephas primigenius	* (sp.?)	*	*
—— *antiquus*	....	*	*
Rhinoceros tichorhinus	....	*	....
Equus (the common fossil species)	*	*	*
Bos (*primigenius?*)	*	*	*
Cervus	*	*	*
—— *tarandus*	....	* ?	....

This list is very small, and would not of itself suffice to prove the character of the climate. We know only that the *Elephas primigenius* and *Rhinoceros tichorhinus* are considered, from their association and their structure, to have inhabited countries possessing cold climates; and that their remains are found chiefly in the subarctic and north temperate zone, and are not known south of the temperate zone. We know also that the Horse and the Ox brave the winters of Siberia and Northern America. The Reindeer is essentially a northern animal.

Of the flora of this period we have very limited means of judging. Generally the high-level gravels contain no vegetable remains, with the rare exceptions of mere fragments of decayed wood. Occasionally, where lodgements have been effected out of the direct course of the main stream, plant-remains are more abundant, and the wood larger and more perfect—so much so as to lead to a hope that ultimately we may find a favoured spot containing the requisite evidence respecting the vegetation of the period. In the mean time there have been found at Hoxne large pieces of the stem and branches of the Oak, Yew, and Fir, and traces also of leaves and seeds*. These trees, common in our latitudes, have at the same time a considerable northern range: and, as with the Testacea, there is thus far an absence of southern forms. If we may consider the Oak as defining an extreme of climate, we shall find ourselves restricted in a northern direction to some moderate degree of cold, for the Oak in Europe does not extend beyond 58° to 63° lat., with a winter temperature of from 15° to 20°. In America it reaches, and that only in a stunted form, no further north than the basin of the Saskatchewan, within a short distance of Cumberland House, in 54° lat., where, however, the winter temperature is $-3^{\circ}{\cdot}7$†. It may be a question whether in those latitudes where the sun would have more power than in the higher latitudes first named, and where consequently the ground in the summer would thaw to a greater depth, the Oak may not have thriven under a winter temperature more nearly like that of the American region.

* I since found, in the autumn of 1863, a few impressions of a leaf, apparently of a Bilberry, in bed *d*, at Hoxne. With these there were also numerous valves of *Cyprides* and some calcareous grains of *Arion ater*.—Feb. 1864.

† Arctic Searching Expedition, by Sir JOHN RICHARDSON, London, 1851; The Vegetation of Europe, by A. HENFREY, London, 1852; Géographie Botanique, par A. DE CANDOLLE, Paris, 1855.

It is evident that if we had to depend only upon the organic remains for decisive evidence of the nature of the climate of the period under inquiry, we might fail to arrive, on the present data, at any exact or positive conclusion. All the recent species are such as are now to be found within the limits of the temperate zone, but they appear to agree better with the fauna and flora of its northern than of its southern provinces; the Fossil Mammalia may also, from their general association and distribution, be considered to have inhabited cold countries; so that there is a balance in favour of the probability of a severer, but not of an extreme climate. On the one hand, we are restricted in the degree of mean winter cold by the presence of trees, and more especially of the Oak; on the other, we are restricted in the degree of heat by the range of the Reindeer and the absence of southern forms.

If, further, we take these indications in conjunction with the physical features before described, the conjoint evidence has more weight and preciseness. Limited as the evidence of the organic remains is, it is at all events in accordance with the physical evidence in favour of a considerable winter cold. It is possible even to attempt some approximate limitation. Thus a climate where the Oak, the Yew, and the Fir (and the Bilberry) throve, where Reindeer lived, where Deer, Horse, and Ox abounded, and where the rivers were subject to periodical floods, and froze so as to transport large boulders for considerable distances, presents conditions which would probably accord with a mean winter cold of not less than 20°, while it may have been as low as 10° or even lower. This would be from 19° to 29° under that which now obtains in these regions, taking the winter temperature of the S.E. of England and N.W. of France at 39°—a difference, under normal conditions, equal to that of from 10° to 20° of latitude on one meridian.

Low Levels.—The organic remains of this series are more numerous and afford better evidence of climatal conditions.

Mollusca.—Of the 36 species of shells enumerated in the high-level gravels, 31 occur also in our lower gravels, together with 20 species which have not yet been found in the higher series of these districts, making a total of 51 species belonging to the beds now in question*. In the present state of the inquiry I attach little weight to the presumed absence of 5 high-level gravel species; while it remains to be seen how many of the additional 20 species may be found in higher beds elsewhere. Amongst the additional species are the *Carychium minimum* and *Helix fruticum*. The former has a wide range in England and over every part of the Continent; the latter, on the contrary, is a temperate and north European species, but does not live in England. The *Helix arbustorum* is also of the small variety characteristic of cold or alpine regions, while the *H. pygmea* is likewise a northern species. On the other hand, several other species of *Helix* (see Appendix) found in these beds range through central and southern Europe only. The other species to be noticed in these newer beds, are the *Pomatias obscurus*,

* The lists from the low levels of Abbeville and Bedford are given in the Appendix. The latter are from Mr. Wyatt's descriptions of the sections at Harrowden and Summerhouse Hill.

Clausilia plicatula, and *Vitrina diaphana*, shells now living in France but not in England, and all of which Mr. GWYN JEFFREYS has recognized in my collection from Menchecourt*. The last-named shell is more especially alpine; whereas the *Cyclostoma elegans*, which abounds at this place, and has not been found at either St. Acheul or Biddenham, has a range essentially southern, not being now found north of central Germany†.

Besides the land and freshwater shells, the following species of marine and estuarine shells have been met with at Menchecourt:—

Buccinum undatum.	*Littorina squalida.*	*Cardium edule.*
Fusus.	*Nassa reticulata.*	*Ostrea edulis.*
Littorina littorea.	*Purpura lapillus.*	*Tellina Balthica.*

These, like the freshwater shells, present, with two exceptions, no differences from the recent species. These exceptions are, according to Mr. GWYN JEFFREYS, *L. squalida*, which is now absent from our shores, but lives on the coast of Norway; and the *T. Balthica*, which is of the northern variety. Both these shells are found in other postpliocene deposits of this country, and range back as far as the Crag.

But the most important shell at Menchecourt is the *Cyrena fluminalis*, of which I have found three specimens‡. This mollusk, as is well known, now lives in the Nile and in mountainous streams of central Asia—a range presenting great extremes of climate.

It is evident that at Menchecourt the waters were saline or brackish. As in the estuary of the Thames at present, the *Cardium edule* and the *Littorina littorea* were then common shells. The *Buccinum undatum* was far from rare. Of the *Ostrea* I have only found one dwarfed specimen. Associated with these are numbers of *Limnæa*, *Helix*, and other freshwater and land shells, washed down into the estuary by freshets of the old streams or rivers. On some of the large flints in bed *e* (former paper, p. 284), which are as fresh and perfect as though just taken from the chalk, I have found attached the opercula of *Bythinia*. These flints were probably carried down undisturbed with the *Bythinia* itself attached, from the bed of some small tributary stream, by the agency of ice.

That shells should be found at Menchecourt and Mautort and not at Montiers and St. Roch, arises, I imagine, from the overwhelming floods, and from the large mass of constantly shifting shingle along the bed of the old river, which would be influenced thereby throughout the length of its main channel above tidal influence. But where the tide met the current, near Abbeville, the force of the latter being much checked—especially where any projecting land sheltered portions of the river from its full effect,

* A curious feature of the period is the abundance of two species of slugs. In some of these beds, and more especially in the Loess, at Menchecourt I had found numbers of small oval calcareous bodies, for the origin of which I was at a loss to account until Mr. GWYN JEFFREYS recognized them as the calcareous grains found in the *Arion ater*. The small shelly shield of the *Limax agrestis* is also found, but less abundantly.—April 1864.

† GWYN JEFFREYS, 'British Conchology,' vol. i. p. 305.

‡ It is singular that in the greater number of places where the *Cyrena fluminalis* occurs in a fossil state the waters have been brackish or estuarine, as at Grays, Chislet, Abbeville, and in Norfolk (the Crag) &c.

as the hill of St. Gilles with respect to Menchecourt—there we might expect a quieter deposition of sedimentary matter; and this we find to be the case at the latter place.

These causes, as in all rivers of the present day subject to heavy periodical floods, must have operated very generally during this quaternary period, and have rendered the remains of freshwater mollusca in these fluviatile deposits the exception and not the rule. As a proof of this, I may remark that I am not aware that land and freshwater shells had been noticed in the lower gravels of the Seine valley until I discovered the few species mentioned at page 261*. Neither the valley of the Lark nor the valley of the Waveney have yet yielded any. In the valley of the Ouse they are more common, though still comparatively scarce.

As with the pulmoniferous Testacea of the high-level gravels, although there is nothing in the individual species found in the low-level series to give a definite clue to the character of the climate of the period, still the group maintains its northern tendencies, there being, out of a total of 52 species, 42 now living in Sweden and 37 in Finland (or nearly one-half of the Finnish species), whereas only one-fifth, or 38, of the Lombardy species occur in these quaternary beds. The marine shells are also common temperate and cold-climate species. The *Littorina squalida* alone slightly weighs the balance in a more northern direction; but, on the other side, we have to notice the introduction of a few more southern land and freshwater species, such as the *Unio littoralis*, of the *Helix caperata*, *Pomatias obscurus*, and the abundance of *Cyclostoma elegans*, which may be taken as some evidence of a more genial climate than that of the period preceding it. The profusion also of the land and freshwater testacea, and the greater abundance and variety of animal life, support this latter view. The great bulk of the species, both of Mollusca and Mammalia, being common to both levels of gravel, we may presume that no very important change in the mean temperature then took place, and that any transition was gradual, although it is possible that the winter climate of the one period may have differed to some extent from that of the other.

The following species of Mammalia have been found in these low-level gravels. I am indebted to Dr. Falconer for the determination of all the Bedford specimens, and to M. Lartet for the Paris list. The species from the Somme valley are the same as given in my former paper.

This list, although more complete than that of the other series, must be taken only as a very partial representation of the fossil Mammalia of the period. There are other localities beyond our inquiry which, as with the Mollusca, would afford a larger and more varied list, like, for example, the valley of the Thames†; but, as I purpose to show their synchronism at length, I consider it better in this more special inquiry to confine myself to the above species. There are enough, independently of other localities, for the general argument, which, so far as regards the Elephant and Rhinoceros, follows the same line as that relating to the high-level gravels.

* Besides these (*ante*, p. 261) I found in a marl in a higher level and corresponding with the Loess, *Helix hispida*, *H. pulchella*, *H. nemoralis*, *Pupa marginata*, *Succinea putris*, *Arion ater*, and *Bythinia tentaculata*.

† And the valley of the Wiley at Salisbury (Dr. Blackmore's remarkable collection).—March 1864.

	Bedford, *Great Northern Railway, or Summer-house Hill.*	Abbeville, *Menchecourt.*	Amiens, *St. Roch.*	Paris, *Grenelle, Ivry, Clichy, or the Rue de Reuilly.*
Elephas primigenius, *Blum.*	*	*	*	*
—— antiquus, *Falc.*	* *s*	....	*	* *c*
Rhinoceros tichorhinus, *Cuv.*	* *r*	*	*	*
—— megarhinus, *Christol.*	* *r*	....	....	* ?[1] *r*
Ursus spelæus, *Blum.*	* *s*	*	....	....
Hyæna spelæa, *Gold.*	....	*	....	* ? *g*
Felis spelæa, *Gold.*	....	*	....	*
Bos primigenius, *Boj.*	* ?	*	*	*
Bison priscus, *Boj.*	* *r*	*	....	* *c*
Equus (possibly two species)	*	*	*	*
Cervus[2] euryceros, *Aldr.*	* *r*	....	....	....
—— elaphus, *Linn.*	*	*	*	*
—— tarandus, *Linn.*	*	*	....	* *c*
Hippopotamus major, *Nesti.*	*	....	*	* *g*
Sus	* *r*	....	....	*

This determination is by Dr. FALCONER, but rests upon a single fragment of a tooth I found in the pit at the Rue de Reuilly. I have a molar tooth of probably another species of *Rhinoceros* (*R. hemitœchus*, Falc.) from Bedford, but it is too low worn for a confident determination. [2] I omit the *Cervus Somonensis*, as Dr. FALCONER and M. LARTET consider its specific distinctness very doubtful. The specimens from the railway cutting are in my collection; those from Summerhouse Hill are in Mr. WYATT's. Where, in columns 1 and 4, the specimens are known to me only from one of the localities, that place is designated by its initial letter.

There is no doubt that the Reindeer lived during the period of formation of the St. Acheul beds, although not found at that spot; in the lower valley series it is a common species. We know that this creature now ranges from the shores of the Arctic Sea to about 46° N. lat. in Asia, to 47° in America, and 60° in Europe *. This corresponds, in the first instance, with a winter temperature of about 19°; in the second with one of 16°; and in the third with 23° Fahr. These parallels, however, give only the line of winter migration of the Reindeer. Their chief home is in the more arctic districts, of which these latitudes are merely the southern boundaries. The Aurochs is now restricted to a region of which the winter climate is 25°.

The Musk Ox, which is found fossil in the low-level gravels of the valley of the Oise† (as well as in the Thames valley), is more essentially an animal of cold countries, ranging now only from the extreme polar regions to lat. 64° N. in arctic America.

On the other hand, there are two animals which might be considered to militate against this northern tendency. The one is a large *Felis*. It is, however, well known that a species of Tiger is common on the Lower Amoor, where the river is frozen for five months in the year. A Tiger also lives constantly in the severe climate of the district around the sea of Aral, where the shore-waters and rivers freeze every winter. In his survey of that district, Commander BUTAKOFF‡ remarks that "Tigers roam constantly in

* RICHARDSON, 'Fauna Boreali-Americana:' DESMAREST, in D'ORBIGNY's 'Dictionnaire d'Histoire Naturelle,' art. "Renne:" LOGAN, 'Geological Survey of Canada for 1857,' Appendix, pp. 227, 244.

† Flint implements have been found in these gravels.

‡ Journal of the Geographical Society, vol. xxiii. p. 95 (1852).

the vicinity of Aralsk, and particularly in the winter, notwithstanding the frost." The January temperature of this part of Asia falls as low as between 14° and 10° Fahr.

The other is the Hippopotamus. Remains of this latter creature are met with at St. Roch, but none are yet recorded from Menchecourt. It is found also in abundance at Bedford. In the various flint-implement-bearing localities it is confined to the low-level gravels. Should this prove to be the rule, which I am not prepared yet to assert, it will be one of some interest. The difficulty felt about the possibility of the Hippopotamus living in a severe climate, arises from the habits of this creature leading it to pass so much of its time in the water. But if the possibility, so far as regards the supply of food and protection by special covering against the cold, of the other large pachyderms living in such a climate be admitted, then why should not the Hippopotamus also have been fitted for a cold climate, provided it partook of the same special conditions. Like its congeners the Elephant and Rhinoceros, this Hippopotamus belongs to an extinct species, and it becomes a question whether, like them, it may not have been adapted to endure the rigours of a severer climate than the living species of these genera can now endure.

Plants.—On this point our ground is almost barren. A few traces of decomposed wood, and one solitary small specimen, apparently of a branch of the common *Chara*, from Menchecourt, are all we possess from the places under review. This plant is found in almost all the rivers of Europe, extending as far as the Volga in lat. 56° and 60° N.

After examining the Fauna and Flora of the low-level gravels, we cannot but feel that the premises from which we have to draw our conclusions respecting the climate of the period are still limited. The physical features show an absence of those marked indications of ice-action we detect in the high-level gravels, but point to the presence of ice in quantity sufficient to transport large boulders. The shells throw a little more light on the question, showing the continued prevalence of a northern group, into which, however, several southern forms have been introduced. The Mammalia continue, with few exceptions, to give evidence of the persistence of a rigorous climate. On the whole, although the climate may have been less severe than that of the previous period, it is probable that the winter temperature was not higher than some point between 15° and 25°. The circumstance that the old valleys differ from the excavations made by existing rivers—which cut deep gorges rather than broad valleys with sloping sides—rather confirms the opinion that the winter cold and spring floods may have diminished from year to year throughout the period of the valley-gravels, the result having been to cause the channels made by these old rivers to be of gradually contracting dimensions: hence possibly the difference in width between the top and the base of C (fig. 19, p. 298), and hence in part the sloping sides of the valleys.

Loess, low-level.—I have found in this deposit at Menchecourt, besides the remains of Mammalia common to the underlying sands and gravel,—

Arion ater.	—— *hispida.*	*Pupa marginata.*	*Pisidium amnicum.*
Limax agrestis.	—— *nemoralis.*	*Vitrina diaphana.*	—— *fontinale.*
Clausilia (*rugosa*?).	*Helix arbustorum*, var.	*Zonites radiatulus.*	Pupa, Helix, and Arion are abundant; Pisidium rare.
Succinea elegans.	—— *pulchella*	*Zua lubrica.*	

LOESS, HIGH-LEVEL.—There is a portion of the horns of *Cervus elaphus* in M. BOUCHER DE PERTHES' collection, from a bed of high-level clay near St. Riquier; exact level not known. Mammalian remains are reported to have been found in a clay-pit on the plateau between Treport and Abbeville, but I have myself never found either shells or bones in such positions.

NOTE.—In the original paper read in March 1862, I had introduced a discussion on the uses of the flint implements, treating them as fossils of this period. The subject, however, is too long and too hypothetical to enter upon here. I would merely remark that these rude implements may almost all be referred to flint-flakes for cutting and flaying, and to pointed weapons of offence and defence. There are ovoid forms to which it is difficult to assign a use. Some of the more spatula-shaped implements I suggested might have been used as ice-chisels: in arctic regions the inhabitants never travel in winter without some such instrument attached to a stick, for the purpose of obtaining water when required, or for making holes in the ice for fishing. I may also remark that in the high-level gravels the lance- or spear-headed instruments predominate, whilst in the lower-level gravels the simple flakes of various shapes are the commoner forms.

§ 6. CLIMATAL CONDITIONS. EXCAVATION OF THE VALLEYS.

I have shown, on the authority both of Continental and English geologists, as well as by the evidence brought forward by myself in this or in my former paper,—

1. That certain beds of gravel, at various levels, follow the course of the present valleys, and have a direction of transport coincident with that of the present rivers.

2. That these beds contain, in places, land and freshwater shells in a perfect and uninjured condition, and also the remains, sometimes entire, of land animals of various ages.

3. That the extent and situation of some of these beds of gravel so much above the existing valleys and river-channels, combined with their organic remains, point to a former condition of things when such levels constituted the lowest ground over which the waters passed.

4. That the size and quantity of the débris afford evidence of great transporting power; whilst the presence of fine silt, with land shells, covering all the different gravel beds, and running up the combes and capping the summits of some of the adjacent hills to far above the level of the highest of these beds, points to floods of extraordinary magnitude.

These conditions, taken as a whole, are compatible only with the action of rivers flowing in the direction of the present rivers, and in operation before the existing valleys were excavated through the higher plains, of power and volume far greater than the present rivers, and dependent upon climatal causes distinct from those now prevailing in these latitudes. The size, power, and width of the old rivers is clearly evinced by the breadth of their channel, and the coarseness and mass of their shingle beds; whilst the volume and power of the periodical inundations are proved by the great height to which the flood-silt has been carried above the ordinary old river-levels—floods which swept down the land and marsh shells, together with the remains of animals of the adjacent shores, and entombed them either in the coarser shingle of the main channel, or else in the finer sediment deposited by the subsiding waters in the more sheltered positions. As the main channel was deepened from year to year by the scouring action of the rivers, the older shingle banks were after a time left dry, except during floods,

when they became covered up with the flood-silt, which, extending also over the adjacent land and shores, was there deposited directly upon the rocky substratum. As the channel became deeper, and the tributary valleys partook of the same erosion, they, being out of the main river-current, tended especially to receive thick deposits of the flood-silt (Loess), while the higher grounds were left permanently dry.

Rivers subject to periodical floods are extremely variable in their course and direction, flowing first on one side and then on the other side of the valley, shifting the shoals and gravel banks, and distributing them in a very irregular manner. Consequently it is by no means necessary to suppose that a bed of gravel like that at Oakley and Abbots Thorpe extended across the valley of the Waveney, or that the gravel bed of St. Acheul extended the whole width of the valley of the Somme, but we may rather infer that local conditions led to the great accumulations of gravel at certain spots, especially on the sides, whilst others would be left more or less bare. The subsequent denudation may therefore have been comparatively slight, and the present outliers of high-level gravels may yet represent a not inconsiderable portion of the alluvium of the old rivers. That these rivers had at times a torrential character, is evident from the nature of their transporting power, as indicated by the prevalence and coarseness of the gravels, by the absence of mud-sediment, and by the rough and irregular lines of bedding. But not only have we these exhibitions of the power of the old rivers; it is further evident, from the presence in the terrace-gravels of large blocks, often but little worn and transported from considerable distances, together with much sharp and angular smaller débris, that there was some other power in operation besides the ordinary transporting power of water, great though that be. For the blocks in the one case would have shown an amount of wear in proportion to the length of transport, and the smaller débris would have been separated from the larger; whereas the blocks are always more or less angular, they are scattered indiscriminately through the gravel, are often associated with the most delicate and fragile shells, and with bones of Mammalia but little or not at all worn. The only cause adequate to produce these results is, I conceive, the action of river-ice, whereby these blocks and a portion of the débris were carried down and deposited along the river-channel, more especially in those parts where the currents may have been checked either by a widening of the river or by the influx of a tributary stream. The recent phenomena, with reference to the transport of blocks by ice on the St. Lawrence at its breaking up in the spring, have been so well proved by Captain BAYFIELD* and Sir W. LOGAN†, and illustrated by Sir CHARLES LYELL and other geologists, that it is unnecessary to enlarge upon them here. I may, however, mention that more lately in sinking the caissons for the Victoria Bridge at Montreal, the bed of the river, through its width of about two miles, was found to be strewed with large rock boulders.

The remarkable contortions in the clay cliffs of Norfolk have been attributed by

* Proc. Geol. Soc., vol. ii. p. 223 (1836).

† Ibid. vol. iii. p. 766, and Canadian Journal.

Sir CHARLES LYELL to the grounding of icebergs on the soft sea-bed, and I am disposed to attribute to a somewhat like action, on a small scale, of the river-ice, the analogous structure exhibited in the St. Acheul and other high-level gravels (figs. 13, 14, 15, p. 269). Mr. A. MURRAY, in exploring the shores of the Mississagui river, noticed instances of similar recent effects of ice, "where the coarse shingle was loosely piled up in great conical heaps. The accumulations were usually at a turn in the river where there was a strong current above. The ice, brought down with violence and impinging on the side at the turn, appeared to have ploughed up the shingle and pushed it forward on to the bank. One of the heaps was estimated to be 10 feet high at the apex, with a diameter at the base of 40 to 50 feet; it rested on closer packed materials of the same kind, which also formed the bed and the margin of the stream in the neighbourhood"*.

These results agree with and confirm the indications furnished by the organic remains, viz. that at the period of the high-level gravels the winter cold, which so froze large rivers as to furnish ice-rafts capable of transporting innumerable boulders, many of 5 to 10 tons weight or more, for great distances, was not less than that of Moscow or Quebec at the present day, and that it may have been even lower. It is generally admitted that previous to this time, in the pliocene or early post-pliocene period, the cold was still more severe. Then the greater part of England was under the sea, whereas Switzerland and the greater part of France had emerged from the sea at an earlier, or Miocene period, and there is no proof of their having been subsequently submerged.

It was during this previous period of intense cold that the wonderful extension of the Alpine glaciers took place, and that many minor chains, such as the Jura and the Vosges, had also their glaciers. On the north of the Alps these old glaciers descended to within 1200 to 1000 feet of the present sea-level, whilst those now existing in Switzerland do not come lower than within 3400 feet of that level. M. LEBLANC† has calculated that such a difference of level might be accounted for by a reduction in the mean annual temperature of $12\frac{1}{2}°$ Fahr. But although that might give the limits to which glaciers could descend in these latitudes under ordinary circumstances and like conditions, it by no means proves that a greatly lower temperature may not have accompanied and hastened their enormous growth; nor, when we look at the length and extent of the valleys, of which the fall is but small, over which the old glaciers passed, can their progress along surfaces so slightly inclined be compared with that where the inclination, as usually in their present beds, is steeper and the channel narrower‡. I do not believe, therefore, that this estimate of M. LEBLANC furnishes us with even an approximation to the extreme cold of that glacial period. If, however, we were to assume that,

* Geological Survey of Canada, for 1858, by Sir W. LOGAN, p. 103.

† Bull. de la Soc. Géol. de France, vol. xii. p. 132 (1841).

‡ Thus in the valley of the Aar, where the inclination of the surface is about $2\frac{1}{2}°$, the glacier of the Aar does not come down lower than within 6000 feet of the sea-line; whereas the glaciers Du Bois and des Bossons, with beds inclined at 8° to 10°, descend to within 3500 feet of the sea. On the Italian side of the Alps the old glaciers descended lower and nearer to the sea-level than those on the Swiss side.

at a certain time towards the end of the glacial period, a temperature of $12\frac{1}{2}°$ below that of the present day had supervened, the further extension of the glaciers may have been thereby checked; and as the present mean annual temperature of the S.E. of England and N.W. of France may be taken at 50°, this would have made it equal to $37\frac{1}{2}°$—the mean annual temperature of the two stations before named, Moscow and Quebec, being respectively 40°·02 and 41°·85 *, and that of Cumberland House (Northern America) being 30°. This mean annual temperature would agree with the conclusions at which we had arrived with respect to a mean winter temperature below 20° and above 5°, or possibly between 10° and 15°, having prevailed during our high-level gravel period.

If there had been no amelioration in the climate at the period of the high-level gravels, the permanent ice and snow accumulated during the preceding long-continued and severe cold on the hills and mountain-chains of Europe would have remained without change, and the discharge of the rivers would only have been in proportion to the annual rainfall, whatever that was; and if that fall were not excessive, we should have no extraordinary agents in operation beyond the winter frosts and snow and the attendant spring floods. But if we suppose that (as must necessarily have happened at some time between the glacial period and the recent period), owing to a further improvement in the climate, the winter temperature became permanently and most probably gradually higher, then it would follow that during each recurring spring the rivers would have had their former ordinary discharge increased by the addition to the annual rainfall of a certain proportion of the snow and ice stored up during the former cold period. This quantity might have been equal to the accumulation of one, two, or more winters, according as the rate of elevation of the mean annual temperature was slow or rapid. In all valleys connected with mountain-chains the result of these climatal changes must have greatly increased the power of the annual floods—whence the greater excavation of the valleys connected with such regions. In our case, however, the extreme conditions do not generally apply, though I believe the foregoing general cause influenced the results. Most of the valleys we have to investigate are not connected with areas of old glaciers. The Waveney, Ouse, and Somme are not so connected. No traces of old glaciers are recorded even in the Ardennes, and those of the Morvan have been contested†, although I think without sufficient reason. Nevertheless with the degree of cold we suppose to have existed at this subglacial time, the mere winter accumulation of ice and snow on the higher ranges of hills must have been large. The effects of the greater water-power observable in the valley of the Oise, and of the Seine more especially, may be due not only to the height of the ranges of hills in which they take their source, but also to the larger areas of drainage.

Starting from the point that the high-level gravels of our district are of an age subsequent to the maximum period of cold, that they mark a period during which the winter temperature was gradually becoming less rigorous, and that the excavation of

* The various mean temperatures are from Dove's valuable Tables, Reports of Brit. Assoc. for 1847.

† Bull. de la Soc. Géol. 2nd series, vol. ii. p. 683 (1845).

the valleys proceeded with greater energy in consequence of successive increments in the mean annual temperature of each succeeding year, let us consider what other effects might have resulted from the operation of these causes.

The mean annual rainfall of the South-east of England and the North of France is 24 inches. The chief fall is in autumn, and the greater portion of it is carried off as it falls; and there is rarely any large accumulation of winter snow. This fall is so small that it requires but a moderate excess in the fall of any one period of the year to produce floods which cover the whole breadth of the present valley-channels. It was a fall of only $3\frac{3}{4}$ inches* in the twenty-four hours that caused the disastrous floods of Morayshire and Aberdeenshire in 1829. Amongst the other remarkable facts connected with that event, Sir T. DICK LAUDER† states that at Invercauld the small river Dee rose $14\frac{1}{2}$ feet above the usual level, and spread 400 yards wide. A tributary stream cut away 6000 square yards of gravel, and spread the débris over thirty acres of land. Lower down, at Maryfield, the Dee rose 25 feet above its ordinary level. At Park the rise was 13 feet, and the breadth of the inundation not less than half a mile‡. At Murtle the river changed its channel from one side of the valley to the other, and acres of land were covered with gravel brought down from the upper parts of the river. The Findhorn rose in one place 50 feet, and in another place cut "a new channel for itself for at least a quarter of a mile"§. Although, owing to the difference in the geological nature of the ground, the effects of such an exceptional rainfall in the south of England would be less than in Morayshire, it would not require any extravagant addition to the small rainfall of the present day to increase both the permanent volume and the floods of our rivers to the extent even of producing inundations more of the character of those indicated (at page 276) by the position of the brick-earth, or of those of arctic regions. Such a result might have been formerly obtained, 1st, by a direct increase in the rainfall; 2ndly, by the accumulation and rapid melting of the winter snow; or by the two causes combined; and 3rdly, by the fall of rain in the spring while the ground was in a frozen state‖.

The line of 35 inches rainfall now touches the north-western point of France, the western point of England, and the south-western part of Ireland. An advance inland of this line, arising from the greater precipitation determined by the low temperature of the land surface, would result from a general winter covering of snow—the accompaniment of a climate of the character we have inferred. It may be objected that, judging from the fact of the decrease generally observed in the rainfall in proceeding

* Sir DICK LAUDER considers, however, that the fall may have been greater amongst the hills at a distance of twenty to fifty miles, but we are without information on this point. The rain for the month was 7·36 inches at Huntley, and $8\frac{1}{2}$ inches at Inverness.

† An Account of the great floods of August 1829, in the province of Moray, &c., 2nd edit. p. 372.

‡ Ibid. pp. 390, 391.

§ Ibid. pp. 38 and 104.

‖ This is of rare occurrence in this country, but when it does happen it leads to disastrous floods. Mr. EVANS informs me that the only occasion on which the valley of the Gade is flooded is when rain falls after a evere winter before the ground is thawed.

from the tropics to the Arctic zone (it being but 17 inches at St. Petersburg*, and 76 inches at the tropics), we might expect the rainfall to have been less, rather than greater than at present, in the subglacial period. But in cases, whatever the latitude, where we have cold surfaces presented to vapour-laden sea-winds, as in the mountainous districts of the north-west of Spain, in our own lake districts, and in Scandinavia, we find a very heavy rainfall, it being 82 inches at Bergen and 104 inches in Westmoreland. At Sitka also, in lat. 57° N., the rainfall is almost constant.

But even if a greater rainfall be problematical, a greater concentration of it cannot be so considered: it would follow as a necessary consequence of the low winter temperature. Sir R. MURCHISON†, speaking of the appearance of part of Russia in the spring time, makes the following apposite remark: "The enormous volume of water, by which large portions of the surface are still covered at every annual melting of the snows, can scarcely be imagined except by those who have travelled (we may say sailed) over some of the central and southern countries in the spring season, when to the eye of the geologist the lands seem to be emerging like isles and promontories on all sides from beneath the waters. It is then that each broad valley is, for six weeks or more, in a condition similar to that which we can imagine to have been the state of England, France, and other countries, when their streams, instead of occupying their present beds, were lake rivers or estuaries of great width, wherein many of the old gravel and sand banks of geologists were accumulated, and in which the bones of extinct mammals are found. The height of the waters during this annual inundation can indeed be exactly read off wherever any great stream has rocky banks. In gorges we have occasionally noted the spring high-water mark as having been 40 feet above the dry summer level."

A very similar observation is made by Baron WRANGELL‡, who says, "the overflowing of many of the rivers on either side of the Ural Chain impeded our journey, but made us amends by the variety which was thus given to the landscape—the valleys being all changed into lakes, and the rising grounds forming green islands." This happens in a country where the rainfall is very small. It is still less in Siberia. Many cases in point are mentioned by the same author in speaking of the rivers of the latter country, and he remarks that the "overflowings of the rivers take place more or less every year;" that "on the 22nd of May the ice, which had covered the river for 259 days, broke up. On the 26th the usual inundation followed, forcing us to take refuge with all our goods on the flat roofs of the houses, there to await the termination of the flood."

Travellers in the Arctic regions of America make the same remarks; but I need not here multiply cases, as the fact is well known, and can be readily observed in most

* The Scandinavian range of mountains diminish the rainfall over a considerable part of north-western Europe by freeing the warm and damp westerly winds of their moisture.

† The Geology of Russia in Europe and the Ural Mountains: London, 1846, p. 572.

‡ Narrative of an Expedition to the Polar Sea; edited by General SABINE: 2nd edit. pp. 5, 63, & 258.

mountain districts. What I wish to point out is the probability of the continuance of severe cold during the period when the high-level gravels were in course of formation, with, at the same time, a concurrent gradual amelioration of the climate, accompanied possibly by a greater rainfall, and certainly by great spring floods.

I have before shown how impossible it would be for the present rivers, even during their greatest floods, to attain a height at all approaching to the level of the high-level gravels; but, taking the additional discharge resulting only from this melting of the snow, independently of any larger rainfall, the floods must formerly have been far greater than those of the same districts in the present day, and have given to the rivers for a portion of the year a torrential character. That the water-supply was adequate to fill at times the broad and shallow old channels is evident from the facts and is borne out by calculation. The Waveney waters may, even now, when the valley is flooded, give a sectional area of, say 1400 square feet. To fill the channel of the old river, supposing it to be on the level and of the width of the high-level gravels, would have only required a volume of water of a sectional area not exceeding 7000 feet, or five times as large. So with the Ouse, the measure, with the valley flooded, may be 4000 feet for the present river, and 20,000 feet for the old postpliocene river; for the Somme of to-day 3000 feet, and for the old river 16,000 feet; and for the Seine 8000 feet now, and 36,000 feet formerly. These are merely rough approximate estimates. They will serve, however, to show that to fill the old channels, before the excavation of the existing valleys, to their entire breadth, would not have required more than, if so much as, four or five times as much water as now flows during floods; but it must be remembered that the normal condition of these quaternary rivers would be like that of rivers of the present day that are subject to heavy periodical floods and have large and wide channels, small portions only of which are filled by the river during a great part of the year,—dry sand and shingle banks then occupying the larger portion of the area. A supply in fact very little if any larger than that drained off by the existing rivers might have occupied the comparatively dry channels during the dry season, whilst these old channels would be filled to overflowing during the melting of the snow in spring, independently of any excess of rainfall, and be subject to periodical floods and inundations, such as now are of annual occurrence in Arctic countries, when the waters rise 40 to 50 feet or more above their ordinary level*.

Although I can conceive that, granting an indefinite length of time, the wearing power of torrential rivers might effect considerable erosions, we shall find that other causes have assisted to produce the immense valley-excavations we are now contemplating. For, if the period is assumed to have been one of severe winter cold, we must follow out the consequences of that assumption, not only with regard to the floods following upon the winter snows, but in all its collateral bearings.

The effect of the freezing of the rivers and the transport by ice of the boulders, gravel, and organic remains lying on the shores, has already been discussed. In addi-

* The periodical rains of tropical countries produce a somewhat similar but smaller result.

tion, however, to the ice so formed, observations of late years have shown that a very considerable formation of ice takes place along the beds of certain rivers, especially when those beds are stony and gravelly. In these climates we rarely have the opportunity of observing this phenomenon on a large scale, although, from a few facts noticed, it appears even here to be far more common than has been supposed.

That this agent is one of considerable power in producing changes of the character we are referring to, is evident from the facts recorded by ARAGO*, and the experiments made by M. LECLERCQ† at Liége, and by Colonel JACKSON in Russia. These observers show that most running streams give rise, under certain conditions, on the setting in of winter, to the formation of ground-ice. In the first place the whole body of water becomes reduced, by intermixture caused by the flow of the river, to a uniform temperature of 32°. Any pointed surfaces in the bed of the river then determine, as is the case with a saturated saline solution, a sort of crystallization, needles of ice being formed, which gradually extend from point to point and envelope the substances with which they are in contact. By this means the whole surface of a gravelly river-bed may become coated with ice, which on a change of temperature, or of atmospheric pressure, or on acquiring certain dimensions, rises to the surface, bringing with it all the loose materials to which it adhered.

According to M. LECLERCQ, whose observations were made in the winters of 1840 and 1841, when the mean temperature of the end of December was 12° Fahr., ground-ice is formed in a current of 3·60 feet per second on the fifth day; and with a current of 9·52 feet to 11·58 feet, on the ninth to the eleventh day. The greatest depth at which he observed the formation of ground-ice was not quite 4 feet, and the greatest thickness the ice attained was 2·63 feet. At one time he found the river-bed, for a length of a mile, covered with lumps of ice, "which became detached from time to time, in angular masses of a metre square, and carried away pebbles and stones, which after a time became detached and fell on the beds over which they were carried." The conclusions at which M. LECLERCQ arrived were—

"1st. That the ice is formed under water so much the more as the cold is the more intense and the sky is the clearer." "2nd. That the ice under water gains in thickness so much the more as the current is less swift."

He also observed that a bed of fine clay and gravel gave rise to no ice, and that "the bed best suited to produce it was one formed of pebbles of considerable size."

Colonel JACKSON‡ experimented on the Neva, which at St. Petersburg is about 1500 feet broad and in places 50 feet deep, and moves with a velocity of about $2\frac{1}{8}$ miles per hour. It is frozen during five months in the winter, and the surface-ice attains a thick-

* "Sur les glaçons que les rivières charrient en hiver," Annuaire du Bureau des Longitudes pour 1833, p. 244.

† "Sur la formation de la glace dans les eaux courantes," Mém. couronnés par l'Acad. de Bruxelles, t. xviii. 1845.

‡ "On the Congelation of the Neva at St. Petersburg, and Temperature of its waters when covered by ice," Journal of the Royal Geographical Society, pp. 2, 7 & 13, vol. v. 1835.

ness of $3\frac{1}{2}$ feet. He found the temperature at top and bottom not to vary one-sixth of a degree*, and that a "flaky congelation" forms in immediate contact with the bed of the river and "becomes gradually transformed into solid ice, which, if not thawed in the spring at the bottom itself, gets detached and rises to the surface." In noticing a paper by Dr. PLOTT, he observes "that the flakes of ice which rise from the bottom of the Angara (in Siberia) often bring up in like manner large stones."

In a subsequent memoir† Colonel JACKSON translates some interesting observations made in Siberia by M. WEITZ, superior officer of the Mining Corps. They are not so exact as the observations of M. LECLERCQ, but they are so important, as showing the effects of such an agent under more favourable conditions of temperature, that I give the greater part of the extract. M. WEITZ remarks that "the great transparency of these rivers (of the North of Siberia) enables us to see clearly what is at the bottom. At a depth of 14 feet and more one might see the ice formed at the bottom, whose greenish tinge gave it an appearance somewhat similar to that of patches of the confervoideæ..... It frequently happens that these pieces in rising from the bottom bring up with them sand and stones, which are thus transported by the current...... When the thaw sets in, the ice becoming rotten, lets fall the gravel and stones in places far distant from those whence they came...... So long as the congealed masses continue small with regard to the volume of the water immediately above them, they adhere as if rooted to the bottom; but when by degrees they increase in bulk, the difference in their specific gravity operates to overcome their adhesion to the bottom, and they rise, bringing with them, as we have said, such gravel and stones as we find attached to them, whence we may conclude that not only does the current occasion a change in the bed of the river by its erosion of the looser soil which it carries from one place to depose in another, but that the ice which forms at the bottom of rapid rivers in very cold countries, tends also to effect a change in the beds of those rivers."

Colonel JACKSON, it is true, thinks that M. WEITZ attributes too much influence to the bottom-ice in effecting changes in the beds of the rivers; but the Neva, where Colonel JACKSON'S own observations were made, is a deep muddy-bedded river, offering precisely the least favourable conditions for the formation of ground-ice.

The interesting narrative of Baron WRANGELL contains amongst much important scientific observation the following remarks:—"In the Anini, as well as in all the more rapid and rocky streams of this district, the formation of ice takes place in two different manners: a thin crust spreads itself along the banks and over the smaller bays where the current is least rapid; but the greater part is formed in the bed of the river, in the hollows amongst the stones, where the weeds give it the appearance of a greenish mud.

* Colonel JACKSON found that the water at the bottom of the river was generally a fraction of a degree ($\frac{1}{6}$) above freezing-point when congelation commenced, an observation since confirmed by Mr. ADIE in a recent communication to the Chemical Society (Proc. vol. xv. p. 90).

† "On Ground-ice in the Siberian Rivers," Journal of the Royal Geographical Society, p. 417–18, vol. vi. 1836.

As soon as a piece of ice of this kind attains a certain size, it is detached from the ground and raised to the surface by the greater specific gravity of the water; these masses, containing a quantity of gravel and weeds, unite and consolidate, and in a few hours the river becomes passable in sledges instead of in boats" (p. 202).

These, and similar observations made in northern America, establish the efficacy of ice in transporting no inconsiderable quantity of shingle along the beds of rivers, and show that it tends both to shift the shoals and to deepen the channels. The conditions of the old postpliocene rivers were precisely such as to favour this formation of ground-ice; for, without exception, the old alluviums are composed of coarse subangular shingle with but little sand, and very rarely with any subordinate seams of clay.

These two agents, floods and ground-ice, would affect chiefly the river-channel. There is another agency which would co-operate in that direction, but would affect more especially the banks and shores of the river; that is, the freezing of the ground and the rending of rocks by great cold. The power of this agent is well known; I will therefore confine myself to a few observations bearing upon our particular case. CRANTZ speaks of the talus of débris at the foot of the hills in Greenland as looking "like a demolished city," and says that some of "the lesser hills or ledges of rock are still more subject to breaking, and many of them grow so rotten and brittle with age that they are pulverized by the air"*. Sir JOHN RICHARDSON† says that near Cape Krusenstern "the whole surface is covered with thin pieces of limestone." "I should infer that the frost splits off the layers and breaks them up more effectively than any agent to which rocks are exposed in warmer climates." The same thing occurs at Point Keats; whilst of the limestone cliffs on Lake Winipeg he says, "Under the action of frost the thin horizontal beds of this stone split up, crevices are formed perpendicularly, large blocks are detached, and the cliff is rapidly overthrown, soon becoming masked by its own ruins. In a season or two the slabs break into small fragments," which go to form the beach.

Dr. SUTHERLAND‡, in describing the effects of a still colder climate, with reference to the great talus generally found at the base of the cliffs in the Arctic regions says, "Strong and bold as this coast may appear to be, and bidding defiance to assault in all directions, time, with its invisible agent, heat alternating with cold, assisted only by water, saps its foundations, and runs mines into its lofty citadels; and the result of this action is an increasing heap of rubbish, upon which the same agents are still exerting their irresistible power, reducing to splinters and small fragments, and ultimately to a fine powder, liable to be washed or blown into the sea, what had been set free in masses of more than a ton weight."

In Siberia the same phenomenon is often alluded to by Baron WRANGELL§.

* History of Greenland, vol. i. p. 53: London, 1767.

† Searching Expedition, vol. i. pp. 295, 281, & 65.

‡ Journal of a Voyage in Baffin's Bay and Barrow Straits, vol. i. p. 286: London, 1852.

§ *Op. cit.* pp. 193, 374.

In our country the effect of frost on freshly exposed perpendicular surfaces of chalk, sandstone, and oolites is very marked. The former especially disintegrates very rapidly. I have seen a low cliff of chalk 15 feet high form a talus at its foot, in the course of one ordinary winter, 6 feet broad by 5 feet high. The wetter the ground the greater, necessarily, are the effects of the frost; so, as we assume in our hypothesis that the excavation of C (fig. 18, p. 298) was effected by the removal of successive layers (c^1–c^4), commencing with the one at the base of D, each layer, when first uncovered, having been at or near the level occupied by the river, must have been at or near the line of general water-level or of springs, and therefore more largely and constantly charged with moisture than the same strata on higher ground, and such surfaces consequently presented conditions the most favourable for the operation of frost.

Sir R. MURCHISON gives some very illustrative instances of what he appropriately terms recent "fluvio-glacial action." Amongst others, in speaking of the Dwina, about sixty-four miles above Archangel, where it flows over a white limestone in horizontal layers, he remarks, "About 30 feet above the summer level of the stream, the terrace on the river-side is covered for two or three versts by a band of irregularly piled loose and large angular blocks of the same limestone, arranged in a long uniform ledge...... In other words, these materials (all purely local) constitute a broken ridge of stones between the road and high-water mark...... When the Dwina is at its maximum height, the water, which then covers the edges of the thin beds of horizontal limestone, penetrates into its chinks, and when frozen and expanded, causes considerable disruptions of the rock, and the consequent entanglement of stony fragments in the ice. In the spring the fresh swollen stream inundates its banks (here very shelving), and upon occasions of remarkable floods so expands that in bursting it throws up its icy fragments 15 or 20 feet above the highest level of the stream. The waters subsiding, these lateral ice-heaps melt away and leave upon the bank the rifted and angular blocks as evidence of the highest ice-mark"*. Dr. BIGSBY also gives a section in illustration of a like case on the banks of the Ottawa river†.

Besides the ordinary eroding power of running water, we have had therefore three main causes in operation in those regions at the period under consideration: viz., 1. the taking-up of the shingle and boulders along the sides of the rivers by the shore-ice, and its transport thereby to points lower down the river; 2. the action of the ice forming on the bottom of the rivers, and lifting, as it rose to the surface, shingle and boulders from the river-bed and carrying them also to a distance down the stream; and 3. the rending and disintegration of the rocks by frost. The districts traversed by the rivers whose courses have been described are peculiarly favourable for the operation of these causes, being formed essentially of sands, chalk, soft sandstones, and fissile limestones; not that the harder rocks do not yield to the influence of the same causes, but that the others are more readily and quickly affected.

The combined operation of these causes is visible in many of the rivers of Russia at

* The Geology of Russia, &c., pp. 566, 567.

† Quart. Journ. Geol. Soc. vol. vii. p. 235.

the present day; but it is proceeding on a grander and larger scale in the vast regions of Northern America, where the streams, flowing through extensive champaign countries, have furrowed the land with deep and precipitous channels, generally much below the level of the great plains they traverse*. In Europe, however, the connexion of cause and effect is by no means so apparent. The regularity so common in the former case is generally wanting in the latter, where the weathering is more excessive.

I doubt also whether, without a change in the general level of the land, the full effects of the changes we are contemplating could have been produced. The excavating power of the rivers would, in a measure, depend upon the adjustment to be made between the inclination of the valley along which they flowed and the sea-level.

The coasts of these opposite shores of England and France are fringed at places by a raised beach. Of this we have evidence at Sangatte near Calais†, Brighton‡, the Sussex coast§, and possibly at Havre‖. In all these places it is about 5 to 10 feet above the level of high water. With this beach I would correlate the estuarine bed connected with the low-level valley-gravels at Menchecourt. But besides this zone we have in each district the higher-level gravels fringing the river-estuaries, and sometimes the coast, at an elevation of from 40 to 100 feet above the raised beaches. These mark the relative difference of water-level at our two valley-gravel periods. It is immaterial to our inquiry whether that difference resulted solely from an elevation of the land or partly from the encroachment of the sea on the coast. Probably both have contributed to the result. A slow elevation of the land may have commenced at the high-level gravel period, leading to an increase in the velocity and erosive power of the rivers until a state of repose again obtained in the low-level gravel period. During such a change of level the causes which we have above alluded to, acting upon the portions of the substrata successively subjected to the action of the maintained water- and ice-power, gradually effected the excavation of those deep and broad channels forming the valleys through which the present comparatively insignificant rivers of these districts now find their way. The sharper angles produced on the river-banks by the erosion of the stream have been rounded off and in great measure obliterated by the action of the severe cold combined with the periodical floods,—operations by which the exposed rock-surfaces were alternately disintegrated and denuded; while at the same time the flood-waters in retreating from the higher platforms, before falling in with the main current, further grooved and furrowed the sides of the valleys, and, breaking the continuity of the river-terraces, helped to give our valley-sides their peculiar and varied outlines.

The following diagram will serve to illustrate my meaning:—

* The geological structure in both instances often greatly facilitates the operation, the country being constantly thickly covered by loose sands and gravels, offering little resistance to the erosive power of the rivers.

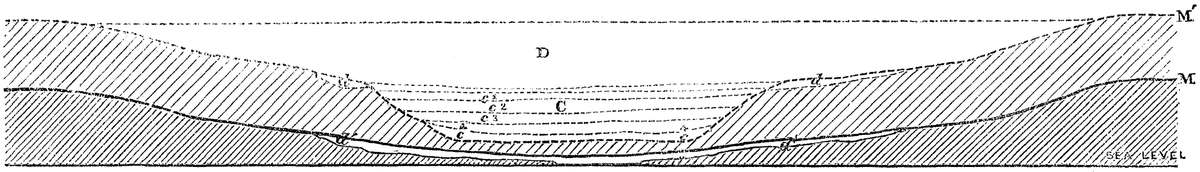
† The author in Quart. Journ. Geol. Soc. vol. vii. p. 274.

‡ Mantell, 'Fossils of the South Downs,' p. 277.

§ Godwin-Austen in Quart. Journ. Geol. Soc. vol. xiii. p. 61.

‖ Passy, Desc. Géol. de la Seine Inférieure, p. 84.

Fig. 18.



M. Original level of the country at the time of the formation of the high-level gravel *d′ d′*.

M′. Present level of the country, with the remaining portions of the high-level gravel *d d*.

M M′. Supposed extent of elevation between the two periods. The dotted lines mark portions of the substrata successively raised to the level $c^1\ c^2\ c^3\ c^4$, and consecutively removed by the denuding action, the total amount of denudation being represented by C (or the space embraced between *d* and c^4). c^1 to c^4 may represent any thickness of strata; the rate of elevation from M to M′ may have been continuous or interrupted or partial, and the extent of elevation variable in different districts. According to any variability in the rate of elevation, to intervals of repose, or to deflections in the flow and velocity of the river, so there may exist intermediate terraces or levels, sudden variations in the slopes, and gravels lodged on different levels. As these not unfrequently occur, they often add much to the complexity of the problem.

§ 7. THE QUESTION OF TIME AND SUCCESSION.

In looking back at the subjects we have discussed, we are forcibly reminded of our dependence on the value of probabilities. On various points geology has not at present, and probably never will have, any other means of inference. All that can be done to give weight to our argument is to multiply probabilities, and by attending to the general concordance to reduce to the minimum the chances of error. The difficulty of one branch of the inquiry is considerably increased by the circumstance that the recent researches of naturalists tend for the present to give less security to any argument founded upon analogy of past with recent life. The case of the adaptation of the large extinct Pachyderms to a rigorous northern climate has long since deprived the remains of such genera of any weight with reference to the climatal conditions of past periods. It has now further become a question with some distinguished naturalists whether even the distribution of recent species is originally dependent on the influence of climate—whether the existence of certain kinds of food, the presence or absence of certain other animals, may not have been amongst the causes regulating the range of the animals. It is certain that the experience gained of late years of the facility of acclimatization indicates the necessity of caution. Nevertheless, in the absence at present of sufficient data with regard to this power of adaptation, we can only in the mean time rely on the evidence furnished by recent life so far as it regards species of known habits and range, provided especially it be supported by independent collateral proof.

I will now proceed to make a few remarks on the question of time. We have to look at it both with reference to geological time, or the order of succession, which is merely relative, and to that which in the present instance more concerns this particular inquiry—the actual date of the existences and changes under consideration. With regard to geological time, I have before shown that the period is subsequent to that of the Boulder Clay—consequently to that of the great extension of the European glaciers

—and that it may be brought down to the time when our valleys and plains began to receive their tranquil and inequality-levelling deposits of silt and peat, and the modern order of things commenced.

To estimate the time to which we have to carry back the high-level gravels, we have to consider what may have been the duration of their accumulation, and that of the subsequent excavation of the valleys with the resulting low-level gravels*. A difficulty here meets us at the onset. The accumulation of sand, gravel, and shingle along the course of rivers is so irregular (sometimes very rapid, at other times slow, what is done one year being undone another) that we are entirely without even the few data by which we are approximately guided in ordinary sedimentary strata. The thickness of the deposits affords no criterion of the time required for their accumulation. They rarely exceed 20 feet, and are more frequently not above 10 to 12 feet thick. It is well known that recent inundations have covered valleys with sand and gravel to the depth in places of 4, 6, or even 10 feet in the course of a few days; and therefore there are no high-level gravels which, so far as thickness is concerned, might not have been deposited in the course of a few weeks or even a few days. But the evidence of time lies in their length, breadth, and extent,—in the life existences of the period,—and in the physical changes in progress, such, for example, as the subsequent valley-excavation, and the wide distribution of the resulting débris. There is also another phenomenon connected with this period which I would point out as containing some elements for an approximate estimate of the duration of time. We have as yet no data to judge of the rate of progress of the operation; but it is one which admits, to a certain extent, of time-measurement, and may hereafter, perhaps, be employed with some chance of success. At present it will merely serve to give us some idea of the time employed; but that even is a step gained. I allude to those cylindrical perforations in calcareous strata filled by the sand and gravel beds overlying or formerly overlying them. These are of various dates, but a large proportion of them commenced, I believe, with the high-level gravel period, or with that of the gravel which immediately preceded it.

These cylindrical and funnel-shaped holes, or gravel and sand pipes as they are termed, vary usually from 5 to 50 feet in depth and 1 to 10 feet in width, though they are sometimes much larger. I have seen traces of them in the chalk skirting the S.E. side of the hill of St. Acheul. Near Picquigny, on the road from Amiens to Abbeville, there is an escarpment of the chalk in which there are the remains of several gravel (high-level) pipes from 10 to 20 feet in depth. Others are to be seen near Mareuil, and again near Yonval; the gravel itself in most of these cases has been denuded from the surface, and remnants only preserved in these natural funnels. The outlier of high-level gravel on the hill above Mautort presents a section of one measuring 15 feet in diameter, but the depth is not shown. The most remarkable instance that has come under my

* I am speaking now of the postpliocene valleys. Where the land, as in Auvergne, was earlier raised above the sea, we may have valley gravels going back to pliocene, or miocene periods, and continued in uninterrupted succession to the recent period.

notice is at Drucat, near Abbeville, and which I take to belong to the high-level gravel period. This outlying mass of sand and gravel is in a depression of the chalk, which probably accounts for its preservation; at the bottom of the depression there was exposed on the occasion of my first visit a deep circular shaft in the underlying chalk 22 feet in diameter at the top and 18 feet at the depth of 30 feet, to which extent the sand and gravel had been cleared out. The prolongation of this great natural excavation in the chalk probably reaches a depth of at least 100 feet. A number of these sand pipes underlie this quaternary outlier, but I saw no others of the dimensions of this one.

These pipes are not filled up indiscriminately, as if they had been formed first and subsequently filled up, but they show, as usual, a succession of concentric and continuous vertical layers, following the encircling surface of chalk and enclosing a core distinct from the outer coats. Further, where the beds of sand and gravel are undisturbed and in their horizontal position, it is found that the core of the pipe always subtends from the uppermost bed or seam of gravel or sand, or not unfrequently from the superincumbent Loess, which proves that the superincumbent beds were deposited before the excavation of the pipes, and that they were lowered into them by the gradual removal of the chalk. These excavations have been referred to various causes, of which I consider the action of carbonic acid held in water as the only one possible*. It is evident that to have an excavation of this sort we must have the slow and constant passage of water. If the line of water-level in the chalk had remained permanently near the level of the high-level gravels, this prolonged downward action could not have occurred. The water-line, although at first necessarily on that level, must, as the excavation of the valley proceeded, have gradually been lowered 50 to 100 feet or more; so that the surface-water collected in these beds of sand and gravel, left standing above the base of the gradually deepening valleys, would, in draining off, have to pass down, along the lines of least resistance, through a successively increasing depth of chalk, before it met with the line of permanent water-level into which it would merge. The gradual and constant operation of this percolation of water through definite lines in the chalk, from the first emergence of the high-level gravels above the old river-bed and continued in the same channels down to the time of the lower valley-gravel, resulted in eroding these perpendicular shafts or funnels, into which, as the excavation proceeded, the overlying gravel and sand coordinately subsided, while the Loess of the periodical floods continuously tended to level the resulting inequalities of surface. The process must necessarily have been extremely slow. That these pipes are connected with a former state of things and not with the present, is shown by there being now no indication of their presence on the surface of the ground †.

* See a paper by Sir CHARLES LYELL in Phil. Mag. 3rd ser. vol. xv. p. 257, and another by the author in Quart. Journ. Geol. Soc. vol. xi. p. 64.

† This in some cases may arise from the cultivation of the surface. In a few favourable localities a slight action of this sort would still, however, appear to be going on, if we may judge from an occasional sinking or giving way of the ground.

The next possible standard of measure is the time required for the excavation of the valleys themselves. I have already described the agents which probably cooperated in this gigantic operation. That it must have been one of great time there can be no doubt; but the like operations at present in progress by no means furnish us with the gauge of the rate of the denuding action. In considering this point there is, besides the greater floods and severer cold, another element which must not be overlooked. This is the varying solvent power of spring- and river-waters. This there is reason to suppose may be greater in cold than in temperate climates, for AGASSIZ has shown that fallen snow holds excessive proportions of air in combination; so that, during inundations resulting from the melting of snow in spring, the flood-waters becoming loaded with soil and vegetable matter must necessarily have presented conditions favourable for generating carbonic acid in large quantities, with which the ice-cold waters would become highly charged. Thus the solution, both of the calcareous beds forming the river-channel and of the strata perforated by the gravel and sand pipes just alluded to, may have been accelerated much beyond any effects now observable in these districts from the present action of ordinary spring- and river-waters.

An indication of time-measurement, which has been often referred to in relation both to the lapse of time and its late date, is the formation or excavation of the British Channel between the South-east of England and the opposite coast of France. The grounds on which it has been inferred are, the identity of the strata on the two sides of the channel, and the community of the fauna and flora. This to a certain and great extent is true, and there can be no doubt that the severance of the two countries took place at a comparatively late geological period; but that it was the last change of all I am not prepared to admit. In fact the question has been treated in its immediate application in a manner purely hypothetical. The geological evidence of the substrata has been constantly had in view, whilst that of the superficial postpliocene beds, which relate directly to the period under consideration, has not been attended to.

Whether or not there may have been a break between the two countries at the high-level valley-gravel period I could not say with certainty. We have evidence of these beds occupying, on or near the coast-line, a level of from 50 to 100 feet above the sea on both sides of the channel. This may arise from the sea encroaching on the land and so intersecting, at varying distances from the old line of coast, the planes of the old river-channels—which, like the present river-beds, necessarily slope from certain heights inland to the sea-level,—or from an elevation of the land. The evidence, probably, is in favour of the operation of both causes. The difference of height between the fossiliferous high-level gravels at Amiens and at Abbeville is 60 feet. This is in a distance of 28 miles. If we prolonged these beds at Abbeville, where they are 96 feet above the sea, on the same plane sea-ward, they would reach the level of the sea at a distance of 45 miles below Abbeville, or 29 miles beyond the present coast-line. The same measurements applied to the high-level gravels of our own coast give nearly similar results. If this be correct, a sea-channel, although very contracted, may then possibly

have existed between the two countries; but as the raised beaches of later date prove an elevation of the land subsequent to the period of the high-level gravels, the old channel must have been larger in the proportion of the difference of level so produced to the difference which would have resulted from the wear of the land alone. That the elevation of the Wealden area had taken place before this period is proved by the occurrence of high-level gravels within its limits (see Map, Plate IV.), whilst the hydrographical conditions of the whole area show that those deposits hold the same relative position to the adjacent coast in one part as in another; whence I should infer both a widening of the sea-channel, and a former somewhat greater extent of land.

With reference to the condition of things at the time of the low-level gravels the evidence is more positive. We have old cliffs running nearly parallel with the present line of coast, and estuarine deposits in position nearly coincident with the like modern deposits. There are the old cliffs and raised beach at Brighton on the one side of the channel, and those at Sangatte, near Calais, on the other, while the deposits near Havre, Abbeville, and on the Stour, near Canterbury, furnish us with examples of estuarine beds of this late postpliocene age. On a coast so exposed to the action of the sea, and with cliffs constantly though slowly yielding to its incessant action, it is not to be expected that traces of old raised beaches should be preserved, except at a few sheltered spots. These we have at places so closely allied to the present contour of coast—showing, too, old cliffs forming, like the present range of cliffs, bold escarpments to an old sea—that although I conceive the channel to have been considerably widened since then, I am satisfied that it existed at the time of the low-level gravels, whatever doubt there may be of its prior existence. There is no palæontological objection to this view, inasmuch as the land and freshwater Mollusca had spread over this country at an anterior period; the greater bulk of them had in fact made their appearance in this country previous to the Boulder Clay, and many at the period of the Crag. A nearly similar observation applies, with few exceptions, to the Mammalia. With a climate, however, such as we have inferred, and with a channel of less breadth than the present one, the sea between the two lands might have been frozen every winter and have allowed of the passage of man and large animals, as happens at this day in latitude 52° at the island of Saghaleen, where the strait between it and the adjacent mainland is frozen every winter for a period of some months*.

Nor are we entirely without evidence, although very slight, derived from the land Mollusca, of the existence at this latter period of a barrier impassable to them. There are two species, the *Pomatias obscurus* and *Clausilia plicatula*, Drap., living French shells, both of which I have found fossil at Menchecourt, but which are not known either living or fossil in England.

All these phenomena indicate long periods of time. I do not, however, feel that we are yet in a position to measure that time, or even to make an approximate estimate

* On the east coast of Saghaleen the sea freezes every winter as far as the eye can reach. Occasionally the Tiger crosses over to that island.—RAVENSTEIN's 'Amur,' pp. 284 & 320.

respecting it. That we must greatly extend our present chronology with respect to the first existence of man appears inevitable; but that we should count by hundreds of thousands of years is, I am convinced, in the present state of the inquiry, unsafe and premature.

Nevertheless, just as, though ignorant of the precise height and size of a mountain-range seen in the distance, we need not wait for trigonometrical measurements to feel satisfied in our own minds of the magnitude of the distant peaks, so with this geological epoch, we see and know enough of it to feel how distant it is from our time, and yet we are not in a position at present to solve with accuracy the curious and interesting problem of its precise age.

Before leaving this subject I would direct attention to one other condition connected with this later division of the glacial period, which possibly may eventually afford an additional clue towards the solution of this important time-question. Here, again, we have not at present all the data we require, but we have enough to show the possibility of obtaining from this source some elements for more exact calculations.

In conducting experiments upon the temperature of the crust of the earth, it is well known that, after passing the limits of the line of mean annual temperature, there is a gradual increase of 1° Fahr. for every 60 feet, nearly, of additional depth. But the rule is by no means constant, the rate of increase being subject to fluctuations and variations for which no sufficient reason has been assigned. Is it not possible that these disturbances may arise from differences between the former (glacial) and the present (temperate) temperature of the place, combined with the variable conductivity of the strata? Let us, for example, take a place like Yakutsk in Siberia, where the ground is perpetually frozen to a depth of 382 feet—the depth, therefore, at that place of the line of 32°. To reach a heat of 53°, the invariable constant under the Observatory of Paris at a depth of 90 feet, we should have to sink at Yakutsk (taking, as a mean, an increase of 1° for every 60 feet) to a depth of $382+(21\times60)$, or 1642 feet, before reaching the same isothermal plane. If, from any circumstances connected with geological changes, we could suppose the mean temperature of Yakutsk to be raised to that of this part of Europe, the isothermal plane of 53° would tend to take a vertical range upwards of $1642-90=1552$ feet. In a perfectly homogeneous mass, and all conditions equal, this plane would travel at all parts in equal times, or would move in lines parallel with the original position it held; but as such uniformity over large areas never obtains, and the strata which it would have to pass through must differ materially in conductivity of heat, it follows that the isothermal planes would, in different places, travel with different velocities, and, until adjusted by lapse of time, aberrations in the increment of heat at different depths must exist. I apprehend that a very long period of time would also elapse before an equilibrium in accordance with the changed mean temperature of the place could be established in each successive zone of depth.

Now if we apply this hypothetical case to these parts of Europe, the question I would suggest is if it might not be possible to determine, by calculations founded upon suffi-

cient data, whether any of the perturbations in the increment of heat at different places and depths within this area may not be due to the circumstance of a very much lower temperature having prevailed here at an antecedent period*; and whether, if so, the date of that period (taking that of the extreme glacial cold) could not be fixed within a certain limit, by the application to this investigation of the known laws regulating the transmission of heat through solid bodies.

The uninterrupted succession of life from this postpliocene period to our own time cannot fail to have been noticed in the course of this inquiry—a succession so large and so important, that it is not possible to contemplate the occurrence of any intervening catastrophe of such a nature as to destroy the life of the period, and seek for an explanation of its return by immigration from adjoining districts. Apparent even as the connexion is in the limited ground we have studied, it is infinitely stronger when the whole series of pliocene and postpliocene deposits comes under review. Even in the aspect here presented the conclusion is inevitable, that no general cause has led to the extinction of life over this part of Europe at any recent geological period. There have been great river-floods and great changes, but no interruption in the succession of life from the time of the great extinct mammals to our own times. There are still serious difficulties in the way of explaining the cause of the disappearance of so many of these large Mammalia; but a sufficient number remain to attest the direct descent of a portion of the old fauna to our day. The Reindeer, the *Bos primigenius*, the Aurochs, are amongst those which survived all the successive changes†. Why the larger Pachyderms should not also have survived we cannot explain, we can only admit the fact, which is the more remarkable from the non-extinction of other classes. The change of climatal conditions could scarcely have been the sole cause, as that would affect one class equally with the other; and besides, as the climate at this time presented no extreme character, they could, as the changes progressed, have found, by migration or limitation, as with the other animals, places still adapted to their former condition. But by far the most remarkable and convincing feature in the case is the transmission from the quaternary period of so large a proportion of the small and delicate land and freshwater shells. Not only are they found inhabiting the same land as formerly, but their distribution follows very much the same law. More than two-thirds of our recent species are found in a fossil state; and when we consider that the list of living species is the result of close examination of numerous observers for a series of years over a large extent of country, whereas that of the fossils is the result of a necessarily limited search at very few places, where they are buried in the ground and rendered fragile by age, it is rather a matter of surprise that the collection should be already so large. Many of these mollusks will no doubt live for a time out of their element, and they might survive

* I apprehend that some of the calculations that have been made on the earth's temperature and refrigeration may also be affected by this disturbing cause.

† On this subject M. Pictet of Geneva has made some interesting observations in a paper published in the 'Archives des Sciences de la Bibliothèque Universelle' for August 1860.

floods and inundations which would destroy their large contemporaries, but there is a limit to this power. Some land mollusks are not destroyed by immersion in water for days, and freshwater mollusks will revive after immersion in salt water; but this applies to some species only, and with these, even, their mode of protection, although it might suffice for days, would not avail for a lengthened period.

Although I may be quitting the strict limits of induction, I cannot conclude this paper without mentioning one impression which a review of the circumstances connected with the subject has made upon my mind. There is no doubt that great vicissitudes in the climate of any particular region may be caused by fluctuations in the isothermal lines resulting from changes in the relative distribution of land and water. But these fluctuations have a limit, which limit seems to me to have been greatly exceeded during the height of the glacial period. Looking at the special nature of such a remarkable reduction of temperature, closing as it were a vast cycle of anterior geological changes, and seeing its exceptional nature with reference to the general indications of higher temperatures which previously prevailed, I confess I feel deeply and strongly impressed with the probability that in this unexpected succession of changes we may trace evidence of great and all-wise design. If the cause were general (and there are strong reasons to believe that such was the case), the fact of the earth having been subjected to the severe and rigorous temperature of the glacial period must have led to a more rapid abstraction of heat from the surface than would have occurred without the intervention of a cold period, establishing, as it were in anticipation, a state of equilibrium which might otherwise have been indefinitely deferred had the refrigeration been gradual and uninterrupted; for on the removal or cessation of the refrigerating cause, the surface would be left in a condition to suffer for a certain period little or no further loss by radiation and no further contraction. The state of repose thus effected may have helped to impart to the earth's crust that stability and immobility which render it fit and suitable for the habitation of civilized man.

Appendix.—List of the Testaceous Mollusca now living in the South of England and North of France, showing those which are found fossil in the High- and Low-level Valley-gravels, and their range to certain points northwards and southwards in Europe.

Species living in the South of England (excepting those marked in italics, which are found in France but not in England). This list (of 110 species) embraces nearly all the freshwater species and the greater part of the land shells of the North of France.	Species occurring in the Valley-gravels.				Species living in Finland and Lombardy (the Alpine districts excepted). In the former country there are 77 species of Testaceous Mollusca, and in the latter 193 species.	
	England.		France.			
	High-level ?	Low-level.	Low-level.	High-level.		
	Bedford, *Biddenham.*	Bedford, *Harrowden* &c.	Abbeville, *Menchecourt.*	Amiens, *St. Acheul.*	Finland.	Lombardy.
Freshwater Bivalves.	1.	2.	3.	4.	5.	6.
Anodonta anatina, *Linn.*	*?	......	......	......	———	———
—— cygnea, *Linn.*	......	......	......	......	———	———
Cyclas (*Sphærium*) cornea, *Linn.*	*	*	*	*	———	———
—— lacustris, *Müll.*	......	......	*	......	———	———
—— ovalis, *Fér.*	......	......	......	......	......	......
—— rivicola, *Leach*	......	......	......	......	......	......
Pisidium amnicum, *Müll.*	*	*	*	*	———	......
—— fontinale, *Drap.*	*	*	*	*	———	———
—— nitidum, *Jen.*	*	*	*	......	———	......
—— pusillum, *Gmel.*	......	......	......	*	......	......
—— roseum, *Scholtz*	......	......	......	......	———	———
Unio *littoralis*	......	*	......	......	......	......
—— margaritifer, *Linn.*	......	......	......	......	———	......
—— pictorum, *Linn.*	......	......	......	......	———	......
—— tumidus, *Phil.*	......	......	......	......	———	......
Freshwater Univalves.						
Ancylus lacustris, *Linn.*	*	......	......	......	———	———
—— fluviatilis, *Müll.*	*	*	*	*	———	———
Bythinia Leachii, *Shep.*	......	......	......	......	......	......
—— tentaculata, *Linn.*	*	*	*	*	———	———
Hydrobia marginata, Mich.	*	......	*	......	......	......
Limnæa auricularia, *Linn.*	*	*	*	......	———	———
—— glabra, *Müll.*	......	......	......	*	———	———
—— glutinosa, *Müll.*	......	......	......	......	———	......
—— palustris, *Drap.*	......	*	*	*	———	———
—— peregra, *Müll.*	*	*	*	*	———	———
—— stagnalis, *Linn.*	*	*	*	*	———	———
—— truncatula, *Müll.*	*	*	*	*	———	———
Neritina fluviatilis, *Linn.*	......	......	......	......	———	———
Paludina contecta, *Müll.*	......	......	......	......	———	———
—— vivipara, *Linn.*	......	......	......	......	———	......
Planorbis albus, *Müll.*	......	*	*	*	———	———
—— carinatus, *Müll.*	......	......	*	......	......	———
—— complanatus, *Linn.*	*	......	*	*	———	———
—— contortus, *Linn.*	......	......	......	......	———	———
—— corneus, *Linn.*	......	......	*	......	———	———
—— glaber, *Jeffr.*	*	*	......	......	......	———?
—— lineatus, *Walk.*	......	......	......	......	......	......
—— Nautileus, *Linn.*	*	......	*	......	———	......
—— nitidus, *Müll.*	......	......	......	*	———	......
—— spirorbis, *Linn.*	*	*	*	*	———	———
—— vortex, *Linn.*	*	*	*	*	———	———
Physa fontinalis, *Linn.*	......	......	......	......	———	———
—— hypnorum, *Linn.*	......	......	......	......	———	———
Valvata cristata, *Müll.*	*	......	*	......	———	———
—— piscinalis, *Müll.*	*	*	*	*	———	———
Land Shells.						
Achatina acicula, *Müll.*	......	......	......	......	———	———
Acme lineata, *Drap.*	......	......	......	......	......	———
Azeca (*Cochlicopa*) tridens, *Pult.*	......	......	......	......	......	———
Balea perversa, *Linn.*	......	......	......	......	———	———
Bulimus acutus, *Müll.*	......	......	......	......	......	———
—— montanus, *Drap.*	......	......	......	......	......	......
—— obscurus, *Müll.*	......	......	......	......	———	———

Appendix (continued).

Species living in the South of England (excepting those marked in italics, which are found in France but not in England). This list (of 110 species) embraces nearly all the fresh-water species and the greater part of the land shells of the North of France.	Species occurring in the Valley-gravels.				Species living in Finland and Lombardy (the Alpine districts excepted). In the former country there are 77 species of Testaceous Mollusca, and in the latter 193 species.	
	England.		France.			
	High-level ?	Low-level.	Low-level.	High-level.		
	Bedford, *Biddenham.*	Bedford, *Harrowden* &c.	Abbeville, *Menchecourt.*	Amiens, *St. Acheul.*	Finland.	Lombardy.
Land Shells (continued).	1.	2.	3.	4.	5.	6.
Carychium minimum, *Müll.*	......	......	*	......	——	——
Clausilia biplicata, *Mont.*	......	......	......	......	——	......
—— laminata, *Mont.*	......	......	......	......	——	......
—— *plicatula*, Drap.	......	......	*	......	——	——
—— Rolphii, *Gray*	......	......	*	......	......	......
—— rugosa, *Drap.*	......	......	*	......	——	——
Cyclostoma elegans, *Müll.*	......	......	*	......	......	——
Helix aculeata, *Müll.*	......	......	......	......	——	......
—— *apicina*,	......	......	* ?	......	......	......
—— arbustorum, *Linn.*	......	......	*	......	——	......
—— aspersa, *Müll.*	......	......	......	......	......	——
—— Cantiana, *Mont.*	......	......	*	......	......	——
—— caperata, *Mont.*	......	......	*	......	......	——
—— Carthusiana, *Müll.*	......	......	*	......	......	——
—— concinna, *Jeffr.*	*	......	*	*	......	......
—— ericetorum, *Müll.*	......	......	......	......	......	——
—— *fruticum*, Müll.	......	......	*	......	——	......
—— fulva, *Müll.*	......	......	......	......	——	——
—— fusca, *Mont.*	......	......	......	......	......	......
—— hispida, *Linn.*	*	*	*	*	——	——
—— lapicida, *Linn.*	......	......	......	......	——	......
—— nemoralis, *Linn.*	......	......	*	*	——	——
—— obvoluta, *Müll.*	......	......	......	......	——	——
—— pomatia, *Linn.*	......	......	......	......	——	——
—— pulchella, *Müll.*	*	*	*	*	——	——
—— pygmæa, *Drap.*	......	......	*	......	——	......
—— revelata, *Mich.*	......	......	......	......	......	......
—— rotundata, *Müll.*	......	......	*	*	——	——
—— rufescens, *Pennant*	......	......	......	......	......	——
—— rupestris, *Stud.*	......	......	......	......	......	——
—— sericea, *Müll.*	......	......	......	......	——	......
—— virgata, *Da Costa*	......	......	......	......	......	......
Pomatias obscurus	......	......	*	......	......	......
Pupa marginata, *Drap.*	*	*	*	*	——	——
—— ringens, *Jeffr.*	......	......	......	......	......	......
—— secale, *Drap.*	......	......	......	......	......	......
—— umbilicata, *Drap.*	......	......	......	......	——	——
Succinea elegans, *Ris.*	......	*	*	*	——	......
—— oblonga, *Drap.*	* ?	* ?	*	*	——	——
—— putris, *Linn.*	*	......	*	*	——	——
Vertigo angustior, *Jeffr.*	......	......	......	......	......	......
—— antivertigo, *Drap.*	......	......	......	......	——	——
—— edentula, *Drap.*	......	......	......	......	——	——
—— minutissima, *Hartm.*	......	......	......	......	——	——
—— pusilla, *Müll.*	......	......	......	......	——	——
—— pygmæa, *Drap.*	......	......	......	......	——	——
—— substriata, *Jeffr.*	......	......	......	......	——	......
Vitrina pellucida, *Müll.*	......	......	......	......	——	——
—— *diaphana*, Drap.	......	......	*	......	......	——
Zonites alliarius, *Müll.*	......	......	......	......	......	......
—— cellarius, *Müll.*	......	......	......	......	——	——
—— crystallinus, *Müll.*	......	......	*	......	——	——
—— excavatus, *Bean*	......	......	......	......	——	......
—— nitidulus, *Drap.*	......	......	*	......	——	——
—— nitidus, *Müll.*	......	......	......	......	——	——
—— purus, *Ald.*	......	......	*	......	——	——
—— radiatulus, *Ald.*	*	......	*	*	......	......
Zua lubrica, *Müll.*	......	*	*	*	——	——

Explanation of the Plates.

PLATE IV.

The uncoloured ground-plan shows the chief geological divisions of the country. The coloured lines indicate the course of the débris derived from the several principal formations. The lines are carried through from the parent rocks to the sea; but it is to be observed that the débris of each of these lines becomes less and less abundant as they recede from their source, so that all traces of some of them sometimes nearly disappear before the end of the river-valley is reached. In places, also, the gravels formed by these débris meet with long interruptions, those on the higher levels especially; the lower-level gravels are more continuous, though they are constantly hidden by recent alluvia. They also vary materially in width. These more minute details are represented for small portions of two river-valleys in Plate V. The scale of the Map does not admit of the delineation of the lines of débris of each valley. The chief river-valleys and their principal tributaries are therefore selected, but the same law of the occurrence of high- and low-level gravels, and of the local limitation of the various rock débris to the several river-basins, is applicable to all the river-valleys in the area comprised in the Map. The authorities for France are the several authors mentioned in the text, with a few observations of my own. The English part of the Map is given from my own personal observations. The commencement of some lines of débris is not unfrequently higher up the valleys than marked on the Map, or from rocks beyond the present range of the river. This arises from the presence of outliers of certain formations more or less beyond the limits of the main mass, which outliers are not represented on the Map: in other cases the débris are derived from secondary sources, like the palæozoic, oolitic, and cretaceous débris of the Boulder Clay; and in a few cases, especially in the Wealden area, they arise from the originally greater length of the rivers.

PLATE V.

Figs. 1 & 2 show the distribution of the high- and low-level valley-gravels, and of the Loess in parts of the valley of the Somme adjacent to Abbeville and Amiens. The relative position of the high-level gravels and of the plateau Loess is not always quite clear. In many cases I consider the latter to be newer than some of the former; but, at the same time, there is a quaternary argillaceous deposit on parts of the chalk hills which I believe to be older than any of the valley-gravels. This is generally more removed from the river-valleys than shown in these plans.

The valley-gravels are here divided into two stages only. Each stage, however, must be considered to represent not one exact level, but the several nearly allied terraces formed during a particular time. It may be assumed, for example, that the high-level gravels include all the terraces at heights

of from 90 to 150 feet above the river, and the low-level gravels those up to 30 or 40 feet above the river. In fact, no definite line can properly be drawn, as all the terraces are members of one series: nevertheless it is not only for the sake of convenience that this division is adopted; it is to a great extent conformable to the phenomena as they exist; for the great bulk of these quaternary gravels occur, one portion on terraces at or near 100 feet above the Somme, and another portion at or near 30 feet. The gravels on both levels, especially the lower one, are often covered by Loess—the low-level gravel being constantly buried under it and hidden, whilst both Loess and gravel disappear under the recent alluvium. The heights are taken in part from the French Ordnance Maps; the others are from observations I have taken with the aneroid barometer. The general topographical outlines of the districts are also taken from the French Ordnance Maps.

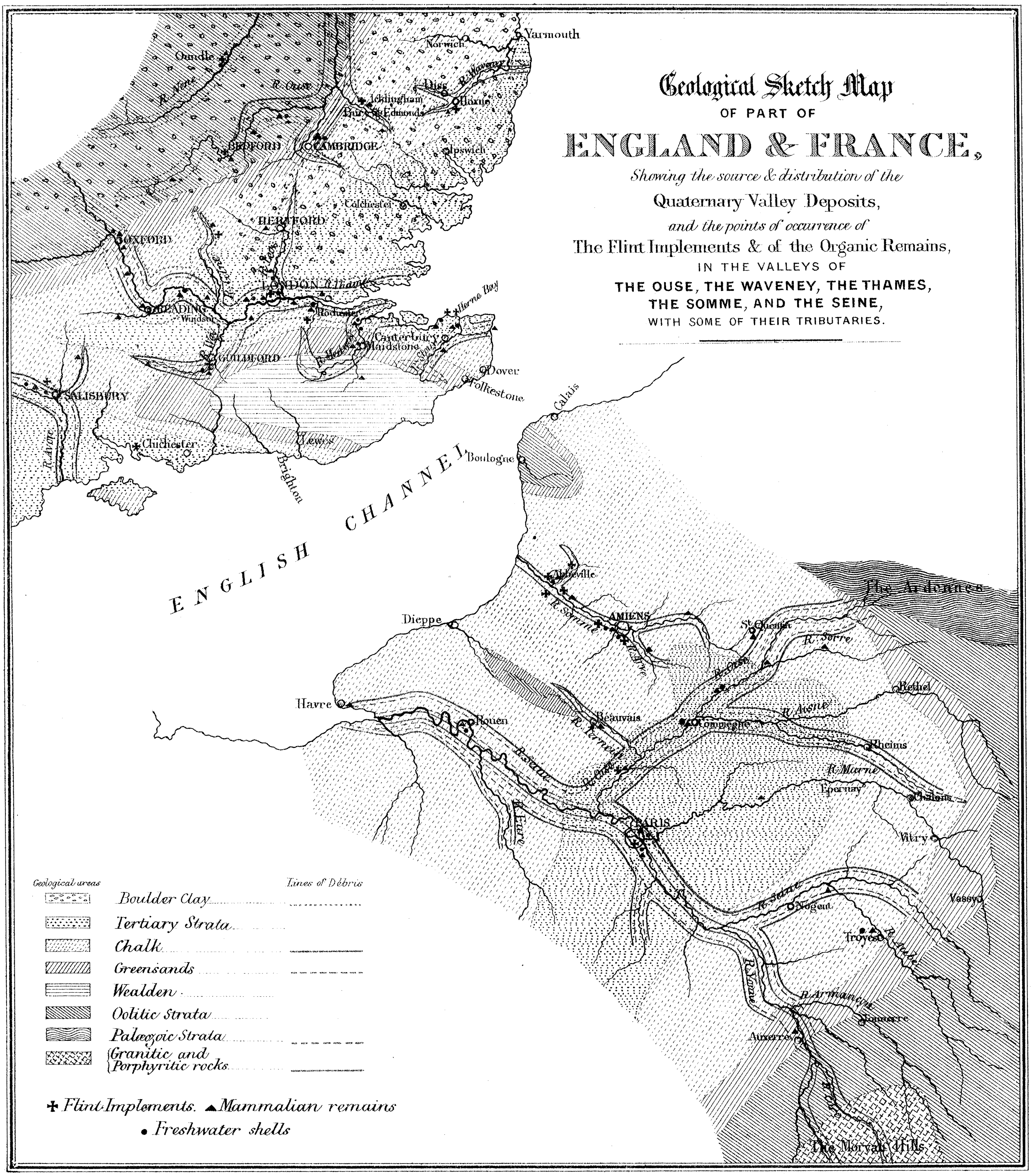
Fig. 3 shows the valley-gravels along part of the valley of the Waveney. The scale is that of the Ordnance Map, from which the topographical outlines are taken. The same observations apply to these gravels as to those of the Somme; only the series is more limited, and the heights to which they rise is not so great; 50 feet is about the extreme height. The Loess is here in so rudimentary a state that I have not laid it down. The heights at Hoxne are from the levellings given in my former paper, or are taken with an aneroid.

Not to interfere with the details, the roads, and all except a few chief places, are omitted, but it is easy to find any particular spot by transfer to the French and English Ordnance Maps, on the scales of which these plans are made.

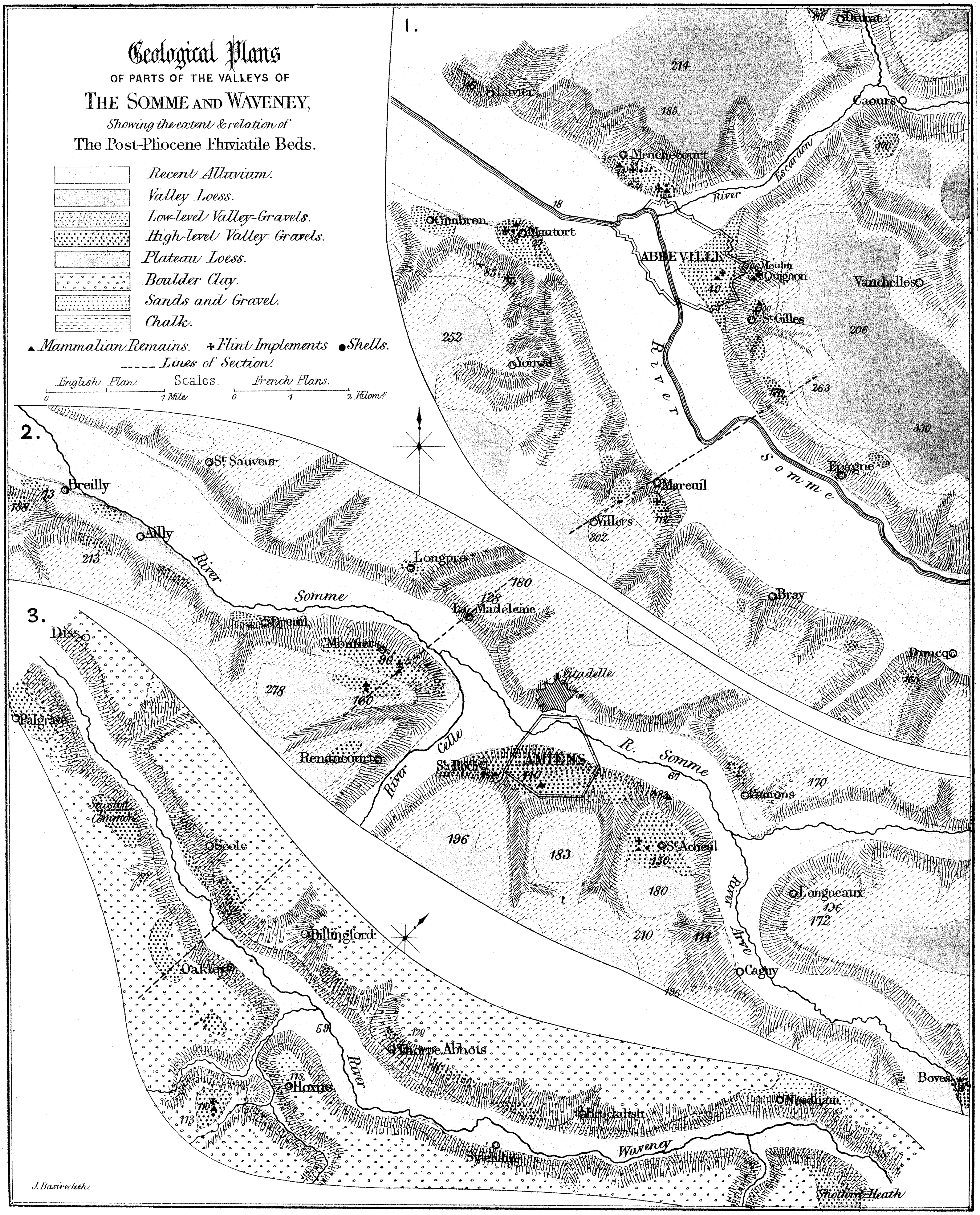
The dotted lines across the valleys refer to the lines of section given in woodcuts pp. 253, 258, and 259.

Note.—There is some obscurity in the shading, arising from a mistake of the artist in taking my rough MS. sketch instead of the Ordnance Maps which accompanied it for his guide in these topographical details. I must refer to the Ordnance Maps therefore for the more correct delineations of the surface. Some errors of geographical detail have from the same cause crept into the Map.

INDEX OF CONTENTS.

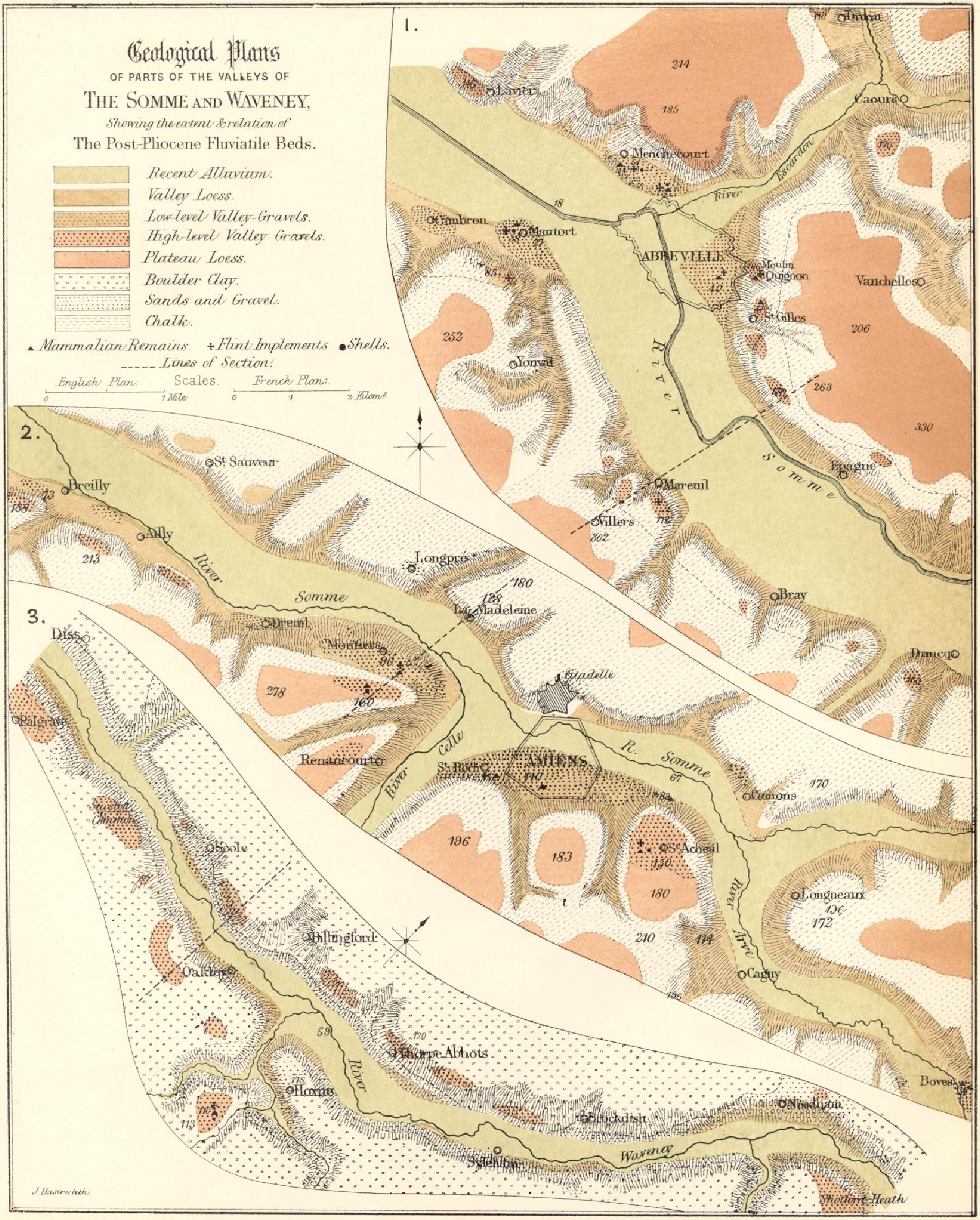


J. Basire, lith.



Geological Plans
OF PARTS OF THE VALLEYS OF
THE SOMME AND WAVENEY,
Showing the extent & relation of
The Post-Pliocene Fluviatile Beds.
Recent Alluvium.
Valley Loess.
Low-level Valley-Gravels.
High-level Valley-Gravels.
Plateau Loess.
Boulder Clay.
Sands and Gravel.
Chalk.
Mammalian Remains.
Flint Implements
Shells.
Lines of Section.
English Plan.
Scales.
French Plans.
0
1 Mile
0
1
2 Kilom.s
1.
2.
3.
ABBEVILLE
Menchecourt
Caours
Mautort
Cambron
Moulin Quignon
Vauchelles
St Gilles
Yonval
River Somme
River Escardon
Mareuil
Villers
Epagne
Bray
St Sauveur
Breilly
Ailly
Longpre
La Madeleine
Montiers
Renancourt
River Celle
Citadelle
AMIENS
St Roch
R. Somme
Camons
St Acheul
Longueaux
Cagny
River Avre
Boves
Diss
Palgrave
Scole
Billingford
Oakley
Thorpe Abbots
Hoxne
Syleham
Needham
Waveney
River
Shotford Heath
J. Basire, lith.

Geological Sketch Map
OF PART OF
ENGLAND & FRANCE,
Showing the source & distribution of the
Quaternary Valley Deposits,
and the points of occurrence of
The Flint Implements & of the Organic Remains,
IN THE VALLEYS OF
THE OUSE, THE WAVENEY, THE THAMES,
THE SOMME, AND THE SEINE,
WITH SOME OF THEIR TRIBUTARIES.
Geological areas
Lines of Débris
Boulder Clay
Tertiary Strata
Chalk
Greensands
Wealden
Oolitic Strata
Palæozoic Strata
Granitic and Porphyritic rocks
✠ Flint Implements. ▲ Mammalian remains
• Freshwater shells
Yarmouth
Norwich
Oundle
R. Nene
R. Ouse
Diss
R. Waveney
Hoxne
Icklingham
Bury St Edmonds
BEDFORD
CAMBRIDGE
Ipswich
Colchester
HERTFORD
OXFORD
LONDON
READING
Windsor
Rochester
Herne Bay
Canterbury
Maidstone
GUILDFORD
Dover
Folkestone
SALISBURY
R. Avon
Chichester
Lewes
Brighton
Calais
Boulogne
ENGLISH CHANNEL
Abbeville
R. Somme
AMIENS
Dieppe
St Quentin
R. Serre
The Ardennes
R. Oise
Rethel
Havre
Rouen
Beauvais
R. Aisne
Compiegne
Rheims
R. Marne
Epernay
Chalons
R. Seine
R. Eure
PARIS
Vitry
Nogent
Vassy
Troyes
R. Aube
R. Yonne
R. Armancon
Tonnerre
Auxerre
The Morvan Hills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0
1 Mile
0
1
2 Kiloms
1.
2.
3.
Caours
Menchecourt
Cambron
Mautort
ABBEVILLE
Moulin Quignon
Vanchelles
St. Gilles
Yonval
River Escardon
River Somme
Epagne
Mareuil
Villers
Bray
St. Sauveur
Breilly
Ailly
Longpré
La Madeleine
Dreuil
Montiers
Citadelle
AMIENS
Renancourt
River Celle
St. Roch
R. Somme
Camons
St. Acheul
Longueaux
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