March 27, 1862.

Major-General SABINE, President, in the Chair.

The following communication was read:—

"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, 1862.

(Abstract.)

In his former paper on the subject of the Flint-implements*, the author postponed the consideration of the theoretical questions, to allow time for a fuller investigation of the physical phenomena. The points then sought to be established were,—the artificial make of the specimens,—their position in undisturbed ground,—and their contemporaneity with the extinct animals. The points for present consideration relate to the structural and physical phenomena, and to various theoretical questions.

In the present paper the author proceeds to show that the flint-implements are found along the line of existing river-plains at heights varying from 20 to 100 feet above the rivers, and that the beds of sand and gravel in which they are imbedded can be divided into two more or less distinct series, one continuous along the bottom of the valleys and rising but little above the river-level, and to which he proposes to apply the term "*Low-level Gravels*," and the other in detached masses on the heights flanking the valleys, and at 50 to 200 feet above the rivers, and which he designates as the "*High-level Gravels*†." Both gravels 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; both are, in fact, related to former plains and present valleys.

* Read before the Royal Society 26th May, 1859; Phil. Trans. 1860, p. 277.

† At the reading of this paper, the author used the terms "Terrace Gravels" and "Valley Gravels;" but he thinks it better to revert, with limitations, to terms which he suggested some years since, but has not hitherto defined.

This structure is then shown to apply to the Waveney, where there is a terrace of gravel on both sides of the valley at a level of about 40 feet above the river, and to which position, but to a more lacustrine condition, the Hoxne deposit belongs. Sections are given of this valley, and also of the valleys of the Lark at Icklingham and of the Ouse at Bedford, showing the constancy of this structure. In the valley of the Thames the phenomena are more complicated and are reserved for future consideration, notice being merely taken of the implements found at Herne Bay and Whitstable.

Owing to the absence of marine newer and post-pliocene beds in the North of France, these gravels are better exhibited and more distinct, being free from rock-fragments and boulders foreign to their own origin and area. Hence it has arisen that this part of the geological series has been more investigated in France than in England. In the admirable review of the Quaternary formations by M. d'Archiac, two general conclusions are set forth. With the first of these the author perfectly agrees. It is that each large hydrographical basin, although the boundaries may not be marked by any important elevation, has its own exclusive *drift*, and that in no case is there a mixture of the transported materials of the separate basins. The author, however, dissents from the opinion that these drifts, containing the remains of large extinct mammalia, have in any way depended on or resulted from any general cataclysm destroying these creatures nearly simultaneously over wide continents and entombing their remains in the sand, gravel, and shingle of the valleys and in the earth of the caverns; neither can he consider the excavation of the valleys to be anterior to the spread of the drift-gravels. On the contrary, he refers the phenomena to long-continued river-action.

An account is then given of the valley of the Somme, and it is stated that the relation between the high- and low-level gravels, which could not be proved with respect to St. Acheul and St. Roch, has been made clearly apparent at Montiers near Amiens, by the opening of a new ballast-pit on the side of the railway, some 50 feet above the level of the old gravel-pits in the valley just below, and in which latter *flint-implements* were first found by the author in the spring of last year. In the upper ballast-pit a considerable number of land and freshwater shells and some mammalian bones have been found,

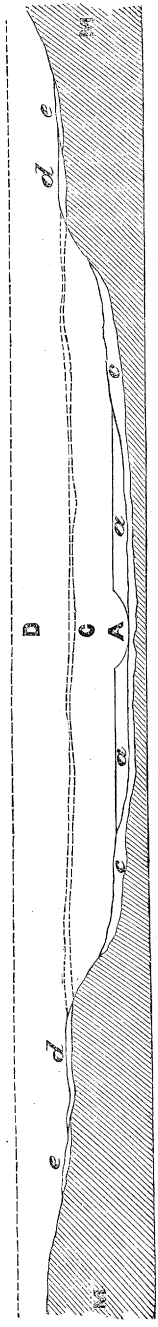
but as yet no flint-implements. This deposit, as also the now well-known flint-implement-bearing beds of St. Acheul, are considered to belong to the high-level gravels, whilst the gravel of St. Roch and that of the old Montiers pits are placed with the low-level gravels. Both sets of gravels are also developed in the neighbourhood of Abbeville, and both there contain flint-implements; Moulin Quignon belonging to the higher level, and Menchecourt and Mautort (village) to the lower level.

In the course of last year M. Gosse discovered flint-implements in association with the remains of the Mammoth in some gravel-pits near the well of Grenelle at Paris. This bed belongs to the low-level gravel. The same gravel is also worked to the S.E. of Paris at the Gare d'Ivry, where, as at Montiers, it abuts against the hill-side. On the hill above, and 115 feet higher, there occurs at Gentilly a deposit of sand and gravel, with land and freshwater shells and mammalian remains, precisely like that at St. Acheul. At Charonne, on the opposite side of the valley and distant 4 miles, a similar deposit, corresponding in its height above the river, in its collection of freshwater shells, and in its mineral contents, is met with. No flint-implements have yet been found in these beds, but in every other respect they agree with the gravel of St. Acheul. These deposits, which have been described by M. Duval and M. Charles d'Orbigny, contain the same débris as the present Seine valley, and amongst it fragments of *granite* derived from the hills of the Morvan, at a distance of 120 miles from Paris.

It is then shown, by reference to the works of M. Leymerie, M. Cornuel and other geologists, that the valleys of the Seine and of its tributaries above Paris are occasionally flanked by heights capped with gravel containing at places remains of the Elephant, Deer, Horse, &c. In some instances these gravels rise to a height of 190 feet above the river, but the general height is from 60 to 150 feet. Sometimes they expand to a breadth of 4 to 5 miles, but they more usually form narrow belts. Various other French authors are then quoted, to show that the same structure prevails in the valleys of the Oise (where one instance of a flint-implement is recorded by M. de Verneuil), of the Marne, the Aire, the Aube, and their numerous tributaries; and in each instance it is shown that the materials, both of the high- and low-level gravels, are derived strictly from the

district through which the valley passes; that only the Seine valley contains granite from the Morvan, the Oise slate-rock débris from the Ardennes, the Marne nothing older than oolitic débris, whilst the Thérain and the Somme valleys contain nothing but débris of the chalk and tertiary strata. The same rule applies to the English area; but the fact is not so apparent, owing to various conflicting elements pointed out by the author who shows, by a map of the two countries, how great are the range and spread of these beds, and how large a proportion of our drift-gravels are of fluviatile origin.

The High-level Gravels.—From the facts recorded by the several independent observers abroad, and from his own observations in this country, the author arrives at a general proposition illustrated by the accompanying diagram, which shows,—1. D, a major valley or plain of denudation anterior to the excavation of the river-valley. 2. *e*, a non-fossiliferous drift on the slope and base of D. 3. C, the river-valley. 4. *d*, the high- and *c*, the low-level gravels. 5. *a*, recent alluvium. 6. A, the present river-channel.



The high-level gravels (*d*) appear on both sides of the valley, and their connexion before the excavation of C is pointed out. This is one of the points insisted upon by the author; the two having been generally considered as contemporaneous, or even sometimes the higher-level deposits as newer than those of the lower level. It is to be observed that the phenomena here referred to relate to broad valleys, and not merely to river-channels.

The *loess* is not shown in the diagram, otherwise the section represents the condition of the case on the supposition that all the parts are complete. But this rarely happens. Some low-

level gravel is constant, but the high-level gravels are only occasionally preserved. Sections are then given to explain the cause of their absence—such as where the valley C being wider than the original bed of the old river which deposited the gravel *d*, the latter has been necessarily altogether removed.

That the formation of the higher gravels can be owing to the action of the present rivers is clearly impossible under existing conditions; for not only are they far above the level reached by the rivers at the highest floods, but also the sectional area of the valleys, compared to that of the present rivers, is so vast, that in no possible way, except by the sea, could they now be filled with water. Sections are given of the valleys of the Waveney, Ouse, Somme, and Seine, showing a disproportion between the rivers at their highest floods and the old valleys, on the average, about 1 : 500; and it is shown, with respect to the great flood of the Seine in 1658, when the waters at Paris rose to a height of 29 feet, that it would require a flood of at least one hundred times that magnitude to fill (with the water even in a state of rest) the valley of the Seine to the level of the high-level gravels of Gentilly and Charonne.

That the isolated beds of high-level gravels must at one time have been connected in length and breadth is evident from the circumstance of these detached parts having certain characters in common, and from the fact that if the deep valleys which they overhang, and the transverse valleys which they pass over, had then existed, they would have presented insuperable barriers to the deposition of the gravels at levels so much higher.

That the transport of this drift could have been caused by the bursting of lakes, by the sudden melting of the glaciers and snow of mountain-chains, or by the transient passage of a body of water over the land is not possible, because the spread of the débris would have been more general, would have held its course more irrespective of the existing watersheds, and would have shown an amount of wear in proportion to the distance travelled; whereas in each basin the débris is local, however low the watershed. None of the slate and oolitic débris of the Oise valley traverses into the valley of the Somme, notwithstanding the watershed between them is only six miles broad and eighty feet high.

There are two ways in which the author conceives the spread of

the débris in the various directions and distinct areas could have been effected; the one by the rise of the land from beneath the sea, and the other by the action of rivers on a larger scale than the present ones. As the later tertiary deposits show the existence of seas or of lakes over the districts in question, it follows as a necessary consequence that when the land rose from beneath them, a mass of débris, in quantity and length of transport proportionate to the greater or lesser rate of elevation, must have been spread over the bottom of the channels along which the water flowed off. Nearly associated with the high-level gravels there are remnants of another drift which may have had this older and independent origin. This mode of formation could not, however, be applied to the valley gravels, as they contain freshwater shells such as live in rivers, with land shells and mammalian remains, proving the existence of a dry land.

The author concludes that the high-level gravels are the result of river-action which took place at a period before the excavation of the present river-valleys. With regard to the mode of formation of these gravels, he remarks on the materials being often transported a considerable distance,—the frequent presence of large blocks or boulders of the harder rocks,—the presence of a certain proportion of angular débris,—and the commonly confused bedding and contortions. He shows this to exist in England and in France, and supports the case by quotations from various French authors. It is then shown that in the valley of the Somme these phenomena are most marked and decisive,—large blocks of sandstone, some weighing four to five tons, and derived from tertiary strata twenty to forty miles above Amiens, being found in the St. Acheul gravels, and the beds being much contorted. These contortions do not depend on any pressure exercised by the blocks, but result from some disturbing power applied and removed. To illustrate this point reference is made to two sections in his former paper (Phil. Trans. for 1860, p. 299).

The author conceives that the only adequate cause to produce many of these effects is river-ice, the transporting power of which is well known, whilst he quotes the observations of travellers in Northern America to prove the power of such ice to pile-up the shore shingle in great conical heaps. That the old pleistocene rivers were also larger and more rapid than the existing rivers is evident from

the great quantity of débris, the prevalence of gravels, the coarseness of the sands, and the general absence of mud-sediments. Another agent of considerable power is referred to, viz. ground-ice, but is reserved for consideration further on.

The Fauna of the High-level Gravels.—The organic remains are considered with reference especially to the climatal conditions of the period, and it is regretted that, owing to the scarcity of fossils except at a few places, and to the want of specific information with regard to the mammalian remains and the levels, the evidence on many points is unavoidably incomplete. The best-determined group is that of the Mollusca, in examining which the valuable assistance of Mr. Gwyn Jeffreys is acknowledged. The author gives a Table showing the group of land and freshwater shells inhabiting, in England and France, the area now described, from which comes out the striking result that out of 109 living species 43 are found in the deposits of the high-level gravel period. There is a scarcity of Unionidæ and Paludinidæ, whereas Limnæidæ and Helicidæ are very common. In many places shells are scarce or altogether wanting; but this is common in all rivers subject to floods or bringing down much shingle. All the species are of existing forms, and all, with four exceptions, inhabit the same districts as formerly. Their range is then reviewed, and it is shown that though a considerable proportion of them are found in the South of France, a still larger proportion exist in Scandinavia, and that as many as thirty-five out of the forty-three species are met with in Finland, including the common forms, such as *Succinea putris, S. Pfeifferi, Helix hispida, H. nemoralis, H. pulchella, Pupa muscorum, Limnæus pereger, L. palustris, L. truncatula, Planorbis corneus, P. vertex, P. marginatus, P. albus, P. spirorbis, Bythinia tentaculata, Valvata piscinalis, Pisidium amnicum,* &c. From these and other facts it is concluded that, while there is nothing in the Mollusca to necessitate a climate different from that of the present day, there is nothing to require restriction to an identical climate, while at the same time the tendency of development of the group is rather in a northern than in a southern direction.

The several genera and species of Mammalia are then considered, the principal being *Elephas primigenius, Rhinoceros tichorhinus, Bison priscus,* with several species of *Equus, Bos, Cervus,* whilst the

Reindeer is found in deposits of the same period; and an opinion is expressed that the evidence with respect to the climatal conditions furnished by the Mammalia, although slight, is more definite than that obtained from the Mollusca, and tends to show the probability of the climate at the period of the high-level gravel having been colder than that of these latitudes at the present day. The flora is scanty and of little avail. It is then remarked 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 should at present fail to arrive at any safe and exact conclusion. If, however, these indications are taken in conjunction with the physical features, the conjoint evidence has weight and more preciseness; and the author concludes, from a review of all the facts, that there must have been a mean winter cold of not less than 20°, and possibly as low as 10°, or from 19° to 29° below the mean winter temperature (39°) of this part of Europe. The cave evidence would have helped this question.

The Flint-Implements.—These works of man are first discovered in beds of the high-level gravel period. The most ordinary shapes are the large spear-head form, either with a sharp point or a flat rounded one, and with the butt end sometimes blunt, and at other times chipped to an edge. With regard to the manner in which they came to be imbedded in the gravel, it can only be surmised from their condition, from our present experience, and by considering the uses to which they could possibly have been applied.

These conditions are then reviewed, and it is shown that the flint-implements rarely or never show indications of atmospheric weathering; that they are rarely worn, but are usually sharp and angular, like some of the large unworn flints which have been attributed to transport by ice; also that they are most common where the evidence of ice-action is the greatest, as at St. Acheul and Moulin Quignon. The climate of the period having been severe, it is essential to keep in mind the usages of tribes under like conditions at the present day. The mode of life of the Chipweyan Indians and the Esquimaux is then considered; and it is shown that a hatchet, an ice-chisel, a file and knives, of stone or metal, are all the instruments they need or use. It is further shown that when in winter the usually abundant supplies of Reindeer fail, these people resort commonly to fishing in the frozen rivers, and then use their ice-chisels

for making holes in the ice. These implements are also in daily use for keeping open the water-holes. Analogous facts are quoted from Wrangel respecting Siberia. The author suggests therefore that some of the mysterious flint-implements (such as fig. 5, pl. 12, Phil. Trans. 1860) of St. Acheul may have been used as ice-chisels. Reasons are then assigned for their presence chiefly at particular spots; and reference is made to other forms of flint-implements, all of which admit of explanation, except those of a flat ovoid shape, common at Abbeville, which are unlike any instrument in use amongst any existing uncivilized tribes.

Notwithstanding the probable severity of the climate, it was one by no means unsuited to the existence of man, whilst the character of the contemporaneous animal life of the period was perfectly fitted for his support and sustenance.

A difficulty has been raised because hitherto no human bones have been found in these gravels; but when it is considered how scanty is the population in northern latitudes, and how disproportionately numerous are the great herds of Deer, Oxen, and other animals (fossil remains of which are yet comparatively rare), this fact, taken in conjunction with the foresight of man, indicates how small are the chances of finding his remains. Nevertheless in other deposits probably of the age of these gravels, such as some of the caves near Liège described by Schmerling, the scattered bones of man have been found in association with a like mammalian fauna.

The Low-level Gravels.—Connected with this subject is the excavation of the valleys, and the duration of that operation. The author mentions how he hesitated to assign at first a much higher antiquity to the higher gravels than to the lower gravels, or rather, admitting a difference of age, to decide whether the excavation of the valleys might not have been effected by some more powerful agency acting through a short interval of time, and by so much contracting the period by which the St. Acheul deposit preceded that of St. Roch; but after repeated visits to Amiens, and looking at the question from every point of view, he finds himself unable to discover a sufficient explanation in the direction first sought, and obliged to adopt, in part, views differing materially in some points from those he at first thought to be the more probable. The low-level gravels

have been frequently described, and the author confines himself chiefly to pointing out the difference between them and the high-level gravels. The climate at the one period has been described as one of considerable severity; but there is evidence to show that in some part of the pliocene period, previous to that time, the cold was still more severe. At the period referred to the greater part of England was under the sea, whereas Switzerland and the greater part of France had emerged at an earlier or a miocene period, and there is no sufficient proof of their having been subsequently submerged. This was the period of the wonderful extension of the old European glaciers, which descended in the Swiss Alps, the Jura, and the Vosges to within 1200 or 1000 feet of the sea-level, the existing glaciers standing at 3400 to 3500 feet. M. Leblanc has calculated that such a difference of level might be accounted for by a reduction in the mean annual temperature of $12\frac{1}{2}^{\circ}$ Fahr.; but the author questions this, as the gradients of the glacier beds were much less after they had emerged from the mountain-passes. The growth of the old glaciers is rather the result of the great cold than a measure of it. Still it can be conceived that their growth would be checked when the temperature had risen from the extreme cold to a point $12\frac{1}{2}^{\circ}$ below the present mean annual temperature. This would reduce the mean annual temperature here to $37\frac{1}{2}^{\circ}$,—that of Moscow and Quebec, with which the climate at the higher gravel period has been before compared, being respectively 40° and 41°,—and would agree with what has been considered the probable mean winter temperature of that period, viz. one between 10° and 20°.

Taking this as the starting-point, the effect of such conditions with reference to the quantity of ice and snow stored up during this period of cold, and to its effect on the river-discharges for many years afterwards during the period of the valley gravels, has to be considered. The melting of the winter snow would necessarily cause spring floods. Another cause of floods is the fall of rain whilst the ground is still frozen. These causes, combined possibly with a larger rainfall, must have afforded to the old rivers, either permanently or at all events during spring-time, a volume of water far exceeding any present supply, and giving them more of a torrential character. Instances are quoted from Sir R. Murchison's 'Russia' and Wrangel's 'Siberia,' and others, to show how this is still the case every spring in northern

countries, causing a rise in the rivers of from 10 to 40 feet, and inundating the adjacent valleys.

Other forces, however, besides an increase in the water-power, seem required to account for the excavation of the great valleys, and the author thinks that cold and ground-ice have performed a very important part in the operation. In support of this view, he adduces the opinion of Arago and the observations of M. Leclercq and Col. Jackson, both of whom show how constantly this ice is formed in cold climates in rivers with stony and gravelly bottoms, such as the old post-pleiocene rivers must have been. Amongst other observations given are those of M. Weitz, who states that in the north of Siberia the formation of ground-ice can be seen in the rivers at a depth of 14 feet and more, and that in "rising from the bottom, the masses of ice bring up with them sand and stones, and let them down at places far distant from whence they came;" and he concludes, "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 deposit 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."

Another agent would co-operate with the last; this is the freezing of the ground and the rending of rocks by frost. Taking extreme cases, Crantz shows to how great an extent this operates in Greenland; Dr. Sutherland gives some still more striking instances on the shores of Barrow Strait, and Sir J. Richardson on the Mackenzie River. Even in our country, the disintegration produced during one severe winter on a fresh vertical section of chalk is very striking. A remarkable instance is quoted from Sir R. Murchison's 'Russia,' of a long terrace of angular blocks of limestone broken up and left by the winter-ice 30 feet above the summer level of the Dwina near Archangel.

With all these combined operations, the author still doubts whether, without an uplifting of the land, the effects in question could have been produced; and he shows that the coasts of this part of England and France are fringed here and there by a raised beach, which he correlates with the low-level gravel of Abbeville, whilst the high-level gravel of St. Acheul is correlated with beds occupying on the coast a level higher by 50 to 100 feet, marking the difference of level

between the two periods. The effect of this slow elevation would be to increase the velocity and erosive power of the rivers. This action, with the other agencies before alluded to, operating upon the successive portions of the substrata, has gradually worn even those deep and long valleys, through which so many of the rivers of these districts flow. According to variability in the rate of elevation, to intervals of repose, or to deflections in the current and velocity of the river, there may exist intermediate levels or terraces of gravel, and variations in the inclination of the slopes, which may add much to the complexity of the problem.

The Fauna of the Low-level Gravel.—Of the forty-three species of Mollusca found in the higher gravels, thirty-four occur also in the low levels, together with seven others, making a total of forty-one species. Added to these, there are eight marine species found at Menchecourt, with the *Cyrena fluminalis* of the Nile and of Grays. With this one exception, they are all common living species of England and France. As with the former group, there is nothing to give a definite clue to the character of the climate of the period. The general absence of southern forms, and the preponderance of such as have a wide northern range, may, however, be noticed. With regard to the Mammalia, the number of determined species is small, and the general argument follows nearly the same line as that relating to the Mammalia of the higher gravels. As with the Mollusca, most of the species are common to the two series, whence it is inferred that there was no great or sudden break, and that the change both of conditions and of climate was transitional. There is one genus only, viz. the *Hippopotamus*, about which some difficulty has been felt with reference to the condition of climate. Four tusk teeth of this creature have been found at St. Roch, and in this country its remains are found associated with those of the Reindeer. Without pretending to explain the difficulty, the author does not see why, if the other large Pachyderms were fitted, as they are now known to have been, by warm covering and special adaptation to inhabit cold climates, this extinct species of Hippopotamus should not also have been so adapted.

The physical phenomena point to an increased volume of water in the rivers, and want those marked indications of ice-action seen in the high-level gravels. Still, boulders of considerable size were trans-

ported. From this fact, and the general balance of evidence furnished by the fauna, and also from the contraction of the excavation as the valleys became deeper, the author infers a gradual amelioration in the temperature, ending in the present climatal conditions.

Flint-implements.—The author observes that flint-implements are nowhere so abundant in the low- as they are in the high-level gravels. The pointed lance-shaped form with blunt butts of the latter is almost wanting in the former, whereas the ovoid disks of Menchecourt are rare at St. Acheul; again, flakes or flint-knives are common in the low-level gravels and rare in the higher beds. Of the twenty-four specimens found in the low-level gravel at Paris, twenty-two are mere flint-flakes. The author is disposed to attach some value and significance to this difference of form, and observes, that, admitting the climate to have become less severe during the low-level gravel period, it would follow that the necessity of having the strong ice-chisels would have diminished. In all these cases we are of course much limited to conjectures, seeking to make them in accordance with what we know of life under like conditions, and guided by the probabilities of the concurring circumstances. The mode of distribution of the flint-implements at the two periods certainly seems to afford some grounds for believing that the difference of form may arise from difference in the pursuits and occupations of the primitive tribes by whom they were used—pursuits necessarily and primarily influenced by the climate and life of the period.

Concluding Remarks.—The question of time is then entered upon, and it is shown that the flint-implements must be carried back through the periods of the low- and of the high-level gravels, and that they must be considered to be antecedent to the excavation of many of our great river-valleys. All these phenomena indicate periods of long and great changes. The author only slightly touches upon the formation of the *loess*, which he concludes to be the result of temporary floods; and he remarks that, so far as the question of the antiquity of the fluviatile gravels is concerned, little value need be attached to the additional element presented by this covering of loam and brick-earth. This deposit is succeeded by the alluvial beds of the valleys connected more immediately with our own times. With regard to a measure of time, the author does not consider that either the excavation of the valleys or the life evidence of the periods

furnish available data; nor does he admit the formation of the channel between England and France in the calculation; and he gives reasons to show that this channel is of older date than generally assumed, and that the separation existed at the time of the high-level gravels, and had attained somewhat of its present dimensions at the time of the newer gravels. Most of the land and freshwater shells and the Mammalia had crossed over at a period anterior to this; and, as even now at the Island of Saghaleen in lat. 52° N., the narrow strait freezing during the winter would admit of the passage of large land animals and man during the cold periods following the more extreme glacial conditions.

The author, however, suggests two new modes by which he conceives that eventually some approximate and more exact estimate may be made both of the age of the high-level gravels and of the lapse of time since the extreme glacial period, and embracing therefore the several periods under consideration. At present the evidence is only sufficient to indicate the possibilities of the problem, but it will need many years of careful observation before sufficient data can be obtained for accurate calculation.

1st. With the high-level gravels there are connected a number of sand and gravel pipes perforating the underlying chalk to the depths generally of from 5 to 50 feet, and from 1 to 10 feet wide, or more. As these are caused by the slow action of carbonic acid in the water gradually percolating through the overlying porous beds, dissolving the chalk or other calcareous strata, and gradually letting down the superincumbent drift, it is evident that if the rate of solution and removal can be determined, one element for the calculation of a certain period will be obtained. In this various meteorological questions will have to be considered.

2nd. In conducting observations on the temperature of deep mines, wells, &c., certain discrepancies in the increment of heat at increasing depths and at different places have been noticed. No explanation of these anomalies has been offered. The author suggests that they may arise from disturbing causes originating with a former period of intense cold. At Yakutsk, where the ground is now frozen to a depth of 382 feet, the permanent line of 53° Fahr. would, taking at an average an increase of 1° for every 60 feet, be found at a depth of 1642 feet. If, from some geological change, the mean tempera-

ture of Yakutsk were raised to that of our own climate, this line of 53° would undergo a vertical displacement of 1550 feet. The time required for its uniform re-adjustment over a large area would depend upon various conditions, the chief one being the conductivity of the different strata. The question, therefore, arises, whether traces of perturbation in the temperature of the outer part of the earth's crust in these latitudes, resulting from the action of the extreme cold of the glacial period, may not yet exist, and, if so, whether they may not admit of exact determination with reference to the time elapsed since the removal of the disturbing cause.

In conclusion, the author thinks that in the present state of the inquiry it would be premature to attempt to fix even approximately the lapse of time attaching to the flint-implements. It is obvious, however, that our present chronology with respect to the first appearance of Man must be very greatly extended; but, like a mountain-chain in the distance, its vast magnitude is felt before an exact measurement of its height and size can be taken.

Attention is then directed to the remarkable uninterrupted succession of life from the pleistocene period under review to the present time—a succession so large and important, that it is not possible to imagine the occurrence of any intervening catastrophe of such a nature as to destroy the life of the period over this part of Europe at any recent geological period. There are difficulties in the problem, especially the disappearance of the larger animals; but the remarkable and convincing feature in the case is the transmission to our time of so large a proportion of the small and delicate land and freshwater shells, which even now follow almost precisely the same law in their distribution as they did at these latest geological periods.

Looking at the special nature of the glacial period, and seeing its exceptional character, the author feels strongly impressed with the belief that its effect has possibly been to give increased rigidity and immobility to the flexible crust of the earth, and to produce a state of equilibrium which might otherwise have been of long and slow attainment, whereby it has been rendered fit and suitable for the habitation and pursuits of civilized man*.

* In this and his former paper the author has used the term "pleistocene" in the sense of post-pleiocene, including also some beds placed in the newer pleiocene.