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DAVID NUTT, LONG ACRE.

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1901.

ORDINARY MEETING.*

THEOPHILUS G. PINCHES, ESQ., LL.D., IN THE CHAIR.

The Minutes of the last Meeting were read and confirmed.

The following elections took place :—

LIFE MEMBER :—Colonel A. W. C. Bell, India Staff Corps.

ASSOCIATE :—Rev. H. D. Griswold, Lahore, India.

The following paper was then read by the Secretary in the absence of the Author :—

TIME DIVISIONS OF THE ICE AGE. By WARREN UPHAM, Esq., M.A., F.G.S.A., Secretary of the Minnesota Historical Society, St. Paul, Minn.

IN a former paper, on the "Causes of the Ice Age," published in the *Journal of the Transactions of the Victoria Institute* (vol. xxix, 1897, pp. 201–223), my concluding words stated my belief that the Ice age was "essentially continuous and single, with important fluctuations, but not of epochal significance, both during its advance and decline." This view is consistent with recognition and emphasis of its time divisions, indicated by oscillations of the boundaries of glaciation and by diverse conditions of drift deposition; but these divisions seem to me to merit designation as stages, rather than as epochs, of geologic time. Numerous and well marked stages of the Glacial period have been distinguished, and may be correlated in the same succession, being therefore in all probability of nearly contemporaneous duration, in North America and Europe.

American glacialists have found it convenient to give to the comparatively short closing part of the Ice age a dis-

* 15th April, 1901.

tinctive name, "the Champlain epoch," referring to the occurrence of fossiliferous marine beds overlying the glacial drift in the basin of Lake Champlain. It was the time of land depression from the high epeirogenic uplift that had caused the snow and ice accumulation. Thereby a temperate climate, warm in the summers, was restored on the borders of the ice-sheet, which retreated rapidly, though waveringly. More vigorous glacial currents were then produced by the marginal melting and increased steepness of the ice-front, favouring the formation of many retreatal moraines of very hummocky and boulder-bearing drift.

The continuous Glacial period or Ice age may be therefore regarded as divisible into two chief parts or stages, which were of quite unequal length, the first being probably at least ten times as long as the second. The first or Glacial stage was marked by high elevation of the drift-bearing areas, alike in America and Europe, and by their envelopment beneath vast ice-sheets, which varied much in their extent during successive long periods of alternating advance and recession. The second or Champlain stage was distinguished by the subsidence of these areas and the departure of the ice with abundant deposition of both glacial and modified drift. Epeirogenic movements, first of great uplift and later of depression, were thus the basis of the chief time divisions of this period. One was the time mainly characterized by the extension and culmination of glaciation; the other included its wavering decline and end. Each of these periods, as they may be named (although merely noting the general growth and general wane of the ice-sheets) was divided into stages, marked in the glacial epoch by fluctuations of the predominant ice accumulation, and in the Champlain period by successively diminishing limits of glaciation, by retreatal moraines, and by glacial lakes temporarily held in basins that sloped toward the departing ice.

Exploration of the European glacial drift by two Americans, Professor H. Carvill Lewis in the British Isles and Professor R. D. Salisbury in Germany, laid the foundations for determining the geologic equivalency of the successive parts of the North American and European drift series. Salisbury especially noted that the marginal moraines of northern Germany lie, as in the United States, at some distance back from the limits of the drift.

Studies by many observers have shown that on both continents the border of the drift along the greater part

of its extent was laid down as a gradually attenuated sheet; that the ice retreated and the drift endured much subaerial erosion and denudation; that renewed accumulation and growth of the ice-sheet, but mostly without extending to its earlier limits, were followed by a general depression of these burdened lands, after which the ice again retreated, apparently at a much faster rate than before, with great supplies of loess from the waters given off during its melting; that moderate re-elevation ensued; and that during the farther retreat of the ice-sheet prominent moraines were amassed in many irregular, but roughly parallel, belts, where the front at successive times paused or readvanced under secular variations in the prevailing temperate and even warm climate, by which, between the times of formation of the moraines, the ice was rapidly melting away.

Such likeness in the sequence of glacial conditions undoubtedly implies contemporaneous stages in the glaciation of the two continents. It also seems to me more reasonably interpreted as a series of phases in the work of a single ice-sheet on each area than as records of several separated and independent epochs of glaciation, differing widely from one another in their methods of depositing drift. The latter view, however, is held by James Geikie, Penck, De Geer, and others in Europe; and it has been regarded as the more probable also for America by Chamberlin, Salisbury, McGee, and others.

Under this view Geikie has distinguished and named no less than eleven stages or epochs, glacial and interglacial.* These divisions of the Ice age are as follows: 1, The Scanian or first glacial epoch; 2, The Norfolkian or first interglacial epoch; 3, The Saxonian or second glacial epoch; 4, The Helvetian or second interglacial epoch; 5, The Polandian or third glacial epoch; 6, The Neudeckian or third interglacial epoch; 7, The Mecklenburgian or fourth glacial epoch; 8, The Lower Forestian or fourth interglacial epoch; 9, The Lower Turbarian or fifth glacial epoch; 10, The Upper Forestian or fifth interglacial epoch; and, 11, The Upper Turbarian or sixth glacial epoch.

The earliest application of such geographic names to the

* *Journal of Geology*, vol. iii, pp. 241-269, April-May, 1895. In the third edition of his *Great Ice Age*, the same time divisions had been recognized and fully described, but without distinctive names.

successive stages and formations of the Ice age was by Chamberlin in his two chapters contributed to the third edition of Geikie's *Great Ice Age*, in 1894, naming the Kansan, East Iowan, and East Wisconsin formations. For the second and third he afterwards adopted the shorter names, Iowan and Wisconsin. Chamberlin correlates, with a good degree of confidence, his Kansan stage of maximum North American glaciation with the maximum in Europe, which is Geikie's Saxonian epoch; the Iowan as the European Polandian; and the Wisconsin or moraine-forming stage of the United States as the Mecklenburgian, which was the stage of the "great Baltic glacier" and its similarly well developed moraines.* According to the law of priority, the names of the Kansan, Iowan, and Wisconsin formations and stages should also be applied to these European divisions of the Glacial series, for the studies of Geikie and Chamberlin show them to be in all probability correlative and contemporaneous.

Differing much from the opinions of Geikie, and less widely from those of Chamberlin, concerning the importance, magnitude, and duration of the interglacial stages, but agreeing with Dana, Hitchcock, Kendall, Falsan, Holst, Nikitin, and others, in regarding the Ice age as continuous, with fluctuations but not complete departure of the ice-sheets, my view of the history of the Glacial period, comprising the Glacial epoch of ice accumulation and the Champlain epoch of ice departure, may be concisely presented in the following somewhat tabular form. The order is that of the advancing sequence in time, opposite to the downward stratigraphic order of the glacial, fluvial, lacustrine, and marine deposits. It should be added that this tabulation, so far as it pertains to North America, is supplied mainly from the field work and correlations of Professor T. C. Chamberlin, in charge of the Glacial Division of the United States Geological Survey, of his assistant, Mr. Frank Leverett, of Professor Samuel Calvin, state geologist of Iowa, and of Dr. George M. Dawson, director of the Geological Survey of Canada. Their special studies and conclusions have been published at various times during the past five years, mostly in the *Journal of Geology* and the *American Geologist*.

* *Journal of Geology*, vol. iii, pp. 270-277, April-May, 1895.

EPOCHS AND STAGES OF THE GLACIAL PERIOD.

I. *The Glacial Epoch.*

1. THE CULMINATION OF THE OZARKIAN EPEIROGENIC UPLIFT, in the later part of the Lafayette period, the earliest of the Quaternary era, affecting both North America and Europe, raised the glaciated areas to so high altitudes that they received snow throughout the year, and became deeply ice-enveloped. Submerged valleys and fjords show that this elevation was 1,000 to 4,000 feet above the present height.*

Rudely chipped stone implements and human bones in the plateau gravel of southern England, 90 feet and higher above the Thames, and the similar traces of man in early Quaternary sand and gravel deposits of the Somme and other valleys in France, attest man's existence there before the maximum stages of the uplift and of the Ice age. America also had been already peopled, doubtless by preglacial migration from Asia across a land area in the place of the shallow Bering Sea.

The accumulation of the ice-sheets, due to snowfall on their entire areas, was attended by fluctuations of their gradually extending boundaries, giving the Scanian and Norfolkian stages in Europe, the Albertan formation of very early glacial drift and accompanying gravels, described by Dawson, in Alberta and the Saskatchewan district of western Canada, and an early glacial advance, recession, and re-advance, in the region of the Moose and Albany Rivers, south-west of Hudson Bay. In that region, and westward on the Canadian plains to the Rocky Mountains, there seem to thus have been three stages recognizable in the glacial results of the epeirogenic uplift, namely, the ALBERTAN STAGE of early ice accumulation, the SASKATCHEWAN STAGE of abundant melting and considerable retreat, and the ensuing great Kansan growth of the continental icefields.

A deposit of glacial drift, the lowest and oldest observed

* The amount of uplift as compared with the present level of the ocean was greater than above stated, as shown by Professor J. W. Spenser for the American side, and by Professor Edward Hull for the eastern side of the Atlantic, in the latter case amounting to 6,000-7,000 feet, at which depth the submerged river-valleys (such as the Loire, the Adour, the Tagus, and the Congo) open out on the floor of the abyssal ocean. See *Trans. Vict. Inst.*, vols. xxx, xxxi, and xxxii.—
EDITOR.

in the Mississippi river basin, probably of Albertan age, stretches south at least to southern Iowa, where it is overlain by interglacial beds, inclosing peat, well displayed in sections at Afton, Iowa. The Aftonian interglacial stage, especially notable for its extensive buried forest bed, containing trunks of hardy northern coniferous trees, has been ascertained to be earlier than the Kansan readvance of glaciation. It is therefore probably equivalent with the Saskatchewan stage of Canada, which name it should then displace according to the rule of priority.

2. KANSAN STAGE.—Farthest extent of the ice-sheet in the Missouri and Mississippi river basins, and in northern New Jersey. The Saxonian stage of maximum glaciation in Europe.

Area of the North American ice-sheet, with its development on the arctic archipelago, about 4,000,000 square miles; of the European ice-sheet, with its tracts now occupied by the White, Baltic, North, and Irish Seas, about 2,000,000 square miles.

Thickness of the ice in northern New England and in central British Columbia, about one mile; on the Laurentide highlands, probably two miles; in Greenland, as now, probably one mile or more, with its surface 8,000 to 10,000 feet above the sea; in portions of Scotland and Sweden, and over the basin of the Baltic Sea, half a mile to a mile.

3. HELVETIAN STAGE.—Recession of the ice-sheet from its Kansan boundary northward about 500 miles to Barnesville, Minnesota, in the Red River valley; 250 miles or more in Illinois, according to Leverett, but probably little between the Scioto River, in Ohio, and the Atlantic coast, the maximum retreat of that portion being 25 miles or more in New Jersey. Deposition of the Buchanan gravels and sands, as named by Calvin in Iowa, during the retreat of the Kansan icefields; and time of the Yarmouth weathered zone and erosion, noted by Leverett in Iowa and Illinois. A cool temperate climate and coniferous forests up to the receding ice border in the upper Mississippi region. Much erosion of the early drift.

The greater part of the drift area in Russia permanently relinquished by the much diminished ice-sheet, which also retreated considerably on all its sides.

During this stage the two continents probably retained mainly a large part of their preglacial altitude. The glacial recession may have been caused by the astronomic cycle

which brought our winters of the northern hemisphere in perihelion between 25,000 and 15,000 years ago.*

4. IOWAN STAGE.—Renewed ice accumulation, extending again from central Minnesota into Iowa, to a distance of 350 miles or more from its most northern indentation by the Helvetian retreat, and readvancing about 150 miles in Illinois, while its boundary eastward from Ohio probably remained with little change.

Previous to the farthest extension of this glaciation in Iowa, on the west side of the Wisconsin driftless area, the ice-lobe east of that area advanced from Illinois into the edge of south-eastern Iowa, giving an Illinoian stage of glaciation which somewhat antedated the maximum of the Iowan, though not probably by a wide difference of time. Between the retreat of the Illinoian ice-lobe and the deposition of the Iowan loess, Leverett notes interglacial deposits and a zone of weathering, the records of his Sangamon stage.

Iowan time seems correlative with the Polandian stage of renewed growth of the European ice-sheet, probably advancing its boundaries in some portions hundreds of miles from the Helvetian retreat.

II. *The Champlain Epoch.*

5. CHAMPLAIN SUBSIDENCE; NEUDECKIAN STAGE.—Depression of the ice-burdened areas mostly somewhat below their present heights, as shown by fossiliferous marine beds overlying the glacial drift up to 300 feet above the sea in Maine, 560 feet at Montreal, 300 to 400 feet from south to north in the basin of Lake Champlain, 300 to 500 feet southwest of Hudson and James Bays, and similar or greater altitudes on the coasts of British Columbia, the British Isles (1,200 feet maximum), Germany, Scandinavia, and Spitzbergen.

Glacial recession from the Iowan boundaries was rapid under the temperate (and in summers warm or hot) climate, belonging to the more southern parts of the drift-bearing areas when reduced from their great preglacial elevation to their present height or lower. The finer portion of the englacial drift, swept down from the icefields by the

* *American Geologist*, vol. xv, pp. 201, 255, and 293, March, April, and May, 1895.

abundant waters of their melting and of rains, was spread on the lower lands and along valleys in front of the departing ice, as the loess of the Missouri, the Mississippi, and the Rhine. Marine beds reaching to a maximum height of about 375 feet at Neudeck, in western Prussia, give the name of this stage.

6. WISCONSIN STAGE.—Moderate re-elevation of the land, in the northern United States and Canada advancing as a permanent wave from south to north and north-east; continued retreat of the ice along most of its extent, but its maximum advance in southern New England, with fluctuations and the formation of prominent marginal moraines; great glacial lakes on the northern borders of the United States.

The Mecklenburgian stage in Europe. Conspicuous moraine accumulations in Sweden, Denmark, Germany, and Finland on the southern and eastern margins of the great Baltic glacier. No extensive glacial readvance between the Iowan and Wisconsin stages, either in North America or Europe.

Later American stages, all of minor importance and duration in comparison with the preceding, cannot probably be shown to be equivalent with Geikie's European divisions in the same time.

During the general glacial recession, slight oscillations of the ice border occurred, with temperate climate nearly as now, at Toronto and Scarborough on the north shore of Lake Ontario, indicated by interbedded deposits of glacial drift and fossiliferous stratified gravel, sand, and clay.* Although the waning ice-sheet still occupied a vast area on the north-east, and twice readvanced, with deposition of much boulder clay or till, during the formation of this fossiliferous drift series, the climate then, determined by the Champlain low altitude of the land, by the proximity of the large glacial Lake Algonquin, succeeding the larger Lake Warren, and by the eastward and north-eastward surface atmospheric currents and courses of all storms, was not less mild than now. The trees of which the wood is found in the interglacial Toronto beds now have their most northern limits in the same region.

Full expansion of the glacial Lake Iroquois, in the basin of Lake Ontario and northward, ensued, with outflow at

* *American Geologist*, vol. xv, pp. 285-291, May, 1895.

Rome, New York, to the Mohawk and Hudson Rivers. In the meantime a gradual re-elevation of the Rome outlet from the Champlain subsidence lifted the surface of Lake Iroquois in its western part from near the present lake level at Toronto to a height there of about 200 feet, finally holding this height many years, with the formation of the well developed Iroquois beach. The glacial and lacustrine geology of the vicinity of Toronto is therefore perhaps of greater interest than of any other locality in America; but its remarkable features of alternating glacial and interglacial formations seem to me wholly referable to the Champlain epoch of wavering departure of the ice-sheet.

STAGES OF PROGRESS OF PRIMITIVE MAN CORRELATED WITH THE STAGES OF THE ICE AGE.

To many members of the Victoria Institute, the history of the Ice age derives its greatest interest from its relation to the earliest traces of man's existence. We are able now, as I believe, to discern a reliable parallelism of the stages of progress of Palæolithic men, using chipped stone implements, with the stages of the Glacial period which have been here reviewed. This correlation has come from my examination of the Somme river valley and its famous implement-bearing and fossiliferous sand and gravel beds, during the summer of 1897. There, between fifty and thirty years earlier, the great geologic antiquity of man had been first fully determined by Boucher de Perthes, Rigollot, Falconer and Prestwich, Evans, Lyell, Lubbock, Tylor, Gaudry, Andrews, and other archæologists and geologists.

The men of the Somme gravel deposits belonged, if I rightly interpret the geologic record, to the early part of the Glacial period, previous to its culmination; the inhabitants of the caverns of Dordogne, in south-western France, possessing greater skill in the manufacture of flint implements and adding others of bone and horn, hunting herds of wild horses and reindeer, seem correlative with the maximum stage of glaciation; and later these people spread northward, following the retreating ice-sheet to the boundary of its Mecklenburgian stage.

De Mortillet and Cartailhac, as archæologists, divide the Palæolithic period of France into four epochs or stages, succeeding one another as follows: 1, Acheulian, named from St. Acheul, a suburb of Amiens in the Somme valley

(or Chellean, from Chelles near Paris); 2, Mousterian, from Le Moustier in Dordogne; 3, Solutrian, from Solutré in Burgundy; and, 4, Magdalenian, from the caves of La Madeleine in Dordogne. These time divisions are characterized by increasing variety and excellence of the implements made, and by concomitant changes of the fauna. The implements found in the Somme valley are referable only to the earliest stage, which had at first a mild and moist climate, changing afterward to severe cold, with thick ice on the rivers in winter, broken and floating large blocks of rock in spring.

Let us now examine the geologic origin and deposits of this valley in their relation to these stages of archæologic development, comparing both records with the ascertained history of the Ice age in the British Isles and northern Europe, and with estimates of its duration and that of the Postglacial period.

Above Amiens the Somme basin has been eroded to an undulating surface of broad but low hills and ridges, and is drained by several streams which converge in and near that city, being the sources of the supply of the Pleistocene gravels extensively excavated at St. Acheul, St. Roch, and Montiers, which are situated respectively in the south-eastern, western, and north-western environs of the city. From Amiens to the sea, a distance of about forty miles, the valley is troughlike, with a bottomland from a half-mile to a mile and a half in width for nearly twenty-five miles, extending down to Abbeville, and thence widening to three or four miles at its mouth, inclosed usually by very gentle or moderately steep slopes, but in a few places bordered by a steeper or precipitous bluff formed through direct undermining by the river at some time during the slow process of the valley erosion.

The river at Amiens is about 65 feet above the mean tide sea level; at Montiers, 58 feet; and at Abbeville, about 15 feet, the high tides having formerly reached above the city, until held back by the engineering improvements of the river course which now restrict its once meandering and dividing waters to a single straight canal along its next nine miles. The bottomland is mostly no more than 2 to 5 feet, and in its highest parts about 10 feet, above the river in its ordinary low water stage. Along nearly all the distance below Amiens it has large tracts of peat, from 10 to 30 feet in depth, thus extending far beneath the level of the

river, or even, in the vicinity of Abbeville, beneath the sea level. During many centuries the peat has been excavated for fuel, and many small ponds occupy these hollows, and in other places mark abandoned parts of the earlier river channel. Since the close of the Glacial period, the Somme valley has received too little alluvium to keep pace with the slight epirogenic depression which has been in progress; but at the mouth it has been filled by the coastwise drift of sand from the marine shore erosion, and by the muddy sediments deposited from inflowing tides.

On each side of the valley the upland extends far away in a great plainlike expanse, as seen in any wide view, though everywhere somewhat undulating, with an elevation of 150 to 250 feet above the river and its bottomland. Rounded outlines descend to the Somme and to the ramifying tributary streams, betokening a prolonged period of subaerial denudation by rains, rills, brooks, and the main river. The Somme, lying south of the European glaciated area, has in its gravel deposits only materials derived from its own drainage basin, which consists of approximately horizontal Cretaceous strata of chalk, with concretionary flint nodules, and here and there overlying remnants of Eocene sand and clay, locally hardened to sandstone and shale. Residuary clay and loam, left in the process of denudation, covers the upland surface to a depth varying generally from 2 or 3 to 6 or 8 feet.

The erosion of the Somme valley to essentially its present width and depth seems to me attributable to the work of the river during the very long Miocene and Pliocene periods, and to have been completed nearly as now before the great epirogenic uplift causing the Ice age, which probably raised the British Isles and northern France at least 1,500 to 2,000 feet higher than now, while south-western France and the Spanish peninsula are known to have been elevated much more. The record of the Glacial period here appears, in my view, to be almost wholly represented by deposition of the gravel and sand on the lower flanks of the valley slopes, chiefly adjoining the mouths of tributaries; and it is in the older of these gravel beds that the flint implements occur, indicating the sojourn of men there at the beginning and through the early part of the Ice age.

In referring the valley erosion thus to middle and late Tertiary times, I agree with Alfred Tylor, whose careful discussions of this valley and those of southern Britain have

hitherto received less attention than they deserve, probably because they differ from the earlier published views of Prestwich, Lyell, Lubbock, Evans, and others, who ascribe the excavation of the lower part of the Somme valley to river action during the Palæolithic period, while the later gravel beds were being deposited, or in the intervals of such deposition and afterward.* The Tertiary erosion extended

* Without attempting reference to all of the multitude of papers and books relating to the evidences of primitive man in the Somme valley, citation of some which are more important or comprehensive may be noted as follows :—

- Boucher de Perthes, *Antiquités Celtiques et Antédiluviennes*, vol. i, p. 628, with 80 plates (1,600 figures), 1847 ; vol. ii, p. 511, with 26 plates (500 figures), 1857 ; vol. iii, p. 681, with 12 plates (104 figures), 1864.
- Sir Joseph Prestwich, *Proc. Roy. Soc.*, 1859 ; *Phil. Trans.*, 1860, 1864 ; many later papers, especially in *Quart. Jour. Geol. Soc.* ; and his *Geology*, vol. ii, 1888.
- Sir Charles Lyell, *Brit. Assoc. Report*, 1859, Part 2, pp. 93–95 ; *The Geological Evidences of the Antiquity of Man*, 1863, chapters vii and viii.
- Sir John Lubbock, numerous papers, 1861–1864 ; *Prehistoric Times*, 1865, 1869, chapter xi.
- Sir John Evans, *Archæologia*, 1862, p. 28, with four plates ; numerous other papers, and *Ancient Stone Implements, Weapons, and Ornaments of Great Britain*, 1872 (exceedingly useful in its fulness of bibliographic references).
- Professor W. Boyd Dawkins, numerous papers, 1862 and onward ; *Cave Hunting, Researches on the Evidence of Caves respecting the Early Inhabitants of Europe*, 1874.
- Alfred Tylor, *Quart. Jour. Geol. Soc.*, vol. xxii, 1866, pp. 463–468 ; vol. xxiv, 1868, pp. 103–125, with two plates (map of Amiens and vicinity and 13 sections), and 13 figures (sections, profiles, and a map), in the text ; and vol. xxv, 1869, pp. 57–100, with six plates (abstract and discussion of this paper in vol. xxiv, pp. 455, 456).
- Dr. Edmund Andrews, *Am. Jour. Sci.*, second series, vol. xlv, pp. 180–190, March, 1868.
- Professor James Geikie, *The Great Ice Age and its relation to the Antiquity of Man*, 1874, 1877, 1894 ; *Prehistoric Europe*, 1881.
- Professor Gabriel de Mortillet, *Matériaux pour l'Histoire Primitive et Naturelle de l'Homme*, 1865 and onward ; *Le Préhistorique*, 1883.
- Emile Cartailhac, *Matériaux*, 1865 and onward ; *La France Préhistorique*, 1889.
- J. Ladrrière, *Annales de la Société Géologique du Nord*, vols. xviii–xx (summarized in Geikie's *Great Ice Age*, third ed., 1894, pp. 629–637).
- Albert Falsan, *La Période Glaciaire étudiée principalement en France et en Suisse*, 1889.

through a duration of probably one or two million years, which would permit the valley to have its origin chiefly by rock solution, as the deepening of the excavation to 200 or 250 feet would be at an average rate of no more than an eighth or a third of an inch for each century.

When the more rainy and snowy climate of the Glacial period caused larger floods of the streams, especially during the spring months, the residuary loam and gravel mantling all the surface were subjected to exceptional denudation. Considerable material was swept down every stream course and ravine, until, on debouching into the main valley, the flood could expand more widely and so lose its velocity and transporting capacity. The gravel and sand were then deposited along the border of the broad bottomland and in alluvial fans upon the lower part of the inclosing slopes wherever tributary streams or the rills of rains and snow-melting descended.

Instead of forming continuous, level-topped terraces, at successive heights, up to nearly equal vertical limits on each side of the valley, like the terraces of modified drift on the Connecticut River along its upper half where it is the boundary between New Hampshire and Vermont, or like the usually less numerous terraces of this kind in most valleys of glaciated countries, the Somme gravel and sand are of less amount, and have gentle or steep slopes toward the centre of the valley, presenting a terrace escarpment only where marginal parts of these deposits have been later carried away by the undermining action of the streams which brought them, or of the main river. Along the Connecticut River a wide flood-plain of modified drift was built up, filling the valley to the level of the highest continuous terraces, 100 to 200 feet above the river; and the terraces are remnants of that flood-plain, and of the lower temporary levels occupied and abandoned by the river during its process of removal of the greater part of that original deposit of the modified drift. In the Somme valley, the supply of material was less than that set free from the melting North American ice-sheet, and it was insufficient to build up a flood-plain in any part of this valley below Amiens, though at many places it formed extensive deposits on either side, which sometimes reach, with slopes nearly like those inclosing the valley, from the bottomland up to heights of 50 to 100 feet; and patches of similar gravel and sand occasionally are observable also at greater heights, nearly to the verge of the uplands.

Levelling done for Mr. Alfred Tylor by the railway engineer, M. Guillom, gave the altitudes of the bottom and the original surface of the large St. Acheul gravel pits (two are each a quarter of a mile long), the richest in flint hatchets among the numerous excavations in and near Amiens, as respectively 140 and 160 feet above the sea, or about 75 and 95 feet above the river, which is a half-mile distant to the north. The pits are not at the upper limit of the gravels, for Tylor remarks, "The sections near Amiens show the valley gravel continuous from a height of 200 feet, at St. Acheul . . . to the River Somme (coated over by a nearly uniform warp of loess), and laid at a low gradient not exactly parallel to the surface of the chalk, but rather in its concavities." These higher gravel beds, however, having no excavation, it is not known whether they contain stone implements and fossil bones; but generally, according to Ladrière, these are absent or rare in the highest beds of the valley gravels throughout northern France. In the vicinity of Montiers, one to two miles north-west of Amiens, nine gravel pits, containing worked flints and bones of extinct animals nearly as at St. Acheul, are shown by Tylor's description and map to range in height from 77 to 155 feet above the sea, or from 17 to 95 feet above the Somme, the upper limit of the excavations being the same in relation to the river as near St. Acheul. The distinction of upper and lower gravel deposits, which Prestwich and Lyell made prominent in their writings, was pronounced by Tylor, as it seems to me with sufficient reasons, to be seldom definitely observable, the series, where developed at considerable heights, being usually continuous thence down nearly or quite to the bottomland and river.

Ladrière, who in 1875 and ensuing years has extensively examined and described the Pleistocene valley deposits of the Seine, Somme, and other river basins of a wide region extending northward into Belgium, divides these deposits into three somewhat similar series, successive in age and stratigraphic order, each of which can be traced from the bottoms of the valleys up to the plateaus, though not to their greatest heights. These series, each consisting of a regular sequence of gravel, sand, loam or loess, etc., representing three distinct stages of the Pleistocene period, are doubtless to be correlated with stages of advancing glaciation, interrupted by times of decrease and recession of the European ice-sheet. The researches of Ladrière thus

present a record of climatic changes south of the glaciated area, by which geologists may very satisfactorily connect the evidences of primitive man in France with the time divisions of the Glacial period. His detailed notes of each of the three Pleistocene series and stages recognizable in these valleys are fully quoted by Professor James Geikie in the third edition of the *Great Ice Age* (1894, pp. 630-632), from which it appears that flint implements of the Acheulian or Chellean type occur throughout the lower series; that such implements are also found in the middle series, but probably, as Ladrrière thinks, through derivation from the older and stratigraphically lower beds; and that the infrequent implements found in the upper series are of the later developed Mousterian type.

We may infer, additionally, that while the still later Solutrian and Magdalenian types of implements were being developed, in the progress of the Palæolithic period, more moderate climatic conditions prevailed in northern France, with no important contribution to the valley gravels. These threefold deposits therefore appear referable to three distinct parts of the Ice age, probably the Albertan, Kansan, and Iowan stages of glacial advance, or rather to the European representatives of these stages. During the interval that ensued, previous to the Champlain subsidence and general recession of the ice-sheet, the Palæolithic men of western Europe passed through their Solutrian and Magdalenian stages; and shortly afterward, about the time of formation of the Wisconsin or Mecklenburg moraines, those men, destitute of metals, of agriculture, or of domestic animals, were practically crowded off from Europe, famished by extinction of the large species of game, and driven out, exterminated, or absorbed, by the immigrating Neolithic people. The invaders, though ignorant of the most useful metals, brought wheat and barley, cattle, sheep, goats, and swine, and, most significant in linking them with later written history, the Indo-European or Aryan languages. Their arrival and settlement, and the end of the Palæolithic period, preceded the departure of the ice-sheet from Scotland and Scandinavia, where no Palæolithic types of stone implements are found, although Neolithic types abound and are collected in immense numbers.

Sections of the Somme gravels at Menchecourt, Mautort, and other localities near and below Abbeville carry back the Acheulian stage of Palæolithic time quite to the beginning

of the Ice age. The many other sections in this valley display ice-floated sandstone blocks and deformations of the strata attributable to the melting of masses of river ice; but these disturbed conditions were absent when human implements and the bones of the mammoth, the woolly rhinoceros, wild horse, urus, stag, reindeer, lion, and hyæna were mingled in the Menchecourt gravel and sand beds, which are about 20 to 30 feet above the sea level, under subsequent deposits of 20 feet of loam and clay, the surface being about 50 feet above the sea or 40 feet above the river. The sections of Menchecourt, Mautort, etc., are further distinguished from others at higher levels near Abbeville, and from all at both low and high levels along the upper part of the valley, by their containing marine shells. Lyell writes of their mode of occurrence at Menchecourt as follows:—

In the lowest beds of gravel sand and in contact with the chalk, flint hatchets, some perfect, others, much rolled, have been found; and in a sandy bed in this position some workmen, whom I employed to sink a pit, found four flint knives. Above this sand occur beds of white and siliceous sand, containing shells of the genera *Planorbis*, *Limnea*, *Paludina*, *Valvata*, *Cyclas*, *Cyrena*, *Helix*, and others, all now natives of the same part of France, [except *Cyrena* [*Corbicula*] *fluminalis*, which no longer lives in Europe, but inhabits the Nile and many parts of Asia, including Cashmere, where it abounds. No species of *Cyrena* is now met with in a living state in Europe. Mr. Prestwich first observed it fossil at Menchecourt, and it has since been found in two or three contiguous sand-pits, always in the fluvio-marine bed.

The following marine shells occur mixed with the fresh-water species above enumerated: *Buccinum undatum*, *Littorina littorea*, *Nassa reticulata*, *Purpura lapillus*, *Tellina solidula*, *Cardium edule*, and fragments of some others. Several of these I have myself collected entire, though in a state of great decomposition. . . . They are all littoral species now proper to the contiguous coast of France. Their occurrence in a fossil state associated with fresh-water shells at Menchecourt had been noticed as long ago as 1836 by M.M. Ravin and Baillon, before M. Boucher de Perthes commenced the researches which have since made the locality so celebrated. The numbers since collected preclude all idea of their having been brought inland as eatable shells by the fabricators of the flint hatchets found at the bottom of the fluvio-marine sands.

This part of western Europe was then slightly lower than now, indicating, with the absence of ice before noted, that the time represented by these sections preceded the great uplift of this region, which culminated in the maximum European glaciation. But earlier, and probably continuing with increased vertical and geographic extent during the early

part of the Ice age, the general epeirogenic uplift of the continental area bridged the Strait of Gibraltar and the centre of the Mediterranean Sea from Tunis to Sicily and Italy, as shown by Dawkins and Geikie, raising the land in both regions about 2,000 feet higher than now, and affording a passage to the great African mammals. They also crossed where the shallow strait of Dover now is, entering Britain; and during the oncoming and culmination of the Ice age the British Isles were united with the continent by a very broad land surface, reaching far west of the Channel and occupying the basin of the North Sea, and nearly all the area between Scotland and Norway, until the Scandinavian ice-sheet covered that land plain to north-eastern England.

LENGTH OF POSTGLACIAL TIME.

Our estimates of the duration of the Postglacial period are based on computations by Andrews from the shore erosion and beach sand accumulation of Lake Michigan; on his investigation of the age of the peat beds in the Somme valley and of the alluvial deposits of the Tinière, tributary to the Lake of Geneva, which latter had been differently interpreted by Morlot; on the study of the recession of the Falls of St. Anthony, by Professor N. H. Winchell; on that of Niagara Falls, by Gilbert and others; on Dr. Robert Bell's observations of the extent of subaerial erosion of limestone rocks in Canada; and on many other careful studies in both North America and Europe. These estimates concur so well that the duration which they give approximately as between 5,000 and 10,000 years may be confidently accepted as the measure of Postglacial time.

It may be otherwise and better stated that the departure of the ice-sheets on these continents probably occupied some 5,000 years, known as the Champlain epoch; and that it was completed, nearly as now about 5,000 years ago, with remnants of the old ice-sheets lingering ever since in Alaska and Greenland and on the mountainous plateaus of Norway. The incursion of the Neolithic men and the doom of their Palæolithic predecessors belong thus probably 6,000 or 7,000 years ago.

LENGTH OF GLACIAL AND PALÆOLITHIC TIME.

The duration of the Ice age cannot be so reliably determined, but the researches of Geikie, Chamberlin, and many others convince us that on both sides of the North Atlantic

glaciation was approximately synchronous, with parallelism in its beginning, fluctuations, and end, through a period ten to twenty times as long as that which has followed it, or of somewhat such ratio. In other words, the Glacial period, from the time of the Palæolithic men at Menchecourt and St. Acheul to the Neolithic immigration and the not widely later retreat of the ice-sheet in Scotland, Sweden, and Norway, measured probably 50,000 or 100,000 years.

It is therefore right that the Acheulian men should be termed primitive. They had not learned how to use God's gifts. The power of invention, ready to bestow dominion and utilization of animate and inanimate nature, lay dormant and was scarcely beginning to awaken.

The beginning of the human epoch, when our species gained such development of body and mind as to deserve its generic and specific name, *Homo sapiens*, we cannot well designate more closely than to say that it antedated the Ice age. But however long we may estimate the duration of the human species, geology confidently affirms that life began upon our globe in an antiquity a hundred or perhaps even a thousand times more remote, and the beginning of the existence of the earth and of the solar system was again vastly more ancient. The duration of the period of written history, or even of mankind, beginning tens or hundreds of thousands of years earlier, seems like the span of one's hand in comparison with geologic time, which was in the mind of the seer writing of the Creator's work, "Of old hast Thou laid the foundation of the earth."

DISCUSSION.

The CHAIRMAN.—Would any lady or gentleman like to make any remarks on this very interesting paper?

The SECRETARY (Professor HULL).—Mr. Chairman, I wish to move the best thanks of the meeting to the author of this paper, which I am sure you will all concur with me in considering of great interest, and showing a large amount of research and labour in preparation. In writing to me since this paper was in type, the author begged that I would not only read it but that I would also take part in the discussion. I thought it was rather cruel to put two such severe tasks upon me in one evening; but as the Chairman has kindly in part relieved me in the first matter I feel I may, and ought to, meet the wishes of the author.

The paper itself may be divided into three portions :—First, a description of the glacial phenomena of North America, with which he has become familiar both by study and examination in the field. Secondly, the correlation of the glacial deposits and divisions of time of North America with those of Europe and the British Isles ; and, thirdly, the question which does not necessarily arise in connection with this subject, although probably too tempting to be resisted, viz., the relation of the appearance of man on the earth to the Glacial epoch itself.

Now as regards the first I have not a word of criticism to offer. I presume that Mr. Warren Upham is as competent an authority on the glacial phenomena of North America as is to be found in that country itself.

With regard to the correlation of the Pleistocene, or glacial deposits of North America with those of Europe and the British Islands, there is certainly room for considerable diversity of opinion.

While I was engaged in the geological survey of the centre and north-west of England—in Lancashire, Cheshire, and other neighbouring portions of England, for a good many years—I made glacial phenomena a special study, and I came to the conclusion that in that part of the British Islands the whole of the glacial deposits may be divided into three successive stages. I have written them down on that board. The British series, as it was developed in Lancashire, Cheshire, Shropshire and the Midlands, consists of three distinct divisions ; and I may say they are laid open in a most beautiful section about 150 feet in height, on the banks of the River Ribble, some miles above Preston. The basement division consists of dark red boulder clay, with pebbles and boulders often glaciated ; everyone who knows that part of England is familiar with the lower boulder clay. That is succeeded by a series, of perhaps 60 or 80 feet in thickness, of beautifully stratified sands and gravels as distinct as any formation could be from the underlying stiff boulder clay, and those gravels (forming the interglacial series) are again overlain by boulder clay which is more or less laminated, and contains small blocks of rock. This forms the upper boulder clay. [*The Secretary here explained the drawing on the board.*] Now what the relations of these divisions may be to those that Mr. Warren Upham has described is not perfectly clear. Still I think we may correlate them in this way—

first by putting the lower boulder clay as representing the great "Epeirogenic uplift," and the extension of the vast sheets of ice in North America and Europe; then the Champlain subsidence, with stratified and laminated beds which may correspond with our interglacial deposits in England, which also contain marine shells; and then the upper boulder clay, which represents a recurrence of semi-arctic conditions, when the lands were partly submerged so that the water surrounding them was blocked with floating ice and mud carried down by the rivers from the unsubmerged portions; this may be correlated with those upper stages in North America. This may be so. It is not a matter of great importance.

I agree with Mr. Warren Upham that the Glacial period was one great division of geological time; but in different districts there were diversities of climate from time to time, due to oscillations of the land, causing a recurrence of cold and warm climates which may have been very limited in their existence; and, of necessity, extending over considerable geographical areas.

So much with regard to the second part of Mr. Upham's paper.

But now I come to the question of the age of man; and you will have observed that the author assumes, as a sort of settled question, that man preceded the Glacial epoch. In several parts of his paper he makes that assertion, and he founds his view upon the character of the beds (plateau gravels) containing palæolithic implements and the remains of animals in the Ouse and the Somme. Now it might have been supposed that there was some stronger evidence of the pre-existence of man to the Glacial period than the evidence that Mr. Upham has furnished; but not in one single case, in the whole of Europe or America, has a trace of man's existence been found below the only deposits which we have a right to assume were developed and produced by the great ice-sheets of the early Glacial period. The beds of sand and gravel containing implements and extinct fossil remains of the elephant, the rhinoceros, cave bear, etc., are absolutely outside the range of the great boulder clay of the northern parts of Europe and portions of the British Islands. It (the boulder clay) does not come within miles of the places where these works of man are found, and therefore one cannot say what the relationship of the boulder clay is to these remains and accompanying deposits. You observe that all these remains that the author refers to are stated, and truly stated, as occurring in beds of gravel and sand, stratified

gravel and sand; but stratified gravel and sand is not a formation which has originated in great sheets of ice; on the contrary, such beds have been deposited in water. I repeat that evidence that man preceded the Glacial epoch is absolutely wanting. I may refer to the views of, I think, the greatest authority on that subject that perhaps the world has ever produced, the late Sir Charles Lyell. If you turn to his *Antiquity of Man*, published in 1873 (and the evidence he gives has not been materially added to since that period), you will find that he says:—

“One step at least we gain by the Bedford section, which those of Amiens and Abbeville had not enabled us to make. They teach us that the fabricators of the antique tools, and the extinct mammalia coeval with them, were all post-glacial, or in other words, posterior to the grand subsidence of Central England beneath the waters of the Glacial Sea.”*

Again he says, “The sections near Bedford and at Hoxne in Suffolk, and a general view of the Norfolk cliffs, have taught us that the earliest signs of man’s appearance in the British Isles hitherto detected, are of post-glacial date.”†

The valley of the Ouse has been scooped out of the boulder clay: so that whatever may be found in the gravel-beds and terraces of the valley is much more recent than the age of the boulder clay which extends over the surface of the country from the edge of the valley. Now, in the valley of the Ouse there are two beds of gravel. There is, first, one within reach of the present waters of the rivers; and another, a raised terrace, and in this upper gravel, in the valley, are these extinct remains and works of art.

Now, Mr. Upham founds his argument for the pre-existence of man to the Glacial period on page 5 of his paper, thus:— “Rudely chipped stone implements and human bones in the plateau gravel of southern England, 90 feet and higher above the Thames, and the similar traces of man in early Quaternary sand and gravel deposits of the Somme and other valleys in France, attest man’s existence there before the maximum stages of the uplift and of the Ice age.” They do not appear to

* *Antiquity of Man*, p. 166. It is to be noted that this subsidence took place *after* the disappearance of the great glaciers and sheets of ice by which the Glacial period was ushered in.

† *Ibid.*, p. 229.

me to bear this interpretation. I know these plateau gravels in the north, centre, and south of England, and have mapped and described them in the Memoirs of the Geological Survey. They are not all of one period, but those which represent the interglacial stage, or epoch of great submergence, contain no traces of man or his works*—while the gravel terraces of moderate elevation to which the author refers as containing these works are of much more recent age. I am, therefore, unable to accept Mr. Warren Upham's views as regards the age of the appearance of man. This I regret: at the same time I am glad to have had so favourable an opportunity for stating the conclusions at which I have arrived by many years of observation, and I heartily join in thanking the author for his paper.

I have been asked to endeavour to correlate the glacial divisions of time as they are represented in the British Isles with those of America as given by the author. There is a great difficulty in doing this with much prospect of success, but the following may be accepted as approximately correct:—

GLACIAL DIVISIONS.		
	<i>British Isles.</i>	<i>North America.</i>
FINAL STAGE.	{ Slight re-elevation of land with increase of cold. Local glaciers in high lands. Submerged areas overspread by waters with icebergs and erratic blocks. (Upper boulder clay.)	{ Wisconsin Stage. (Moderate re-elevation of land and partial re-advance of glacial ice.)
MIDDLE STAGE. (Interglacial.)	{ Depression and submersion of land Climate moderate. Formation of raised beaches and shell beds. (Middle gravels.)	{ Champlain subsidence. (Fossiliferous marine beds.)
INITIAL STAGE. (Great Ice age.)	{ Great elevation of land. Maximum of cold and exten- sion of glaciers and ice- sheets. (Lower boulder clay or "till.")	{ Iowan Stage. Helvetian " Kansan " Ozarkian "

At the close of the Final and Wisconsin Stage—the relations of land and sea gradually approximated to those of the present day, with slight oscillations of sea-level and formation of raised

* Unless the "eolithic" flints of Mr. Bullen be of this period; but even so, they would be later than the epoch of the lower boulder clay (see *ante*, p. 223).

beaches. The Initial Stage (Ozarkian uplift) was probably coincident with the great elevation of the lands and ocean-bed, during which the submerged river channels were eroded down through the continental platform both in Europe and America.

Professor J. LOGAN LOBLEY, F.G.S.—The thanks of the Members of the Institute are, I am sure, due to Mr. Warren Upham for his interesting and suggestive paper, and we are also much indebted to Professor Hull for his very lucid additional exposition of the subject of the paper.

Although I can make no claim to be any authority on the great glacial question, I may perhaps be allowed to say a few words on some of the important points raised by Mr. Upham.

With Professor Hull's opinion that the Somme Valley has been cut since the glaciation of Northern France I am quite inclined to agree. The well-known Bedfordshire valley of the Ouse has been cited as evidence of an important valley formed subsequently to the age of the boulder clay, and of the advent of man not being pre-glacial. But may I not ask, have we not in the Thames Valley similar evidence? There is boulder clay at Finchley, but none in the lower levels of the great Thames Valley. No human implements have been found anywhere in this valley in beds older than the Pleistocene gravels and brick-earths which contain abundant mammalian remains, as at Acton, where human implements in considerable numbers occur, as shown by Mr. Allen Brown. The important discoveries of implements in the Somme Valley by Boucher de Perthes and Prestwich were in similar flint river gravels, indicating, I think, a similar period for the formation of that valley. The Miocene beds of the Alps, 5,000 feet above sea-level, and the Pliocenes of East Anglia, indicate a submergence of this part of the earth's surface in Pliocene times when instead of erosion there would be a deposition, but subsequently at the close of the Glacial epoch the conditions, from the great melting of ice and snow on higher ground, would be favourable to the rapid cutting of chalk valleys consequent upon the combined erosive and solvent action of water. Thus the evidence appears to be in favour of the view that man was not pre-glacial; that is, not before the glaciation of Mid-Europe; for a "Glacial period" may be said to be still in existence in Greenland and the Polar Regions, due to high latitudes, while the glaciation of regions further from the poles was due, I believe, to greater elevation of land

areas as indicated, among other things, by the sub-oceanic river-valleys.

With respect to the astronomical explanation of a presumed glacial recession to which reference is made in this paper, I may remark that the Southern Hemisphere is towards the sun, when the earth is in perihelion, and yet the climate of the Antarctic is quite as rigorous as that of the Arctic Regions. There is reason therefore to think that if the northern summers were brought into perihelion the climate of the Northern Hemisphere would be scarcely, if at all, affected.

Neither can I agree with the attribution of depression of land areas to the weight of accumulated ice, referred to as "burdened land," since I ascribe any such depression to contraction of vast thicknesses of terrestrial matter consequent upon a lowering of temperature, and elevation to expansion of similar enormous masses from a rise in temperature.

The palæontological evidence certainly seems to me to be strongly against the pre-glacial age of the Somme gravels. In addition to Lyell's statement of it I may mention that that interesting little fresh-water Lamellibranch the *Cyrena fluminalis*, is to be found in abundance as a fossil in the brick-earths of the Lower Thames Valley, as at Grays, Crayford, and Ilford, and that though not now living in European rivers, but abundant in the waters of the Nile. I have also found it in the gravels of the Orange River of South Africa.

The CHAIRMAN.—I would just say that from my own point of view there is one important matter in this paper, and that is, the date of the ending of the Ice age, which the author sets down at about 5,000 years ago.

Now in Babylonia, civilization, such as it was, extends back certainly 5,000 years; and if in that country the estimates of the American excavators of Niffer may be accepted, it ought to go back 10,000 years from now.

That means, I suppose (I am speaking under correction of course), that the temperature of Babylonia must have been in those times, 5,000 to 10,000 years ago (and the farther back you go the more so), greatly affected by the presence of ice in other parts of the world, and that is a matter of some interest to people who consider the civilization and state of the country in ancient times and especially in connection with the products. The tempera-

ture, it seems to me, must have been lower in consequence of the extra nearness of the ice, and therefore the same plants and animals could not have existed there as in later days. One hardly likes to regard the temperature of the country as having been, such a short time ago, different from what it is now, and therefore one has to receive a statement of this kind with, I should say, a certain amount of caution.

I desire, as I am sure we all do, to return a very hearty vote of thanks to the author of the paper, which is exceedingly interesting, and to Professors Hull and Logan Lobley, who have added such important comments upon it.

Rev. JOHN TUCKWELL.—May I say with regard to that point that has just been raised, that in Professor Tyndall's volume, published some years ago on *Heat and Motion*, he makes reference to the Glacial period, and says the enormous accumulation of ice and snow in the northern regions would point to a very high temperature with an enormous amount of evaporation in some other parts of the world, otherwise we could not have the enormous accumulations of ice and snow in the northern regions. If so, that might, it seems to me, to some extent meet the difficulty which the Chairman referred to that there must have been as high a temperature in Babylonia as exists now. There are references on many of the Babylonian and Assyrian tablets to various forms of grain which may indicate what the temperature was, and would point to a temperature similar to that which it is now.

I notice in the paper that the author speaks of this—that there seems to be a break somewhere between the Palæolithic and the Neolithic periods. I should have liked to call attention to the fact that Professor Prestwich, in a paper he read here some years ago, referred to the deluge and to the extinction of a large number of those animals mentioned here, as if their extinction were occasioned, in some way, by a deluge,* and it may have occurred to the author that the enormous number of mammoths buried in Siberia must have lost their lives very suddenly and by a very sudden and excessive fall of temperature. They were, apparently, buried alive under many feet of ice, and have continued in such a condition to the present day that their flesh remains as sound as when they died, which would point to a

* *Journ. Trans. Vict. Inst.*, vol. xxvii, p. 263 (1893-4).

sudden fall of temperature and might possibly, therefore, in some way be connected with the event Sir Joseph Prestwich referred to in his paper here, and throw some light on the occurrence of the deluge.

The SECRETARY announced that arrangements had been made for the Annual Meeting to be held in the rooms of the Society of Arts, when the address would be delivered by Professor Sir Robert S. Ball, LL.D., F.R.S., of Cambridge University.

The meeting then adjourned.