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VIEW OF THE ICE AGE AS TWO EPOCHS, THE GLACIAL AND CHAMPLAIN.*

THE present paper supplements that presented by the author in the Proceedings of this Association a year ago, which showed the Quaternary era as divided into the Lafayette, Glacial and Recent periods. The Glacial period or Ice age is here more particularly reviewed, and is found divisible into two parts or epochs, the first or Glacial epoch being marked by high elevation of the drift-bearing areas and their envelopment by vast ice sheets, and the second or Champlain epoch being 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, are thus regarded as the basis of the two chief time divisions of the Ice age. Each of these epochs is further divided into stages, marked in the Glacial epoch by fluctuations of the predominant ice accumulation, and in the Champlain epoch by successively diminishing limits of the waning ice sheet.

Studies by many observers have shown that both in North America and Europe 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 underwent much subaërial erosion

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and denudation; that renewed accumulation and growth of the ice sheets, but mostly without extending to their 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 of its melting; that moderate reëlevation ensued, and that during the farther retreat of the ice sheets prominent moraines were amassed in many irregular but roughly parallel belts, where the front at successive times paused or re-advanced 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 melted away.

Such likeness in the sequence of glacial conditions doubtless implies contemporaneous stages in the glaciation of these two continents; and the present writer believes that it is rather to be 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.

Under the latter view, however, Geikie distinguishes no less than eleven stages or epochs, glacial and interglacial, which he has very recently named (*Journal of Geology*, Vol. III., pp. 241-269, April-May, 1895), since the publication last year of the new edition of his 'Great Ice Age,' in which, however, they were fully described. These divisions of the Glacial period 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 successive stages and formations of the Ice age appears to be that of Chamberlin in his two chapters contributed to the new third edition of Geikie's admirable work before mentioned, in which he names the Kansan, East Iowan, and East Wisconsin formations. For the second and third he has since adopted the shorter names, Iowan and Wisconsin. This classification he has more recently extended (in the *Journal of Geology*, Vol. III., pp. 270-277, April-May, 1895), the interglacial stage and deposits between the Kansan and Iowan till formations being named Aftonian, and the Toronto interglacial formation, previously named, being referred, with some doubt, to an interval between the Iowan and Wisconsin stages. 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 Aftonian stage as Geikie's Helvetian; 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, Wright, 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.

EPOCHS AND STAGES OF THE GLACIAL PERIOD.

I. The Glacial Epoch.

1. THE CULMINATION OF THE LAFAYETTE EPEIROGENIC UPLIFT, 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. 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 gravels of southern England, 90 feet and higher above the Thames, and the similar traces of man in high terraces of the Somme valley, attest his existence there before the maximum stages of the uplift and of the Ice age. America appears also to have been already peopled at the same early time.

The accumulation of the ice sheets, due to snowfall upon their entire areas, was attended by fluctuations of their gradually extending boundaries, giving the Scanian and Norfolkian stages in Europe, and an early glacial recession and re-advance in the region of the Moose and Albany rivers, southwest of James Bay.

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 Greenland ice sheet, then somewhat more extended than now, 700,000 square miles or more, probably connected over Grinnell land and Ellesmere land with the continental ice sheet [the area of Greenland is approximately 680,000 square miles, and of its present ice sheet 575,000 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 basins of the Baltic sea, a half mile to one mile.

3. HELVETIAN OR AFTONIAN STAGE. Recession of the ice sheet from its Kansan boundary northward about 500 miles to Barnesville, Minn., 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. 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 accumu-

lation, covering the Aftonian forest beds, and extending again into Iowa, to a distance of 350 miles or more from its most northern indentation by the Aftonian retreat, and re-advancing about 150 miles in Illinois, while its boundary eastward from Ohio probably remained with little change.

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 less altitudes on the coasts of British Columbia, the British Isles, 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 ice fields by the 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 reëlevation of the land in the northern United States and Canada, advancing as a perma-

nent wave from south to north and northeast; 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 re-advance between the Iowan and Wisconsin stages, either in North America or Europe.

7. WARREN STAGE. Maximum extent of the glacial Lake Warren, held on its northeast side by the retreating ice border, one expanse of water, as mapped by Spencer, Lawson, Taylor, Gilbert and others, from Lake Superior over Lakes Michigan, Huron and Erie, to the southwestern part of Lake Ontario; its latest southern beach traced east by Gilbert to Crittenden, N. Y., correlated by Leverett with the Lockport moraine.

This and 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 belonging in the same time.

8. TORONTO STAGE. Slight glacial oscillations, with temperate climate nearly as now, at Toronto and Scarboro', Ont., indicated by interbedded deposits of till and fossiliferous stratified gravel, sand and clay. Although the waning ice sheet still occupied a vast area on the northeast, and twice re-advanced, with deposition of much till, during the formation of the Scarboro' 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 northeastward surface atmospheric currents

and courses of all storms, was not less mild than now. The trees whose wood is found in the interglacial Toronto beds now have their most northern limits in the same region.

9. IROQUOIS STAGE. Full expansion of the glacial Lake Iroquois in the basin of the present Lake Ontario and northward, then outflowing at Rome, N. Y., to the Mohawk and Hudson rivers. Gradual reëlevation of the Rome outlet from the Champlain subsidence had lifted the surface of Lake Iroquois in its western part from near the level of the present lake at Toronto to a height there of about 200 feet, finally holding this height during many years, with the formation of the well developed Iroquois beach.

Between the times of Lakes Warren and Iroquois, the glacial Lake Lundy, named by Spencer from its beach ridge of Lundy's Lane, probably had an outlet east to the Hudson by overflow across the slope of the highlands south of the Mohawk; but its relationship to the glacial Lake Newberry, named by Fairchild as outflowing to the Susquehanna by the pass south of Seneca Lake, needs to be more definitely ascertained.

10. ST. LAWRENCE STAGE. The final stage in the departure of the ice sheet which we are able to determine from the history of the Laurentian lakes and St. Lawrence valley was when the glacial Lake St. Lawrence, outflowing through the Champlain basin to the Hudson, stretched from a strait originally 150 feet deep over the Thousand Islands, at the mouth of Lake Ontario, and from the vicinity of Pembroke, on the Ottawa river, easterly to Quebec or beyond. As soon as the ice barrier was melted through, the sea entered these depressed St. Lawrence, Champlain and Ottawa valleys; and subsequent epeirogenic uplifting has raised them to their present slight altitude above the sea level.

Later stages of the glacial recession are doubtless recognizable by moraines and other evidences, the North American ice sheet becoming at last, as it probably also had been in its beginnings, divided into three parts, one upon Labrador, another northwest of Hudson Bay, as shown by Tyrrell's observations, and a third upon the northern part of British Columbia. From my studies of the glacial Lake Agassiz, whose duration was probably only about 1,000 years, the whole Champlain epoch of land depression, the departure of the ice sheet because of the warm climate so restored, and most of the reëlevation of the unburdened lands, appear to have required only a few (perhaps four or five) thousand years, ending about five thousand years ago. These late divisions of the Glacial period were far shorter than its Kansan, Aftonian and Iowan stages; and the ratio of the Glacial and Champlain epochs may have been approximately as ten to one. The term Champlain conveniently designates the short final part of the Ice age, when the land depression caused rapid though wavering retreat of the ice border, with more vigorous glacial currents on account of the marginal melting and increased steepness of the ice front, favoring the accumulation of many retreatal moraines of very knolly and bouldery drift.

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HELIUM AND ARGON.

BRIEF accounts of the discovery of helium and argon have already appeared in the pages of this journal. More recently, several important observations have been made, which, while not establishing with certainty the nature of these substances and their places in the system of the elements, at least afford a reasonable basis for speculation.

Helium was originally obtained from the