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PLEISTOCENE GLACIATIONS OF THE NORTHERN HEMISPHERE[1]

As this has been announced to be a centenary year for glacial geology a few words of explanation may be needed. The relevancy of 1928 as a centenary of glacial geology is based on the fact that two important investigations of glaciers date from the year 1828. That year marks the beginning of glacial studies by Jean de Charpentier, who with Louis Agassiz took high rank in early investigations and who led Agassiz to take up glacial studies. His most important work, "Essai sur les Glaciers," was not published until 1841, but for several years previous he had presented the results of his investigations before Swiss scientific societies. In 1828 also occurred the first publication by F. J. Hugi, a bold mountaineer, of results of his studies of Alpine glaciers, entitled "Beobachtungen in den Alpen."[2] His studies brought out many facts about the structure and condition of the snow, neve and ice at different heights, and observations on fissures and crevasses, and the rock material carried on and in the ice. He continued studies and publications for nearly twenty years, an important paper by him in 1846 being entitled, "Das Wesentlichste über die Gletscherfrage."

Scientific studies and publications on glaciers were begun at a much more remote time than 1828, some of which were of considerable importance. What appears to be the oldest scientific paper on glaciers was prepared by an Icelander, Theodor Vidalin, and published in 1695.[3] He explained the cause of the movement of glaciers by expansion due to freezing of water and a movement down the valley due to gravitation.[4]

[1] Paper presented at the symposium on the occasion of the celebration of the glacial theory, at a joint session of the Geological Society of America and Section E of the American Association for the Advancement of Science, December 27, 1928. Published by permission of the director of the U. S. Geological Survey.

[2] *Leonard Zeitschrift für Mineralogie,* Heidelberg, 1828, pp. 81–103; 117–213.

[3] "Dissertationcula de Montibus Islandia Chrystallines," Skaltholt, 1 July, 1695. Translated in *Hamburgisches Magazin,* Hamburg and Leipzig, 1754, pp. 9–27, 197–218.

[4] This paper is cited and reviewed by Hans Reck in an important paper on the glacial studies of the recent and ancient glaciated districts of Iceland in the *Zeitschrift für Gletscherkunde,* Band V, 1911, p. 241.

Perhaps the earliest glacial investigations in the Alps were by J. J. Scheuchzer, who carried on studies there between 1702 and 1711. One of his publications, entitled "Reisebeschreibung der Schweizer Alpen," is mentioned in K. von Zittel's "History of Geology and Paleontology" as the first paper on scientific investigation in the Alps.

A treatise in four volumes on Alpine glaciers was brought out by G. C. Gruner, in 1760, which gives important results of personal studies, and which was regarded by de Saussure as the most extensive and thorough up to that date.

H. B. de Saussure was among the earliest students to note evidence that the Alpine glaciers had been more prominent than now. He pursued studies in the Alps between 1760 and 1764 the results of which were published in 1780 under the title "Voyages dans les Alps." Reference is made (vol. 2, p. 269) to lateral moraines on the valley walls at levels higher than the surface of the present glaciers, and also to their extent down the valleys beyond the ends of the present glaciers. De Saussure is considered by von Zittel an ideal student, with his love of truth, accuracy of observation and freedom from bias.

Leopold von Buch is credited with the discovery that the erratics of northern Germany came from Scandinavia. In his travels in Norway and Lapland from 1806 to 1808 he noted ledges from which the erratics were derived. He also seems to have been the first to note that the old shore-lines of Scandinavia have suffered northward differential uplift, their altitude above present sea-level being greater in the northern than in the southern part of Norway. That the glaciation of Norway had once been more extensive than now was brought to notice by Jens Esmarck in 1824. In 1832, A. Bernhardi, without knowledge of the studies of Venetz and Charpentier, conceived the idea that the polar ice had once extended to the southern border of the North German Lowland.[5] In 1839, Böthlingk, a Russian geologist, described glacial deposits in Finland and Lapland, and referred the wide distribution of erratic blocks to glacial action. It is the opinion of von Zittel that this paper brought the glacial theory into favor among geologists of northern Europe, who had hitherto been skeptical of the glacial theory of the Alpine geologists. This paper antedated by only a year the visit of Louis Agassiz to Great Britain that gave an impetus to glacial investigations there and also in America.

To John Playfair apparently belongs the credit of noting evidence that the elevated shore-lines of Scotland are due to an uplift of the land, and not to a lowering of sea-level.[6] Playfair, in Scotland, and Venetz, in Switzerland, appear to have each at about the same time discovered that erratic blocks had suffered distant transportation, and referred the transportation to glacial extension. Playfair made his views known in 1815 and Venetz in 1816, the latter without knowledge of the former's views. In notes of a tour made in 1815 Playfair remarked:

> That a glacier which fills up valleys in its course, and which conveys the rocks on its surface free from attrition, is the only agent we now see capable of transporting them to such a distance, without destroying that sharpness of the angles so distinctive of these masses.[7]

Venetz noted the transportation of large erratic blocks from the Alps across to the Jura Mountains, a view which was at first opposed by Charpentier on the basis of its calling for a colder climate in the past than that of the present, which seemed inconsistent with the generally accepted theory that the earth is a cooling globe. But by field studies Venetz finally won Charpentier over to his view, and Charpentier then enthusiastically carried on extensive investigations, not only of the Alps, but also of the Pyrenees. As above noted, Charpentier took up these studies in 1828. He presented a notable paper in Luzerne in 1834. But his main work, "Essai sur les Glaciers," a volume of 363 pages, appeared in 1841.

Louis Agassiz became interested through Charpentier in glacial studies in 1836, and pursued them enthusiastically for the next four years, when he brought out his notable work "Études sur les Glaciers." These volumes by Charpentier and Agassiz aroused widespread interest in the study of glacial phenomena, and investigations were carried on with much zeal not only in Europe but also in North America in the decade 1840 to 1850. There was, however, less interest in Germany, since von Buch, who then had great influence, did not favor the theory of the Alpine students.

The first recognition of periodicity in glaciation appears to have been by E. Collomb in 1847.[8] He noted erratic blocks in elevated cols far outside and at much higher levels than the ends of the morainic loops which are conspicuous in the bottoms of valleys radiating from the Vosges Mountains. Evidence of

[5] Neues Jahrbuch für Mineralogie, 1832.

[6] See "Illustrations of the Huttonian Theory," by John Playfair, Edinburgh, 1802, pp. 411–457.

[7] Works, vol. 1, p. 29. Quoted by Charpentier in "Essai sur les Glaciers," p. 246.

[8] "Preuves de l'existence d'anciens Glaciers dans les vallées des Vosges," E. Collomb. 1847. Considered by J. Geikie a classical work. See "The Great Ice Age," 3d. ed., 1895, p. 514.

two distinct drifts in the Alps was brought to notice by A. Morlot in 1854,[9] and in Wales in the same year by A. Ramsay.[10]

The presence of fossiliferous beds between sheets of glacial drift was noted by E. von der Linth near Lake Zurich in the Alps about 1844,[11] and plants in them were later identified by Oswald Heer to be such as require a mild climate, like that which now prevails in that region.[12]

Very little additional study of interglacial deposits, or of other evidence of periodicity of glaciation, was carried on either in Europe or America until about 1870. But from 1870 to 1900 attention was concentrated on the evidence of the complexity of glacial history in both continents, and by the latter date was sufficiently complete to show the full series of drift sheets.

The state of investigations in Asia is far less advanced than in Europe or North America. The results thus far obtained seem to indicate clearly but two glacial stages, and it remains to be determined whether the glacial history there is as complex as in Europe and North America.

DISTRIBUTION OF GLACIATION IN THE NORTHERN HEMISPHERE

About four million square miles, or more than half of the Pleistocene glaciation of the northern hemisphere, was developed on the North American continent, and an area half as great on the European, leaving less than one fourth of the glaciated area for the Asiatic continent and the parts of the African and South American continents north of the equator. The Laurentide ice-sheet, which covered the northeast part of the North American continent, probably had a maximum extent of not less than three million square miles in the last, or Wisconsin, glacial stage, or more than 90 per cent. of the entire area of Laurentide glaciation. If the Iowan is included with the Illinoian glacial stage, there was an area similar to that of the Wisconsin stage. The two earlier stages, Kansan and Nebraskan, were probably of similar extent to the Wisconsin in the area covered. They were more expanded west of the Mississippi Valley, but less extended to the east. Granting the correlation of the Iowan with the Illinoian, each of the glacial stages apparently covered more than 90 per cent. of the total area embraced in the Laurentide glaciation. In the Cordilleran area of glaciation, in the western part of North America, the last glacial stage embraced much more than 90 per cent. of the total area of that field. In Europe the last glaciation covered more than 90 per cent. of the total glaciated area. This is true of the Alpine glaciation as well as of the northern or Scandinavian glaciation. It appears remarkable that in several successive and independent glacial stages the ice should have had so similar an extent.

In Asia the glaciation was largely confined to prominent mountain ranges, though the northern border of Siberia seems to have carried ice at low altitudes. The prominent ranges, from the Caucasus and mountains of Asia Minor eastward along the Tian-Schan and Himalayan ranges to the high mountains of China, and northward over northeastern Siberia, carried glaciers of more or less extent. Glaciation in northern Africa was restricted to small areas in the Atlas Mountains and the prominent volcanic peaks in the Mountains of the Moon. In northern South America the glaciation was restricted to a few of the high mountains of Colombia.

Glaciation on islands was conspicuous not only in the Arctic but also in the North Atlantic and the North Pacific as far south as northern Japan. However, some of the Arctic archipelago north of the North American continent may not have been glaciated. This is inferred from the fact that a considerable part of Alaska escaped glaciation. It is somewhat remarkable that a light glaciation was found by R. A. Daly to have occurred on Mauna Loa, a prominent volcanic cone in the Hawaiian Islands, in north latitude 19° 30′.[13] It was above 3,500 meters.

The initiation of glaciation in the Laurentide region of North America and also on the Scandinavian peninsula of Europe was in the belt of greatest storm frequency of the northern hemisphere. In the Laurentide region it was in the elevated southern part of the Labrador peninsula and the "Height of Land" south of Hudson Bay. In Europe it was in the high range along the western coast of Norway. The Cordilleran glaciation of western North America was developed in the humid district bordering the North Pacific. Aridity increased in passing eastward so that the glaciers had but slight extent east from the crest of the Rocky Mountains. But from these mountains westward there was a general filling with ice between the several ranges, from near the line

[9] *Bull. Soc. Vaud Sc. Nat.*, 4: 41, 1854; 6: 101, 1857.

[10] As cited by Sir Archibald Geikie in his "Life of Sir A. C. Ramsay," p. 361.

[11] In G. Meyer von Knonaus, "Gemälde der Schweiz," Band I. "Der Kanton Zurich." II Auflage. St. Gallen und Bern 1844, p. 162.

[12] Heer first published the results of his studies in 1858, and later incorporated them in his work "Urwelt der Schweiz," 1865.

[13] *Proc. Am. Acad. Arts and Sciences*, 51: 158, 167. 1915.

of the United States and Canada northward nearly to the Arctic. As the Arctic was approached the glaciation became weaker because of diminished precipitation. In the western United States and also in the mountains of central and southern Europe, altitude and relief above border districts seem to have been the controlling factors, and the relation to storm frequency a matter of less consequence. It is found, however, that the snow-line was lower and glaciation heavier on the windward than on the leeward slopes of the mountains. In the Alps and Pyrenees it was also lower down in the more humid western section than in the less humid eastern part.

In the elevated central portion of the Asiatic continent general aridity seems to have prevailed in the Ice Age as it does to-day. The Pleistocene glaciation was of slight extent beyond present glaciation. It seems to have owed its extension to a lower temperature rather than to increased precipitation, though there may have been a moderate increase. The greater extension of lakes in that region in the Ice Age was probably dependent mainly on lessened evaporation. There appears to have been only a moderate extension of ice eastward from the Ural Mountains into Asia. In the last glaciation of central Asia the snow-line, as estimated by Machatscheck,[14] was only six hundred to eight hundred meters lower than to-day, or much less than in the humid European districts, a feature indicating relatively high aridity. The last glaciation in northeastern Siberia seems to have been less extensive than an earlier one, and to have been restricted to the mountain slopes. In the earlier one the ice extended widely over the Siberian coastal slopes.[15]

As already indicated, the ice-sheets in successive glacial stages occupied areas with somewhat different limits, so that the entire glaciated area of each of the main fields of glaciation was never completely covered in any of the glacial stages. So also the ice-sheet of a given glacial stage had successive phases of growth and the whole area that it is represented to have covered was not completely covered at any one time. In the last or Wisconsin glacial stage in North America the Laurentide ice-sheet started on the Labrador Peninsula and the "Height of Land" south of Hudson Bay and took a southwestward course through the lowlands now occupied by the Laurentian Great Lakes into central Illinois, in what is termed the early Wisconsin substage or stadium. Following this the part of the ice-sheet south of Hudson Bay became dominant and a more pronounced southward movement took place. It extended into districts from central Ohio eastward that had not been covered in the earlier movement, but at the same time shrank materially in Illinois and Indiana and southwestern Ohio. It was probably at this time that the ice culminated in the district south of the St. Lawrence Valley from New York eastward and covered mountains which in early Wisconsin time had developed local glaciers. At this time the Kettle interlobate moraine of Wisconsin was formed. For some years this was considered a late Wisconsin limit, but it has recently come to be termed the middle Wisconsin limit, or stadium, because of the recognition of a well-defined later stadium. In this later stadium the ice became prominent in the district west and southwest of Hudson Bay, and then reached its culminating position in Iowa and the Dakotas. The eastern part at that time barely filled the Ontario, Huron and Superior basins.

What is true of the last or Wisconsin stage is demonstrable to a certain extent for the Illinoian glacial stage. It had first a southwestward movement from the same district as the early Wisconsin into western Illinois and southeastern Iowa. This was followed by a southward movement through the Lake Michigan basin over eastern Illinois and western Indiana and a marked recession of the border in western Illinois. It may have been at this time that the Illinoian ice reached its culminating position in Ohio, Pennsylvania and New Jersey. It seems to the writer not improbable that a later phase of this glaciation is represented in the Iowan drift, and that the earlier idea that the Iowan is a distinct and later glacial stage than the Illinoian is incorrect. The earlier idea still has its advocates and the question of the place and rank of the Iowan thus remains unsettled.

Whether the two earlier drifts, the Kansan and Nebraskan, went through a similar growth and culmination westward is not easily determined, since these drifts have very limited exposure east of the Mississippi Valley.

Turning now to Europe, it is found that the Scandinavian ice had an early movement in the last glacial stage southwest and south from Norway, which covered the North Sea and reached the coast of Great Britain. With the growth of this ice-sheet the axis of movement became shifted to the Baltic lowland and the movement across the North Sea became relatively weak. Meantime the Scottish glaciation became prominent, and strong enough to encroach upon the part of the British coast in England that had been

[14] *Geographische Zeitschrift*, Band 20, pp. 368–383. 1914.

[15] For a summary statement and references to the literature, see "Geology of Mongolia," by C. P. Berkey and F. K. Morris, vol. 2, pp. 382–393. 1927.

covered by the ice from Norway. It seems probable that the Scottish glaciation came largely as a result of the lowering of temperature induced by the neighboring Scandinavian ice-sheet. The Scottish ice may have had a similar rôle in inducing glaciation in the relatively low mountains of Ireland. After the Scottish ice had filled the Irish Sea and carried shells from its bed over the Irish coast, the Irish ice developed and encroached somewhat on territory that had been covered by the Scottish ice. What is true of the last Scandinavian glaciation seems to have been the succession in earlier glacial stages, the earliest advance from Norway being southwest and south into the British Isles and into Holland, while the advance through the Baltic depression came later. In the earlier glacial stages the ice extended considerably farther southeast into Russia and Poland than in the last glacial stage. The area of outlying drift here compares favorably with that of the outlying Kansan drift of the Laurentide ice-sheet west of the Mississippi Valley.

In high latitudes the ice of the last glacial stage, both in Europe and North America, had fully as great extent as in any of the earlier stages. In North America the Laurentide ice-sheet in the Wisconsin stage extended westward nearly to the base of the Rocky Mountains in Canada and terminated at an altitude of 3,000 to 4,000 feet or more. The Scandinavian ice-sheet extended eastward 900 miles from the center of dispersion in Scandinavia to the base of the Timan Mountains in northern Russia. There probably is some significant factor of the glacial history which determined that the glaciation of the earlier stages should extend into lower latitudes than that of the last stage that awaits interpretation. It appears that the centers of dispersion were essentially the same in all the glacial stages.

The mode of development of the Cordilleran glaciation in western North America is not well worked out, even for the last glacial stage, and very little is known as to the earlier ones. It was largely a confluence of piedmont glaciers. This also seems to have been the case with the glaciation in Scotland, Wales and Ireland. There seems also to have been a confluence of piedmont glaciation in the most extensive glaciation of northeastern Siberia. A similar type of glaciation probably was developed in northeastern Russia.

It is a matter of some significance, concerning the influence of planetary winds on the oceans in the glacial epoch, to note that the southern limit of glaciation on the European side of the Atlantic is 10° to 12° of latitude farther north than on the North American side, from which it may be inferred that the isotherms showed a difference in latitude on opposite sides of the Atlantic similar to what is found to-day. This relation shows clearly that the warm waters were driven northeastward across the north Atlantic by winds in the Pleistocene glacial stages about as they are to-day. While the mean annual temperature may have been a few degrees lower than now on both continents the relative temperatures seem to have been but slightly affected.

Evidence has been presented above that the main ice-sheet in the North American continent in each of the stages of glaciation started on the elevated land east and south of Hudson Bay. There is, however, a prevalent view that an independent center, known as the Keewatin center, was developed on the low plain west of Hudson Bay. The view has also been advanced that the Keewatin center of glaciation reached large dimensions before the ice on the elevated district east and south of Hudson Bay had reached great size. In the light of present knowledge, however, it is necessary to reject the latter view and perhaps so to modify the interpretation of the Keewatin center as to restrict it to a closing phase of ice radiation. In this closing phase a part of the ice-sheet may have persisted about as long on the west side of Hudson Bay as on the Labrador peninsula. On this peninsula, as shown by Low,[16] the center of ice dispersion migrated northward from about latitude 50° to latitude 55° in the course of the waning of the last stage of glaciation.

COMPARISON OF THE SNOW-LINE OF THE LAST GLACIAL STAGE WITH THE PRESENT SNOW-LINE

Two important papers on this subject, published in the *Zeitschrift für Gletscherkunde,* have summarized the relations between the Ice Age and present snow-lines in various glaciated areas. They pertain chiefly to the mountain glaciations because the areas covered by the great ice-sheets are almost entirely below the level of the present snow-line. The earlier paper, by Fritz Machatschek, appears in volume 8, 1913. A later paper by Fritz Klute appears in volume 16, 1928, and deals with the significance of the depression of the snow-line in Ice Age problems. It is illustrated by several profiles showing the Ice Age and present snow-lines in various parts of the earth.

Data by Klute show that the Ice Age snow-line on the Rocky Mountains in latitude 45° is 600 to 700 meters lower than the present snow-line, which is placed at 4,000 meters. In the Cascades, near the Pacific Coast, the Ice Age depression is estimated to

[16] A. P. Low, Geol. Survey of Canada, Ann. Rept. New Series, vol. 13, p. 81D. 1900.

range from 1,000 to 1,400 meters, and the present snow-line is placed at 3,000 meters. It thus appears that the humid district was affected to a markedly greater degree than the arid district.

Machatschek estimates the depression of the Ice Age snow-line of the Rocky Mountains in latitude 39° to be 1,000 meters lower than the present, which is put at 4,300 meters. In the Wasatch Mountains, in latitude 40° to 41°, the western slope shows 1,000 meters depression of the snow-line, while the eastern more arid slope shows only 700 meters. The present snow-line is put at 3,500 meters.

Klute estimates the Ice Age depression on Mt. Whitney, in the Sierra Nevada, latitude 36° 40′, to be 1,000 meters, and the present snow-line 4,200 meters. Machatschek estimates the depression of the snow-line on the arid east slope of the Sierra Nevada to be only 650 meters below the present snow-line, which is put at 3,650 meters.

The snow-line in Scandinavia is estimated by Klute to have been depressed in the Ice Age at least 1,000 meters below the present snow-line. In the Alps the depression in the Ice Age is estimated by Machatschek to range from about 900 meters in the drier parts to 1,300 or 1,400 in the most humid parts. Klute, however, estimates a depression of only 800 meters in the central Alps. In the Pyrenees Machatschek estimates the humid western part to have had a depression of 1,200 meters (from 2,500 to 1,300 meters), while the middle part had a depression of 1,000 meters (from 2,700 to 1,700 meters) and the eastern part 900 meters (from 2,900 to 2,000 meters). As one passes south from the Pyrenees to the more arid districts the depression of the Ice Age snow-line becomes less, being estimated by Klute to be 800 meters in the Sierra Nevada and in the Atlas Mountains. He estimates the depression in the Mountains of the Moon in equatorial Africa to have been only 700 to 800 meters. In the Caucasus Mountains the depression of the Ice Age snow-line is estimated by Machatscheck to have been 1,300 meters in the humid western part and 900 to 1,000 meters on the north slope of the middle part, while in the interior of the mountain system it was about 700 meters.

In the Tian-Schan of central Asia the Ice Age depression is estimated by Machatscheck to have been only 600 to 700 meters. In the northwest part of the Himalayas he estimates a depression of about 800 meters, while on the humid south slope it was much greater, possibly 1,600 meters. In the Chinese and also in the Russian parts of the Altai Mountains he estimates a depression of 800 to 900 meters. Klute estimates an Ice Age depression of 900 to 1,000 meters in the mountains of Kamtschatka, and a similar depression in the mountains of the north part of Japan.

In this connection it is of interest to note that the Driftless Area of the Upper Mississippi valley is an indication that the Ice Age snow-line was farther north than its northern limits, otherwise it would have been glaciated. The present annual mean temperature at the north border of the Driftless Area is only 42° F. From this it may be inferred that the lowering of temperature in the Ice Age was somewhat moderate. As the Driftless Area was not overridden by ice in any of the glacial stages the above-mentioned moderate amount of lowering applies to each of the stages. The unglaciated part of the Allegheny Plateau in southwestern New York, standing 2,000 to 2,400 feet above sea-level, was also outside the limits of the Ice Age snow-line. The great extension of the ice-sheet beyond the Great Lakes in the district lying between the Driftless Area and the Allegheny Plateau is thus an ice invasion into districts standing outside the Ice Age snow-line. The low basins now occupied by the Great Lakes gave the ice a free passage.

Evidence that the Ice Age lowering of the snow-line in the Alps was mainly due to a lowering of the temperature, and in but a minor way to higher precipitation, has been repeatedly set forth by Penck and Brückner in their publications on the Alpine glaciation. They have called attention to the fact that there was but little increase in the height of the snow filling in the higher part of the Alps in the Ice Age than the present filling. A lowering of temperature seems to be required to give rise to ice-sheets in northeastern North America and northwestern Europe of the dimensions reached in each of the glacial stages. It seems highly improbable that increase of precipitation could have been a leading factor. The very moderate lowering of the snow-line in the mountains of what are now relatively dry areas as shown in the above data seems to indicate that they were relatively dry in the Ice Age.

Evidence of Warm Interglacial Stages

The estimates of the warmth of the interglacial stages are based on the presence of a warm climate fauna and flora in beds lying between glacial deposits. Estimates of the length of interglacial stages are based on the amount of weathering and erosion a given drift had suffered prior to the next succeeding glacial stage. The conditions for the preservation of remains of terrestrial animals and plants in interglacial beds are much more favorable in the early relatively cool part of an interglacial stage than in the warmer middle

part, owing to the slow rate of decomposition under cool conditions. But conditions for the preservation of the remains of fresh-water and marine species are favorable under warm as well as cool climate. As a consequence the greater part of the evidence as to the degree of warmth reached in an interglacial stage is based on the species imbedded under water. If there are found species that are now restricted to warm or temperate climates it may be inferred with some confidence that the fossil species lived under similar climatic conditions.

The studies of the fauna and flora of interglacial beds are now sufficiently advanced both in Europe and America to bring out clear evidence that climatic conditions at least as warm as the present were prevalent in each of the interglacial stages. In some cases, as in the beds at Toronto, there is some uncertainty as to which interglacial stage the fossiliferous beds belong. But usually the geological horizon has been determined with a fair degree of certainty. In the Alps nearly all the fossiliferous interglacial beds are referred to the last or Riss-Würm interglacial stage, but in northern Europe and in America they are fully as abundant in each of the earlier stages.

The beds of interglacial plants in the Alpine region are known as "Schieferkohlen" in the German literature. They seem to have attracted attention earlier than the interglacial beds associated with the deposits of the Scandinavian and North American ice-sheets. Some of the beds near the east end of Lake Zurich were brought to notice by Escher von der Linth in 1844, and the fact that the plants are of warm temperate species was first announced by Oswald Heer in 1858, and repeated in his first edition of "Urwelt der Schweiz" in 1865. A bed at Morschwyl on the south shore of Lake Constance was first brought to notice by F. C. Deike in 1858, and its warm temperate flora was discussed by Heer in the first edition of his "Urwelt der Schweiz." The occurrence of interglacial warm temperate plants was noted later in the "Hötting breccia" near Innsbruck, in the midst of the Alps. These plants indicate a warmer climate than the present. These beds all seem referable to the Riss-Würm, or last interglacial stage. A fossiliferous bed at Leffe, in the Serio Valley, on the south slope of the Alps, underlies gravel of the Riss glacial stage, so is at least as old as the second or Mindel-Riss interglacial stage. Some geologists refer it to early Pleistocene, or to the Pliocene. There is no uncertainty as to the interglacial age of the other beds mentioned, for they lie between glacial deposits, and the overlying drift appears to pertain entirely to the last or Würm glacial stage. The Hötting flora is thought to call for a snow-line 400 meters higher than the present, and the others to require a raising of the snow-line at least 1,000 meters above that of the last glacial stage.

Passing to northern Europe we find that its earliest glaciation was followed by a stage in which conditions of climate were fully as mild as the present. The Cyprina clays of Denmark, North Germany and Holland, also known as the Eemian deposits, carry estuarine and marine molluscan fossils that are chiefly of species whose present habitat is somewhat farther south. Two species of *Cardium* now have their northern limit in the English Channel; one species of *Mytilus* now has its northern limit on the west coast of France and another is confined to the Mediterranean. These and others whose northern limit is now in the south part of the North Sea are all characteristic forms. The whole assemblage is thought to indicate that the present equivalent of the Eemian Sea of Denmark is to be found in or near the English Channel.

In the vicinity of Berlin borings have brought to light beds containing the fresh-water mollusk *Paludina diluviana* in such abundance as to give them the name "Paludina beds." The present habitat of this mollusk is in streams tributary to the Black Sea, so it is of decidedly warm temperate type. The beds, as in the case of the Eemian deposits, appear to fall in the first interglacial stage. They lie between the old and the oldest drift of that region.

The Cromer Forest-bed of the coast of Norfolk in eastern England has been found to carry no less than sixty-eight species of plants, which have had careful study by Clement Reid, and been found to indicate a climate very similar to the present. There is an absence of Arctic plants. But above the Forest-bed and below the oldest known glacial deposit of Norfolk are two beds, the first a marine bed characterized by *Leda myalis, Astarte borealis,* and other shells of Arctic type, and above this a fresh-water or flood deposit with Arctic plants, the Arctic willow, the dwarf birch, etc. The overlying till is thought to be referable to the second glacial stage, in which case the Cromer Forest-bed may have a similar age to the Eemian beds. It is underlain by the Weybourn crag, of marine origin. This has a fauna with a much higher per cent. of northern species than the beds below it, and is thought to show the influence of neighboring glaciation, such as may have then been present on the Scandinavian peninsula.

At many places in north Germany interglacial beds carrying the remains of extinct vertebrates, as well as of both extinct and existing species of mollusks of temperate habitat, and of plants have been brought to notice by various students. The essential data

down to 1909 have been summarized by Felix Wahnschaffe in the third edition of his "Die Oberflächengestaltung des norddeutschen Flachlandes." It is clearly shown that there are at least two horizons at which interglacial beds carrying fossils of temperate types are present. Similar beds have been noted over wide areas in Russia, reports of which are scattered through the Russian literature.

In North America the most comprehensive treatise on the life of the Pleistocene is a volume of 476 pages by F. C. Baker, issued as a bulletin of the University of Illinois. It lists nearly every published occurrence of interglacial beds carrying plant or animal remains, and attempts to refer them to the proper horizon. In some cases the references are manifestly incorrect, but in the main they appear to be correctly placed. There are also some cases in which the horizon is in doubt.

In regard to the climatic conditions in the first or Aftonian interglacial stage, Baker states, on the basis of a study of the fauna and flora, that the climate was moist, and the winters were not too severe for such animals as the elephant, horse and peccary. The type of mollusks, of which fifty species have been identified, indicates a climate not essentially different from that of to-day. The land snails attest the presence of a rich flora. The plants include trees such as pine, larch, spruce, elm and poplar, all of existing species. The mollusks show some varietal differences from the existing species. Of twenty-five species of vertebrates twenty-three are now extinct. The mammalian fauna resembles most closely the Equus zone or "Sheridan formation" described by Osborn.[17] The large mammals probably found refuge in the preceding glacial stage south of the ice-sheet and migrated northward as soon as the Aftonian climate became favorable.

In regard to the life of the second or Yarmouth interglacial stage, Baker states that as far as the plants and mollusks are concerned the life was very little if any different from that of to-day. Of ninety-two species of mollusks only two species are extinct. That a portion of the country was dry is attested by the loess deposits and their fossils. The presence of the giant sloth, tapir and peccary point to a warmer climate than the present. This interglacial stage is known to have been much longer than the third interglacial stage, and may have exceeded the first interglacial stage in length. This is the case in the Alps and probably elsewhere in Europe as well as in America.

[17] U. S. Geol. Survey. Bull. 361, 1909, pp. 85–86; also *Jour. Geol.*, 18: 214, 1910.

There is some uncertainty as to the place of the interglacial beds at Toronto. Baker refers them provisionally to the third interglacial stage, but it seems to the present writer more probable that they are to be put in the second interglacial stage. There have been forty-five species of plants identified in this deposit, three of which are extinct. Such plants as the papaw and osage orange, as well as species of maple, ash, oak, hickory, elm and basswood, are cited by Baker as evidence of a genial climate. He thinks the Unio molluscan fauna indicates the same condition. Three species do not now live in the St. Lawrence drainage, being confined to the Ohio and Mississippi valleys farther south. Four species still live in Lake Erie, but not in Lake Ontario. There are other species now common in Lake Ontario and tributary streams. It is a matter of some interest to note that immediately above and adjacent to these warm-climate beds, known as the Don beds, there are deposits of stratified peaty clay, known as the Scarboro beds, carrying a cold-climate fauna and flora. In them the remains of thirty-one genera and seventy-two species of fossil insects have been identified by S. H. Scudder, all but two of which are extinct.

According to the writer's interpretation the third interglacial stage is divisible into an early part in which peaty formation and gumbotil were formed, known as the Sangamon, which was followed by a period of loess deposition, which has been called "Iowan loess," and this became moderately leached in what is termed the Peorian stage, prior to the culmination of the early Wisconsin substage of the last glacial stage. On the Iowan drift there is, instead of peat and gumbotil, an eroded surface with a pebbly concentrate, over which a loess deposit of somewhat patchy character is found whose relation to the "Iowan loess" is not as yet clearly determined.

The plants found in the peat and gumbotil of Sangamon age are largely gymnosperms, spruce and cedar being conspicuous, and seem to indicate a somewhat colder climate than the present. The "Iowan loess" is characterized by a molluscan fauna similar to the present fauna, and changing from north to south with the present fauna. The climate may have been somewhat drier than now and it was apparently fully as warm.

THE SUCCESSION OF ICE INVASIONS

Studies in each of the large areas of glaciation have shown that there was a series of ice invasions separated by long intervals of more or less complete deglaciation. In each of these intervals, as already indicated, the climate became at least as mild as to-day. From this it seems a fair inference that the

ice in these interglacial intervals had no greater extent than at present.

Evidence of four glacial stages has been found in the Alps, and of at least four stages in North America. There is some division of opinion as to whether there were five glacial stages, which it is to be hoped will be cleared up in the near future. The controversy is as to the relation of the Iowan drift to the third or Illinoian drift. No serious difference of opinion has been expressed as to the place and rank of the three other drifts.

The students of the northern European glaciation are still battling over the question whether there were any intervals of complete deglaciation, such as are considered established in the Alps and in North America. Those who are favorable to the view that such intervals of deglaciation occurred have in most cases been unable to differentiate clearly more than three drifts. Intense interest in the matter is shown by German, Polish and Russian glacialists, so it is probable that the succession of ice invasions in that field will soon be satisfactorily settled.

From what has been already stated, it seems clear that a lowering of temperature, rather than an increase of precipitation, was the chief factor in bringing on the glacial stages. But the cause for the lowering of temperature is still a matter of wide difference of opinion, and will not be entered into at this time.

FRANK LEVERETT

U. S. GEOLOGICAL SURVEY

SCIENTIFIC EVENTS

THE LENGTHENED LIFE OF THE GERMAN POPULATION

ACCORDING to the Berlin correspondent of the *Journal* of the American Medical Association, the mortality statistics, as set forth in the new German mortuary tables for the years 1924 to 1926, may be regarded as comparatively favorable. The mortality of all age groups, in comparison with the decade 1901–1910, has been greatly diminished. The mortality for the first year of life for the years 1924 to 1926 was 115.4 and 93.9, respectively, per thousand living births (boys and girls), as compared with 202.3 and 170.5, respectively, for the decade 1901 to 1910, and 252.7 and 217.4, respectively, for the period 1871 to 1880. It is evident, therefore, that infant mortality has decreased, since the beginning of the twentieth century, by about 44 per cent., and since the founding of the German reich (1871), by more than 50 per cent. Still greater has been the decline of mortality among young children aged 1 to 5. Of 1,000 children who have withstood the dangers of infancy, 16.2 boys and 14.9 girls die in the second year of life, or only two fifths as many as twenty years ago and only one fourth as many as during the period 1870 to 1880. In the 3 to 6 age group the mortality of boys and girls has dropped to from one fifth to one sixth of what it was formerly. The mortality of 10-year-olds has decreased from 2.4 per thousand, for boys, in the years 1901 to 1910, to 1.4 per thousand, and from 2.6 per thousand, for girls, to 1.2 per thousand.

The mortality of men of the 45 and the 50 age groups also is about 40 per cent. lower, according to the recent tables, than it was according to the tables for the period 1901 to 1910. In the age groups above 50, however, the improvement in the mortality rates becomes less and less with increasing age. Nevertheless, the attained reduction of the mortality of 70-year-old men and women from 69.4 and 62.1, respectively, to 58.1 and 52.0, respectively, per thousand, and likewise the lowered mortality of 80-year-old men and women are noteworthy. The marked diminution in the mortality of all age groups results naturally in a considerable lengthening of the life of the population as a whole. Corresponding to the especially marked reduction of mortality in infancy and the early years of childhood, the lengthening of life is most noticeable in the first five years of life. Starting with a given number of new-born (omitting still-births), 12 per cent. more reach the self-supporting age than in the decade from 1901 to 1910, and even 23 per cent. more than under the mortality conditions of the period 1871 to 1880.

According to the mortality conditions of the period 1871 to 1880, the new-born boys reached an average age of 35.6, and, according to the conditions that prevailed during the decade 1901 to 1910, they attained an average age of 44.8. Under the present conditions, however, the average length of life of boys is 56. The entire reduction in mortality brought about since 1870 amounts, therefore, to an average lengthening of the life of new-born boys of 20.4 years. During the same period of fifty years, the life expectancy of new-born girls has increased from 38.5 years to 58.8 years, or a net gain of 20.3 years. In Denmark, England and Wales, Australia and New Zealand, the new-born, chiefly because of a lower infant mortality and a lower mortality of young children, attain, on the average, a still higher age than in the German reich.

THE USE OF ETHYL GASOLINE AS MOTOR FUEL

THE use of gasoline containing ethyl fluid as an automobile engine fuel does not affect materially the percentage of carbon monoxide contained in the exhaust gases, says the Department of Commerce, fol-