



Very truly yours,

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PLEISTOCENE IOWA.

BY SAMUEL CALVIN.

The Pleistocene is a term applied by geologists to the latest division of geologic time. It includes the present; and it reaches back beyond the present to the beginning of a special series of events, which, marking a decisive epoch in geologic history, have brought about the present relations of land and sea, the conditions of climate, the peculiarities of soil, the specialization and distribution of living forms, and in general all the phenomena that distinguish the modern from the geologically ancient world. No part of the geologic record is at the present time receiving more attention from students of world history than that which belongs to the Pleistocene; and in no part of the world are certain chapters of the Pleistocene record clearer, or fraught with greater interest, than in our own fair Iowa.

Before the beginning of the Pleistocene, Iowa had been subject to numerous vicissitudes of climate; for long eras it had lain beneath sea level and so received its load of limestone, sandstone and shaly sediments; at other times it was part of the nascent continent; in common with other parts of the globe it had undergone numerous gradual, but complete changes in its animal and plant life. The pre-Pleistocene history of Iowa was varied; but it was on the whole progressive; and eventually the region became fairly established as a part of the dry land.

That portion of geologic time which immediately preceded the Pleistocene is generally known as the Tertiary; but with

many geologists the term Tertiary is now discarded, and the time which has usually been assigned to it is divided into two periods known respectively as the Eocene and Neocene.

During the Neocene Iowa was a fair and sunny land, clad in forests of tropical species, and revelling in all tropical luxuriance. Birds of gay plumage flitted back and forth in the open glades; savage beasts related to the lion and the tiger sought the shadowy recesses; herbivorous animals not very different from the elk, the camel, the rhinoceros and the horse, found pasturage in the grassy savannas, while troops of monkeys swinging from branch to branch, and from tree top to tree top stirred the woodland echoes with noisy exclamations.

Now it is against this background of genial climate and abounding tropical life that we are to project the picture of the early Pleistocene in Iowa. Some cause or causes, at present not well understood, brought all the happy conditions of the Neocene to an end and introduced a series of changes whereby the climate and conditions that now obtain in central Greenland were established over some of the most favored areas of Europe and North America. Iowa was involved in the general change, and, together with all adjacent regions, was buried under persistent accumulations of snow and ice. Two things stand out distinctly in this part of the history. The change from Neocene to Pleistocene was attended by a very great depression of temperature; it was followed by centuries of unparalleled precipitation of snow.

Many attempts have been made to assign a cause for the stupendous climatic changes recorded in the Pleistocene deposits of Europe and America, but no explanation of the facts, so far offered, has met with anything like general acceptance. Dana, Croll, Geike, Wallace, Upham, and a host of others, have each sought to find a cause, either in upward movements of the earth's crust, in changes of oceanic currents, in increased eccentricity of the earth's orbit, or in some other event, or combination of events, assumed to have been concurrent with the oncoming of glacial conditions. But it must be said that unanimity of opinion has not yet been reached

even among those best qualified to express themselves on this subject. One fact, however, remains patent. Whatever may have been the cause, or combination of causes, desolation, dreary and arctic, overtook Neocene field and forest.

There is abundant evidence that the beginning of Pleistocene conditions was coincident with elevation of some portions of the crust within the areas subsequently covered with glacial ice. According to the best observers the crustal movements varied from a few hundred to three or four thousand feet, but it may be remarked that this amount of elevation would, of itself, produce no very marked effect upon the climate. The region about Denver and the high plateaus of Montana, Wyoming, Colorado and Utah have even now a greater elevation than was probably reached by any part of the glaciated areas in eastern North America or western Europe, yet the climate of the regions named is not as rigorous as that of the New England coast or the Upper Mississippi valley. The most important factor in the production of glaciers is copious precipitation of snow, and any cause that resulted in the inordinate piling up of snows during the severe winters of the northern United States and Canada would bring about perennial glaciation even without the aid of crustal elevation.

Not at once, but apparently some time after the movements of elevation that marked the transition from Neocene to Pleistocene, glaciers formed on a scale comparable to the great ice fields of the Antarctic continent, over the northern highlands both of Europe and America. The centers of accumulation in the case of all the North American glaciers have not been definitely located, but from some centers north and northwest of Iowa streams of glacier ice descended with slow grinding movement until, with the exception of a small area in the northeast, they overran the entire state and covered it with an ice sheet hundreds and even thousands of feet in thickness. The conditions that prevailed in Iowa, during the Neocene may approximately be duplicated in the forests of southern Florida, or probably better in Central America; to find examples of conditions that culminated and prevailed

here during the early Pleistocene we shall have to look to the inhospitable shores of Greenland. Southward to the middle of Missouri the glaciers extended before they encountered a climate sufficiently mild to produce complete melting of the onwardly flowing ice. All eastern Nebraska and northeastern Kansas lay beneath the same mantle of ice and snow. The eastern part of the Dakotas was similarly submerged. North of Iowa the ice prevailed in full force for many hundreds of miles, but its northern limits are not definitely known. To the eastward a practically continuous ice sheet spread away in cold monotonous desolation until its ragged edge was broken into icebergs by the waves of the wintry Atlantic.

The transformation from tropical to glacial conditions in Iowa was, however, not necessarily abrupt. It may indeed have extended over thousands of years. The elevation of the land that marked the transition from Neocene to Pleistocene was slow. Even admitting that this elevation was a cooperating cause of glaciation, a long time elapsed before a stage favorable to the development of glaciers was reached. Then after glaciers accumulated at the points of maximum precipitation of snow, the ice spread slowly. It progressively occupied larger and larger areas until the utmost limit of the glacial movement was reached. The principal centers of accumulation from which ice streams flowed into Iowa were some six hundred to seven hundred miles away, and glaciers must have flowed or been progressively developed over all the intervening space before the first ice invasion of the state could have taken place.

There is, however, some positive evidence that a long time elapsed between the close of the Neocene and the coming on of glacial conditions in Iowa. During the Neocene the state stood lower with reference to sea level than it does at present. The effect of erosion under long continued stable conditions of the crust had cut the surface down to base level. The streams were no longer capable of eroding their channels. The divides had been brought down practically to the level of the flood plains. The country was low, flat,

ill drained, and marshy. The sluggish streams may even have felt the influence of the tides, for the Gulf of Mexico extended up beyond the mouth of the Ohio. Pysiographers would say that this part of the valley of the Mississippi was reduced to a pene-plain.

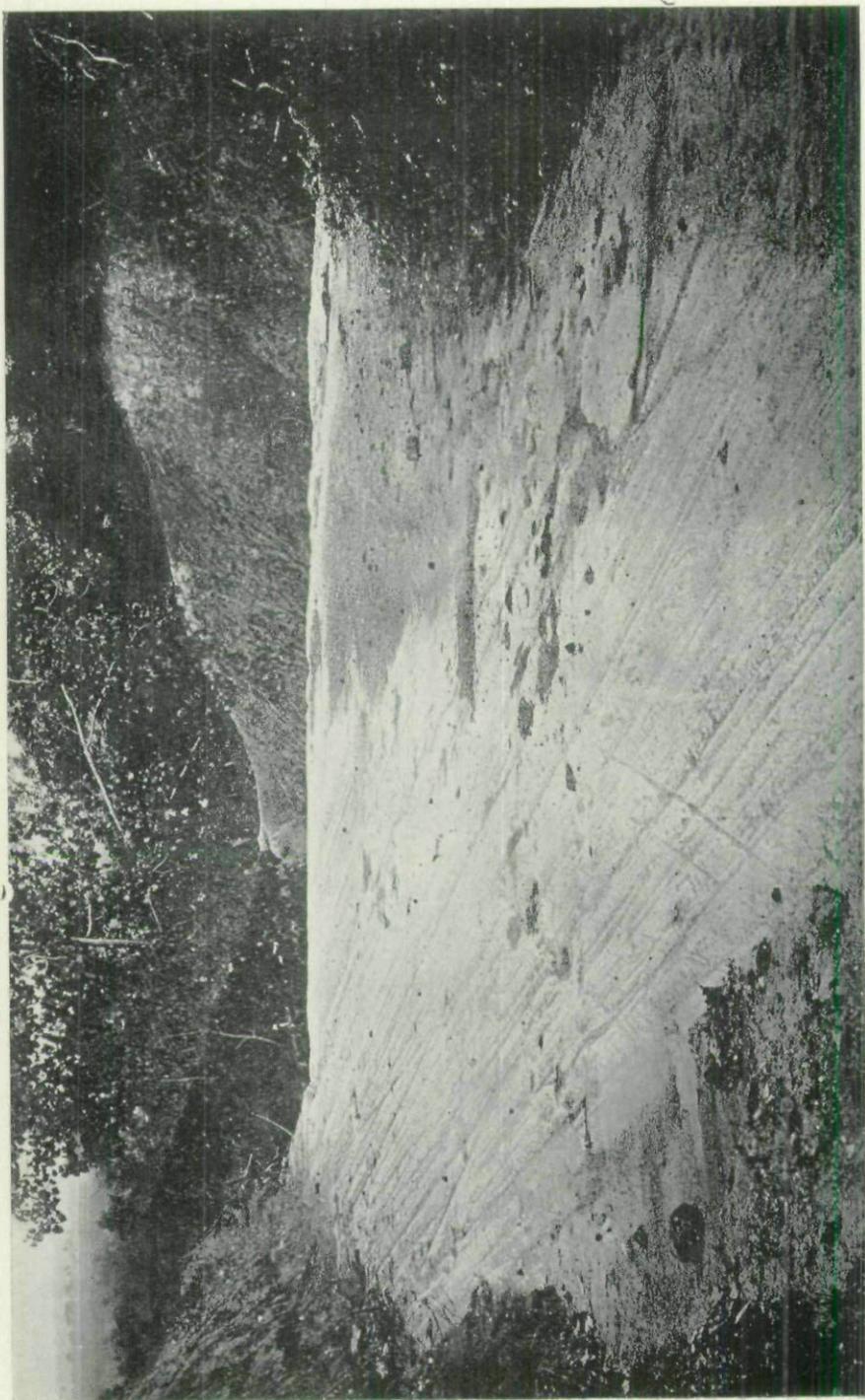
The elevation that marked the close of the Neocene introduced new conditions. The streams were quickened into new life. They began anew the work of scouring and cutting their channels. As the elevation of the land increased the surface was carved into a series of ever deepening, v-shaped river valleys separated by broad, flat-topped divides. In this way stream channels were cut through system after system of limestone and shales, to depths ranging from three hundred, to six hundred feet. And all this was done in an interval between the close of the Neocene and the approach of the glaciers that finally buried Iowa under a sea of ice. For when the first great Pleistocene ice sheet had fully taken possession of the state, stream cutting was brought to an end. The channels already made became choked with glacial detritus; and when the ice retreated it left an evenly spread mantle of drift that effectually concealed most of the preglacial hills and valleys. The ancient topography would probably have remained for a long time a mere matter of conjecture had not the exigencies of the past few years compelled the boring of numberless deep wells in all parts of the state; and the records of these wells are locating for us once more the drift filled channels and affording an accurate measure of their depth. By such means it is known that at Fort Madison, Iowa, there is a buried channel of the Mississippi river, wider and deeper than the present channel, and walled on either side by rocky cliffs, 250 feet in height. The old channel was filled with glacial drift; but when the ice retreated and the drainage waters of the great valley were collected into a new Mississippi, the stream failed at this point to find the old bed in which its preglacial work had been done, and so has since been cutting for itself a new channel east of the old one. Borings near Lone Tree reveal the presence of an old valley of the Iowa river cut to a depth of 200 feet below the

level of the modern stream. The bottom of a buried river bed near Washington, Iowa, is more than 300 feet below the level of ledges of Burlington limestone that crop out at the surface not far away. The glaciers, by planing off the hill tops and filling up the valleys, reduced wide areas to the same grade, so that we now drive our plows and build our railroads over gorges and precipices without so much as suspecting their existence. The whole state of Iowa is traversed by an intricate system of river valleys that are buried out of sight and are wholly unknown or undreamed of so far as concerns the ordinary observer. And these old valleys tell of two things in connection with the Pleistocene history of Iowa. First, they record the fact, already stated, that the Pleistocene was ushered in by an elevation of the land which carried the surface up to an altitude of several hundred feet above its present level; and, second, they tell in unmistakable terms of a time interval, long enough to enable the streams to accomplish the work of valley making, between the close of the Neocene and the advent of the ice which marked the culmination of Pleistocene conditions.

STAGES OF THE PLEISTOCENE IN IOWA.

The history of Pleistocene Iowa as now known is far more complex than was formerly supposed. Twenty years ago the whole history would have been summed up in (1) a stage of preparation, or transition from Tertiary to glacial conditions, (2) a stage of glaciation, (3) a stage of ice melting and attendant floods in the river valleys south of the glacier margins, and (4) the recent stage which was characterized by the introduction of man and the modern types of plants and animals. The record as now read shows the following succession of events:

1. *Ozarkian Stage.* There was first a stage of preparation or transition, a stage of continental uplift and cutting of the buried river channels already described. By some writers this stage is called the Transition Epoch, by Upham it is the Lafayette Epeirogenic Uplift, by Hershey it is made a distinct Pleistocene epoch under the name Ozarkian.



GLACIATED SURFACE OVERLOOKING THE MISSISSIPPI AT KINGSTON, IOWA.

2. *Pre-Kansan or Albertan Stage.* The Ozarkian stage, or stage of epeirogenic uplift, was followed in time by the first glacial stage which, for reasons to be noted later, is provisionally named pre-Kansan. Ice streams having their sources in remote northern highlands, at length invaded Iowa, but how much of the state during this first invasion was brought under the dominion of the Ice King has not been determined. The record of this first glacial stage has only been partially recovered. Evidence of a pre-Kansan ice sheet, however, is found in a bed of till of marked individual characteristics, varying from dark drab to bluish gray in color and charged with numberless pebbles derived from very obdurate crystalline rocks. This, the oldest known glacial drift in Iowa, is exposed at a number of points in the neighborhood of Thayer and Afton Junction in Union county. Mr. H. F. Bain has found it in Polk county. Till occupying the same relation to later Pleistocene deposits is found beneath a bed of peat at the base of the great railway cut near Oelwein in Fayette county. It is probable that it is somewhat generally distributed, but it is only recently that it has been recognized at all as a definitely differentiated glacial deposit. Its separation from the overlying Kansan drift may possibly be indicated by an old peaty soil and forest bed at a depth of 115 feet in the deep well at Washington, Iowa.

In both Europe and America one stage of the glacial series stands out pre-eminently above all the rest as marking the time of maximum glaciation. Without doing violence to legitimate inference, it has been assumed that the stage of maximum glaciation on one continent coincided in point of time with the maximum glaciation on the other. This has led to the correlation of the Kansan stage of America with Geike's Saxonian stage of Europe. Until recently the Kansan stage, from the best evidence at hand, was believed to represent the first ice invasion—at least in the United States—while Geike has shown that the Saxonian was the second glacial stage of Europe. On the other side of the Atlantic, therefore, the time of greatest intensity, widest distribution and longest duration of glacial conditions was preceded by

the formation of glaciers and distribution of drift on a less extensive scale. To this earlier stage of glaciation Geike has given the name Scanian; and it is quite possible that the pre-Kansan drift of Union, Polk and Fayette counties in Iowa may be referable to the Scanian stage of Europe. Evidences of early glaciation, preceding the stage of maximum intensity, have been observed by Dr. Dawson in the province of Alberta in Western Canada. If our pre-Kansan drift can be correlated with that observed by Dawson, this first glacial stage in the Pleistocene history of Iowa will be called Albertan. At all events the discovery of a pre-Kansan drift sheet brings the glacial series of Iowa into better harmony with the corresponding series of Europe, and for this interesting discovery science is indebted to Mr. H. F. Bain of the Iowa Survey.

3. *Aftonian Stage.* There are two distinct drift sheets in the hills and the sides of the valleys around Thayer and Afton Junction. Between the two sheets there are interglacial deposits of unusual interest. First, there is an old soil bed testifying to a long period of temperate conditions during which the surface was free from ice, and numberless generations of plants found the situation congenial. Then there are beds of stratified sand and gravel, 50 feet in thickness, that were laid down upon the old drift surface before the soil was formed. The Afton gravels were derived from the pre-Kansan drift, and show the effect of torrential action in connection with the melting of the pre-Kansan ice. These gravels have been extensively excavated for railway ballast, and very satisfactory sections are found at a number of localities within a radius of four or five miles. Some of the layers are so firmly cemented as to form a conglomerate hard and compact as the basal conglomerates of the Paleozoic or Algonkian. These gravels may be seen resting on the pre-Kansan drift in the valley of Grand river, a mile and a half below Afton Junction; the same relation is seen at Thayer; while less than half a mile north of the Junction they are overlain by a heavy bed of Kansan till. South of the Junction, indeed, both drift sheets may be seen with the whole thickness of the intercal-

ated gravels between them, but here only a thin layer of Kansan drift has escaped erosion.

A word of explanation may be necessary with reference to the position here assigned to the Aftonian beds. McGee's studies of Pleistocene deposits in northeastern Iowa led to the recognition of two drift sheets that he called respectively the lower and the upper till. Prior to McGee's work the belief in the unity of the Glacial period, a single ice invasion, and a single sheet of till, as far as Iowa is concerned, was very general. Science is always conservative and the announcement that our glacial period was dual and not single, and that the two ice invasions were separated from each other by a long interglacial period of comparatively warm climate, was regarded with more or less distrust. Gradually the evidence produced conviction in the minds of those observers who had personal knowledge of the facts. The recognition of the duality of the glacial period, however, was as far as conservatism could go at a single step; and therefore when the Aftonian beds were seen to lie between two sheets of drift, it did not seem possible that these two drift sheets could be other than the lower and upper till of McGee. Later McGee's lower till was called Kansan and the upper till Iowan, and the Aftonian beds came to be looked upon as representing interglacial deposits between these two stages. Recent detailed studies of the Kansan and Iowan tills have made it possible to recognize and differentiate them over extended areas, and to fix with a fair degree of accuracy the limits of their distribution. The Iowan drift does not extend southward beyond the latitude of Iowa City nor to Des Moines, but the Kansan till with easily recognized characteristics is continuous southward and southwestward far beyond the limits of Iowa. It is the Kansan till, as determined by Bain, and not the Iowan, that overlies the Aftonian gravels. The till beneath these gravels is therefore provisionally named pre-Kansan, and the Aftonian interglacial stage is transferred to a different position from that first assigned to it, a position preceding, and not following the Kansan drift.

The length of the Aftonian interglacial stage is not very

clearly indicated. The gravel beds were piled up in connection with the melting of the pre-Kansan ice and do not necessarily indicate any great interval of time. The soil bed at Afton Junction, the peat and forest bed in the Washington well, the peat bed at Oelwein,—these, together with other beds on the same geological horizon elsewhere, are more significant. They tell of a protracted period of time during which forests were fully established, and the climate was at least as mild as that of Maine and New Hampshire. That the Aftonian interval was of considerable length is further indicated by the fact that the gravels near Afton were trenched and eroded on an extensive scale during the time of their first exposure, between the retreat of the pre-Kansan and the advance of the Kansan ice.

It should be noted that since the Aftonian interglacial stage of Iowa preceded the Kansan instead of following it as was at first supposed, it must now be correlated with the Norfolkian stage of Europe, and not with the Helvetian as has been done in some American publications.

4 *The Kansan Stage.* The second glacial stage in Iowa is represented by a very heavy body of drift that, excepting the Driftless Area in the northeast, occupies the entire state. During the Kansan stage the ice covering Iowa was but an insignificant fragment of the great *mer de glace* that spread over more than half the continent of North America. South of Iowa, the ice continued down to the Missouri river. During this stage it reached its extreme southwestern limit and spread a sheet of drift over all northeastern Kansas. The same drift sheet passes without break into the states north and east of Kansas and may be traced continuously to the Atlantic seaboard. The Kansan was the period of maximum glaciation for North America. It has been correlated with the Saxonian, the time of greatest severity of glacial conditions in Europe. As compared with other glacial stages there is evidence that the Kansan was long, the snow fall was excessive, and the ice sheet attained a great thickness as well as great horizontal dimensions.

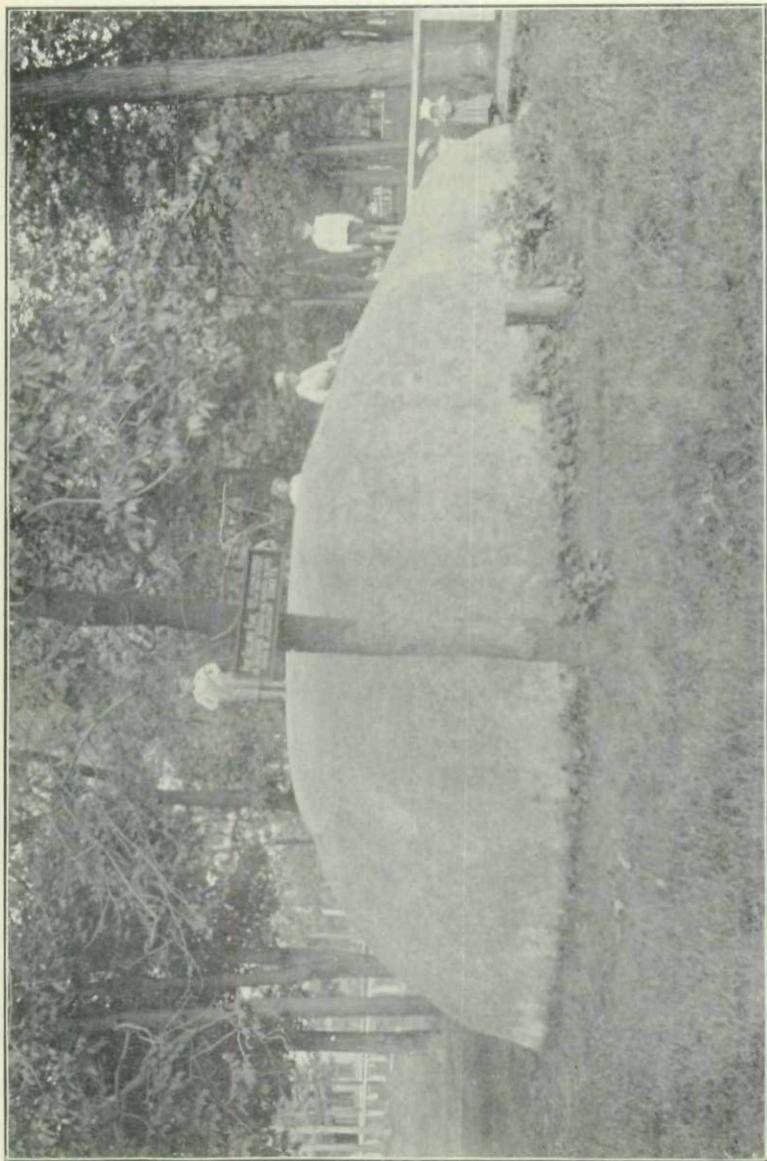
The thickness of the ice during the time of maximum glaciation in New England was sufficient to fill up the valleys and overtop the highest mountains. The Green Mountain range was completely submerged by a gigantic ice stream flowing southeast from the Adirondack region, across the Champlain valley, over the mountain range and on across New Hampshire to the Atlantic coast. The upper surface of the ice, as in the case of the continental glaciers of Greenland, may have had a uniform slope; and as this surface had an elevation so far above the mountain tops that the direction of the flow was not affected by the topographic features of the country, bold as they were and still are, the depth of the ice over the valleys could not have been less than 7,000 or 8,000 feet. Dana estimates the height of the ice over the Laurentide mountains at 10,000 feet. In Iowa we have no mountains to aid in estimating the thickness of the Kansan ice. But this is known; the flow of glacial ice depends on the slope of its upper surface or rather on the average gradient of the entire mass. The Greenland glaciers have a surface slope varying from 30 to 200 feet to the mile. It is scarcely possible that ice would flow if the gradient of the surface were much less than 30 feet to the mile. Now the Kansan ice flowed across Iowa and down to the latitude of Jefferson City and Saint Louis, Missouri. The movement from central Iowa was toward the southeast, nearly in the direction of a line drawn from Des Moines to Saint Louis. The distance from Des Moines in that direction to the southern margin of the drift is about 250 miles, and a gradient of 30 feet to the mile would make the surface of the ice at Des Moines 7,500 feet higher than at the margin. The present difference in elevation between Saint Louis and Des Moines is about 250 feet. The difference may have been greater then than now, but it certainly never much exceeded 500 feet, which would leave the thickness of the ice over the present site of Des Moines 7,000 feet. Reduce the gradient to 20 feet per mile, which is below the limit at which energetic ice flow is possible, and the thickness of the ice at Des Moines cannot even then be estimated at less than 4,000 feet. Carry this same

slope northward to the sources of the ice streams, and instead of feet, the thickness will be measured in miles.

An immense amount of detrital material, varying in dimensions from finest rock flour to boulders eight or ten feet in diameter, was transported by the Kansan ice and strewn over the whole glaciated area to form the present mantle of Kansan drift. In Iowa the Kansan drift is largely composed of blue clay, but other materials such as sand and gravel, disseminated pebbles, and multitudes of boulders, enter into its composition. A large proportion of the pebbles and boulders are fragments of crystalline rocks derived from Archæan and Algonkian areas in northern Minnesota, Wisconsin and Michigan. Some may have come from the Hudson Bay region away beyond the national boundary. A few are of local origin and represent the limestones and sandstones of more immediate neighborhoods. One of the most interesting that has been seen by the writer is a mass of native copper,* thirty-two pounds in weight, the property of Lt. Gov. Dungan, which was found in the drift of Lucas county. This copper was brought by the glaciers from Keweenaw Point in the upper peninsula of Michigan. There are two flattened sides to the mass, and both show the effect of abrasion consequent on its long journey beneath a sheet of ice thousands of feet in thickness. The distance from Keweenaw Point to Chariton is about 500 miles in a straight line. But it is known that the glaciers did not follow straight lines. Their course from Keweenaw Point was southwest, following the basin of Lake Superior, into northern Wisconsin and Minnesota, then southward and finally southeastward to Chariton. The direct course was not the direction of least resistance nor the direction of maximum slope.

The boulders of the Kansan drift are small as compared with those of some of the other drift sheets of Iowa. Not many exceed a foot in diameter, and specimens ten feet in diameter are exceedingly rare. Many of the boulders are granites, but those that are most common and most character-

*This piece of copper was presented by Lt. Gov. WARREN S. DUNGAN to the Historical Department of Iowa, where it is now on exhibition.



Granite boulder of Iowan age near the southeast corner of the Public Park, Nora Springs, Iowa.

Length 30 feet, width 25 feet, height above ground 12 feet.

istic of the Kansan stage are dark colored, basic eruptives popularly known as greenstones. Furthermore, a large proportion of the Kansan boulders are planed and scratched on one or two sides as a result of having been dragged along over the subjacent rocks while firmly imbedded in the lower surface of the moving ice.

There is no direct measure of the length of the Kansan stage, but it is certain that the time must be expressed in thousands of years. It was long enough for boulders embedded in the lower surface of the ice to be transported through a distance of 600 to 1,000 miles. The Lucas county copper travelled more than 600 miles. The rate of flow of a glacier depends on a number of factors, such as the gradient of the surface, the depth of the ice and the temperature of the air. When the ice has great depth, as in the case of the Pleistocene glaciers, the flow at the surface may attain a rate of speed equal to 50 or 100 feet a day. But the base of the glacier, retarded by friction of the bed, moves more slowly than the surface. Depth of ice, by increasing the weight tends to increase the friction at the base. The multitude of rock fragments with which the lower surface of the glacier is studded, cutting into the underlying rocks, tends still farther to emphasize the effect of weight and retard the flow at the bottom. On the steep slopes of the Alps, where the temperature is relatively high, and the thickness and consequent weight of the ice is comparatively small, the daily motion at the base, as shown by Tyndall, does not exceed three or four inches. Allowing that the movement at the base of the Kansan glaciers equalled the rate observed in the Alps, allowing the rate to be doubled, or more than doubled, it still took many thousand years for sub-glacial boulders to accomplish a journey of 600 or 800 miles.

5. *Buchanan Stage.* The extreme severity of climate that characterized the period of domination of the Kansan glaciers, at length relaxed. The glaciers melted and Iowa was once more released from fetters of ice. Then followed a second interglacial stage which is here provisionally named Buchanan, but which may be found equivalent to that called

Helvetian in Europe. Three miles east of Independence in Buchanan county there are interglacial gravels twenty feet in thickness, resting upon the blue clay of the Kansan drift, and overlain by a sheet of till differing in character and differing widely in age, from the drift sheets already discussed. The Buchanan gravels were deposited by strong currents of water, but the evidence of torrential action is less marked than in connection with the Aftonian beds. They are composed of materials derived from the Kansan drift, striated greenstones being conspicuously numerous. The gravels are stratified, in part they are obliquely laminated. There is a larger proportion of sand and small pebbles than in the Aftonian beds, and none of the layers have been cemented into a conglomerate. Like the Aftonian, the Buchanan gravels have been used extensively for railway ballast.

The gravels just described were deposited at the beginning of the second interglacial stage, while the Kansan ice was retreating. The stage thus initiated was one, however, of long duration. Forests once more took possession of the land. Complete drainage was established over the whole surface of Iowa, and streams cut valleys, wide and deep, in the materials of the Kansan drift. The superficial portion of the drift was profoundly modified by organic and meteoric agencies. The blue clay which forms so large a part of the second till, is rich in ferrous oxide, a compound that on exposure to air and moisture undergoes farther oxidation. In the surface materials this compound was changed in part to the red oxide of iron, and in part to the brown hydrated oxide. During the Buchanan interval therefore the surface portion of the drift was changed in color to dark reddish brown, and the time was long enough to affect the materials to a depth of eight or ten feet. A large proportion of the small granite boulders embedded near the surface of the Kansan drift were softened and decayed. Dense forests and other forms of vegetable growth were not without their effect in modifying the upper portion of the deposit. Carbonate of lime, which is a normal constituent of the unchanged Kansan drift, was completely removed to a depth of several feet. Mea-

sured by the amount of erosion of the surface, by the perfect oxidation of the superficial materials, by the removal, by leaching or otherwise, of the calcareous constituent, by the decay of granites, by the development of forests, by all the changes that are known to have been wrought in it, the Buchanan interglacial stage was one of long duration, probably as long as all the time that has elapsed since its close.

6. *The Illinois Stage.* As shown by Leverett there is a small area in southeastern Iowa over which till was distributed by an ice sheet that approached from the northeast, traversing Illinois, and covering the greater part of that state with a sheet of drift that is evidently much younger than the Kansan. So far as Iowa is concerned the Illinois drift is comparatively unimportant.

7. *Third Interglacial Stage* (unnamed). While only a small part of Iowa was actually invaded by the Illinois glacier, yet the presence of an ice sheet in the neighboring area was doubtless coincident with a marked depression of temperature that probably destroyed the forests of the Buchanan interval, or seriously interrupted their growth. The retreat of the Illinois ice marks the beginning of a third interglacial stage for which at present no name can be proposed. During this stage the growth of forests was renewed and was continued until a fourth depression of temperature and a fourth ice invasion brought it to an end.

8. *The Iowan Stage.* The Iowan is the fourth glacial stage recorded in the Pleistocene deposits of Iowa. During its progress glaciers advanced from the northwest toward the southeast, but only the northern half of the state was directly affected by this fourth ice invasion. So far as relates to our own state, the area covered by the Iowa drift sheet may be circumscribed by a line drawn from the northwest corner of Winneshiek county to Bellevue, thence down the Mississippi river to Clinton, then westward through Clinton, Cedar, Johnson and Iowa counties on toward Marshalltown and thence northwesterly to the Sioux river in Plymouth county. The southern boundary of this drift sheet is a very irregular and sinuous line that in many places falls far short of the

limits indicated above. In the northwestern part of its area this drift is overlapped by the till of a fifth glacial period whose eastern boundary passes in a southerly direction through the town of Clear Lake. The typical development of the Iowan drift may be observed in Blackhawk and Buchanan counties, and in the counties lying north and slightly west of these to the state line. This drift is fundamentally a bright yellow clay. In places it contains large quantities of sand. Its boulders are chiefly light colored granites. Large boulders from four to ten feet in diameter are very common, and enormous granite masses 20 to 30 feet in diameter are by no means rare. The boulders in most cases stand out conspicuously above the general surface, and the great numbers strewn over the fields within the Iowan area is a striking feature that wherever it occurs proclaims without further investigation the presence of the Iowan drift. The granites are usually sound and fresh as when they left the parent ledge, a fact which when compared with the decayed boulders of the Kansan is proof of the recency of the Iowan stage, and emphasizes the great length of the interval since the close of the Kansan. While the granite boulders carried by the Iowan glaciers are large and very numerous, the amount of fine material such as sand and clay, is comparatively scant. Overlying the Buchanan gravels there are only from three to five feet of drift. From four to ten feet is the more common thickness. A thickness of twenty feet or more is quite unusual. In well sections the bright yellow Iowan clay often rests on the dark brown oxidized upper surface of the Kansan till without the intervention of a forest bed. The relations of this drift sheet, however, whether resting on water-laid gravels, on old peaty soil and forest bed, or directly on the older till, show that the glaciers by which it was distributed often rode over the pre-Iowan surface materials without cutting into or disturbing them to any appreciable extent. It is possible that the ground in front of the advancing Iowan glaciers was frozen solid, or it may have been protected by a sheet of ordinary ice over which the glaciers moved without cohesion with it.

In Buchanan, Blackhawk and some of the other counties included within the Iowan area, the enormous boulders peculiar to this stage are literally granite quarries. For bridge-piers and other heavy masonry they are annually utilized to a large extent. A boulder 30 feet long and more than 20 feet in width and thickness furnished a number of the massive blocks in the foundation of the great mill at Independence. A similar boulder furnished the material for building the Presbyterian church at Waterloo. A considerable number of the granite blocks in the foundation of the State Capitol were cut from Iowan boulders in Buchanan and Blackhawk counties; while the entire foundation of the main building of the Independence Hospital for the Insane, and all of some of the other structures connected with it are built of granite, transported from the north, free of cost, by the Iowan glaciers.

A very instructive artificial section of Pleistocene deposits occurs in a recently made railway cut at Oelwein. This section preserves a record of all the glacial and interglacial stages that directly affected this part of Iowa. The Albertan or Pre-Kansan drift is shown near the base of the cut. The Aftonian interglacial stage has left its record in a bed of peat four feet in thickness. The Kansan drift composed of blue clay beneath and oxidized near the surface, with many decayed boulders in the oxidized zone, overlies the Aftonian peat. The Buchanan gravels are probably represented by certain stratified sands above the Kansan drift; and the Iowan till, composed of yellow clay and hard fresh granites, rests in places on the stratified sands of Buchanan age and in places on the dark brown oxidized surface of the Kansan drift. Nowhere else so far as known is there such a complete section of the Pleistocene deposits of northeastern Iowa.

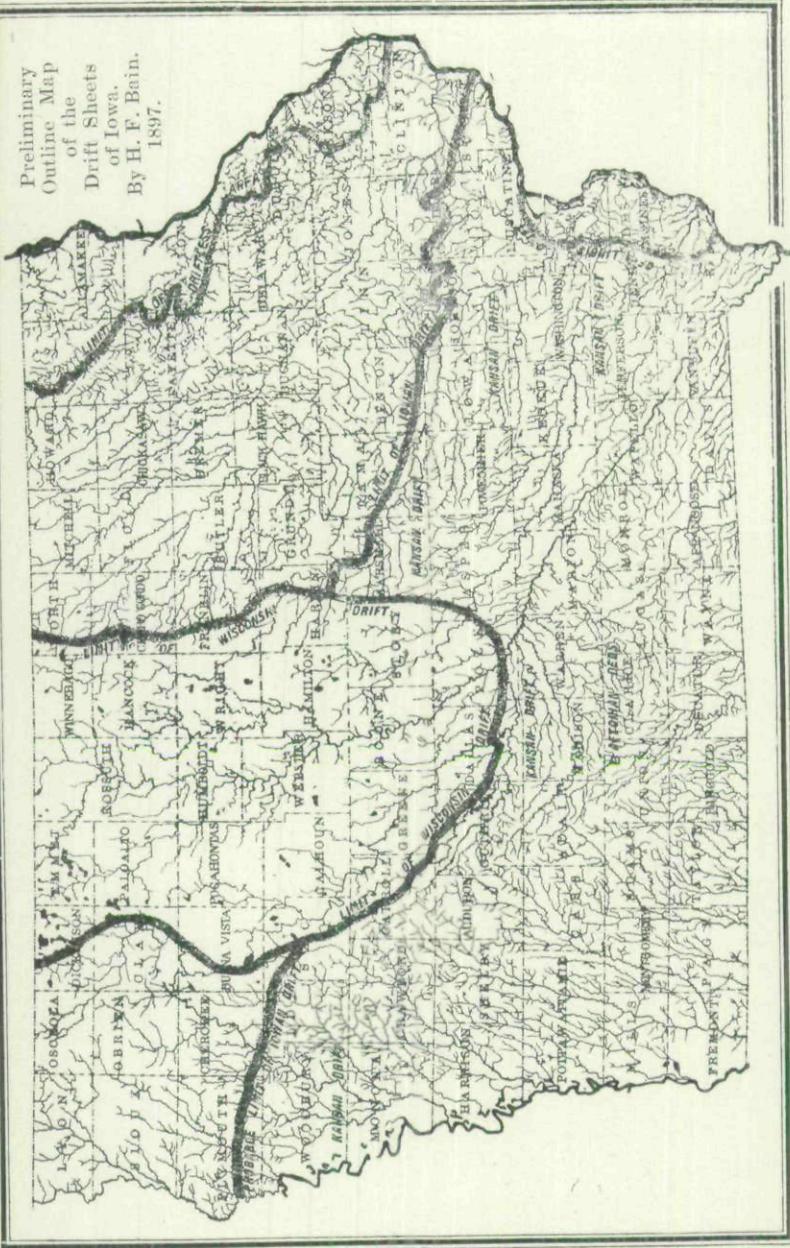
9. *Toronto Stage* (?) A fourth interglacial stage followed the melting of the Iowan glaciers. Professor Chamberlin, with some expressions of possible doubt as to its accuracy, has correlated this stage with the time represented by certain interesting interglacial deposits near Toronto, Canada, from which fact he calls it the Toronto stage. By whatever name it may hereafter be called it follows the disappearance of the

Iowan glaciers, and was introduced by the deposition of extensive beds of sand and clay that are now conspicuous in certain latitudes from the Mississippi to the Missouri river. The characteristic, homogeneous yellow clays that mark the beginning of the Toronto stage receive the name of loess. From Des Moines eastward the loess was laid down in connection with the melting of the Iowa ice and is related to this event as the Buchanan and Aftonian gravels are related to the melting of their respective antecedent ice sheets. When the gravels were deposited the land stood high enough to make energetic current action possible; when the Iowan ice melted, the resulting waters, owing to great depression of the continent or for some other reason, were too sluggish to transport gravel and so carried only finest sand and fine glacial silt. Loess deposited near the margin of the ice is usually very arenaceous, while that laid down at greater distances from the margin is wholly free from sand. East of the meridian of Des Moines a heavy belt of ridged, and frequently arenaceous loess marks the entire eastern and southern border of the area occupied by Iowan drift, and finer loess silt forms a thin coating over the deeply eroded surface of the Kansan drift throughout all that part of Iowa which lies south and southwest of the area named. All this eastern loess is a direct product of the Iowan drift.

Loess of different composition, and evidently of different origin, covers extensive areas in western Iowa, beginning at the mouth of the Sioux river and extending southward to the Missouri state line. This loess is practically identical with the silt now carried by the Missouri river; and it is probable that the cause, depression of the land or whatever else it may have been, which checked the flow of waters from the melting Iowan ice, may have ponded back the Missouri, causing it to overflow the loess-covered area of western Iowa, and so deposit its load of sediment to form the western loess.

The Pleistocene deposits of Iowa afford no very conclusive evidence respecting the length of the fourth interglacial interval. It was certainly very much shorter than the second or Buchanan stage. The amount of erosion, oxidization of

Preliminary
Outline Map
of the
Drift Sheets
of Iowa.
By H. F. Bain.
1897.



Compiled principally from published notes by McGee, Upham and Chamberlain, and unpublished material of Calvin, Leverett, Beyer, Leonard and the author. The drift borders are not necessarily morainic and are in part only approximately located.

the surface materials, and decay of granitic boulders that have taken place in the Iowan drift up to the present time, is insignificant. While the loess was forming, Iowa was occupied by herds of reindeer and musk oxen, and it is possible that these arctic forms were present in parts of the state even while the Iowan ice was at its maximum. Portions of the skeleton of a musk ox (*Ovibos cavifrons*), including a fairly perfect skull now in the museum of the State University, were some years ago taken from loess beds at Council Bluffs, and Professor Witter has found bones of the reindeer in the loess at Muscatine. The loess also contains as fossils numerous species of land snails that have been carefully collected and studied by Professor Shimek of Iowa City. The most common and characteristic belong to the genus *Succinea*.

10. *The Wisconsin Stage.* The last glacial invasion of Iowa is known as the Wisconsin stage. The Wisconsin glaciers, however, covered only a small part of the state. When the Wisconsin glaciation was at its height, a lobe of ice crossed the northern boundary of the state with a width reaching from Worth to Osceola county, and with a somewhat attenuated extremity resting upon the present site of Des Moines. The Wisconsin drift overlaps the Iowan area. In the city of Des Moines and for some distance north, Wisconsin drift rests upon the fossil-bearing loess laid down at the beginning of the fourth interglacial stage. Along its southwestern margin the newer drift sheet rests in places upon the Kansan.

The Wisconsin drift is largely a pale buff, very pebbly clay. The boulders are granitic, but they are finer grained as a rule, and the average size is smaller than those of the Iowan drift. The ledges whence they were derived were intersected with numerous veins of trap. Very generally the smaller pebbles are fragments of limestone.

The Wisconsin glaciers, more than those of any other glacial stage in America, heaped up the drift around their margins in the form of moraines. These moraines are usually very conspicuous topographic features. In some instances they form ranges of hills rising from 50 to 150 feet above the adjacent plains. The largest moraines belonging to this

stage are found in Wisconsin and the Dakotas, but irregular ridges of drift, more or less conspicuous, may be traced along the eastern margin of the Wisconsin lobe, through Worth, Cerro Gordo, Franklin, Hardin, and Story counties in Iowa. At its extreme southern limit the drift of this stage thins out without forming any terminal ridge. The western margin is marked in many places by morainic ridges.

The retreat of the Wisconsin ice is so recent, geologically speaking, that the drift surface remains almost as the glaciers left it. Drainage has not been completely established. Numerous lakes occupy depressions in the irregular surface, particularly in the moraines. Basin-like marshes are still numerous. Many square miles are still in a condition to be flooded after any unusual rainfall. The channels of even the largest streams traversing the area are cut only a few feet below the level of the general surface. The beautiful rolling country traversed by the Great Western railway southwest of Des Moines, where every acre is thoroughly drained and the stream valleys are wide and frequently more than 100 feet in depth, may be contrasted with the level lands of Winnebago, Hancock, Kossuth, Emmet and Palo Alto. Southwest of Des Moines the topographic forms are the result of erosion acting continuously since the close of the Kansan stage. In the northern counties mentioned we see how inappreciable have been the effects of erosion during the relatively short period since the close of the Wisconsin.

11. *Warren Stage (?)* Mr. Upham uses the term Warren stage for the time immediately following the melting of the Wisconsin ice; but no records of deposits made during this stage, and no facts throwing light on its duration or climatic conditions, have been recognized in Iowa. With the disappearance of the Wisconsin ice lobe the state was freed from its latest glacial invasion so far as known. For a long time, however, the ice fields must have lingered north and northeast of Iowa. Upham notes a number of advances and recessions of the ice that took place after the close of the Wisconsin stage, but none of these movements affected the state except so far as they may have produced fluctuations in the annual

temperature. The general climate of the state, however, must have felt the influence of great bodies of ice so long as they lingered very far outside of the limits to which the Greenland and other northern glaciers are now confined. When that limit was essentially reached, when modern conditions as to climate were established, the recent stage was introduced and the geological history of the globe was practically ended.

During the Warren stage, or at least while the temperature of Iowa was still affected by the retreating glaciers to the north, Iowa became populated with a mixed fauna, part of which persists among our modern species, part of it has become extinct. Among the more conspicuous animals were three species of elephant, or probably three varieties of the same species. Remains of the elephants are not uncommon, and some may be found in almost every museum collection in the state. The Historical Department has its share, and some are interesting as showing a very close relation to the typical Mammoth or hairy elephant of the eastern continent (*Elephas primigenius*.) The larger number of elephant remains found in Iowa are referable to De Kay's species, *Elephas americanus*.

Entering the state later than the elephant, but apparently contemporaneous with it for some time, was the Mastodon, another elephantine creature differing from its great congener principally in the structure of the molar teeth. Only one species is indicated in Iowa, *Mastodon americanus*. There are reasons for believing that the Mastodon survived later than the elephant and continued to inhabit Iowa until comparatively recent times.

There were horses too, in our Pleistocene fauna as demonstrated by a number of discoveries, but the horse, like the Mastodon and the elephant, became extinct before the Columbian discovery of America. But the extinction of the older types of life, the retreat of glaciers to the fields they now occupy in high latitudes or at high altitudes, the coming of man, and the introduction of modern faunas and floras, mark the close of geologic history. Pleistocene Iowa becomes

modern Iowa, and its subsequent history belongs to the Botanist, the Zoologist, the Ethnologist and the Historian.

The divisions of the Pleistocene which are indicated by the present state of our knowledge on the subject, may be summarized as below. The names applied to some of these divisions are subject to future revision.

12. *Recent*.—Establishment of modern biologic and climatic conditions.

11. *Warren* (?)—Dominance of extinct faunas including elephant and Mastodon.

10. *Wisconsin*.—Invasion of Iowa by narrow lobe of ice extending down to Des Moines; distribution of pale yellow, pebbly till; formation of moraines.

9. *Toronto* (?)—Interglacial conditions and growth of forests. Introduced in Iowa by deposition of loess.

8. *Iowan*.—Glaciation of northern half of Iowa; distribution of enormous granite boulders and thin sheet of yellow till.

7. (*Unnamed*).—Interglacial conditions; growth of forests; development of soil. Continued modification of surface of Kansan drift.

6. *Illinois*.—Invasion of small area in southeastern Iowa by glaciers flowing southeast through Illinois.

5. *Buchanan*.—Erosion, oxidation and leaching of surface of Kansan drift, development of soils, growth of forests. Introduced in Iowa by deposition of Buchanan gravels.

4. *Kansan*.—Time of maximum glaciation, covering all of Iowa except driftless area; distribution of heavy body of blue till with small boulders and pebbles.

3. *Aftonian*.—First interglacial stage; growth of forests, erosion and oxidation of Pre-Kansan drift. Introduced by deposition of Aftonian gravels.

2. *Albertan, or Pre-Kansan*.—First glacial stage; full extent of glaciated area unknown. Distribution of dark blue or greenish till with small boulders and pebbles.

1. *Ozarkian*.—Elevation of surface through some hundreds of feet and rapid cutting of deep gorge-like river channels found beneath the drift.

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