RELATIONS OF THE

WISCONSIN AND KANSAN DRIFT SHEETS

IN CENTRAL IOWA,

AND RELATED PHENOMENA.

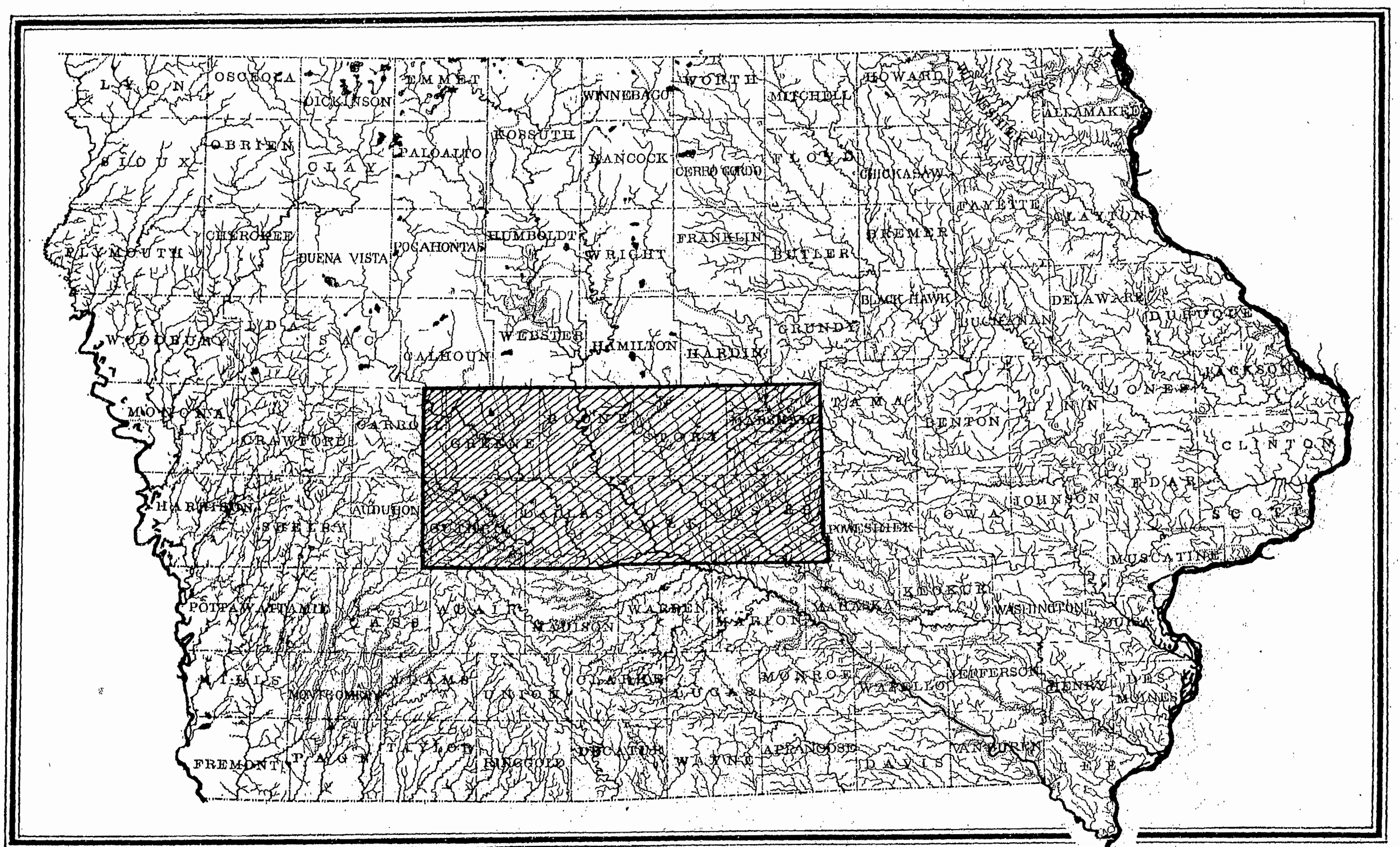
BY

H. FOSTER BAIN.

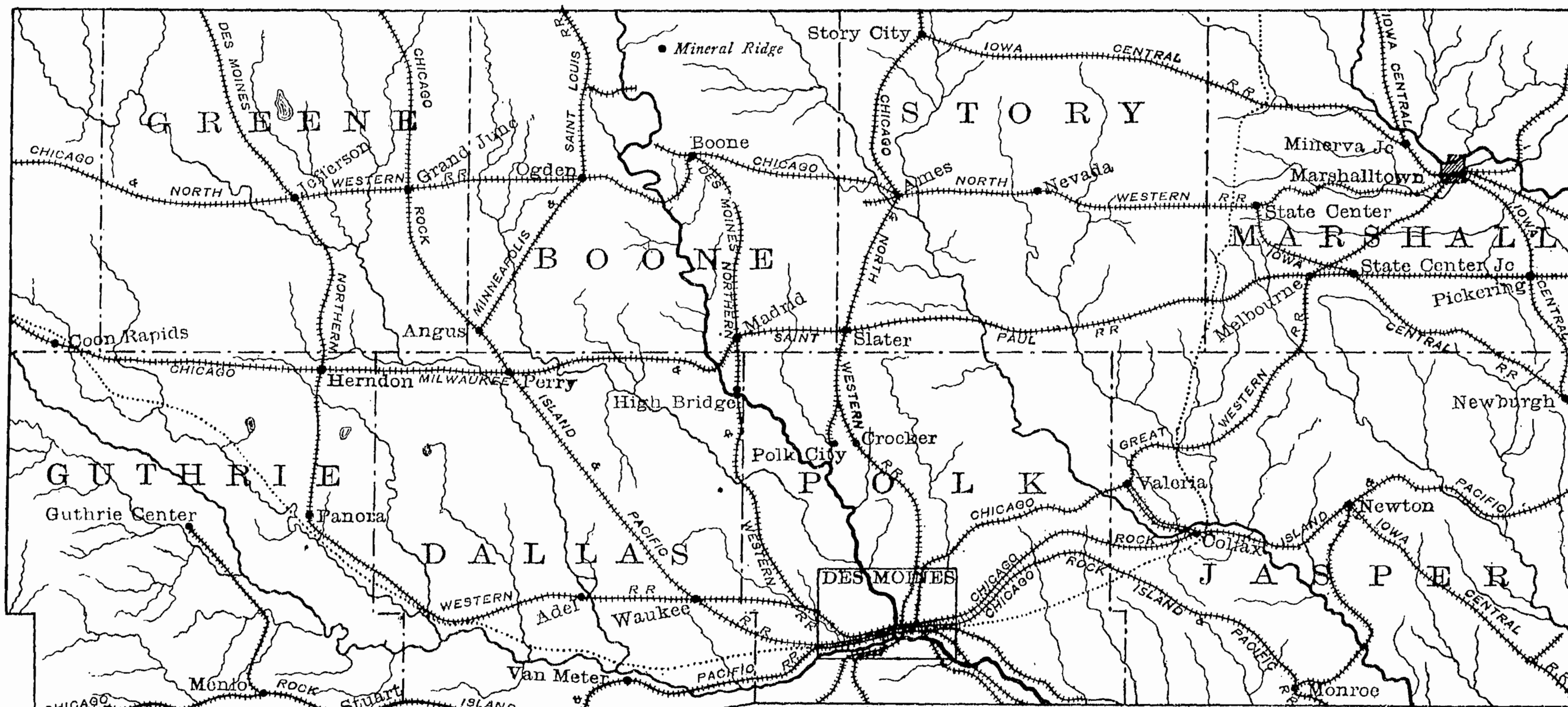
RELATIONS OF THE WISCONSIN AND KANSAN DRIFT SHEETS IN CENTRAL IOWA, AND RELATED PHENOMENA.

BY H. FOSTER BAIN.

CONTENTS.



THE REGION DISCUSSED.



THE SOUTHERN END OF THE DES MOINES LOBE.

DEFINITION OF REGION.

The area which has been studied in the preparation of the following memoir lies in central Iowa and includes Marshall, Story, Boone, Greene, Guthrie, Dallas, Polk and Jasper counties and a portion of Carroll. Its geographic features are represented upon the accompanying map (plate xxvii) and its relations to the state as a whole, are shown upon plate xxvi. It is an area of prairie plain with moderate relief, the altitude varying from 810 to 1,042. The country rock of the region includes both the Des Moines and Missourian divisions of the Upper Carboniferous and the Dakota formation of the Cretaceous. The distribution of these beds may be seen upon the geological map of the state published by the Iowa Survey* and the details of the geology may be learned from the county reports issued by the same organization.† It is intended here to treat only of certain specific problems connected with two of the drift sheets of the region; for fuller details the reader is referred to the reports just cited, and particularly to the author's reports upon Polk and Guthrie counties. In the following paper no attempt will be made to cite the portions of each of these reports which bear out individual statements since the number of such citations would be so great as to to become cumbersome.

The author's particular studies have been in Polk and Guthrie counties, in which he has mapped in detail the surface formations.‡ These counties lie on the southern and southwestern border of the Des Moines lobe, and within their borders the relations herein discussed were first made out. The remaining portions of the area have been repeatedly visited, at times in company with other members of the Survey, and the results obtained in Polk and Guthrie counties have thus been compared with the phenomena in various portions of the larger area.

*Iowa Geol. Surv., vol. VI, plate v. Des Moines, 1897.

†Marshall; (Beyer) vol. VII. Boone; (Beyer) vol. V, pp. 175-240. Polk; (Bain) vol. VII. Guthrie; (Bain) vol. VIII. Dallas; (Leonard) in preparation.

‡See maps of surface deposits accompanying the county reports mentioned.

The region outlined includes the southern termination of the Des Moines lobe of the Wisconsin ice sheet, and it is the relation of the latter to the outlying drift which it is proposed to discuss. The Des Moines lobe was a long tongue of ice eighty to 100 miles wide, running almost due south from the Minnesota line to the central portion of the state. It overrode and buried certain earlier drift sheets and loess deposits which now appear along its edge coming out from under the later drift. With the exception of certain reconnoissance work, but little had been done on the drift of the region previous to the detailed work results of which are given herein. This paper is in a sense preliminary, as not all the area has yet been mapped, but the general results are believed to be final.

Acknowledgments are due to Dr. Beyer and Mr. Leonard for field assistance and for notes generously contributed, and to State Geologist Calvin, of Iowa City, and Head Professor Chamberlin of Chicago, for valuable suggestions both in the field and the office. Professor Salisbury of the University of Chicago, has also been so good as to read the manuscript, and has made many valuable suggestions and criticisms.

DEFINITION OF TERMS.

In the earlier geological work in this region no attempt was made to separate the drift into different formations. As was true in all the work of the period the attention was concentrated upon the underlying rocks and the drift received but little attention. Nicollet* speculated some upon the origin of the boulders. Owen† recognized and correctly interpreted the loess along the Des Moines river, and made many observations of value upon the drift throughout the state. The Hall survey‡ neglected entirely the superficial deposits and did little within the area outlined. White§ studied both the drift and the loess. In consonance with the thought of the time the drift was treated by him as a single

* Sen. Doc., 26th Cong., 2d Sess., vol. V, pt. ii. No. 237. Washington, 1841.

† Geol. Surv. Wis., Iowa and Minn., p. 121. 1852.

‡ Geol. Iowa., vol. I, pts. i and ii. Albany, 1858.

§ Geol. Iowa, vols. I, II. 1870.

formation. Such differences as were noted in the distribution of the boulders and in the character of the drifts were explained by other hypotheses. The striking differences at Des Moines were supposed to be the result of a change in the direction of the ice currents.* Many observations upon the drift were published and these have, to some extent, formed the basis of later generalizations. All these earlier investigations were pursued under severe limitations as regards time and money, and it was but natural that the rich field of Pleistocene geology should be passed over for the better known problems connected with the indurated rocks.

In the neighboring states and throughout America it was long after the glacial nature of the drift was accepted that the complexity of the processes through which it originated was fully recognized. It was long the custom, and it is one perhaps not yet wholly obsolete, to consider the glacial period as consisting of (1) a time of transition, (2) the glacial period proper, (3) the Champlain epoch of submergence and melting, and (4) the recent epoch of terrace work and stream cutting. As the studies became more detailed and the results were better organized, it became recognized that the simplicity of this classification was not in accord with the complexity of the facts. At several points opposing phenomena were noted, and several observers at about the same time began to emphasize the necessity for finer discriminations. The pioneer in this work was Professor T. C. Chamberlin who, in the course of his work in Wisconsin, recognized two well-marked divisions in the drift series; the later, or inner drift, being bordered by the Kettle moraine. In the final reports of the Wisconsin Survey he definitely recognized two drift sheets,† though in the earlier descriptive portions of the reports no such distinction was observed. In a paper read before the International Congress of Geologists at Paris in August, 1878,‡

* Op. cit., vol. I, p. 91.

† Geol. Wisconsin, vol. I, pp. 271, 272 1883.

‡ La Moraine terminal du Amerique du Nord, Compte Rendu Cong. International Géol. Paris, 1878.

he correlated the Kettle moraine of Wisconsin with certain moraines in the other states, including Iowa, and gave an approximate outline of the Des Moines lobe. This outline was based in part upon personal observations and in part upon information derived from the reports of the White survey. An earlier paper,* revised and published in English about 1878, contained much the same matter. The drift within the Kettle moraine was recognized as distinctively later than that without, and an interglacial interval of unknown extent was tentatively suggested. It is this later drift which is now known as the Wisconsin and the earlier which is recognized as Kansan.

At about the same time Mr. W J McGee was carrying on his studies of the Pleistocene in northeastern Iowa. In a series of papers,† extending from 1878 to 1893 when his monograph upon the region was issued, he showed that the forest bed found in the region was a definite horizon and that two drift sheets were present.

In 1882, apparently the upper drift of northeastern Iowa was considered to be the same as that contained within the Kettle moraine.‡ It was not until later that the difference in age was appreciated. Eventually McGee's upper till became the Iowan, and his lower till has very naturally been considered to be the Kansan.

THE DES MOINES LOBE.

Early work.—White§ in his summary of results doubtfully recognized certain ranges of hills as morainic. Among them was Mineral Ridge in Boone and Story counties, now known to form a portion of the Gary moraine, and certain hills in Hancock county belonging to the Altamont moraine. No

* On the Extent and Significance of the Wisconsin Kettle Moraine, Trans. Wisconsin Acad. Sci., Arts and Letters, vol. IV, pp. 201-234. 1876-77.

† Amer. Jour. Sci., (3), XV, 339-341, 1878; Proc. Amer. As Adv. Sci., XXVII, 198-231, 1878; Amer. Jour. Sci., (3), XVIII, 301-303, 1879; Geol. Mag., (2), VI, 353-362, 412-420, 1879; Proc. Iowa Acad. Sci., 1875-1880, 19, 1880; Ibid., 25. 1880; Bull. Philos. Soc. Washington, VI, 93-97, 1883; Pam. 14 pp., 1884; Trans. Iowa State Hort. Soc., XVI, 227-240, 1884; Proc. Amer. As. Adv. Sci., XXXVII, 248-249, 1890; *The Pleistocene History of Northeastern Iowa*, U. S. Geol. Surv., Eleventh Ann. Rept., 190-577, (1891) 1893.

‡ Am. Jour. Sci., (3), XXIV, pp. 204, 206, 215, 222.

§ Geol., Iowa, vol. I, p. 98. 1870.

attempt was made to trace these ridges from point to point, and their significance was not at that time fully recognized. Chamberlin was, as has been seen, the first to draw a crude outline of the Des Moines lobe. He regarded Mineral Ridge as marking its southern limit.* The range of hills was described as not being continuous and well defined, but suggestive rather of a half buried moraine. The presence and significance of the lakes within the area was recognized, and the fact that outside the moraine the existing surface contour was formed in the presence, and to some extent, under the modifying influences of a fairly established drainage system, while in the interior the drainage system has not even yet become fully established, was definitely stated.

In 1880 Mr. Warren Upham, in connection with his work in Minnesota, traced out definitely the limits of the Des Moines lobe† and to him our knowledge of it is mainly due. He recognized a continuous moraine, now known as the Altamont,‡ around most of the border of the lobe, though the extreme southern limit was not visited. Mineral Ridge was considered to be most probably an inner belt of the terminal moraine. This inner moraine is now known as the Gary. The Altamont moraine was studied by him in this region at Coon Rapids and in neighboring portions of Guthrie and Carroll counties.

Subsequently the southern limit of the lobe was studied by McGee and Call,§ while general correlations of interest in this connection have been published by Chamberlin.‖

Topography.—The area included within the Des Moines lobe has the characteristic drift-plain topography well developed. The landscape shows a predominant flatness. There are no prominent elevations and no marked valleys. In detail the flat plain breaks up into a series of low, rounded, often circular swells, irregularly disposed, and separating a series

*On the Extent and Significance of the Wisconsin Kettle Moraine, p. 15.

†Geol. Nat. Hist. Surv., Minnesota, Ninth Ann. Rept. (1880), pp. 298-314

‡Chamberlin: Third Ann. Rep. U. S. Geol. Surv., p. 388. 1883.

§Loc. cit.

‖U. S. Geol. Surv., Third Ann. Rept., pp. 291-404. 1883. Ibid, Seventh Ann. Rept., pp. 147-248, 1888.

of interlocking saucer-shaped basins which are in contour the reverse of the swells. The relief, except near the larger streams, is slight and is normally less than thirty-five feet. The low swells do not have sharp contours and are hardly pronounced enough even to deserve the name of hills. They have little individuality and are not arranged according to any order or system. Between them lie ill-defined basins occupied usually by shallow ponds, swamps or swales—areas of slough or shallow water. There are very many basins without outlets and the whole is clearly a region of immature drainage. At many points springs and shallow artesian wells attest the superabundance of water. The streams present are usually small. They wander aimlessly through the basins and are, in most instances, finally lost in some small swamp or miniature lake. Much of the land is not sufficiently drained to allow cultivation, and much more is worked only as a result of artificial drainage. The larger streams, such as the Des Moines river, have narrow recent channels and very limited tributary drainage. Near the edge of the area some of the rivers, among them the Skunk, flow in wide old valleys, but even in such a case the tributary drainage is very slight. The numerous lakes and ponds, the undrained sloughs, the peat bogs, the narrow river valleys, the incomplete drainage, the undissected upland between the rivers, some of which flow 200 feet below the general plain, and many other features all point to one conclusion—that the topography is extremely young and that it was formed by glacial agencies.

The drift.—The sheet of till which was formed by the Des Moines lobe of the Wisconsin ice possesses certain characteristics which usually allow its ready recognition. They are not always so distinctive as sharply to differentiate it from the till of the other ice sheets, and in such cases attendant phenomena must be relied upon in making the discrimination. In general, however, the till itself is such as to prevent confusion. As seen near Des Moines, the Wisconsin till usually shows a buff color at surface exposures. It has much the same color as the loess and is in this regard sharply contrasted with the reddish brown common at the surface of the Kansan, as well as the yellow, which usually marks the Iowan. When the Wisconsin is buried the color is usually a drab or gray. The pebbles contained in it are very largely fresh and hard, and show very little weathering. This is true of those occurring in all portions of the till. There are some which show advanced stages of decay but the proportion is relatively small. It is believed that many of the decayed pebbles were derived from the older drift and have merely been worked over into the newer. As contrasted with the Kansan drift the Wisconsin contains less local material, but if the two sorts of material occurring in the Wisconsin itself be compared, the proportion which is extra-limital is found to be much inferior to that which might have come from within the state. Lime concretions, such as are known as loess-kindchen when found in the loess, are widely distributed in the Wisconsin drift, whereas localities at which they occur to any extent in the Kansan are, in this region at least, quite rare. Occasionally, not only pebbles derived from the lower drift are incorporated in the upper, but blocks of the lower till itself. In such cases the newer drift frequently shows foliation around the older material.

As contrasted with the Kansan, the Wisconsin drift is characterized by numerous surface boulders. In this vicinity these are not usually so large nor are they so numerous as over areas covered by the Iowan in eastern Iowa, and yet they often afford a valuable means of discrimination. In the region studied, one of the most ready means of recognizing the Wisconsin drift is the absence of the covering of loess which is so universal throughout the Kansan areas. The absence of loess is a general characteristic of the Wisconsin* and in this regard the formation as exposed near Des Moines has the normal characteristics. At a few points a thin surface sheet of silt of undetermined origin occurs, but in

*Salisbury: Jour. Geology, vol. IV, p. 929-937. 1896. Chamberlin: Third Ann. Rept. U. S. Geol. Surv., p. 395. 1883.

most instances the pebbles of the drift are turned up by the plow.

The drift border.—Perhaps the most characteristic and significant feature of the Wisconsin drift of the region, aside from its topography, is the character of its border. That the Wisconsin was a moraine-forming ice sheet is shown wherever deposits of this age occur.* This feature is characteristic of the Des Moines lobe down almost to its termination. In Guthrie county the moraine is in places quite well developed though it is not continuous. In Polk and Dallas counties

FIG 45. Pond on Wisconsin drift at south end of kame near Kelsey.

there is nothing answering to a moraine. The drift becomes thinner and thinner until it disappears altogether. This is not a result of later erosion as is readily determined in the field, but it is an original difference. It forms a notable exception to the border of the rest of the lobe and of the Wisconsin drift in general.

Kames have been, to some extent, developed in connection with the Wisconsin ice. In Polk county there are no well defined kames near the ice edge, but near High Bridge and Corydon, some ten to fifteen miles back from the edge, they

*Chamberlin: Third Ann. Rept. U. S. Geol Surv., pp. 291-494. 1883.

occur. The Kelsey kame is quite perfectly developed. It stands upon a drift plain which is about 150 feet above the Des Moines river. The plain is fairly smooth and is dotted with swales some of which contain small ponds, one being represented in figure 45. Above this plain the kame rises forty feet. It forms an irregular ridge three-quarters of a mile long and a little more than one-quarter wide. At its southern end, and partially separated from it, is an oval hill which does not rise quite so high. The upper surface of the kame is smooth but is somewhat hummocky. Its direction is not rectilinear but sinuous. It is cut off rather abruptly at

FIG. 46. Kame near Kelsey.

the ends and the whole ridge forms a prominent landmark. It general appearance from the west is shown in figure 46.

In composition the kame is made up of Wisconsin material. Large boulders are found on its surface, and pits at three points show that, to a depth of four feet at least, it is made up of coarse water-laid gravel. Stratification is partial only. The pieces of gravel are one-half to three-quarters of an inch or more in diameter. The kame is manifestly the result of combined ice and water work and is better developed than any other known to occur in central Iowa. Others of less perfect form occur near Crocker in Polk county, and Panora in Guthrie. Opposite the latter place on the main Guthrie Center road, water-laid gravels of kame-like character are found well toward the top of the hill. The gravels are shown at several points in the vicinity, and at one or two take an imperfect kame-like form with a general northwest-southeast direction of axis. South of town and at lower levels, though considerably above the terrace found along the river, are similar kame-like aggregations. In other portions of the state large and well developed kames are found along the edge of the Des Moines lobe.

Within the area studied overwash plains have not been found to any great extent, though a faint expression of the overwash occurs along the drift border on the low plain between Capitol Hill and Fair Ground Ridge at Des Moines. In Beaver and other abandoned portions of the older Des Moines valley there are gravel and sand accumulations aside from the ordinary river terraces. The material in all these cases is coarse and shows stratification which is furthermore marked by cross-bedding.

Gravel trains constitute one of the most obvious phenomena connected with the Wisconsin border. They are found all along the southern edge of the Des Moines lobe stretching down the rivers whose head waters were cut off by the ice. They occur in Polk county on Camp, Mud and Four Mile creeks, and on the Des Moines river. In the counties farther west the Raccoon bottoms are underlain by gravel. In all these cases the material is firm and hard and the pebbles are of the sort found in the Wisconsin drift. Occasionally boulders, which might have come from the Kansan, are incorporated. In the case of Four Mile creek and the Des Moines river the gravel trains may be traced up the valley, taking the form of a terrace for several miles inside the drift limits.

The gravel terraces are not conspicuous features. They are frequently covered in their lower portions by later alluvium, as at the Avon gravel pits, or they rise ten to twelve feet above the modern bottom land, as at the newly opened pits in Highland Park. Their origin as valley trains is better seen in Polk than in Guthrie county. In the latter the edge of the Wisconsin ice stood approximately parallel to the Middle Raccoon river, and the drainage was effected by the latter. Instead of a gravel train there is, in this valley, a well-developed gravel terrace. It rises usually twenty-five to thirty feet above the river and may be seen very sharply defined at Rocky Bluff, near Fansler, in the vicinity of Clark's mine (Tp. 80, N., R. XXXI W., Sec. 24, Ne. qr.), and near Panora. It is usually about a quarter of a mile wide and is clearly a terrace of aggradation.* The material of which it is composed is moderately coarse water-laid gravel with more or less coarse sand. In this region it contains a large amount of material derived from the Cretaceous gravel beds, but in all other respects it is similar to the gravel trains and corresponding terraces in Polk county.

These gravel trains show the same relations to the drift border and are in all essential particulars, save the feebleness of their development, similar to those which are so characteristic of the Wisconsin drift in other states. In Wisconsin† the Green Bay glacier filled up the old valley of Rock river to a depth of 350 feet (including earlier drift) with a deposit of finely assorted sand and gravel, producing a level plain three to five miles wide and extending forty miles or more southward from the moraine. The Iowa gravel trains rarely extend ten miles from the drift border and do not often, so far as can be positively known, show a thickness of more than thirty feet of gravel.

As has been suggested, some of these trains are found not only outside the area covered by the Wisconsin ice, but they may be followed up the streams to well within the Wisconsin area. The gravel trains of Camp and Mud creeks are abruptly terminated at the upper end by the Wisconsin till. This is not, however, true of those of Four Mile creek, and the Des Moines river. The pits of the Chicago Great Western

* Salisbury: Geol. Surv. N. J., Ann. Rept. 1892, pp. 102-105. 1893.
† Chamberlin: Geol. Wisconsin, I, 284. 1883.

railway at Berwick, are about six miles within the limits of maximum extension of the ice. The Polk City pits are fully twice as far from the drift border, and the gravels are present along the Des Moines river well up toward High Bridge.

Along the Delaware river a somewhat similar series of phenomena occur. The explanation in this case has been worked out by Salisbury.* The deposit on the Delaware is not a single continuous train, but is rather a series of individual trains each of which was formed successively farther up the river, and each corresponding to one of a series of moraines of recession. Apparently this explanation is equally good for the case in hand, except that here all the phenomena are more feebly developed, and there are no moraines. The ice seems to have retreated, not by definite stages, but continuously, so that the terrace is practically unbroken. That there were minor stages in the retreat is of course altogether probable, and future study may render it possible to discriminate them.

There is a well marked forest bed which is frequently encountered in wells all along the edge of the Wisconsin drift. North of Yale, in Guthrie county, the Eastwood well passed through two feet of wood and muck with drift below. Near Berwick, in Polk county, the forest bed is frequently encountered, and at many points within the area studied it is present. It seems in this place to mark a definite stratigraphic plane, the base of the Wisconsin drift.

Relations to the loess.—Loess of normal character and abundantly fossiliferous is found around the southern edge of the lobe.† It does not occur within the limits of the lobe, but is in these counties everywhere present without it. It spreads out in a thin sheet over the outlying drift, covering the hills and running down into the valleys. Such a relation is susceptible of two interpretations. The loess may have been washed out from the front of the ice and deposited around its

*Geol. Surv., N. J., Ann. Rept., 1894, pp. 21-23. 1895.

†It has been especially described by Call: Amer. Nat., XV, 585-586, 782-784. 1881; Ibid, XVI, 369-391, 542-549. 1882.

edge, or it may have been previously present and overriden by ice and buried beneath the later drift. Upham was inclined to the former view. He suggested* that the presence of the loess immediately west of the moraine in Guthrie, Carroll, Sac and Buena Vista counties, and the fact observed by him that in places the loess rises fifty feet above the drift hills, proved the contemporaneity of the loess and the moraine. To the writer it does not seem that this interpretation is necessary or indeed well in accord with the other observed phenomena.

In Guthrie and the other counties studied no cases have been observed in which the loess stands higher than the Wisconsin drift. Such phenomena, if present, would however be equally susceptible of explanation by the second hypothesis. There seems no necessity for assuming that the ice was present and acted as a retaining wall at the time of the loess deposition. The deposit laps up over and covers the Missouri-Mississippi divide which lies west of the moraine; the two being in this region, roughly parallel. The land rises from the east to the divide, and this was apparently true before the Wisconsin ice invaded the region. The land west of the moraine would, therefore, be expected to be higher, and where the moriane approaches the divide, the difference might be locally great. This would be equally true if the rise to the west were mainly a function of recent elevation, for which belief there is some evidence. In either case, if the loess were older than the Wisconsin drift, the fact would afford a satisfactory explanation of its local elevation above the drift plain.

If the explanation offered by Upham be the correct one, it would be expected that the loess should be found along the eastern front of the moraine as well as its southern and western. That it does not occur in this position has been shown by Calvin in his report on Cerro Gordo county.† The loess is well developed outside the Des Moines lobe, where

*Geol. Nat. Hist., Surv., Minnesota, 1880, p. 338.

†Iowa Geol. Surv., vol. VII.

the latter has overlapped the Iowan, but not, so far as now known elsewhere.

Again, it has just been shown that the Wisconsin drift is persistently fringed by gravels and similar deposits indicative of free drainage, whereas the loess is itself indicative of conditions under which the water could not, or at least did not, carry anything but the finest material. The two deposits are mutually antagonistic. A drift sheet which is constantly fringed by gravel is to be differentiated from one constantly fringed by loess. Loess and gravel require different conditions for their deposition. The general attitude of the land was in one case such as to make vigorous, and in the other sluggish streams. This is not of course to be interpreted as meaning that local exceptions may not occur, but applies to causes where the conditions along the entire drift border are taken into account. In the case in hand there is the additional fact that the loess passes directly under the Wisconsin drift whenever the relations have been made out.

In 1882 Messrs. McGee and Call,* in a valuable and suggestive paper, brought out the fact that at Des Moines the loess passes under the upper drift, which is now known as the Wisconsin. Since knowledge of the drift formations was not then so well organized, the fact was interpreted as being of local import only and as due to a slight re-advance of the ice. By inference the loess was correlated with the Wisconsin, since the upper drift of McGee, which we now know as the Iowan, was distinctly stated to occur south of the city. In the course of the present work the fact that the loess passes under the Wisconsin as stated by McGee and Call has been abundantly verified. The exposures mentioned by the authors are now obscured, but others equally good may be found wherever the drift on either the West Hill or in Highland Park is dug through. During the summer of 1896 the relations were particularly well shown at the top of the Sixth Avenue hill, in the cuts along Grand Avenue, near Greenwood Park, and in the

* Amer. Jour. Sci. (3), XXIV, 202-223.

street railway cuttings in Hamilton street in Oak Park, Des Moines. The relations are unmistakable, and the facts may be verified at any time. The upper drift is quite distinctive, and the buried loess may be recognized with equal ease, particularly as it is very frequently fossiliferous.

The relations found to obtain in the city are equally true of the loess to the north. In the wells near Saylor, in Polk county, the normal section is as follows.

3. Yellow and blue boulder clay
2. Fine pebbleless clay with shells.
1. Blue clay with pebbles and streaks of gravel.

Loess fossils have been obtained from No. 2 of this section at several points. On the farm of Mr. Tom Saylor, thirty feet of pebbleless clay containing "periwinkle shells" is reported below twenty-two feet of Wisconsin drift, which forms the surface soil. Near the mouth of Beaver creek a roadside ravine shows the loess, with its usual characteristics, outcropping below the drift. The same phenomena may be seen along the Des Moines river valley west of Polk City. In Guthrie county the kame gravels west of Panora are clearly deposited over the loess, and well records near Herndon, as well as at certain points in Dallas county, show that the loess extends back under the drift for fifteen or twenty miles at least. In view of these facts, and the phenomena are believed to be general, it is clear that the loess is earlier than the Wisconsin drift, and, if differences in surface erosion be taken as a guide, it must be considered to be considerably more ancient.

THE OUTLYING DRIFT.

General characteristics.—The outlying drift is that known as the Kansan. The Iowan does not appear upon the southern and southwestern borders of the Des Moines lobe. The drift present agrees in character with that which has been called Kansan by the Iowa Survey.* It is fundamentally a

*Norton: Iowa Geol. Surv., IV, 169. 1895. Bain: Ibid. V, 153. 1896. Beyer: Ibid. V, 203. 1896. Calvin; Ibid. V, 63. 1896.

blue boulder clay weathered above into a yellow, which in turn is usually a deep reddish brown at the surface. It contains a large proportion of pebbles derived from local sources, with many varieties from outside the state. An examination at one point showed quartzite, probably from the Sioux formation, sandstone from the Cretaceous, quartz pebbles from the same formation, shale and limestone from the coal measures, light gray granites, pink quartz, porphyry, greenstones, vein quartz and other varieties of rock from outside the state. Another examination showed bits of chert, limestone, sandstones, coal, quartzite, badly weathered gray granite, diabase, fine-grained greenstone, mica-schist, dark green slate, etc.

The greenstones are predominant among the particles from foreign sources. The pebbles are largely striated and flattened, much more frequently than in the case of the Wisconsin. The granite boulders are badly rotted and easily break to pieces. The upper surface of the drift shows marked ferrugination and leaching. The ferrugination has gone on to such an extent that the horizon is a dark reddish brown and resembles in color the red fields of the south. It is easily recognized when seen in road cuts some distance away, and is a convenient horizon of reference in field work. The red color fades gradually below, but it is cut off sharply above when the Kansan is covered by loess or later material. The drift has suffered prolonged leaching as acid tests show no reaction to a depth of several, in places as much as fourteen, feet. In the case of the Wisconsin and even the Iowan, reaction may usually be obtained up even to the grass roots.

The till has all the physical characteristics of an old drift long exposed to weathering agencies *in situ*. In these particulars it is contrasted not only with the Wisconsin but with the Iowan as found in eastern Iowa. The latter is likewise of different color, a light yellow, carries many large surface boulders, shows many fresh cobbles, and only a few that are badly decomposed. It has a smaller percentage of local material and a higher percentage of gray granite, and shows almost no leaching or ferrugination. Upon these differences alone there would be ground for separating the two.

Topography.—The topography gives farther warrant for such a separation. That of both drift sheets is a river erosion topography and the drainage is complete. The Kansan topography has, however, a much greater relief than the Iowan. The latter is characterized by a series of wide, shallow river valleys having no river trenches. The marked, though not easily expressed, contrast between the typical river valley of the Iowan drift and that of the Kansan affords an excellent means of discriminating the two.

The land forms in the area covered by the Kansan are, as has been said, erosion forms. They have been developed upon the drift surface by the action of weathering and running water. In part this water has been collected in gullies and ravines and has taken the form of rivulets, creeks and rivers. In part it has acted as a broad sheet over wide surfaces. By these two methods of erosion the topography has been developed. The two different modes of action have produced different forms of surface which in cross-section yield different curves. These curves, as developed in the region under discussion, are so well developed, so characteristic, and reveal this region so clearly that a brief analysis of their mode of production may not be out of place.

ANALYSIS OF EROSION CURVES.

The materials in which the erosion has taken place, while somewhat diverse, are in a general way homogeneous. They include drift, soft sandstone and shales. These materials weather and erode differentially, and yet in a broad way the action is uniform. The differences induced by differential weathering are slight, are not at first operative, and in the end serve merely to modify the general results. The erosion dates in the main from the retreat of the Kansan ice, and with exceptions to be noted later the surface may be considered to have been a fairly even drift surface.

The problem then is that of the action of erosive and weathering forces upon a fairly even plain of homogeneous material. It will be simpler to consider first the action of weathering and pluvial or sheet-water erosion. Stream action may be considered as merely a special case of the latter. Let us assume then that the stream channels are already cut. They form narrow gashes dividing the plain into a series of blocks. Our problem becomes that of the retreat of the valley sides. The cutting down of the valleys is the equivalent of the lifting of the inter-stream areas. For certain reasons it is clearer to look at the problem as if the latter were the true relation. Of course pluvial erosion and weathering do not wait till the streams have corraded to grade before beginning their work, but the problem is exactly the same when a stream has an abrupt bank one foot high as when the latter is many times that height. The bank will be attacked by the same agencies acting in the same manner. While in nature the corrasion of the river bed and the retreat of the valley sides take place *pari passu*, it is after all not so far wrong to make the opposite assumption since the latter action does not become prominent, and never becomes dominant, until the former is accomplished.

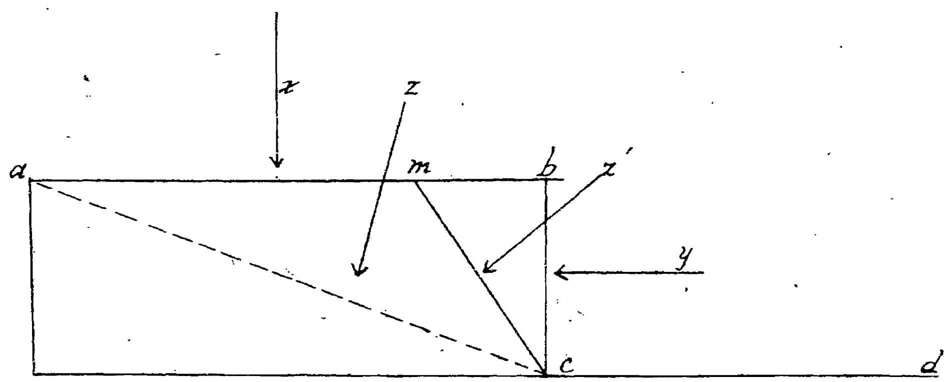


FIG. 47. Case 1.

Case 1.—Let us assume a block of homogeneous material elevated a certain distance above a level plain. Let *a–b–c–d* be a cross-section normal to the edge of this block. Weathering and intermittent showers attack it. Consider first the action of the former. The complex series of forces which together produce the effect known as weathering tend to soften or disintegrate rock. Other things being equal they act normal to the surface exposed. In Case 1, the weathering would then act along the lines *x* and *y*. Running water with a given load erodes in proportion to its volume and velocity. Conceive a slope extending from *a* to *c* such that water may traverse the entire distance. Suppose the rain to fall equally along the line *a–b*. At any given point upon the slope the amount of water passing would be the sum of all that has fallen on the slope above. Past the point *c* must run all the water which has fallen between *a* and *b* and hence there will be maximum erosion at *c*. At *a*, the head of the slope, will be minimum erosion. The relative amounts of erosion at intermediate points may be represented by the line *a–c*, and the effect of this component of erosion may be considered as a force acting normal to this line or in the direction *z*. It should be kept clearly in mind that only the portion of the area which has become slope is subject to this force. Hence when the slope only extends back as far as *m*, z^1 represents what may be called the volume component. In the retreat of the slope *z* occupies different positions and acts in various directions; that is, *z* is a variable, whereas *x* and *y* are constants.

The second factor of water erosion is its velocity which, with given friction, is dependent upon volume and slope. The effect of volume we have just seen. The effect of slope must be simply to accentuate previous inequalities. Steep slopes, because they induce greater velocity and hence greater erosion, tend to perpetuate themselves and to increase their steepness. The effect of velocity is then to reinforce the action along the line *z* and to increase the steepness of any slope resulting from the other forces.

Case 2.—The action of simple weathering upon such a block would be to disintegrate the material. The point *b*, being exposed to attack upon two sides, is affected more than either of the points *e* and *c*. The result is that the line between the fresh and the disintegrated material becomes the arc of a circle, *e–f–c*. The line *b–c* is a stable line of slope for solid rock, but not for loose material. The action of gravity forces the latter to rearrange itself until the slope *m–m*[1] is reached, that being the slope of stable equilibrium for

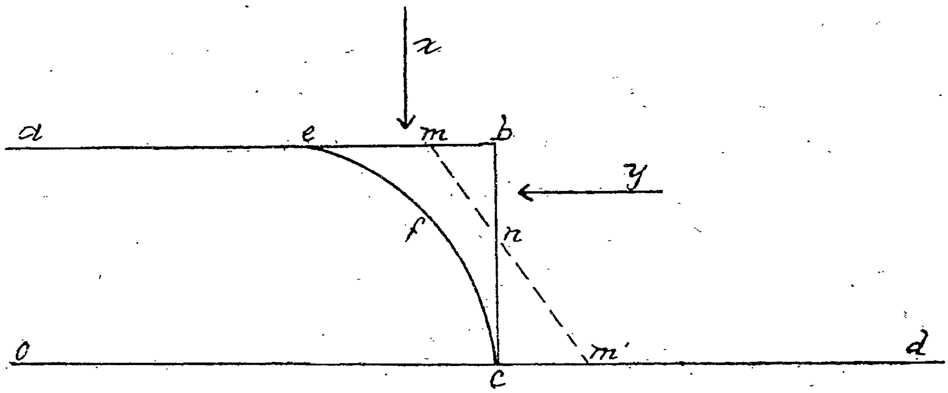


FIG. 48. Case 2.

the loose material in question. The inclination of *m–m*[1] against *c–d* varies with the character of the material and the fineness of its texture. If no running water were taken into account, the process would stop at this point. The result would be a flat table land bounded by talus slopes.

Case 3.—Conceive for the present the point *e* to be a fixed

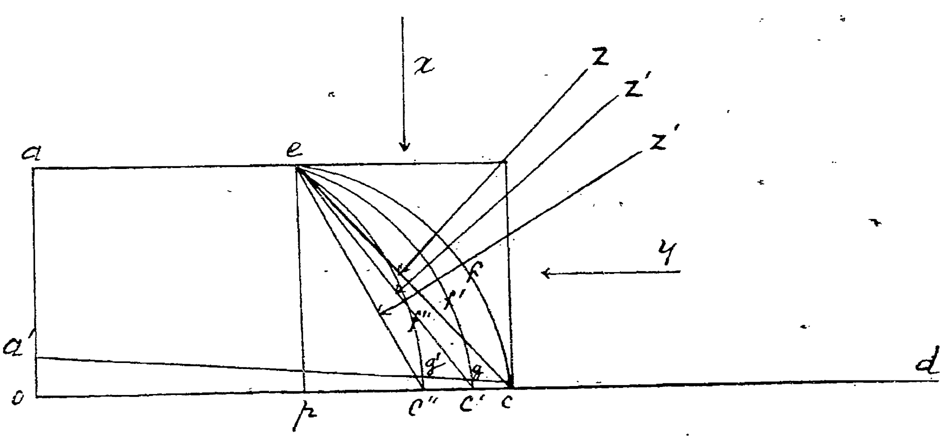


FIG. 49. Case 3.

point beyond which erosion cannot go, introduce the action of running water and neglect the detritus, then *x* and *y* are equal and starting with the curve *e–f–c*, *z* is normal to *e–c* and bisects the angle between *x* and *y*. The tendency of the velocity to increase with the slope disturbs the equilibrium by producing relatively more rapid erosion at *c*, and *e–c* retreats along the lines $e–f^{I}–c^{I}$, $e–f^{II}–c^{II}$, *z* occupying the positions *z*, z^{I}, z^{II}, etc.

Water will not erode down to an absolute level. There must be a slight slope in order to allow the water to remain in motion. Let $a^{I}–c$ represent the slope beyond which there is no erosion. It is evident that the retreat of the lower portion of the curve is along the line *a–c* rather than *o–c* and the point *c* really moves through the positions $g–g^{I}$ rather than $c^{I}–c^{II}$.

Case 4.—If the material be conceived to be carried away as fast as it is brought down so that no talus slope is formed, and if, furthermore, the action of the volume and the velocity components of erosion be neglected, the curve *e–c* may be

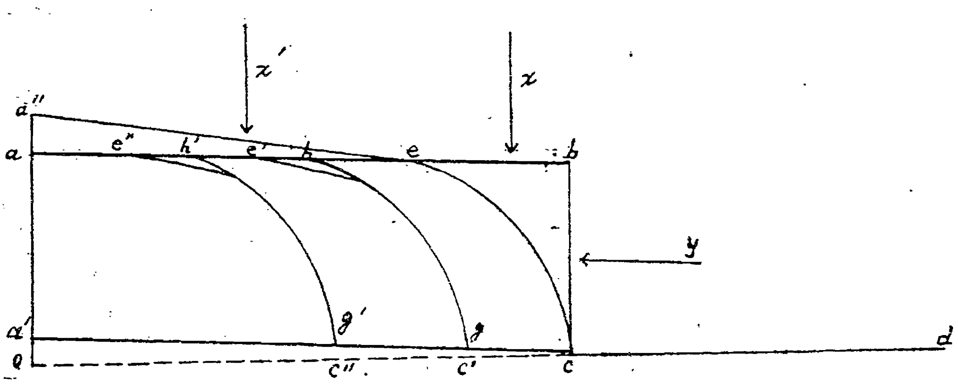


FIG 50 Case 4.

thought of as retreating toward *a–o* in a series of parallel curves $h–c^{I}$, $h^{I}–c^{II}$. Since, however, the force x^{I}, active from the beginning of the process, has prepared the material along the plane *a–e*, there would be a tendency to produce more rapid results along the upper portion of the curve and the retreat would be by $e^{I}–c^{I}$, $e^{II}–c^{II}$ rather than by $h–c^{I}$, $h^{I}–c^{II}$. As has just been shown the base of the curve would in fact occupy the position $g–g^{I}$ instead of $c^{I}–c^{II}$. The tendency of the upper portion of the curve toward a more rapid retreat would be accentuated by a second factor. During the time the curve *e–c* is formed the surface *a–e* is still an uninvaded flat. There is no slope, and hence the water falling upon it is largely without motion. It is not, however, true that water on a flat surface has no tendency to move. If we conceive an inch of water spread upon the surface, it must be true that at the edge the water stands with a perpendicular face an inch high, or that it flows. The latter is obviously the correct hypothesis. If then we have one inch of rainfall we have one inch for the perpendicular element of slope along a^{I}–*e*. In consequence the flat becomes a very slight slope, and a portion of the water falling upon it runs off at the point *e*. The water running past this point has a certain erosive force and the process leads to a flattening of the upper portion of the curve *e–c*.

Case 5.—At the point *c* the water must cease eroding and confine its attention to transportation, since by hypothesis the slope ends at this point. As will be shown later, deposition begins here, so that instead of *c* being the point of great-

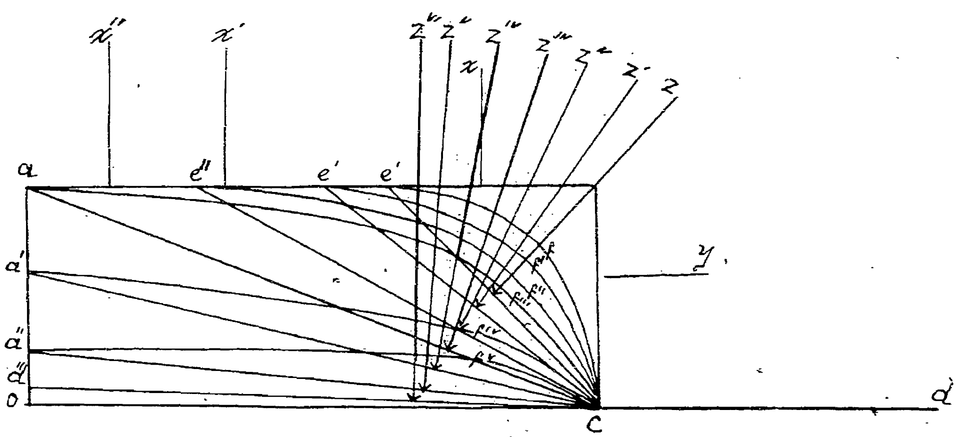


FIG. 51. Case 5.

est, it is, as a matter of fact, the point of least erosion, and the hypothetical conditions of the last case are very nearly the true field conditions. In this case *e–f–c* becomes e–f^{I}–c, e–f^{II}–c, a–f^{III}–c, etc. The point *a* is fixed by the intersection of the curve a–f^{III}–c with a corresponding curve, developed from the opposite side of the block, and not figured; that is, *a* marks the position of a divide. If the divide be stable the curve progresses through a–f^{III}–c, a–f^{IV}–c, a–f^{V}–c, etc., until it becomes the straight line a^{III}–c, which represents the trace of the plane having only such slope as will allow rain water to overcome the friction against its base without carrying any load. In this progress z passes through the positions z, z^{I}, z^{II}, etc., retreating from y and continually approaching x. If c be conceived to have a certain very slow rate of retreat the retreat must occur along the line a^{III}–c as noted previously.

Case 6.—In turning to consider what becomes of the eroded material under the action of sheet water let us assume as before an elevated block a–b–c–o, over the edge of which at b water, loaded with debris, passes in the direction of the arrow m. This debris-laden water takes the direction m^{I} along the

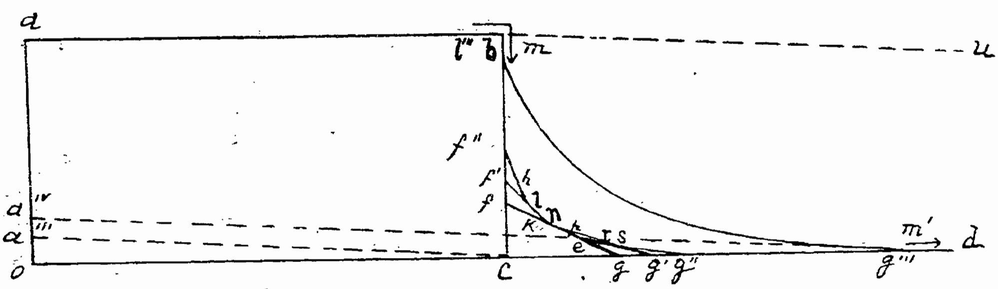


FIG. 52. Case 6.

plane c–d. In the direction b–c, water is falling perpendicularly, and hence has an infinite carrying power. Along c–d, it is running over a horizontal surface and can carry nothing. In changing from m to m^{I} it must lose all its load. The first water which comes over the cliff drops all its load at the foot of the latter. Let f–c–g represent this material. Now more debris-laden material comes over the bluff. The water strikes the slope f–g, and runs down on it. Water on the slope f–g can carry some material, but not so much as when following the line b–c; hence a portion of its load is deposited, forming the increment f^{I}–f–k. The partially burdened water upon reaching the level surface at e must deposit another increment making e–g–g^{I}. The water following finds now four points at which it parts with its load and so deposits the bodies f^{II}–f^{I}–h, l–k–n, p–e–n, and s–g^{I}–g^{II}. Successive portions of water find more points at which to deposit till the number becomes infinite, and a concave curve b–k^{I}–g^{III} results. Continued deposition builds up the curve to the line m–u parallel to a^{III}–c, already defined.

Case 7.—The development of the curve a–f^{III}–c of Case 5, and the curve b–k^{I}–g^{III} of the last case would of course be *pari passu*. When e–f is developed above, f^{VI}–l is developed below; e^{I}–f^{I} corresponds to f^{V}–l^{I}, and so on until a–f^{III} meets f^{III}–l^{III} and there is a continuous slope.

One very important element has so far been omitted. If rain falls along the line a–b it must also be supposed to fall along the line c–d. The rain falling along the latter line

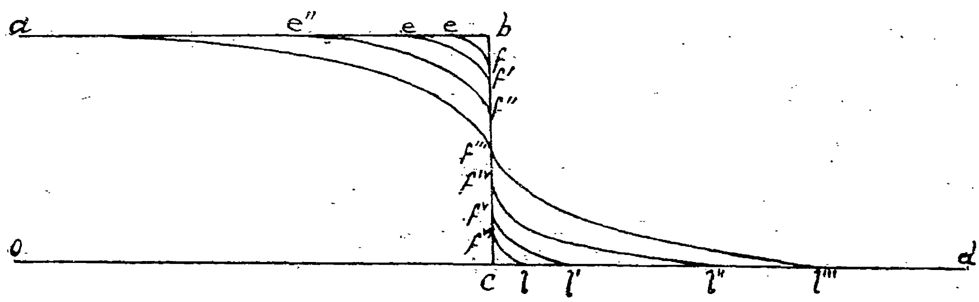


FIG. 53. Case 7.

would be free from load and hence free to erode. The volume would progressively increase from f to l and with it the tendency to erode. The slope would, however, decrease in the same direction, and hence there would be a decreased tendency to erode. The relative values of the two factors would determine which portion of the curve would suffer most rapidly, but it seems probable that erosion would occur along almost its entire length. There could be no erosion at d, since beyond that point there is no slope and hence the waters deposit. The final result must be the destruction of the curve f^{III}–l^{III}, and the spreading of the material f^{III}–c–l^{III} over the plain in a sheet whose upper surface would be a plane with a slope equal to that of the line a^{III}–c of the preceding case, but slightly above it. In final result then the base level would take the line a^{IV}–d of Case 6. The erosion along the lower portion of this double curve is the factor which releases the point c and allows its slight retreat as previously noted.

Case 8.—If between c and d a river capable of transporting the eroded material be introduced, we have a limit to the extension of the curve of deposition. Above it is a long convex curve of erosion which decreases in convexity as the distance from the cliff increases. This is the normal curve for cliff recession under the conditions obtaining in the area under discussion. The base of the cliffs is marked by a concave

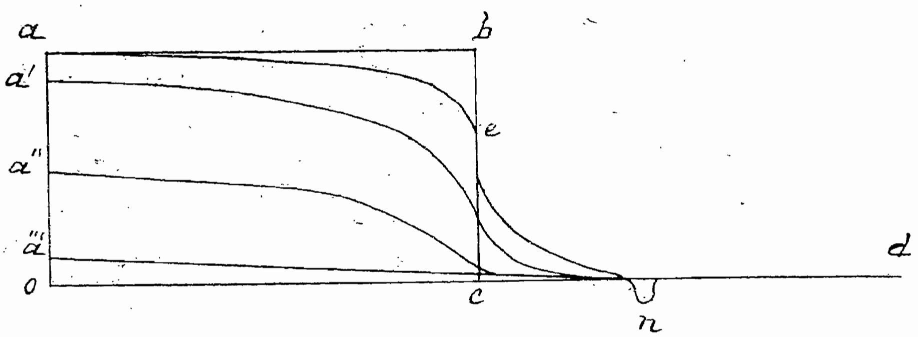


FIG. 54. Case 8.

curve of deposition above which is a sharp convex curve merging beyond into one of decreasing intensity.

It has been customary to speak of the concave curve as the normal curve of erosion,* and the convex curve has been believed to be the result of weathering forces. In the area under discussion this law does not hold true and from the analysis given it will be seen that it is very unlikely to be true in any case where the conditions are the same. This immediate region, while old as compared with the area covered by the younger drift, is young as compared, for example, with the driftless area. In the latter, as has been shown by Chamberlin and Salisbury,† the country has been reduced to a series of ridges whose major slopes are concave.

*Gilbert: Geology Henry Mountains, p. 110. 1880. Hicks: Bull. Geol. Soc. Amer., vol. IV, p. 135. 1893.

†Sixth Annual Report, U. S. Geol. Surv., 234-235.

In a sense these slopes are analogous to the longitudinal profiles of river valleys which are normally concave. Owing to the excess of water which in a stream passes the point *c*, the erosion there becomes most active, and the major portion of the erosion is transferred to the concave portion of the curve. This concave portion once established tends to perpetuate itself and the relative insignificance of the convex curve at the head of the stream causes it to be overlooked.

In all normal erosion it is the concave portion of the curve which tends to lengthen, and so in a very old topography the long concave curves are predominant, and the short convex curves over the divide are insignificant. In the production of these curves the retreat of the point *c* is probably in a curve first rising toward the divide and later falling. The concave curves, however, are originally established as a result of deposition and the normal curve of erosion is convex, not concave.

This does not, of course, apply to the curves produced by the erosion of alternating beds of hard and soft strata where concave curves are often produced in the manner discussed by Noe and Margerie.* In this immediate region the sandstones of the Dakota, the limestones of the Missourian, and the sandstones and limestones of the Des Moines all tend to break up the general curves developed in the drift and to produce such abnormal curves.

River changes.—As has already been pointed out the areas covered by Wisconsin drift show immature drainage. The streams present are, with few exceptions, of very recent age. Occasionally a portion of their course is through an older valley, but in the main, for the region studied this does not seem to hold true. The valleys are sharp, narrow gorges, the tributary streams are short, have high gradients and show active headwater erosion. The rivers are simple consequent streams, and in most cases have not yet cut through the drift to the underlying rock. The streams of the outlying drift

*Les formes du Terrains, pp. 24-28, et seq. Paris, 1888.

are of a sharply contrasted type. The completeness of the drainage system has already been noted. The upland is quite generally dissected. The major streams show regularly developed secondaries, and these in turn support tertiaries of almost equal regularity. The whole forms a complex dendritic system which has required long time for its development. The major streams, and many of their branches, are flowing in preglacial valleys. They have maintained themselves with often only slight modifications, since before the ice invasion. Almost the whole of the present drainage system of the outlying drift area was developed before the deposition of the loess. The latter forms merely a wash over the old drift surface. The streams are not consequent upon the loess, but represent rather the type of rivers for which McGee has proposed the name resurrected.* They differ from the simple consequent rivers in that their direction is really determined by an older land surface than the one over which they now flow. They are not merely revived streams, since between the earlier and later stages of their history there have been periods of total inactivity; times when the river was completely destroyed. The same fact prevents their being considered as merely antecedent streams, though they belong to that general class. The later river is, however, a direct descendant of the one before, and has inherited its channel from its predecessor. After a period of non-existence such a stream is re-formed and takes up the work of the earlier stream. In view of their history the name seems particularly appropriate.

The rivers here, in a certain sense, represent an extreme type of the resurrected river, since they have survived at least two glacial invasions and one submergence. They are not to be thought of as persisting throughout these various vicissitudes, but rather as being re-formed after each. Where the ice has crossed a wide valley it has in many instances failed entirely to fill up the old rock trough, and a broad

* Bul. Geol. Soc., Am., I, 549. 1890.

shallow sag now appears at the surface. Beaver creek in Polk county affords an excellent example of such a sag, and others are not infrequently encountered. In those cases in which the valley may be supposed to have been filled entirely, there would probably still be a tendency for it to be reproduced on the surface. If one imagine a valley 200 feet deep, and suppose drift to be deposited fifty feet thick over the upland at the same time that the valley is filled to the same level, then there would be 250 feet of drift in the valley with only fifty feet over the adjoining upland. Drift as now exposed, and probably as deposited, is not so compact as rock. One of the important processes in the solidification of rocks is the compacting of the loose material and a portion of this change results from settling.* However unimportant this factor may be, it is evident that there would be more settling in 250 than in fifty feet of drift, so that in time the old valley would show at the surface as a depression and would afford most favorable opportunity for the development of a stream. The two factors of original inequality of deposition and of secondary settling work together and become cumulative. Together they make it possible for a river to be resurrected time and again.

The rivers on the older (Kansan) drift are of the resurrected type. Some of them, the lower Des Moines and Raccoon for example, have histories reaching back into preglacial time. Most of the streams are younger, but all save the smallest are pre-loessial. Probably the largest number are post-Kansan and pre-loessial. Among the latter are the Raccoon rivers and Bushy Fork in Guthrie county.

The invasion of the Wisconsin ice produced important changes in many of the rivers. Thus the upper portion of the older Des Moines valley is now deserted by the main stream and is occupied by the smaller Beaver creek. A portion of the valley near the old mouth of the river is deserted altogether and a new connection with the Raccoon has been

*Van Hise: Principles of Pre-Cambrian Stratigraphy, p. 684.

established. Above the mouth of Beaver creek the Des Moines is engaged in cutting an entirely new valley.

Correlation of outlying drift.—An erosion such as outlined would necessarily require a considerable lapse of time for its accomplishment and this is one of the best evidences of the antiquity of the older drift. The complexity of the drainage system points in the same direction as does the physical condition of the drift, and all these features unite in proclaiming the high antiquity of the Kansan as contrasted with the Wisconsin. Some of the reasons for correlating the outlying drift of Polk, Dallas and Guthrie counties with the Kansan rather than the Iowan have already been suggested. The stratigraphy of the region, particularly the relations of the loess, affords others.

The loess found in the region has been referred to the Iowan since it is believed to be in this region the equivalent of the Iowan drift farther north and now in part buried under the Wisconsin. It is believed that loess of widely different ages occurs in the Mississippi valley, and there is some evidence of an older loess in this immediate region, so that the qualifying term has been added for the purpose of definitely fixing the age of this particular loess. The basis of the correlation is the fact that loess, apparently the same, may be traced around the southern limit of the Wisconsin to Marshall county, where it comes into contact with and laps upon the Iowan. It follows the border of the latter southeast, never extending far up on the Iowan, to Johnson county, where its genetic relationship to the latter is excellently shown.* Furthermore the Iowan ice sheet, as shown by its non-morainic border and other phenomena, marked a period of low level and clogged drainage, such as is known from the relations of the loess to the river valleys to have occurred in the region under discussion. This period was, in each case, between the Kansan and the Wisconsin, as is shown by the fact already mentioned, that the loess covers the Kansan and passes beneath the

*Calvin: Geol. Johnson County. Iowa Geol. Surv., vol. VII.

Wisconsin in the one region and was connected with the Iowan in the other. It is separated from the Kansan by a considerable interval since the major portion of the erosion of the outlying drift was accomplished before the loess was deposited. The time between the loess and the Wisconsin was also considerable, as the loess had been quite deeply eroded before the gravel trains of the Wisconsin were formed. The difference in the character of the two deposits is itself suggestive. The gravel trains contain both fine and coarse material, while the loess consists of fine material only. Such a difference in deposits is indicative of a difference in the competency* of the waters. This in turn depends upon declivity and volume, mainly upon the former. A change in declivity, with a resulting change in the grade of the streams is another indication of a considerable time interval between the two, since the conditions noted here are such as are true in the neighboring states and over a considerable portion of the drift area of the United States. Such general changes of level are not rapidly accomplished and in themselves are indicative of a considerable time interval.

The loess of this region was then deposited at a time between the Kansan and the Wisconsin and separated from each by a considerable interval. Conditions favorable to loess deposition prevailed when the Iowan ice occupied eastern Iowa, and this time accords well with that suggested by the facts in the present case, and the whole point to the Iowan age of the loess at the southern borders of the Des Moines lobe.

There is in the northwestern portion of the state a drift which in physical constitution and topographic development resembles the Iowan of eastern Iowa, and it has been provisionally correlated† with that formation. There are many reasons in support of the view that this correlation is correct so that the headwaters of the pre-loessial streams of the region were doubtless cut off by the Iowan ice. In a period

*Gilbert: Geol. Henry Mts., p. 110. 1877.

†Chamberlin: Great Ice Age (Geikie), pl. XV. 1894. Calvin: Iowa Geol. Surv., VII, 20. 1897.

of general low level, contemporaneous with that ice, the rivers became greatly expanded and the conditions for the distribution of the loess over the territory in question were afforded.

As has been seen the preliminary classification of the drift deposits recognized but two major drift sheets earlier than the Wisconsin.* This was the view current when the present work was taken up in the summer of 1895. The Des Moines lobe was recognized as belonging to the Wisconsin, and the Iowan was assigned no definite limits to the south.† McGee and Call, as well as Chamberlin‡ had considered it to be present south of Des Moines. In 1895 Calvin began his work in Johnson county and quickly recognized that the drift sheets present in the northern and southern portions of the county respectively were radically different in age. If the surface drift of the paha region were Iowan, that of southern Johnson county must be something earlier, and he accordingly referred it to the Kansan. After spending some days in Johnson county in company with Professor Calvin, the present writer extended the work into Washington county and assigned the drift there to the Kansan and the loess to the Iowan.§ These were known to be in all respects identical with that previously studied in Keokuk and Mahaska counties‖ and present throughout much of the southern portion of the state¶ and accordingly the deposits of Appanoose and Warren counties were placed with those of Washington.**

Since the upper drift at Afton had been considered to be Iowan a number of visits to the locality were made for the purpose of studying the relations of the drift sheets at that point. The drift found in Polk county was traced southward and found to be the same as the upper drift at Afton Junction. At the latter point it showed the upper zone of ferrugination, the leaching, the weathered boulders, and all the physical

*Chamberlin: Great Ice Age (Geikie), pp. 773, 774. 1894. Jour. Geol., III, 270-277. 1895.
†McGee: Eleventh Ann. Rept. U. S. Geol. Surv., 472-496. 1893.
‡Chamberlin: Loc. cit.
§ Geol. Washington County. Iowa Geol. Surv., vol. V, pp. 153-156. 1896.
‖ Iowa Geol. Surv., vol. IV, 287, 288, 342, 343. 1895.
¶ Iowa Geol. Surv., IV, 230-234. 1895.
** Iowa Geol. Surv., V, 320, 406. 1896. Ibid., V, 318-320, 406-408. 1896.

characteristics which had come to be recognized as peculiar to the Kansan in the surrounding region. Its relations to the loess were the same, as was also its topographic development. In short the upper drift at Afton was found to be the same as that which was elsewhere recognized as Kansan. The Aftonian beds accordingly were found to be below rather than above the Kansan, and a still lower pre-Kansan drift sheet was recognized. A preliminary examination as far south as Kansas City seemed to show that the older drift did not come to the surface, and accordingly the upper drift at Afton Junction is presumably the surface drift of eastern Kansas, though the matter has not been fully studied. The older pre-Kansan drift is known to be present at a number of points in southern Iowa and adjacent portions of Missouri, and has more recently been found in northeastern Iowa. Beds probably representing this horizon outcrop near Hastie, in Polk county, and there is some evidence of their presence in Guthrie county.

The pre-Kansan drift is probably the equivalent of the Albertan as described by Dawson* though the connection has not yet been worked out and quite probably never can be placed beyond dispute.

About the time these studies were being carried on in central Iowa Leverett† determined the fact that a drift sheet invaded Iowa from Illinois at some time between the Kansan and the Iowan, and another member was added to the series. As now recognized by Chamberlin‡ the entire drift series is as follows:

9. Wisconsin till sheets (earlier and later).
8. Interglacial deposits (Toronto, perhaps).
7. Iowan till sheet.
6. Interglacial deposit.
5. Illinois till sheet (Leverett).
4. Interglacial deposit (Buchanan of Calvin).
3. Kansan till sheet.
2. Aftonian beds. Interglacial.
1. Albertan drift sheet (Dawson).

*Jour. Geol., III, 507-511. 1895.
†Jour. Geol., IV, 756, 874. 1896.
‡Jour. Geol., IV, 872-876. 1896.

Calvin* has given essentially the same section summarizing the Iowa formations as follows:

I. First stage of glaciation, Albertan. Invasion of Iowa by glaciers and distribution of lowest sheet of till.

II. First interglacial stage, Aftonian. Melting and retreat of glaciers and deposition of gravels, followed by a long period of forest growth, development of soils and modification of the original drift.

III. Second glacial stage, Kansan. Cold more intense and glaciation more general than during the first stage. Distribution of McGee's lower till.

IV. Second interglacial stage, Buchanan. Introduced by deposition of gravels in Buchanan, Black Hawk, Floyd, Cerro Gordo and other counties. This stage was very long, and the surface of the second drift sheet was profoundly modified by erosion, oxidation and leaching before it came to a close.

V. Third stage of glaciation, Illinois. During this stage only a small part of Iowa, embracing portions of Louisa, Des Moines and Lee counties, was invaded by glaciers. The ice came from the northeast, bringing boulders from the eastern shores of Lake Huron.

VI. Third interglacial stage (unnamed), during which the modification of the second drift sheet proceeded over the greater portion of Iowa. The small area occupied by the third deposit of drift also suffered more or less of modification.

VII. Fourth glacial stage, Iowan. During this stage the northern half of Iowa was overrun by glaciers. The southern limit of this incurson may be traced a few miles north of a line drawn from Iowa City to Des Moines, and then deflected northwestwardly to Plymouth county. It was during this stage that the enormous granite boulders so conspicuous in Bremer, Black Hawk, Buchanan and other counties in northeastern Iowa were transported and deposited where they now lie.

*Iowa Geol. Survey, VII, 18, 19. 1897. Amer. Geol., XIX, 270-272. 1897. Annals of Iowa, (3), III, No. 1, 1-22. 1897.

VIII. Fourth interglacial stage, Toronto (?). This fourth interglacial stage was short as compared with the second, and probably the third. The amount of erosion, oxidation and leaching which, during this interval took place in the surface of the fourth sheet of drift, is altogether inconsiderable. The amount of change that has taken place since the beginning of the interval up to the present time is comparatively small.

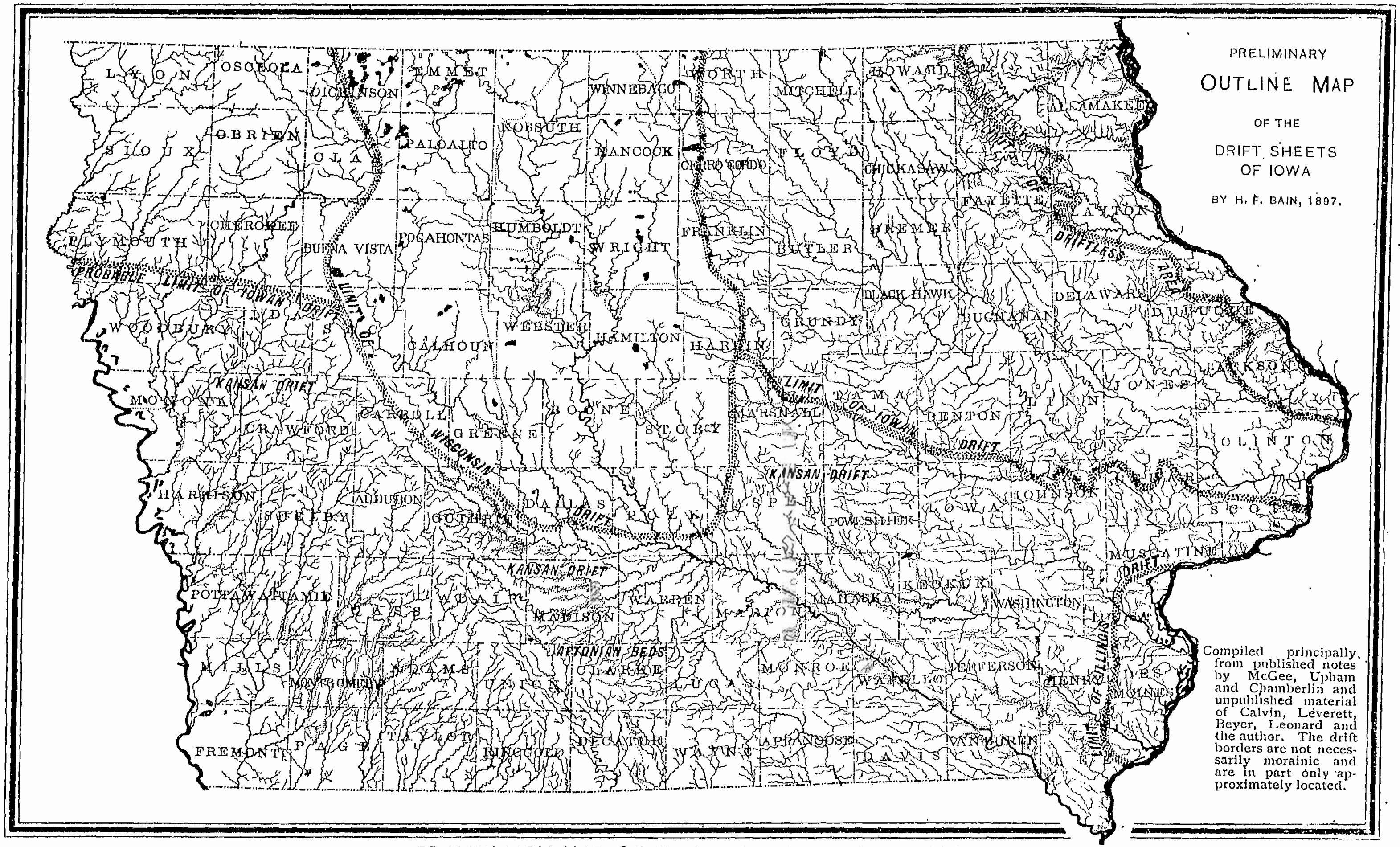
IX. Fifth glacial stage, Wisconsin. The last invasion of Iowa by glacial ice occurred in times so recent, geologically speaking, that the youngest sheet of till exists practically in the condition in which the glaciers left it. The area in Iowa affected by this last invasion is nearly triangular in shape, the base of the triangle coinciding with the north line of the state from Worth to Osceola counties, with the apex located at Des Moines. In the northern part of this area there are numerous stretches of ill-drained lands, the surface is only very gently undulating, and the stream channels, where defined at all, have cut only a foot or two into the prairie sod.

X. The recent stage, since the retreat of the Wisconsin ice, brings Pleistocene history down to the present. The recent stage, while long as measured in years, has been too short to produce any appreciable effect in the surface of the Wisconsin drift.

The Kansan has heretofore been correlated with the lower till as recognized by McGee* but certain recent observations seem to indicate that the latter may find its correlative in the pre-Kansan rather than the Kansan. At Oelwein in Fayette county, some excavations made by the Chicago Great Western railway have revealed the presence of a well developed till below the Kansan and separated from it by an important peat bed. Above the Kansan the Iowan is characteristically displayed though its thickness is small. The three drift sheets with representatives of the Buchanan and Aftonian interglacial beds are shown in the one section.† Pre-Kansan beds

*Chamberlin: Iowa Geol., III, 273. 1895.

†This section and its relations were quite fully discussed at the winter meeting of the Iowa Academy of Sciences, December, 1896. See proceedings for 1896; also Science, p. 317, Feb. 19, 1897.



PRELIMINARY MAP OF THE DRIFT SHEETS OF IOWA.

have been found also in Marshall county and at other points. A review of sections published by McGee* makes it more than doubtful whether the forest bed which he has so clearly shown to be present does not mark the Aftonian rather than Buchanan horizon. In plate xxviii is given a preliminary outline map of the drift formations of the state as they are now understood.

TIME RATIOS.

The problem of the length of the interglacial intervals has attracted considerable attention, though as yet but few numerical estimates have been made. The data are not such as readily lend themselves to this manner of expression. It is obvious that no very exact results can be obtained where so many factors are uncertain. At best, approximations are all that one can hope for. Yet for certain purposes these, when supported by a fair degree of probability, are of quite large value; and in all cases, in the absence of anything better, they perhaps serve a useful purpose.

The problems which it is hoped may be solved, or to whose final solution the correct determination of the length of the interglacial periods contributes, are principally two: (1) the taxonomic rank of the divisions of the glacial series, and (2) the larger problem of the age of the earth.

Whether the ice age is to be considered as consisting of one, or two or more periods, as the term period is used in geology, has provoked much discussion.† It is not proposed to review what has been brought out in this discussion but simply to indicate the bearing upon this problem of certain of the phenomena exhibited in the Des Moines region. It should first be pointed out that for purposes of this question evidence

*Eleventh Ann. Rept., U. S. Geol. Surv., 514-542.

†Chamberlin: Geol. Wisconsin, I, 271-391; Am. Jour. Sci. (3) XLV, 171-200; Jour. Geol., III, 270-278: Geikie's Great Ice Age, chapt. XLII: Bul. Geol. Soc. Am., I, 469-480; V, 16. Coleman: Jour. Geol. III, 622-645. Hershey: Am Geol. XII, 314-323 Lewis: Glacial Geol., Great Britain and Ireland, 51-52 Leverett: Jour. Geol. I, 129-146. Bul. Geol. Soc. Am., V., 17. McGee: Pleistocene History of Northeastern Iowa, loc. cit., Bul. Geol. Soc. Am., V, 17. Russell: Mon. XI, U. S. Geol. Surv., 254-268. Salisbury: Ann. Rept. State Geol. N. J. 1892, 60, 72; Jour. Geol., I, 61-84; Bul. Geol. Soc. Am., III, 173-182. Upham: Minn. Geol. Surv.. 1879, 48; Am. Nat. XXIX, 235-241; Am. Jour.Sci. (3), XLVI, 358-365; Bul. Geol. Soc. Am., V, 16. Williams, E. H.: Bul. Geol. Soc. Am., V, 281-296. Wright, A. A.: Bul. Geol. Soc. Am., V, 7-15 Wright, G. F.: Great Ice Age in N. Am. 475 et seq (with citations): Man and the Glacial Period, 106 et seq; Amer. Jour. Sci., XLIV, 351-373; Ibid, XLVI, 161-187.

may be admitted, and even accepted as conclusive, which from its very nature is of much less value in any discussion of the other problem mentioned. It is not the absolute length of glacial and interglacial time which is wanted so much as their relative lengths.

Estimates of the actual length of time since the retreat of the ice have been made at a number of points.*

In all cases the results are obtained by assuming that some process, such as erosion, has progressed in the past at its present or at some known rate. It is obvious that the absolute results are uncertain to the extent of the unknown error in the assumed value of the rate. This error may be, and in some cases undoubtedly is, large. For purposes of comparing different portions of the glacial period this error is not so important. If, judged by the same test and making the same assumptions, a given interglacial period is found to be as long as, or a certain number of times longer than, the time since some fixed event of the glacial period, the fact has an independent value. The assumed rate of erosion may, it is true, have varied in one case and not in the other, or the two rates may have varied together or in opposite directions, and yet unless such variations be proved or probable they may be neglected without seriously impairing the value of the result. The latter, of course, increases with the difference between the total result and the possible effect of a wrong value for the variable. If, for example, it be found by comparative erosion that the length of a given interglacial stage was as long as the stage since the retreat of the ice from a given point, a variation of one-half in the rate of erosion during the glacial stage reduces or increases largely the force of the argument for the duality of the glacial period. If, however, it be found that with the same assumptions comparative erosion shows the interglacial stage to have been twenty times as long as the postglacial, a doubling of the erosive activity in interglacial times still leaves the stage ten times as long as the postglacial.

*Wright: Great Ice Age in N. A., 448-475, with citations.

Studies of comparative erosion constitute as yet the only method appealed to to furnish numerical data as to the length of the interglacial stages. Ferrugination, oxidation, leaching, changes in altitude and other phenomena have been used in making up general impressions and have frequently been emphasized as showing that the earlier drifts are vastly older than the newer. In a few cases these general impressions have been put in mathematical form. Thus McGee states that if the period of written history represent a day then a month or a year will measure the period which has elapsed since the first Pleistocene ice sheet invaded northeastern Iowa.*

Chamberlin,† after consultation with various workers in the Mississippi valley, has given the following:

	UNITS.
From later Wisconsin to the present	1
From earliest Wisconsin (Shelbyville moraine) to the present.	2½
From Iowan to the present	5
From Illinois invasion of Iowa to the present	8
From Kansan to the present	15
From sub-Aftonian (Albertan) to the present	x

N. H. Winchell‡ has carefully compared the amount of erosion shown by the present gorge of the Mississippi from Fort Snelling to Minneapolis with that necessary for the excavation of a neighboring gorge, believed to be interglacial. Assuming that the conditions of erosion were the same except for 25 per cent greater erosion in the case of the interglacial channel, allowed as a factor of safety, he finds that if postglacial time be 7,800 years, interglacial time would be 9,750. With regard to the estimate it may be pointed out that the allowance of 25 per cent is wholly a matter of opinion. One might make it greater or less, and, aside from a desire for a conservative attitude in discussing disputed questions, there would seem no sufficient reason for fixing the amount of the allowance, or perhape any inherent reason for making any

*Eleventh Ann. Rept. U. S. Geol. Surv., p. 507.
†Jour. Geology, vol. IV, p., 876. 1896.
‡Amer. Geol. vol. X, pp. 67-80. 1892.

allowance. The estimate lacks also in value in that there is no evidence as to which of the interglacial stages it pertains to. Since the region has probably been occupied successively by the pre-Kansan, Kansan, Iowan and Wisconsin ice sheets one has wide latitude in interpreting the phenomena. The estimate is of a great value, however, as showing that by the same tests which the advocates of the unity of the glacial period have used to determine the length of post-glacial time, it may be proven that during the ice age there was at least one interval fully as long as post-glacial time. This fact is of more significance since the measurements were made by the same observer, in the same region, and using the same methods that he used in making an estimate of the length of post-glacial time which has been widely quoted and approved by all, including advocates of the unity of the glacial period.*

It does not, of course, follow that the ice age consisted of two or more rather than one glacial period because of a long interglacial period. The passage of time alone, and aside from any climatic changes would not be sufficient to warrant a separation. There might be one or many interglacial stages fully as long as all post-glacial time, but if the climate remained much the same the whole might well be considered a unit. The long interglacial stages are, however, strongly confirmatory of all independent evidence† of climatic changes, and, though not sufficient to warrant a division of the ice age, they are strong presumptive evidence of climatic changes. It is hardly likely that the climate would for a long time hover so close to the point of glaciation without reaching it. The value of this latter presumption increases with the length of the interglacial periods and for that reason certain results obtained in the course of the present work may be offered.

In the eastern portion of Polk county there are certain streams which antedate the Wisconsin ice. The latter cut off their head waters, and from its front gravel trains stretched

* Wright: Ice Age in North America. pp. 458-466; Man and the Glacial Period, 310-342. Upham: Amer. Naturalist, vol. XXIX, p. 238. 1895.

† Leverett: Proc. Boston Soc. Nat. Hist., XXIV, 455-459. See also previous citations.

down the old valleys. These gravel deposits have since been cut through and remain as terraces along the river. Their age can be definitely fixed as being that of the maximum extension of the Wisconsin ice. The valleys themselves are earlier than the loess as is shown by the latter mantling their sides and partially filling the bottom of the troughs. This is not a result of later creep as was ascertained by careful study in the field. The drift under the loess is Kansan and shows all its normal characteristics. In such a valley one has an opportunity to measure the amount of erosion required to cut out the larger valley in terms of that required to excavate the smaller channel cut since the terrace was formed.

Camp creek, south of Nobleton (Tp. 79, N., R. XXII, N., Sec. 26) show such relations in typical form. A cross section of the stream is shown in figure 55. With such an outline it is

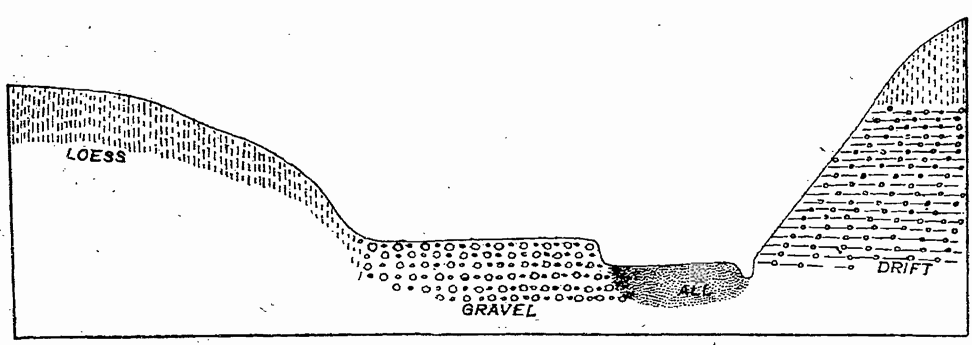


FIG. 55.

clear that there is some latitude with regard to the interpretation of the past history of the stream.

It may simply be assumed that the valley before the terrace was formed was cut down to a depth indicated by the present slopes of the old valley sides, and that before the present alluvium was filled in the recent valley had been cut to a depth indicated by the sides of the recent valley. Such a history is suggested by the accompanying sketch. (Fig. 56.)

If now the amount of loess filled in over the upland be taken as equivalent in this cross-section to that cut out of the valley, added to the amount of drift cut off the upland before the loess was laid down, and extended observations upon the streams of the region indicate that the assumption is perhaps approximately correct, the old section *a–a–a* may be taken as equivalent to the post-Kansan section. The line *a–b–b–a* would

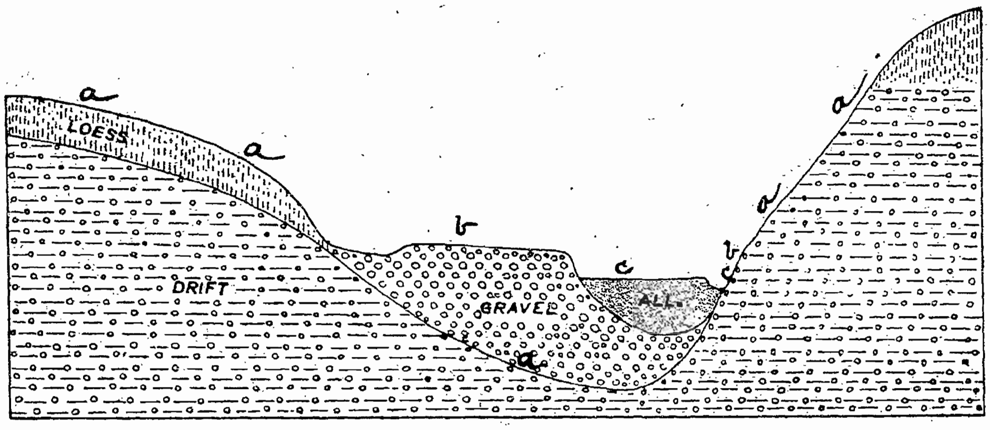


FIG. 56.

represent the cross-section after the terrace was formed, and *a–a–b–b–a* would represent it when the newer stream ceased to cut down and began to build up, while *a–a–b–c–c–a* would represent the present cross-section. The actual cross-section has been carefully measured and is plotted in figure 57.

The figures given are dimensions in feet. The line *a–b–c–d–e–f–g–h* represents the present cross-section. Following out

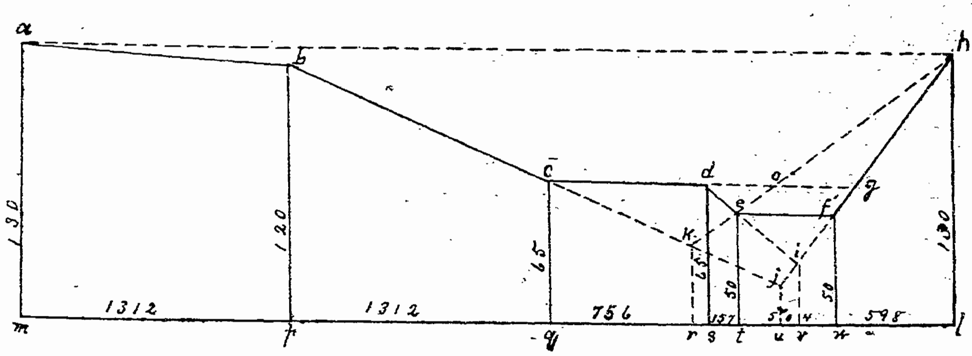


FIG. 57.

the history of the stream just suggested let it be assumed that the post-Kansan surface be *a–h*. It may have been higher, as one can not tell exactly how much was cut from the upland before the loess was laid down over it, nor what is the average thickness of the latter on the upland. If, as has been suggested, we assume that the amount of Kansan eroded from the upland before the loess, and the amount of loess eroded from the valleys before the Wisconsin, together equals the amount of loess left on the upland, then *a–b–c–k–j–g–h* may be taken as the post-Kansan valley and its cross-section equals 254,285 square feet. Before the retreat of the Wisconsin ice the valley was filled up to the level *c–d–g*. Now if it be assumed that the time occupied in this filling was equal to the time necessary for the equivalent erosion, then this area 51,282 should be added to the previous figures and the major erosion may be taken at 305,567. Let the secondary valley be *d–i–g*, equal to 16,442 square feet. It was filled up to *e–i–f*, equal to 6,930 square feet. Assume that the deposition of the alluvium required the same time as the erosion in the gravel, and the secondary erosion equals 23,352. Under these assumptions the older valley shows 13.09 times the erosion of the present valley.

If it be objected that the gravel filling would take place more rapidly than the previous erosion, though it seems probable that the larger supply of water from the oncoming ice would increase the action of the erosion enough to compensate any error here, an allowance of a double rate may be made for the deposition. Then the ratio is 1:11.98.

It may be objected, however, that the history sketched is improbable in some particulars. The presence of the loess capping the east bank and not running down the slope, with the greater steepness of the western bank shows that the pre-loess shape of the valley has been considerably altered. It may also be urged that the amount of alluvial filling is unknown. Ten feet only is shown by the stream, and under some circumstances no more need be assumed. Keeping these objections in mind the following estimates may be made.

Let the assumptions as to the loess be the same as before. Let the original stream be supposed to have begun its work upon the level plain *a–h*. Let it be assumed to have cut to *k*, leaving a nearly symmetrical valley before the Wisconsin. Let the terrace be assumed to have filled the valley *a–b–c–k–h* to the present line *c–d–o*. Let the resurrected stream have begun its work at the most westerly point *d*, and have cut continually against its east bank; an assumption which involves the least time for the work of producing an asymmetrical valley. Take the alluvial filling as equal to ten feet. Then take the major valley *a–b–c–k–h*=175,316. The filling (deposition equalling erosion) *c-k–o*=33,300, and the total major erosion =208,616. The secondary valley *d–e–f–g*=9,492. The alluvial filling taken twice=10,080, and the minor erosion=19,572, giving a ratio of 1:15.55. If *o–g–h* be added to the recent erosion the figures become 33,590 and 208,616, and the ratio is 1:6.21.

By varying the assumptions, ratios as high as 1:18 may be obtained, the whole series calculated being 1:6.21, 1:11.98, 1:13.09, 1:15.55, 1:17.43, 1:18.60. It is believed that the truth in this case lies between 1:10 and 1:15, and nearer the latter than the former figures. This is less than the writer would have given as a result of general field impressions.

While, as has been suggested, these are essentially calculations of relative erosion and the actual time ratio may have been widely different, it is believed that with the allowances made for the building up of the terraces as well as their destruction, the estimates may be taken as fairly accurate guides to the time relations. Whatever errors there are on one side are probably counterbalanced by similar errors on the opposite. For example, if it be suggested that the stream which cut the later gorge did not work so rapidly as the one which excavated the earlier valley, since it was a smaller stream after the ice had cut off its head-waters, it may be urged that when the antecedent stream began its work upon the Kansan drift plain it was probably as puny as the stream now working. The first stages of valley erosion are accomplished by small forces, and if there be any difference it is possible that the resurrected stream had more water in its earlier stages than its antecedent since it received water from the melting glacier, while the older stream probably excavated this portion, at least, of its valley by simple head-water erosion.

The whole of the evidence derived from comparative erosion indicates that the time since the Kansan, as compared with the Wisconsin of this region, was long; at least ten and probably fifteen or more times. It points unmistakably to the conclusion that the two drift sheets were widely separated in time, and in connection with other evidence of less specific character, warrants their separation theoretically, as they must be separated practically in any detailed mapping.

With regard to the broader question of the total time consumed in the Pleistocene, it should be remembered that the ratio here derived is between the retreat of the Wisconsin from this region and the beginning of erosion after the retreat of the Kansan. In using the ratio it must be kept in mind that Des Moines stands at the extreme southern limit of the Wisconsin ice west of the Mississippi. The estimates of the length of post-glacial time most commonly quoted all date from much later events than the retreat of the ice from this region.

Three of the estimates which seem most reliable and most widely accepted, those of Gilbert,* Andrews† and Winchell‡ are based respectively upon the life of Niagara Falls, the rate of wave cutting and sand filling on Lake Michigan, and the life of the Falls of St. Anthony. The results arrived at respectively give 7,000, 10,000 and 7,800 years as length of post-glacial time at three points if the observed present rate has remained constant in the past, which is not true in the case of Niagara at least.§ The birth of Niagara and St. Anthony Falls and the beginning of wave work on Lake Michigan are

*Proc. A. A. A. S., XXXV, 1886, 222, 223; Sixteenth Ann. Rept, Com. State Res. Niagara, Smithsonian Report, 1890, pp. 231-257.

†Am. Jour. Sci., XCVIII, p. 172. 1864.

‡Geol. Nat. Hist. Surv., Minnesota, Fifth Ann. Rept. 1876, pp. 75-189; Final Rept., vol. II, 1888, pp. 313-341; Quart. Jour. Geol. Soc., XXXIV, 886-901. 1878.

§Gilbert: Nature, vol. L, p. 53. Spencer: Amer. Jour. Sci., (3). XLVII, 455-472; Appleton's Pop. Sci. Mon., XLIX, 1 20.

very recent events and if the figures obtained in these cases be applied to the region under discussion an unknown quantity must be added for the length of time during the retreat of the ice from Des Moines. For calculating the total length of the glacial period more must be added for the length of Kansan and pre-Kansan time so that for the final result certain portions of the data are not yet known. Stated as a formula the present state of knowledge is

$$\text{Pleistocene time} = x + 10 \text{ to } 15\,(y + 7{,}800)$$

in which x = the length of pre-Kansan and Kansan time, and y = the length of time occupied in the retreat of the ice from Des Moines, the multiple 10 to 15 is from the calculations here given and 7,800 is Winchell's estimate of the life of St. Anthony's Falls. It will probably be possible to get an approximate value of y, but the value of x seems not so easy to estimate.