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that the Illinoian is a markedly younger sheet than the Kansan. This difference in age was suspected to occur from a comparison of maturity of valleys in the two districts, but the testimony of the weathered zone preserved below the Illinoian was of value to confirm it.

THE AFTONIAN AND PRE-KANSAN DEPOSITS IN SOUTHWESTERN IOWA.

BY H. FOSTER BAIN.

INTRODUCTION.

The Aftonian deposits of southwestern Iowa have peculiar interest in that within the area is the type locality for the Aftonian. So far neither the drift of the region nor the Aftonian as a unit has received a general discussion. The references to the beds extant are merely incidental to broader studies. The type locality and several other critical exposures have been visited by many geologists but no one has presented a complete account of the beds in question. The time has not even yet arrived for an adequate discussion of the Aftonian, but in order to prevent possible misapprehensions it seems advisable to present a brief summary of present knowledge. It should be remembered that the exposures of the Aftonian and the sub-Aftonian are scattered; that their importance was unsuspected until quite recently; that in the nature of things the phenomena may be expected to be somewhat illusive, and that but little of the area has received detailed study. In view of these facts the present must be taken as a preliminary statement only and subject to considerable future revision.

Scattered evidence of a forest bed was found by White in his survey* of the region. The most noteworthy occurrence recorded by him was that of a peat bed two to three feet in thickness in Adair county.† There is some uncertainty, however, whether this peat occurs below the loess merely, or is beneath true bowlder clay, and hence, presumably of Aftonian age. A recent visit to the locality by Mr. Cowles, of the United States Geological Survey, failed to clear up the doubt on this point.‡

* Geol. Iowa, Vol. I, p. 97, 1870.
† Op Cit., p. 339.
‡ Private communication.

McGee, in his great storehouse of facts regarding the drift sheets of Iowa, mentions several points in the southern portion of the state where there are more or less clear evidences of the presence of two drift sheets. The Albia exposure, judging from the figure given,* represents the Kansan-loess contact. Presumably the Durham exposure† is to be referred to the same horizon.

The Afton-Thayer exposures were visited by McGee and Chamberlin in company, and the evidence of an interglacial interval here, in connection with the facts derived from a study of other portions of the Mississippi valley, was considered sufficient to warrant the reference of the beds to two distinct periods of glaciation. With a wise conservatism the two periods were assumed to be the same as had been demonstrated in northeastern Iowa, and accordingly in the nomenclature eventually proposed by Chamberlin,‡ the upper drift at Afton was considered to be the Iowan, and the lower the Kansan. The Aftonian beds proper were considered to represent the interval between the Kansan and the Iowan. It is important to note that in the original paper by Chamberlin the term Aftonian was not applied to the gravels which form so conspicuous a feature of the Afton-Thayer sections. These were considered to represent rather, kame-like accumulations upon the surface of the older drift sheet. This distinction has not been always clearly observed.

The Afton-Thayer outcrops are for many reasons the most important of those bearing on the question of an interglacial interval in southwestern Iowa and will be described in some detail. Preliminary to this it is desired to examine briefly what sort of evidence may properly be required to establish the presence of two drift sheets. An excellent discussion of the criteria for distinguishing between drift sheets has been given by Salisbury§. At this point it is intended merely to indicate certain of these criteria found to be of value in the Iowa work, and to discuss briefly the importance which may be legitimately attached to them.

* Pleistocene History, N. E. Iowa, Eleventh Ann. Rep. U. S. Geol. Sur., p. 493.
† Op. Cit., p. 494, pl. lii.
‡ Great Ice Age (Geikie), pp. 773-774, 1894; Jour. Geol., Vol. III, pp. 270-277. 1895.
§ Jour. Geol., Vol. I, p. 61.

CRITERIA FOR THE DISCRIMINATION OF DIFFERENT DRIFT SHEETS.

Forest and Peat Beds.—Among the common and obvious evidences of interglacial periods none are more widely recognized than buried forests and peat beds. These constitute the one phenomenon which appeals alike to layman and geologists, and buried forests are a constant element of wonder in regions in which they are common. Their wide recognition and frequent citation has probably been out of proportion to their true importance. It is recognized alike by advocates of one and of more than one glacial period that not all forest beds may be cited as legitimate evidence of important interglacial intervals. The admitted fact that forests may and do crowd up to the edge, and even grow upon, the ice of some of our largest glaciers, makes it evident that any temporary readvance of the ice would be apt to cover up a forest bed. Whether the vegetation would follow the edge of a continental ice sheet as closely as a smaller glacier is unknown, but may fairly be considered doubtful. The real significance of a forest bed, however, arises not from the fact that it shows that during the ice period there was a retreat of the ice for a period long enough to allow vegetation to gain a foothold over areas later reburied by the ice, but from the light which they sometimes throw upon the climatic and physical conditions prevailing during the interval. If the vegetation includes plants indigenous to warm or temperate climates, it indicates a considerable climatic change, which can hardly be assumed to mean anything but a considerable time interval. The only escape from this conclusion is to assume a change in the habit of the plant in question; which would need independent proof but might be indicated by its associations.

The vegetation may, however, be of such a character as not to prohibit the assumption of a cold climate and yet its disposition be such as to indicate a relatively long and quiet period of accumulation, and, inferentially, a freedom from glacial conditions. A case in point is the Oelwein peat bed as pointed out by Professor Macbride at the last meeting of the academy.* The evidence in such a case is obviously, while still important, of less value than in the former.

It is conceived that if a forest bed, even if it showed only a boreal or possibly boreal vegetation, could be proven to occupy

*Proc. Iowa Acad. Sci., Vol. IV, pp. 63-68.

the same or approximately the same horizon over a wide stretch of country, the legitimate inference would be an extensive retreat and readvance of the ice. In the nature of things, however, it is impossible often, if ever, to apply this test alone, and in general forest beds, except where they show tropical or temperate floras, have little independent value.

Buried Soils.—This term is intended here to cover only the black soil proper; the clay mixed with humus. Under ordinary circumstances this is not deep, and in general over the Wisconsin drift it is about 8 to 12 inches in thickness. Since the soil comes from the successive growth and decay of vegetable matter, and since but a small fraction of the latter is usually preserved, a soil calls into consideration an important time factor. It is true there are instances of rapidly formed soils but such may in most cases be discriminated. The peat represents the forms of relatively rapid vegetal accumulations and six inches of true soil means a much longer time period than the same thickness of peat. It is important, however, to carefully discriminate true soils from apparent soils found by the washing in of soil material. At Fort Dodge the Des Moines valley is apparently post-Wisconsin; yet, in some drift exposed down in the valley, is a soil as deep, and as well marked as that over the upland drift. The explanation seems to be, not that the lower drift is older and separated from the Wisconsin by an interval as long as post-Wisconsin time, but that the exposure represents a buried terrace, and that the soil was not altogether developed *in situ.* When, however, the soil is clearly developed *in situ,* it has a considerable significance. In such cases it will, with certain rare exceptions, be accompanied by concordant phenomena and occasionally the latter afford the only means by which its genuineness may be proven.

Leached Horizons.—That the drift contains a large amount of mechanically pulverized material has been abundantly shown. In Iowa one of the most abundant materials is pulverized limestone, and it is pertinent to remark that this material is quite abundant even in the material covering the Des Moines formation, our most important series of beds relatively free from limestone. One of the first processes becoming active in the formation of a soil is that of leaching. The soluble materials begin at once to go into solution and drain out of the upper portion of the soil. As a result acid finds little to dissolve in old soils and much in new drift soils. In the process of time

the leaching progresses farther and farther down from the surface, so that the width of the leached zone comes to be an index to the age of the soil. It is obvious that the amount of leaching is really proportional, not directly to the time, but to the amount and strength of solution draining through the soil. An exposed point may be subjected to a greater amount of solution running through it. Conceivably also, the strength of the solution might vary from point to point and from time to time. A leached zone, then, to have value in this connection must be shown to be general, and these local factors must be eliminated. A widespread and well marked zone with the strength of the acid reaction uniformly proportional to the distance below the presumed horizon can, however, hardly be explained, except as a true index of time. It is believed also, that at least in an approximate degree, the amount of leaching shown by two surfaces gives a reliable means for comparing their ages. It may be noted in passing that to get accurate results hot acid should of course be used in testing till derived from dolomitic regions.

Ferretto Horizons.—To those who live in the southern portion of the state where the Kansan drift is exposed beneath the loess, no phenomenon is more common than the reddish-brown horizon marking the upper limit of the drift This old, red soil, for such it is, is of the type known to the Italian geologist as ferretto, and the name seems fitting and is useful. The ferretto zone is manifestly due to the high state of oxidation of the iron. The red-brown color shades off through orange and yellow into the blue of the lower portion of the till, the change being gradual, and the yellow clay being usually ten to thirty feet thick.

The reddish zone is narrower, and while its lower limit is naturally but poorly defined, the ferreto zone proper is usually but two to three feet in thickness. The progressive increase in the oxidation of the iron toward the surface is accompanied by a similar increase in general oxidation, and increasing rottenness of the bowlders and pebbles. There are exceptions and fresh bowlders occur well to the top, and even on the surface of the drift, while rotted cobbles are found to the bottom. Such, however, is not the rule. In the formation of ferretto and in the broader work of general oxidation and decay of pebbles local causes favoring or hindering the action come into play, and it is the relations of the phenomena to an old general surface that cause its significance. The local variations are

usually easily discriminated, and in practical field work only occasionally lead to confusion.

Waterlaid Beds.—In general geologic work the record of the past is read in the deposits of the succeeding periods. In a large majority of cases these deposits are waterlaid, and each class of waterlaid beds, river, lake and beach, have distinctive characteristics. If, then, waterlaid deposits be found buried in the drift they may show, either by their physical character and distribution, or by their contained fossils, something of the length and prevailing climate of the period in which they were laid down. Unfortunately, perhaps, there is always a considerable amount of water action in connection with an ice sheet and large bodies of waterlaid beds, contemporaneous with one stage of the ice, may be buried beneath the drift after a wholly unimportant interval.

The gravel beds may, and do, grade laterally into the drift, proving their contemporanity. They may also carry large numbers of flattened and striated stones, obviously not long subjected to the wearing action of running water. On the other hand they may be well rounded and water worn and indicate deposition at a considerable distance, at least, from the ice front. The gravels, whatever their form and origin, may be fresh, hard and uncemented, or they may be weathered, soft, ferruginated and cemented into conglomerate. Since gravel beds are readily permeable and afford easy channels for underground water it may be granted that all the processes indicated might leave their marks upon a really young gravel. As a matter of fact, however, the gravels found in connection with the Wisconsin drift are almost uniformly fresh, while the Buchanan gravels, and the few which have been referred to the Aftonian quite as uniformly show signs of age. It would seem that this possible source of error is really after all quite unimportant. Furthermore, it has often been shown that in many cases the weathering of the bowlders, both in the gravel and in the older tills, took place after they were glaciated.

Topographic Changes.—One of the most easily recognized and significant phenomena indicative of differing ages is topographic change. It is true that the rate of development of topography is dependent on several variable factors, and may differ both in relation to position and time, but the elements due to these factors may often be eliminated, and in such cases the topographic differences become probably the best indices

of the time relations. In considering drift sheets which are deployed, the topographic element is of great importance. The pre-Kansan drift is, however, so far as is now known, unexposed except where the Kansan drift has been cut through. The topography of its surface is accordingly almost wholly unknown. The little which we do know, however, is especially significant.

Physical Character of Till.—When in studying the indurated rocks one finds above a widespread and characteristic sandstone, a limestone, a dolomite, or even a sandstone of different character, he suspects at once that he has to deal with a different formation. To a certain extent the same sort of criteria may be applied in a study of the drift. It has long been recognized that marked differences in the character of the bowlders carried betokens differences in the genesis of the drift. Originally this was interpreted as meaning a change in the direction of the ice currents. Recently this has been synthesized and now the phenomena are used to discriminate centers of dispersion. Aside, however, from the differences in the bowlders, there are certain differences in the physical aspect of the drift itself which come to mean much to the field worker. Such differences are hard to put into words, and it is not always possible to analyze them and so detect the underlying cause. They cannot always be detected and there are many things which may be deceptive; yet the character of the drift is often very helpful. For example, the yellow clay of the Iowan drift is usually more friable than that of the Kansan. The well known "feel" of the loess is another case in point. As a rule the blue clay of the Kansan has the character of a joint clay, breaking with little cubical blocks on drying, etc.

Cumulative Value of Evidence.—It is a well recognized fact that many isolated bits of evidence have a cumulative value. A fact which standing alone would fail to do more than excite a languid curiosity, when ranged side by side with many similar facts, takes on a deeper significance; while a study of the assemblage of independent evidences will often convince the veriest skeptic. Out of small and individually weak brick, a large and trustworthy wall may be erected. So in the study of the drift sheets. As has been suggested, one class of evidence is rarely found alone; but the whole often unite to make clear a record which could not be deciphered from any one. Even the most intangible of all, the physical aspect of the drift, is often the one first observed, and it serves in no small number

of cases to give the primary suggestion of the solution of the difficulty, leading one to seek for and find other and surer evidence.

THE AFTON-THAYER EXPOSURES.

The Aftonian beds are not positively known to occur in or immediately adjacent to the city of Afton; the latter is, however, the best known town near the original exposures. The beds are seen well exposed at three abandoned gravel pits located three to six miles east of Afton proper. These are (1) between Afton Junction and Talmage; (2) about one mile southeast of the Junction on the south side of Grand river; (3) about three-quarters of a mile west of Thayer on the south side of the Chicago, Burlington & Quincy railway. For convenience these will be called the Afton Junction, Grand River, and Thayer pits, respectively. The Afton Junction pit shows the overlying loess, the Kansan drift and the gravels with certain buried silts or loess beds below the latter. The Grand River exposure shows the upper and lower drifts with the gravels between. The Thayer exposure shows the gravels and the overlying drift with certain sands and fine clays between.

Afton Junction.—The pits at this place are about 1,500 feet north of the railway station, on the west side of the Chicago Great Western. They have been opened along the sides of a small stream running east and emptying into Grand river. The north side of the pit is bilobate, the minor lobe being to the east and not directly in line with the main face of the pit. The two lobes in fact form an arc of a rude circle rather than a straight face. Between the two lobes is a small ravine which has cut down to, but not through, the gravels. The main face (Plate v) is about 1,000 feet long and has a maximum height of probably seventy feet. The minor or east lobe is about 400 feet long and fifty feet high. The bottom of the pit, said to rest on "quicksand," is cut down to about the level of Grand river bottoms (1030 A. T.). The stream is here of post-Kansan age. The section exposed at the main face is as follows:

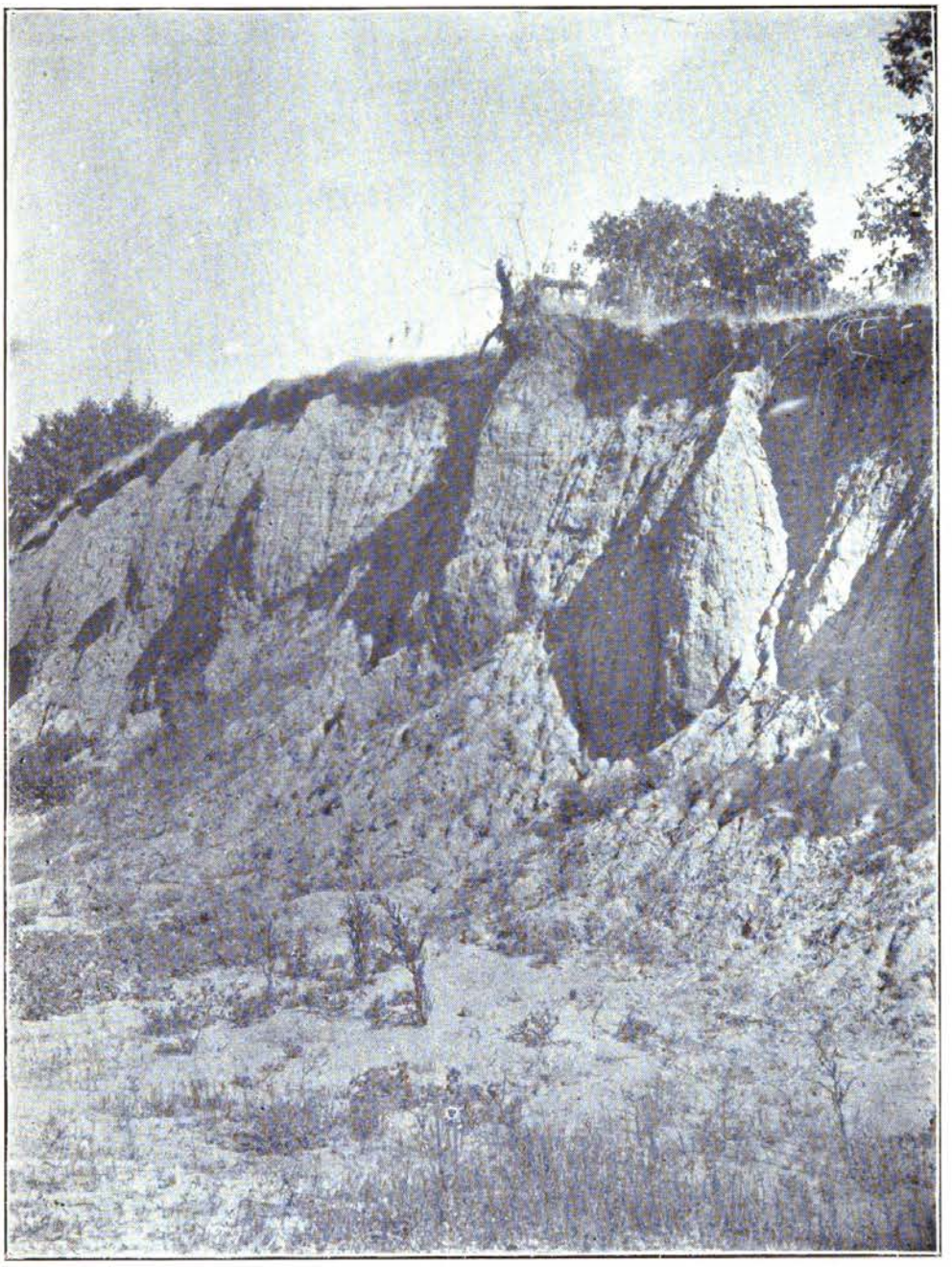
	FEET.
Loess of the usual upland or older type, characteristic of the region	10
Yellow bowlder clay with upper portion much oxidized, leached and highly colored; lower portion running into a blue with weathered joint cracks, containing much weathered material and planed and striated bowlders, characteristic Kansan	30

	FEET
Gravel, coarse, cross-bedded, iron-stained, cemented in part into hard conglomerate; made up to considerable extent of very badly weathered material, manifestly an old gravel.....	40

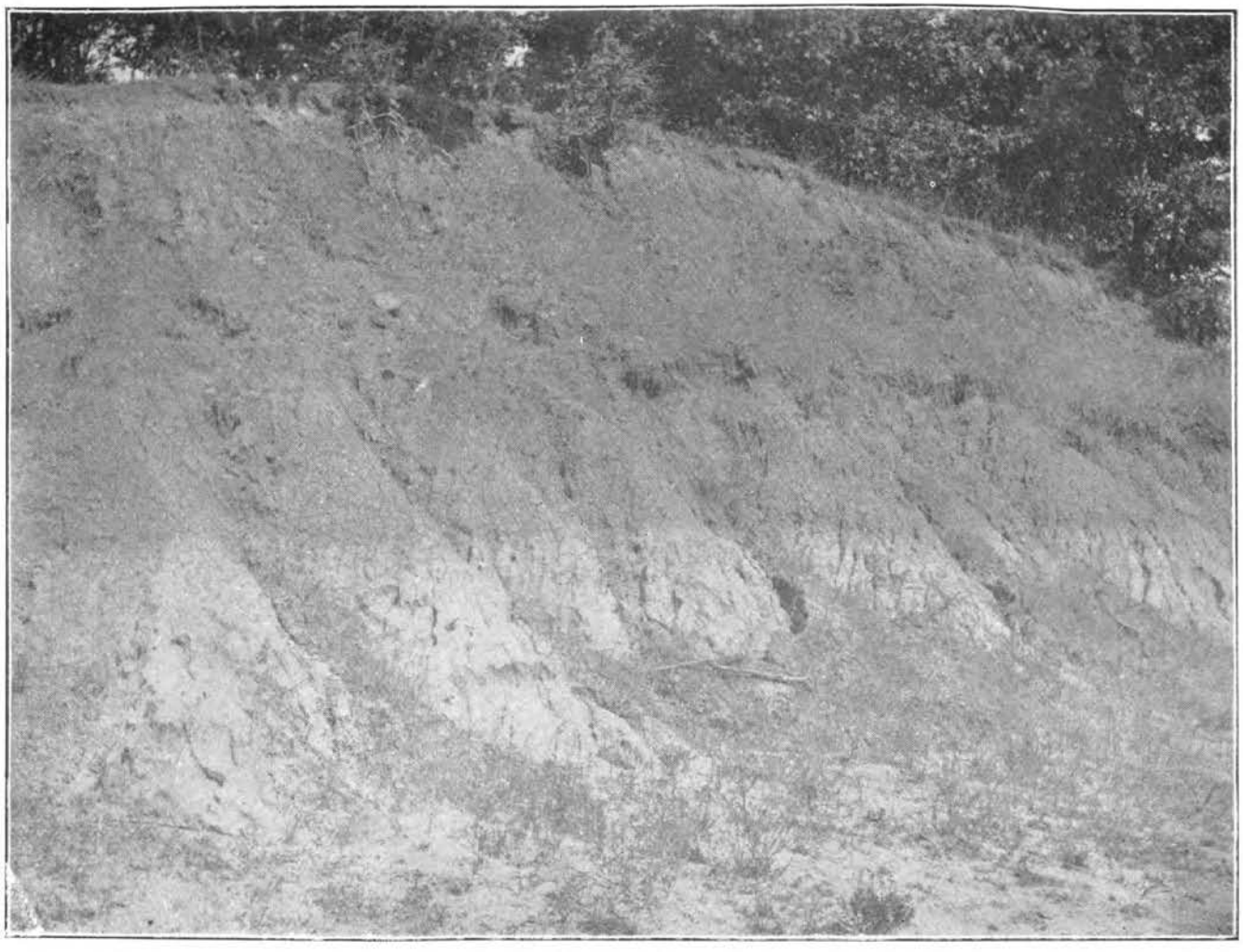
Down to the gravels this is the normal section for the region and could be duplicated at hundreds of points. The ferretto zone is well developed and its coloring is dark enough to show excellently in a photograph. The drift and loess are identical in every particular with that found throughout southern Iowa and there can be no doubt whatever that the drift is Kansan.

The drift shown in the east lobe is of the same character as that overlying the gravels in the main face, and the identity of the two has not been questioned as far as is known to the writer by any who have visited the place. Among the latter may be mentioned Professors T. C. Chamberlain, Albrecht Penk, Samuel Calvin and S. W. Beyer. Prof. G. F. Wright has seen the exposure but his opinion on this point is not known to the writer. The drift in the east lobe lies at a considerably lower level than in the main face, extending in fact down to the bottom of the pit. As the railway near the station just cuts into the top of the gravels a few feet, this was, when first seen, interpreted to mean that the gravels formed a kame-like ridge with a northwest-southeast trend and that the drift had been laid down over this ridge running down over its side. It was thought likely that there had been some erosion whereby an eastern extension of the gravels had been cut away before the drift of the east lobe was laid down, and that, accordingly, the position of the drift indicated, or at least accorded with, a certain time interval between the gravel and the overlying drift. Recent studies fail to sustain this view. The Great Western Railway company undertook to open up the gravels at the point near the station where they showed above the track. As the steam shovel traveled to the north it was found that the gravel contained more and more clay until ordinary bowlder clay was being handled, and the work was stopped. An examination of the east lobe of the old pit apparently indicates that the same transition occurs there. In the photograph (Plate vi) faint lines of stratification will be noticed running through the bowlder clay. So faint are these in that portion some distance from the gravels that they were at first entirely overlooked. Re-examination showed, however, that the bowlder clay is

General view of the Afton Junction gravel pit, showing the gravel exposed in the face of the main lobe and covered by the Kansan and loess. The east lobe is seen in the middle right. The dark line near the top of the section marks the position of the ferretto.



East lobe of the Afton Junction gravel pit showing lines of stratification in the drift.



Old loess-like material below drift, presumably Kansan, at the extreme end of the Afton Junction gravel pit.

really stratified, the lines of stratification becoming more distinct as one passes towards the gravel and stringers of the latter becoming more frequent in the bowlder clay. The relationship has been somewhat obscured by the circumstances of a stream pouring down at the contact of the two lobes, but it seems quite clear that the east lobe is composed of stratified material which is intimately connected with the gravels. In the opposite direction the signs of stratification become more and more obscure until the drift can not be told from the ordinary yellow clay of the Kansan. The transition is not, however, so open to observation and there is a possibility that the stratified drift is distinct from the yellow clay of the region, though there is no known evidence proving it so.

At the extreme east end of the east lobe there is exposure showing the beds below the drift. This exposure is in a borrow pit made in getting material for the railway fill and is represented in the third photograph (Plate vii.) The overlying bed here is the yellow clay of the Kansan. It is the continuation to the east of that shown in the former photos. It is here so far from the gravels that it shows no signs of stratification nor indeed anything to indicate that it is anything more than the ordinary yellow clay of the Kansan. Beneath the bowlder clay will be noted a pebbleless clay resembling the loess. Indeed one might imagine it to be the ordinary drift-loess section of the region reversed and minus the ferretto zone. In fact that is exactly what it is, a loess buried beneath yellow bowlder clay. In all important respects it so closely resembles the ordinary upland loess that the two could probably be discriminated only with difficulty. The loess shows under the stratified bed of the east lobe, though it carries here some very fine gravel and is more of a silt than a loess.

Grand River Section.—The exposure on the river proper is about one mile away though one exposure is in view from the other. Between, ordinary erosion has cut away the connecting beds; but looking across the amphitheater the connection is obvious. This section is the only one in the region showing the lower till and is accordingly of exceptional interest. The full exposure shows the loess, Kansan drift and gravels as seen elsewhere. Beneath them are the following beds:

	FEET.
Bowlder clay (sub-Aftonian), a blue-black clay not weathered at top and coming into sharp contact with the ferruginated gravels, containing mainly small pebbles, predominantly of vein quartz, but with a fair proportion of granite. Many, if not most, of the pebbles fresh and hard	40
Red and blue shales of Missourian.....	20

The peculiar physical character of the lower bowlder clay is striking. It is dense and breaks usually in flakes rather than joint blocks. It is of a strikingly dark color. There are few joint cracks and these show no special signs of weathering. The sharpness of the contact between the gravels and the bowlder clay, with the presence of many hard pebbles in the latter, indicates apparently one of two things, (1) either this lower clay was not exposed to surface action before the gravels were laid down, or (2) it was so vigorously eroded immediately before the deposition of the gravels as to cut away all evidence of former surface exposure.

Thayer Section.—The Thayer section is of interest, since it seems that here the evidence of two drifts was detected. The section as now shown varies a little from point to point in the pit but a representative exposure shows the following beds:

		FEET.	INCHES.
9.	Black soil.....		6
8.	Reddish gravelly clay (ferretto).....	1	
7.	Yellow bowlder clay becoming gravelly below and containing quartzite, greenstones and granite; flattened and striated pebbles with lime concretions.....10 to	20	
6.	Fine sand	1	6
5.	Drab to blue pebbly clay with sticks and bits of undetermined wood.....	4	
4.	Fine sand.....	3	
3.	Drab pebbly clay as above.....	12	
2.	Fine sand.....	2	
1.	Gravel as seen before, striated and cross-bedded; pebbles mainly less than 1½ inch in diameter but with some large bowlders. Material seemingly of the usual Kansan facies, much weathered and highly colored.....15 to	20	

Summarizing the above, we have loess and yellow and blue clay phases of the Kansan with the underlying gravels. The

blue clay phase of the Kansan is unusual in the presence of interstratified beds of fine sand and in the abundance of woody material. It is dark and might readily be taken for a buried soil, though there is some doubt whether this is the true interpretation. The portion of the pit examined by McGee and Chamberlin is not now open to examination. It seems to have then presented much better evidence of a soil above the gravel than can now be found. The material seen is stated to have given a clear impression that it was a mucky soil accumulated on the lee slope of the gravel hill. It contained much vegetal material, and while normally but three to four feet thick, was at one place bunched up to a thickness of six or eight feet. The material now found at that horizon some few feet farther east is full of pebbles and, except for the darker color and woody material, does not differ from blue bowlder clay.

The question raised by the various Afton exposures are numerous. The principal ones are (1), are there two distinct drift sheets present? and (2), if two drift sheets be present is the unconformity above or below the gravel beds? The earlier interpretation was that two drift sheets were present, that the gravels represented kames connected with the retreat of the earlier ice, and that the blue-black clay at the base of the Kansan as seen at Thayer was in part, at least, a soil, and marked the Aftonian horizon proper. An alternative hypothesis would consider the evidence of two drifts, so far only as these particular exposures are concerned, as perhaps not wholly unassailable, and would place the dividing line below the gravels. In support of the latter hypothesis, it may be urged that so far as the exposures now show there is nothing comparable to a soil above the gravels except at Thayer, and that even here the beds may be explained, though perhaps with some difficulty, as merely a portion of the blue clay phase of the Kansan. The passing of the gravels by lateral transition at three points into bowlder clay undistinguishable from, and apparently connected with, the overlying Kansan, would seem to argue a contemporaneity of age. It is possible, however, that the effect of a later ice sheet working against the edge of a loose gravel hill would be to obscure the distinctness of the two deposits more than has been thought. Perhaps the loess-like clay seen beneath the stratified beds and proven by test pits to run beneath some, at least, of the gravel, may be urged as evidence of an unconformity below the gravel. As it is quite probable that the gravel pits

will soon be extensively reworked and final evidence upon some of these questions will then be at hand, no attempt will be made for the present to determine the balance of probabilities between the two hypotheses.

CO-ORDINATE PHENOMENA.

Before taking up the question of the presence of two drifts in the larger region it will be advisable to mention certain additional exposures. In the immediate vicinity of Afton a buried peat bed has been reported from several wells, and specimens of peat collected by Mr. William Haven, leave no doubt as to its nature. This bed is found at a depth of about forty feet in situations which seem to indicate that it is lower than the base of the loess.

Following down Grand river traces of the gravels are occasionally seen and at Reynolds ford, near where Union and Decatur counties corner, the beds are exposed with a thickness of 15 feet. They rest as at the exposure already described upon a blue-black bowlder clay of peculiar physical character and unlike the usual blue clay of the Kansan. In the southern portion of Decatur county below Davis City (southwest of northwest section 18, Hamilton township) is another exposure of bowlder clay of this character and over it are some beds of stratified material. Between the two points south of a small country town called Terre Haute (section 28, Burrell township) is an exposure in the south bank of the river showing a soil below yellow bowlder clay answering to the Kansan and having here stratified material below. This exposure is not altogether satisfactory and has been discussed elsewhere* but should be kept in mind in offering an interpretation for the region.

In the southwestern portion of the county a forest bed has been reported from several wells. Mr. Fitzpatrick has noted it at Lamoni at a depth of 85 feet with 100 feet of bowlder clay below. In Harrison the adjoining county in Missouri, Dr. Keyes informs the writer that a peat bed as much as nine feet thick has been found at considerable depths. Near Osceola and again near Leon there is a buried gumbo which, while it is believed to represent merely an episode in Kansan history is possibly susceptible to another interpretation.† Near Sigourney, in Keokuk county, Mr. Leverett has noted an old soil in the drift far outside the limits of both the Iowan and the Illinoian.

*Geol. Decatur Co., Iowa Geol. Sur., Vol. VII. In press.

†Geol. Decatur County.

The forest bed at Washington has often been referred to. Buried forests have been reported in the region at Murray, Fontanelle, and points in Taylor county and, while the phenomena have not yet been carefully collected and studied, enough is known to prove that the facts are not isolated; and some of them, at least, seem worthy to serve as a basis for generalizations.

The exposure near Hastie, first described in a meeting of this Academy* and more fully described in the reports of the Geological Survey†, is probably to be considered in this connection. In view of the results of the past season's work in the discovery of correlative evidence it now seems that the argument from erosion then suggested is a good one and that there is an important time break between the gravels and the Kansan drift. Certainly a time break which was sufficient to allow the Des Moines to clear out of its old valley forty feet of drift so completely that only a few scattered remnants are left, is not to be considered trivial.

SUMMARY.

In considering the conclusion to be drawn from the evidence now in hand the remarks relative to the value of the various lines of evidence should be kept in mind.

First.—It is submitted that there is widespread evidence of buried forest and peat beds in the region. It is admitted that nothing of importance bearing on the character of this flora as regards climate is known. It is further admitted that these notes on forest beds have not been sifted, and much of the evidence is of uncertain value. It is, on the other hand, to be noted that certain of the beds are well attested as to position, occupying a horizon fitting well with the hypothesis of two drifts, and that some are of a thickness worthy of consideration. Upon the whole, however, the argument from forest beds alone probably has but slight value.

Second.—Buried soils have been shown to be not unknown, though the value of the evidence derived from them is uncertain.

Third.—It has been impossible so far to apply the ordinary tests based on leached and ferretto zones to the sub-Aftonian.

Fourth.—Waterlaid beds are present at several points at the Aftonian horizon. In Polk county they are believed to be

* Keyes and Call, Proc. Iowa Acad. Sur., 1890-91, p. 30.
† Vol. VII, Geology of Polk County, pp. 336-338, 1897.

notably earlier than the overlying drift. At Afton they seem to represent kame-like aggregations, but whether made during the advance of the Kansan, or the retreat of the pre-Kansan, is not entirely certain. In general the waterlaid beds are such as might have been formed by agencies closely connected with the ice. The possible exception is the buried loess at Afton Junction, which, however, would only necessitate a considerable change in the vigor of deposition between the time of its formation and the laying down of the overlying gravel.

Fifth.—Since the presumed sub-Aftonian drift is thought to be wholly covered by the Kansan, and is certainly known to be in the region studied, there is but little chance to contrast the topographic development of the two drift surfaces. Relative to erosion in the period between the two drift sheets it may be stated that the Hastie exposure strongly favors such a supposition. The evidence pro and con at Afton exposures is in too uncertain a condition to warrant any conclusions. It may be said, however, that there is much which indicates a notable period of erosion and very little, if any, evidence against it.

Sixth.—It has been shown that there are exposures in the region of a drift of peculiar physical type That this drift is wholly unlike any known phase of the Kansan, and that in every instance there are some independent phenomena favoring the hypothesis that it is distinctly older than the Kansan. Whatever one may think of correlations based upon physical characters these facts are certainly of some significance. Furthermore the same facts are true of the known exposures of the presumed pre-Kansan drift at Muscatine, Oelwein, Albion, and indeed throughout the state.

General Conclusion.—It is believed that the argument for a pre-Kansan drift sheet derived from erosion is strong, and that it has independent value. The arguments from other sources tend to greatly strengthen it, and the cumulative force of the whole is believed to be sufficient to put the burden of proof upon those, if any, who would attempt to deny the existence of a pre-Kansan drift. All would, however, probably agree to the statement which the writer believes warranted by the evidence in hand, and which he expects future investigations to amply confirm, but for anything beyond which there is probably as yet no sufficient evidence: that there are in Iowa traces of a drift sheet older than the Kansan and separated from it by an unknown, but probably considerable, interval.

It may be mentioned in conclusion that it has been suggested, notably by Chamberlin,* that a complete series of deposits recording a glacial period should theoretically include a series of early deposits made by minor advances of the ice of increasing intensity, covered by those of the maximum advance which in turn should be covered by a second series of deposits made by minor advances of decreasing extent. So far only the maximum and some of the later drift sheets have been discriminated. It is believed that the pre-Kansan drift probably represents one of these earlier and minor extensions of the ice sheet.

It is to be noted that the Aftonian as first used was correlated with the "forest bed" of McGee. Recent work has shown that in northeastern Iowa two separate horizons were confused under the latter title. Inasmuch as at some points the "forest bed" is now believed to be between the Kansan and pre-Kansan, rather than what is now known as the Iowan and Kansan, the original determination was in so far correct, and these would accordingly be legitimate reasons for applying to the upper drift of southern Iowa the term Iowan. The final usage will be to some extent determined by the fact as to whether or not the pre-Kansan or the Kansan of present usage, is really the surface drift of eastern Kansan.

The recent changes are in the matter of dividing the formation which McGee called his "upper till." Since the peculiar topographic forms which he so well described, and which are so generally associated in mind with his "upper till" belong to that portion of it now recognized as Iowan, and furthermore, since northeastern Iowa has been considered the type region for the Iowan, present usage will probably prevail, but this possible change should not be lost sight of.

In studies in the Alpine glaciation of Europe three periods of glaciation have been made out. These include, (1) a fresh, young till, (2) an older widespread till, and (3) a very old and imperfectly known till.† In a general way the Iowa section may be correlated with these beds. No. 1 answering to our young drift, Iowan or Wisconsin, or both; No. 2, the Kansan; No. 3, the pre-Kansan.

The Illinoian seems to have no correlative in the Alpine section, unless possibly this middle drift should prove capable of division. Until, however, much more is known of the pre-Kansan such correlations must rest on rather slender data.

*Great Ice Age (Geikie), p. 736. 1895.

†Le Systeme glaciare des Alpes, Penck, Bruckner et du Fanquier.