GEOLOGY OF WASHINGTON COUNTY.

BY

H. FOSTER BAIN.

GEOLOGY OF WASHINGTON COUNTY.

BY H. FOSTER BAIN.

CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Washington county lies well towards the southeastern corner of the state, being twenty-five miles west of the Mississippi river and fifty miles north of Missouri. The Iowa river forms a portion of its northeastern boundary, but with that exception the county has no natural limiting lines. Iowa and Johnson counties lie north of it, and the latter, with Louisa county bounds it on the east. On the south it is bounded by Henry and Jefferson counties, while Keokuk county lies immediately west.

The area of the county is 570 square miles, being disposed in the form of an approximate square having sides twenty-four miles long. Within this area there is a considerable variety both in topographical and geological detail.

PREVIOUS GEOLOGICAL WORK.

One of Owen's field parties under Mr. C. B. Macey in 1849 ascended the Iowa river, but no special observations seem to have been made in the county. Worthen* in 1856 made a geological survey of the county which was necessarily of a preliminary nature only. White† referred to the presence of coal measures in the county, but did not review Worthen's work. Calvin‡ has published an account of the deep well bored at Washington, and J. Gass and W. H. Pratt§ in 1882 called attention to the discovery of a mammoth skeleton within the area.

Since the survey carried on by Hall and Worthen a number of new outcrops have been discovered and considerable change has been made in the classification of the rocks exposed within the limits of the county. It was thought that the relations between the Devonian and the Carboniferous could be well studied within this county, and the hope of

*Geology of Iowa, vol. I, pp. 239-248. Albany, 1858.
†Geology of Iowa, vol. II, p. 273. Des Moines, 1870.
‡American Geologist, vol. I, pp. 28-31 Minneapolis, 1888.
§Proc. Davenport Acad. Nat. Sci., vol. III, pp. 177-178. Davenport, 1882.

obtaining information upon this point was one of the principal reasons for taking up its study at this time.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Washington county is in the main of the type known as the "loess drift." It is characterized by long, low swells with broad-bottomed, shallow, grass-covered swales between. Near the large streams the country becomes decidedly rougher. The slopes are covered with loess, which merges more or less into the alluvium. Along English river, Crooked creek and a few other streams, sharp rocky bluffs are sometimes found. The bottom lands are usually broad. Both along the major streams and the smaller tributaries the present cutting is confined usually to sharp, narrow channels running through the alluvium. Cutting in the hills along the rivers is, on the whole, exceptional. The slopes are usually gentle and are grassed over.

Away from the streams the normal drift plain topography is common. Northeast of Washington, around Keota, and near Wyman, this type of land form is excellently developed. The flat, almost even surface, the straight highways, the black roads and the occasional, but on the whole very rare boulders, are all characteristic. The streams, if it be proper to call them such, which cross such areas show very little if any cutting. Where Long creek runs over the drift plain northeast of Washington, it can scarcely be recognized as a distinct landscape feature. Only a low, gentle swale, marked by bunches of marsh grass and occasional sloughs, indicates the beginning of the stream. Where the country roads cross its course the bridges stand up above the surrounding surface and are reached by long, low dirt embankments.

These drift plains form flat-topped divides of considerable breadth between the rivers. Occasionally the minor streams have pushed back so far into the inter-stream areas that little semblance of a plain remains. The general elevation of the

upland is about 800 feet in the north and west, and varies from that to about 750 feet in the south and east.

The broad flood plain of the Iowa and Mississippi rivers which forms so marked a physical feature of Louisa county to the east, does not extend far into this county. Indeed the Iowa river here flows against its west bank, which is a series of abrupt drift bluffs 100 to 120 feet high.

The elevations of the principal towns as well as a number of other points are shown in the following table.

STATION.	Altitude.	AUTHORITY.
Ainsworth	704	C., R. I. & P. Ry.
Brighton	752	C., R. I & P. Ry.
Brighton quarries	700	Survey.
Cedar creek, near Verdi	713	C., R. I. & P. Ry.
Crooked creek, west of Washington	684	C., R. I. & P. Ry.
Crooked creek, south of Washington	673	C., R. I. & P. Ry.
Dayton	823	Survey.
East county line	658	B. & N. Ry.
East county line	749	C., R I. & P. Ry.
East county line	668	B., C. R. & N. Ry.
English river, Kalona bridge	650	Survey.
Havre	733	B. & N. Ry.
High land between Verdi and Skunk river	738	C., R. I. & P. Ry.
Iowa Junction	649	B., C. R. & N. Ry.
Iowa River station	638	B., C. R. & N. Ry.
Iowa River bridge	633	B , C. R. & N. Ry.
Kalona	665	B., C. R. & N. Ry.
Keota	803	C., R. I. & P. Ry.
Nira	770	B., C. R. & N. Ry.
North county line	645	B., C. R. & N. Ry.
Northeast corner of county, on high lands north of English river	710	U. S. G. S.
Northwest corner of county, on high lands north of English river	810	U. S. G. S.
Riverside	648	B., C. R. & N. Ry.
Skunk river, north of Brighton	613	Survey.
Stream southeast of Crawfordsville	668	B. & N. Ry.
South county line	703	C., R. I. & P. Ry.
Verdi	673	C., R. I. & P. Ry.
Washington	769	C., R. I. & P. Ry.
Wassonville mill	706	Survey.
Wellman	730	B., C. R. & N. Ry.
West Chester	784	C., R. I. & P. Ry.
West county line	772	B., C. R. & N. Ry.

In the above table the elevations credited to the United States Geological Survey are taken from the topographic atlas sheets of that organization. Those credited to the different

railways are from the engineer's profiles. The elevations credited to the survey itself are corrected barometric observations connected with the nearest known point. While not wholly free from error, they may be relied upon as approximately correct.

A comparison of these elevations gives some interesting results. Dayton, it is seen, lies on the high ridge between English river and Smith creek, and is 117 feet above the former stream and 93 feet above the latter. Wellman is in the valley of Smith creek. Kalona, Riverside, and Iowa Junction are built on the flood plain of English river. Keota, while scarcely more than a mile distant from Crooked creek, is yet built upon the high land, while West Chester, at the same or slightly greater distance from the creek, lies on land which has been degraded a few feet. Washington is built upon a tract of land lying thirty-five feet below the general upland level and eighty-five feet above Crooked creek. Ainsworth is in the valley of Long branch. Havre and Crawfordsville are on the ridge forming the watershed between the Iowa and Skunk river systems. Verdi, Brighton, and Coppack are all within the influence of the Skunk river erosion, while Noble and Wayland Crossing are built in the valley of Williams creek.

DRAINAGE.

The drainage of the county belongs to two systems, the Iowa and the Skunk. The former drains the northern and northeastern portion of the county, while the southwestern half, approximately, is drained by the Skunk river tributaries.

The Iowa river itself does not flow within the county, but forms a portion of the northeastern boundary. Its immediate drainage basin is, in this county, very inconsiderable; the main portion of the water which reaches it coming rather from a series of long, non-branching tributaries which flow almost at right angles to its own course. Of these latter, English river, Davis and Goose creeks are typical, while Long creek belongs to a slightly different category.

English river is formed near the northwest corner of the county by the junction of North and South English. It flows almost directly across the county, with but slight deviation from its general easterly course. It is remarkable for its considerable length in proportion to the width of its drainage basin and for the small number of its tributaries. Of

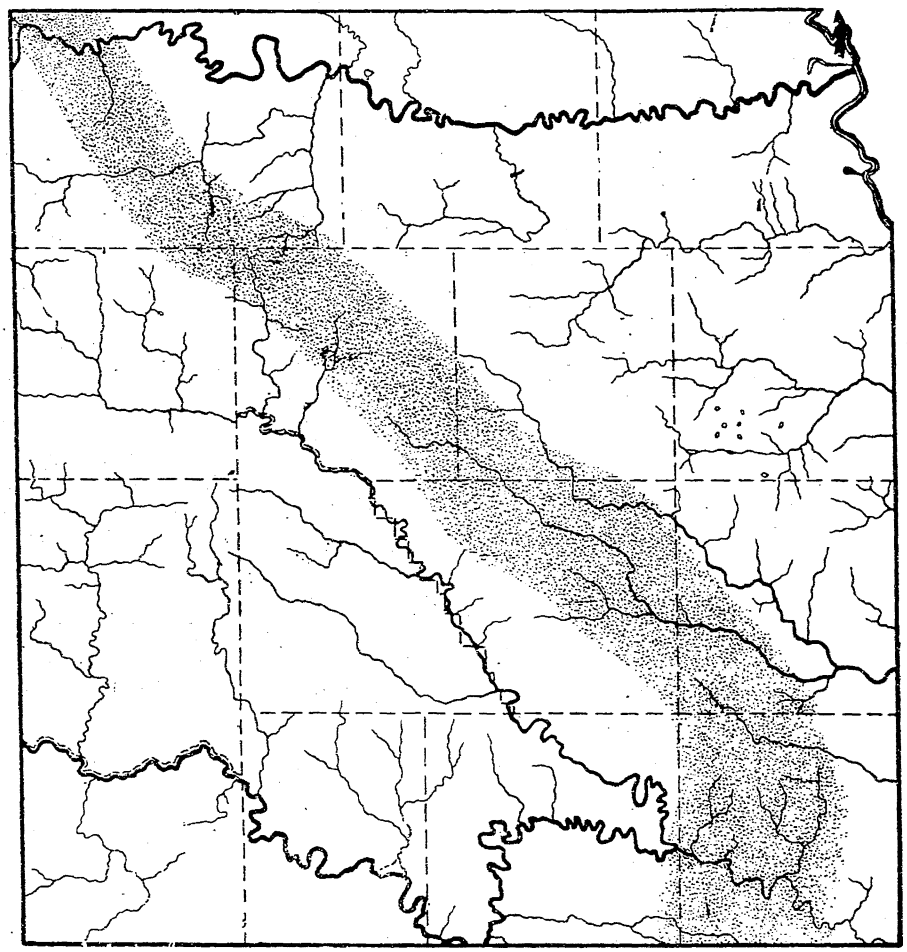


FIG. 9. Drainage of Washington County.

these latter, Smith creek, joining it a few miles below Wellman, is the most important. It is a representation in miniature of the larger stream. English river, at the point where the north and south branches unite, is about 700 feet above sea level. Its mouth is nearly 80 feet below this point, so that within the county it has an average fall of about 3.3 feet to the mile. As has been noticed by McGee, the steeper

slopes and higher bluffs are on the south bank of this stream. With but one important exception the rock outcrops are confined to the southern slope.

Davis creek, which in its upper portion is called Continue creek, rises in Jackson township, flows northeast, then east to Iowa river. It is a narrow stream, with few tributaries, and has at only one or two points succeeded in cutting through the drift.

Goose creek rises in Highland township and flows southeast to the county line, within a mile of which it is joined by Whisky run. These streams have cut from seventy to ninety feet below the upland level, but only expose the indurated rocks at wide intervals. In general character they resemble English river markedly.

Long creek with its two branches, north and south, flows southeast, reaching the Iowa river near Bard in Louisa county. It belongs, rather, to the class having many widely branching affluents.

The Skunk river system includes within the county, the Skunk river itself, with its immediate tributaries, and the subordinate system formed by Crooked creek and its branches. The Skunk enters the county about six miles north of the southwest corner, and flows east of south to Coppack, where it makes an abrupt turn due south and leaves the county. It is a stream of considerable size and has an average fall of about two feet eight inches per mile. It has a wide valley, with broad bottom lands, and has cut its channel nearly 200 feet below the general plateau level, the last seventy feet or more being channelled through the limestones below the drift.

This stream, a short distance after it enters the county, receives Richland creek from the south. A mile or more below, a second small stream, also from the south, flows into the larger river. The principal stream flowing into Skunk river from the north is Dutch creek, which has a course almost directly south for some six miles.

Crooked creek enters the county near Keota, and flows southeast to about two miles north of Noble; here it turns directly west, but after flowing five miles in this direction it turns due south and joins Skunk river near Coppack. In its upper portion the south bank is the better defined, most of the tributaries flowing in from the north. In its lower portion the reverse is true. Near Washington, Clemons and Cedar creeks flow in from the west. At the point where Crooked creek makes its abrupt change, north of Noble, it receives the East Fork of Crooked creek. This is a small stream flowing in a rather large valley, which is a direct continuation of the main valley of Crooked creek. At one time Crooked creek probably flowed on up the valley now occupied by its east fork and over the low divide north of Marsh into Otter creek, through which it had a direct course to the Iowa. At the bend north of Noble it then received a tributary from the west. Near Coppack the Skunk received a similar tributary from the north, which does not seem to have been a large stream at that time, but had the advantage of a more rapid descent and worked its way back till it captured the stream flowing into Crooked creek. Since the Skunk river is nearly sixty feet lower than Crooked creek where they are parallel, the new channel thus opened up afforded a short cut, and what is now the west fork of Crooked creek began to flow up its tributary and across the divide, marked now by a cut in the limestone, into the small branch of Skunk river. The increase of volume caused the stream to cut down rapidly into the underlying limestones, and so we have here a stretch of valley which is not relatively wide, but which is cut well down into the indurated rocks. In the adjustment, a part of the lower portion of Crooked creek was reversed and became what is now the East Fork. This change in the course of Crooked creek was probably due in part to the incursion of the ice from Illinois, though there is good grounds for the belief that it would ultimately have occurred in any event. This incursion is represented in Iowa by a moraine, traced by Mr.

Frank Leverett, which crosses the former course of Crooked creek, and forms the present divide between the East Fork of that stream and Otter creek near Morning Sun. This later cutting gives then, a measure of the stream erosion occurring after the incursion of the Illinois lobe.

These adjustments were the more easily accomplished as the region near the great bend is drift covered and easily cut through. The stream is now wearing on its west bank which is here composed entirely of drift, and sooner or later it will find a channel across the narrow neck of unconsolidated deposits.

Williams creek is a small stream flowing into Crooked creek from the east. It has a narrow valley and in the lower part has cut some twenty feet into the limestone.

ORIGIN OF THE DRAINAGE SYSTEM.

The drainage system of the county seems to have had its origin in or immediately succeeding glacial times. The explanatian given by McGee* for English river, that it flows along the southern edge of a gently sloping plain, seems in a general way to be also applicable to the upper portion of Crooked creek. These streams would then have had their origin subsequent to the deposition of the drift.

Skunk river is a large stream and seems to have had a longer history. In general direction, and in the presence of the abrupt turn at Coppack, it simulates the Iowa, Cedar and other rivers farther north. It seems probable that its history may have been much the same as that of those rivers. Though drainage lines evidently existed in this region previous to the ice invasion, the evidence at hand does not show any very close connection between the two. Indeed, some of the present streams cross almost at right angles the older valleys. There is, at some points on Williams creek and Skunk river especially, some evidence of the present valleys being in part drift-filled, but by far the greater portion of

*Eleventh Ann. Rep. U. S. Geol. Sur., pt. 1, pp 412-413. Washington, 1892.

stream erosion must clearly have taken place between the deposition of the drift and the loess. In crossing the country exposure after exposure may be seen where the sides and bottoms of the small valleys are covered by a thin veneer of loess. The latter is not usually thick on the upland. Indeed, it can scarcely be said to occur over the drift plains. East of Bethel church, in Highland township (Tp. 76 N., R. VI W., Sec. 30), the wagon road crosses a number of small ravines which have the relations indicated by figure 10. The drift may be seen in the cutting at the side of the road in both

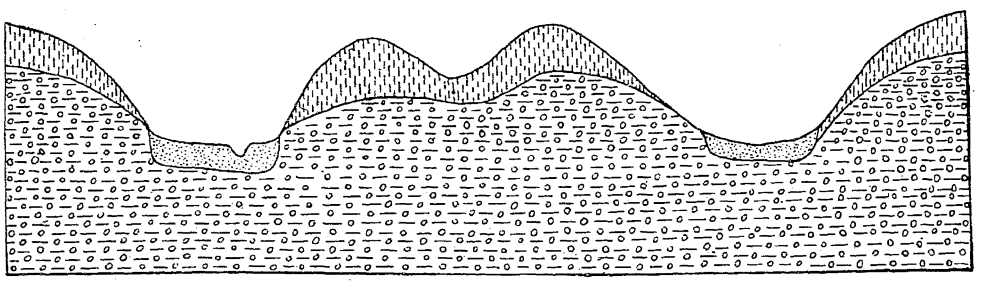


FIG. 10. Relations of present to preglacial drainage.

of the outside ravines. The loess follows right down the slope, veneering the drift. In the middle ravine the road cuttings have not been deep enough to expose the drift. Similar relations between the drift and the loess may be seen north of Riverside and at very many other points. One can not escape the conviction that the streams made their present valleys, even in the case of the minor tributaries, before the loess was deposited, and that the amount of erosion since that time has been comparatively insignificant. If the correlation of the loess with the later or Iowan ice be correct, it would follow that the stream erosion took place in interglacial or Aftonian time, and the relative amount of stream action before and after the loess would be a strong argument for the great length of interglacial time as compared with postglacial.

While the divides of the county are, as has been said, flat-topped, and there are regions of immature drainage, the general impression which one gains from a study of the streams

of the county is one of relatively great age. As contrasted with the areas farther north, now covered by the drift of the Iowan and Wisconsin ice sheets, the amount of erosion is great. As has been said, there is but little evidence that this erosion was accomplished in preglacial time. It has been largely, if not wholly, effected since the drift of this region was laid down—in post-Kansan time. Apparently but little of the erosion has taken place in post-Iowan.

STRATIGRAPHY.

General Relations of Strata.

The geological formations comprised within the county belong entirely to the Carboniferous and the Pleistocene. The classification of the strata is shown in the following table.

Classification of Formations.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.		Alluvial.
		Glacial.	Iowan.	Loess.
			Kansan.	Drift.
Paleozoic	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Mississippian.	Saint Louis.	Pella beds. Verdi beds. Springvale beds.
			Augusta.	(Keokuk?) Burlington.
			Kinderhook.	Wassonville limestone. Maple mill shale. English river gritstone.

STANDARD SECTIONS.

The following sections may be taken as representative of the different geological formations of Washington county. Together they form a general section of the indurated beds.

MAPLE MILL SECTION.

(Tp. 77 N., R. VIII W., Sec. 4, Se. qr., Nw. ¼.)

		FEET.	INCHES.
4.	Limestone, ferruginous, arenaceous in places, fine-grained, red, containing numerous casts of fossils and with thin chert layers 2 to 8 inches thick, also fossiliferous	10	
3.	Sandstone, or gritstone, very fine-grained, white to buff, very fossiliferous	18	
2.	Limestone, fine-grained, non-fossiliferous		2
1.	Shale, argillaceous, dark blue to drab, becoming almost black in places	12	

The whole of this section may be referred to the Kinderhook. Numbers 1 and 2 represent the Maple Mill shales, number 3 the English river gritstone, and number 4 the Wassonville limestone. The upper member (No. 4) may be readily traced up the river to the Wassonville mill where it is somewhat thicker. At this latter place the Augusta limestone is seen to lie above it, but is better seen in the following section on Crooked creek.

ECKELS QUARRY SECTION.

(Tp. 75 N., R. VIII W., Sec. 2, Sw. qr.)

		FEET.
3.	Loess	12
2.	Local drift	6
1.	Limestone, coarsely sub-crystalline, blue, gray and white in color, running in ledges from 3 to 20 inches	20

The stone here belongs to the Augusta, or more specifically to the Burlington layers of that formation. The top of the formation is not seen at this point, nor indeed is the contact between it and the next upper member, the Saint Louis, found at any point in this county, though it may be examined at a number of exposures in Keokuk county immediately west.

The Saint Louis is excellently shown near Brighton, all the members being present. The whole formation, however, and each of its subdivisions, is much thinner than usual, the greatest diminution being in the middle member or Verdi beds. A complete section along the small ravine running north from Brighton to the river is as follows.

BRIGHTON SECTION.

(Tp. 74 N., R. VIII W., Sec. 29.)

		FEET.	INCHES.
17.	Clay, purple to brown; full of Saint Louis fossils, and with irregular pieces of Saint Louis limestone but no erratics; 8 inches to 3 feet	2	
16.	Limestone, gray		8
15.	Limestone, fine-grained, compact, ash-gray in color	1	8
14.	Limestone, as above	1	6
13.	Limestone, gray	3	
12.	Limestone as above	3	
11.	Sandstone, with irregular shaly limestone, the two replacing each other in whole or in part at intervals	8	
10.	Limestone, fine-grained, ash-gray, compact	1	6
9.	Limestone, as above	2	6
8.	Limestone, as above, water worn and cavernous, the face covered in part by stalactitic matter	7	
7.	Limestone, as above, water worn	7	
6.	Clay, blue to drab	3	
5.	Unexposed talus, of brecciated limestone and sandstone	20	
4.	Limestone, soft, brown, earthy	2	
3.	Unexposed	6	
2.	Clay, blue to green, soft	4	
1.	Limestone, above, thin-bedded, ash-colored, sandy, non-fossiliferous; below, in bed of river, hard, black, with obscure fossils	8	

This whole section may be referred to the Saint Louis, with the possible exception, as will be noted farther on, of the lower member which may represent the upper Keokuk or

Warsaw layers. Numbers 17 to 13 inclusive may be seen in the Martin quarry; numbers 13 to 7 inclusive are shown in the Chicago, Rock Island & Pacific quarry now abandoned; number 6 is not exposed, but was at one time encountered in working the latter quarry; numbers 5 to 1 inclusive are shown in the bluff on the Skunk river at the Brighton mill.

The lower four members belong to the series recognized in neighboring counties as the Springvale beds, but are not typical. The upper six members represent the Pella beds, while the intervening layers are referred to the Verdi. The latter series of beds is typically developed about two and a half miles north of here and has probably a much greater total thickness. The two heavy limestone ledges, numbers 7 and 8, do not appear to extend much north of the railroad quarry. In their place, as seen at the mill, is the talus, which thus probably, in part at least, represents them instead of being wholly beneath as given above.

As has been stated, there are within the country a few small coal measure outliers. None of these now exhibit complete sections. At the time of Worthen's visit coal was being taken from the outlier west of Verdi. The following section is given by him.*

LIEBS MINE SECTION.

(Tp. 74 N., R. VIII W., Sec. 5, Ne. qr., Ne. ¼.)

		FEET.	INCHES.
5.	Clay, shaly	3	
4.	Coal	3	6
3.	Coal, slaty	2	3
2.	Sandstone, quartzose, ferruginous, partly exposed	?	
1.	Limestone, concretionary	10	

The upper four members belong to the Des Moines formation (coal measures) while the lower is the Saint Louis. The surface of the limestone is exposed some fourteen feet below the coal and the interval is probably filled by the sandstone.

*Geology of Iowa, Vol. I, p. 242. Albany, 1858.

DEEPER STRATA.

Our knowledge of the strata lying below the Kinderhook of this county is derived entirely from a deep well put down at Washington, the record of which has been interpreted by Calvin.

The strata passed through may be summarized as follows.

FORMATIONS.	THICKNESS.
Drift	350
Kinderhook, shales	82
Devonian limestone	68
Niagara limestone	170
Maquoketa shales	91
Galena limestone	160
Trenton limestone and shales	132
Saint Peter sandstone	100
Oneota, blue shales	?
Saint Croix sandstone	?

Geological Formations.

The areas covered by each of the different formations exposed within the county may be seen by reference to the accompanying map. It will be noticed that in general the older rocks are in the northeast; each later formation outcropping successively to the southwest. An exception to this rule is seen in the coal measures outliers which overlap the earlier beds. The considerable erosion which has taken place since their deposition is evidenced in the small size of the remnants of this formation.

The limits as indicated on the map are not considered absolutely correct at all points as the mantle of drift which conceals the beds makes considerable error possible.

MISSISSIPPIAN SERIES.

With the exception of the few areas covered by the Des Moines formation the indurated rocks of the county belong exclusively to the Mississippian or Lower Carboniferous series. They are of considerable interest, since within the county all three of the major divisions of that series found in Iowa, the

Kinderhook, the Augusta and the Saint Louis, are well exposed. The Mississippian rocks have heretofore been most extensively studied along the river from which the series takes its name, and the typical outcrops of the major as well as the minor divisions are found along its banks. There are few points in Iowa at least, where the whole series may be found at a distance from the main river. The rocks of Washington county form an independent section which might be called the Central Iowa section of the Mississippian. It is of considerable interest to find how closely this section may be correlated with that previously studied.

The Washington county section of the Mississippian series has been studied from an independent standpoint, and the results reached are not due to simply tracing into the area formations already recognized in the southeast. Rather, such correlation as has yet been attempted, has been made by working in the contrary direction and the general agreement arrived at is therefore the more interesting and valuable.

KINDERHOOK.

The beds of this formation which are exposed within this county, and which here form a stratigraphic unit, are well shown in the Maple Mill section previously given. The exposures are entirely confined to English river and its tributaries with the exception of one or two small outcrops on Goose creek and Whisky run.

The members of the section exposed at Maple Mill may be recognized at several points farther up the river. On the opposite side of the river at the head of the big bend (Tp. 77 N., R. VIII W., Sec. 6, Sw. qr.) the limestone forming the upper member (No. 4) of the Maple mill section has been quarried. The old opening shows the following.

		FEET.	INCHES.
10.	Limestone, earthy, arenaceous, red, fossiliferous		12
9	Chert, in thin layers from 2 to 4 inches thick; very fossiliferous		4

		FEET.	INCHES.
8.	Limestone, as above	10	
7.	Chert, as above		3
6.	Limestone, as above	1	6
4.	Limestone, as above	2	6
3.	Chert, as above		2
2.	Limestone, as above	4	
1.	Unexposed to water	4	

The above section is typical of this portion of the Kinderhook. The lower beds are not seen here, though they are imperfectly exposed on the opposite side of the river at the Wassonville mill (Tp. 77 N., R. IX W., Sec. 12, Se. qr.). Worthen's section of this point is as follows.*

		FEET.	INCHES.
5.	Slope with outcropping masses of quartzose sandstone	6	
4.	Burlington limestone	3	4
3.	Massive, brown, arenaceous, limestone	2	
2.	Ash-colored gritstone	2	2
1.	Buff-colored gritstone	6	6

The lower portion of this section is now largely covered, but enough can be seen to prove the presence of the gritstone, which corresponds to number 3 of the Maple mill section. At the latter place the two beds (numbers 3 and 4) are not sharply separated, but seem to merge slightly along the line of contact. It is of interest to note that at Wassonville a blue argillaceous shale, similar to number 1 of the Maple Mill section, at one point occurs interbedded with the limestone. In general the massive brown limestone is similar to that in the section on the opposite side of the river already given. The presence and thickness of the chert layers is the same. The thickness of this bed as exposed at the mill is considerably less than Worthen's estimate; not more than twenty-four feet being exposed. The Burlington limestone is not seen at the mill but is exposed in some quarries farther back on the ridge. A careful search has failed to reveal the coal measure sandstone, though at one point a huge boulder,

*Op. cit., p. 245.

lithologically identical with the sandstone seen at Leib's mine and elsewhere, was found. Further up the river the Kinderhook appears from beneath the drift at two points, both on the north side of the river (Tp. 77 N., R. IX W., Sec. 1, Sw. qr., and Sec. 3, Ne. qr.). On the south side it may be traced nearly a mile.

Near Wellman, in the valley of Smith creek, and twenty-four feet higher than English river at Wassonville, the Augusta is exposed. At one point west of town (Tp. 77 N., R. IX W., Sec. 24, Nw. qr.) the Kinderhook was struck in a well, at a depth of eighty-five feet. Southeast of Wellman the creek soon cuts through the Augusta into the Kinderhook. In section 19 (Tp. 77 N., R. VIII W.) the latter was encountered in the base of a quarry on a level with the stream.

In the old Burlington, Cedar Rapids & Northern railway quarry (Tp. 77 N., R. VIII W., Sec. 16) the limestone layers as exposed are twenty feet thick, with the base twenty feet above the bridge on Smith creek. The stone is of the usual earthy magnesian character and runs in ledges two to four feet thick, separated by thin layers of chert. The Augusta is reported to occur immediately above the top of the quarry, though it is not now exposed.

On the river, south of Kalona (Tp. 77 N., R. VII W., Sec. 16), there is an interesting Kinderhook exposure. Near the river the lower shale member (Number 1 of the Maple mill section) is exposed with a thickness of twelve feet. In a small tributary stream a half mile back from the river the following is seen.

		FEET.	INCHES.
5.	Limestone, earthy, soft, reddish-yellow	4	
4.	Chert		4
3.	Limestone, as above	1	4
2.	Limestone, as above	1	8
1.	Limestone, softer, shaly	4	

The beds seen here seem to lie immediately beneath the drift over a considerable portion of Highland township, out cropping at several points along the streams (sections 21,

33 and 34.) The heavy drift accumulations prevent exposures along Iowa river and the lower part of Davis creek.

An examination of the preceding sections shows that we have here three different beds, or series of beds, which are referred to the Kinderhook. They are from the top downward:

(1) Wassonville limestone:—An earthy magnesian limestone in places becoming arenaceous, itself fossiliferous, and with thin chert bands also containing fossils.

FIG. 11. Wassonville limestone on English river opposite Wassonville mill.

(2) English river gritstone:—A fine-grained sandstone, or gritstone to use Worthen's name, also well characterized by fossils. This bed, at all observed points, merges into the bed above lithologically, though it is quite distinct within a few feet of the contact. The gritstone is thickest toward the west and northwest and thins out, finally disappearing, towards the southeast.

(3) Maple mill shale:—A bed of argillaceous shale which is at one point sharply separated from the gritstones above, while at others it is interbedded with them. The shale itself is non-fossiliferous, and its base is not exposed. In the

Washington well a shale very closely resembling this was penetrated at a depth of 350 feet to 432 feet. At 458 feet a light-colored magnesian limestone was encountered containing the typical Devonian fossils *Atrypa reticularis* Lin., and *Athyris vittata* Hall*.

The Wassonville limestone and the English river gritstone are both fossiliferous. In the gritstone the fossils occur as molds and, while numerous, are badly preserved so that identification is difficult if not impossible. A collection made at the typical locality, the Maple mill northwest of Wellman, included the following forms as determined by Professor Calvin.

Allorisma, Sp.
Aviculopecten, Sp.
Bellerophon bilabiatus Wh. & Whf.
Chonetes fischeri N. & P.
Chonetes, Sp. nov.
Edmondia, Sp.
Othothetes inequalis Hall.
Orthis, Sp.
Orthoceras heterocinctus Winchell(?).
Productus burlingtonensis Hall.
Productus concentricus Hall.
Rhynchonella opposita Wh. & Whf.
Rynchonella pustulosa White.
Spirifera, Sp.
Straparollus, Sp.
Terebratula, Sp.

The Aviculopecten is the of type *A. fasciculatus* Keyes, but is a different species. The Orthis is closely related to *O. impressa* Hall. The Spirifer is doubtless the ancestral form of *S. grimesi* Hall. There are two species of Straparollus.

The Maple mill shale has, within the limits of this county, proven to be non-fossiliferous, and its age must be determined

*Calvin, Op. cit., p. 29.

by its relation to the other beds. It is significant that near Kalona it is found interbedded with the gritstone, the latter containing the same species of fossils that are found at the typical exposure of the English river gritstone, and that at Wassonville a thin bed of gritstone strata is at one point interbedded with the limestone.

The beds which, in southeastern Iowa, are now referred to the Kinderhook, were first studied by Owen. By him and his immediate successors they were recognized as of Carboniferous age. Later, in deference to the published opinion of Prof. James Hall, they were referred to the Devonian, and were correlated with the Chemung. It was in accordance with this idea that Worthen referred the Wassonville section to the Chemung*.

Later Meek and Worthen† proposed the name Kinderhook to include all the strata lying between the Burlington limestone and the black slate of the Devonian, and called attention to the Carboniferous affinities of the beds. Among the localities given by them as typical for the new formation was Burlington.

The rocks found at this point which are referred to the Kinderhook are described by Keyes‡ as follows.

		FEET.
6.	Rather soft, buff limestone, probably somewhat magnesian, apparently sandy locally	5
5	Gray oölite	4
4.	Soft, fine-grained, yellow sandstone; highly fossiliferous	6
3.	Gray, impure limestone, fragmentary, with often an oölitic band below	9 to 13
2.	Soft, fine-grained bluish or yellowish clayey sandstone passing into sandy shales in places	20 to 30
1.	Blue clay shale, fossiliferous, shown by borings to extend 50 to 100 feet or more below the water level; exposed	50

* Op. cit., 245.

Am. Jour. Sci., (2), Vol. XXXII, p. 238. 1861.

Bul. Geol. Sec. Am., Vol. III, p. 285. 1892.

The Kinderhook, as found at Burlington, has been traced along the foot of the Mississippi escarpment to the northern edge of Des Moines county. About two and a half miles north of Huron (Tp. 72 N., R. II W., Sec. 22, Se. qr., Nw. ¼), it is exposed as follows.*

		FEET.
2.	Sandstone, friable, argillaceous	20
1.	Shale, blue, reported from well	4

In Louisa county the Kinderhook may be traced along the bluffs, being exposed north of Morning Sun at several points on Otter creek. It is here a massive, arenaceous, soft, earthy limestone, of brownish-yellow color and is underlain by the usual blue shales. These exposures have not been directly traced to the Washington county outcrops, but the presence of Burlington limestone on Long creek, southwest of Columbus City, renders it probable that the brief intervening gap may be bridged. There can, however, be no doubt as to the equivalency of the two sections.

The upper members of the Maple mill section (numbers 3 and 4) may be considered as the equivalents of all the layers above the blue shale at Burlington (numbers 2–6) referred to the Kinderhook. Worthen considered the magnesian limestone at Wassonville (No. 4) as the equivalent of the oölitic layers. The English river gritstone occupies the same relative position as the yellow sand layer (number 2) at Burlington, and the fauna shows close affinities. Number 2 of the Maple mill section is of local occurrence only. The shale at both points is undoubtedly the same. Number 6 of the Burlington section has been correlated† with the Chouteau limestone of Missouri, and numbers 2 to 5 are considered to represent the buff sandy shale exposed immediately below the Chouteau at Louisiana, Missouri, and forming the upper portion of the Hannibal shales (Vermicular shales and sandstones of Swallow). The blue shale at the base of the Burlington section represents the green shale at the base of the Hannibal shales as seen at Louisiana, Missouri.

*Geology of Des Moines county, Iowa Geol. Surv., Vol. III, p. 425. Des Moines, 1895.
†Keyes: Bul. Geol. Soc. Am., Vol. III, pp. 285-286. Rochester, 1892.

The exact thickness of the lower bed (Maple mill shale) is unknown. There is in Washington county a maximum exposed thickness of about forty feet. At Burlington borings have shown it to have a thickness of at least 160 feet. In the deep well at Sigourney 229 feet of shale, which may be referred to this horizon, were penetrated. A comparison of the levels of the outcrops on English river with the base as revealed in the Washington well, allowing for a slight southerly dip, gives a thickness of at least 200 feet.

An interesting question arises as to the base of this lower member. The exact relations between the Carboniferous and Devonian have not been definitely determined in Iowa. Meek and Worthen in defining the Kinderhook included all the strata between the Burlington limestone and the black shale which has been found at many points in the Mississippi valley and which frequently contains Devonian forms. This shale does not occur in Iowa, unless the Lime creek shale described by Calvin be its representative. Instead we have at the base of the Kinderhook a heavy shale which in Missouri is underlain by a third member, the Louisiana or lithographic limestone. The Louisiana limestone is supposed to be of Kinderhook age, though evidence has recently been produced* suggesting that it may be Devonian. In the Washington well the shales recognized as Kinderhook were found resting directly upon limestone from which typical Devonian forms were obtained. The Devonian outcrops nearest to the Kinderhook shales of Washington county are found in the vicinity of Iowa City and Muscatine. The intervening territory is heavily drift covered so that the exact relations can not be observed. It is possibly significant that the country between the mouth of English river and the Muscatine outcrops is a low level bottom land and represents exactly the lateral enlargement in the Mississippi channel which would take place during a long period of erosion where the country rock was a soft shale. There is no topographic

*Keyes: American Geologist, vol. X. pp. 300-384. 1892.

indication of any hard beds intervening between the shale and the Cedar Valley limestones of the Devonian. While the different members of the Devonian have not yet been definitely differentiated for the whole state, making it difficult to say just what is its uppermost limit, the Lime creek shale constitutes the highest member known. Apparently then we have on the one hand at the top of the Devonian a series of shales containing Devonian forms, and on the other hand at the base of the Carboniferous an exactly similar shale interbedded at the top with gritstones containing Kinderhook forms.

In Washington county the Maple mill shales have not been found to contain fossils. The beds at Burlington which may be correlated with it do, however, contain certain forms. Collections made at the Granite Brick works at Burlington by Mr. E. H. Lonsdale have been recently investigated and shown to include forms with Devonian affinities.

The sandstones of Muscatine county, which were at one time correlated with the yellow sand layer at Burlington, have been shown by Calvin to be of Devonian age, and it seems not improbable that ultimately a considerable portion of the beds now recognized as Kinderhook may be proven to be pre-Carboniferous. Some of the evidence at hand supports the belief that the shale at the top of the Devonian and that at the base of the Carboniferous is the same. The difference in the fossils in that case would be due to geographic causes. According to this view, while the Lime creek beds, which contain a prolific Devonian fauna, were being laid down, corresponding sediments were being deposited 120 miles away to the southeast. The conditions of life at the latter point seem not to have been favorable, and most of the fauna which wandered so far from the shore perished. The few which survived became modified in important regards. Among them is *Orthis iowensis* Hall var. which shows a marked change in the muscular scars. In time new Carboniferous forms

were introduced and in the succeeding deep sea deposits became supreme.

AUGUSTA.

In Washington county, as also in Keokuk county, the limestones composing the Augusta formation, and which elsewhere are known by individual names, are not separable. There are slight differences in lithology, more marked, however, between the exposures of Louisa and Washington counties

FIG. 12. Augusta limestone on Rock creek in Keokuk county.

than between any within the immediate limits of this county, and a few forms occur at some points which have not been found at others. The greater number of fossils found belong to the Burlington fauna, though a few Keokuk forms occur. The formation is however, as a whole, a distinct, well marked, stratigraphic unit for the region studied. It is neither advisable nor possible to divide it into formations which could be separately mapped. It underlies the county in a broad irregular band stretching from the northwest to the southeast as shown on the map. The area covered by the Augusta narrows somewhat towards the east. There is also an area toward

the northwest where the Augusta has been cut out by preglacial erosion and the Kinderhook is shown by well records to underlie the drift. This is also true of Washington. These areas are, however, too imperfectly known to be represented on the map.

The best exposures of the Augusta are seen on Crooked creek northwest of Washington. The Eckles quarry section at this point has already been given. Sections from the quarries in this vicinity exhibit two facies: (1) a hard, heavily bedded, light gray to brown, sub-crystalline limestone, with abundant Burlington fossils, and (2) a buff, sandy rock containing small calcite geodes. The main portion of the rock belongs to the first type.

Farther up the creek an imperfect exposure may be seen north of West Chester (Tp. 76 N., R. VIII W., Sec. 20, Sw. qr.) where the presence of layers similar to those just described is shown. In the region around Keota the limestone immediately underlies the drift and is usually encountered at a depth of about sixty feet. In the northern portion of Keokuk county the Augusta appears at one point on English river (Tp. 77 N., R. IX W., Sec. 16). In Washington county the most northwesterly outcrop is at the Whitstine quarry near Dayton (Tp. 77 N., R. IX W., Sec. 13, Ne. qr., Ne ¼). This is a small local quarry located on the ridge between English river and Smith creek. The following layers are shown.

		FEET.
3.	Limestone, buff arenaceous	5
2.	Limestone, brown, coarsely crystalline, fossiliferous	½
1.	Limestone, blue-gray, fine-grained, sub-crystalline, fossiliferous	4

The fossils found at this point are Burlington forms, and in character the layers agree closely with those found at the Eckles quarry.

Directly southeast of Wellman on Smith creek (Tp. 77 N., R. IX W., Sec. 24), similar layers are exposed in the bed of the creek and have been quarried locally. The buff,

arenaceous layer is here only one foot thick; the white or light drab layers beneath are seen at intervals down the stream to the old railway quarry (Tp. 77 N., R. IX W., Sec. 16), where, as already stated, they cap the Kinderhook with a thickness of about four inches. East from this point the Augusta has not been seen along English river. Exposures, however, occur four miles south of Riverside on Davis creek (Tp. 77 N., R. VI W., Sec. 31, Sw. qr., Se. ¼). The stone is seen at this point in Wingler's quarry; a small opening supplying the local stone trade. The rock is a white to light drab, coarsely crystalline, fossiliferous limestone, similar to that seen elsewhere in the county. Only one ledge is exposed. This has a thickness of 3½ to 4 feet and is covered by 20 feet of drift. The stone is exposed along the creek for a short distance only. About four miles still farther southeast similar stone is exposed on Goose creek (Tp. 76 N., R. VI W., Sec. 20).

On the ridge between Goose and Whiskey creeks the Augusta seems to have been eroded, and the Kinderhook immediately underlies the drift. Stone belonging to the Augusta formation is quarried in Louisa county at a number of points southwest of Columbus Junction on Long creek.

As has been said, the Augusta is in this county a stratigraphic unit. The divisions found elsewhere can not here be traced. The main portion of the stone shows a closer affinity with the Burlington layers, though there are beds which contain fossils suggestive of the Keokuk and the Warsaw.

The actual contact between the Augusta and the Kinderhook has been nowhere observed within the county, though such a contact was formerly exposed in the old railway quarry near Wellman. At one or two points on Smith creek yellow magnesian layers, answering in description to the Kinderhook, have been penetrated in taking Augusta stone from the bed of the creek. There seems to be no doubt that the coarse, crystalline limestone of the Augusta rests directly upon the earthy magnesian rock of the Kinderhook without transition beds. The upper limits of the Augusta are even more poorly

defined. On Crooked creek, between the outcrops of lowest Saint Louis and highest Augusta, a drift interval of nearly five miles intervenes, and there are no outcrops by which it may be bridged. As a result the line between these two formations can only be drawn on the map approximately and without detail.

SAINT LOUIS.

The rocks of the Saint Louis stage cover the southern and southwestern portions of the county. It will be seen from the Brighton section already given that they are composed of limestones, brecciated beds, clay shales and sandstones. These different beds are shown more in detail in the following sections taken from a number of different points in the field.

A section on Crooked creek, three miles south of Washington, at the crossing of the Wayland road (Tp. 74 N., R. VII W., Sec. 5, Ne. qr.), gives the following.

		FEET.	INCHES.
6.	Drift	30	
5.	Shale, blue to green, calcareous	4	
4.	Limestone, earthy, brown		10
3.	Shale, similar to No. 5	3	
2.	Limestone, earthy brown as above	2	
1.	Shale, imperfectly exposed to water	4	

These beds may be correlated with the beds below No. 5 of the Brighton section. They may be traced up the stream something more than a mile, and are exposed, though not so perfectly, near the upper bridge (Tp. 75 N., R. VII W., Sec. 32, Sw. qr.). Down the stream they may be traced by frequent imperfect outcrops on both sides, showing the presence of similar stone, though not apparently continuous with the layers given, nearly two miles. At one point (Tp. 74 N., R. VII W., Sec. 4 ?), the shaly member is seen to be covered by the usual brecciated beds, imperfectly exposed and rising thirty-five feet above the stream. Around the big bend in the stream there are no exposures, the country being deeply covered with drift.

Almost directly south of the last mentioned exposure (Tp. 74 N., R. VIII W., Sec. 21, Nw. qr.) limestone is again found on Crooked creek. The exposure here shows:

		FEET.
2.	Shale, arenaceous, with thin bands of earthy limestone	12
1.	Limestone, heavily bedded, dark blue, fossiliferous; to water	4

A mile or more farther down the stream is the following.

		FEET.
1.	Shale, blue, clayey and arenaceous; exposed to water's edge	12

About half a mile east of Coppack, in a cut on the Burlington & Western railway, the following section is exposed.

		FEET.
4.	Shale, arenaceous, with interbedded sandy limestone layers 2 to 4 inches thick, showing slight, irregular deformations	8
3.	Shale, arenaceous, green	12
2.	Limestone, soft, earthy, red	1
1.	Limestone, soft, earthy red; to track	2

The base of this section is about fifteen feet above Crooked creek, the interval not being well exposed but apparently being made up of beds similar to number 4 of the above section. A quarter of a mile up the stream these beds are seen to be covered by four to five feet of limestone, similar to that occurring in the brecciated beds, and with thin layers of oölitic material interbedded.

With the exception of the limestone just mentioned, all the beds of these sections belong to the lower portion of the Saint Louis and are below number 5 of the Brighton section.

In the hill above the Coppack mill the beds of the brecciated division (Verdi) appear. South of Coppack both these beds and the lower division (Springvale) are exposed at intervals along the Skunk river. An excellent section* is exposed near the mouth of Crooked Creek (Tp. 73 N., R. VII W., Sec. 6, Nw. qr., Ne. $\frac{1}{4}$) in Henry county.

*Measured by Mr. Arthur C. Spencer.

		FEET.
4.	Loess	15
3.	Sandstone and limestone, irregularly alternating (Verdi beds)	25
2.	Shale, light blue, argillaceous (Springvale beds)	26
1.	Limestone, white, unfossiliferous; seen in bed of creek	6

Between Coppack and Brighton on the Skunk river there are numerous points at which the Saint Louis outcrops, but few good clear exposures occur because of the easy disintegration of the beds. Near a spring in section 27 (Tp. 74 N., R. VIII W.) a blue calcareous shale is seen at the head of a bend in the river. Only a foot or two is exposed, lying about ten feet above the water. Above the shale are four feet of thin-bedded fine-grained limestone over which lie sixteen feet of impefectly exposed limerock and sandstone. The former is earthy and of a brown color. Fenestella and other obscure fossils occur in blocks of limestone in the talus. The shale, and possibly a portion of the beds above, apparently represent the Springvale beds, while the higher beds probably belong to the Verdi.

A somewhat similar, though better exposed section occurs about a mile farther up the stream (Tp. 74 N., R. VIII W., Sec. 28, Nw. qr., Nw. ¼).

		FEET.
2.	Slope, talus of brecciated limestone and sandstone	10
1.	Shale, blue, argillaceous, non-fossiliferous; to water	12

Between the Brighton mill and the west county line, limestone crops out at a number of points on Skunk river and its branches, but few good exposures are found. The following section is one of the best. (Tp. 74 N., R. IX W., Sec. 9, Sw. qr.).

		FEET.
5.	Drift	15
4.	Limestone, hard, black, nodular	2
3.	Shale, blue, calcareous	4
2.	Limestone, hard, black, nodular	2
1.	Shale, blue, calcareous; to water	10

The entire section may be referred to the Springvale beds. The same beds are again seen above the wagon bridge in section 9 (Tp. 74., R. IX W.) where the usual shaly beds are exposed for a thickness of twenty feet above the water.

About five miles north of Brighton, near Verdi station, the middle member of the Saint Louis is excellently exposed. As seen here in an old railway quarry, it is made up of very irregularly interbedded limestone and sandstone. The limestone is the usual fine-grained, ash-colored, compact variety

FIG. 13. Irregular beds of limestone in the Saint Louis; Verdi quarry.

found in the upper layers. In parts of the quarry the brecciated phase of the rock is particularly well developed. The sandstone bands are as much as five feet thick and are in part fine-grained and white, while in part, particularly in a bed at the top of the quarry, they are coarse and red. The quarry abounds with apparent unconformities. The sandstone rapidly thickens and thins and contains great blocks of the limestone, occasionally as much as four feet long and six inches

thick, standing at various angles, some as high as 30 degrees, such as is shown in figure 14.

Since the origin of the brecciation in these beds is a matter not yet fully explained, it is of interest to note that at this locality all the phenomena seen are exactly similar to what is found now at the base of any high cliff on a sea shore.

In Washington and the neighboring counties the Saint Louis has been differentiated into three members called the

FIG. 14. Limestone block resting on sandstone bands; Verdi quarry.

Springvale, Verdi and Pella beds. All three members of this series of beds occur in Washington county.

The Springvale beds derive their name from the exposures near the old Springvale mill south of Delta in Keokuk county, and form the lowest member of the formation. In Washington they are most typically shown in the exposure on Crooked creek at the crossing of the Wayland road in the section already given. Their lithological character is well shown in the various sections which have already been referred to

them. It is noticeable that in this county the shaly character becomes the more prominent, while to the west the division is more generally represented by brown, earthy limestones. The maximum thickness is usually in the neighborhood of twenty-five feet. Where the base can be seen the beds invariably rest directly upon the coarse, crystalline limestone of the Augusta.

The Springvale beds cover the entire southern portion of the county. In the middle eastern portion a few feet of thin yellowish limestone is frequently encountered in drilling wells. This is never of any great thickness and immediately overlies the heavy limestones of the Augusta. On Long creek near Ainsworth there has been quarried on a small scale a stone which greatly resembles the Springvale beds and not improbably represents an outlier. The beds are usually non-fossiliferous; the few forms which have been found are imperfectly preserved and are valueless for purposes of correlation. The determination of the age of the beds in this region must for the present rest upon their stratigraphic position alone. The lowest portion of the formation as seen at Brighton was referred by Worthen to the "Argillaceous marlites of the Geode bed"* and the layers above were correlated with the magnesian portion of the formation as exposed elsewhere. The only fossil noted by him was *Lithostrotion canadense* Cast., though it is not quite clear from which layer it was collected, nor does it appear upon just what decisive evidence his correlation was based.

Gordon has recently traced throughout southeastern Iowa a bed apparently occupying the same stratigraphic position as the Springvale, and strikingly like it in lithological character. This formation he has called the Arenaceo-magnesian bed* and it is characterized by the abundant presence of *Lithostrotion canadense*. The affinities of the Arenaceo-magnesian bed seem to be with the Saint Louis and to that

*Op. cit., 243.

*Geology of Van Buren county, Iowa Geol. Surv., vol. IV, p. 215, 1895.

formation it is referred. It seems probable that the Springvale beds may be correlated with the Arenaceo-magnesian bed, though careful search has failed to reveal at any point the characteric fossil.

The only fossils which so far have been collected from the Springvale bed came from limestones in the bed of the river at the Brighton mill, and in the bluff at the spring mentioned above as located some distance farther down the river. Apparently the fossil-bearing limestone at the mill was not exposed at the time of Worthen's visit.

None of the forms found are sufficiently clear to allow a definite correlation to be based upon them. The close relation existing between the shale found along the Skunk river, in Washington county, and the arenaceous earthy limestone more generally present at the same horizon in Keokuk county, is in this region apparent. On Crooked creek, south of Washington, they are interbedded. In Keokuk county they pass by lateral transition into each other; everywhere it is evident that they belong together and are simply phases of a variable sedimentation.

This series of beds seems, in this immediate region, to be intimately related to the Saint Louis, and to that formation they have been referred, while the possibility is recognized that ultimately it may be necessary to refer them in part to lower formations. In accordance with the usage of the survey, they have been given a local name, Springvale, for immediate purposes.

The Verdi beds lie immediately above the Springvale. Their character is sufficiently shown by the sections described and is particularly well exhibited in the old Verdi quarries from which they are named. It has been customary where this middle member of the Saint Louis has been differentiated to refer to it as the brecciated beds. The name does not seem applicable for the reason that, while the brecciated beds occur in this formation they are only one phase of it. In the counties lying farther west of Washington, the outcrops

are more frequently of alternating layers of sandstone and limestone, as seen at Atwood and many other points in Keokuk and Mahaska counties. The sandstones often become very important. At points in southeastern Mahaska county single beds are twenty-five to thirty feet thick. The brecciation, while usually present, is not always found, and at many points, well-bedded limestones of considerable thickness ocur.

The Verdi contains the record of a time of considerable disturbance. Shore formations and open sea deposits succeed each other in rapid alternation. Huge blocks of the previously-formed limestone were torn from their beds and buried in the sands, apparently at the foot of a series of cliffs; or they were beaten upon each other and reduced, in part, to fragments of varying degrees of coarseness, and in part to finest powder that eventually cemented the fragments together. Considering the turbulent conditions under which the beds were formed, it is not strange that fossils are rare. Such as occur are found usually in the limestone and are the brachiopods and kindred forms which become so prominent in the succeeding quieter times when the Pella beds were deposited. The reference of the brecciation in the formation to coral-reef structure is untenable by reason of the practical absence of corals in the region studied. The very few specimens collected from these beds were found in the compact limestone and belong to species which are most abundant in the succeeding strata where there are no signs of brecciation. Furthermore, they are not reef-forming species.

The Pella beds form the upper member of the Saint Louis, and are marine deposits made in the quiet waters succeeding the stormy Verdi. They have only been preserved from erosion in the immediate neighborhood of Brighton, in the bottom of what is probably a broad, shallow synclinal. They are well represented in the quarries, and the stone taken out here comes from these beds. As elsewhere, they consist of compact, fine-grained, ash-colored limestone, breaking with a

distinct conchoidal fracture, and lying in ledges separated by thin beds of clay marl completely filled with fossils. The stone is itself fossiliferous, but only sparingly so as compared with the interbedded clays. The fauna found is not so noticeable for the large number of species as for the abundance of individuals.

UPPER CARBONIFEROUS.

The beds of the Upper Carboniferous series occupy but a small portion of the county and belong entirely to the lower division or Des Moines formation.

DES MOINES.

The deposits of this stage within the county occur in the form of small outliers. The only one which has yielded coal to any extent is about one mile west of Verdi. A section of the strata here, as exposed at the time of Worthen's visit, has already been given. A quartzose ferruginous sandstone, red to yellow in color, is found on Goose creek (Tp. 76 N., R. VII W., Sec. 21), lying above the Kinderhook. It is probably of Des Moines age. A similar stone is found on Davis creek over the Augusta.

On Whiskey Run (Tp. 76 N., R. VI W., Sec. 34, Ne. qr.), a thin coal seam occurs and was at one time mined a little. It varied in thickness between six and twenty-two inches; it was covered only by drift and apparently rested on clay. In some of the wells near here a sandstone similar to that on Goose creek has been encountered, though it apparently does not occur at the old mine workings. A similar sandstone has been reported as occurring near Wassonville, and clay shales similar to the "slate" of the coal regions have been reported from Clay township about two and one-half miles west of Brighton.

It must be remembered that this region suffered profound erosion both previous to the deposition of the coal measures and during later periods. The first erosion trenched the surface deeply and prepared a series of basins for the

subsequent deposition of the coal. Later the coal measures were cut away except only in the most favored of these previously formed basins. It may even perhaps be doubted if the coal-bearing strata ever covered the whole of Washington county. Certain it is that they now cover only a very small fraction of the territory. Whether this is altogether the expression of the profound erosion to which they have been subjected, or whether it is in part the expression of the original conditions of deposition is not known. There are some reasons for the belief that the outliers between the main portion of the Iowa and Illinois field were developed in small independent basins.

PLEISTOCENE.

The Pleistocene deposits of Washington county include the Kansan drift, the loess, certain stratified gravels and sands, and the modern alluvial deposits. Together they form a mantle of unconsolidated beds which spread over and very largely conceal the indurated rocks. The thickness of this mantle varies from nothing to as much as 350 feet. The minimum is found only along lines of present drainage, while the maximum marks lines of former stream action. Over the smooth, upland drift plains the depth to rock is not always the same. Near Keota it is usually about sixty feet, this, seemingly, being less than usual. Near Wellman rock has been encountered at a depth of about eighty-five feet. The drift covering the plain around Wyman has been penetrated by numerous wells. Usually the rock is encountered at a depth of seventy-five to 100 feet. The Edward Umphrey well, on a level with the railway station, is 120 feet deep, with 100 feet to rock. The Uriah Beachman well, west of town, is 180 feet deep, with 100 feet to rock. Near Havre the drift is sixty-five feet thick. Northeast of Washington, within the limits of the Washington channel, the drift is more than 300 feet thick. Near Crawfordsville a well 70 feet deep failed to reach the indurated rocks.

KANSAN DRIFT SHEET.

The drift plains of the county are covered by a very few feet, two to six, of "overwash" loess-like material. Below this are the heavy till beds of the Kansan drift. There are here, as elsewhere, two phases of dirt. The upper is excellently shown on Williams creek, on the north side of the stream, at Wayland crossing. It is a deep, reddish-brown color, and contains numerous pebbles including large quantities of local material. The rocks are very frequently subangular and planed. A large proportion are striated. Granitic types are common, though greenstones are not infrequent. All of the material, with the exception of local chert pebbles from the Augusta, is badly weathered. Large boulders are not present. The only noticeable exception is a light-gray granitic boulder, two and a half feet in diameter, lying at the foot of the hill.

North of this exposure between Wayland crossing and Washington, the streams have frequently cut into the drift. It is quite uniformly of the character just described; at some points the color is a bright yellow beneath the reddish-brown. At one point (Tp. 74 N., R. VII W., Sec. 27, Ne. qr.), small lime concretions were found in the till; at the same point the underlying blue clay in a weathered condition is exposed.

South of Riverside on Goose creek (Tp. 77 N., R. VI W., Sec. 35), the blue clay is shown in a much fresher condition; it is here sharply separated from the yellow clay as shown in the following section:

		FEET.
3.	Sand, coarse, yellow, alternating with fine gravel	25
2.	Yellow clay with pebbles	½
1.	Blue clay, plastic, few small pebbles	12

The contact between the two clays is here marked by a row of springs. The presence of the heavier blue clay throughout the county is attested by well borings, though the clay is not frequently seen at least in a fresh condition in

exposures. Its relation to the yellow clay can not be definitely stated further than that it is always beneath, and shows considerable difference in the variety and character of the contained pebbles. The two clays evidently represent quite different conditions of deposition, but it does not seem clear that they must be referred to two separate ice sheets.

No well defined forest bed which can be traced from point to point has been found. In the Washington well pieces of wood and twigs of trees were encountered at a depth of 115 feet. Among the remains were a few small cones of the spruce *Abies nigra*. The significance of these facts, however, as indicating a well defined forest bed, is impaired by the fact that the Washington well did not go through the normal undisturbed drift sheets, but rather encountered an unusual phase of the drift.

Above the yellow clay at the Goose creek exposure is a series of stratified sands and gravels. Similar beds were at one time exposed in a stripping at Brighton. Here they rested directly upon the limestones and were covered, apparently unconformably as shown in figure 15, by loess-like material. The age of these sand beds is open to doubt.

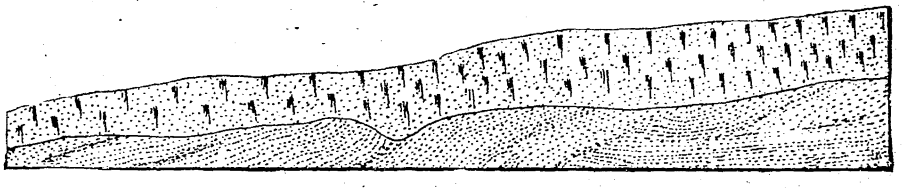


FIG. 15. Sub-loessial sands; Washington.

The loess-like material found at Brighton is of no great thickness, and apparently merges above into black soil and below into pebbly clay. It should probably be looked upon as of different origin from the more typical loess found in other parts of the state. In the Martin quarry a section of the drift deposits shows the following phases.

		FEET.
5.	Soil, black, fine	½
4.	Clay, gray, loessial	2 to 2½

		FEET.
3.	Clay, yellow and gray irregularly mingled, sandy in part; small pebbles throughout, upper and lower limits more distinctly gravelly; larger erratics more frequent at the base	14
	Unconformity.	
2.	Clay, purple to brown, full of Saint Louis fossils and limestone blocks	1 to 3
1.	Limestones, Saint Louis	4+

The clay found here immediately above the limestone is very similar to the clays and marls found in the upper layers of the Saint Louis upon which it rests. It has, however, a much darker color, and may, perhaps, be not improperly considered as being to a certain extent residuary in origin. It cannot be of glacial origin since it never contains foreign pebbles, and under it the limestone shows no marks of glaciation, though where it is absent such marks are found. The pebbly clay lying above it represents well the general character of the yellow clay. It shows a more or less complete merging into the loess clay above.

Glacial striæ have been noted at two points in the county. The first of these is at Brighton, where they appear upon the upper surface of the Saint Louis limestone. The striations are frequently half an inch deep and ten feet or more long. They take the directions (corrected) south 4° east and south 6° east. One shorter irregular groove varied from south 6° west to south 4° east. It was not so well marked as the others. The planing action of the ice is even better shown in the Eckel's quarry on Crooked creek, where, in 1894, a surface was exposed showing characteristic ice planing. The direction of the ice planing at this point was south 67° east (magnetic).

THE LOESS.

While the true nature of the loess-like material occurring at Brighton is open to some doubt, there are many exposures in the county which show material which can be definitely correlated with the loess of the counties farther north. Indeed the loess of Johnson county may be directly traced

from the thick fossil-bearing beds at Iowa City south into Washington county. Along English river and indeed over the greater portion of the county the loess is normally found veneering the earth forms cut into the drift before its deposition.

The loess of Washington and neighboring counties shows important differences from the loess of the Missouri river. It is not porous, but rather the opposite. It does not stand long in vertical faces, but crumbles readily; it is stiffer, more plastic, freer from lime concretions, and while better adapted for use in the clay industry, is not so good a soil material. It apparently bears definite relations to the Iowan ice of Johnson county and probably represents fine water-laid material washed out from the front of the ice. It is not improbable that it has been in some regards modified since laid down, and because of this possibility and on account of the wide difference between it and more typical loess deposits it has been previously spoken of as the "altered loess," a name which is perhaps not strictly applicable on account of implying too much.

THE ALLUVIUM.

Alluvial deposits have been developed along the major and most of the minor streams. They are of the usual black loam character and resemble in appearance the black soil of the drift plains.

Geological Structure.

The general geological structure of the county is simple. The rocks have a slight prevailing dip to the southwest, and have been practically undisturbed. No regular series of anticlinals, similar to those traced in neighboring counties, has been found. With the exception of one very broad, shallow synclinal the rocks follow the prevailing dip. There are, however, two great erosion unconformities and one overlap known. The latter exhibits no marked signs of unconformity.

CROSS SECTIONS.

Skunk River Section. (Plate iii, figure 1.)—The section along the Skunk river is valuable in showing the general absence of all undulations in the strata. A short distance west of the county line the Augusta is exposed above the river at Manhattan mill, a thickness of forty feet being shown. These beds do not, however, appear at any point along the Skunk river in Washington county, though the lowest member of the Saint Louis is exposed along the entire distance, and the Augusta can not be very far below the level of the water. Brighton lies in the base of a very broad and very shallow synclinal to which fact may probably be due the preservation there of the Pella beds, while the underlying Verdi forms the surface exposures over so much of the county both west and north. The preservation of these beds is also largely due to the local thinning of the Verdi, allowing the Pella to be deposited at a level considerably below its outcrops elsewhere.

Cotters to Keota. (Plate iii, figure 2.)—A section made along the line of the Chicago, Rock Island & Pacific railway, from Cotters to Keota, shows excellently the variation in the topography produced by stream action. The abruptness of the change from upland to stream bed is greatly disguised, since the railway necessarily follows the easiest grade. That the upland forms one general plain is, however, evident. The level country from Keota west to Crooked creek, is indicative of the small amount of erosion accomplished by the tributaries of that stream since, for the greater part of the distance, the railway is within a mile of the main stream.

Brighton to Washington. (Plate iii, figure 3.)—On the line from Brighton to Washington the deep channels of the Skunk river and Crooked creek are crossed as well as the high lands between these streams.

English River Section. (Plate iii, figure 4.)—The best east and west section across the county is exhibited by the exposures along English river. This does not, however, show

very well the dip of the strata as it runs at only a slight angle with the strike. South of Riverside the Maple mill shale of the Kinderhook is seen to be covered by the Wassonville limestone. At Kalona, the English river gritstones begin to intervene. At Maple mill they attain their maximum thickness. At Wassonville they have thinned and largely passed beneath the river, while the Augusta appears over the Kinderhook. Two miles west the strata are cut out, and there intervenes a broad, deep valley filled in with drift. Some distance beyond, the Augusta again appears.

EXPLANATION OF PLATE III.

Geological cross-sections in Washington county.

Figure 1. Skunk river section (a-b).
Figure 2. Cotters to Keota (c-d).
Figure 3. Brighton to Washington (e-f).
Figure 4. English river section (g-h).
The numbers refer to the formations as follows:

- Drift 8
- Saint Louis—
  - Pella beds 7
  - Verdi beds 6
  - Springvale beds 5
- Augusta 4
- Kinderhook—
  - Wassonville limestone 3
  - English river gritstones 2
  - Maple mill shales 1

DEFORMATIONS.

No deformations of any importance occur within the county. The series of small parallel undulations which are so well developed in Keokuk county, and which show traces in Mahaska county, can not be recognized in this area. This is more interesting as the series show a gradually increasing intensity toward the east. Apparently the culmination was reached in the Manhattan anticlinal.

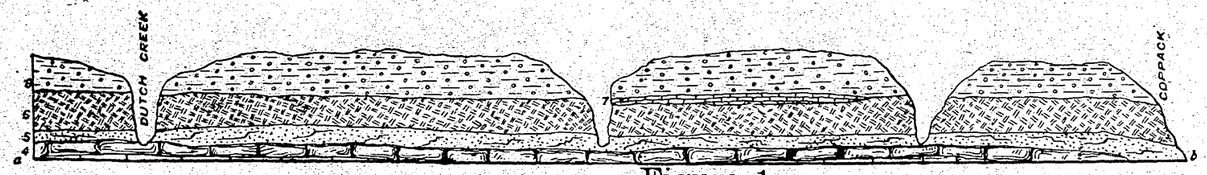
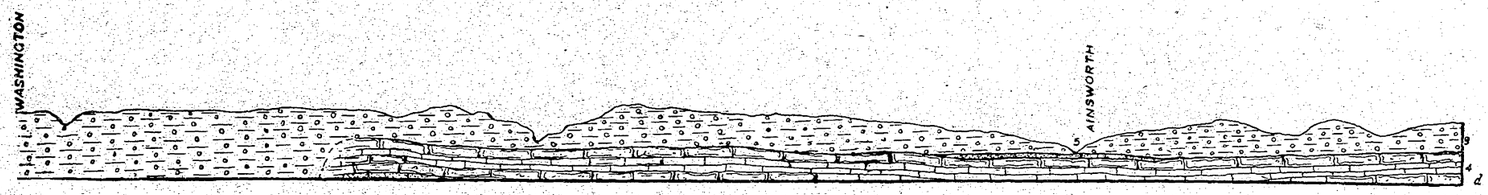


Figure 1



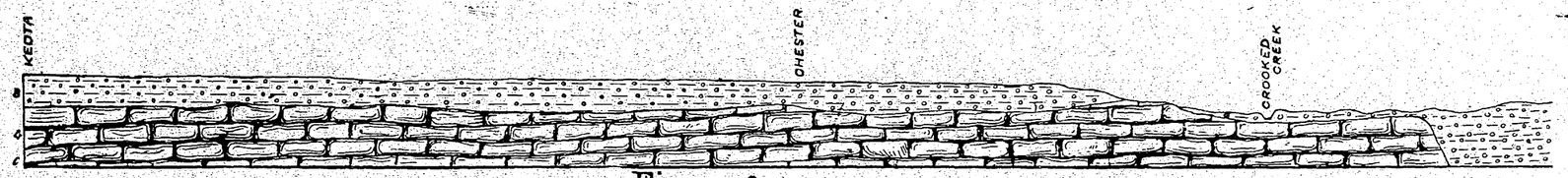


Figure 2

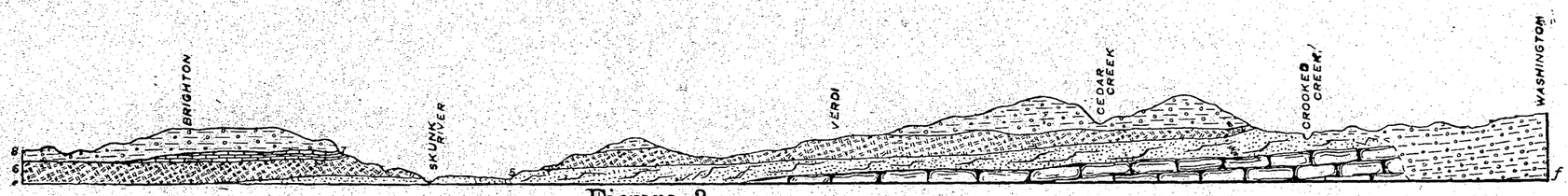


Figure 3

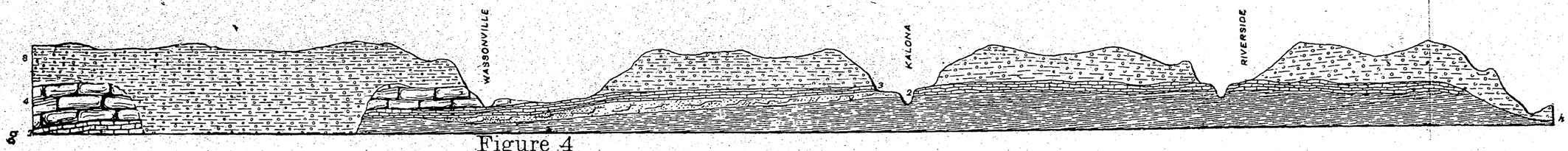
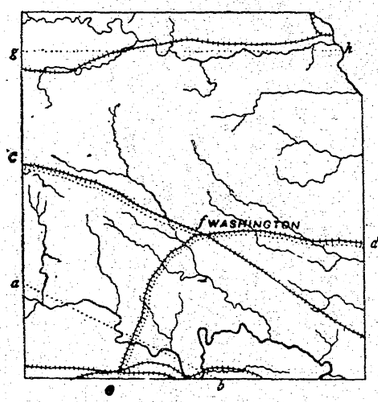


Figure 4



Vert. 100 FEET

Scale

Hor. 1 MILE

GEOLOGICAL CROSS-SECTIONS IN WASHINGTON COUNTY.

UNCONFORMITIES.

UNCONFORMITY BETWEEN DRIFT AND INDURATED ROCKS.

The general unconformity between the indurated rocks and overlying unconsolidated beds is particularly well shown in this county. Just what had been accomplished by the preglacial streams in their efforts to base level the country is not definitely known. A reasonably even surface of rock seems to underlie the drift at a present elevation of 700 feet. At Keota it is 743 feet which seems higher than usual. If, however, such a surface at one time obtained there is abundant evidence that at some time preceding the ice age, probably but a short time before, it was elevated and attacked by vigorous erosion. Calvin in 1888 called attention to the remarkable thickness of drift at Washington and interpreted it as evidence of a preglacial channel. The drift here is 350 feet thick, and the channel in which it lies is cut down nearly through the Kinderhook, or 285 feet below the nearest outcrop of limestone at Eckle's quarry on Crooked creek, and 324 feet below the higher limestone farther west. The width of this old valley, which has been called the Washington channel*, is not however known.

In the northwestern corner of the county similar evidence of profound erosion is found. The valley of English river here shows a remarkable expansion on its southern side. The river has built up a flood plain south of the river a mile and one-half wide for a distance of nearly six miles. On the south this plain is bounded by gently rounded hills of drift, such as are more common on the northern side of this stream elsewhere, rising sixty to seventy-five feet above the flood plain, or to an altitude slightly below 800 feet. At its eastern limit the plain is abruptly cut off by sharp-contoured hills of rock capped by drift. Similar phenomena are seen on the northern side of the river, but are not so noticeable, and the limits of the expansion in the valley appear a little west of that described. It was not a surprise to find here that

*Proc. Iowa Acad. Sci., vol. II, p. 23. Des Moines, 1895.

borings on the hills south of the river had failed to reach rock, though carried to depths of 170 to 212 feet, or more than 100 feet below the water level of the stream. There is an old channel here which has cut down at least 150 feet into the rock and probably much deeper. Near Deep River in Poweshiek county, northwest of this point, a channel has been located cutting 250 feet below the level of the adjacent rock.

Southeast from Washington evidence of this channel is again seen. It has been noted that on Crooked creek there are no exposures of rock close to the great bend north of Noble, while west of the bend the exposures begin to appear at about the same point on both the upper and lower courses. Near the bend the deepest borings carried on, some going to a depth of 200 feet, fail to strike rock, though carried much below the nearest outcrops and much below what can be fairly attributed to any filling in by the present stream.

In the counties still farther southeast there are traces of similar channels, but as yet the one found in Washington county has not been connected with them. The location of the Washington channel is approximately shown in the sketch map of the drainage of the country. (Figure 9.)

The depth of this ancient channel gives a measure of the amount of the elevation of this region preceding the ice period. It has been exactly measured at Washington only, where the stream had cut down to 419 feet above present sea level. The exact figures at Deep River are not known, but they evidently agree quite closely with these. In Des Moines county, near Kossuth, a buried channel has been encountered which was believed to have cut down to 274 A. T. More recent evidence renders it probable that these figures may not be quite reliable.

It has been shown by Gordon* that, preceding the ice invasion, the Mississippi had cut down to about 350 feet above sea level in the region near Keota. Into that river the stream

*Iowa Geol. Survey, vol. III, p. 248. 1895.

following the Washington channel probably flowed. The small amount of fall which it must have had between these points accords well with the equally slight grade between Deep River and Washington, and indicates that the stream, when it was overwhelmed and buried, was engaged in widening its channel. This agrees well with the surface indications of a considerable width near Wellman, though there is some reason for believing that near Deep River the valley could not have been wide. A glance at the sketch map will show that the present drainage has no close connection with this ancient system. English river flows directly across it while Crooked creek, after reaching its former channel, turns abruptly aside and attacks the hard ledges of the Saint Louis.

UNCONFORMITY BETWEEN THE DES MOINES AND SAINT LOUIS STAGES.

The unconformity between the coal measures and the underlying rocks, which has such weighty economic import in the counties to the west, loses here its significance. The general absence of the coal measures is due, perhaps, most largely to the vigorous erosion succeeding the period of deposition. The erosion occurring in the long period between coal measure deposition and the ice invasion cut down far below the previous plane of drainage, and, while the erosion between the close of the Saint Louis and the beginning of the coal measures must have largely influenced the deposition of these beds, their probable originally limited extent, and subsequent almost complete removal, reduce greatly the relative importance of the pre-coal measure erosion.

UNCONFORMITY BETWEEN THE SAINT LOUIS AND AUGUSTA.

White* in 1870 called attention to the overlap of the Saint Louis upon the underlying rocks. It is of some interest to study this question in Washington county, as it must have been about here that the retreat of the sea southward was checked and the advance of the line to the north began. As has been shown, in Washington and Keokuk counties the

*Geology of Iowa, vol. II, p. 225. 1870.

Keokuk is not recognizable as a distinct formation. It has become so merged with the Burlington that its distinctive characters are lost. The greater portion of the Augusta seems more closely related to the Burlington, though at a few points Keokuk forms are found.

Over the Augusta lies the series of shales which show everywhere close stratigraphic relations with the Saint Louis. Between these shales and the Augusta limestone there are no certain evidences of unconformity, though at the contact near Ollie in Keokuk county, certain obscure phenomena might be so interpreted.

In the Brighton section the lower member shows close relations with the Saint Louis, and yet the fossils while obscure, have a Keokuk facies. On the whole it seems now probable that in this region there is no unconformity of erosion, but rather that sedimentation was continuous, though very slight, during the time that the main portion of the Keokuk and what has been called the Warsaw were being deposited farther south.

ECONOMIC PRODUCTS.

COAL.

As has been shown, there are at present no productive coal areas in the county, though in the past two at least have yielded supplies of the much coveted mineral. All the known coal territory in the county has been worked out. While it is possible that other outliers may occur, the probability is hardly great enough to warrant prospecting. The discovery of such beds, if they be present, must be left to chance. So far, the small outliers seem to have cost as much as they have been worth. The reported presence of coal measure sandstone near Wassonville led to the sinking of a shaft eighty feet deep, in part through the Augusta. Slightly bituminous shales probably belonging to the Kinderhook were encountered. Altogether a considerable sum has at various

times been spent in this county in prospecting, with practically no return.

Even if the coal measures ever covered any considerable portion of the county, a conclusion not wholly free from doubt, the very great erosion to which the area has since been subjected precludes the possibility of more than limited outliers remaining.

CLAYS.

CHARACTER AND DISTRIBUTION.

Of the five formations exposed in this county three, the Kinderhook, the Des Moines, and the Pleistocene, may be considered as clay producers. At present the latter furnishes all the clay used.

The lowest formation exposed within the county is the Kinderhook. Its distribution and the divisions of which it is composed have already been given. Of the three divisions present, the lower, or Maple mill shale, is the only one important as a clay producer. This shale exists in large quantities and is at several points conveniently located for working. It is suitable for both paving and building brick, and probably could also be used for sewer pipe when wisely mixed with other clays which are more highly refractory and which have a lower shrinkage.

So far as known, the formation resting upon the Kinderhook, the Augusta, does not yield clays of any value within the limits of Washington county. The Saint Louis, which in turn overlies the Augusta, is not usually a clay producer. In the southwestern part of this county the middle and lower portions of the formation contain some shale, though, so far as observed, it has too large a proportion of sand and other impurities to be available.

The coal measures, which farther west and south furnish such a variety and abundance of clay shales, are here almost entirely absent. As yet but three small outliers have been located. These are three miles west of Brighton (Tp. 74 N.,

R. IX W., Sec. 27), one mile west of Verdi (Tp. 74 N., R. VIII W., Sec. 4) and five miles northeast of Ainsworth (Tp. 76 N., R. VI W., Sec. 34). At each point the formation has been at some time worked for coal, at which time the presence of the usual fire clay was demonstrated. These deposits are not now of any economic importance.

All the clays at present used are derived from the later or Pleistocene deposits. Alluvium, loess and drift are here present and available. The drift is made up largely of pebbly clays in two well marked divisions—an upper yellow clay, and a lower blue clay. The latter is freer from impurities and better adapted for use, though hardly likely ever to be of much value in this connection. The loess deposit described elsewhere is found covering nearly all the county; it is the clay most largely used at present and differs in no regard from that in adjoining counties, showing the same disposition to check upon drying. The alluvium is as usual developed along the large streams. In the valley of English river it seems to be closely connected with the loess.

CLAY INDUSTRIES.

KALONA.

The Farley Brothers' plant is located on the hills south of English river. A drift clay is used and the section is as follows.

		FEET.
3.	Yellow, soil-like clay	3½
2.	Sand	2½
1.	Clay, drab, plastic, clean	3

The upper and lower clays are mixed together and then tempered and moulded on a Freese side-delivery machine. Both brick and tile are made; the ware is dried under closed sheds and gives very little trouble from checking; only cased kilns are used in burning. The ware is smooth, hard and of good color. Experiments show that a hard burned brick suitable for paving can be made from the clay, though the Kinderhook shale outcropping near by could probably be used for this purpose to better advantage.

RIVERSIDE.

R. L. Swift & Company operate works located in the valley of the English river south of town. The clay used, which is carted from a neighboring field, seems to more nearly resemble the loess than alluvium. It is run through a Brewer crusher and moulded on a Brewer No. 6, new style, side-delivery machine. The ware is dried in part under open sheds, and in part in a steam-heated dry house which has a capacity of 22,000 brick, and in which the moisture is driven off in forty-eight hours. Two round and one oblong down drafts, and one cased kiln are used. Coal slack is mixed with the clay—two-thirds of a bushel to 1,000 brick, and a considerable saving in the cost of burning is thereby effected.

WASHINGTON.

James Eckels owns a tile factory four miles northwest of Washington. This factory has been in operation several years. The loess is used, being moulded on a Brewer machine and dried under closed sheds. Considerable care must be exercised in drying to avoid cracking. The ware is burned with wood in a single kiln.

The F. W. Swift plant is located in the southwestern part of Washington. The common altered loess clay is used; it is run through a Brewer crusher and moulded on a Brewer side-delivery machine. The brick are cut slightly curved so that in drying they become straight. Closed sheds are used for summer drying, but for winter use there is a large dry house having steam pipes under the floor. The clay checks as usual and must be dried slowly. In burning, three round and one oblong down draft, and two patent up draft kilns are used. Both brick and tile are made.

BRIGHTON.

Andrews Brothers formerly manufactured brick and tile at Brighton, using the loess and having a well equipped plant. Work has not been carried on since 1893.

WAYLAND CROSSING.

The plant of the Morris Brick, Tile & Lumber Co. is located directly north of the station in the valley of Williams creek. The section of the pit shows:

		FEET
5.	Soil, black	½
4.	Soil, ash-colored	2
3.	Gumbo	2
2.	Clay, yellow, some pebbles	4
1.	Sand, yellow	

The clay is moulded on a Kells & Son machine, dried under closed sheds and burned in two cased kilns. The plant is new. No tile has yet been made, although the manufactured brick show that the clay might readily be used for this purpose.

WAYNE.

The Brown Brothers' tile factory is situated in the west half of section 34, Crawford township, about a mile and a half north of Wayne, a station on the Burlington & Western railway. Ware was first made on a Penfield plunger, then a No. 5 Brewer was put in and recently a No. 6 A of the same make has been substituted. The material is run through a Bennett smooth-roller crusher. Heretofore the output has been exclusively drain tile from threes to eights, but to meet an urgent demand the firm recently turned attention to the production of brick. The clay used is a yellowish-red loess-like deposit, from two to five feet thick, and a blue drift clay of the same thickness. This grades into a more sandy clay lying above twenty feet of quite hard sand. The exhaust steam pipes run under the dry shed floor and assist in drying the green ware. Checking occurs when any considerable portion of the blue clay is used. Tightly closed sheds are used to prevent this loss. The yellow clay is ordinarily preferable on account of the ease with which it is handled. Two round down draft kilns are used in burning and from three to four days are required.

BUILDING STONE.

Stone of suitable quality for building purposes may be obtained from any one of the three major geological formations. The sandstone of the Des Moines formation is not altogether unsuitable, but its limited quantity throws it out of consideration.

SAINT LOUIS.

The Saint Louis affords the greater portion of the stone now taken out. The ledges quarried belong to the upper portion, and the stone presents the usual lithological characters which mark it throughout the region. The sandstone of this formation is not now used, though at the old railway quarries near Verdi some was at one time taken out. It is, however, too irregular in bedding to be of value for anything but ballast, and is too soft to be of much value for that.

The limestone of the Saint Louis formation are mainly quarried in the vicinity of Brighton. It is here covered by from two to twenty-three feet of drift, below which there are two ledges, quarried principally for bridge and dam rock, and two of which furnish paving flags. Below these latter layers are the heavy beds once worked in the old Chicago, Rock Island & Pacific railway quarry. These lower ledges are more or less water coursed, frequently badly so. It was this difficulty which led to the abandonment of the quarry.

The vicinity of Brighton affords a number of openings. The Faber quarry, on the west side of the Chicago, Rock Island & Pacific railway, immediately north of town, shows the following layers:

		FEET	INCHES.
6.	Stripping; drift	5 to 15	
	Calcareous marl	2 to 4	
5.	Shell rock		8
4.	Bridge stone	1	3
3.	Bridge stone	1	11
2.	Paving flags and rubble stone		3
1.	Paving flags and rubble stone		3

The Martin quarry, on the opposite side of the railway, shows slightly different thicknesses.

		FEET.	INCHES.
6.	Stripping: Drift	23	
	Calcareous marls 8 inches to	2	
5.	Range and rubble stone		8
4.	Bridge stone	1	8
3.	Bridge stone	1	6
2.	Paving flags		3
1.	Paving flags		3

This quarry is worked principally for the bridge stone, and supplies considerable quantities for railway use. Equivalent ledges are worked at a number of neighboring points. The Morris quarry is immediately south of the Martin. The Wood quarry is one and a half miles east; the Lloyd and Emery the same distance northwest of town (Tp. 74 N., R. VIII W. Sec. 28, Nw. qr., Ne. ¼), and the Slater, two miles northeast (Tp. 74 N., R. VIII W., Sec. 28, Nw. qr., Ne. ¼). At the latter point the stone is shipped by means of a switch from the Burlington & Western railway. Both compact and finely brecciated layers are represented at the quarry; the ledges being six to twelve inches thick. The output is small.

The stone quarried in this region is fine-grained, compact, breaks with a conchoidal fracture, and is of a pleasing ash-gray color. It is of fairly good quality but limited in quantity, as only the few ledges noted are workable. Below, are the disturbed beds of the Verdi. Formerly the stone was burned, and made a clear-white, mild lime. No stone is now used for this purpose.

Near Verdi, S. Richardson operates a local quarry (Tp. 74 N., R. VIII W., Sec. 5, Nw. qr., Ne. ¼); also in the Saint Louis. The old railway quarries, near this place, have been long since abandoned.

About three miles southeast of Washington on Crooked creek is the Jacobs quarry at which stone is taken from the lower or magnesian portion of the Saint Louis (Springvale beds). This quarry is worked for local trade only. In the southeast portion of the county there are no quarries, though tone is obtained in the adjoining portion of Henry county north of Winfield.

AUGUSTA.

The Augusta formation furnishes the best quarry stone obtained within the county and to it must any great expansion in the quarry industry be due. This stone is well shown in the Eckels quarry section, already given. In addition to the Eckels quarry there are two similar openings in the same vicinity which supply rock. These are the Thompson (Tp. 75 N., R. VIII W., Sec. 2, Sw. qr.) and the Humpston.

In the Thompson quarry there is an exposed face of about six feet. The stone is a hard, heavy bedded, light gray to brown, sub-crystalline limestone with abundant fossils. In the Humpston quarry the rock is, at least in part, coarser. It is interbedded with a poorer grade of buff sandy stone containing small calcite geodes. Chert bands run through the rock at both points. This group of quarries supplies considerable stone for local trade, nearly all the foundation stone at Washington coming from here. Near Dayton (Tp. 77 N., R. IX W., Sec. 13, Ne. qr., Ne. ¼) there is a small quarry in the Augusta. At this opening, the Whetstine quarry, the following layers occur.

		FEET.
3.	Limestone, buff, arenaceous	5
2.	Limestone, brown, coarse, sub-crystalline, fossiliferous	½
1.	Limestone, blue to gray, finely sub-crystalline, fossiliferous	4

This stone very closely resembles that found in the Crooked creek quarries. Similar stone has been taken from the bed of Smith creek immediately southeast of the Wellman, and extends down the stream some distance. It has been opened up at several points. The Augusta is also quarried at the Wingler's quarry on Davis creek south of Riverside (Tp. 77 N., R. VI W., Sec. 31). The ledge opened up is three and one-half to four feet thick and covered by twenty feet of drift.

KINDERHOOK.

The upper magnesian layers of the Kinderhook (Wassonville limestone) are available over a part of the county but are not extensively quarried. South of Riverside, stone has been taken from these layers and used in the construction of a mill (Tp. 77 N., R. VI., Sec. 18, Sw. qr.) and the beds have also been opened up a little for local purposes on Goose creek (Tp. 77 N., R. VI W., Sec. 21, N. ½). Southeast of Wellman (Tp. 77 N., R. VIII W., Sec. 16) the Burlington, Cedar Rapids & Northern railway formerly quarried considerable stone. A working face 150 feet long was opened up.

Near Wassonville there are many local quarries which obtain stone from these layers. Immediately at the mill is the Yoder and Pfeil quarry from which stone was taken for the piers of the bridge and the foundation of the mill. At present a small amount of stone is sold. It is used for foundations, wells, window sills and wall rock. The stone is rather soft but frequently is better than first appearance seems to indicate.

SOILS.

The soils of Washington county belong to two general types; the loess soil and the alluvial soil. There is a close connection between the two in character, properties and origin. Both are black, loamy, soils of great fertility, both are water deposits, and both consist of fine silt-like beds laid down in quiet water. Indeed, the alluvial soil is at present receiving direct addition from the loess by the simple process of wash from the uplands and re-deposition over the bottom lands. There are, however, important differences between the two soils. The loess soil is formed *in situ* from the underlying loess by changes in that deposit. Its subsoil is, therefore, always the loess, which is usually of considerable thickness. Over some regions it is thin, and then the drift itself acts, to some extent, as a second subsoil.

The alluvial soil is not formed *in situ* but is derived from other ready-made soils and may overlie anything. It is

usually of considerable depth, so that the subsoil is the same as the soil itself, except that it may be coarser. This is not, however, necessarily true, as the soil covering may be thin and may have any kind of a subsoil. The relations between the two types are quite close, and they are in the main adapted to the same kind of culture.

WATER SUPPLY.

In common with the other counties of the region, Washington is well supplied with surface waters. The English and Skunk rivers, with their tributaries, contain an abundant supply for general farm use, which is readily available throughout the greater part of the county.

Good wells are rarely difficult to obtain. The drift contains here numerous lenticular bodies of gravel and sand, interbedded with more impervious clays, which thus form natural basins for the collecting and storing of water. Such layers are found throughout the county, usually within 100 feet of the surface, though not always so. Immediately above the indurated rocks is a good water-horizon. In the underlying rocks water may also be usually obtained. In Des Moines and Louisa counties the Augusta frequently yields good water along the planes between the heavy limestone bands. West of here the Saint Louis is water-bearing in the middle member and might be found to yield water in the southwestern portion of this county.

In the deep well at Washington a good supply is obtained at a depth of 1,611 feet. It probably comes from one of the upper layers of the Saint Croix, or from one of the sandstones of the Oneota. The water stands forty-four feet one inch below the top of the casing and has a temperature of 74°. It has a slight mineral taste, but is well liked. It is pumped at the rate of ninety-five gallons per minute, the smallest casing being four and one-half inches in diameter.

WATER POWER.

The power afforded by the streams of this county is used at only four points. Two mills are located on English river, one at Wassonville and one at Riverside, and two on Skunk river at Brighton and Coppack respectively. These mills use an aggregate of 150 to 200 horse power and there is considerable room for expansion.

ROAD MATERIALS.

The materials which are here adapted to the purpose of road making consist of gravel, clay and stone. The first occurs in greater or less quantity throughout the drift, but it is only at a few points that it has accumulated in sufficient quantity and purity to be readily available. These points are along the larger streams. At Coppack there is a gravel terrace from which considerable material has been taken by the Burlington & Western railway and used for ballast along its line. The gravel is rather fine and is mixed with considerable sand. The output has been decreasing.

The number of cars loaded of recent years has been as follows:

1892	2,100
1893	400
1894	100

Clay of good quality, such as is elsewhere burned for ballast and road materials, is everywhere present but has not been used for these purposes.

Rock suitable both for ballast and general road purposes occur in all formations. The Saint Louis has been used to some extent for the former purpose by the Chicago, Rock Island & Pacific railway, and the Kinderhook has been used by the Burlington, Cedar Rapids & Northern. Rock has not been used on the common country roads except at local points. It is of excellent quality for such purposes and readily available.

ACKNOWLEDGMENTS.

The author wishes to acknowledge the important aid received in the preparation of this report from the citizens of the county. The hearty co-operation of the quarry owners and brick makers has been especially helpful. To Professor Calvin and Dr. Keyes he is indebted for many valuable suggestions and for identification of fossils.

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF WASHINGTON COUNTY, IOWA.

BY

H. FOSTER BAIN

1896.

R. IX W. R. VIII W. R. VII W. R. VI W.

Tp. 77 N.

Tp. 76 N.

Tp. 75 N.

Tp. 74 N.

LIME CREEK ENGLISH IOWA SEVENTY SIX CEDAR JACKSON HIGHLAND DUTCH CREEK WASHINGTON OREGON FRANKLIN BRIGHTON MARION CLAY CRAWFORD

Wassonville Dayton WELLMAN Kalona RIVERSIDE Yatton Nira Richmond Pilotsburg Lexington Keota West Chester Dublin Paris Grace Hill Vedi Havre Ainsworth Crawfordsville Clay BRIGHTON Noble

LEGEND

GEOLOGICAL FORMATIONS

- DES MOINES (Coal Measures)
- SAINT LOUIS
- AUGUSTA
- KINDERHOOK

INDUSTRIES

- QUARRIES
- COAL MINES
- CLAY WORKS

IOWA PRINTING CO. DES MOINES, IA.

DRAWN BY F. C. TATE