GEOLOGY OF POLK COUNTY.

BY

H. F. BAIN.

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INTRODUCTION.

LOCATION AND AREA.

The country to be described in this report is of interest to the layman as containing the capital city of the state and to the geologist as being located at the apex of the Des Moines lobe of the Wisconsin ice sheet. It lies slightly southwest of the center of the state and is bounded by Boone and Story counties on the north, Jasper and Marion on the east, Warren on the south and Dallas on the west. Of these regions Boone and Warren counties have been previously described by Dr. S. W. Beyer* and Prof. J. L. Tilton† respectively. Polk county is the meeting place of the formations described in these reports. The county includes the usual sixteen congressional townships with 586 square miles; an area divided into twenty civil townships as shown upon the accompanying map.

Physiographically, it lies mainly in the valley of the Des Moines river and within its limits the Raccoon joins the latter stream. The northeastern portion of the area belongs to the valley of the Skunk river and that of its tributary, Indian creek.

PREVIOUS GEOLOGICAL WORK.

The early establishment of a military post at the juncture of the Des Moines and Raccoon rivers led to the region being visited from time to time by various geologists in the employ of the national government. Many of these expeditions were more especially directed to the accomplishment of geographical or military purposes. Such was that led from the fort to the source of the Des Moines river by Capt. J. Allen‡ in 1844, though the incidental topographic and geological notes given in the account of this expedition are very suggestive.

Information more directly geological may be obtained from the report of the expedition of J. N. Nicollet.§ In it is

*Iowa Geol. Survey, vol. V., pp. 175-239.
†Ibid., 301-359.
‡Ex. Doc., House of Rep., 29th Cong., 1st Sess., No. 168, 18 pp. Washington, 1845-46.
§Sen. Doc., 26th Cong., 2d Sess., V., pt. ii, No. 237. Washington, 1841.

given a list of fossils collected from the Des Moines river above the Raccoon fork by Lieut. Fremont. Knowledge of the stratigraphy of the region began with the explorations of Dr. D. D. Owen, carried on in the summer of 1849. In his trip up the Des Moines river* he located and described the principal exposures, recognizing the presence of coal measures, drift and loess.

Worthen† in 1856 visited Des Moines and noted some of the exposures near the city.

In the course of the work of the White survey the county was visited by both Mr. St. John and Dr. White,‡ though no detailed survey of the county was made. The drift deposits within the county have been since written upon by Call,§ McGee and Call,‖ and Keyes and Call,¶ while Keyes has made extensive studies of the coal measures and of the paleontology. The latter has published numerous papers upon the region, the more important being referred to in the following pages. His studies upon the coal have been summed up in his general report upon the coal deposits of the state.**

PHYSIOGRAPHY.

TOPOGRAPHY.

Polk county is not a region of strong contrasts. Topographically the region belongs to the type called "prairie plain" by Powell.†† In a broad way it may be conceived to be an essentially even plain cut into by river channels. The evenness of the upland surface can never be lost sight of, and from any high point in the county one can see the surrounding region rising to the same general level. There are no points of greater altitude and the divides all belong to this

*See Geol. Surv. Wis,. Iowa and Minn., pp. 121-123, with plates. Philadelphia, 1852.

†Geol. Iowa (Hall), vol. I, pt. i, 170-172. Albany, 1858.

‡First and Sec. Ann. Rep. State Geolgist, pp. 167-176. Des Moines, 1870. Geol. Iowa, vol. II. pp. 261-262. Des Moines, 1870.

§Amer. Nat., XV, 782-784. 1881.

‖Amer. Jour. Sci., (3), XXIV, 202, 223. 1882.

¶Proc. Iowa Acad. Sci., 1890-1891, 30. 1892.

**Iowa Geol. Surv., vol. II, pp. 267-294. Des Moines, 1894.

††Nat. Geol. Mon., vol. I, No. 3, p. 63. New York, 1895.

general plain. This plain has an altitude at Bondurant of 975 feet, at Mitchellville of 976, at Altoona 966, at Orilla 975, at Ankeny 1,005, and at many other points occurs at the same general level. Into this plain the rivers have cut channels to various depths. The Skunk at Santiago is about 175 feet below the high land on each side. The Des Moines river has cut from fifteen to twenty-five feet deeper. The minor streams have cut to various depths, depending on their size and the distance from the main stream.

When one examines the topography in greater detail, certain differences are noted which at once separate the region into two portions, between which the contrasts are as sharp, as constant and as multitudinous as those between an alluvial valley and the adjacent uplands. To the sympathetic student of land forms, these contrasts of topography are as definite and as full of meaning as are the contrasts in fossils obtained from different formations. The line separating the two areas is marked upon the map of the superficial deposits as the northern border of the loess, and runs approximately from south of Nobleton through Rising Sun, around the nose of Four Mile ridge, across Capitol and West hills, just north of Valley Junction and between Commerce and Ashawa. The region north of this line has had a different history from that which lies south of it, a history differing in the length of the erosion period and hence shown in the character of the streams; a history differing in origin of the surface material and hence reflected in the landscape. North of

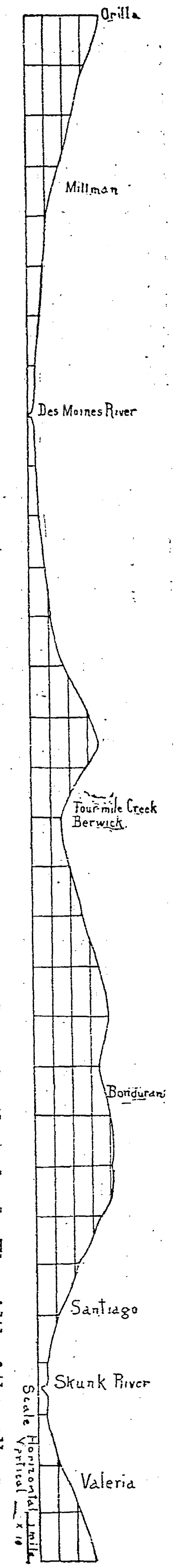


FIG. 38. Profile along the Chicago Great Western crossing the Skunk and Des Moines valleys and showing the upland. The width of the valleys is much exaggerated owing to the direction of the section.

the line the general appearance of the country differs radically from that south of it despite the fact that the surface as a whole rises to the same plane and the surface material is in each case loose detritus. The contrasts are not always so sharply preserved along the border, and yet, on the whole, one is constantly struck by their presence rather than by their absence. There are few places where the contrasts between the two drift sheets are so excellently shown and so readily studied as at Des Moines.

NORTHERN AREA.

In the northern portion of the county the prevailing landscape is flat. The divides are broad and have practically no slope. This is well shown in crossing the divide between Four Mile creek and the Skunk river. In the region near Bondurant is a broad even surface of immature drainage. Only the faintest contrasts in elevation are noticeable. The same type of upland is shown between Mitchellville and Altoona and may be readily examined in its most typical aspect near Ankeny. As seen at the latter point especially, the presence of swales and inter-swales is quite striking. It gives a topography which may be called a saucer topography, since the low circular, grass-grown and often water-holding swales are similar in outline and cross-section to shallow saucer-like depressions. The higher portions of land between the swales are almost the exact reverse of the latter; being low, very gently rounded hummocks. The swales vary in diameter from mere depressions a dozen feet across to well defined basins, often holding ponds and, in regions a little farther north, small lakes. Over such a surface there are no drainage lines. Many, indeed most of the ponds, have no outlets.

While the saucer topography is characteristic of the region covered by the Wisconsin drift, and indeed is not known to occur south of its limit, other phases occur with it. In the region near Kelsey there is a bit of rather rough country. The hills are of considerable height, irregular form, and are independent of the streamways. The drainage conforms to the hills rather than forms them. Drift seems to be the materials which make up these ridges. It is somewhat sandy and full of gravel in the upper portion and seems to indicate a certain amount of water action. The general aspect of the hills is morainic. Their nature will be described more in detail in another portion of the report.

In the northern portion of the county the valleys are, as a rule, narrow. In certain cases they are broad though the streams are unimportant and narrow. In such instances the stream has usually a narrow recent valley, with a very moderate development of alluvium, winding through the older larger valley. The broad bottoms of such a valley, for example that of the Beaver, is covered by irregularly disposed hills of sand, gravel and till in its less typical phases. These hills are low, very gently rounded and often merge into almost terrace-like forms. The boundary of such a broad valley is ordinarily imperfectly defined. The slopes rise with increasing steepness until they meet the upland plain. The whole represents rather a long, broad, fairly shallow sag in the surface of the latter. An excellent example of such a sag may be seen just north of Highland Park or North Hill, and separating the latter from the main upland plain upon which Saylor station is located.

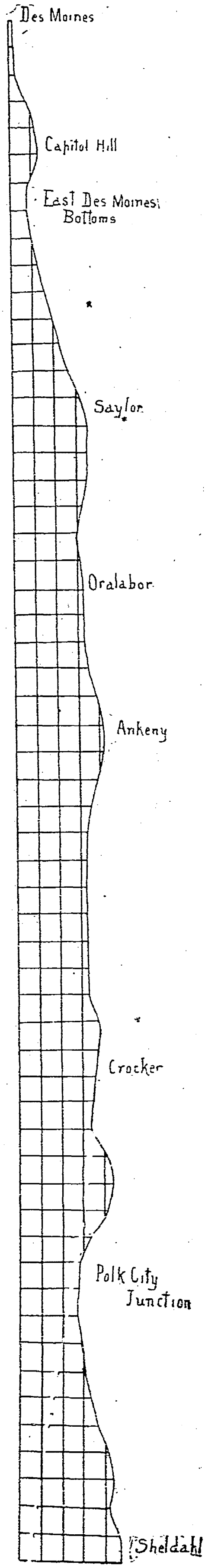


FIG. 39. Profile along the Chicago & North-Western railway from Des Moines to Sheldahl. The section starts on the Des Moines bottom land, crosses Capitol Hill at a low point, traverses the old valley of the Des Moines and from Saylor runs over the upland. Scale: Horizontal, ½ mile; vertical, 250 feet.

It takes but little observation to satisfy one that in this northern portion of the county the topography was not formed by the present streams, and is, in fact, not a normal erosion topography. There is no constant relation between the size of the stream and its valley. There are areas of rough, hilly topography where the streams wander in and out in aimless fashion. In such regions especially, and the same is true for the region in general, the streams have no flood plains or such as are only very slightly developed. The land forms also exhibit anomalous curves which are not characteristic of stream erosion. In short, the land forms are glacial and the country is in extreme youth. The stream action has only just begun. The upland plain is barely cut into. It is crossed rather than dissected by the streams, and the latter have merely cut gashes in its surface.

SOUTHERN AREA.

South of the dividing line mentioned, a very different topography is encountered. The surface material is still drift. The land forms are, however, erosion forms. The saucer topography of the northern upland and the hummocky topography noted near Kelsy have disappeared. The inter-stream divides rise to an even surface which is, in a general way, level. There are flat-topped divides but these are relatively narrow. The plain is thoroughly dissected and the drainage is in early maturity. Much, however, of the upland is yet unreduced and not all of the streams have ceased to cut down and begun to fill up. The landscape accordingly marks an intermediate stage in which the surface is largely reduced to slope.

The region is crossed from west to east by the broad valley occupied in part by the Raccoon river and in part by the Des Moines river. Numerous tributary streams subdivide the area. The larger of these streams, for example Camp creek, simulate the master streams in having definitely marked alluvial bottom lands. Indeed all the streams of the southern area have developed alluvial plains of greater or less extent.

Alluvium is found along the lower courses of even the smaller creeks. If, for example, one examines West Four Mile he finds at its embouchere upon the bottom land of the Raccoon a rather definite flood plain which may be traced up the stream some little distance. In passing up stream it becomes narrower, takes on more and more slope, and thus by degrees merges into the side slopes. At a certain stage it is difficult to separate the flood plain from the slope. A little farther on the flood plain has altogether disappeared, the change being almost imperceptible.

It is interesting to contrast this with the change which the flood plain undergoes in the case of those streams which start upon the Wisconsin drift and flow down upon the Kansan. In such cases the alluvial plain, which is broad in the lower portions of the valley, narrows up at once when the stream is traced back over the later drift border. This is shown in the case of East Four Mile creek and is also marked on Spring, Mud, and Camp creeks. The development of alluvium along a river is indicative of considerable stability and a long time of work. New streams rarely have flood plains. Old ones usually do. The inference, then, is that the upper courses of the streams mentioned are much younger than the lower courses. That the disappearance of the flood plain along East Four Mile is not due to the same causes that have obtained in the case of West Four Mile is shown by the fact that in the former it is abrupt; in the latter it is gradual. The land forms of the southern area, then, are the results of stream action. They have required a long time for their development; a longer time than that necessary for the development of the northern landscape. The measure of this time and the details of the contrast between the two areas may well be noted in connection with the description of the individual streams.

DRAINAGE.

The streams of Polk county belong to two systems, the Skunk and the Des Moines. By far the larger portion of the county is drained by the latter river and its tributaries. Within the county the valley of the Des Moines is separated into two sharply contrasted portions lying respectively above and below the mouth of the Raccoon river. The upper valley is narrow, steep-sided and very recent. The lower is broad, has a well developed flood plain, usually well rounded sides, and in fact shows all the marks of an ancient stream. That portion of the course lying between the mouth of Daily's run and the Raccoon river is intermediate in age, though in topography it more closely resembles that along the upper reaches of the river. The Des Moines river is a stream of consider-

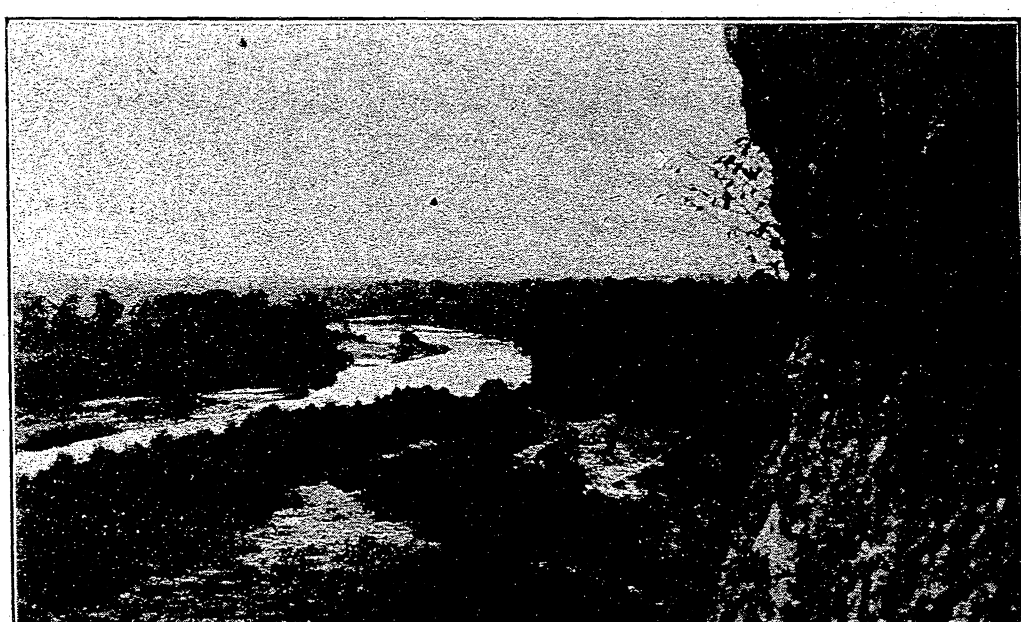


FIG. 40. Des Moines valley, older portion, below Hastie. The bluff at the right shows loess over Kansan drift.

able magnitude; so much so that in early days it was traversed by small Mississippi river steamboats as far as the mouth of the Raccoon and even beyond. The bottom land below the forks is, as is shown upon the accompanying map, from three to four miles wide. Its borders are usually well marked, the hills rising abruptly from 100 to 135 feet above the flood plain. There is a slight farther rise until the land reaches a general altitude of about 160 feet above the river. In this portion of its course most of its tributary streams flow in from the north.

They include East Four Mile, Spring, Mud, and Camp creeks, all of which have already been partially described. East Four Mile creek is a long stream with a narrow valley. It has no tributaries of any great length and few that are branching. Practically all of its course is upon the later drift. The last two miles is across the flood plain of the Des Moines, and the mile just above is through a relatively broad and well marked valley which is of preglacial origin. The upper course is a mere trench across the drift and seems to be of no great age.

Spring and Mud creeks have their sources just within the border of the upper drift in poorly defined valleys. Below the border they follow well marked valleys and receive numerous small branching tributaries. Camp creek has its source upon the drift plain between Altoona and Mitchellville and flows south, reaching the Des Moines just outside of Polk county. It receives few tributaries though it is a stream of some size and age. From the south the Des Moines receives a few small streams of which Yader creek, itself an insignificant branch, is the larger. The streams, including West Four Mile and Elm branch, which flow into the Raccoon river from the south, are also of small size. The reason for this seems to be that North river, which joins the Des Moines just below Avon, has preempted the territory which might have been drained by Yader, Four Mile and Elm branches. North river empties into the Des Moines below these streams and hence has a lower outlet. It is an older stream and in the struggle for territory has succeeded in capturing by far the larger portion of the area between it and the Raccoon-Des Moines valley.

In the intermediate portion of its course the Des Moines river flows through a narrow valley flanked by high bluffs mainly composed of coal measure strata capped by loess and Wisconsin drift. The valley sides are veneered with loess, and hence this channel is of interglacial and possibly of preglacial age. The river in this part receives no tributaries of any consequence. At the upper end of the narrow portion there is a broad expansion of the valley marked by a wide alluvial tract extending from Highland Park to Saylorville. Within this portion of its course the river receives Beaver creek from the west and Saylor creek and Daily's run from the east. The two latter are very small streams which do not have well marked valleys. Saylor creek, after coming out from the drift covered region, crosses the alluvial bottom land in a shallow ditch-like channel two miles or more long, following close along the eastern edge of the bottom land.

Above Saylorville the Des Moines valley narrows rapidly and for a considerable distance parallels the broader valley now occupied by the Beaver. The relative width of the two is shown upon the map. The Ridgedale ridge is usually narrow. It slopes very abruptly down to the Des Moines river, which is bounded on the east by equally abrupt slopes. On the west the ridge normally slopes down to the Beaver with a regular, gentle inclination. This is not however always true. In sections 36, 25 and 26 of Tp. 80 N., R. XXV W., the slope is quite as abrupt as in the opposite direction. This abrupt slope towards the Beaver is however exceptional. The river receives in this portion of its course Rock, Big and Mosquito creeks, all from the east. Big creek is the largest stream, but though it carries considerable water, it has only a narrow valley and a narrower strip of irregularly developed alluvium.

The Raccoon river flows into the Des Moines from the southwest. It has a marked valley, with a well developed flood plain. Its tributaries from the south are small but evidently old. From the north it receives Jordan branch, a recent stream flowing down from near Ashawa, and Walnut creek, which flows in east of Valley Junction. Walnut creek is rather well developed and has through a considerable portion of its course a definite flood plain. It does not seem however to be an old stream.

The Skunk river system does not drain an important portion of the county. The main stream enters the county about eight miles west of the northeast corner, flows southeast and leaves the area ten miles south of the same point. It flows in a broad flat-bottomed valley bounded by low rounded sides. The valley is evidently of considerable age, though the present river has only insignificant tributaries. It receives White Oak creek, Swan, and Byers branches from the west but no streams of name from the east. The branches drain a strip parallel to the main stream and less than four miles wide. Indian creek, which flows across the extreme northeastern corner of the county parallel to the Skunk and about five miles distant, joins the latter stream near Colfax. Within the area now being considered it is wholly independent of the Skunk and flows in a valley which is a smaller homologue of that of the parent stream.

HISTORY OF THE DRAINAGE.

The main outlines of the drainage of Polk county were evidently developed in preglacial time. The Des Moines, the Raccoon, North river, East Four Mile, the Skunk and Indian creek evidently run in valleys which are, in part at least, preglacial. The origin of these rivers was due to causes antecedent to the glacial period. Their preglacial valleys, as we know them, seem not unlikely to have been excavated in the period immediately preceding the advent of the ice. Their deeper channels are cut in a moderately flat rock surface which probably represents a Tertiary, or later, base-level. The channels are most probably the result of the post-Lafayette emergence.* That the streams had before this been developed, and by the post-Lafayette emergence were merely revived, is altogether probable, but this, and indeed all except the fact of the existence of certain of the channels before the ice came, lies largely in the domain of hypothesis and is, at present at least, not susceptible of field demonstration. The lower course of the Des Moines river, that below the mouth of the Raccoon, has been filled in with drift to a considerable depth. The shaft of the Gibson mine No. 1, located on the edge of the bottom land, passed through fifty-six feet

*McGee, Twelfth Ann. Rept. U. S. Geol. Surv., pt. i, p. 515. 1891.

of drift. The Hastie mine working at a depth of 100 feet below the river was much interfered with by water. Wells driven down upon the plain at Avon pass to considerable depths without encountering rock. The hills, however, contain rock at levels considerably above the water level. Good sections and rock exposures are common wherever there has been recent cutting. This is not, however, true in all cases. Usually the drift alone is seen and at points the recent cutting of the river against its sides shows only the undisturbed

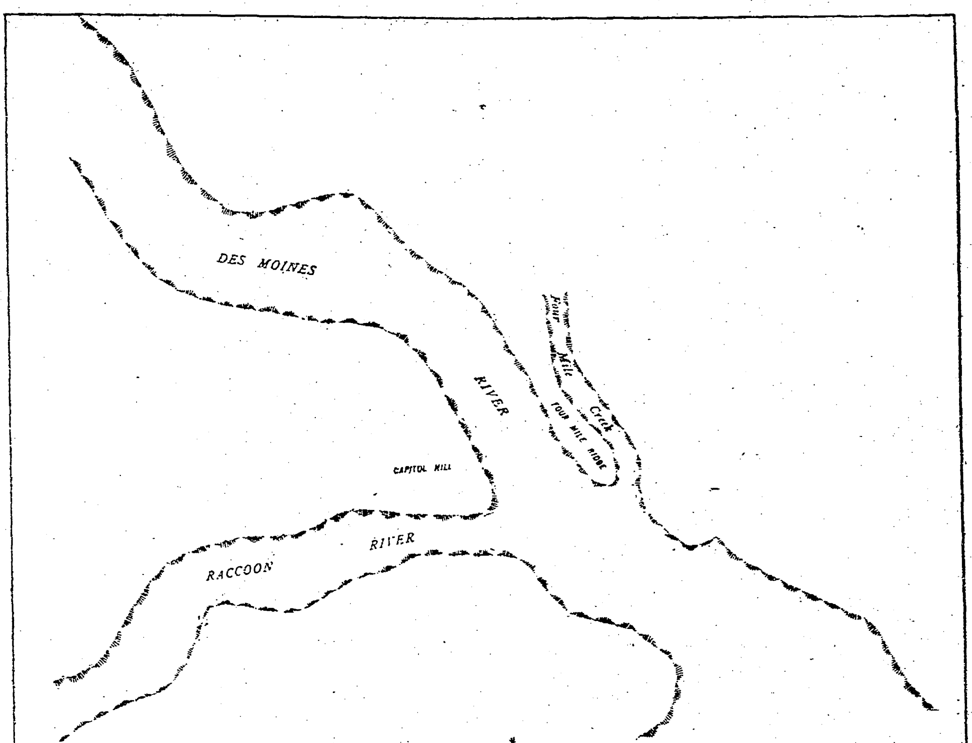


FIG. 41. Preglacial drainage at Des Moines.

drift down to water level. The valley in this portion seems then to have been formerly deeper and perhaps slightly wider; at least its present form is not its original form. The material which fills in this older valley is the Kansan drift and loess, and will be described later.

In that portion of the old valley which lies between Capitol Hill and Four Mile Ridge it has been found impossible to mine a bed of coal which lies about ninety to one hundred feet below the river level, because the overlying slate roof is so thin that it crushes in and fills the mine with drift and water. In the

Giant mine, located on the western edge of this plain, at a depth of about 100 feet, a preglacial drift filled valley was encountered*. Similar channels have been encountered by other mines located at the edge of this plain. The rock rises in Capitol Hill to a height of seventy-three feet above the plain which is itself about twenty feet above the water of the river. On the crest of North Hill, or in Highland Park, sandstone belonging to the coal measures is encountered at a depth of twenty-five feet. On the low land between Highland Park and Saylor station wells go through seventy-five to 100 feet of drift. The Poor Farm well, 140 feet above this bottom land, only passes through eighty feet of drift, which is perhaps an unusual depth, as rock is found in the same region at depths of fifty feet and less. On the high land near the Union mine the rock is encountered at about twenty feet. The nose of Four Mile Ridge is made up largely, to a depth of 116 feet or more, of loose material, and yet it has a core of coal measures, as has been proven by recent drilling in Grandview park. There is then here a drift filled valley with rock-bound sides. The filling material is, in part at least, Kansan drift.

The Beaver valley shows topograpic characteristics similar to those of the old valley just described. Its width is comparable to that of the latter valley, and if to it be added the width of the narrow valley occupied by the upper course of the Des Moines the sum is about equal to the width of the Des Moines below the mouth of the Raccoon. The bottom of the Beaver valley is covered by the modified Wisconsin drift. Wells in this bottom land do not reach rock at depths of fifty feet. The side slopes show rare rock exposures, though the coal measures rise in them to heights considerably above the stream. At points undisturbed Kansan drift is found low down in the valley.

There is then a broad preglacial valley running across the county, now occupied in part by the Beaver, in part by the Des Moines and in part unoccupied. For reasons to be con-

*Keyes: Iowa Geog. Surv., II, 183. 1894.

sidered later it is known that the course of the Des Moines above the mouth of the Beaver is much more recent, so this older valley may reasonably be considered to be that of the Des Moines. That the Raccoon river also flows in a preglacial valley seems well established. The topographic relationships, the drift-veneered sides, and the at least considerable filling up which it has undergone, all point to an age comparable to that of the Des Moines.

That East Four Mile, in its lower course, runs in a preglacial valley is shown by a drift filling of sixty-one feet encountered in sinking the shaft of the Gibson mine No. 2, and by several wells at Berwick. Walnut creek may in part occupy a similar valley, though this is by no means sure. There were doubtless other tributaries, but they do not at present admit of being traced.

With the advent of the Kansan ice sheet these rivers were of course blocked and at its retreat the valleys were left buried beneath the debris. Broad and deep valleys under the drift tend to reveal themselves by low sags in the surface. Even if we suppose the valley to have been filled up to a surface even with that of the surrounding plain, the difference in the amount of loose material present in the valley and over the plain would tend to show itself as a result of settling, and hence the sags would be developed. These sags afford the conditions best adapted to the establishment of drainage lines, and as a result the consequent rivers take the same general course as the older streams and tend to dig out the older valleys. Such a stream is not a revived stream in the sense in which that term is ordinarily used; neither is it an antecedent or a simple consequent stream. It stands in a class of its own and is fittingly called a resurrected stream.

After their resurrection these streams had a long period of undisturbed activity and developed a large number of tributaries which are sketched in figure 42. Some of these may themselves have been resurrected streams, but of that we have no proof. In this period two small streams *a* and *b* were developed which later played an important part in changing the course of the Des Moines river. The first was a tributary of the Raccoon and ate its way back by headwater erosion along the line now occupied by the Des Moines from Thompsons bend to its mouth. The second, *b*, was tributary to the Des Moines as it then was, and worked back toward the south along the line now occupied by the Des Moines river from the mouth of Dailys run to Crocker park. These streams cut back farther and farther, *a* encroaching upon *b* until the valleys were continuous. Possibly *a* captured *b* and a portion of the Des Moines was diverted to the new course. More probably the valley was not cut to that depth, and the Des Moines

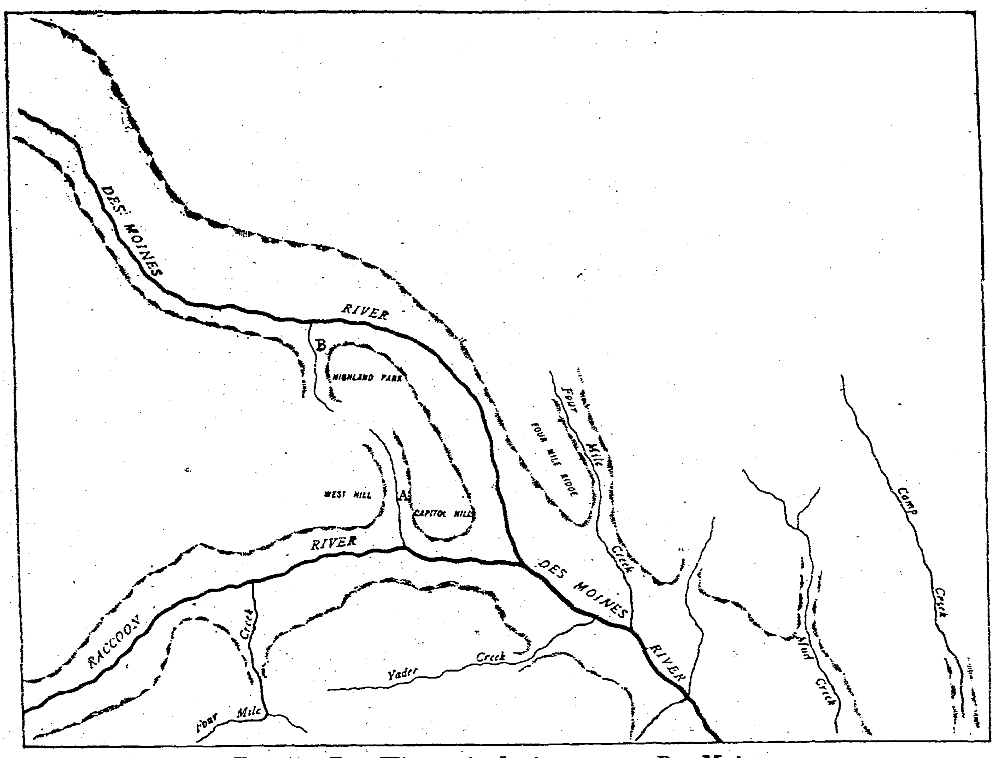


FIG. 42. Pre-Wisconsin drainage near Des Moines.

had not begun to flow through the new channel at the time the loess was deposited. The latter spread in this region in a fairly uniform mantle over the Kansan drift both upon the upland and in the valleys. It did not materially affect the arrangement of the streams though it changed the contours of their side slopes and softened the cross-sections. The streams began at once to clear out their valleys and were engaged in that work at the advent of the Wisconsin ice.

It is probably legitimate to suppose that the ice advanced in a direction normal to the present limit of Wisconsin drift, and that its advancing front occupied lines successively farther south and parallel to this line of drift limit. Such an advance would have forced the Des Moines, as it then was, over against the southwest side of its valley and would probably have blocked its course between Saylorville and Dailys run before the upper portion of the stream was thrown entirely

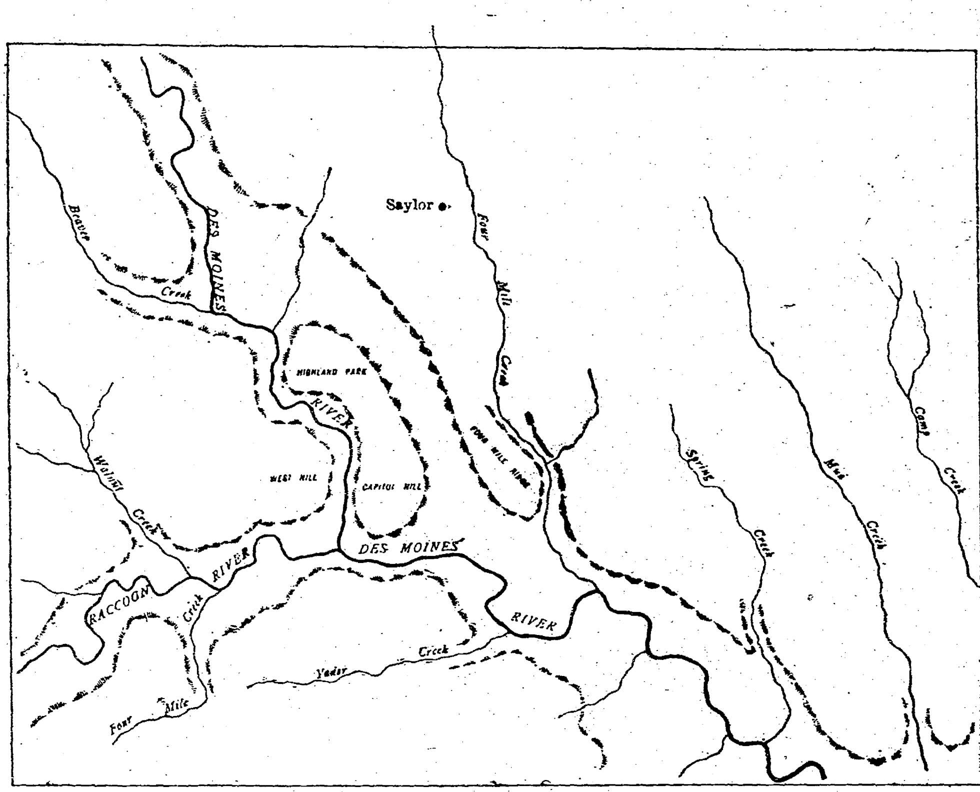


FIG. 43. Present drainage near Des Moines.

out of its valley. The waters of the upper course, swollen and powerful, seeking an outlet, flowed up the stream *b*, across the low divide, and through *a* into the Raccoon. The ice advanced but a short distance beyond before coming to its final halt, and it is not impossible that the stream held its course under the ice for a considerable portion at least of this time. As the ice melted back the river held to the new course and abandoned the old one.

With the continued retreat of the ice certain other rearrangements took place in the streams. The Des Moines abandoned its upper valley, now occupied by the Beaver, and cut the newer and narrower channel in which it now flows. The reasons for this change are obscure and no satisfactory explanation can now be given. But little is known of the course of the older channel except in Polk county. In Guthrie county situated to the southwest, there are three streams, Middle Raccoon, Brushy Fork, and South Raccoon, which have parallel courses, the general direction being northwest-southeast. These streams are outside the area covered by the Wisconsin ice and were uninfluenced by it. In a general way the master streams of the entire region, where so uninfluenced by later operating causes, flow in the same direction. This is also the direction followed by the old Des Moines valley as far as we know it, and it would seem not unfair to suppose it to be the true direction of the old stream. The upper portion of the Des Moines river, however, has a course much more nearly due south. This is shown much more strikingly above High Bridge than below.

This upper portion of the Des Moines is consequent upon the slope of the surface at the retreat of the Wisconsin ice. The valley was, in a certain sense, formed all at once, not by simple and progressive headwater erosion. This is seen from the fact that on the bluffs opposite Corydon undrained saucer depressions occur almost in sight of the river a hundred feet or more below. It is hardly supposable that a river could by simple headwater erosion cut back half way across the state and yet not have time to invade the territory so near itself and so exposed to attack. The larger portion of the river course must then have been established with great rapidity, and was doubtless an immediate result of the ice melting. It is but natural that a stream which owes its origin to so intimate a connection with the ice should take the same direction that had been taken by the ice lobe itself, and the Des Moines river follows quite closely the median line of the Des

Moines lobe of the glacier. Such a line was bound to make an angle with the older drainage lines and it seems not unnatural that this angle should be at the apex of the lobe, particularly when, as has been explained, the river course had at this point already taken the new direction.

The history of the Skunk river and its tributary Indian creek can not be traced in so great detail. That both these valleys are preglacial and that they are resurrected streams has already been indicated. The noteworthy difference between the Skunk and the Des Moines is that in Polk county the former has a very limited tributary area. It has not, it is true, cut quite so deeply as the Des Moines, but since the tributaries of the two streams have not cut back far enough to interfere, the matter is of but slight significance. The resurrection of the Skunk occurred at the same time that the upper portion of the Des Moines was formed. The Skunk had softer material to work upon, and it also had an established course, so it would be expected to have been the gainer. It, however, follows the old course from northwest to southeast and hence was out of harmony with the new drainage. The major portion of the water ran south and hence the Des Moines, running directly in the course of the new drainage, was favored, while the Skunk was starved. In Hamilton and Story counties the Skunk has taken the new direction and has a corresponding increase in tributary drainage.

TABLE OF ELEVATIONS.

The following table gives the elevation above sea level of the principal towns in Polk county so far as they are available, with a few in adjoining counties which are given for reference.

STATION.	Altitude above sea level.	AUTHORITY.
Altoona	966	C., R. I. & P.
Ankeny	1,005	C. & N.-W.
Ashawa	844	C., R. I. & P.
Avon	740	C , R. I. & P.
Berwick	845	C. Gt W.
Bondurant	963	C. Gt. W.
Carbondale	791	Barometer.
Commerce	845	C., R. I. & P.
Crocker	995	C. & N.-W.
Cummings	985	C. Gt. W.
Des Moines—		
Low water at mouth of Raccoon	776	
Fourth and Walnut	807	City Engineer.
Capitol avenue and East Eleventh street	888	City Engineer.
Grand avenue and East Seventeenth street	835	City Engineer.
Cottage Grove and Western avenue	969	City Engineer.
Hastie	779	Wabash.
Milliman	830	C. Gt. W.
Mitchellville	976	C , R. I. & P.
Oralabor	975	C. & N.-W.
Polk City Junction	960	C. & N -W.
Runnells	750	Wabash.
Santiago	832	C. Gt. W.
Saylor	965	C. & N.-W.
Sheldahl	1,042	C. & N -W.
Tamworth	762	Wabash.
Valley Junction	810	C , R. I. & P.

STRATIGRAPHY.

Geological Formations.

GENERAL RELATIONS OF STRATA.

The rocks of Polk county belong to two series of very different character, age and origin. The more obvious surface material consists of a sheet of drift, loess, sand, gravel and alluvium which has been spread over, and very largely conceals, the underlying indurated beds, which alone are commonly known as rock. The latter includes the usual coals, shales and sandstones common to the coal measures of the state. The former includes the glacial and river deposits of the Pleistocene. The major physiographic features are due to the coal measures. The flat uplands, the main river divides and many of the minor stream partings are formed of these beds. Exposures of coal measures occur quite generally along the Des Moines river and throughout the southern portion of the county. The whole area of the county, however, with the exception of the limited outcrops of coal measures, is covered by a heavy mantle of Pleistocene beds which give character to the minor physiographic features.

The taxonomic rank of the formations exposed in the county is shown in the following table.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Alluvium.
		Glacial.	Wisconsin Iowan. Kansan. Aftonian Pre-Kansan.	Drift. Loess. Drift Gravels. Drift.
Paleozoic.	Carboniferous	Upper Carboniferous.	Des Moines.	

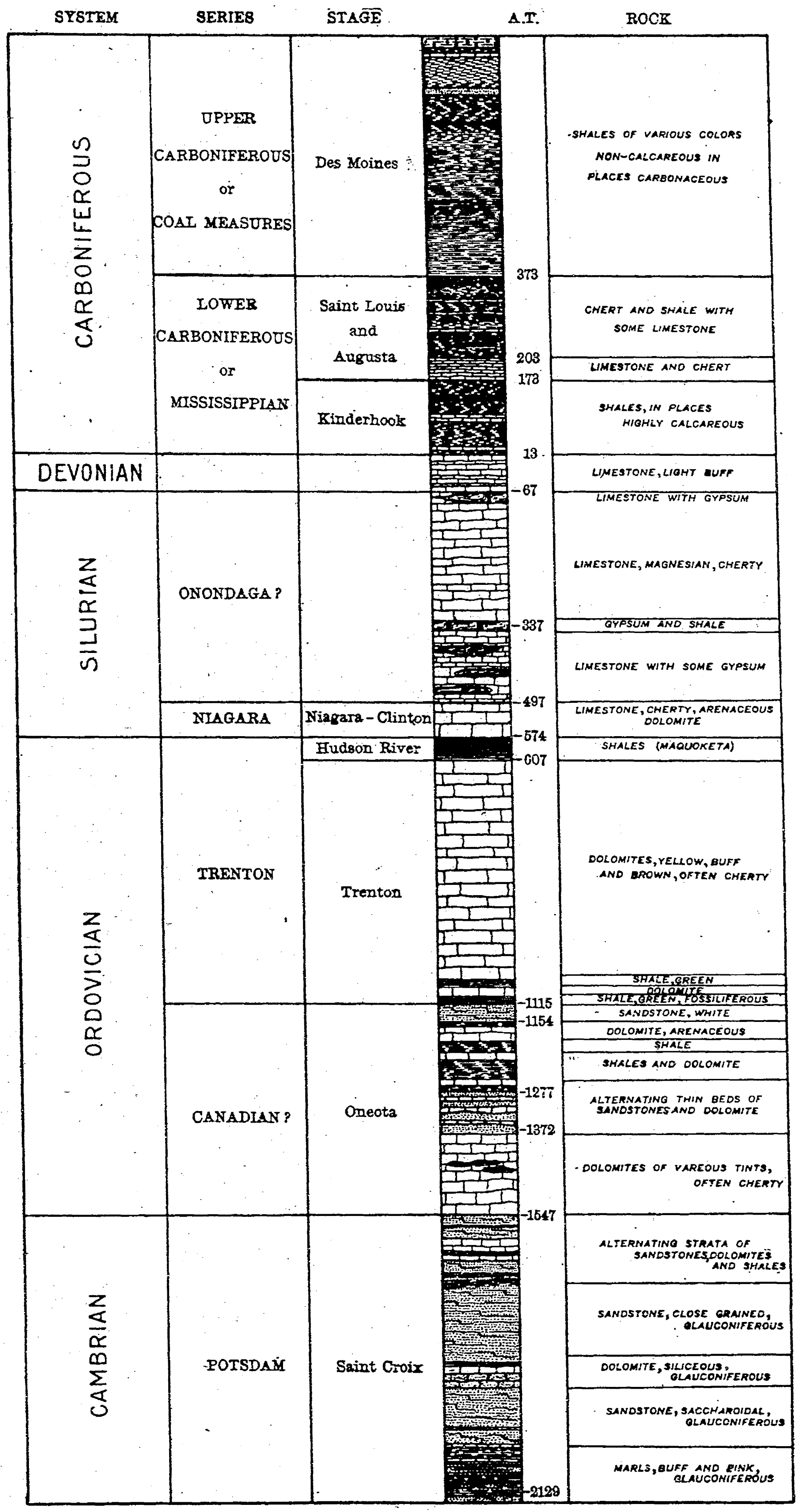
CARBONIFEROUS.

UNDERLYING FORMATIONS.

No formations lower than the coal measures are exposed within the county. The nearest outcrops of the next underlying strata, the Saint Louis limestone, occur in Story county on the north and Marion county to the southeast. The rocks still lower, outcrop in regular sequence to the northeast. Some deep boring has been done within the county so that we know a little of these underlying beds. The Greenwood park well, recently completed, was carried to a depth of 3,000 feet. Samples of the drillings were carefully preserved by Mr. E. Van Hyning and were studied by Prof. W. H. Norton of this survey. The record of this well with Professor Norton's correlations is given below.

GREENWOOD PARK WELL.

	RECORD OF STRATA.	THICKNESS.	DEPTH.
78.	Till, buff, sandy with a few pebbles, non-calcareous	14	14
77.	Shale, black, brittle, carbonaceous	1	15



GREENWOOD PARK (DES MOINES) WELL.

RECORD OF STRATA.	THICKNESS.	DEPTH.
76. Shale, gray "fossiliferous"	1	16
75. Shale, black, carbonaceous, calcareous, highly pyritiferous	3	19
74. Shale, gray	4	23
73. Shale and limestone, bluish gray, highly fossiliferous	15	38
72. Shale, varicolored	67	105
71. Shale, bluish gray, highly and finely arenaceous, hard	10	115
70. Shale, bluish gray, slightly calcareous	60	175
69. Shale, dark drab and black, carbonaceous	11	186
68. Shales, gray, drab and purplish, practically non-calcareous, one foot of gray chert at 284 feet	292	198 (?)
67. Shale with chert, heavy bed, very hard to drill. The most of the sample is an argillo-calcareous powder of 250°; 34° remain after washing as sand of white chert, flint and limestone. Of this residue 8° are soluble in acid. Of the 216° washed out as powder 62° are soluble in acid. The shale is reported as caving in from above, but its calcareous nature indicates that it is in part interstratified with chert and limestone	170	668
66. Limestone and chert, brownish gray	30	698
65. Shale, light blue and gray	40	738
64. Shale, terra cotta red, highly calcareous	10	748
63. Shale, light blue, gray	25	773
62. Shale, light gray, highly calcareous, fine cherty residue	85	858
61. Limestone, light buff, with much gray chert	80	938
60. Limestone, light blue, gray, crystalline, saccharoidal, effervescence slow, with considerable white gypsum	20	958
59. Limestone, cherty, crystalline, blue-gray, effervescence moderately rapid	53	1011
58. Limestone, cherty, crystalline, saccharoidal, dark blue, gray and buff, effervescence indicates magnesian limestone, but not dolomites	197	1208

	RECORD OF STRATA.	THICKNESS.	DEPTH.
57.	Gypsum and shale, gypsum gray and white in flakes, shale green, perhaps from above	15	1223
56.	Limestone, light blue, gray, highly seleniferous, with some flakes of gypsum	145	1368
55.	Limestone, cherty, arenaceous, grains of sand minutely rounded, much shale in rounded fragments, perhaps from above	22	1390
54.	Dolomite, buff, crystalline, granular, with much chert and some chalcedonic silica, three samples	55	1445
53.	Shales in large fragments, purplish yellow and green, non-calcareous, finely laminated, gritty	33	1478
52.	Dolomite, in yellow gray powder, cherty	260	1738
51.	Dolomites, yellow, buff and brown, mostly cherty and residue finely quartzose, five samples	155	1938
50.	Shale, green, very slightly calcareous	8	1946
49.	Dolomite, brown, arenaceous	30	1976
48.	Shale, dark green, hard, "fossiliferous," practically non-calcareous	10	1986
47.	Sandstone, fine white grains moderately well rounded	39	2025
46.	Shale, drillings consist of greenish powder of dolomite chert, fine quartz sand, green shale and pynte	7	2032
45.	Dolomite, arenaceous and cherty	30	2062
44.	Shale, drab, calcareous in part, finest powder containing grains of buff cherty dolomite	23	2085
43.	Dolomite, gray	5	2090
42.	Dolomite, same with minute rounded vesicles resembling matrix of oölite from which grains have been dissolved	5	2095
41.	Dolomite	5	2100
40.	Shale, as No. 44, exceedingly hard to drill	4	2140
39.	Dolomite, arenaceous, gray, two samples	8	2148
38.	Shale, drab, calcareous	6	2154
37.	Sandstone, white, fine, calciferous	10	2164

RECORD OF STRATA.	THICKNESS.	DEPTH.
36. Dolomite, buff	7	2172
34. Sandstone, clean white quartz and grains rounded	10	2182
33. Dolomite, buff	15	2197
32. Sandstone, buff, grains broken, with much dolomite	11	2208
31. Sandstone, friable, white, fine	2	2210
30. Shale, drab, slightly calcareous	4	2214
29. Sandstone, white	5	2219
28. Dolomite, buff, white, much quartz sand	3	2222
27. Shale	2	2224
26. Sandstone, gray and buff, calcareous, grains largely broken	14	2238
25. Shale, light blue	5	2243
24. Dolomites of various tints, often cherty, argillaceous at 2250, 2272, 2333, 2340, arenaceous at 2270 and 2333; at 2305 there are 17 feet of chert of various colors, white, blue and green; 32 samples	175	2418
23. Sandstone, white, fine-grained, mostly rough surfaced, with some dolomite.	12	2430
22. Dolomite, brown, in chips	2	2432
21. Sandstone at 2455	4	2436
20. Dolomite, rough, gray and brown	4	2440
19. Sandstone, fine, white and reddish, three samples	12	2452
18. Shale, light blue, gray	2	2454
17. Sandstone, calciferous, buff	4	2458
16. Dolomite, arenaceous, gray, buff and brown, six samples	30	2488
15. Shale, light blue, gray	10	2498
14. Dolomite, gray and buff, quartziferous	9	2507
13. Sandstone, gray, fine, calciferous	27	2534
12. Marl, highly quartzose, dolomitic, argillaceous yellowish powder, two samples	19	2553
11. Sandstone, calciferous, gray and white, three samples	12	2565
10. Sandstone, in sand and small chips resembling superficially dolomite, calciferous, glauconite, close grained, grains white, gray and buff, ten samples	145	2710

RECORD OF STRATA.	THICKNESS.	DEPTH.
9. Shale and dolomite, shale hard, dark bright green slaty Dolomite white, highly siliceous, with much greenish translucent amorphous silica. Two samples of the second; over one-half the weight of the sample is soluble in acid	20	2730
8. Sandstone, buff in color, in powder, glauconiferous. This rock is termed sandstone although composed chiefly of light colored partings of impure cryptocrystalline silica which effervesces freely in acid; fragments of crystalline quartz form but a small proportion of the drillings	20	2750
7. Sandstone, saccharoidal, dark, with purplish tinge, dark color owing to numerous grains of glauconite, purplish tinge to ferruginous stains on quartz sand; sand grains rough surfaced, imperfectly rounded, many fractured of crystalline silica	130	2880
6. Dolomite, dark gray-greenish tinge, macrocrystalline, glauconiferous, sparingly arenaceous	5	2885
5. Sandstone, greenish, grains microscopic	5	2890
4. Shale, dull gray, fine grains and exceedingly finely laminated	5	2895
3. Sandstone, glauconiferous, calciferous, grains imperfectly rounded, with hard dark green slaty shale	15	2910
2. Marl in buff flour, microscopically arenaceous, calciferous, glauconiferous	50	2960
1. Marl, pink, calciferous, arenaceous, one-third of drillings by weight insoluble in acid, to bottom of well	40	3000

SUMMARY.

NOS.	FORMATIONS.	THICKNESS.	DEPTH.	A. T.
78	Pleistocene	14	14	858
68-78	Des Moines	484	498	374
66-67	Mississippian	200	698	174
62-65	Kinderhook	160	858	14
61	Devonian	80	938	-66
54-60	Silurian (upper)	507	1,445	-573
53	Maquoketa	33	1,478	-606
48-52	Galena-Trenton	508	1,986	-1,114
47	Saint Peter	39	2,025	-1,153
39-46	Upper Oneota	124	2,149	-1,277
25-38	New Richmond	94	2,243	-1,371
24	Lower Oneota	175	2,418	-1,546
8-23	Saint Croix	332	2,750	-1,878
1-7	Basal sandstone	250	3,000	-2,128

BASE OF THE COAL MEASURES.

At Mitchellville, with an altitude of about 976 feet, a boring put down to a depth of 264 feet* passed through forty feet of material which probably belongs to the Saint Louis. This would make the altitude of the base of the Saint Louis about 760 feet at this point. In borings made upon the river bottom near Carbondale, the Saint Louis was reached at about 200 feet below the river, or at about 600 feet A. T. At Valley Junction the limestone is said to have been found at about the same level, while south of Millman one boring, if properly interpreted, would bring it still nearer the surface. In the Greenwood Park well the coal measures were found to extend to a depth of 498 feet, or to altitude 374. At Commerce, on the other hand, Saint Louis lies at least 550 feet below the surface, or about 300 feet A. T.

While a certain amount of doubt is attached to some of these borings, and it is impossible to verify them at this date, it is believed that the underlying limestone will be found to exhibit in this region the same irregular surface which it shows farther east in its area of outcrop. Indeed the differences shown by the borings are even greater than those known to occur elsewhere.

*Second Bien. Rept. State Mine Inspector, p. 115. Des Moines, 1885.

The Greenwood Park drillings were carefully collected and studied and the record is believed to be especially trustworthy, despite the fact that it shows certain exceptions to the stratigraphy of the region. The well shows no coal, though situated not far from mines now producing and very near to points at which coal has been mined. As will be seen later, however, this fact is not a matter of so much surprise, as barren holes are frequently put down in the midst of productive coal fields, particularly in the Iowa-Missouri region.

GENERAL CHARACTER OF THE COAL MEASURES.

The coal measures of Polk county belong to the stage which the survey has called the Des Moines formation. When first studied by Owen* and later by Worthen,† no attempt was made to divide the coal measures. White‡ considered them to be made up of three formations which he called Lower, Middle and Upper Coal Measures. The beds of the southwestern portion of Polk county were assigned to the middle division, while those underlying the remainder of the county were put in the lower division. Keyes§ has divided the series into two terrains, the Missourian and the Des Moines, and more recently has considered the two divisions to be independent series.‖ It is the Des Moines, or lower stage, which is represented in Polk county.

The beds which have been included under the name Des Moines formation form a complex of shales, sandstones and coals, with a few thin limestones intercalated. Their variety is quite well shown in the following general section of the Carboniferous strata found above the water level in the vicinity of Des Moines.

		FEET.	INCHES.
18.	Variegated clay shales	13	
17.	Blue limestone, nodular, impure, weathering brown, fossiliferous		8
16.	Variegated shales	8	

*Owen: Geol. Surv. Mo., Iowa and Minn., p. 121. 1852.
†Worthen: Geol. Iowa, vol. I, p. 171. 1858.
‡White: Geol. Iowa, vol. I, p. 231. 1870.
§Keyes: Iowa Geol. Surv., vol. I, p 85. 1893.
‖Am. Jour. Sci. (4), vol. II, pp. 211-225. 1896.

		Feet.	Inches.
15.	Bituminous shale, with concretionary calcareous masses below, fossil-bearing	3	
14.	Coal	2	
13.	Light yellow and drab shale	7	
12.	Variegated clay shale	4	
11.	Limestone		8
10.	Shales, variegated, clayey	4	
9.	Limestone, nodular, earthy, passing in places into marl, highly fossiliferous		6
8.	Clay shale, light colored	5	
7.	Sandstone, soft, micaceous, becoming in places an arenaceous shale	20	
6.	Shale, clayey, gray, yellow and red in color	8	
5.	Sand rock, grayish, soft	4	
4.	Coal, impure, divided in places into three thin seams, varying considerably in thickness	2	
3.	Shale, light gray, fissile	5	
2.	Shale, light to dark gray, micaceous below, bituminous above	6	
1.	Shale, white, siliceous	10	

Nos. 1 to 7 inclusive are shown at the pit of the Iowa Pipe & Tile Co.; Nos. 7 to 12 are exposed at the south end of Capitol Hill; Nos. 12 to 18 are shown in street cuttings and clay pits in the northwestern portion of Des Moines.

As will be seen, the shales are predominant, and exhibit many facies. Details of their lithological characters are shown in the sections later described and are noted in the descriptions of the brick pits. There are three fairly well defined types. The more common perhaps is the argillaceous phase. This shale varies widely in color, showing shades of red, blue, green and yellow. It is in the main a clay, and may or may not show the shaly partings often considered the distinguishing feature of shales. The absence of these partings is often a matter of weathering, as shown by their greater prominence at fresh exposures.

At certain points argillaceous shale grades directly into the clay found under coal seams and commonly known as fire clay. The suggestion, of course, is that the change here was due to weathering, and that loss of structure was one of the steps in the process of change from shale to soil. If we are to believe that each coal seam rested upon a soil, this might be the correct explanation, and probably is in some cases. Many coal seams, however, do not rest upon soils or anything of the nature of soils, and it seems not unlikely that the closeness of the relations between the coal and its

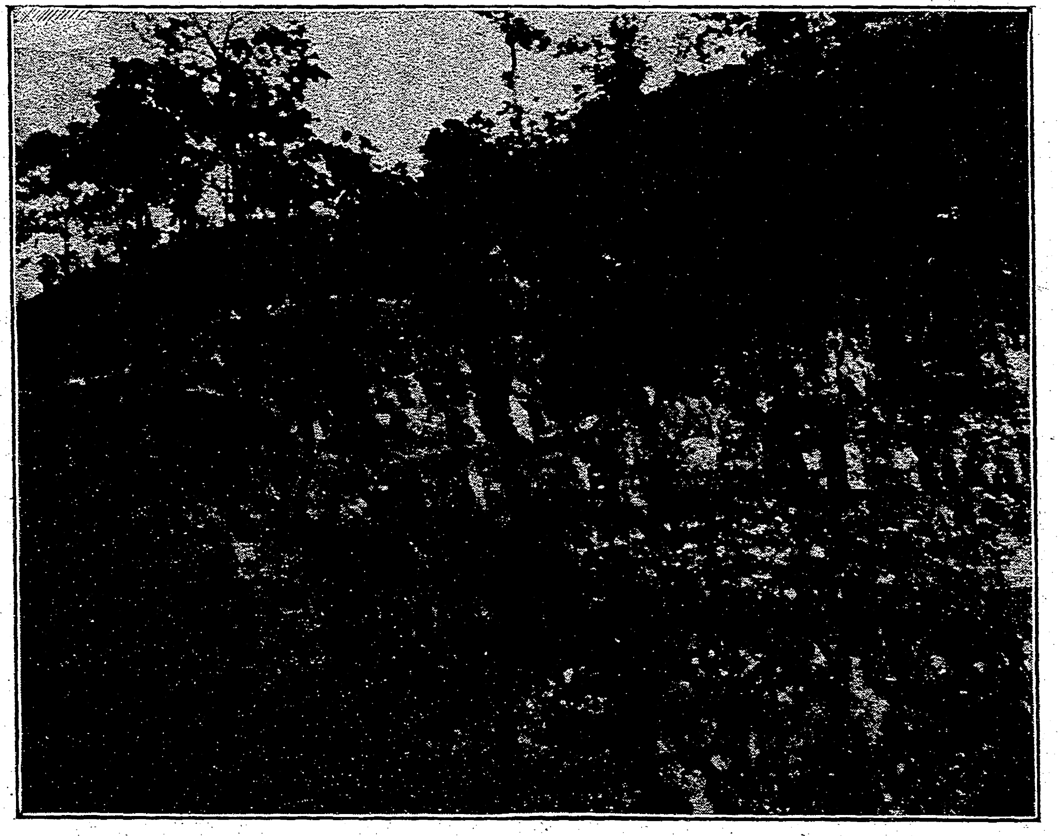


FIG. 44. Clay shales in the pit of Newman Bros. Brick Co., near Hastie.

underlying fire clay has been too much insisted upon. The presence of considerable bodies of loess showing no lamination whatever, in such situations and under such conditions that its origin by aqueous deposition can not be doubted, may be taken as evidence that lamination is not a necessary characteristic of sedimentary beds, and it may reasonably be maintained that much of the non-laminated material forming the so-called fire clays of the coal measures was originally deposited in its present condition. This explanation is in accord with the fact that analyses and physical tests of many of these clays show that they have not passed through the process of leaching by which others have lost their percentage of fluxing impurities, lime, magnesia, iron oxide and alkalies. This is quite commonly true of the so-called fire clays of the coal measures. The main mass of the argillaceous material shows, however, a distinct shaly structure. This is probably the expression of cleavage developed parallel to bedding. The sedimentary lamination may be quite fine but is frequently the opposite. It is shown in perhaps average character in figure 44, a detail from the pit of the Newman Brothers Brick Co. near Hastie. It may be seen equally well in any of the large clay pits near Des Moines.

The argillaceous shale passes by insensible gradations into sandy shales and this again into well defined sandstone. This transition is excellently shown along the railway track at the foot of Capitol Hill. Sandy shales are common throughout the coal measures. They are frequently of considerable thickness and lateral extent, and they exhibit most intimate relations with the great body of the argillaceous shale. They are in marked contrast with the sandstones into which they grade, in that the latter occur over narrow limits usually in sharply defined bodies. The shale gives long gentle erosion slopes. The sandstone yields narrow tortuous ravines with steep sides. Within Polk county the silicia is usually disseminated throughout the shales. Sandstones are relatively rare. In the southeast portion of the area is the Ford sandstone. On the north of the river between Runnells and Adelphi thinner sandstone beds are encountered at several points, and borings on the upland north of Morgan Valley shows sandstone common in the region. At the foot of Capitol Hill is the sandstone shown in figure 45 which, passing over the anticline at the Center street dam is seen at Thompsons bend and again near the Sixth street bridge at the locality long known as the Devils Gap. Across the river a sandstone, probably of the same horizon, is frequently struck in wells at Highland Park. East of this point, and across the old valley already described, sandstone is frequently encountered near the surface in the ridge between the old river valley and that of Four Mile creek. A thin sandstone occurs immediately under the drift at the Saylorville mine, and heavy sandstone ledges outcrop along the south side of the Des Moines immediately below

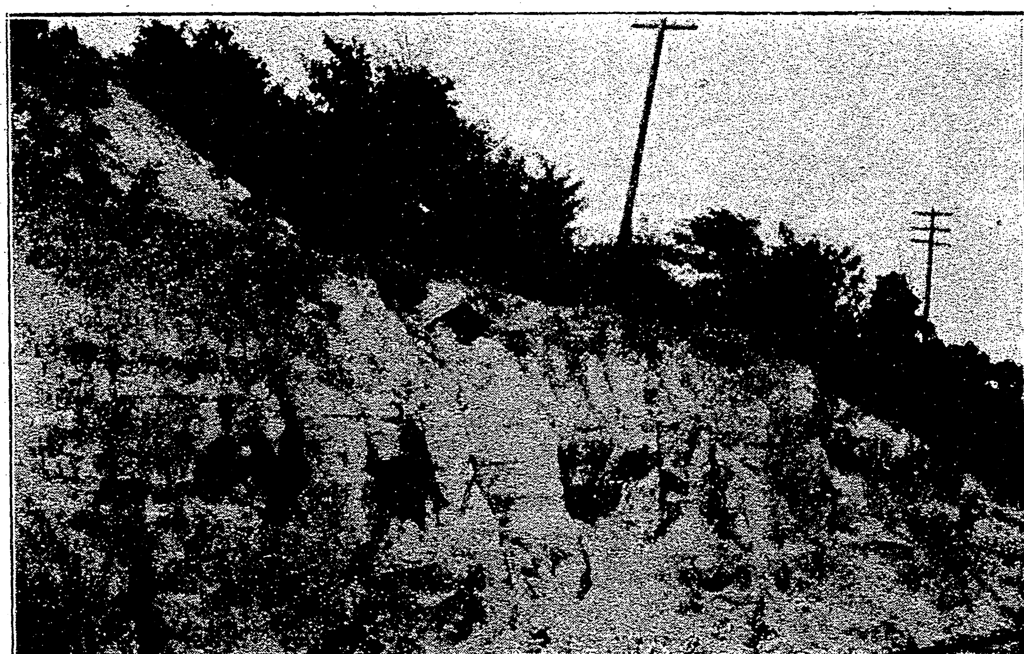


FIG. 45. Sandstone at the foot of Capitol Hill.

the mouth of Beaver creek. South of the river thin sandstones occur near the old Eclipse mine and south of Commerce. Nowhere, however, are there any massive sandstone deposits comparable to those found at Red Rock, in Marion county, and at many other points in the state. The sandstones present are essentially local in distribution, and while the Capitol Hill, Thompsons bend, Devils Gap and probably Beaver creek sandstones not improbably belong to the same horizon, their correlation is made upon other grounds than their lithological identity and proximity.

The third phase of shale is that exhibited in the bituminous facies. This is black, usually shows well developed cleavage parallel to the bedding, frequently contains a considerable amount of coaly material, and passes by gradation through "black jack" to coal. It is closely connected genetically with coal and frequently occurs directly over coal seams. For this reason it is considered a hopeful sign by prospectors and is eagerly sought. It occurs, however, not rarely where no coal seam is present, or where the latter, though present, is not workable, so that it is far from being a reliable guide.

Bituminous shale usually contains a certain percentage of both lime and iron. In some instances these assume undue proportions and the result is the formation of clay-ironstone, a low carbonate iron ore known usually to the miners as "nigger heads." These clay-ironstone masses occur in the coal, along the horizon between the coal and the overlying shale or slate, and up in the latter. They frequently cause considerable trouble in mining, though at other times when the material is disposed in the form of a sheet rather than a lenticular mass they make an excellent roof.

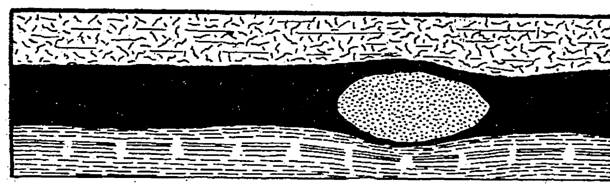


FIG. 46. Ironstone mass in coal bed of Bloomfield mine, Des Moines.

These clay-ironstones have been found in several of the mines and were quite well shown in the old Bloomfield mine on the south side.* As seen here they varied in size from horizontal dimensions of a few inches up to ten or twelve feet. In thickness some were as much as six feet. An analysis of similar material from a mine in Mahaska county showed the presence of about 88 per cent of limestone, with 8 per cent of organic matter and small percentages of iron oxides and sulphides. The rock is therefore essentially an impure limestone.

The bituminous shale also grades into that of the argillaceous type. It becomes less and less black and usually shows

*Keyes: Iowa Geol. Surv., vol. II, pp. 279-281. Des Moines, 1894.

a corresponding decrease in the perfection of the cleavage. This is well in accord with the fact that coal which has suffered much compression is finely laminated and splits easily. The bituminous shale often contains notable percentages of coal and has suffered corresponding diminution in bulk. Cleavage of the grade found here, which perhaps to some extent depends upon original lamination, is brought out by pressure and the changes due to it. The sandstones and sandy shales have suffered little compression, the clays and argillaceous shales more, the bituminous shales still more and the coal most of all. The cleavage increases in a corresponding order, the exceptions being certain clays probably not originally laminated, and coal where the chemical change has often been sogreat as to ob-scure the texture. The clay-ironstones have withstood the pressure, so where they occur in the coal the lamination planes of the latter bend round them as noted by Keyes.* In this they follow the law formulated by Van Hise,† that cleavage develops normal to the pressure, the latter being in this case normal to the surface of the ironstone mass which resisted compression. The phenomena is analogous to that of a bowlder of hard material in a squeezed conglomerate, and possibly the foliation sometimes observed in drift‡ may be explained by the same process.

In general throughout the shales the pressure is normal to the bedding and in the direction of gravity. While the results are slight, and in that particular correspond to the pressure, they seem to differ only in degree from the better developed phenomena known usually as cleavage. As defined by Van Hise, the phenomena of capacity to split into thin plates, so commonly seen in the bituminous and other shales of the coal measures and described in the previous reports of the Iowa Survey as fissility, falls rather under the definition of cleavage as seen above.

*Keyes: Iowa Geol. Surv., vol. II, p. 281. Des Moines, 1893.
†Prin. N. A. Pre-Camb. Geol., Sixteenth Ann. Rep. U. S. G. S., pt. i, p. 639. 1896.
‡Salisbury: Jour. Geol., vol. II, pp. 720, 721. Chicago, 1895.

The coal measures of Polk county contain a large number of coal horizons, along many of which workable coal is found. As developed at present, the productive portion of the Iowa coal field is largely in the neighborhood of the Des Moines river. In the counties southeast of Polk this is due to the outcrop of the basal or more productive portion of the Des Moines formation. These basal horizons are, however, buried to a considerable depth in Polk county and the coal mined comes from higher horizons. It is impossible to say exactly how many different horizons are represented in the different outcrops and boring records. It is also impossible to be sure in every case of the correlation of even neighboring outcrops. The coal measures are characterized by such rapid lithological transitions and such marked non-persistence of strata that the stratigraphy is exceedingly complex. In a drift covered region, without a topographic map, it is even more difficult to obtain results of more than approximate accuracy. The coal horizons themselves can not be used as bases of correlation except when careful checking is possible. A thick seam of coal at one point may be represented by a very thin seam, or by black shale, at another. Again the coal itself varies in altitude. In the old Eureka mine on the south side the coal went down twenty-four feet in a distance of 1,400 feet. In the Proctor there are variations of twenty to twenty-five feet in 225* feet.

This change in altitude of coal seams, or "rolling" as it is known among the miners, is usually accompanied by corresponding change in thickness; the coal thinning to the rise. It is a common feature throughout the Iowa field. It seems to be due to two conditions; first, it may result from an underlying unconformity, the irregular features of the underlying surface being faintly reproduced in the overlying coal seam; or second, it may be due to the presence of underlying coal.† There is abundant evidence that coal in the process of its formation suffers considerable diminution in bulk and in time

*Keyes: Op. cit., p. 279.

*Jour. Geol., vol. III, pp. 646-654. Chicago, 1895.

settles to a thickness of from one-tenth to one-sixteenth of that of the original mass of vegetal matter. This settling would under favorable circumstances show itself in the formation of a basin above, the basin in turn giving favorable conditions for coal formation. The formation of one coal seam thus opens the way for the formation of a second after such a time as would allow the accumulation of sufficient material to afford effective pressure. Where a coal seam is found under such conditions it should show in the upper bed the inequalities of the lower, and it is a suggestive fact that in the old Eureka mine when two seams were worked, this was found to be true. It must not, however, be considered as necessarily true that when two seams are found they fit together in this manner. In the Keb mine of the

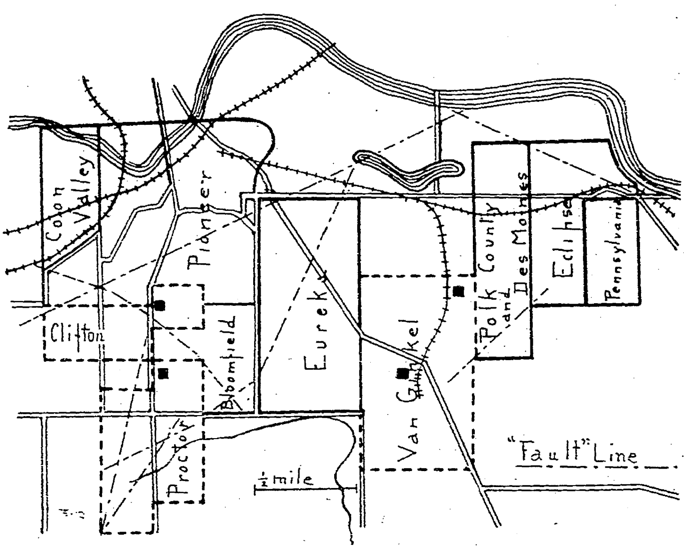


FIG. 47. Coal leases and "fault lines" in South Des Moines.

Whitebreast Fuel Co. at Ottumwa, there are two seams in which the thin parts of the upper overlie the thicker portions of the lower seam. In this case the two beds are only separated by a few feet of intervening strata, and it is possible that the amount of pressure due to the superincumbent material was not sufficient to be effective at the time of the formation of the second seam.

In the mines south of the river at Des Moines the rolling of the coal is a constant factor. The thinning of the beds is also common. The field is divided up into a number of smaller areas by a series of what are known as faults by the miners. With one exception these are probably not true faults in the sense in which the term is used by a geologist. They do not, so far as known, mark lines of disturbance. The coal rises towards them on both sides and thins in the same direction, so that they seem rather to mark the original dividing lines between separate coal basins rather than lines of subsequent fracture. Since many of themines are now closed and in others the faults cannot now be examined this cannot be positively stated, and their distribution as shown on the sketch map may not be quite accurate though the map is made from the best obtainable information.

If, however, their origin be that surmised, the explanation of the fact that in no case was the coal found by drifting is easy. The limits of that particular basin had been reached in that direction. The presence, however, of a similar basin at about the same general level a short distance away is exactly what would be expected, so that the field as a whole shows a typical development of a coal horizon.

The exception among these fault lines is the one found east of the Coon Valley mines. From descriptions given by men who examined this, it seems to have been a true fault. If, however, this be the case, and there is some independent evidence favoring such an hypothesis, the throw is slight and the region affected is limited. An examination of the section from Capitol hill to Walnut creek indicates that within narrow limits the beds have suffered no disturbance.

The limestones of the coal measures are not prominent in the lower portion of the Des Moines terrain. In Polk county a few thin limestone bands alone outcrop. These rarely attain a thickness of so much as a foot. Their importance is, however, quite out of proportion to their thickness since they form such excellent stratigraphic horizons. In the vicinity of Des Moines there are at least three persistent limestone bands which afford the means of definitely correlating many of the exposures. Their use is seen in the sections which follow.

GENERAL CROSS-SECTIONS.

It is not possible at this time to present detailed sections across the entire county which would be of any value. Sections starting from Capitol Hill have been made north of the mouth of Beaver creek and west as far as Walnut creek. These sections were possible because of the presence of the thin limestones mentioned above. In the remainder of the county it is not felt that the data are of such value as to permit the exact form of statement given by a section.

SECTION FROM CAPITOL HILL TO THE MOUTH OF BEAVER CREEK.

The exposures along the Des Moines river from the mouth of the Raccoon to the mouth of Beaver are quite numerous and are typical for the region. At Capitol Hill the following excellent section may be made out.

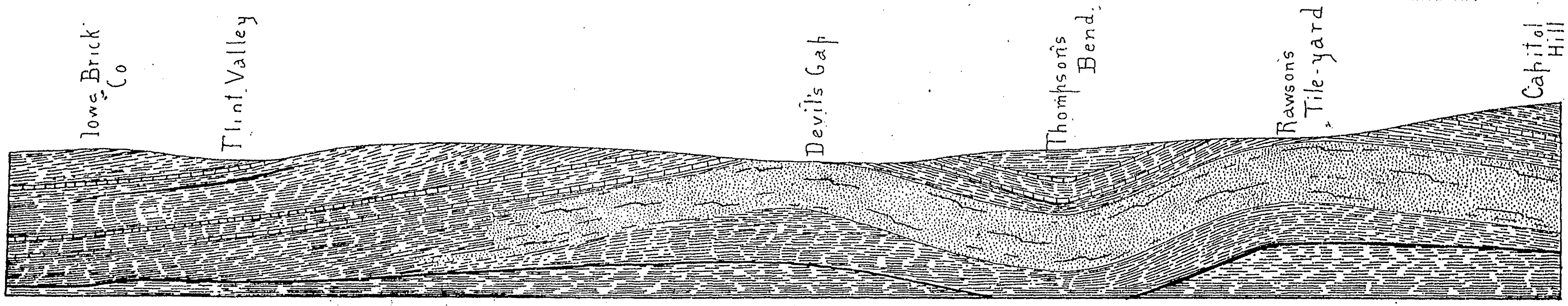
CAPITOL HILL SECTION.

		FEET.	INCHES.
11.	Variegated clay shales	25	
10.	Limestone		8
9.	Light gray to drab shale	4	
8.	Limestone		6
7.	Light gray shales	5	
6.	Sandstone, irregularly bedded, well exposed along the railway tracks at the foot of the hill	25	
5.	Shale, light gray	2	
4.	Coal	2	
3.	Shale, sandy	3	
2.	Coal		3
1.	Shales, light gray	2	

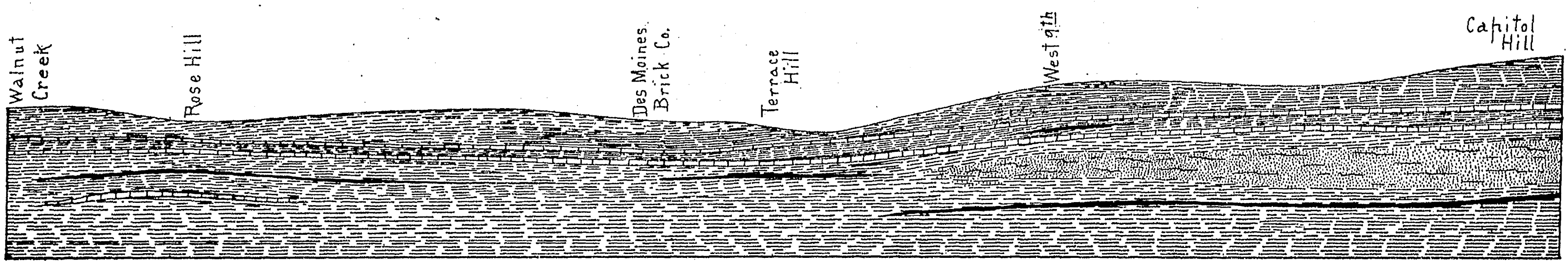
Numbers 1 and 5 are well shown at the east end of the exposure, but the rather unusually pronounced dip to the southwest carries them below the level of the railway track east of Ninth street.

TILE YARD SECTION.

At the east front of the hill, in the pit of the Iowa Pipe & Tile Co., the following excellent section is exposed.



GEOLOGICAL SECTION FROM CAPITOL HILL TO THE MOUTH OF BEAVER CREEK.



GEOLOGICAL SECTION FROM CAPITOL HILL TO WALNUT CREEK.

		Feet.
9.	Shale, argillaceous, yellow	20
8.	Shale, clayey, gray, yellow and red in color	8
7.	Sandrock, gray, soft	4
6.	Shale, black, in part clayey	1½
5.	Sandrock, gray	4
4.	Coal, impure, shaley	1½
3.	Shale, light gray	5
2.	Shale, light gray to dark	6
1.	Shale, white, siliceous	10

Number 9 of this section may be correlated with number 6

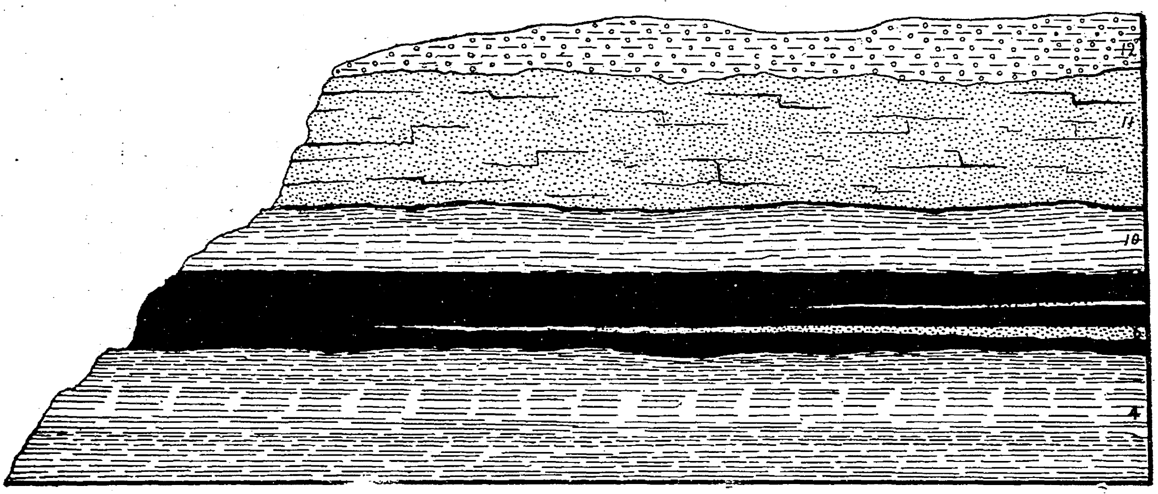


FIG. 48. Bluff on Des Moines river above milldam, at city of Des Moines. Shows coal seam separated by sand bands.

of the preceding. Above it in the hill numbers 8 and 10 of the Capitol Hill section are found at the correct level.

Across the river from the exposure just given is a better section, showing the coal bed divided into three parts. The dip is to the north and the three parts of the coal seam come together, the intervening sandstone partings wedging out as shown in the figure.

		Feet.	Inches.
12.	Drift	6	
11	Sandstone, soft, micaceous, buff in color, massive in places	10	
10.	Clay shales, light colored	5	
9.	Coal	2	6
8.	Sand, loose		6
7.	Coal	1	6

		FEET.	INCHES.
6.	Sandstone, massive, fine grained	2	
5.	Coal	1	
4	Clay shale, yellow and blue in color	10	
3.	Clay shale, dark drab in color	4	
2.	Shale, somewhat sandy	5	
1.	Shale, black, bituminous (exposed)	8	

The relations between these two exposures are seen in figure 49, representing a section across the river at the dam.

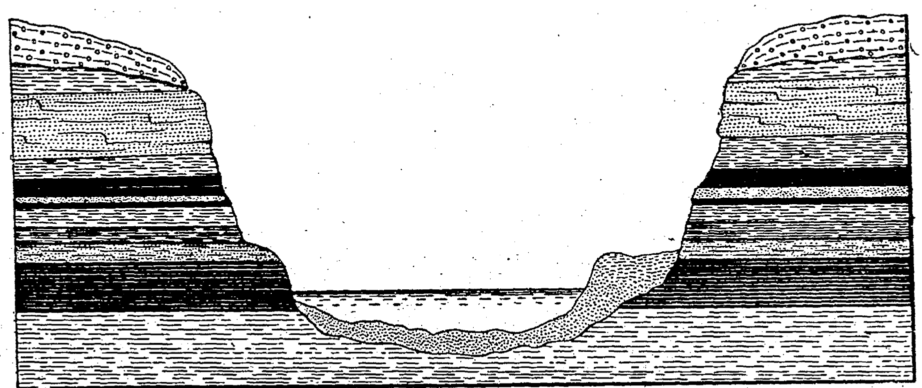


FIG. 49. Gorge of Des Moines river at city of Des Moines.

The heavy dip north carries the coal down to the water level at Thompsons bend. It is here a good workable seam and has been opened up from time to time by means of drifts.

Towards the west the strata rise a little from Thompsons bend to Sixth avenue where the coal was formerly worked by drifting. In this vicinity at the point known as the Devils Gap is the following exposure.

DEVILS GAP SECTION.

		FEET.
4.	Sandstone, yellow, massive	15
3.	Shales, variegated	2½
2.	Shales, light, sandy	15
1.	Hidden to river, with talus of coal and sandstone	20

The sandstone seen here is probably number 9 of the Rawson section. In the clay pits of the Flint Brick Co. and at neignboring exposures the strata exposed are as follows.

		FEET.	INCHES.
13.	Light colored clay shales	10	
12.	Limestone		8
11.	Green and yellow clay shale	5	
10	Bituminous shale	2	
9.	Purple and variegated shale	4	
8.	Yellow and white sandy clay	4	
7.	Limestone		8
6	Light colored clays	6	
5	Limestone		10
4.	Massive variegated clays and shale	20	
3.	Sandstone	1	
2.	Coal	3	
1.	Shales, drab	5	

Numbers 5 to 6 correspond to Nos. 8 to 10 of the Capitol Hill section. The other numbers are readily correlated.

Opposite Flint valley corresponding beds are shown at the pit of the Iowa Brick Co. and were found in the shaft of the Eagle Coal Co. The record of the latter is given below.

EAGLE COAL SHAFT.

		FEET.	INCHES.
27.	Drift	14	10
26.	Red sandstone		8
25.	Red shale	3	
24.	Blue shale	11	7
23	Red and variegated shale	2	4
22.	Gray shale	4	8
21.	Coal	1	4
20.	Sandy shale	2	4
19.	Brown rock, hard		8
18.	Shale, sandy, light colored, hard	6	
17.	Blue shale	3	8
16.	Dark shale	2	6
15.	Light, sandy shale	31	4
14.	Hard rock	2	8
13.	Light shale, with hard bands	2	
12.	Light shale	3	
11.	Variegated shale	2	3
10.	Hard rock		6
9.	Coal, traces	4	
8.	Black shale	11	6
7.	Coal		9
6.	Light shale	2	7
5.	Dark shale	3	
4	Black shale	14	5
3.	Cap rock	1	5
2.	Coal	4	7
1.	Fire clay	6	

Number 21 is to be correlated with number 2 of the preceding section. Beyond the Eagle mine are the two Keystone shafts and that of the West Riverside Coal Co., all of which reach the same coal horizon. Between the West Riverside mine and the mouth of Beaver creek the bluffs show the presence of both sandstone and shale, but neither here nor on the opposite side of the river are the exposures of such character as to warrant definite correlation. Along Beaver creek there are practically no exposures of the underlying rock as would be expected from the history of that stream. The narrow gorge of the Des Moines shows many exposures of shale and thin beds of sandstone with a few coal outcrops, but the strata have so little to characterize them they yield nothing to stratigraphic study.

SECTION FROM CAPITOL HILL TO WALNUT CREEK

The beds found at Capitol Hill may, by means of the limestones present, be readily correlated with those on the south side of the river. These are quite well exposed at the south end of the West Ninth street bridge, where the following beds may be seen beneath the drift.

		FEET.
8.	Shales, light gray	6
7.	Limestone	½
6	Brown sandy shales	5
5.	Dark drab shales	2
4.	Light shale	1½
3.	Limestone	1
2.	Light colored shales	10
1.	Shaly sandstones	6

The base of this section is the Chicago Great Western railway track, which is here forty feet above the river. The upper limestone, number 7, is fifty feet below the mouth of the Clifton mine on the hill. The Pioneer mine was located near this point, the "third" vein being found at a depth of 150 feet. On top of the hill, south of the section just described, is the Clifton shaft.

CLIFTON SHAFT RECORD.

		Feet.	Inches.
42.	Drift	11	
41.	Soft sandstone	2	
40.	Clay shale	9	
39.	Limestone		8
38.	Clay shale	8	
37.	Limestone		9
36.	Clay shale	5	
35.	Black shale	2	
34.	Coal		10
33.	Fire clay	2	
32.	Hard sandstone	3	
31.	Soft sandstone	3	
30.	Fire clay	3	
29.	Clay shale	12	
28.	Black shale	6	
27.	Coal	2	
26.	Fire clay	6	
25.	Sandstone	9	
24	Fire clay	6	
23.	Brown shale	2	
22.	Coal	1	11
21.	Fire clay	16	
20.	Hard sandstone	6	
19.	Fire clay	8	
18.	Clay shale	4	
17.	Coal	6	
16.	Fire clay	13	
15.	Shale, black	10	
14.	Limestone		10
13.	Shale, black	3	
12.	Coal, impure	3	
11.	Rock		3
10.	Coal	2	3
9.	Fire clay	8	
8.	Sandstone	2	
7.	Black shale	5	
6.	Sandstone	3	
5.	Black shale	5	
4.	Coal	1	8
3.	Fire clay	4	
2.	Black shale	10	
1.	Coal	5	6

The elevation of this shaft is about 890 A. T. The section cannot be exactly correlated with others in the vicinity though numbers 37 and 39 may represent the two limestones which, near the bridge, lie thirty feet lower. The coal of the Pioneer mine is believed to have belonged to the horizons now worked in the Clifton mine.

The beds seen at the Ninth street bridge are again exposed in the pit of the Capital City brick works a short distance southwest. The upper of the two limestones does not show in the pit but is seen in the following section.

CAPITOL CITY BRICK COMPANY.

		FEET.
5.	Shale, ash gray	6
4.	Limestone	$\frac{2}{3}$
3.	Shale, drab to yellowish	6
2.	Fire clay, purplish	4
1.	Shale, light gray	10

Opposite this pit is the section at the foot of Terrace hill, which is readily correlated with those already given.

TERRACE HILL SECTION.

		FEET.	INCHES.
9.	Shale, light colored; exposed	2	6
8.	Limestone, impure, nodular, weathering brown and containing fossils		8
7.	Shale, argillaceous, white and drab	5	
6.	Limestone, nodular, like number 8, but containing fewer fossils		8
5.	Shale, dark drab below, light colored above	4	
4.	Shale, bituminous, fissile, with coaly streaks	2	6
3.	Coal	3	
2.	Shale, light colored, somewhat sandy	6	
1.	Sandstone, somewhat shaly, concretionary in places, exposed above track level	6	

Still farther west in the pit of the Des Moines Brick Manufacturing Co. the same beds may be seen.

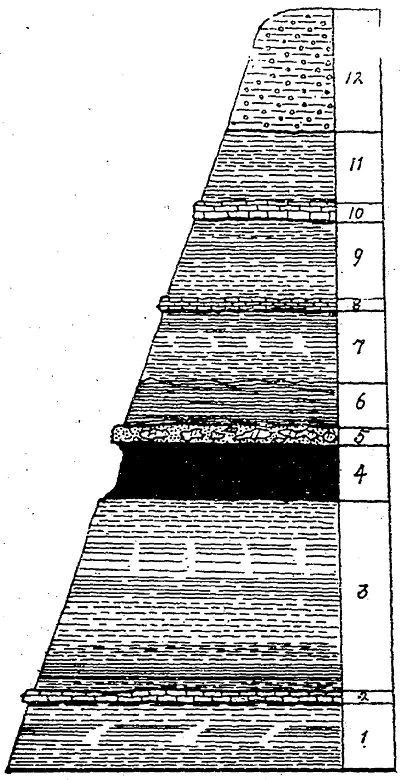
SECTION AT DES MOINES BRICK WORKS.

		FEET.	INCHES.
10.	Shale, variegated, with weathered band of limestone	7	
9.	Shale, dark gray	2	
8.	Shale, light gray	3	6
7.	Shale, impure, sandy	3	
6.	Limestone		7

		Feet.	Inches.
5.	Shale, dark gray, clayey	4	6
4.	Limestone		6
3.	Shale, dark and light gray	16	
2.	Sandstone, shaly	2	
1.	Shale, hard, siliceous	8	

The coal seen at the Terrace Hill section appears again at the usual horizon on the south side of the river near the old Rose Hill mine.

RAILWAY CUTTING NEAR ROSE HILL MINE.



		Feet.
12.	Drift	10
11.	Clay shales, red and drab, variegated	6
10.	Limestone, earthy, nodular	½
9.	Shales, variegated	5
8.	Limestone, impure, nodular	½
7.	Clay, yellow and drab, variegated	4
6.	Clay shale, dark drab, somewhat bituminous	2
5.	Ironstone, black, nodular	1
4.	Coal, impure	3
3.	Clay shale, hard, drab, somewhat sandy in places	15
2.	Limestone, nodular	1
1.	Clay shale, blue (exposed to track level)	6

FIG. 50. Railroad cutting near Rose Hill mine. Four miles west of Des Moines.

Below the base of this section, at a depth of seventy feet, the Rose Hill Coal Co. formerly mined a seam two to four feet in thickness. Near the mouth of Walnut creek (Tp. 78 N., R. XXV W., Sec. 11, Ne. qr., Se. ¼) beds corresponding to the last exposure may be made out.

		Feet.
13.	Red clay	3
12.	White sandy clay	3
11.	Sandstone	8
10.	Clay shale	1½

		FEET
9.	Limestone	½
8.	Dark drab clay shale	3
7.	Clay-ironstone	½
6.	Coal	2
5.	Fire clay	1
4.	Variegated clay shale	5
3.	Limestone	½
2.	Sandstone	8
1.	Clay, light colored	1

This section fails to show the upper of the two limestones exposed in the other sections. Its close resemblance, however, to the last preceding section leaves little doubt as to the correctness of the correlation of the outcrop.

Beyond Walnut creek the sections are not sufficiently numerous to warrant definite correlation of the outcrops.

DETAILED STRATIGRAPHY.

In discussing the stratigraphy of the coal measures of the county it will be convenient to consider individual districts separately. The divisions are of course quite arbitrary as the strata of each region are represented in the adjoining areas. Between the districts, however, it is not possible in all cases to make correlations with any degree of certainty. In some cases the same uncertainty obtains as to the correlations within the districts. The results obtained, however, are not thought to be valueless. They may be considered in each case as the expression of the greatest probabilities as shown by evidence now in hand. Later prospecting and further mining development will test them and make more definite stratigraphic correlation possible. Until the details are much better known, and this knowledge can only come as the results of work with the drill, general conclusions only are possible, and the correlations here made must be considered as working hypotheses only to be constantly checked and amended.

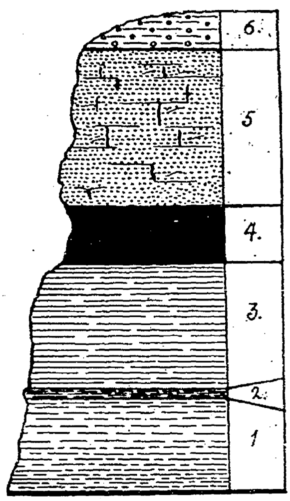
The term coal horizon is used here in the sense proposed by Keyes.* It does not mean a coal bed, but rather a strati-

*Jour. Geol., vol. II, pp. 178-186. Chicago, 1894. Iowa Geol. Surv., II, 168. Des Moines, 1894.

graphic horizon along which coal may be generally expected to occur. Coal is not found at all points along a coal horizon; nor is it found in equal thickness. The horizon does not maintain a constant level, entirely aside from any folding, or recent deformation. The coal may vary greatly as to thickness and position, and yet the general horizon is a marked stratigraphic feature, and is often constant for a considerable area, as will be seen in the following pages.

RUNNELLS-CARBONDALE DISTRICT.

The exposures along the Des Moines and its side ravines, taken together with the results of mining and prospecting, give quite full data throughout the district. About a mile east of Runnells a cutting along the Wabash railroad shows a coal seam as indicated below.



		FEET.
6.	Drift	4
5.	Sandstone, buff, heavily bedded	15
4.	Coal impure	4
3.	Clay, drab	10
2.	Shale, bituminous	1
1.	Shale, light colored, exposed	8

FIG. 51. Railroad cutting near east county line, below Runnells.

At Runnells the same coal seam outcrops and has been worked by slopes along the face of the bluff. More recently new mines have been opened back from the river, the coal being reached at a depth of forty feet. The coal has an average thickness of about three and a half to four feet. The related strata are better exposed across the river at Ford, where the bed has also been opened up by drifts. The Howell Coal Co. in working here found that the seam thinned down to six inches at one point, though elsewhere it was of normal thickness. At a point near by a section measured by Dr. Keyes* showed the horizon occupied by highly bituminous shale. His section is as follows:

		FEET.
9.	Drift and loess	10
8.	Light yellow sandstone, soft, heavily bedded above, thinly bedded below, with much clay	35
7.	Dark shale, highly bituminous in places, with hard concretionary layers	2
6.	Fire clay with sigillarid roots	¼
5.	Drab shales, somewhat sandy above	12
4.	White clay	3
3.	Soft sandstone, buff, heavily bedded	4
2.	White clay	4
1.	Sandy and clayey shales, exposed to water level	25

The sandstone of this section, number 8, is well exposed along the river for some distance, and has been called in the survey reports the Ford sandstone. It is not so well marked north of the river, though the corresponding horizon shows sandy shales with interbedded sandstone layers. Near Avon, where the Chicago, Rock Island & Pacific railway cuts off the nose of the bluffs north of North river, sandy shales, presumably of the same horizon, are exposed above the railway track. Below the sandstone the following section is shown by mining operations.

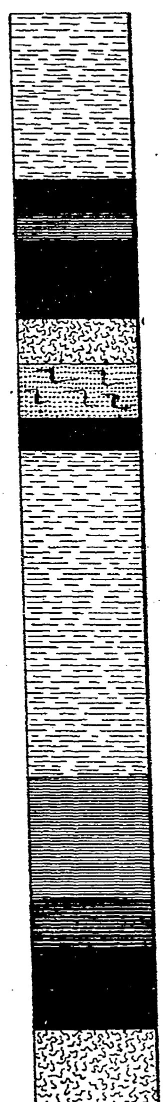
		FEET.
5.	Clay shales	5
4.	Coal, soft	1
3.	Sandstone, hard	1
2.	Shale, black	1
1.	Coal	3

Near here a boring was put down and no coal was found within forty feet of the horizon now worked. The elevation of the coal is about 800 A. T. It maintains the same elevation for a quarter of a mile, being reached by numerous drifts, in one of which the following section was measured.

		FEET.	INCHES.
6.	Shale, clayey, drab	2	
5.	Coal	1	8
4.	Clay	1	6
3.	Coal	1	3
2.	Fire clay	2	6
1.	Sandstone, in beds 3 to 8 inches thick	2	6

*Keyes: Iowa Geol. Surv., I, 97. Des Moines, 1893.

The coal is about on a level with the railway track. Toward the north the coal and sandstone rise till the latter is exposed to a thickness of ten feet, and underlying shales are seen. The dip on the north side of the anticline is slightly to the north, but mainly to the west, and is so pronounced as to carry the coal down to the old level, within 400 feet, where it has again been opened by drifting. The loess covers everything more or less, so that the relations are not well shown, but the sections in the drift mines and the pronounced dip to the west make them evident. Still farther north the coal maintains its usual level, as is shown by a series of abandoned drift mines. At the Manbeck mine, still farther north, the division in the coal seam becomes more pronounced. The general section at the mine is as follows.



		FEET.	INCHES.
12.	Shale, light colored above, bituminous below	6	
11.	Coal	1	3
10.	Clay, drab, carbonaceous, "clod"	1	
9.	Coal	3	
8.	Fire clay, light colored	1	5
7.	Sandstone, massive, yellow	2	
6.	Coal	1	2
5.	Fire clay and gray shale, "soapstone"	12	
4.	Shale, bituminous, hard and compact	3	
3.	Ironstone, irregular, nodular	1	8
2	Coal	3	4
1.	Fire clay	3	

FIG. 52. Part of shaft of Manbeck mine. North of Avon.

Numbers 9 and 11 seem to represent the Ford coal horizon. Number 6 not improbably also belongs with them.

Just north of the mine the railway makes a cut along the face of the hill. Here Keyes has measured the following section.

		FEET.	INCHES.
10.	Drift	6	
9.	Drab and brown clay, white in places, sandy above	6	
8.	Coal		8
7.	Sandstone, thin bedded	4	
6.	Clay, white, sandy	3	
5.	Sandstone, heavy bedded	5	
4.	Sandy shale	1	6
3.	Coal	1	4
2.	Drab clay, exposed	1	2
1.	Unexposed to water	25	

Number 3 of this may best be taken as representing number 11 of the preceding section.

Across the river from the Manbeck mine, at the location of the Newman Brothers brick plant, is a seam of coal marking the same horizon and represented in figure 53.

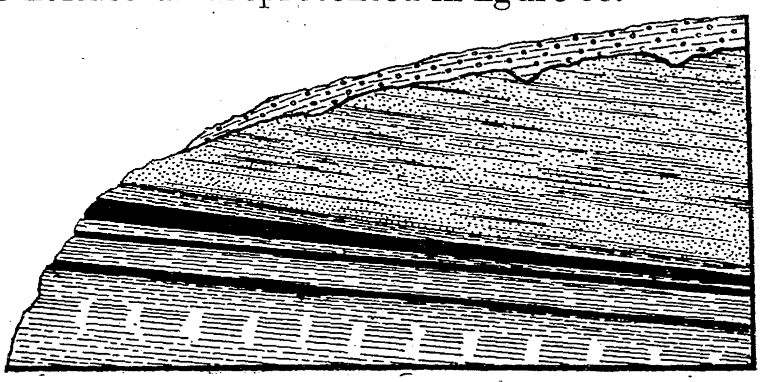


FIG. 53. Railroad cutting. One mile east of Hastie.

		FEET.	INCHES.
9.	Drift	4	
8.	Shale, sandy, yellow	30	
7.	Shale, bituminous	3	
6.	Coal	3	
5.	Clay, white and ash colored	2	
4.	Coal, impure		6
3.	Shale, yellow and white	4	
2.	Coal, impure		
1.	Shale, dark drab; exposed,	6	

The coal of this horizon was formerly worked by the Woodlawn Coal Co., by means of a drift. A higher seam with a thickness of twenty-eight inches is known to outcrop about thirty-five feet above its level. The mine of the Iowa Coal & Mining Co., located at the same place, shows a lower seam three to three and a half feet thick, lying about thirty-five feet below the Ford coal horizon. Still lower by an interval of twenty-five feet, a seam three feet eight inches thick occurs, and fifty-four feet below this a fifth horizon is marked by three inches of coal. At Hastie coal which would seem to represent this lower horizon four feet thick was formerly worked at a depth of 100 feet. The coal worked in the Carbondale mine seems to belong to the same horizon. A boring just put down near their new mine, number 2, showed the following strata.

		FEET.	INCHES.
21.	Soil	2	
20.	Marly clay	17	
19.	Sand and clay	3	
18.	Gray shale	39	5
17.	Sand rock and shale	3	9
16.	Limestone, white, brittle	1	10
15.	Shale, light blue	1	6
14.	Shale, sandy	8	4
13.	Shale, light blue	1	4
12.	Sandstone	1	6
11.	Shale, gray	2	
10.	Sandstone	3	4
9.	Sandy shale	12	9
8.	Gray shale	5	5
7.	Coal and blackjack	1	2
6.	Fire clay	1	8
5.	Gray shale	1	1
4.	Rock, hard, gray		7
3.	Rock, hard, blue	3	8
2.	Shale, black	3	
1.	Coal	4	4

This record was proved when the shaft was sunk. In section 10 (Tp. 78 N., R. XXIII, W.) a boring showed a slight difference. The record is as follows.

		FEET.	INCHES.
34.	Soil	4	
33.	Yellow clay	15	
32.	Sand and clay	23	
31.	Blue clay	4	
30.	Gray soapstone	5	
29.	Blue clay	39	
28.	Black shale	3	
27.	Sandstone	2	
26.	Gray shale	6	
25.	Black slate	1	6
24.	Coal		8
23.	Fire clay	3	
22	Gray soapstone	4	
21.	Black shale	22	
20.	Coal	4	
19.	Pyrites		6
18.	Fire clay	3	
17.	Soft sandstone	1	
16.	Shale, clayey, white	6	
15	Sandstone	1	6
14.	Shale, clayey, brown	2	6
13.	Shale, black	10	6
12.	Sandstone	1	6
11.	Shale, clayey, white	1	
10.	Sandstone, gray, hard	3	7
9.	Pyrites		1
8.	Shale, gray	19	
7.	Sandstone, hard	6	
6.	Shale, gray	13	
5.	Rock, hard	1	6
4.	Shale, black	2	6
3.	Pyrites		3
2.	Shale, black	2	
1.	Coal	4	9½

Number 1 in each record seems to represent the same horizon. Number 7 of the first apparently is not represented in the second, while numbers 20 and 24 of the latter are not represented at the shaft. In the same section with the last given boring a seam twenty-eight to thirty-two inches thick crops out along a ravine. It not improbably represents number 24 of the boring. A boring made in section 9 (Nw. of Ne.) shows five feet of coal at sixty feet. As this boring was started on the upland, the coal probably belongs to the horizon of number 24.

The thin seam outcropping along the ravine would seem to belong with the Ford coal horizon. The thicker vein found below number 20 of the last record, not unlikely represents the lower coal mined at the Manbeck mine, or the Manbeck horizon. This horizon does not seem to be generally represented and is apparently of local importance only.

Not far from this point the Crescent Coal Co. of What Cheer, Iowa, did some prospecting in 1893. One of the bore holes was carried down to the Saint Louis, and through the courtesy of Mr. S. W. White, vice-president and general manager of the company, the record is given below. It is of interest in that it was put down by experienced men with a diamond drill, and hence is particularly reliable. The coal seams found agree well in position with those known in the surrounding mines, number 17 probably representing the Hastie horizon. The nearness of the Saint Louis to the surface and the absence of lower coal seams is disappointing. The presence of black slate, number 11, twenty feet below the coal worked, may be considered as hopeful.

		FEET.	INCHES.
31.	Surface material	10	
30.	Sand and gravel	26	
29.	Blue clay	5	
28.	Slate	12	8
27.	Coal	1	4
26.	Fire clay	3	
25.	Slate	3	
23.	Fire clay	4	
22.	Sandstone	22	
20.	Fire clay, mixed with coal	1	
19.	Sandy fire clay	4	
18	Soapstone	4	
17.	Coal and fire clay	1	
16.	Fire clay	2	
15.	Slate	2	6
14.	Sandstone	8	6
13.	Slate	3	
12.	Sandstone	2	

		Feet.	Inches.
11.	Black slate	2	
10.	Fire clay, with soft sandstone	6	
9.	Sandstone	16	
8.	Blue hard rock	4	6
7.	Sandstone	6	6
6.	Slate	6	6
5.	Blue rock	1	3
4.	Soft slate	5	3
3.	Hard blue rock	1	
2.	Soft slate	17	
1.	Limestone	3	6

The horizon found here, number 17, with that worked in the Carbondale mine, is probably the one worked in the Christy and Gibson mines on Four Mile creek. Near the Gibson number 2, a bore hole showed the following strata.

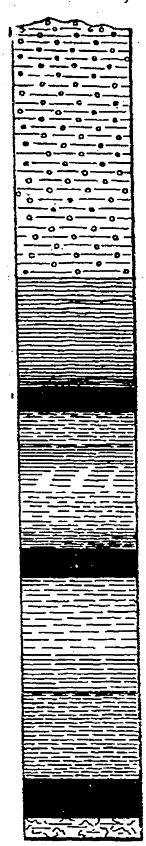
		Feet.
13.	Soil	2
12.	Red sand	12
11.	Blue clay	32
10.	Soft clay and sand	10
9.	Shale, black	32
8.	Coal	$3\frac{5}{6}$
7.	Fire clay	4
6.	Sandstone, soft	5
5.	Shale, black	15
4.	Cap rock	1
3.	Coal	$4\frac{1}{2}$
2.	Fire clay	$2\frac{1}{2}$
1.	Sandstone	7

The upper coal here, number 8, is not shown in several other borings and does not seem to be particularly persistent. In general position it corresponds to the first seam below that now worked by the Iowa Coal & Mining Co., but nothing more than this can be safely asserted. The lower seam, number 3, has been located over a considerable territory by the Gibson and Christy mining companies. But little doubt of its equivalence with the seam mined at Carbondale and formerly mined at Hastie, need be entertained. Since it was first mined at Hastie it may conveniently be referred to as the Hastie horizon. The Runnells, Ford, Avon and Woodlawn drifts took coal from the Ford horizon. The Manbeck horizon is probably represented over the Carbondale lands and possibly includes the Morgan Valley coal. The coal lying thirty feet below that now worked at Morgan Valley can not be correlated, unless it be with the seam lying twenty-five to thirty feet above the Hastie horizon at the Gibson mine. This correlation is, however, doubtful.

In general the Ford and Hastie horizons are workable throughout the regions. At the Manbeck mine the Ford coal is not now worked because of the clay slips present, and for the same reason the Woodlawn company found it an expensive vein to work. The Hastie horizon seems to show less coal to the southeast, but is fairly reliable throughout most of the district.

EAST DES MOINES DISTRICT.

Mines were early established along the south and east fronts of Capitol Hill and the region has been very thoroughly prospected. The record of the strata at the Giant mine is typical for the district and has been recently verified by the sinking of the new Eureka shaft, where the first vein, 4½ feet thick, was found at 54 feet; the second, 3½ feet, at 71 feet; and the third, 4 to 5½, at 107 feet.



GIANT SHAFT RECORD.

		FEET.	INCHES.
11.	Drift	40	
10.	Shale, black and bituminous below, light colored above	16	
9.	Coal	4	
8.	Fire clay	2	
7.	Shale, light colored	12	
6.	Shale, bituminous	5	6
5.	Coal	4	6
4.	Fire clay	4	
3.	Shale, light colored above, bituminous below	30	
2.	Coal	6	
1.	Fire clay	1	

FIG. 54. Shaft of Giant No. 1. East Des Moines.

The three veins found here were worked by several mines. The coal of the lower vein was found to thicken and dip to the east. In mining in that direction the entries were driven into a region where the thin roof broke through and flooded the works.

The Giant shaft was sunk on the west side of the old Des Moines valley previously noted. Along its eastern side a series of mines, the Maple Grove, Union, and Western, have more recently been opened. These are on higher ground, so that it seems most probable that they do not mine the "third" vein, if indeed they get down to the "second" vein. Any correlation, however, across this valley is quite open to question. In a general way the Gibson number 1, which correlates well with the mines of the Carbondale-Runnells district may stand as a connecting link between the two districts. In this case the third vein at the Giant shaft would probably represent the Hastie horizon.

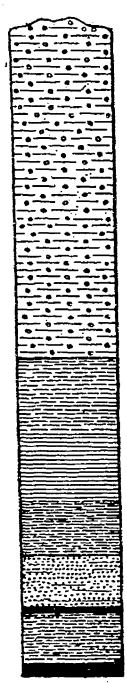
At the south foot of Capitol Hill the old Watson mine formerly took coal from a depth of forty feet below the railway track. If this Watson coal represents the first vein of the Giant shaft, as will be seen to be quite probable, and if, furthermore, the coal at the foot of Capitol Hill be the same as that now exposed at a corresponding level near the old Pennsylvania shaft on the south side, then the first vein on the east side would represent the horizon of the second of South Des Moines. The three veins of East Des Moines are believed to be represented in the three horizons mined in North Des Moines.

BERWICK DISTRICT.

In the vicinity of Berwick there are no mines, and but little prospecting has been done. A well put down for Mr. H. H. Taylor was carried down to a depth of 307 feet. The well started in the valley of Four Mile creek, perhaps ten feet above the railway, which would give an altitude of about 860 feet. The drift was about ninety to 100 feet thick and a three-foot vein of coal was struck at about 200 feet. In a second well put down upon Mr. Taylor's land a thickness of seventy-two feet of drift was penetrated, below which were 100 feet of alternating sandstone and shales. In the Clendenin well near Berwick (Tp. 79 N., R. XXIIIW., Sec. 17, Nw. qr., Sw. ¼), situated well up on the upland, with an altitude of about 900 feet, coal four feet thick was encountered at 270 feet. The coal struck in these two mines would seem to lie lower than that worked upon the west side of Four Mile Ridge in the Union and Western mines. It not improbably represents one of the horizons worked in East Des Moines, but it is impossible at present to say which one.

ALTOONA-MITCHELLVILLE DISTRICT.

A mine was formerly operated at Altoona, being located just west of the station on the Chicago, Rock Island & Pacific railway. A section as shown by the shaft is figured below.



		FEET.
7.	Drift and Carboniferous clay	110
6.	Shale	60
5.	Sandstone	15
4.	Coal	1½
3.	Shale	15
2.	Coal	4
1.	Fire clay	1

FIG. 55. Shaft of mine at Altoona.

The coal bed showed the usual undulations and had a general dip to the south. Both east and west of the shaft the coal became thinner, but it thickened in the direction of the dip. The mine was closed because of the water which came into it. Near Mitchellville, and just outside the county, coal was formerly mined at the Cook shaft at a depth of ninety feet. The section shown by the shaft was as follows:

		Feet.
8.	Drift	27
7.	Black shale	3
6.	Coal	1
5.	Shale, gray and black	40
4.	Coal	$\frac{2}{3}$
3.	Shale, black and gray	15
2.	Coal	4– 5
1.	Fire clay	--

Three miles north of Mitchellville a test hole showed the following strata.*

		Feet.	Inches.
17.	Drift	64	
16.	Yellow sandstone	4	
15.	Blue shale	11	
14	Black shale	2	
13.	Limestone		6
12.	Coal, impure		2
11.	Gray clay shale	8	
10.	Black shale	66	
9	Blue clay shale	21	
8.	Sandstone with pyrites	3	
7.	Gray clay shales	5	
6.	Sandy shales	4	
5.	Gray shales	12	
4	Sandstone with pyrites	16	3
3.	Gray clay shales	6	4
2.	Calcareous laminated rock	23	6
1.	Limestone with marly partings	16	

Numbers 1 and 2 of this section may be referred to the Saint Louis. It is quite impossible to correlate the strata at Altoona and Mitchellville with those occurring elsewhere in the county. On all sides between those points and the nearest productive mines is unprospected territory.

SAYLORVILLE DISTRICT.

On the north side of the old valley previously mentioned, coal has been encountered at a few points. The only mine at

*Second Bien. Rept. State Mine Inspector, p. 115. Des Moines, 1885.

present being operated is that of the Des Moines Coal Co. This shaft is 166 feet above the water level or 942 A. T. Three coal horizons were penetrated as is shown by the following record.

		FEET.
24.	Drift	49
23.	Soft sandstone	6
22.	Black shale	12
21.	Fire clay	12
20.	Rock	1
19.	Fire clay	3
18.	Black shale	5
17.	Fire clay	4
16.	Sandstone	3
15.	Fire clay and sandstone	22
14.	Hard rock	1
13.	Fire clay	6
12.	Shale, gray	4
11.	Coal	2½
10.	Fire clay	2
9.	Black slate	2
8.	Hard rock	1
7.	Black slate, with some coal	4
6.	Fire clay	2
5.	Hard rock	3
4.	Gray shale	31
3.	Coal	4½
2.	Fire clay	1½
1.	Sandstone	3

The lowest seam here seems to be best correlated with the first seam worked in the mines in East Des Moines. It has only been opened up by the one mine near Saylorville, though the upper seam was formerly worked out under the Poor Farm.

POLK CITY DISTRICT.

At Polk City the White Ash Fuel Co. operate a mine, taking coal from a depth of of 238 feet. The seam is split into two benches by an eight inch layer of black shale. The upper bench measures two and one-half feet, while the lower is one foot thick. The altitude of the mine is about that of the Saylorville shaft. There is no good record of the strata at this shaft, and no satisfactory correlations are now possible.

Farther north no coal is mined along the Des Moines within the limits of Polk county. A short distance beyond High Bridge (Tp. 89 N., R. XVI W., Sec. 14, Nw. qr.) there is a small country mine. Five seams of coal are claimed at this place. The first is shown in the bed of a stream near the mine and is fourteen inches thick. It was encountered in the shaft at a depth of sixteen feet. At forty feet a twenty inch vein was encountered, and at eighty-seven feet is the twenty-eight inch vein now worked. Borings are said to have shown a twenty-four inch bed, twenty-one feet still lower down, and four feet of coal at a depth of 171 feet. The property has not been developed and the extent of the beds is unknown.

COMMERCE DISTRICT.

The coal measures are exposed in the north river bank at at this place as is shown by the following section.

		FEET.
6.	Drift	25
5.	Clay shales, passing into sandy shales	20
4.	Buff sandstone, soft, thinly bedded	15
3.	Variegated clays	10
2.	Blue limestone, in three layers, separated by partings of marl	2½
1.	White shales (exposed to water level)	1

The three limestone bands are thought by Dr. Keyes to be the three which are seen in the hills at Des Moines. It is, however, impossible actually to trace the connection, though the correlation has every element of probability. The buff sandstone, number 4, is about on a level with the railway track. The mouth of the Merchant mine is not far from the same level, so that the coal now worked lies at about 750 A.T.

NORTH DES MOINES DISTRICT.

The thin seam of coal, number 2 of the Flint Valley section, which crops out along the river, was formerly worked at several points by drifting. More recently the Bloomfield, Flint, Lake Front, Oak Park, Eagle, Keystone 1 and 2, and the West Riverside mines have been sunk to a lower horizon number 2 of the Eagle shaft section. These two horizons seem to be persistent throughout the district while certain intermediate ones are not so well marked. The upper coal is seen by the section from Capitol Hill to Beaver creek to be the same as that exposed at the dam and at the foot of the hill. The lower horizon would accordingly represent the third worked in East Des Moines.

The limits of the two horizons are not as yet worked out, and it is to be expected that considerable additional territory will be found to be underlain by workable coal.

SOUTH DES MOINES DISTRICT.

On the south side of the river at Des Moines, there are three horizons along which coal has quite generally been found. The first lies but little above the river, and has been at some points opened by drifting. The second is found about sixty to eighty feet below the bottom lands, and the third from 120 to 150 feet below the same datum. These three are not, however, the only horizons present, as may be seen by a study of the Clifton section already given. They do not always occupy the same level, as is evident if one compares the Clifton record with the following boring made near the old Bloomfield mine and starting fifty feet below the Clifton.

		FEET.	INCHES.
55.	Drift	15	
54.	Clay shale	10	
53.	Shale, light colored	3	8
52.	Sand and clay shale	3	2
51.	Light gray clay shale	3	2
50.	Soft sandstone	2	2
49.	Light colored clay shale	3	10
48.	Sandstone		10
47.	Light clay shale	4	2
46.	Gray shale, hard	4	9
45.	Soft sandstone	6	5
44.	Clay shale	3	8
42.	Sandstone	9	10
41.	Clay shale, hard	6	
40.	Potters clay and sand	8	4
39.	Sandstone, hard	3	2

		Feet.	Inches.
38.	Clay shale, light	6	3
37.	Clay shale, dark gray	2	2
36.	Coal	6	
35.	Dark clay with coal	1	6
34.	Fire clay	3	
33.	Sandstone	2	4
32.	Gray clay shale	2	4
31.	Coal		5
30.	Fire clay		3
29.	Sandstone	5	5
28.	Hard sandstone with pyrites		6
26.	Brown coal and shale	1	6
25.	Sandstone	4	
24	Clay	5	
23.	Sandstone	1	
22	Light clay	5	8
21.	Dark brown clay shale	1	4
20.	Light hard clay shale	2	6
29.	Soft clay	2	2
18.	Hard light clay shale	1	6
17.	Sandstone	4	10
16.	Hard dark brown clay shale	6	
15.	Sandstone with pyrites	1	3
14.	Dark brown clay shales	6	5
13.	Coal	1	6
12.	Fire clay	2	1
11	Sandstone	1	
10.	Dark brown clay shale	12	5
9.	Impure coal and pyrites	1	
8.	Coal	1	6
7.	Impure coal with pyrites	1	4
6.	Coal		6
5.	Impure coal with pyrites	3	
4.	Coal		7
3.	Brown clay		10
2.	Fire clay		4
1.	Sandstone	2	

If the lowest of the seams present, including numbers 4–9, be considered as the equivalent of the "third" vein at the Clifton, Proctor, Coon Valley and other mines, then the "upper" vein at these latter mines is represented in the Bloomfield boring by three other bands, numbers 26, 31 and 36. The "middle" vein, as developed elsewhere, is not present, and instead, number 13 stands as the representative of number 4 of the Clifton record, a vein not taken into account in current nomenclature. The lower vein has been shown by mining operations to be continuous in many of the south side mines and may well be taken as a datum plane. Upon this basis the three major veins fall into order fairly well when proper allowance is made for the rolling which is characteristic of all of them. There is some doubt, however, as to the correlation of these horizons with those worked elsewhere in the city. Opposite Capitol Hill, at the south end of the Chicago, Rock Island & Pacific railway, the following section is exposed.

		FEET.
13.	Light shale	6
12.	Limestone	½
11.	Light and dark shales	8
10.	Thin bedded sandstone	15
9.	Talus	6- 10
8.	Coal	2½
7.	Fire clay	1½
6.	Variegated clay shales	3
5.	Light sandy clay shale	10
4.	Thin bedded sandstone	3
3.	Drab clay	1
2.	Clay-ironstone	1
1.	Bituminous sandy shale	2

The coal (number 8), sandstone (number 10) and limestone (number 12) all find their counterparts in the Capitol Hill section in sight from this exposure, and there accordingly seems little doubt that the coal here, which is the "upper" seam of the South Des Moines district, is number 4 of the Capitol Hill section. This would, as has been seen, make the second vein on the south side the first on the east side. It is probable, though not certain, that the third is the same on both sides of the river. The second as found on the east side may be unrepresented in South Des Moines, or may be equivalent to the coal already mentioned as occurring in the Clifton and Bloomfield mines, a short distance above the "third" coal. This correlation takes into account a thickening of the strata with a dip to the southwest.

LOWER COAL HORIZONS.

Whether or not coal of workable thickness exists below the horizons now worked is a matter of considerable economic importance. While the coal horizons now known are more than sufficient to supply present demand as well as any additional probable demand for some time to come, still when the mines near the city have worked out their territory, it will be necessary for them either to move farther out or to find new horizons lower down. The former entails considerable initial expense and the permanent charge for transportation into the city. Under such circumstances lower coal seams will become valuable. With almost no exception the actual location of workable coal throughout the Iowa coal field is the result of drilling. The horizon may in most cases be approximately located by stratigraphy, but the location of the workable coal is by drilling. What holds true in general is equally true of the case in hand. The general stratigraphy shows that the seams now worked are some distance above the base of the coal measures. Indeed they lie well toward the middle of the formation as it occurs in the county. In all the mining in the counties south and east of Polk it has been abundantly proven that the lower is the most productive portion of the formation. Indeed, the coal found in Keokuk, Mahaska and Wapello counties occurs so near the underlying Saint Louis limestone that its deposition has been conditioned by the irregularities in the surface of that formation. This portion of the coal measures is below that which has been prospected at Des Moines, and while it may not prove as productive in this area as it has elsewhere in the state there is no reason to doubt that it carries considerable coal. Aside from this general fact, however, there are certain others which seem to be confirmatory. A section along the Des Moines river from Harvey to Des Moines* shows the presence of several coal horizons which are stratigraphically beneath the beds exposed in Polk county. It is certainly to be expected that some of

*Keyes: Iowa Geol. Surv., I, 94. Des Moines, 1893.

these will be found to be productive in part at least. In a previous portion of this report it was suggested that the irregularities in the position of the coal beds of South Des Moines were to be explained by the presence under them of either an unconformity or a lower coal seam. There is no independent evidence of unconformity though local unconformities are known to occur throughout the coal measures. It would seem, accordingly, that the evidence here would at least fit in with that derived from other sources, and would indicate the presence of lower coal. The actual test of the matter must of course be by drilling, but, if one or even a half dozen drill-holes were to be considered conclusive, the question would now be settled. A very brief experience with such work will convince any one that a large number of carefully made drill-holes are necessary to obtain any reliable results. For example, it has already been shown that the drill at Greenwood park passed far below the horizons known to carry coal on all sides of the park and yet no coal was found. It is certainly fair to conclude that the absence of coal lower down in the same hole is no proof of its absence throughout the county. Two other deep holes have been put down in the vicinity. One was at the court house, the other near Saylorville. At this time it seems impossible to get any definite and accurate information with regard to these holes, but it is reported that they did not show deeper coal. Some time since the Crescent Coal Co. of What Cheer put down two diamond drill holes, starting on the bottom lands near Des Moines and carrying the borings down to the Saint Louis. These showed the probable presence of lower coal horizons, but not, at that point, of coal. The drill hole at Valley Junction is said not to have shown coal, while a deep hole at Commerce shows several horizons, at least one of which is workable.

On the whole it may be said that the prospect for finding lower coal is quite good but that there is no reason to suppose that the coal is any more evenly distributed than that now known, and its definite location calls for the same persistent search that is made elsewhere when new coal fields are developed along the horizons already known. In all such work definite negative evidence is only obtained by carrying the holes down to the limestone, which may be anywhere from 200 to 400 feet below the river level.

FAUNA OF THE COAL MEASURES.

The beds exposed at Des Moines are quite frequently fossiliferous and considerable collections of characteristic forms may easily be made. Many of these forms were described and others were noted by Dr. C. R. Keyes during his residence in Des Moines. He has been so good as to summarize his published notes upon these fossils and to add to the list certain more recently noted forms. The species found belong to two distinct faunas, the one characterizing the thin limestone beds noted previously and the other occurring in the shales associated with the coal seams. In the following list, prepared by Dr. Keyes, the two faunas have been separated.

List of Carboniferous Fossils from Des Moines.

(BY C. R. KEYES.)

SPECIES IDENTIFIED FROM THE SHALES.

PROTOZOANS.

Fusulina cyclindrica Fisher.

CORALS.

Lophophyllum proliferum McChesney.

ECHINODERMS.

Archæocidaris edgarensis Worthen and Miller.
Eupachycrinus sp.?

BRYOZOANS.

Rhombopora lepidodendroides Meek.
Synocladia biserialis Swallow.

BRACHIOPODS.

Lingula umbonata Cox.
Orbitoidea nitida Phillips.
Productus nanus Meek and Worthen.
Productus cora D'Orbigny.
Productus muricatus Norwood and Pratten.
Chonetes lævis Keyes.
Chonetes flemingi Norwood and Pratten.
Chonetes mesoloba Norwood and Pratten.
Derbya crassa (Meek and Hayden).
Spirifer cameratus Morton.
Spirifer lineatus Martin.
Spirifer rockymontanus Marcou.
Athyris argentea Shepard.
Hustedia mormoni Marcou.
Rhynchonella uta Marcou.

LAMELLEBRANCHS.

Lima retifera Shumard.
Myalina swallovi McChesney.
Aviculopecten coxanus Meek and Worthen.
Aviculopecten neglectus (Geinitz).
Aviculopecten whitei Meek.
Avicula longa (Geinitz)
Nuculana bellistriata Stevens.
Nucula beyrichi Schauroth
Nucula parva McChesney.
Nucula ventricosa Hall
Macrodon obsoletus Meek.
Schizodus sp.?
Schizodus alpina (Hall).
Pleurophorus permianus Swallow
Pleurophorus subcuneatus Meek and Hayden.
Clinopistha radiata Hall
Solenomya soleniformis Cox
Astartella vera Hall.

GASTEROPODS.

Dentalium meekianum Geinitz.
Dentalium annulostriatum Meek and Worthen.
Dentalium sublæve Hall.
Bellerophon percarinatus Conrad.
Bellerophon monfortianus Norwood and Pratten.
Bellerophon carbonarius Cox.
Pleurotomaria brazoenis Shumard
Pleurotomaria grayvillensis Norwood and Pratten.
Pleurotomaria carbonaria Norwood and Pratten

Pleurotomaria modesta Keyes.
Pleurotomaria sphærulata Conrad.
Pleurotomaria valvatiformis Meek and Worthen.
Murchisonia quadricarinata (Worthen).
Straparollus catilloides (Conrad).
Straparollus pernodosus Meek and Worthen.
Naticopsis nana (Meek and Worthen).
Trachydomia wheeleri (Swallow).
Loxonema scitula Meek and Worthen.
Loxonema multicosta Meek and Worthen
Soleniscus newberryi (Stevens).
Soleniscus humilis (Keyes).
Soleniscus gracilis Cox.
Soleniscus paludinæformis (Hall).
Sphærodoma medialis (Meek and Worthen).
Bulimorpha minuta (Stevens).
Bulimorpha? chrysalia (Meek and Worthen).
Orthonema conica Meek and Worthen.
Actæonina minuta Stevens.
Aclisina minuta (Stevens).
Aclisina robusta Stevens.
Streptacis whitfieldi Meek.
Anomphalus rotulus Meek and Worthen.

CEPHALOPODS.

Orthoceras rushensis McChesney.
Orthoceras fanslerensis Keyes.
Nautilis lasallensis Meek and Worthen.
Nautilis occidentalis Swallow.
Nautilis winslovi Meek and Worthen.
Goniatites nolenensis Cox.

CRUSTACEANS.

Cythere nebracensis Geinitz.
Phillipsia sp.?

VERTEBRATES.

Thrinacodus duplicatus? (Newberry and Worthen).
Deltodus intermedius St. John and Worthen.
Petrodus occidentalis Newberry and Worthen.

SPECIES FROM THE LIMESTONES AT DES MOINES.

CORALS.

Lophophyllum proliferum McChesney.
Cyathophyllum torquium Owen.

ECHINODERMS.

Eupachycrinus cragini Meek and Worthen.

BRYOZOANS.

Rhombopora lepidodendroides Meek.
Synocladia biseralis Swallow.

BRACHIOPODS.

Chonetes flemingi Norwood and Pratten.
Chonetes mesoloba Norwood and Pratten.
Rhynchonella uta Marcou.
Hustedia mormoni Marcou.
Athyris argentea (Shepard).
Productus semireticulatus Martin.
Productus muricatus Norwood and Pratten.
Productus cora D'Orbigny.
Productus costata Sowerby.
Spirifer lineatus Martin.
Spirifer cameratus Martin.
Spirifer planoconvexus Shumard.
Spiriferina kentuckensis Shumard.
Derbya crassa (Meek and Hayden).

"These faunas are remarkable on account of both the number and variety of species represented and the great numerical representation of individuals The fossils are in an excellent state of preservation, enabling the minutest details of ornamentation to be clearly made out. Hence they are of more than local interest from several points of view.

There are two very distinct faunas represented. The one is a characteristic shore or brackish water phase, and is distinguished by great the predominance of gasteropods and lamellibranchs. It is found repeated at a number of horizons Its best development is in the bituminous shales over the coal beds. The other fauna is a more strictly marine one, in which the species are prevailingly bachiopodous and coralline. It occurs at three different horizons, in as many thin bands of limestone, none of which are over ten inches in thickness. All three horizons are present in the tops of the hills along the Des Moines. At the south end of Capitol and Terrace hills and in the bluffs of the Raccoon river the fossils are abundant.

In the general section already given the limestones from which the above fossils were collected are numbers 9, 11 and 17. The shales yielding most of the fossils were number 15, and the beds found immediately over the coal seams in the various mines

With regard to the fossils, certain general conclusions have been drawn.

(1) In those zoological groups having an optimum marine habitat, there are not only a small number of species present, but also an extreme paucity of individuals.

(2) The brachiopods, though well represented in both genera and species, were not proportionately as abundant as might be expected when it is remembered that this type of life had nearly reached its greatest expansion and culmination at the time these beds were deposited.

(3) The fauna was predominantly molluscan, more than three-fourths of the entire number of species being gastropods and lamellibranchs.

The Protozoa, Cœlenterata, Bryozoa and Echinodermata form a very inconspicuous proportion of this local fauna, only three or four specifically distinguishable members of each group being obtained Although the branchiopods are represented by fifteen species included in nine genera, they were, with three exceptions, of comparatively rare occurrence—*Productus muricatus*, *Chonetes mesoloba* and *Orbitoidea nitida* only being abundant. The brachiopods are also all depauperate, attesting conditions at the time that they lived extremely unfavorable to their full development and to the attainment of a normal size.

Molluscan forms, while certain of the black shales were being laid down, flourished luxuriantly, especially the gastropods, which in number of species composed more than one-third of the entire fauna. Not only did they exceed in species but they far outnumbered all others in individuals, and while as a rule they were small and some of them even minute, their vast numbers made up, in great part at least, for the conspicuity of large but fewer forms.

Although the majority of the forms of this group are small it is not a depauperation as among the brachiopods, as is shown by the average size of the individuals of each species being normal, and in some instances even considerably above. Some of the species are also of interest because of their recognition at this point for the first time within the limits of the state, and thus to a considerable extent their own geographical range has been increased Others of the species enumerated are now known to have a wide geographical distribution which is suggestive of a somewhat extended vertical range. Among recent mollusca and especially land forms a wide geographical distribution, as has been remarked by Binney, appears to be indicative of a high antiquity for the group The corroborative evidence is abundant; a notable instance is the living Zonites, four or more species of which are circumpolar in their distribution; and the genus—even a subgenus Conulus to which one of these living forms belong—ranges back to the Carboniferous, while the genus Pupa is represented in the Carboniferous by four species. Cephalopods are not abundant in the region under consideration, and are represented by only two genera and species, yet a Nautilus attained a diameter of twenty centimeters, and an Orthoceras was fifty centimeters in length, with a diameter at the larger extremity of five centimeters.

Of the lamellibranches the majority are small, though two of them are comparatively large, attaining a length of nearly ten centimeters, yet having an extremely thin and fragile shell. One of the specimens collected is of especial significance as exhibiting in all its details the internal features of the shell, the characteristic, well defined muscular scars and the edentulous hinge margin; in fact, it so closely resembles, in these characters—the general form and external appearance—a modern Anodonta, that it is difficult to see how it can be generically separate, and should further investigation prove that the specimen under consideration really belong to that genus, it would be of unusual interest in its bearing upon the distribution of fresh-water or non-marine mollusca during geologic times. The modern Unio and allied genera certainly have both a wide geographical and geological distribution, as is shown by the rich discoveries of Unionidea in the Mesozoic strata of the west: and the genus Anodonta is, if the opinion of Hall is adhered to, represented in the Devonian by two species, but that these two forms really belong to Anodontais questionable. Dawson has described several allied forms from the Carboniferous of Nova Scotia; but their family position is as yet also unsettled. With these considerations in view, the evidence thus far obtained points to a high antiquity for this group of bivalves which now is so abundantly represented in all our streams and ponds. As will be noted, Crustaceans are represented by a species of Cythere; and a trilobites by a single pygidium."

PLEISTOCENE.

The Pleistocene series of Polk county includes the deposits of several separate stages. There are records of two and probably three ice sheets. Gravel horizons and a loess horizon indicate considerable changes in the freedom of drainage and by inference tell of changes in general altitude. There are unconformities and periods of considerable erosion. Buried soils tell of former climatic changes, and as has already been seen, the surface configuration reveals the fact that there have been in recent times marked changes in local geography. The series, for all its complexity, is not complete, and to obtain the full history of the region one must go outside the county for a portion of his facts.

PRE-KANSAN DRIFT.

In southern Iowa and northern Missouri there is at several points a distinct drift sheet lying below the Kansan drift, which forms the surface formation over much of the region. This pre-Kansan drift as exposed near Afton Junction, has been provisionally correlated by Chamberlain* with the Albertan† as proposed by Dawson. It has not yet been traced northward from the Union county outcrops, so that its equivalence with certain other exposures of drift presumed to represent the same horizon is at present open to some slight question. There are in Polk county two known exposures of a drift which is most probably to be referred to this horizon though the evidence is not quite so clear as might be desired.

* Editorial, Jour. Geol., IV, 872-876. Chicago, 1896.
† Jour. Geol., vol. II, pp 507-518. Chicago, 1895.

One of these exposures is at Thompsons Bend, in the city of Des Moines. Worthen,* in his notes on the Des Moines valley, mentions at this point, at the base of the drift deposits, a bed of ferruginous conglomerate three feet in thickness. The conglomerate is not now exposed, though pebbles, which apparently are derived from it, are abundant at the horizon mentioned. These pebbles include various greenstones and granites not found in any coal measure or Cretaceous conglomerates known in the state. They are of the same sort of material found in the drift and that is evidently their origin. They are badly weathered and iron-stained and in these particulars are easily differentiated from the pebbles of the overlying Wisconsin drift. They may safely be considered as pre-Wisconsin, but beyond that there is no certainty with regard to their age. In position and general appearance they strikingly resemble the older gravels occurring southeast of Hastie, yet to be described.

The exposure near Hastie (Tp. 76 N., R. XXIII W., Sec. 23) is one of the best along the river. The stream has been thrown against the eastern side of its wide valley and has cut back the bluff until a precipitous face 130 feet high fronts the bottom land, as shown in figure 40. The bluff has a historical interest since Owen† noted it and suggested that the marly earth capping the bluff was probably of the same age as the loess of Germany. Later Keyes and Call‡ studied the exposure and determined the presence of loess, till and stratified sands. The loess fossils mentioned below were collected and determined by them. The section shows the following beds.

		FEET.
5	Loess, usual texture and buff color, showing vertical jointing and perpendicular face, containing *Succinea avara* Say; *S. obliqua* Say; *Helicina occulta* Say; *Pupa muscorum* Linne; *Vallonia pulchella* Muller; *Zonites arboreus* Say; *Patula strigosa* Gould; *Mesodon thyroides* Say(?)	40

*Hall: Geol. Iowa, I, 171. 1858.
†Owen: Geol. Surv. Wis., Iowa, Minn., 121. 1852.
‡Proc. Iowa Acad. Sci., 1890-91, p. 30. Des Moines, 1893.

		FEET.
4.	Till, reddish brown above, becoming yellow below, and passing indefinitely into the formation below	20
3.	Till, blue, containing with the above, bits of chert, limestone, sandstone, coal, quartzite, badly weathered gray granites, diabase, fine-grained greenstone, mica schist, and dark green slate	30
2.	Stratified sand and conglomerate, imperfectly exposed	40
1.	Till, very dark blue, containing small pieces of fine-grained greenstone and rotten schist with bowlders of granite	1

All of these beds with the exception of number 1 are exposed in the bluff, though the lower portion of the latter is much obscured by talus. Number 1 is found in the bed of a small tributary and is seen to be covered by conglomerate similar to that seen in the bluff. The appearance of the lower drift is quite different from that above the conglomerate. It is darker in color, more compact, and contains fewer large bowlders so far as might be judged from the limited exposure examined.

The conglomerate is made up mainly of chert, but it also contains bits of quartzite, greenstone and of very badly weathered granite. It is quite firmly cemented by oxide of iron. It contains much the same sort of pebbles as are found in the accompanying drifts. Nothing distinctive in the character of the material could be made out between the different drifts or the conglomerate, though the lower drift and the conglomerate seemed to be more weathered. In the bluff there are apparently two ledges of conglomerate, each two to three feet thick, but the slipping which has taken place makes it impossible to be sure of this. Associated with the conglomerate are stratified sands of a bright orange color, bearing pebbles of chert and of northern rocks up to three-fourths of an inch in diameter.

The loess and the upper drift represent the formations common throughout the region and the drift is that called the Kansan. The sands and conglomerates are obviously water-laid. In appearance and position they resemble the gravels found below the Aftonian peat beds. The drift below answers well to the sub-Aftonian drift. There is, however, no positive evidence here that the gravels are separated from the lower drift by any considerable interval, that is, that they are strictly interglacial. Neither is there, perhaps, conclusive proof that they are distinct from the Kansan drift. Until more is known of the drift of the region south the alternative theory, that the stratified beds simply represent water work during the advance or retreat of the Kansan ice, can not be altogether set aside. The beds seem to lie in the side valley of an older tributary of the main stream rather than in the main valley. The latter was apparently almost entirely cleared of such beds, if they were present, before the Kansan ice invaded the region. If this be indeed true, it would of course necessitate a certain amount of stream adjustment and a very considerable amount of erosion in the interval between the gravels and the Kansan. This is not in conflict with any known facts and is favored by not a few.

THE KANSAN DRIFT.

The principal drift sheet found in the county is that which in the previous reports of the survey has been referred to the Kansan period. It is in the main a stiff blue bowlder clay. It contains numerous pebbles, including especially greenstones of various types. It has a large amount of local material incorporated. The bowlders are predominately small as compared with those dotting the surface of the newer drift. In the area not covered by the Wisconsin, large surface bowlders are rare, and it does not seem that this is altogether the result of the obscurement due to the loess mantle. In the region south and west of Polk county there are considerable areas from which later erosion has removed the loess and within such areas the bowlders found on the surface and collected in the streams are neither so large nor so abundant as within similar areas covered by either of the later ice sheets which occur in Iowa. The difference in this regard is not so striking when the Kansan and the Wisconsin areas of Polk county are contrasted as when corresponding regions covered by the Kansan and the Iowan in eastern Iowa are studied. It is, however, none the less a real difference and a valuable criterion for discrimination. The bowlders occurring in the Kansan are more frequently flattened and striated.

In the bluffs south of the Raccoon river and along the bluffs of the Des Moines below the city, the Kansan frequently outcrops and may be readily examined. While the bulk of this drift is a blue clay the portion most commonly seen is yellow, brownish or even red. Before it was buried under the loess it was exposed for a long period to surface action. The iron contents became highly oxidized, the soluble constituents were largely dissolved out, and at many places the finer material had been washed away, leaving a gravelly surface. It is this upper surface which is most frequently seen. It appears as a belt or zone along the sides of most of the streams of the loess-covered area. Above, the slope is covered by loess. Not far below, the alluvium obscures the drift. When any of the larger streams have been thrown to one side so as to cut away the over-wash one may get a complete section, such as the one described near Hastie, except that the beds below the Kansan are not known to occur elsewhere. Good sections of the Kansan drift are rarely seen in this region. This is due to the fact that the topography of the country south of the Wisconsin drift area was almost wholly developed before the loess was deposited. The latter forms a mantle over this older surface, covering the Kansan almost entirely. Whenever there have been recent stream changes the Kansan is found. Its upper surface is readily recognized by the reddish brown color and the presence of many badly weathered bowlders. These characteristics are maintained not only when it is covered by the loess but when the latter becomes covered by the Wisconsin. On the west side of the Des Moines river at the Polk City bridge (Tp. 80 N., R. XXV W., Sec. 10), in passing up the hill one goes over the normal succession of coal measures, Kansan drift, loess and Wisconsin drift. The same may be observed in crossing a small stream a mile north (Sec. 9, Ne. qr.), and indeed at a large number of points along the upper Des Moines valley. It is the normal succession. Lower till with the same characteristic outcrops has been noted by Beyer* still farther north, in Boone county.

Throughout the southern portion of Polk county this weathered horizon is constantly seen. Wherever the loess is cut through, the latter crosses the hill-tops, but is also found in the valleys as well. In road cuttings it is often possible to see the old Kansan horizon under the loess running down the slope to the bottom land. In such cases it is obvious that both the valley and the weathered horizon are earlier than loess. This is true for the major and most of the minor valleys of this portion of the county. Since the drainage is quite perfectly developed it must be clear that both lines of evidence point to the conclusion that there was a very considerable interval between the Kansan drift and the loess.

THE LOESS.

The loess of the Des Moines valley early attracted attention. Owen, as we have seen, correctly interpreted it. It was later studied in considerable detail by Call,† who made extensive collections of fossils from it. As usually exposed near the city it is the normal buff colored, fine-grained pebbleless material of porous texture, vertical jointing and calcareous reaction. It frequently contains fossils and lime concretions known as loesskindchen. It is quite irregular in thickness. At the fruit farm of Hon. J. G. Berryhill (Tp. 78 N., R. XXV W., Sec. 19) a well showed it to be seventy feet deep, on the west side of West Four Mile creek, while upon the opposite side of the valley the underlying Kansan outcrops near the top of the hill. In general, it is from ten to twenty feet thick over the southern portion of the county.

*Beyer: Iowa Geol. Surv, V, 203. 1895.

†Call: Amer. Nat. XV, 585-586, 783-784, 1881; XVI, 369-381, 542-549. 1882.

It may be seen particularly well developed in the brick pits on the south side of the river, or in the road cuttings along Clifton avenue, but is quite commonly exposed over the area indicated on the accompanying map. It is quite easily recognized by its texture, color, and freedom from pebbles. It is usually very fine-grained, but at points grades downward into a rather coarse sand. This may be seen at the south end of the Valley Junction bridge over the Raccoon river (Tp. 78 N., R. XXV W., Sec. 14). These coarse sands seem to be, in part at least, genetically related to the loess. They have not been found except in the Raccoon-Des Moines valley, or on the edge of uplands along it. At one point similar sands are found between two loess beds. This may be seen at the Dale-Goodwin brickyard (Tp. 78 N., R. XXIV W., Sec. 24, Ne. qr., Ne. ¼). The section shown in the hillside is as follows.

		FEET.
4	Soil, black	2+
3	Loess, buff to brown, with vertical jointing and normal appearance	3
2.	Sand, orange colored, cross-bedded, irregular in amount	1½
1	Loess, light gray, clayey, fossiliferous	8+

Under the lower loess is said to be a stronger brown clay. In the vicinity only the normal Kansan drift and loess is exposed. It is possible that the brown clay belongs to the coal measures. The presence of the bed of sand and the difference in character shown by the beds of loess suggest that they are here two separate loess sheets, the product of two widely separated periods of time. Two loess sheets have been noted at certain points in the older drift area.* In the present case, however, it does not seem necessary to resort to such an hypothesis. The sand bed is not present throughout the pit, wedging out entirely at the eastern end. It has not been observed elsewhere, and for the present at least there seems to be no necessity for considering the phenomena as of more than local significance.

* Salisbury: Ark. Geol. Surv., Ann. Rep. 1889, vol. II, pp. 224-248. 1891. Tilton: Iowa Geol. Surv., V, 318, 356. 1896.

The relations of the loess to the underlying drift have been already described. It remains to point out its relations to overlying drift. It has long been known that over the area covered by the Des Moines lobe no loess is found. South and west of the lobe, however, the loess appears. In 1882 Messrs. McGee and Call,* in a valuable and suggestive paper, brought out the facts that at Des Moines the loess passes under the upper drift, that now known as Wisconsin. Our knowledge of the drift formations was not then so well organized and the fact was interpreted as of local importance only and as due to a slight readvance of the ice now known as the Wisconsin, since what we now know as the Iowan drift was distinctly stated to occur south of the city. In the course of the present work the fact that the loess passes under the Wisconsin drift, as stated by McGee and Call, has been abundantly verified. The exposures mentioned by these authors are now obscured, but others equally good may be found wherever the drift on either the West Hill or in Highland Park is dug through. During the summer of 1896 the relations were particularly well shown at the top of the Sixth Avenue hill and in the cuts along Grand Avenue near Greenwood Park, and the street railway cutting on Hamilton street in Oak Park. The relations are unmistakable and may be verified at any time. The upper drift is quite distinctive and the buried loess is equally easy to recognize, since it is very frequently fossiliferous.

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

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

Loess fossils have been obtained from number 2 of this section at several points. On the farm of Mr. Tom Saylor thirty feet of pebbleless clay containing "periwinkle shells" is

* Am. Jour. Sci., (3), XXIV, 202-223. 1882.

reported below twenty-two feet of Wisconsin drift which forms the surface soil. Near the mouth of Beaver creek (Tp. 79 N., R. XXV W., Sec. 20, Nw. qr., Ne. ¼) a road side ravine shows the loess with its usual characteristics outcropping below the drift. The same phenomena may be seen at the localities west of Polk City, which have been already mentioned.

The relations observed in Polk county are not by any means local, but have quite as characteristic development in Dallas and Guthrie counties. It is believed that they are generally true of the southern border of the Des Moines lobe. It is not to be expected that the loess will be found to be preserved under the drift for any great distance back from its edge, though local bodies of buried loess may be found.

In view of this relationship it seems evident that the loess is not to be correlated with the Wisconsin drift. There is no good reason for separating it from the loess of eastern Iowa, with which it is continuous and which sustains such definite relations to the Iowan drift. The latter extends as far west as Marshall connty and is presumably the same as the drift of northwestern Iowa. The loess near Des Moines would seem to belong to the general loess sheet which was formed around the edge of the Iowan ice. It records a period of low levels when the drainage was clogged and the expanded waters of the rivers met across the divides. Under such conditions the deposition of coarser sands along the river valleys such as are found at Valley Junction would be natural.

The loess throughout the county is unusually fossiliferous. At many points in and near Des Moines considerable collections of the forms characteristic of the formation may readily be made. The fossils were thoroughly studied by Call during his residence in the city, and his results will be found in the papers already cited. Dr. C. R. Keyes has also made numerous collections and notes upon these forms, and has kindly prepared the following list.

REVISED LIST OF LOESS FOSSILS FROM DES MOINES.

Zonites arboreus Say.
Zonites minusculus Binney.
Zonites limatulus Ward.
Zonites fulvus Drap.
Patula alternata Say.
Patula strigosa Gould.
Patula striatella Anthony.
Helicodiscus lineatus Say.
Strobila labyrinthica Say.
Stenotrema monodon Rackett.
Mesodon clausus Say.
Mesodon multilineata Say.
Mesodon thyroides Say.
Vallonia pulchella Muller.
Pupa pentadon Say.
Pupa armifera Say.
Pupa muscorum L.
Pupa corticaria Say.
Pupa blandi Morse.
Vertigo simplex Gould.
Succinea obliqua Say.
Succinea avara Say.
Carychium exiguum Say.
Limnophysa desidiosa Say.
Limnophysa humilis Say.
Limnophysa caperata Say.
Helicina occulta Say.
Ferrussacia subcyclindrica Linn

WISCONSIN DRIFT.

The larger portion of Polk county was covered by the ice of the Des Moines lobe which ran down in a long tongue from the greater development of the Wisconsin ice in Minnesota. The area in this county which was so covered is shown on the accompanying map. The deposits of this ice sheet include not only the unstratified drift or till but a considerable amount of stratified gravel, more perhaps than has been so far observed in connection with any of the other drift sheets in Iowa.

The unstratified drift forms the great bulk of the Wisconsin formation. It is characterized usually by a buff to whitish color, and by the presence of relatively unweathered material. There are some weathered bowlders, but these are, as compared with the Kansan, quite rare. The amount of local material found in the Wisconsin is notably less. There is a large amount of fine material in the matrix which is much like the loess. Ferrugination is quite rare. Lime is present in abundance, and the drift usually gives a reaction with acid up almost to the grass roots. Large bowlders seem more common upon its surface. So far it has not been found possible to base distinctions upon any difference in the kind of bowlders and pebbles found in the Wisconsin as contrasted with the Kansan. Apparently the material of both sheets was derived from much the same source. The most distinctive features of the Wisconsin till are its topography and relations to the loess, both of which have been discussed.

The Des Moines lobe seems to have been first recognized by Chamberlain,* who spoke of it as bordered by a half buried moraine. Previous to this White† had tentatively recognized Mineral Ridge in Story county as morainic, this being apparently the earliest recorded recognition of a moraine in the open country, away from mountain ranges. In 1890 Upham‡ traced the limits of the lobe but does not seem to have visited its southern terminus. In the portion visited by him it is quite generally bounded by a rather definite moraine. This has been called the Altamont moraine from a point in South Dakota, where it is particularly well developed. This moraine was quite fully described by him, and through association it has become common to think of the Des Moines lobe as terminated by the Altamont moraine. This is not, however, true for all parts of the border. The southern border of the Des Moines lobe as developed in Polk and adjacent counties has no definite terminal ridge answering to a moraine. Moranic patches are occasionally seen in neighboring counties, but in

*See La moraine terminal du Amérique du Nord; Compt. Rendu. Cong. Intern. géol., Paris, 1878; and Trans. Wis. Acad. Arts and Lit., vol. IV 1876-77, pp. 201-234.

†Geol. Iowa, vol. I, p. 98. 1870.

‡Geol. Nat. Hist. Surv. Minn., 1880, p. 298.

Polk county there is nothing whatever moranic or of the nature of a ridge about its border. The topography within the lobe is very different from that without. The drift within has also marked physical characteristics. But toward the border the drift becomes thin and the topography indistinct until it is often impossible definitely to locate the line. The outwash plain which might, from the known conduct of the Wisconsin drift in other states and the known presence of gravel trains be expected to aid in the discrimination, is rarely present. Around the end of Four Mile Ridge there is a certain development of sands and stratified drift, but this is a notable exception. In general the best field test is the presence or

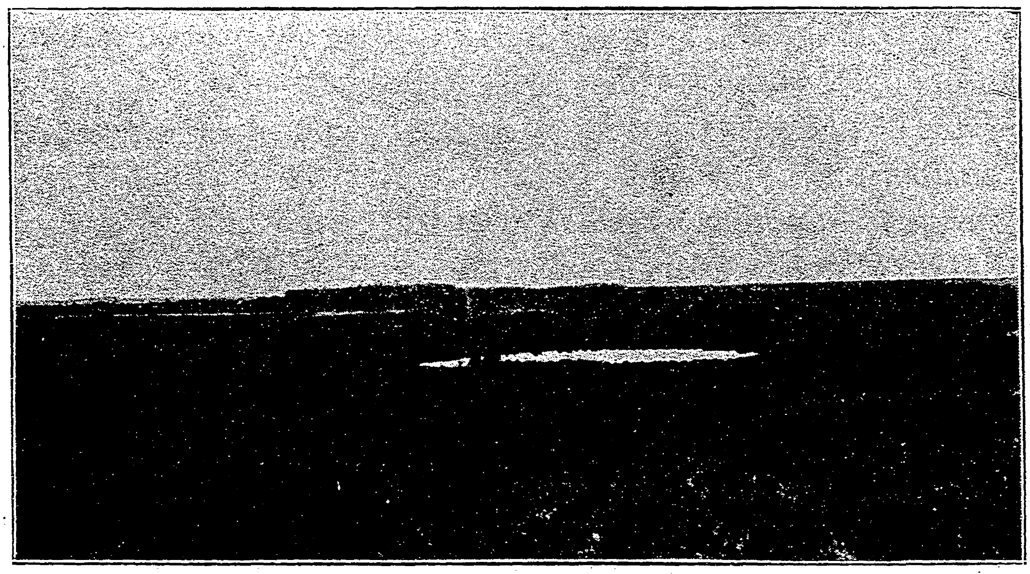


FIG. 56. Pond on Wisconsin drift at south end of kame near Kelsey.

absence of loess at the surface. Where the loess has become covered by pebbly clay one is within the limit of the lobe, but where the loess forms the surface material the reverse may be assumed to be true.

The assorted drift found in connection with the Wisconsin drift sheet belongs to three categories, kames, gravel trains and gravel patches.

Kames are developed not at the immediate edge of the drift as is perhaps most commonly true, but are found some distance, ten to fifteen miles, back from the border. Two well marked kames are known; one immediately west of Crocker and a second about two miles south of High Bridge, or immediately east of the old town of Kelsey (Tp. 80 N., R. XXV W., Sec. 31). The Kelsey kame stands upon a drift plain which is about 150 feet above the river. This plain is fairly smooth, and is dotted with swales, some of which contain small ponds, one being represented in figure 56. Above this plain the kame raises forty feet. It forms an irregular ridge three-quarters of a mile long and a little more than one-quarter wide. At

FIG. 57. Kame near Kelsey.

its southern end, and partially separated from it, is an oval hill which does not rise quite so high. The upper surface of the kame is not smooth, but is somewhat hummocky. Its direction is not linear but sinuous. It is cut off rather abruptly at the ends, and the whole ridge forms a prominent landmark. Its general appearance from the west is shown in figure 57. In composition the kame is made up of Wisconsin material. Large bowlders are found on its surface and pits at three points show that to a depth of four feet at least it is made up of coarse water-laid gravels. Stratification is rude only. The pieces of gravel are one-half to three-quarters of an inch or more in diameter.

The Crocker kame stands among a group of hills which have a relief somewhat greater than is usual for this region. In form and dimensions it is very similar to the Kelsey kame. Its constitution can not be so confidently stated, but gravel is found over portions at least of its surface, so that it is presumed to be the same as in that of the Kelsey kame. There are other gravel accumulations in the county, particularly between Crocker and Polk City. They do not, however, assume the definite form associated with the term kame, and are perhaps best known by the more indefinite term of gravel patches.

The origin of the gravel patches and kames is doubtless to be referred to water which arose from the melting of the ice during its retreat. The definite form of the kame* is perhaps best accounted for by the influence of surrounding ice. So far as observed the one found in Polk county offers no new data upon which to base a conception of the details of the process of their formation.

One of the most obvious phenomena connected with the edge of an ice sheet is the presence of trains of gravels stretching down the rivers whose headwaters are cut off by the ice. That the diverging streams which depend upon the glacier should become loaded with gravel and should build terraces of that material stretching away from the ice seems in every way harmonious with the modern conception of an ice sheet and its work. This is, of course, possible only upon the hypothesis that the drainage be free and the rivers have sufficient velocity to carry the gravel for some distance. Free drainage as contrasted with a clogged drainage, such as has been suggested to have been prevalent at the time of the maximum extension of the Iowan ice sheet, means relative elevation; and the following of one by the other may be interpreted to mean a change in the altitude of the land.

In Polk county gravel trains are found along the streamways which lead out from the drift border. The gravel pits

*Chamberlin: Third Ann. Rep. U. S. Geol. Surv., pp. 307, 308. 1883.

of East Des Moines and farther down the river at Avon are in such a gravel train. Four Mile creek shows similar phenomena. Camp creek and Mud creek also have gravel terraces. In the counties farther west the Raccoon river bottoms are underlain by gravel. The gravel in all three cases is firm, hard material such as makes up the pebbles of the Wisconsin. Occasionally bowlders which might have come from the Kansan are also incorporated.

The gravel terraces are not conspicuous features. They are frequently covered with later alluvium, as at the Avon gravel pits, or rise ten to twelve feet above the modern bottom land, as at the newly opened pits in Highland Park. In this particular they differ from the gravel trains which are so characteristic of the Wisconsin drift in other states. In Wisconsin* the Green Bay glacier filled up the old valley of Rock river to a depth of 350 feet (including earlier drift) with a deposit of finely assorted sand and gravel, producing a level plain three to five miles wide and extending forty miles or more southward from the moraine.

The gravel trains in Polk county are found not only outside the area covered by the Wisconsin ice, but may in some instances be followed up the streams to well within the Wisconsin area. The gravel trains of Camp and Mud creeks are abruptly terminated at the upper end by the Wisconsin till. This is not, however, true of those of Four Mile creek and the Des Moines river. The pits recently opened by the Chicago Great Western railway at Berwick are about six miles within the limits of maximum extension of the ice. The Polk City pits are fully twice as far from the drift border, and the gravels occur along the Des Moines river well up toward High Bridge.

Along the Delaware river a somewhat similar series of phenomena occur. The explanation for them has been very carefully worked out by Salisbury.† The gravel train in that

* Chamberlin: Geol. Wis., I, 284. 1883

† Ann. Rep. State Geol. N. J., 1892, 106-112. 1893.

case is not a single continuous train, but is rather a series of individual trains, each of which was formed successively farther up the river, and each corresponding to one of a series of moraines of recession. Apparently this explanation is equally good for the case in hand, except that here there are no moraines. The ice retreat seems not to have been by definite stages, but continuous. That there were minor stages in the retreat is, of course, altogether probable, and future detailed study may render it possible to discriminate them.

Belonging in a sense with the gravel trains, and yet to a certain extent differing from them, are the beds which have been represented on the map as stratified drift. They do not include all the stratified drift found in the county, since no attempt has been made to discriminate the gravel trains from the alluvium. Only those bodies of stratified drift have been represented which were of considerable extent and significance. These are confined to the old valley formerly occupied by the ancestor of the upper Des Moines river. As seen east of the capitol, this drift presents the characteristics common to outwash plains. It is sandy, mixed with gravel, and rises a little above the present bottom land. It has a slightly hummocky surface. The diversity of relief increases to the north, so that between Saylorville and Oak Park sandy drift hills of irregular form are common. In that portion of the valley which is now occupied by Beaver creek, the drift becomes more and more the normal bowlder clay, so that a short distance west of the county line the distinction between the two can not be drawn. In general it may be said that the drift of this valley is a bowlder clay deposited in the presence of considerable water. The anomalies are probably a result of the topography existing at the time of the ice retreat, the beds of material being in a valley 120 to 160 feet below the upland. Probably stagnant ice may account for some of the peculiarities.

ALLUVIUM AND TERRACES.

The extent of the alluvium is indicated upon the accompanying map with the correction that the terraces have not there been discriminated from it. It will be seen that alluvial bottom lands form no small proportion of the whole area. It will also be seen that the proportionate alluvial area is notably greater in the southern than the northern portion of the county. This becomes the more striking if the valley of the Skunk river, which is exceptional, be left out of account, and the comparison would be more striking still if it were possible accurately to map the small alluvial bottom lands found along the minor tributary stream-ways throughout the southern division. This distribution of the alluvium reinforces the argument derived from the drainage and topography for the relative youth of the northern portion of the county.

The alluvium forms a terrace along the streams. It is evidently a terrace of aggradation as defined by Salisbury.* Above it at many points along the upper Des Moines river, for example opposite the Sixth avenue bridge, near the Keystone mines, at the north of Beaver creek, directly west of Saylorville and near the mouth of Big creek, is a second terrace. This is made up of sand, gravel and gravelly drift, and seems to mark the stage where the Polk county gravels were laid down. It is essentially a gravel train, and its origin has just been discussed.

In the vicinity of High Bridge there are terraces which lie still higher. The main one is about fifty feet below the general upland surface and sixty-five to seventy feet above the river. It is about 300 feet wide and slopes back to the bluffs to such a degree that a small stream has located itself along the back of the terrace which is now in places six feet lower than the river edge. The side streams have cut away sharp gullies in this terrace, and the action has been so rapid that the divides between these gullies, even when less than six feet wide, remain flat topped. The material of the terrace

*Ann. Rept. State Geol. N. J., 1892, 103, 104. 1893.

is unstratified drift, and shows no trace of water action in its deposition. Twenty to twenty-five feet below the main terrace is a second, which is narrower and quite ill defined. These are along a portion of the valley less than half a mile wide. They are evidently not terraces of aggradation, but mark rather definite periods in the down-cutting of the stream, and hence correspond to the type discussed by Gilbert.*

Along the Skunk valley near Valeria is a low terrace which belongs to the second class.

ECONOMIC PRODUCTS.

Coal.

Polk county is one of the largest coal-producing counties in the state. In 1893 it stood second to Mahaska alone, but since then has been passed by Appanoose, where the coal lies nearer the surface and is more cheaply mined. The most productive portion of the Iowa coal measures consists of a long strip of territory running south from Fort Dodge and parallel to the Des Moines river. Polk county is about midway of this productive strip. The coal mined near Des Moines is mainly taken from seams lying at some depth, so that the area is neither so cheaply prospected nor is the coal so economically mined as in the counties to the north and south. Despite these facts mining has been carried on here since the first settlement of the country, and the coal industry is now a large and important one. At the time Fort Des Moines was occupied as a military post, coal was obtained from the surface vein still exposed near the Center street dam. For a long time this was the only vein worked, though it was opened up at a number of points both north and south of the river. Worthen,† as a result of observations made here in 1856, urged the propriety of sinking shafts to the lower seams which he indicated as present. It was some years, however, before this was done. The state census of 1856 records four miners

*Gilbert: Geol. Henry Mts., 126, 127. 1880.

†Hall: Geol. Iowa, I, 171. Albany, 1858.

in Polk county. In 1859 coal to the value of $337 was produced. In 1862, 35,468 bushels were mined. In 1865 the amount was 27,922 bushels, and in 1866 it had increased to 332,769 as a result of the opening of shaft mines. In 1867 the Watson Coal Co. sunk a shaft at the foot of Capitol Hill to the "first vein" of the east side, and for a long time this mine supplied the railroads. The Hall, Rawson, Reese, Dahl and numerous other mines in the meantime furnished coal from the surface seam. In the same year that the Watson mine was opened the Iowa Central shaft was put down on School street between West Fifth and Sixth. Apparently this shaft went only to the upper seam.

In 1873 Mr. Wesley Redhead resolved to open up the lower seams and the Des Moines Coal Co. was organized by him to sink a shaft on the south side opposite the present West Ninth street bridge. The shaft went down 150 feet to the "third vein," the "second" not being workable at that point. This mine, which was afterwards known as the Pioneer, was one of the most important in the district and worked out a large area, as is indicated on the sketch map (figure 47). Its success led to the opening of a number of mines in the vicinity, among which were the Sypher (1874), later known as the Polk County, the Eclipse (1873), the Pennsylvania, the Pleasant Hill (1875) and the Eureka (1875). About the same time or later the east side mines began to be opened up and mining was active there, particularly in the eighties. In 1893 the last of the east side mines, the Garver, was closed and the field deserted until the present season, when the new Eureka was opened.

In the earlier days, as has been seen, the upper vein was quite extensively worked north and west of town, but afterward the region was abandoned until 1893, when the newer group of mines now including the Keystone, Flint, Eagle, West Riverside, Bloomfield, Oak Park and Lake Park began to be opened up. West of the city the Two Rivers and other mines at one time took out coal, but the region has been abandoned for some years.

There has been a constant change in the center of mining activity, but it has been a change, not a loss. As individual leases were worked out the mines were closed, but new ones have in almost every case been opened. In addition, new capital has been coming in, new fields have been opened up, and in some cases the deeper veins in abandoned portions of the field have been tapped. As a whole the industry has been constantly growing. There have been periods of stagnation, but these have been temporary, and for some time to come there will be opportunity for profitable mining, though the returns are not now so large as in earlier years. Here as elsewhere there has been concentration of capital, and a new order of things with larger dealings and a narrower margin of profit has developed. At present there are twenty-five mines in the county exclusive of the small drifts worked only for local trade and a few mines engaged in taking out the pillars and neglected blocks of coal in territory already worked by larger companies. According to the report of Mr. M. G. Thomas, State Mine Inspector,* there were in 1895 twenty-three plants operating on a commercial scale. These plants represented a capital of $430,000 and paid $329,190 in wages exclusive of the salaries of superintendents, mine foremen and other officials. If in addition to the capital invested in the plants the value of the lands undergoing development were to be reckoned, the total would me much larger. The output for 1895 was 334,881 tons, with a value of $458,707 at the mines. The small country banks were not taken into account in these figures and, while the amount of coal mined at each drift is small, the price paid is often relatively high, so that the value of the total output as given is low. Within the last year the industry has expanded quite notably. Old mines have been reopened for closer working, and many of the established plants have increased their working force.

A large amount of the coal mined goes on the home market. Very little coal is shipped into Des Moines, and the local

* Rept. State Mine Inspector, 1895, p. 69.

mines have a large trade to supply. The outside trade is growing, large quantities of coal being shipped north and west throughout Iowa and adjoining states. The exceptional railway facilities enjoyed by the mines of the city gives them a great advantage in competing for the trade of the northwest. One mine, for example, by means of two switches is able to ship over five of the main railway systems of the state without transfer charges.

The coals mined are bituminous and free-burning. They are not usually block coals, though there is occasionally a tendency in that direction. More frequently the horizontal lamination is most pronounced. The coals are quite firm and may, in most cases, be blasted from the solid. They make relatively little slack, and are of good quality for general steaming purposes. The percentages of ash and sulphur are about the same as in the average coals of the state. Even the fine coal is fairly clean, as is shown by the fact that it is the main boiler fuel throughout the city. Coking and gas coals have not been found to any extent. Occasional analyses of picked samples* show coal suitable for these purposes, but so far nothing of the kind has been developed on a commercial scale.

The following analyses, by Prof. G. E. Patrick, show the character of the coal as put on the market. The samples were not picked, but represent rather the average character of the coal. The percentage of ash is higher here than in much of the coal even in the same mines, and yet is probably fairly representative of the coal as marketed. At present the coal is nowhere cleaned except by screening. It is probably only a question of time until regular washing works will be erected in this direction. By their aid the ash can be almost wholly removed and the quality of the output proportionately increased. This will, of course, make it possible largely to expand the trade, since the cleaned coal is fully the equal in value of the eastern coals, which now have the advantage in

*Davis: Eng. Min. Jour., vol. LIX, No. 7, pp. 149-150. February 16, 1895.

much of the territory north and west of the Iowa fields. The difference in freight rates will more than offset the cost of cleaning, which has lately been very much reduced.

	Moisture.	Total combustibles.	Ash.	Volatile combustible matter	Fixed carbon.	Coke-fixed carbon plus ash.	SULPHUR.		
							Sulphides.	Sulphates.	Total.
Christy mine	6.10	82.59	11.30	39.06	43.53	54.83	4.99	.14	5.13
Gibson mine	7.04	82.89	9.72	40.06	43.17	52.89	4.09	.16	4.25
Manbeck mine	6.82	76.68	16.19	36.93	39.65	56.84	4.44	.29	4.73

The mining equipments are usually good. With the exceptions of a very few of the smaller mines, the Merchant and

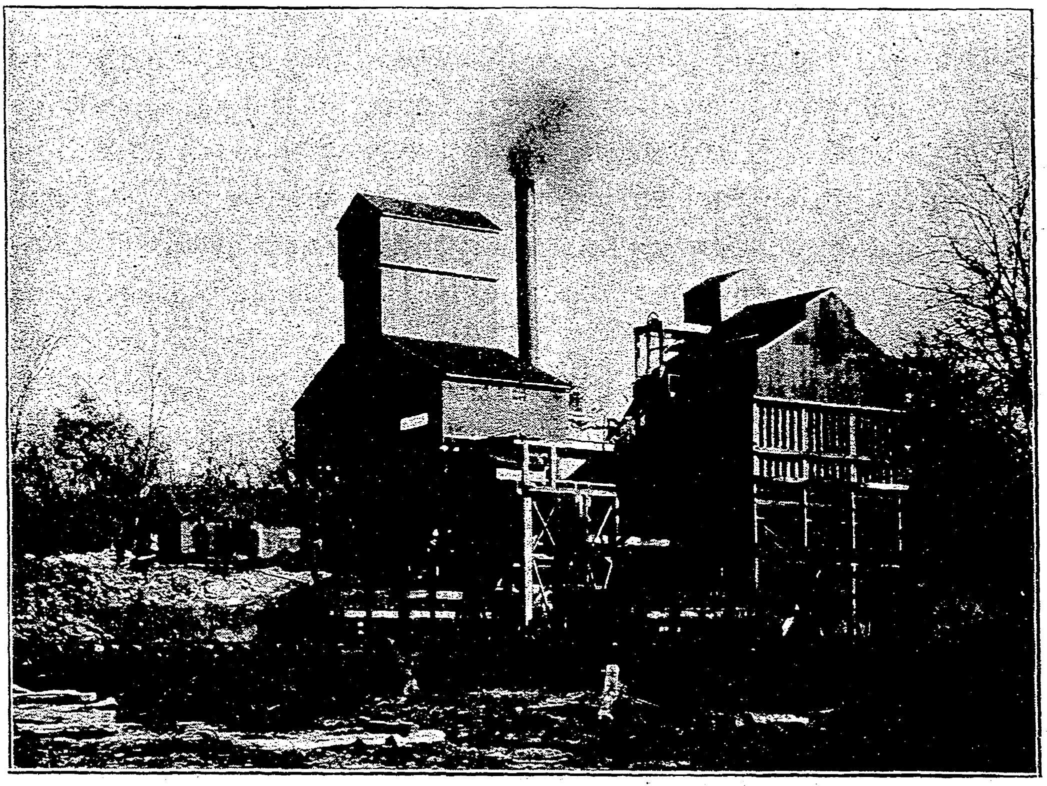


FIG. 58. Shaft house and tipple of Carbondale No. 2.

Hulme at Commerce, and some of the reopened mines of South Des Moines, substantial steam hoists are used throughout the county. In most of the mines mules alone are employed for underground haulage, but at the old Eureka and the Christy tail rope plants have been installed. Sliding screens are most common, but there are a few mines equipped with revolving screens. There has been a constant improvement both in mining methods and equipment. The Carbondale mine No. 2, recently opened, is one of the most substantial and well arranged plants in the state. It is represented in figure 58.

This plant includes well built and well arranged top works, with revolving screen, chain conveyers, storage bins, extensive trackage and other features of a complete plant. At all the mines the cheaper types of boilers are used, and little attention is paid to economy in steam generation. The low price of fine coal which is used for fuel compared with the high cost of boilers of greater efficiency, together with the notoriously rough usage which machinery of any kind receives in coal mines, allows this system to prevail.

In mining, the work is all done by hand. Shooting from the solid prevails throughout the district, and the blast holes are drilled by means of the common hand drill with auger bit. Power has not been introduced in this work. At the Carbondale mines a power plant was recently put in. It includes both coal-cutting machines (Jeffery pattern) and drills. The machines were found to undercut nicely, but the blast left the coal in such shape that it was difficult to get it out, and the work has been discontinued.

The major development of the coal industry has heretofore been in the immediate vicinity of Des Moines, and here as elsewhere the mines have been located along the streams. It is believed that much of the remainder of the county will prove as rich as any which has so far been opened up. As has been shown in the preceding pages, the development of the streams was long posterior to the formation of the coal, and there are no known relationships between the two. The opinion sometimes entertained that productive beds are to be found only along the streams has no foundation except in the history of the industry where the coincidence is manifestly the result of cultural factors. It is being constantly negatived as rapidly as prospecting is extended over the uplands, and the latter may be expected to prove as rich as the valleys.* These considerations enforce the belief that the industry in Polk county is in its infancy only, and that much the larger portion of the coal is yet untouched. Of a total of 375,200 acres within the county, about 8,000 only are now held for development by mining companies. In addition 2,200 acres have been more or less completely worked over so far as the known horizons are concerned. Much of the latter territory will not be reworked unless lower horizons should be located. A considerable portion, however, contains enough coal to be available for local mines.

In all less than six-tenths of one per cent of the area of the county has been worked out, even in the sense in which that term is used here. About 2.13 per cent is now being developed; 97.27 per cent of the region has not even been prospected.

It would be difficult to arrive at any estimate of the total amount of coal mined. Up to 1881, when the state mine inspectors were appointed, there was no agency for collecting and recording the statistics. The various census reports issued by the state give notes for the years of issue, but the intervening years are blank. In the following table the data so far as they are available are tabulated, the amount being recorded in short tons. The figures for the years 1881–95 are from the reports of the mine inspectors. Those for previous years are taken from the state census reports, except for 1860. The amount for that year is taken from the eighth federal census.

1856	600
1860	1,858
1862	1,418
1865	1,116
1866	13,310

* Since the above was written the extensive prospecting of the Consolidation Coal Co. over the highlands north of Des Moines has shown the presence of good coal at several points.

1869	27,796
1874	69,327
1881	473,893
1882	327,819
1883	558,821
1884	619,921
1885	462,895
1886	337,964
1887	305,094
1888	386,321
1889	356,039
1890	508,149
1891	397,833
1892	371,389
1893	466,408
1894	355,000
1895	334,881

The mine inspectors are restricted by law so that they take account only of mines employing more than four men. In 1893 the Geological Survey collected statistics of production from all the mines in the county and obtained a total of 693,-103 tons. The year was notable for the exceptional output of Iowa mines, so that the ratio can not perhaps be fairly applied to the whole period, but if an allowance of one-fifth be made for the small mines the total coal mined since 1881 would be about 7,600,000 tons. The total amount mined before that time may be less accurately estimated at 2,300,000 tons. In round numbers Polk county has produced 10,000,000 tons of coal. As has already been indicated, only 2,200 acres have been "worked out," aside from the empty rooms in the mines now working. Since in mining practice about 3,200 tons per acre are, in this region, produced from a four foot vein, it may be estimated that about 3,000 acres have been mined out. Upon this basis the lands now prospected and under lease should yield approximately 32,000,000 tons. Whether or not the unprospected 97 per cent of the county will prove equally productive can not, of course, be foretold, but if it should prove very much less rich, Polk county would still have enormous reserves of coal within its borders.

The mines now operated are included in the following list. Their location is shown upon the map accompanying this report as well as in the small sketches introduced in the text. Since the stratigraphy of the coal measures and the distribution and character of the coal beds has already been given it only remains to note here the position and relations of the mines, together with a few details regarding the workings. The mines readily group themselves around eleven localities.

Runnells.—There are two mines in operation at this point. The larger is the Acme, which is a shaft mine with steam hoisting plant and a switch from the Wabash railroad. The coal is reached at a depth of forty feet and is the same vein which was formerly worked by a slope driven in from the bluff. The coal reached by the slope was cut by a preglacial erosion channel.* It was also cut off at the north by sandstone and shale which was drilled into to a depth of eighty feet without locating coal. The territory now developed is west of that mined by the slope and east of the territory which was worked out by the Midland mine, abandoned some time since. West of the Midland territory and north of town is the Star, a small mine worked for local trade. Still farther west, at the edge of the town, the Skandia mine was formerly located. About forty acres were opened up by this drift, but the work was abandoned because of fire.

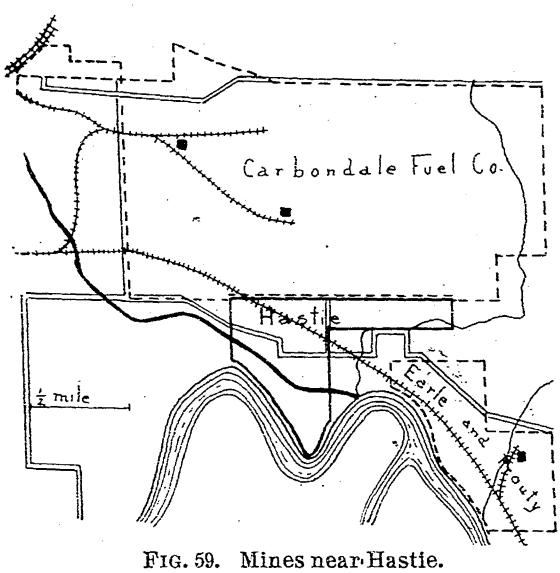


FIG. 59. Mines near Hastie.

Hastie. — A mine was sunk some years since at this point by Adams and Hastie. A four foot vein of coal was worked at a depth of 100 feet. Upon attempting to mine toward the south

*Keyes: Iowa Geol. Surv., II, 292. 1894.

water was encountered and the mine was eventually drowned out. A second shaft was put down farther east by J. M. Christy and a small area worked out. Near this point Earle & Prouty have a tract of land where the Iowa Fuel Co. now operates a mine. The shaft has a steam equipment and a track from the Wabash railroad. So far the output has been mainly used by the Newman Brothers' brickyard, which is located upon the same land. An upper seam of coal was worked to a slight extent by the Woodlawn Coal Co., but the shaft has been abandoned.

Manbeck.—Opposite Hastie is the mine of the Coal Valley Coal Co., which was owned formerly by the Manbeck and Coon Valley companies. The section as shown by mining operations has already been given. The coal now mined is reached by both shaft and slope. The upper seam, which is not worked, is reached by a slope driven up from the lower vein. This upper vein outcrops along the railway almost to Avon and has been opened up by local drifts at several points.

Carbondale.—The Carbondale mines form a group lying on the north side of the Des Moines river near Four Mile creek. They include the two mines of the Carbondale Fuel Co., the Christy mine and the two mines of the Gibson Coal & Mining Co.

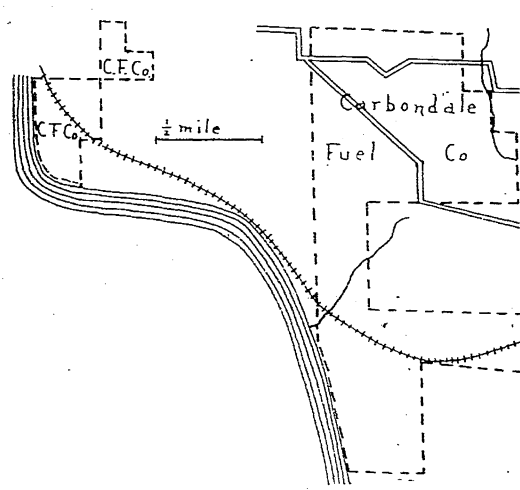


FIG. 60. Carbondale Fuel Co.

Mine number 1 of the Carbondale Fuel Co. was formerly operated by the Iowa Fuel Co. Number 2 is a new mine opened by the company immediately after its recent organization. Both mines are well equipped steam plants. The mines have connections with the Chicago, Rock Island & Pacific railway and the Des Moines Union, through which all the other roads in the city are reached. The company has a large tract of land under lease at the mines, as well as two small tracts lying respectively south and east of the Earle & Prouty land, and a large tract near Adelphi (Tp. 76 N., R. XXIII W., Secs. 13, 24, 25.)

The Christy mine is located between the two tracks of the Chicago, Rock Island & Pacific railway, and works a large tract of land lying mainly to the west of the mine. It is a will equipped plant with a tail rope for underground haulage and a revolving screen for cleaning the coal.

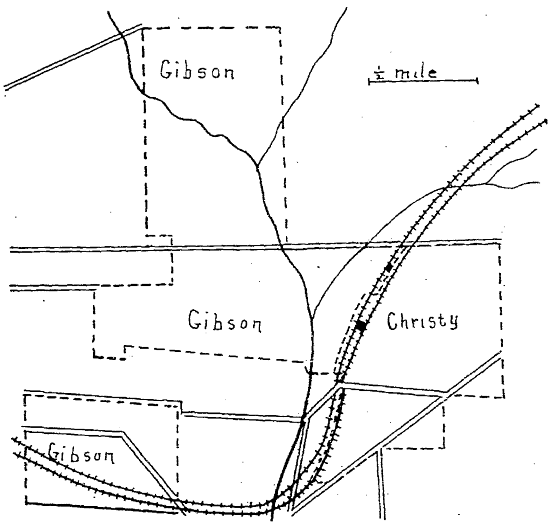


FIG. 61. Gibson and Christy tracts.

The Gibson No. 2 is a new mine located a quarter of a mile north of the Christy. It is also located between the two railway tracks. The land controlled by the Gibson company lies north and west of the shaft. In sinking the latter considerable trouble was experienced with a bed of quick sand. The section encountered showed the following beds.

		FEET
6.	Drift	12
5.	Sand	40
4.	Blue clay	4
3.	White pebble clay	5
2.	Black shale	22
1.	Coal	4

This differs in the upper portion very considerably from the record of a bore hole about 100 feet from the shaft. Since the mine is in the valley of Four Mile creek the explanation is found in the preglacial age of that stream.

Northeast Des Moines.—About three miles northwest of the Gibson No. 1, and likewise located upon the west flank of Four

Mile Ridge, are two mines, the Maple Grove and the Western. The Maple Grove is 105 feet deep, with coal three to four feet in thickness. The mine has a switch from the Chicago Great Western, but sells a large portion of its output on the local market. South of the Maple Grove was the Union, which worked out a tract of eighty acres and was abandoned. North of the Maple Grove is the new mine of the Western Coal Co., which has been opened up. A considerable tract of land has been prospected and leased, and substantial top works erected. Coal is shipped over the Chicago Great Western.

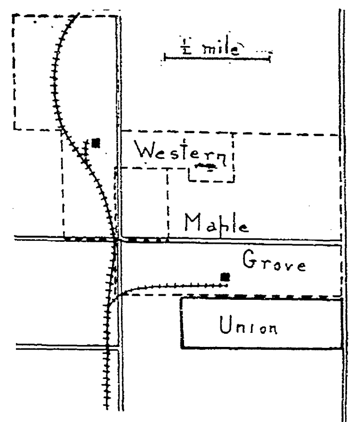


FIG. 62. Northeast Des Moines mines.

East Des Moines.—The only mine now operated in this famous mining district is the Eureka No. 2, which was opened in the fall of 1896. It is operated by the same company which owned the Eureka No. 1 on the south side of the river, and the mining equipment is the same. The company has a switch from the Chicago & North-Western railway. The strata found in sinking the shaft agree closely with those already given as found at the Giant mine. The thickness of the three veins as found here has already been given. The lowest vein is covered by twenty-five to thirty-four feet of back shale, so that the company anticipates no trouble from water. The company has 160 acres leased (Tp. 79, R. XXIII W., Sec. 36, Nw. qr.) of which a small portion only has been previously worked out by the Diamond mine. North of this lease (Sec. 25, Se. of Sw.) is the land mined over by the Miller mine. East of the Eureka (Sec.

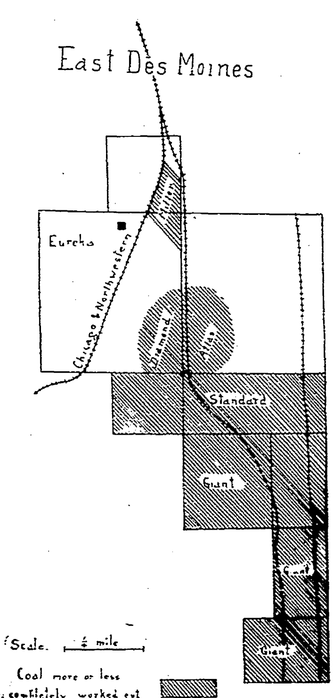


FIG. 63. East Des Moines mines.

36, Ne. qr.) is the old Atlas property, a very considerable portion of which was not mined because of trouble with water. South of the Atlas was the Standard (Sec. 36, N. ½ Se. qr.), and still farther south were the Giant mines (Sec. 36, Sw. of Se.; Tp. 78 N., R. XXIV W., Sec. 2, E. ½ of Ne. qr.). Directly south of the Eureka (Sec. 36, Ne. of Sw.) the Garver mine was located.

Saylor.—On the north side of the old valley previously described, the Des Moines Coal Co. have a mine near Saylor postoffice. The shaft record has been already given. The mine is connnected with the Chicago & North-Western railway. The lease includes 240 acres. The only other mining carried on in this vicinity was on the county farm. Over a portion of this land the upper seam shown at the Des Moines mine was worked out some time since.

Polk City.—But one mine has been open at Polk City. That is now owned by the White Ash Fuel Co. The shaft has steam equipment. So far local trade only has been supplied, but a switch from the Chicago & North-Western railway is to be built at once.

North Des Moines.—Along the Des Moines river from Sixth avenue to Beaver creek mining is being carried on quite vigorously. On the north side of the river are the Oak Park, Flint Valley and Lake Forest mines, of which the last two ship coal over the tracks of the Street Railway Co. On the south side of the river are the Bloomfield, Eagle, Keystone 1 and 2, and West Riverside mines. All of these mines are shafts, with steam hoisting plants, and all depend almost wholly upon the city trade. The Flint Valley furnishes coal to the brickworks

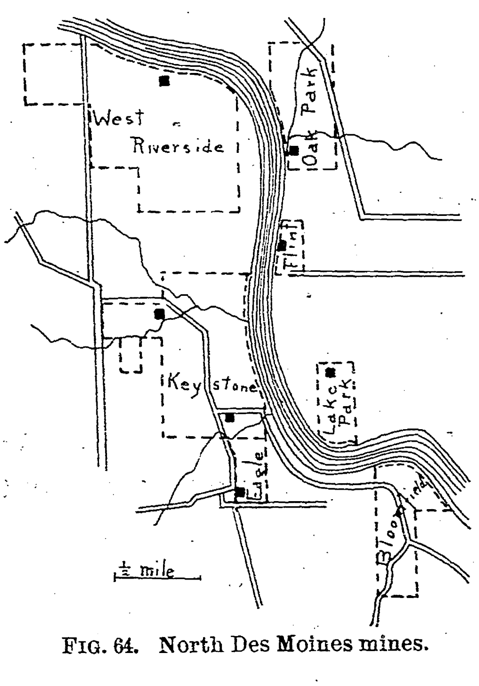


FIG. 64. North Des Moines mines.

of the same company, while the Keystone mine and the Iowa Brick Co. use the same territory.

South Des Moines.—At present there are but four mines in South Des Moines which are opening new territory. These are the Clifton, Proctor and the two mines of the Van Ginkle Coal Co. All are shafts operated by steam power. In addition, coal is being taken out from the second horizon on the land formerly worked by the Polk County and Des Moines mines by small gin shafts. The Riley mine, a small gin shaft, is located near the Des Moines.

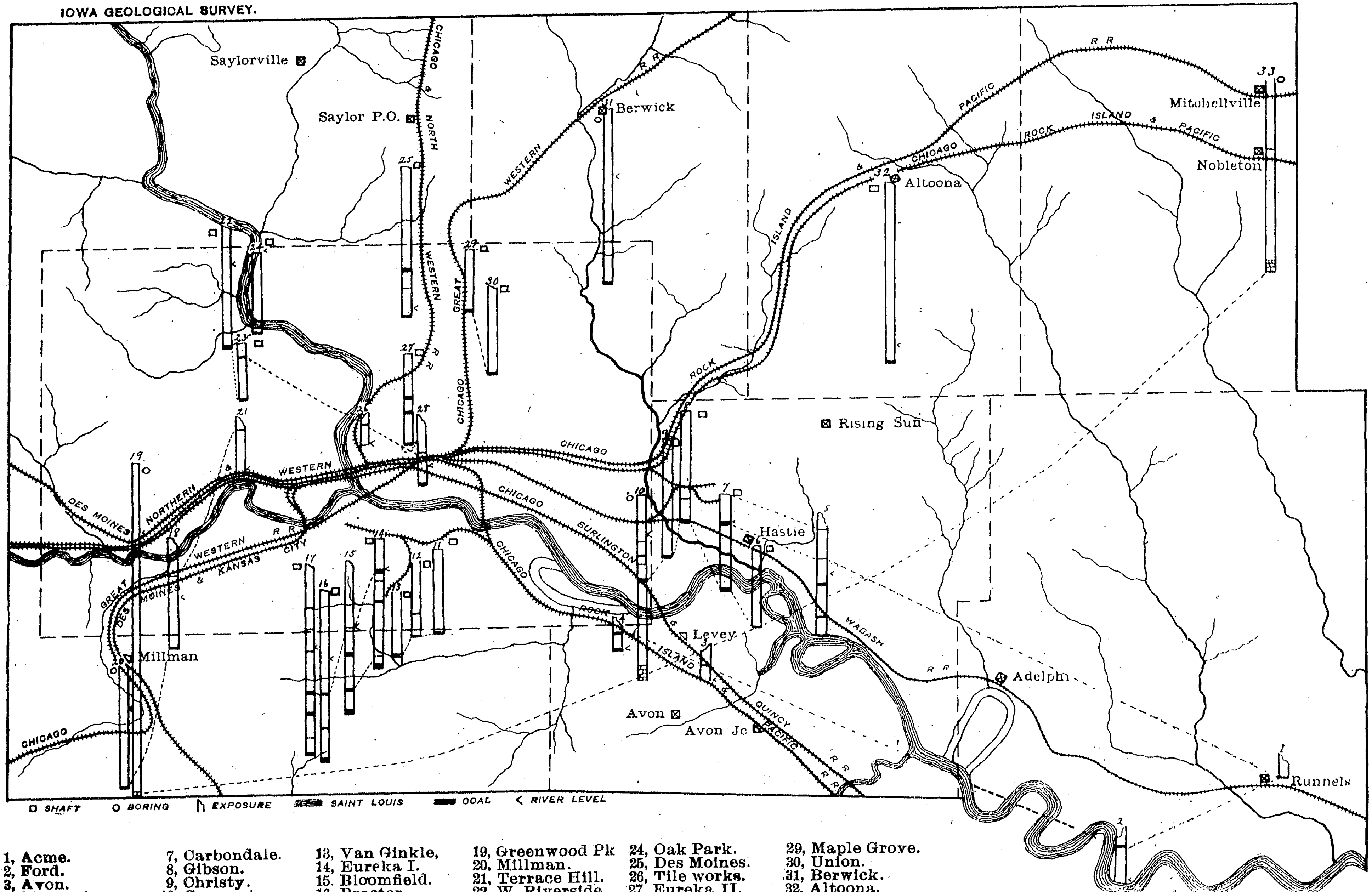
The Scott mine is a small drift worked in the first vein upon the territory of the Pennsylvania. All this territory is, however, in the main, worked out, and the mines now operating obtain coal from areas neglected by the older mines. The Van Ginkle mines, one of which is now known as the Pleasant Valley mine, have a switch from the Chicago, Rock Island & Pacific railway. (See figure 47.) The Clifton and Proctor mines have no railway connection. The Clifton mine is located on Clifton avenue, at the top of the hill leading up from the Raccoon. South of it a half mile is the Proctor. Between the two is a small strip of territory worked out by the Bloomfield. Between the Proctor and the Bloomfield is a "fault" towards which the coal rises and thins. It has been worked into 200 feet without being crossed. The Bloomfield lease lay east of the Clifton and Proctor. Beyond it was the half section controlled by the Eureka. East of the Eureka lease is the Van Ginkle land. Next to it is a strip worked out in part by the Polk County, and in part by the Des Moines mine. Beyond the latter was the Eclipse lease, and in part south and in part east of the Pennsylvania. The Pioneer land lay north of the Bloomfield and Clifton, and in part west of the Eureka. It extended north beyond the river. West of it was the Coon Valley, and near the latter a small area was worked out by the Great Western Coal Co.

Commerce.—There are two mines in operation at Commerce, both of which are gin shafts, and both of which sell only to the local trade. The Merchants mine has a lease of forty acres at the western edge of town north of the river. The Hulme mine is just east of town. The land owned here by Dr. Hulme includes 240 acres, part of which is south of the river. It has been prospected and shown to contain coal.

In connection with the sketches showing the location of the mines plate ix may be studied. Upon this plate the coal beds shown at the principal exposures, or found in mines or borings, are represented. The details of the sections have been in most cases given in the descriptive portion of this work. The correlations, so far as they can be made, are indicated by the dotted lines. Where they are not indicated the probable correlations may be inferred from the relations of the coal to the river level. The basis of the correlations has been already discussed. The plate shows graphically much of the evidence upon which they are based, as well as the difficulties which are encountered in any attempt at detailed correlations. It will be noted that the coal beds of the southeastern portion of the county form one group; those of South Des Moines form a second; the East Des Moines, and along the river to the Beaver, are readily correlated, and the sections near Millman fit together; but between these separate groups correlation is less easy, and for reasons already given, has not been attempted. The great irregularity in the surface of the Saint Louis is brought out, as is also the irregularity of the present topography. The thickness of the coal beds is necessarily exaggerated. Their distribution and vertical relations are better indicated.

Clays.

Des Moines is rapidly becoming known as one of the great centers for the manufacture of clay goods. It already manufactures more paving brick than any point west of the Mississippi, and the whole clay industry of the county is yet in its infancy. Polk county contains vast quantities of material suitable for manufacture into all grades of clay goods, and



1, Acme.
2, Ford.
3, Avon.
4, Manbeck.
5, Woodlawn.
6, Hastie.
7, Carbondale.
8, Gibson.
9, Christy.
10, Crescent.
11, Polk County.
12, Pleasant Hill.
13, Van Ginkle,
14, Eureka I.
15. Bloomfield.
16, Proctor.
17, Clifton.
18, Rose Hill.
19, Greenwood Pk
20, Millman.
21, Terrace Hill.
22, W. Riverside.
23, Eagle.
24, Oak Park.
25, Des Moines.
26, Tile works.
27, Eureka II.
28, Capitol Hill.
29, Maple Grove.
30, Union.
31, Berwick.
32, Altoona.
33, Mitchellville.

COAL BEDS NEAR DES MOINES.

while at present the output is limited, it may be expected to expand with increasing demand.

Both the coal measures and the Pleistocene beds yield material suitable for manufacture. The loess is at present used mainly for the common grades of brick, but it is so abundant, so easily worked, and is capable of yielding such excellent results, that it may be expected to be brought more and more into requisition. The alluvium is quite generously developed along the streams, particularly of the southern portion of the county, as is shown upon the accompanying map. While it is in places quite thin, and forms merely a sheet over underlying gravel or till, the aggregate amount present is enormous, and at any given point is far in excess of any probable demand.

Alluvium is one of the most easily manipulated of clays. It usually occurs with about the proper proportions or silica and other ingredients, so as to require no mixing with other material. It is spread over flat land, and hence is readily accessible. It is easily dug and requires no crushing. It will stand, in most instances, sun drying, and is most commonly burned in simple cased kilns. By the hand process, when properly carried out, it yields an excellent brick of fair strength, good color and low cost. The sand-rolled brick made from alluvium are not so beautiful as more expensive brick, but they are equally well adapted to inside work and all classes of construction when fair strength and low cost are the main considerations. There must always be a good demand for such brick, and Polk county is well supplied with material for all such local and probable foreign demand.

The second class of Pleistocene material available is the loess, whose properties and distribution have already been discussed. The loess occurring near Des Moines is mainly of the type which for want of a better name is known as typical loess, to distinguish it from the phase called white clay. It is highly silicious, contains considerable lime, and allows a freer circulation of water than the white clay. The loess found here is best adapted to the dry-press process, though it also yields fair results when treated as a stiff mud, provided too much water is not used, and the drying is carefully watched. When dried rapidly it is apt to check. It burns to a cherry red and when properly handled, particularly if moulded on the dry-press, will yield a firm, hard brick of smooth surface and uniform pleasing color. It is a clay which is easily handled and, except for the lime, has no detrimental impurities. The lime is not always present in such quantity and form as to prove harmful, but it is one of the things which should be carefully examined before an attempt is made to utilize any deposit.

The till is usually so full of lime concretions and pebbles that it is not used. At Polk City it has, however, been made into tile with very fair results. In other parts of the United States till is used quite extensively in the manufacture of common brick, and if the need should arise there is no reason for supposing that the till present throughout Polk county would not be equally available. In the presence, however, of so much material that is more easily worked, it will not at present pay to introduce the necessary cleaning machinery.

In the northern portion of the county where the loess and coal measures are deeply buried and the streams have not yet developed alluvial bottom lands, recourse may be had to the slough clays. These are of essentially the same nature as alluvium, being collected in basins by the water which falls on the sides and runs down to the center. They are not of great depth but may form important local deposits. Clay of this character is in use at Bondurant, and has been used to some extent at Altoona. It is quite free from lime pebbles, and, except for a tendency toward checking, is easily handled.

The great bulk of the clay used in the county is derived from the coal measures of the Des Moines formation. These abound in clays and shales which vary greatly in composition, texture and adaptabilities. They are used for the manufacture of all grades of building and paving brick, sewer pipe and drain tile, and common pottery, and have been proven by careful experiment to be well adapted to the manufacture of certain classes of terra cotta and pottery. The differences in appearance and texture of these clays have been noted in the sections given on preceding pages. Their wide distribution may be inferred from the same data. Certain minute differences and adaptabilities as at present known are noted in the sections which follow. The coal measures are used largely in the manufacture of pavers and various grades of building brick.

Of pottery only the coarser grades are now made. There are no kaolin deposits in the region, so that if the finest wares be attempted kaolin must be imported and mixed with the local clay, which may be used as a base. Since, however, this is advantageously done at other points, it is to be expected that in time the local demand at least will be supplied by the home product. An excellent grade of kaolin has been for some years supplied from southeastern Missouri to Ohio, where it is used in connection with coal measure clays in the manufacture of medium and fine pottery. There seems to be no good reason why a pottery industry similar to that of Ohio should not be built up in Iowa. The coal measures of this state contain beds of clay well adapted to this use and the Missouri kaolin deposits are nearer Iowa than Ohio.

In this connection it is of interest to note that the Carbondale Fuel Co., as a result of experiments made both in this country and in Scotland upon clays found upon their lands, have shown that their clays are not only suitable for the paving and various colored building brick already manufactured within the state, but are adapted for enameled brick and probably for ware of finer grades. It is expected that plants will be erected for manufacturing these various lines of ware.

One very important use for clays of the grade found here is the manufacture of sewer pipe and chimney tops. At present there is but one plant in operation, but the business is one which may be expected to expand.

In general, it may be said of the clay industry of Polk county, that there is room for great expansion. With inexhaustible quantities of clay of such widely varied adaptabilities, with coal at hand, and with exceptional transportation facilities, the region must become famous for its clay products. There will always be a considerable local demand to be met, and so long as clay goods are shipped into the state there will be trade to be won by local companies.

The methods adopted in working the clays vary with the material, the object to be attained, and the individual preference of the operator. They are brought out in the descriptions of the individual plants.

PAVING BRICK.

Among the most important industries of Des Moines is the manufacture of paving brick. This industry is of recent establishment, and its rapid development is very gratifying. Paving brick have been used in Holland for more than a hundred years, but the use of brick for street paving in the United States is quite recent. In 1870 an experimental block was laid in Charleston, W. Va., and in 1873 several blocks were laid in the same city. These brick are still in good condition in spite of having been laid upon a board foundation and of being of inferior quality, as judged by present standards. At Bloomington, Ill., several blocks were laid in 1875, and have stood twenty years of service. These were merely hard burned building brick, and much inferior to the modern pavers. It was not until 1890 that the paving industry showed any notable tendency to expand, but since then its development has been very rapid. Brick paving is being gradually introduced into the larger cities. Saint Joseph began to use it in 1888, Kansas City adopted brick paving in 1889, and Saint Louis in 1895. Paving brick are now being used for residence streets in Philadelphia, and more recently brick have been laid in Minneapolis, Omaha and several other cities. In Chicago a few residence streets are paved with brick, and experimental blocks have been put down by the Purington Brick Co. on Michigan avenue and the Des Moines Brick Co. on La Salle street.

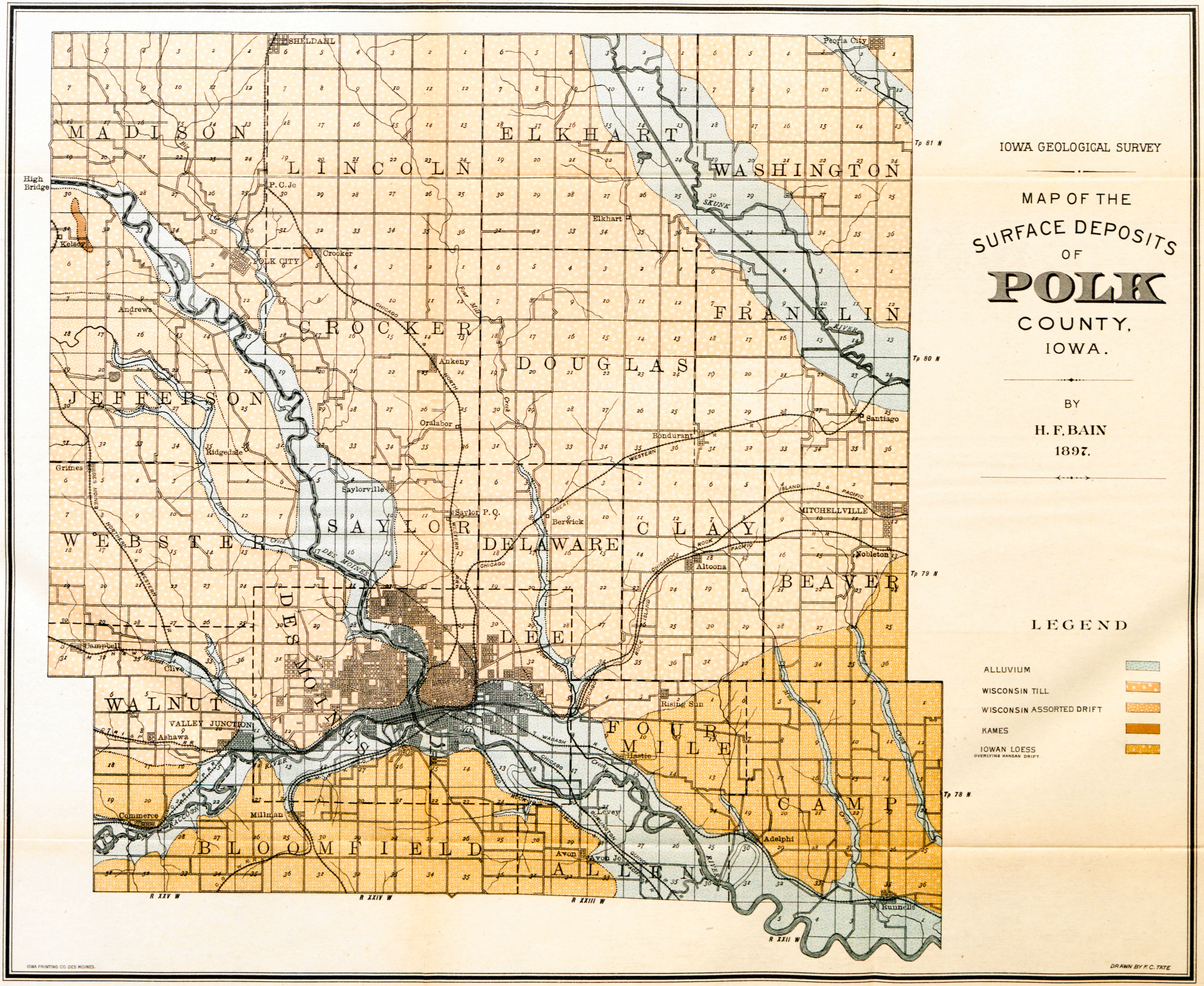
In Des Moines the first brick was laid in 1889. They came from Saint Joseph, and were laid on Forest avenue. The first pavers made here were turned out in 1891 by the Des Moines Brick Co., and were used with outside brick. The first brick paving done exclusively with Des Moines brick was in 1892, when East Grand avenue to the fair grounds was paved with brick furnished by the Des Moines Brick Co. To this company is largely due the credit for demonstrating that the shales found here could be made into pavers second to none. Since the first success the industry has rapidly expanded until now four large paving brick plants are in operation, and others are contemplated. The brick is used at home so extensively that Des Moines is becoming known as the city of brick-paved streets, and is gaining an enviable reputation for its fine driving and haulage ways.

Brick paving has of recent years become rapidly popular. It has, as compared with other forms of paving, many important advantages, among which may be mentioned the fact that it is clean, nearly noiseless, healthful, smooth, durable and cheap. When properly laid it has always exceeded expectations. A not unimportant advantage of brick paving is the fact that it allows the cleaning of the streets by flushing, particularly if the sewers be made of the same brick, and so are not affected by the wearing action of the muddy water. Brick paving is easily and cheaply repaired, and like granite blocks, is easily torn up for the purpose of laying or repairing tracks, pipes, conduits, etc. It is less noisy than granite, and since it forms a more even surface, is cleaner. It is not slippery like asphalt, and is much more durable as well as more healthful than the wooden blocks.

A most important factor in the life of a pavement is the character of the roadway upon which it is laid. It should be well drained and well packed. In Des Moines the brick are laid in either single or double course. The single course brick rest upon a concrete (six inch) or macadam (five inch) foundation, with the brick set on edge with their longer diameters across the street. Between the brick and the concrete is a two-inch cushion of clear sand. When the brick have been set in place fine gravel and coarse sand are brushed over the surface, so as to fill the interstices, and hot pitch is run into the seams. A top surface of fine sand is spread over the pavement and allowed to remain for a few days, after which it is brushed off. Double course pavement is not ordinarily laid on concrete. The ground is prepared by grading and rolling, and a course of hard burned brick laid over sand. Above this is a second sand cushion, on which the paving brick are laid, as in single course work.

One course paving requires sixty-six brick and costs with concrete according to recent contracts, $1.35 to $1.68 per yard. Two course paving requires 105 brick and has been costing, with concrete, about $1.25 to $1.50 per yard. It is impossible to compare these figures with the cost of other work, since nothing but brick has been laid in Des Moines in recent years. At Minneapolis recent bids were $1.85 for one-course brick and $2.51 for asphalt.

For very heavy traffic streets the foundation should be strengthened. The Michigan avenue work in Chicago consists of one course brick over sixteen to eighteen inches of crushed stone and concrete. For such streets only the best brick should be used. While clays capable of being manufactured into average paving brick suitable for residence streets and smaller cities are not rare, clays which yield the higher grade of pavers are not so common. For heavy traffic streets or steep grades only the finest quality of material should be used. Even such material will probably not be so long lived as well selected granite blocks, but the first cost is very much


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
POLK
COUNTY,
IOWA.
BY
H. F. BAIN
1897.
LEGEND
ALLUVIUM
WISCONSIN TILL
WISCONSIN ASSORTED DRIFT
KAMES
IOWAN LOESS
OVERLYING KANSAN DRIFT
MADISON
LINCOLN
ELKHART
WASHINGTON
FRANKLIN
CROCKER
DOUGLAS
JEFFERSON
WEBSTER
SAYLOR
DELAWARE
CLAY
BEAVER
DES MOINES
LEE
WALNUT
FOUR MILE
CAMP
BLOOMFIELD
ALLEN
Tp 81 N
Tp 80 N
Tp 79 N
Tp 78 N
R XXV W
R XXIV W
R XXIII W
R XXII W
IOWA PRINTING CO. DES MOINES.
DRAWN BY F. C. TATE

less, and the difference in noise and resistance to traction offsets the shorter life of the pavement. In the latter particulars brick is only exceded by asphalt which, however, can not be used on grades of over five per cent, can not be flushed, and is expensive both to lay and to keep in repair. The only cheaper pavements are the Macadam and Telford, which require constant care and repairs.

The durability of brick paving has not yet been determined. No first class pavers have yet been worn out and some of inferior quality have stood hard service for more than twenty years. From the evidence of the last ten years it seems probable that well made and well laid brick are only surpassed in durability by granite blocks. The popularity of brick paving in Iowa and the central west is established by the fact that Des Moines brick are now in use in Chicago, Minneapolis, Saint Paul, Omaha, Council Bluffs, Dubuque, Cedar Rapids, Waterloo, Marshalltown, Davenport, Muscatine, Keokuk, Iowa City, Waverly, Adel and other cities. In 1896 18,000,000 pavers were sold, and for 1897 the home orders alone call for about 7,000,000.

The paving brick industry is so new that its technology is still in the process of development. It is only within the last few months that even a uniform series of tests has been formulated, and improvements in the process of manufacture and burning are constantly being introduced. The reported failures of brick in some of the early experiments are now known to have been as often the result of improper selection and lack of familiarity with the proper methods of laying brick, as of the poor quality of the brick itself. The quality is, however, being constantly raised as the requirements are better understood and the properties of the clays are more studied.

The most valuable treatise on the manufacture of paving brick is that recently issued by the Missouri Geological Survey* and written by Prof. H. A. Wheeler, of Washington

*Mo. Geol. Surv., vol. XI, 622 pp., 38 pls. Jefferson City, 1897.

University. The report covers all of the clay industries of the state, and from the chapter on paving brick clays much of the following is condensed. According to Professor Wheeler a vitrified brick is one that is burned so hard as to be almost non-porous. It should have a close, dense, compact structure, a very high degree of hardness, and the individual particles of the clay should be no longer visible, even with a lens. In Des Moines practice brick are accepted for street use if upon a chipped surface it does not show individual grains. Since all such tests are matters of degree, and since the quality of the brick has been amply attested both by use and experiment, this seems to be a safe test.

If the brick are cooled slowly they will have a crushing strength that exceeds granite and a toughness nearly as great. In these particulars they are sharply differentiated from building and fire brick. If they are burned so hard as to be completely vitrified they are glassy and are not so tough. The lower heat only slightly vitrifies the material and produces a brick with stony fracture. It is this "incipiently vitrified" brick which is desired. The materials used for paving brick are shales and impure fire clays. The primary requisite is ready fusibility which is induced by what are called the fluxing impurities, iron, soda, potash, lime and magnesia. The greater the amount of the first of these constituents the easier it is to fuse the material. The Des Moines clays carry from 2.05 per cent to 13.12 per cent of this material, and the percentage of total fluxes varies from 2.88 to 17.60, the majority falling between 6 and 10 per cent. The extremes are of course only used in combination. The clays as mixed and put into the pug-mill carry according to one series of determinations 7.48, 6.13, 10.52 and 5.53 per cent of fluxes. The higher percentage of fluxes has the advantage of causing vitrification to set in at relatively low temperatures and hence allows fuel economy. Too high a percentage, however, causes too ready a fusing, and yields glassy brick which fail in toughness.

The toughness of brick seems to depend largely upon the physical properties of the clay, including particularly the fineness of grain and the density. It is also influenced very largely by the manipulation of the clay and the manner of the burning.

The chemical composition of the shales used for paving brick shows the widest variation. This is illustrated in the analysis of the Des Moines shales, and in the following table given by Wheeler, and based upon fifty carefully selected analyses.

	Minimum per cent.	Maximum per cent.	Average per cent.	Total averages.
Silica ($Si\,O_2$)	49.0	75.0	56.0	------
Alumina ($Al_2\,O_3$)	11.0	25.0	22.5	------
Ignition loss ($H_2\,O$, S, CO_2)	3.0	13.0	7.0	------
Moisture ($H_2\,O$)	0.5	3.0	1.5	------
Total non-fluxing constituents	------	------	------	87.0
Iron sesquioxide ($Fe_2\,O_3$)	2.0	9.0	6.7	------
Lime ($Ca\,O$)	0.2	3.5	1.2	------
Magnesia ($Mg\,O$)	0.1	3.0	1.4	------
Alkalies ($Na_2\,O$, $K_2\,O$)	1.0	5.5	3.7	------
Total fluxing constituents	------	------	------	13.0
Grand total	------	------	------	100.0

As a matter of fact the majority of clays used approximate quite closely to the average given. The wide range in composition is possible because of a compensating range in the manner of combination of the fluxing constituents and in the specific gravity and fineness of grain.

The requisite physical properties are summarized by Wheeler as follows.

(1) The clay should have sufficient plasticity to allow it to be readily moulded. If it is so lean as not to admit of being worked into a continuous bar by an auger machine it cannot compete in cost and quality with the clays that can be so

worked unless a fat or bond clay is mixed with it. The air dried clay should have a tensile strength of about 100 to 150 pounds per square inch. If it is too fat, or the tensile strength be above 200 pounds, the clay is apt to laminate in moulding and check in drying. The checking can be prevented by mixing in lean clay, grog or sand, but the resulting brick are never so strong, and there is danger of lack of uniformity in the brick as a result of imperfect mixing.

(2) The shrinkage in air drying or burning should not exceed 12 per cent. Greater shrinkage leads to checking and increases the difficulty of burning.

(3) The clay should allow the brick to be put through a properly constructed dryer in twenty-four to thirty-six hours. Slower drying causes delay and extra expense for added drying room.

(4) The speed in burning should permit a vitrifying heat to be put on in five or six days. A tender clay, demanding slow firing, greatly increases the cost.

(5) The point of incipient vitrification to which all paving brick should be brought should be low, from 1,500° to 2,000° F. It should be readily obtained in an ordinary kiln.

(6) The point of viscous or scoriaceous vitrification should be at least 300° and preferably 400° F. above that of incipient vitrification. Unless there is an ample margin there is heavy loss from either soft unburned, or warped overburned brick. It is impossible to control the heat of the kiln within a very narrow margin.

(7) The density both before and after burning should be as high as possible, since it is an important factor of durability.

(8) It is often desirable, in order to meet a popular prejudice which seems to have some foundation in reason, that the clay should burn to a dark color.

The quality of the output is very largely influenced by the character of the process of manufacture adopted. The details of the process as carried on in the Des Moines plants are given in the descriptions of the individual works. In general the process includes (1) mining of the clay, (2) pulverizing, mixing and tempering, (3) moulding the brick, (4) drying, and (5) burning. Thorough pulverizing and mixing is important to secure a homogeneous product. The tempering controls largely the ease of moulding, drying and burning. In this work, because of the uniformity which may be attained by its use, the automatic tempering machine used by the Iowa Brick Co. has many important advantages. In moulding it is important to avoid excessive lamination since this is particularly unfortunate in paving brick. The amount of lamination may be controlled by proper tempering which may be in turn controlled by regulating the feed of the machine.

Recently it has become common to repress the brick. This process gives them better shape, makes them denser and usually stronger. In drying the usual care must be exercised to avoid checking, which is particularly liable to occur in paving clays because of their considerable shrinkage. The burning is perhaps the most important part of the process. In this work down draught kilns are exclusively used. The bricks should be set very open and the heat thrown first to the center. As color is not important water-smoking with wood is unnecessary and the whole burning may be done with coal. After the water-smoking two to four days, firing should be maintained four to six days, so as to bring the entire kiln up to a cherry red heat, 1,600° to 1,900° F. The kiln should be cooled slowly allowing plenty of time, six to twelve days, for the annealing. The slower the cooling the tougher will be the brick. It is impossible to burn a uniform kiln of brick. Only from 60 to 90 per cent will be No. 1 quality. At Des Moines the percentage ranges usually from 75 to 85 per cent. The remaining brick, while unsuitable for paving, are excellently adapted for use as hard burned building brick and usually command a ready sale.

The testing of paving brick is a matter which has attracted much attention, and the proper methods of testing have been much misunderstood. An experienced inspector can tell much from the appearance of a brick and the character of a fractured surface. He may, however, be much deceived in examining brick with which he is not familiar, and in any event such a test can not be formulated so as to be either useful for comparison or available for future reference. A number of mechanical tests, including crushing, cross-breaking, absorption and the rattler test have been used. The present tendency is to rely mainly upon the eye inspection and the rattler test.

The paving brick companies of Des Moines have recently had a very complete set of tests made upon their brick. The work was done by Mr. E. P. Boynton, C. E., city engineer of Cedar Rapids, with the exception of the chemical analyses which were made under his direction by Prof. C. O. Bates of Coe College. The tests were carefully planned and were carried out with great detail. Through the courtesy of the managers of the four companies concerned, the Survey is permitted to publish here the summary results of the tests. It should be remembered that these are only the summaries and in each case represent a large number of individual tests. A few of the detailed tests are given under the description of the individual plants. At this place, in Table I, is given a general summary, together with the results of similar tests on certain other well known brick for comparison.

TABLE I.

PAVING BRICK TESTS—GENERAL RESULTS.—E. P. BOYNTON, C. E.

NAME OF MANUFACTURER.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST.			Porosity. Absorption.	TRANSVERSE STRENGTH RUPTURE.			Comparative rating by formula.
		AVERAGES.							
		PER CENT OF LOSS.				MODULUS OF RUPTURE			
		Actual.	Rational.	Average of 3 and 4.	Per cent of gain.	Actual.	Rational.	Average of 7 and 8.	
1	2	3	4	5	6	7	8	9	10
Diamond Brick & Tile Co., Kansas City, Mo.	End cut	----	----	----	----	----	----	----	----
	Common	15.17	15.17	15 17	.71	2,190	2,190	2,190	62.14
Purington Brick Co., Galesburg, Ill.	End cut	----	----	----	----	----	----	----	----
	Repress	9.09	9.09	9 09	1 85	3,365	3,365	3,365	104.14
Galesburg Vitrified Brick Co , Galesburg, Ill.	End cut	----	----	----	----	----	----	----	----
	Repress	11.89	11.27	11.58	1.05	3,122	3,122	3,122	90.70
Des Moines Brick Manufacturing Co., Des Moines, Iowa	End cut	11 07	11.07	11.07	.93	2,584	2,584	2,584	89 36
	Common	12.80	12.13	12 49	1.17	2,621	2,621	2,621	80 39
Capital City Brick & Pipe Co , Des Moines, Iowa	End cut	17.78	17.61	17 70	.54	3,896	4,080	3,988	62.89
	Common	12 49	12.49	12.49	.60	3,429	3,429	3,429	89.82
Iowa Brick Co , Des Moines, Iowa	End cut	12 28	11.45	11.87	.80	----	----	----	80.61
	Common	16.80	15.65	16.23	.86	2,193	2,193	2,193	54.21
Iowa Brick Co , Des Moines, Iowa	Side cut	12.23	11.81	12.02	.55	----	----	----	92.12
	Repress	14 80	13.63	14.22	.96	3,348	3,714	3,531	77.28
Flint Brick Co., Des Moines, Iowa	End cut	----	----	----	----	----	----	----	----
	Common	12 49	12 49	12.49	.93	2,740	2,740	2,740	82.25
Davenport Paving Brick & Tile Co., Davenport, Iowa	End cut	----	----	----	----	----	----	----	----
	Common	15.03	14.67	14.85	.93	2,056	2,056	2,056	61.88
Ottumwa Paving Brick Co., Ottumwa, Iowa.	End cut	----	----	----	----	----	----	----	----
	Common	12.95	12.95	12.95	2.10	2,343	2,343	2,343	71 20

The tests included the determination of the abrasion and impact loss by means of the rattler, the porosity by the absorption test, and the transverse strength. The latter is expressed in terms of the modulus of rupture. The rattler used was polygonal in form, twenty-nine inches in diameter, and forty-eight inches long. It was charged with eleven brick and a standard charge made up of 300 pounds of two-pound cubes, 340 pounds of two-pound cast iron spheres, and 120 pounds of smooth cast iron foundry shot one-fourth to one-half pounds each in weight. This charge was itself determined to be best adapted to the work as the result of a series of experiments. The test consisted of 800 revolutions at a rate of thirty-three revolutions per minute, the rattler being driven by steam. The loss is calculated in per cent by weight.

The absorption test was made upon brick which had been subjected to the rattler treatment and had accordingly lost their external glaze. The brick were brushed clean, dried at 174°–178° F. for seventy-two hours, cooled one hour at 60° F., weighed to .0025 pounds, set on edge in running water at 40°–42° F. for seventy-two hours, wiped dry with a cotton cloth and re-weighed. The gain is expressed in per cent by weight.

The transverse strength was tested by cross-breaking and from this the modulus of rupture was calculated as usual.

The formula used for calculating the general rating was adapted from one used by Wheeler. It is as follows:

$$V=(20-R)\,6+(8-A)+\frac{T}{110}$$

R=Rattler loss in per cent by weight.
A=Absorption in per cent by weight.
T=Modulus of rupture per square inch.

The actual ratio in each case was obtained by comparing all the specimens tested. The rational ratio takes account only of those which show no signs of having suffered accidents during the tests.

Des Moines Brick Manufacturing Co.—This company was the pioneer in the paving brick industry of Des Moines. They formerly operated a small plant for the manufacture of tile, but in 1891 undertook the manufacture of building brick and pavers. The first large contract which the company filled was to furnish the brick for the Equitable building, both the face and roof brick being furnished. Later they began to make pavers as already noted. Their success has been to a high degree gratifying, and the original plant has grown until it is now one of the largest brick plants in the west. The works are located in west Des Moines between the tracks of the Chicago, Rock Island & Pacific and the Des

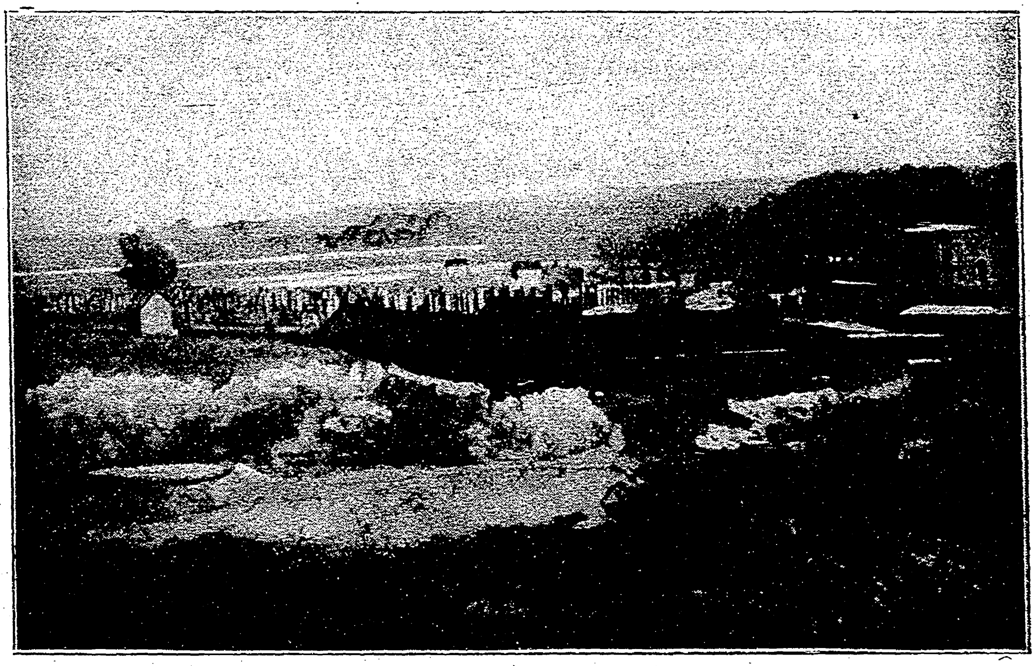


FIG 65. Des Moines brick works.

Moines & Northern railways. A considerable portion of the output was at first placed on the local market, but of recent years the shipping trade has been increasing. The pit is in all about forty-five feet deep.

The clay, as exposed at the time of Mr. Boynton's tests, and character of the brick which may be made from each stratum is given below.

D—1. Clay, variegated, highly refractory, burning to a brick of medium toughness, high porosity and low breaking strength; thickness, three to eight feet; average, five feet.

D—2. Shale, streaked in color, medium fusibility, high in iron and fluxes; burns to a brick of medium toughness, medium porosity and low resistance to rupture; thickness, three to eight feet; average, four feet.

D—3. Shale, solid chocolate brown color, clear definition; brick show medium toughness, low porosity and high modulus of rupture; thickness, five feet.

D—4. Shale, solid color, clear to poor definition; an average clay with medium iron, and fluxes lower than the clays above; brick show low toughness, low porosity, high modulus of rupture; thickness, five feet.

D—5. Shale, variegated, clear to poor definition, low iron and fluxes, high alum ina; brick show medium toughness, low absorption, high modulus of rupture; thickness, three feet.

D—6. Shale, sandy, solid color; brick show low toughness, low absorption, medium modulus of rupture; thickness, ten feet.

D—7. Shale, sandy, clear definition, solid color, granulated texture, pulverizes in the hand; not tested separately; thickness, five feet.

D—8. Shale, gray, clear definition, easily fused; brick, good toughness, high porosity, low modulus of rupture; thickness, twenty to twenty-five feet. This clay forms 38 to 40 per cent of the bank and runs to the underlying coal.

The chemical analysis of the individual clays is shown in table II. In considering the results of the tests on each clay of this and the other pits, it should be remembered that the different clays need different treatment, particularly in the burning. It was not possible to give this, so that many of the clays rank lower than they deserve. This brings down the averages shown in table I.

TABLE II.

CHEMICAL ANALYSES, DES MOINES BRICK MANUFACTURING CO.

—C. O. BATES, *Chemist.*

DESIGNATION.	*D-1.	D-2.	D-3.	D-4	D-5.	D-6.	D-7.	†D-8.
Silica, total, SiO_2	70.29	59.18	64.60	64.41	63.23	76.01	67.76	55.56
Alumina, Al_2O_3	15.18	21.63	19.20	20.43	24.52	11.94	14.46	21.33
Water, combined, H_2O	2.18	3.80	3.95	3.93	2.55	1.41	3 53	4.65
Clay and sand	87.65	84.61	87.75	88.77	90.30	89.36	85.75	81.54
Oxide of iron, Fe_2O_3	7.32	9.00	7.68	5.88	5.28	5.40	8.52	10.56
Lime, CaO	.80	1.06	1.02	.34	.32	1.57	1.16	1.59
Magnesia, MgO	1.72	1.85	1.37	1.71	.99	1.04	2.36	2.94
Total alkalies	1.49	1.52	1.25	1.90	1.16	1.80	1.24	2.38
Fluxes	11.33	13.43	11 32	9.83	7.75	9.81	13.28	17.47
Water, free, H_2O	1.02	1.95	.92	1.27	1.75	.65	.67	.97
Total	100.00	99.99	100.01	99.77	99.80	99.82	99.70	99.98
Oxygen in acid to oxygen in base 1	3.52	2.21	2.75	2.71	2.42	4.74	3.29	1.92
Oxygen in alumina to oxygen in flux 1	2.07	2.49	2.64	3.24	4.97	1.98	1.65	1.89

*Top clay worked. †Bottom clay worked.

The clay is mined by means of a Barnard steam shovel which loads the material into small cars. The latter are hoisted and dumped, the material falling into the dry-pans, one of which is of the Eagle Iron Works pattern and the other that of the Des Moines Manufacturing & Supply Co. The crushed clay is conveyed by an elevator to screens with openings $\frac{3}{4}\times\frac{3}{32}$ inch, and thence to bins. A portion of the material is pugged in a Wallace mill, and the remainder passed through a Chambers pug-mill. Two Chambers brick machines are used in moulding. They have a combined capacity of 70,000 brick in ten hours. Four Eagle represses are used. The bricks are loaded at the machines into iron cars, upon which they are pushed through the dryer to the kilns. The dryer has six tunnels and is held at 230° to 300° F. It takes thirty-six to fifty hours to dry the brick. In burning, Eudaly kilns, of which there are ten, of 200,000 to 225,000 capacity each, are used. Water-smoking consumes two to three, and the burning takes about six days. The brick have a high and well deserved reputation, as is shown by the subjoined tests. They have been used in most of the important paving contracts filled by Iowa contractors. When the works are in operation the out-put is about 120,000 per day with 80 to 85 per cent pavers. In all, about 76,000,000 paving brick have been made at this plant. It takes about thirty days to get the plant fully in operation.

TABLE III.

DES MOINES BRICK MANUFACTURING CO.

ABRASION AND IMPACT—RATTLER TEST.

General pavers, end cut common, from brick for paving Cedar Rapids, Iowa, season of 1896. E. B. BOYNTON, C. E.

MARKS.	Revolutions per minute.	Total revolutions	WEIGHT—LBS. Original.	Final.	Loss.	Loss, per cent.	CONDITION AFTER TEST.
C. 4 VI.	33	800	6.25	5.76	.49	7.84	Even wear.
I. 3 IX.	33	800	6.32	5.76	.56	8.86	Chipped corners.
B.-S.-1.	30	800	6.22	5.76	.46	6.40	Some chipping, were generally even.
L	33	800	5.95	5.43	.52	8.74	Chip off corner.
1-7-X.	32	800	6 37	5.85	.52	6.16	Wear even.
Z	32	800	6.50	5.96	.54	8.31	Chip off one corner.
Av'g.	----	------	---	----	--	8.05	

TABLE IV.

DES MOINES BRICK MANUFACTURING CO.

ABSORPTION TEST.

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895. E P. BOYNTON, C E.

MARKS.	WEIGHT IN POUNDS. Dry.	After immersion	Gain.	Per cent of gain
D-6-II	4.95	4.97	.040	.90
D-6-V	4.36	4.385	.025	.57
D-6-T	4.80	4.82	020	.41
D 6-L	5,09	5.11	020	.39
D-6-IX	4.87	4.90	.030	.61
D-6-X	4.82	4.845	.025	.52
Average	-------	----	-------	.56

TABLE V.

DES MOINES BRICK MANUFACTURING CO.

TRANSVERSE RUPTURE TEST

Broken in registering hydraulic press. Modules of rupture $= M = \frac{3 l w}{2 b h^2}$ in which $l =$ length between supports, $= 6$ inches, $b =$ breadth and $h =$ depth of brick, $w =$ breaking load

General pavers, end cut common, from brick for paving Union station grounds, Cedar Rapids, Iowa, in 1896, made in 1895

E. P. BOYNTON, C. E.

MARKS.	b.	h	w	m.	REMARKS
D-S-I	4.05	2.40	7,000	2,695	Medium dark reddish.
II	4.02	2.38	6,200	2,453	Brown color, with many white and red pebbles
H	4.00	2.35	6,900	2,810	Few lamination cracks
Z	4.10	2.32	5,600	2,291	Break on two or three edges.
V	4.11	2.35	7,200	2,856	With square even fracture.
Average				2,621	

The figures given in tables III, IV and V are obtained from tests made on the general paving brick manufactured by the company. A combination of the results according to the general formula, $V = (20 - R) 6 + (8 - A) + \frac{T}{110}$, gives a rating of 101.95, a most satisfactory showing. The ratings given in table I, are somewhat lower, though still quite satisfactory. This is explained by the fact that the latter figures were in part based upon special brick manufactured from each clay. The difference demonstrates that in practice the clays are so combined as to compensate individual defects. The high rank is largely a result of the toughness. This indicates very careful burning.

Flint Brick Co.—This company has an extensive plant located in Oak Park upon the Des Moines river. They ship over the Flint Valley line of the street railway and are also within easy hauling distance of all parts of the city. The property includes a coal mine and a brick plant, both having been opened in 1893. The details of the section exposed in the pit are given below.

		FEET.	INCHES.
12.	Clay (Pleistocene)	3	
11.	Shale, varicolored, the lower portion of the nature of a fire clay	8	
10.	Shale, buff to gray, gritty	6	
9.	Limestone, impure		6
8.	Shale, red and bluish gray; laminated	6	
7.	Shale, brick-red in color, clean unctuous	4	
6.	Shale, light gray		4
5.	Shale, crumbly, gray	1	6
4.	Shale, "blue"	28	
3.	Shale, bituminous		8
2.	Coal, soft, "pockety"	1	
1.	Fire clay	1	

Above number 4, the entire section is fully exposed. The lower numbers were encountered in sinking the shaft. The coal is the seam exposed along the river and already mentioned. Excepting numbers 9 and 12 the entire section of clay is suitable for use.

Analyses of the clays are given in table VI, the analyses being made by Professor C. O. Bates, and published through the courtesy of the company. The samples are taken from the top down. As these samples were taken at a different time from that at which the section just given was made they cannot be exactly correlated with the members noted.

TABLE VI.

CHEMICAL ANALYSES FLINT VALLEY CLAYS.—C. O. BATES, *Chemist.*

	1.	2.	3.	4.	5.	6.	7.
Silica, total, $Si\ O_2$	70.23	69.89	58.92	50.38	62.70	64.31	64.03
Alumina, $Al_2\ O_3$	15.68	17.68	21.45	27.25	21.32	17.64	20.73
Water, combined, $H_2\ O$	1.82	1 97	4.13	3.62	4.90	5.47	3.50
Clay and sand	87.73	89.54	84.50	81 25	88.92	87.42	88.26
Oxide of Iron, $Fe_2\ O_3$	7.44	5.68	8.40	11.54	5.88	7.68	6.72
Lime, Ca O	.47	1.05	.98	.96	.16	1.12	.36
Magnesia, Mg O	1.50	1.68	2.90	2.93	1.77	2.40	2.57
Total alkalies	1.26	1.15	2.49	1.65	1.15	1 15	1.30
Fluxes	10.67	9.52	14.77	17.08	8.96	12.35	10.95
Water, free, $H_2\ O$	1.50	.85	.57	1.45	2.12	.42	.42
Total	99.90	99.91	99.84	99.78	100.00	99.99	99.63
O. in acid to O. in base	3.87	3.18	2.15	1.48	2.59	2.81	2.57
Ox. in Alk. to O. in fluxes	3.29	2 76	2 29	2.43	3.62	2.16	2.84

The clays are carried to a dry-pan of the Eagle Iron works make. After being crushed the material is elevated to a screen from which the coarse material is returned to the dry-pan and the fine is sent to a Penfield pug-mill. From this machine it goes to a No. 20 Penfield brick machine with a revolving cut-off. The brick are dried in an iron-clad dryer, the temperature ranging from 160° at one end to 220° at the other. Little or no checking occurs unless too much of No. 12 is used. The brick are burned in Eudaly kilns of 225,000 capacity. The main output of the plant is paving brick, but hard burned building brick, both rough and smooth, in dark red and buff colors, are also marketed.

In the Boynton tests the pavers from this plant, taken from stock, gave a per cent of absorption of .93 as an average of ten tests, the results ranging from .53 to 1.22. The modulus of rupture was found to be 2,740 as a result of three tests. The rattler test gave 12.49 (actual and rational) as a result of ten tests ranging from 9.57 to 14.59. These figures give the brick a rating of 82.25 according to the formula.

Iowa Brick Co.—The works of this company are located in the northwestern portion of the city across the river from the

Flint brick works. The plant, which is quite extensive, was opened in 1893. The shale is mined by blasting and digging and hoisted by tail-rope to the receiving room, where it is dumped into two Frey-Sheckler dry-pans. From the latter it is elevated and run through a revolving screen (4 x 9 feet), the tailings returning to the dry-pans. The clay goes from the screen to a Frey-Sheckler pug-mill, being fed into the latter through a Cook automatic mixer. This is an ingenious machine in which the amount of clay passing through the

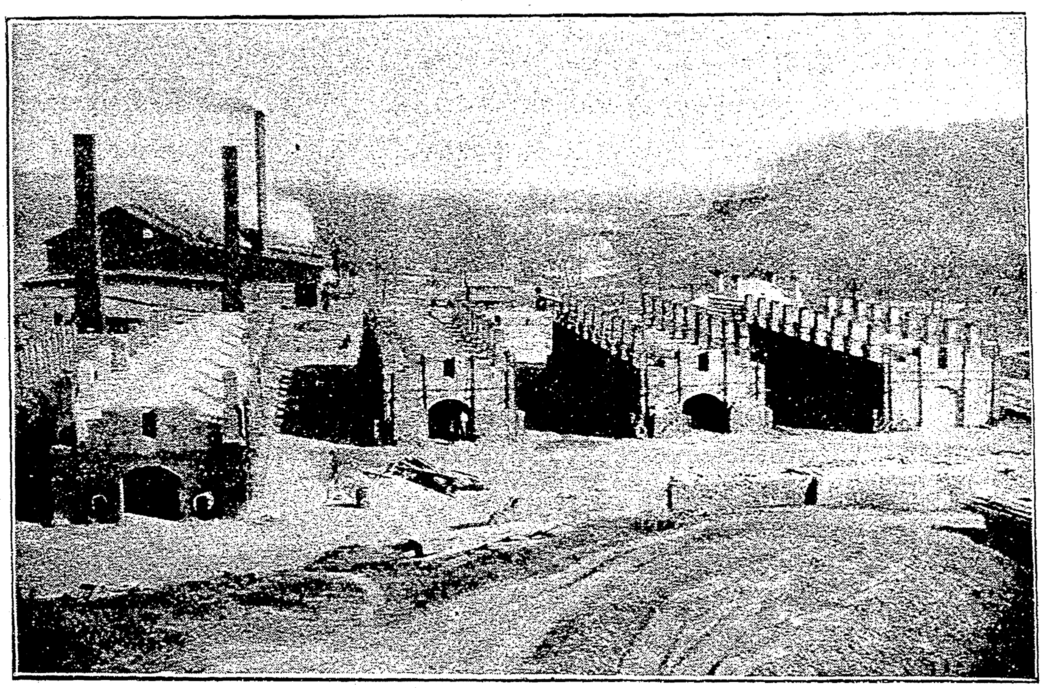
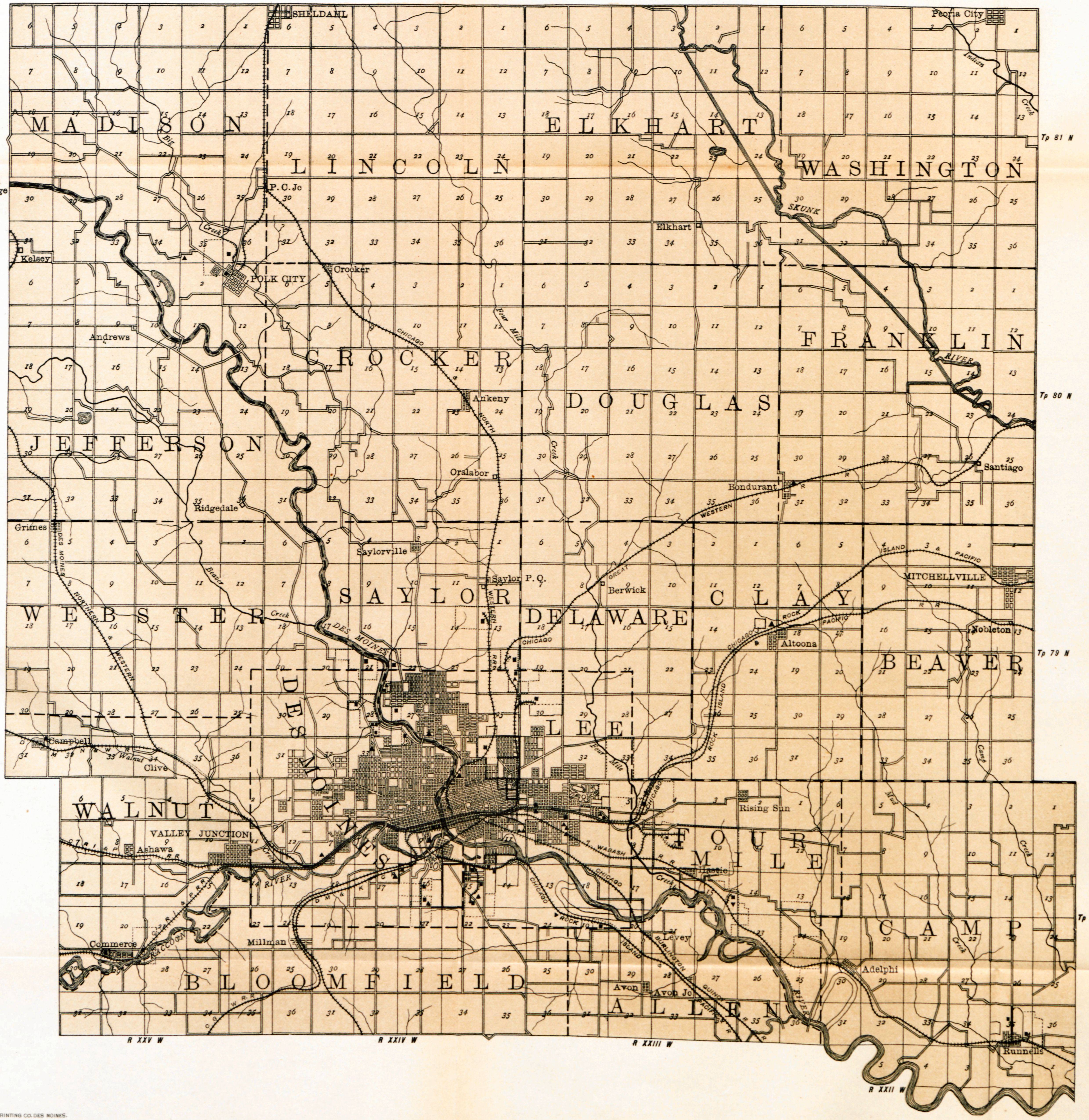


FIG. 66. Iowa brick works

hopper and spread upon an endless belt regulates the amount of water turned into the pug-mill. The mixer can be set so as to furnish a certain percentage of water and beyond that preliminary gauging requires no attention. It does away with the necessity for a man at the pug-mill and has many important advantages in addition. From the pug-mill the clay passes to a Cunningham brick machine. From the latter the brick go the repress, of which they are three of Bonnott make. At the repress they are loaded upon iron cars which run through the dryer. The latter has fifteen tracks, each holding twelve cars, giving a total capacity of 75,000 brick. It is heated by live steam and ordinarily 65,000 brick are run through in twenty-four hours. At the discharging end of the dry-house is a transfer track so that the cars may be run into the kilns. Of the latter there are seven large ones of Dewhirst pattern, and one bee hive. The plant includes a 250 horse power Bass engine and four 80 horse power boilers of the same make. This company makes both building and paving brick and in the past three years has put out about 26,000,000 brick. In making the pavers the whole of the section is used. The clays vary greatly in appearance and character as is shown by the following section and analyses taken from the report made to the company by Mr. E. P. Boynton.

		FEET.
1-1.	Shale, variegated, reddish brown, mahogany reds, yellowish, bluish drab, dark gray, almost black; the colors mottled parallel to bed	6
1-2.	Sandy, light yellowish white, solid color	6
1-3.	Slightly sandy at top to clear shale below, pale blue streaked with chocolate brown, to chocolate brown	5
1-4.	Shale, clear chocolate brown	4
1-5.	Shale, granular, dark solid drab with reddish purple nodules	3
1-6.	Shale, bluish drab	6
1-6½.	Same as No 6, exposed at western end of cut, weathered	
1-7.	Shale; streaks of brownish drab and greenish, to chocolate brown. Stratification well defined	6
1-8.	Clear dark drab, with olive green tinge	2



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF POLK COUNTY, IOWA.

BY

H. F. BAIN

1897.

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES (Coal Measures)

INDUSTRIES

CLAY WORKS ▲

COAL MINES ■

COAL LEASES

COAL LANDS WORKED OUT

TABLE VII.

CHEMICAL ANALYSES IOWA BRICK CO. CLAYS—C. O. BATES, *Chemist.*

	1-1	1-2	1-3	1-4	1-5	1-6	1-6½	1-7	1-8
Silica, total, $Si\ O_2$	55.98	81.79	68.50	52.88	66.73	64.60	64.82	57.25	53.05
Alumina, $Al_2\ O_3$	25.65	10.25	18.45	24.27	20.28	20.25	21.00	22.50	25.92
Water, combined, $H_2\ O$	3.73	1.27	2.82	3.28	4.92	3.74	3.10	3.62	4.40
Clay and sand	85.36	93.31	89.77	80.43	91.93	88.59	88.92	83.37	83.37
Oxide of Iron, Fe_2O_3	5.88	3.24	5.28	11.28	3.24	6.72	5.76	7.92	8.76
Lime, Ca O	.74	.52	1.19	.52	.70	1.20	.42	.90	1.00
Magnesia, Mg O	1.88	.57	1.42	2.03	.90	1.02	2.48	2.28	2.73
Total alkalies	1.95	1.75	1.27	1.92	1.46	1.33	2.11	1.41	1.29
Fluxes	10.45	6.08	9.16	15.75	6.30	10.27	10.77	12.51	13.78
Water, free, H_2 O	3.72	.58	.88	3.46	1.70	1.14	.33	3.88	2.70
Total	99 53	99.97	99.81	99.64	99.93	100.00	100.02	99.76	99.85
O in acid to O in base	1.95	6.61	3.17	1.73	3 11	2.12	2.61	2.10	1.77
O in Al. to O in fluxes	3.81	2.78	3.13	2.39	5.14	3.12	2.99	2.72	2.84

The properties of the individual clay beds of this section may be inferred from the analyses as also from the following physical tests (see table VIII). These tests were made upon brick from the separate clays, the numbers corresponding in the two tables and the section. In addition it will be noticed that averages are given for brick made from the combined clays, end cut and side cut, both repressed and common. The brick put on the market are represented by these later tests.

TABLE VIII.

TABLE OF AVERAGES AND COMPARATIVE RATINGS—IOWA BRICK COMPANY.

E. P. BOYNTON, C. E.

MARK.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST.			Porosity, absorption.	TRANSVERSE STRENGTH, RUPTURE TEST.			Comparative rating by formula.
		AVERAGES.							
		PER CENT OF LOSS				MODULUS OF RUPTURE.			
		Actual.	Rational.	Average of 3 and 4.	Per cent of gain.	Actual.	Rational.	Average of 7 and 8	
1	2	3	4	5	6	7	8	9	10
1-1	End cut common	16.53	14.68	15.60	.82	2,812	2,812	2,812	64.78
1-2	End cut common	15.01	14.07	14.54	5.74	1,929	2,176	2,052	44.45
1-3	End cut common	17.01	13.88	15.44	1.39	2,765	3,203	2,984	69.93
1-4	End cut common	17.29	15.93	16.61	.54	3,086	3,086	3,086	62.24
1-5	End cut common	22.12	20.53	21.82	4.98	2,921	2,921	2,921	11.72
1-6	End cut common	14.16	13.81	13.96	2.62	2,300	2,450	2,375	63.24
1-7	End cut common	14.28	14.28	14.28	.30	3,174	3,174	3,174	77.98
1-8	End cut common	28.00	25.00	26.50	.73	2,101	2,318	2,210	15.82
1-S	Side cut repress	14.80	13.63	14.22	.96	3,348	3,714	3,531	77.28
1-S	End cut common	16.80	15.65	16.23	.86	2,193	2,193	2,193	54.21
1-S C	Side cut repress	12.23	11.81	12.02	.55	3,348	3,714	3,531	92.12
1-E C	End cut common	12.28	11.45	11.87	.80	2,193	2,193	2,193	80.61

The company also manufactures terra cotta, using for this purpose carefully selected clays. In making terra cotta the clay is run through the dry-pan and pug-mill as usual and then spread upon the floor and covered with a cloth to keep moist. The pieces are moulded in plaster moulds and carefully dried. The ware is burned in a muffled kiln, so as to be protected from the fire, and requires seventy to seventy-five hours firing. Red and dark purple cornice pieces have so far been the principal output.

Capitol City Brick and Tile Works.—This plant is located on on the south side near the intersection of the Keokuk & Western and the Chicago Great Western railways. A section of the pit has already been given. At the time Mr. Boynton visited the works the exposure measured about fifty feet. His section from the top down is as follows:

		FEET.
C-0.	Clear, medium light drab with slight seams of rust, mastic, very slightly gritty	7
C-1.	Shale, mottled and streaked, maroon to sea green, greenish and purplish brown, rust in seams	4½
C-2.	Shale, medium dark bluish drab, clean	7
C-3.	Bastard fire clay, mottled purplish blue, dark grey, slight rust in seams	4
C-4.	Shale, soapy, but containing some grit, clear greenish drab	15
C-5.	Shale, very dark greenish grey with slight seams of rust	1½
C-6.	Shale, clear blue sandy	10

Samples taken from each layer were analyzed (see table IX) and brick made from the individual layers were tested with results as shown in table X. The numbers designating the individual layers of the section correspond with those of the analyses and tests.

TABLE IX.

CHEMICAL ANALYSES OF CLAYS—CAPITAL CITY BRICK & PIPE CO.

C. O. BATES, *Chemist.*

	C-0.	C-1.	C-2.	C-3.	C-4.	C-5.	C-6.
Silica, total, $Si\ O_2$	55.25	53.08	61.18	68.60	65.62	51.35	58.42
Alumina, $Al_2\ O_3$	25.60	24.93	21.69	18.93	16.83	27.38	20.04
Water, combined, $H_2\ O$	5.07	5.73	5.01	2.80	4.10	5.42	5.40
Clay and sand	85.92	83.74	87.88	90.33	86.55	84.15	83.86
Oxide of Iron, $Fe_2\ O_3$	5.52	9.00	5.88	6.12	8.64	6.60	7.80
Lime, Ca O	1.75	.94	.51	.25	.42	1.45	1.60
Magnesia, Mg O	1.49	1.84	1.92	.68	2.00	2.62	2.67
Total alkalies	1.79	1.19	1.96	.74	1.66	2.34	1.56
Fluxes	10.55	12.97	10.27	7.79	12.72	13.01	13.71
Water, free, $H_2\ O$	3.27	3.29	1.27	1.80	.60	2.81	2.39
Total	99.74	100.00	99.42	99.92	99.87	99.97	99.96
O in acid to O in base	1.93	1.78	2.43	3.23	2.95	1.62	2.27
O in alumina to O in fluxes	3.82	2.95	3.28	3.80	2.04	3.25	2.23

In making the brick the material is hoisted to a Frey-Sheckler dry-pan with a tailings crusher of the same make, and is moulded on a No. 10 Penfield machine. There are two large brick-walled tunnel dry-houses of nine tracks each and with a total capacity of 60,000 brick. The temperature used is about 200° F. The kilns include three Eudaly, one round and two rectangular, seven round down-drafts and one open kiln. The burning, including water-smoking, requires ten days. Paving brick of excellent quality is the main output, though large quantities of building brick are also marketed.

TABLE X.

PAVING BRICK TESTS—CAPITAL CITY BRICK AND PIPE CO.

E. P. BOYNTON, C. E.

MARK.	METHOD OF MANUFACTURE.	ABRASION AND IMPACT, RATTLER TEST. AVERAGES. PER CENT OF LOSS. Actual	Rational.	Average of 3 and 4	Porosity, Absorption test. Per cent of gain	TRANSVERSE STRENGTH, RUPTURE TEST. MODULUS OF RUPTURE. Actual.	Rational.	Average of 7 and 8	Comparative rating by formula.
1	2	3	4	5	6	7	8	9	10
C-1	End cut common	16.91	16.30	16.64	.97	3.375	3,544	3,460	63.74
C-2	End cut common	18.73	18.73	18.73	1.03	2,858	2,858	2,858	45.48
C-3	End cut common	12.91	17.17	15.04	8.60	1,714	1,714	1,714	28.76
C-4	End cut common	18.60	16.61	17.60	.67	3,930	3,930	3,930	63.45
C-5	End cut common	69.49	69.49	69.49	1.38	1,998	1,998	1,998	......
C-6	End cut common	12.49	12.49	12.49	.60	3,429	3,429	3,429	89.82
C-G. P	End cut common	17.78	17.61	17.70	.54	3,896	4,080	3,988	62.89

The brick marked C. G. P. represented the general pavers. They did not, however, represent the general stock of the company since they were in part of 1895 manufacture, and at the time they were selected the yard was entirely stripped. It is interesting to note that the bastard fire clay, C-3, produced a brick of high absorption and low transverse strength, though of considerable toughness. The best brick are made from the lower clay, C-6, and at this plant, as at the others, the more recent brick are much better than those first turned out. It is also interesting to note in connection with the analyses, the variations in color and other physical properties. These are summarized by Mr. Boynton as follows:

C–1. All of good form; medium dark buff color with purplish tinge. All show slight kiln marks. No ring.

C–2. All good forms, good corners; light reddish buff color; appear glassy; brittle; sharp clear ring.

C–3. Good form; very light pale yellow with pinkish tinge; blotches of lemon yellow on ends; dull spongy appearances and no ring; looks like fire brick.

C–4. Good form; light buff color with purplish tinge; good ring.

C–5. Good form; buff color with reddish tinges; poor ring; glassy, brittle appearances.

C–6. Good form, but slightly kiln marked; medium dark buff with purplish tinge; good ring.

The effect of the lime and magnesia in holding down the color is excellently illustrated by the brick. The clays carry from 5.52 to 9 per cent of iron (Fe_2O_3) enough to give a good red color under ordinary conditions, and yet they are predominantly buff. Variation in color seems to be due in but slight part to the burning, since it is nearly proportional to the change in composition. This is suggested by the following comparison between the color and the ratio existing between the total iron and the sum of the lime and magnesia.

		RATIO.
C–1.	Buff, pinkish tinge	1:.308
C–2.	Light reddish buff	1:.413
C–3.	Pale yellow, with pinkish tinge	1:.157
C–4	Buff, pinkish tinge	1:.280
C–5.	Buff, reddish tinge	1:.516
C–6.	Dark buff, purplish tinge	1:.574

BUILDING BRICK.

As has already been suggested the loess and the alluvium are the materials chiefly used for manufacturing building brick. The clays and shales of the coal measures have not been much used except at the paving brick works. Where the shales are used for building brick they are usually mixed with loess.

For building brick, clays of great variety in composition and texture may be used. The sandy alluvium and the dense shales each have their use. The qualities to be desired in building brick are (1) low cost, (2) good shape, (3) suitable color, and (4) moderate strength. For "common" brick, a fair strength being secured, the matter of cost becomes most important. For this reason hand-made alluvial brick and rejects from other grades make up the bulk of the material supplying the trade. "Stock" brick require more care as to shape, and a careful sorting so as to secure uniformity in color. "Roman brick" require very careful manipulation in order that the desired shape and color may be perfectly maintained. Enameled brick are made by treating the better class of stock brick.

In those grades where smooth surfaces and sharp edges are required the results may be obtained by using either the repress or the dry-press. If a change in color be desired it can often be brought about by a change in treatment. The red color of most brick is due to the presence of 3 to 5 per cent of iron and the absence of lime and magnesia. In the presence of the latter double silicates of lime and iron are formed and a cream or buff brick results. According to Wheeler the red color will sadden if 5 per cent of lime and magnesia be present, at 10 per cent the brick has a yellowish cast and at 15 per cent it becomes a deep to pale cream. The temperature of burning also influences the color. A brick which is a dull salmon color when burned at red heat (1,000° to 1,200° F.) becomes a deep salmon at slightly higher temperatures (1,300° to 1,400° F.), a light red at bright red heat (1,500° to 1,600° F.) and deep red at still higher heat (1,800° to 1,900° F.). At bright cherry heat (2,000° to 2,200° F.) it becomes a very dark red and at slightly higher heat (2,300° F.) it usually fuses and turns black.

If the brick be very slowly heated in the water-smoking stage the color is deeper and richer from the more thorough oxidation of the iron. When very dark brick are desired they may be secured by burning with a smoky flame.

By proper manipulation a wide range of color may be obtained, as is indicated by the results of the tests at the Capital City plant. A still wider range would have been obtained if the conditions of burning had been purposely varied. So far only common and stock brick have been regularly placed on the market from Des Moines. At present the main output is red brick, with a few buffs. Smooth faced brick are generally preferred, but recently there has been a growing demand for rock faced. The paving brick works supply an important portion of the building trade as the brick which are not good enough for use as pavers are excellent for building purposes. A considerable portion of these are sold for rock-face work.

Newman Brothers. This firm formerly operated a small plant in East Des Moines for the manufacture of building brick; recently, however they have opened more extensive works on the Wabash railway near Hastie. The locality has already been noted in connection with the mines of the Iowa Fuel Co. The clay consists of coal measure shale and is crushed by means of a Bonnot dry-pan, made at Dayton, Ohio. From the dry-pan it goes into a pug-mill of the same make. After being mixed and tempered it is moulded as a stiff mud upon Bonnot end-cut machines. The green brick are dried by live steam in twenty-four to thirty-six hours in an eight track dry-house of 40,000 capacity. The clay drys with no checking. In burning, two cased kilns of 150,000 capacity each, and one round down-draft of 60,000 capacity are used. The brick are water-smoked in two or three, and usually burn in seven or eight, days; occasionally they require nine or ten days burning. So far few pavers have been made, the trade being mainly in building brick. The two styles of brick are made from the same clay, but the pavers are burned harder.

Merrill Brick Works.—This plant is located on the Keokuk & Western railway, some distance south of the Capital City plant. The material is taken from the foot of the Raccoon river bluffs and consists of coal measures capped by loess. The following section is shown in the pit:

		FEET.
7.	Soil and loess	3
6.	Slate, bituminous	$\frac{5}{6}$
5.	Shale, blue to gray and buff	4
4.	Shale, red to brown, more or less variegated, containing ironstone concretions	20
3.	Shale, blue to gray	6
2.	Coal	$1\frac{1}{2}$
1.	Shale, light gray	7

All of the material in the pit except the coal and bituminous shale is used in the brick. Numbers 1 and 3 are of particularly good quality. In treatment the clay passes through a Des Moines Supply Co. dry-pan, a Wallace pug-mill and a Great Wonder brick machine. From the machine the brick go to a tunnel dryer heated by exhaust steam in the day time and live steam at night. Three Pike kilns and one open kiln are used in burning, the process requiring ten days, including four days of water-smoking. At present building brick only are made, though it is the intention of the company to arrange for the manufacture of pavers, repress and finish brick. The material now turned out is strong, dense and of good color.

Dale-Goodwin Pressed Brick Co.—The works of this company are located upon the Winterset branch of the Chicago, Rock Island & Pacific railway, southeast of Des Moines (Tp. 78 N., R. XXIV W., Sec. 24). The material used is the loess. A descriptive section has already been given. The surface material is plowed and allowed to become almost dry before it is carted to one of the large sheds under which it is stored. From the sheds the clay is passed through a Ross pulverizer, and after being screened it goes into the bags of the machine. The latter is a Ross-Keller No. 2, six-mould, with a pressure of 30,000 pounds per square inch. The green brick are wheeled directly to the kiln, four up-drafts of Repell pattern of 240,000 capacity each. The brick burn in seven days with coal, after eight days water-smoking with wood. A good cherry red color is obtained and the brick meet with ready sale. This is the only plant in the city using the dry-press process, and the success attained is quite encouraging in view of the large amount of loess available. The plant was erected in 1893, and has not been operated so continuously as would have been possible under normal business conditions. As a result the product is not so uniform in quality as has been obtained from the loess at some other points, but it has been abundantly proven that brick of the best quality can be made.

Local Brickyards.—There are a large number of small plants scattered throughout the city which make brick in the main by the hand process. They are not always permanent, but many have been operated for several years. Most of them are noted below.

The Minear Brothers brickyard, southeast corner of Twenty-first and Maury streets, was started in 1889 and has since continued in operation. Slap brick are made from clay taken from a seven-foot bank. Soily material at the top to a depth of one foot is removed and the underlying alluvium is utilized. At a depth of twelve feet quicksand and water are reached; this is near the water level of the Des Moines, which flows less than a half mile away.

Louis Shackelford has a brickyard at the northwest corner of Fair avenue and West street. A Chief machine operated by horse-power was put in in 1893. Prior to this time slap brick were made. The moulded product is dried in open air and burned in either clamp or cased kilns. The raw material is taken to a depth of three and one-half feet from the flood-plain of the Des Moines. In the upper part it contains considerable vegetable material. Below it is brown in color and more clay-like. The clay grades into quicksand and gravel. The brick from here have been used in various buildings, including the National Starch Works, the Windsor Packing House and the Painter block.

Lincoln Shackelford operates a small brickyard just east of Victoria street, between West street and the Wabash railroad. Two pug-mills with one gang of men are employed, the product being common slap brick made from alluvial material taken to a depth of nearly three feet. The brick are burned in down-draft kiln, with a capacity for 65,000 brick. The product is of very good grade, and has been used in the construction of some of the principal business houses in Des Moines, including the Turner block.

T. J. Fredregill is the owner and operator of a brickyard just to the northwest of the Lincoln Shackelford plant. The force consists of but one squad of men. Alluvium from the Des Moines valley is used to a depth of three feet. The brick are dried on the yard and burned in cased kilns with wood as fuel. They have a good red color and are quite firm for a hand-made article.

J. M. Fredregill makes slap brick on a yard north of the Wabash track and east of the York addition. Work has been carried on at the point several seasons. The clay is similar to that used at the other points in this vicinity, but here it is taken to a depth of from three to four feet, utilizing the surface loam. Under the clay gravel is struck.

J. Bailey now operates the once abandoned Cook Brothers brickyard, located east of Twentieth street on the north side of the Chicago, Rock Island & Pacific railroad. Here again hand made brick is the product, the material being the alluvial clay which is, including the soil portion, about four feet thick, and below which is gravel of the Wisconsin gravel train. The yard is supplied with two stationary kilns with a total capacity of 250,000 brick. The product is used principally for interior walls and sidewalks.

The J. D. Hill brickyard is just east of Twentieth and north of Maury streets. This plant is quite extensive. The brick are made from alluvial soil and subsoil taken to a depth of seven feet. The Old Reliable soft-mud horse power machine is used and about 22,000 brick is the daily capacity. Two clamp kilns holding 275,000 brick are used in burning.

Louis Youngerman is the owner of a brickyard which lies just north of the western end of Dean Lane. A triple force of men are employed. Ordinary silty clay of the Des Moines "bottoms" is mined four feet deep. This affords a very fair common brick. Two clamp kilns are used in burning. These have a capacity of 125,000 each.

N. Haskins has been making brick in Sevastopol for about ten years. The brick are now made on two Old Reliable soft-mud machines, each having a capacity of 7,500 daily. Five clamp kilns and one Haskin patent are used in burning. The raw material is loess from the hillside by the yard. The upper six feet of the deposit is yellowish to brown, slightly ocherous, and at the bottom it grades into a grayish sandy variety. The burned product has a good rather bright red color and is quite substantial in quality.

South of the street from the N. Haskins yard and just north of the Van Ginkel coal mine is situated the brickyard operated by G. Van Ginkel. Loess is taken from a bank two to eight feet deep near the plant and moulded by two Tiffin Old Reliable and one Chief soft-mud machine. The clay is of good quality and suitable for the manufacture of even a much higher grade of brick, although those manufactured are of very good quality for a common brick.

Tippey & Decker operate a hand yard two miles beyond the eastern limits of Des Moines, about half a mile from the Wabash tracks. This brickyard was started in 1893 and has since been running on a small scale. Alluvial material is utilized.

The Frank Collins brickyard is situated a short distance north of the Des Moines river to the east of Sixth avenue. Work was commenced in the spring of 1893, using the soil and under clay of the flood plain. The product is hand made and the annual output is small.

In the northwestern part of Des Moines, north of Franklin avenue and west of Twenty-third street, G. L. Winburn operates the brickyard formerly owned by E. S. Close. Upland soil is used to a depth of two feet; below this the moulded material is too liable to crack when becoming dry, as there are no sheds to protect the slap brick. The brick have good color and do very well for basement and interior walls.

L. J. Williams has been making slap brick about one-fourth of a mile north of St. Joe street and west of Twentieth street for several seasons. The material used is upland soil. It is taken to a depth of eighteen inches. The clay is prepared in ordinary pug-mills and the moulded articles dried on the yard.

On Twentieth street and Hickman avenue is a brickyard now owned and operated by Kuntz & Hall. It has been operated for more than fifteen years. The surface eighteen inches are stripped off and the under sixteen feet are utilized by being put through an Ideal machine of the Decatur Leader Manufacturing Co., which machine was put in at the beginning of the season of 1893. This plant is well arranged so far as methods and location with respect to the raw material and kilns are concerned. It is the only one in Des Moines making brick of loess alone on a stiff-mud machine, and the product is of good strength and appearance. Three stationary kilns are employed.

SEWER PIPE AND POTTERY.

Aside from brick the clays found near the city have, as yet, been but little used. There is, however, one extensive sewer pipe plant and a few small potteries.

Iowa Pipe and Tile Co.—This is the largest factory in the state devoting attention to the manufacture of sewer pipe and other articles which are made by the same processes. It is situated on the east bank of the Des Moines river about half a mile north of Locust street. The plant has been in operation for some years and has just been rebuilt, having been burned within the year. The buildings include the main structure, 167 by 90 feet, three stories high; a wing, 90 by 37 feet, two stories high, and a small office building. The clay is brought from the bank to a Vaughn dry-pan from which it passes into a screen; from the screen the mass is conveyed to a bin, from which it is transported into two Frost wet-pans, from which it is taken to press feeders, and then into the two Vaughn presses for sewer pipe, or into the Brewer press for drain tile. The raw material is as conveniently located as could be desired, the plant being situated immediately between the pit and the river. The section has already been given.

Of the sandy material at the top only a part can be used, as it stands only moderately high heat. For sewer pipe the best grades are selected and various combinations are taken for the other products. The ten feet of shale at the base of the section is of very fine quality. It is the extension of the layer which is mined just across the river and used at the Updike and at the Weeks potteries. A few impurities are shown in the burnt ware and if these were removed by washing the material could probably be used for white glazed and unglazed ware, for glass pots, crucibles and many other products.

The factory is well equipped and well managed. The sewer pipe made are of excellent quality, and fully attest the fact that the local clays are able to not only supply local demands but to make their way into the general market.

Eagle Pottery Works.—This is an old established pottery, located on Elm and South Second streets. Common coarse stoneware, glazed and unglazed, has been manufactured for a number of years, though the plant is not at present in operation. The clay is from the coal measures. It is mined from the J. Fox slope, opposite the plant of the Iowa Pipe & Tile Co. The best part of the vein is seven feet in thickness. It is quite hard when first mined, and for this reason the material is allowed to weather for a year or more. It becomes thoroughly broken up and disintegrated and is more readily worked. After a thorough grinding in a wet-pan or chaser of the Webster, Camp & Lane manufacture, it is prepared by hand for the wheel. The wet ware is placed in steam-heated apartments and dried. It is then put in a rectangular down-draft kiln and burned. It stands much firing and readily takes a very fine glaze, for which purpose Albany slip is used. The style of ware is varied, and all sizes of jars, from the quart to the twenty gallon are made. There are minute impurities in the clay and the unglazed products disclose their presence. Washing would no doubt remove them, but the glaze conceals the impurities and makes the extra expense unnecessary.

Weeks Pottery Works.—This plant was started a few years ago on South Sixth street near Raccoon street. It is quite an extensive factory, with brick buildings, two rectangular down-draft kilns, a wet-pan or clay chaser, with dry-rooms, wheels and other necessary appliances. The factory was started with the intention of making pottery especially, but early in 1893 this plan was abandoned, and chimney tops were manufactured. The expense of purchasing the raw material made the factory only an indifferent success, and it is not now operated. The clay itself is of good character. It is the same as used at the Eagle works, and is taken from above the milldam, where it is mined by means of a slope. The material is a fine arenaceous clay. It stands much firing, does not "cripple," and readily takes a bright glaze.

BRICKYARDS OUTSIDE OF DES MOINES.

Altoona.—The E. E. Haines brickyard and tile factory is situated on the north side of the Chicago, Rock Island & Pacific tracks, a short distance west of the station at Altoona. The surface deposit is a sloughy clay, which has accumulated in one of the saucer depressions of the Wisconsin drift. It is three feet thick, and below it there is a yellow bowlder clay bearing numerous lime concretions. The slough clay was at one time mixed with coal measure shale in the ratio of one to two. This latter material was mined from the Haines coal shaft near by, at a depth of 215 feet.

The so-called fire clay underlying the vein was taken out by the miners from the entries and runs. Since the coal seam was undulatory and not very thick, the removal of the under clay was necessary to get work room. This fire clay is a grayish to blue shale, white when first mined and very plastic. It contains numerous pyrite concretions, which, in the long exposed heap of clay used in the factory, have been changed into the hydrous oxide. The raw material is run through a Penfield corrugated roller crusher and disintegrator, then into a No. 7 Penfield plunger. The wet product is placed in sheds and allowed to dry. After drying the brick are burned in two round down-draft kilns. The burning consumes from three to three and one-half days; water-smoking about a third of the time. The brick and tile, the latter three to eight inches in diameter, are quite strong, and, except for occasional dark spots due to the presence of pyrites, the general appearance and color is excellent.

Polk City.—The C. Billington brickyard is in the southwest corner of section 35, Madison township, nearly two miles northwest of Polk City. Work was inaugurated at this point about fifteen years ago. The yard is on the upland, and the material used is from one to ten feet thick, being entirely superficial. It is a bleached drift clay, and lower down has the jointed character typical for the bowlder clays. While drying the brick are placed on racks in roofed sheds; they are burned in temporary kilns in about eleven days. For a hand-made article the product is quite good. Its use is almost entirely local.

Polk City Tile Works.—This factory, operated by Harmon & Hug, is near the station, but the raw material, which is used principally for drain tile from three to twelve inches in diameter, is hauled from near the Des Moines river, a little more than a mile southwestward. This clay is of coal measure age and the greater portion of it is of very good quality. It is mixed with drift clay taken from near the plant. The bottom bed shown in the pit from which the coal measure clay is taken, is a more or less variegated shale. The lower third is a dark gray variety with some iron stainings, and containing certain lenses of nearly pure red hematite, which are removed by the disintegrator. The upper portion is brick red in color and is of excellent quality. Above this is a clean gray shale which is separated from the purple shale just below the drift by a thin limestone ledge. The upper shale is three feet thick; the color is gray to red and purple. The bowlder clay is of little value since it either bears many concretions of lime or is too arenaceous for use.

The different beds of the section are mixed together. After being run through the Brewer crusher and disintegrator the mixture is put through a Continental brick and tile machine, Tiffany patent. This machine has been in service since the erection of the plant in 1882. The product is dried on pallets in closed sheds into which are run exhaust steam pipes. Two common down-draft kilns are used in burning, and four days are required for the process, the water being driven off in a single day. Building brick of a good cherry red color have been produced from the material used in making tile, and some fire brick for use in the kilns have been manufactured of the white shale clay which is just below the base of the section described. A clay upon which rests the coal vein at the Polk City mine near the tile plant has also been used for fire brick. Both afford a very fair grade of brick.

Campbell.—Thomas & Son have a small drain tile and brick factory just north of Campbell station. The product is largely drain tile in sizes from 3's to 6's. A few brick are also made some seasons. The machinery is a horse power plunger, the Hocker, and the product is dried in closed sheds to prevent its cracking. The material for the tile is taken from a twelve foot bank of yellow bowlder clay at the foot of the slope northwest across the branch. At the northwest corner of the cut a fine quality of argillaceous coal measure shale is exposed and by digging, a heavy deposit of this shale, which will do well for brick, tile and other products, could probably be found. Thus far scarcely anything but the bowlder clay has been utilized. The process of putting salt in the burning kiln, is practiced at this yard. It is claimed that by the introduction of five or six gallons of salt in each of the round down-draft kilns a harder and redder tile is secured.

Bondurant Tile Works.—This plant is owned and operated by Mr. A. M. Austin and is located near the Chicago Great Western, just west of town. It was opened in 1893, but was not operated during the past season. The clay used is a slough clay and is mined to a depth of five feet. It is moulded on a Penfield machine, dried under a shed and burned in a down-draft kiln.

Soils.

Among its sources of wealth Polk county has none of greater importance than its soil. The annual value of the farming products of the county amounts to more than the value of all the other products combined. The county is essentially a farming county. The mining interests, as compared with the agricultural interests, are small.

The soils of the county are drift soils. Throughout the northern portion, the area mapped as Wisconsin drift, the till itself comes to the surface, being only occasionally covered to any considerable thickness by pebbleless material. The drift soil is black, and is usually not so open as the loess or alluvium. It suffers from the disadvantage of imperfect drainage, and considerable areas are slough-covered, though the percentage of slough land is not so great as further back on the Wisconsin. The area covered by modified drift, in part imperfectly drained, is usually more available. The material has been better sorted, is more sandy, and, except where the surface is too gravelly, affords an excellent soil. The alluvium covers a not inconsiderable portion of the county and is of well known value. The bottom lands of the rivers are particularly well adapted to the culture of corn. They are rarely overflowed. Owing to the fact that in many cases the alluvium forms merely a top dressing over the gravel trains or other drift with which the old valleys were partially filled, the bottoms usually have free underground drainage.

Over the southern portion of the county the surface material is the loess. This rests upon the Kansan drift, the upper surface of which is usually gravelly. The combination affords a most excellent soil. The loess being fine and homogeneous is easily worked and has an important mechanical effect upon the water content. The material is so porous that the water instead of running over runs down into it. The even regular texture makes the distribution of the surface tension exceptionally even. As a result, any given area of loess becomes a vast reservoir, which, upon being tapped by plants, gives up its moisture in regular quantity. This is a distinct advantage, particularly in raising fruit, and the region south of Des Moines should become a great fruit region. The farm of Berryhill & Shaul is located on a loess area, and the excellent results there obtained show what may readily be done with this soil.

Gravels and Road Materials.

While the drift as a whole contains a vast amount of broken rock, definite gravel beds are not always easy to locate. As has already been suggested the deposition of gravels by the streams flowing out from an ice sheet is a function of the general attitude of the land. The gravels are only possible when there is free drainage so that the water may have sufficient velocity to carry the material long enough to sort it. These conditions obtained at the time of the Wisconsin ice invasion, and as a result we have the gravel trains leading out from the drift border. They are well defined along Camp creek, Four Mile and the Des Moines river.

In the valley of Four Mile, at Berwick, the Chicago Great Western railway takes gravel from a terrace rising twenty feet above the stream. The stripping, which is removed by scrapers, consists of two to two and a half feet of brown loam running up into black drift. Below this is twelve to fifteen feet of gravel resting on a blue to green apparently pebbleless clay. The gravel is new, fresh and hard. It is cross-bedded and interlaminated with some sand. It has a fair percentage of cobbles, but very few large stones. It shows very little ferrugination, no noticeable coloration or cementation, and weathered rocks are relatively rare. It is known to extend along the stream for some distance, the terrace being easily followed. The gravel is mined by a steam shovel and used for ballast along the railway.

At Avon the Chicago, Rock Island & Pacific railway has gravel pits which have been worked for eighteen years. They are located upon the flood plain of the Des Moines near the station. The stripping consists of six to eight feet of alluvium, below which is twelve to fifteen feet of gravel, cross-bedded, sand streaked, and resting on fine sands. The extent of the gravel is not known, but the presence of driven wells throughout the region indicates a rather large area. It does not extend up North river, but seems to belong to the body shown in the numerous abandoned gravel pits in East Des Moines.

At Polk City the Chicago & North-Western railway has gravel pits in the valley of Big creek. The stripping consists of one and one-half to three feet of black loam, below which the gravel is about eighteen feet in thickness. It is fresh, hard and sandy, as at Avon. It forms a well marked terrace, appearing on both sides of the valley, Polk City being built upon one of the benches. The terrace may be traced down the stream to its mouth. It appears at intervals along the Des Moines valley, and is well shown near Saylorville and Highland Park, where it has recently been opened up. Gravel may be obtained from it at a number of points.

The Polk City gravel is of quite recent age, since it forms a part of a terrace made in that portion of the Des Moines river valley which is itself post-Wisconsin. Reasons have already been given for thinking that the excavation of the upper portion of the Des Moines valley was relatively rapid, and the facts in this case fit in with that assumption. The gravels mark stages in the retreat of the ice, but so far they have not in all cases been connected with definite moranic accumulations. In the valley of Camp creek the gravel train may be followed up the valley to the point where the Wisconsin drift appears, but not beyond.

While the gravel occurs in the terraces, and farther from the drift border under the alluvium, it should not be forgotten in locating gravel pits that there are terraces in the region which have had other origin, and which do not contain gravel. Neither is all the gravel in the terraces. The kames afford a supply, and there are in addition scattered patches and aggregates of irregular form, such as occur between Polk City and Crocker. Throughout the northern portion of the county these gravel patches are common. They may be looked for anywhere within the Wisconsin area as mapped.

The importance of the gravel patchs, kames and terraces arises from the excellent material which they afford for railway and road ballast. The gravel found at Highland Park has recently been used for making concrete, and the railways have for many years hauled gravel from Avon and Polk City. It is, however, in connection with the common roads that the gravel beds are destined to have their highest value. The material occurring here is mainly of hard, undecomposed pebbles. In general it is moderately coarse and much freer from sand than at many gravel pits. It has rarely been cemented at all so that it can be easily worked. All that is necessary is to shovel up the material and haul it to the roadway. In most cases the haul would be short, since the grave patches are quite widely scattered throughout the northern portion of the county.

Mine slack has been to some extent used for road improvement near Des Moines. It is good material, and can often be used to advantage. It, with river gravels, must be the main reliance of the southern portion of the county. The small total quantity of slack and its limited distribution as compared with the gravel, makes it of less general value than the gravel.

Some of the slough clays resemble in character the impure black clays which, in Wisconsin and Missouri, are burned for railway ballast and road metal. They have not yet been tested, but some, at least, would probably be suitable. Burned clay may be very simply produced by hand process, at a cost of about 50 cents a cubic yard. A machine plant will produce it at from one-half to two-thirds of this price. It is an excellent material, and well adapted to road use.

Building Stones.

The coal measures as developed in the county do not afford any considerable quantity of good building stone. The sandstones already mentioned have been quarried a little, but are of indifferent value in comparison with the clay goods made from the same formation. At the foot of Capitol Hill are the most extensive quarries. These afford a sandstone which has been used for foundations, walls, and to some extent for buildings. It is stated that Fort Des Moines was built from rock quarried at this point. The material is limited as to quantity, and has little to recommend it as regards either looks or quality.

Water Supplies.

In common with other drift covered regions Polk county is well supplied with water. Shallow wells are abundant and easily obtained. The gravel beds and more open portions of the drift afford valuable water horizons. Below the drift water can commonly be found in the coal measures, but it is in such cases so impregnated with minerals in solution as to be unpalatable. In the underlying limestones of the Mississippian water has been obtained at several points. The quality is usually excellent. The most complete record of the lower water horizons available is that obtained from the Greenwood park well.

The well obtains its water supply from the Saint Peter sandstone at a depth of 2,025 feet, the elevation being 872 feet and the water head 827 feet A. T. Water was first struck in the Mississippian beds between 498 and 668 feet below the surface. This water rose to 842 A. T. and was heavily charged with sulphurated hydrogen (hydrogen sulphide). Apparently minor flows were encountered at 1,011 to 1,208 feet and in the

Niagara at 1,425 water rose to the surface and overflowed in a quarter inch stream. The flow now used is from the Saint Peter. It was tested by pumping fifty-two gallons per minute for eighteen hours, in which time the water was lowered 125 feet, but rose again when pumping ceased. At 2,208 feet in the New Richmond a stream with lower head was struck and the water fell from 866 to 822 A. T. At 2,331 it fell to 812, indicating a vein in the lower Oneota. No other fluctuations were observed and on the completion of the well the water rose to its present level.

At the court house there is an artesian well of small flow. It is 580 feet deep and probably derives its water from the Mississippian or from the beds immediately above that formation.

Near Saylorville (Tp. 79 N., R. XXIV W., Sec. 12, Se. Qr., Ne. ¼) a boring was put down to a depth of 1,800 feet, but no reliable data regarding it are available. In the vicinity (Sec. 3, Ne. qr., Se. ¼) is a flowing well less than 400 feet deep and probably deriving its water from the Mississippian or the basal coal measures. Its discharge is given as above 5,000 gallons per hour.

Natural Gas and Oil.

From time to time finds of gas and oil have been reported from the northern portion of the county. In the year 1895 such a discovery was reported from the farm of Mr. Henry Davis located about seven miles northeast of Des Moines. Some years since a similar discovery was made near Saylorville and an exploring company did some deep boring in search of larger supplies. So far as can now be determined their search was wholly unrewarded.

In considering these reported occurrences it should be remembered that the region is within the area covered by the Wisconsin drift and that below the latter a forest bed is quite generally present. The decomposition of the buried vegetal matter at this horizon is an ample source for all the gas or oil yet found. In no case, so far as reported, has gas been found in the rock. In every instance it occurs at slight depth in the drift. The assumption that it came up to its present position and had its origin in the rocks below is wholly unsupported by facts and entirely gratuitous. So for as present knowledge extends there are no reasons for expecting large supplies of either gas or oil within the county, though it is not impossible that some gas may be found. The gas wells of the drift have at several points in this and other states proven sufficiently productive to be of value for domestic purposes, but not for any thing more. In Kansas the lower portion of the Des Moines formation, known as the Cherokee shales, has produced both gas and oil. In that state the distribution of these materials is quite irregular, but is limited to those portions of the field where the shales are under cover. Since they crop out at the surface in Polk county they have probably long since lost any gas which they may have once contained.

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