
GEOLOGY OF BREMER COUNTY.

BY

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INTRODUCTION.

LOCATION AND AREA.

Bremer county bears the name of the distinguished Swedish novelist and traveler, Fredrika Bremer, being the only county of the state which thus honors one eminent in literature. Miss Bremer's Christian name is recorded on the county maps, though with an unfortunate interpolation of a letter, in the township and village of Frederika.

Bremer county is situated in northeastern Iowa. Two counties, Chickasaw and Howard, intervene between it and the Minnesota line and two, Fayette and Clayton, lie between it and the Mississippi river. Comprising townships 91, 92, and 93 of ranges 11, 12, 13, and 14 west of the 5th principal meridian, it is a rectangle twenty-four miles long from east to west and eighteen miles wide from north to south, with an area of 432 square miles. While Bremer county includes twelve congressional townships, it is subdivided into fourteen civil townships. Township 93, range 12, is divided between Frederika and Leroy townships, the valley of the Wapsipinicon falling to the former and the valley of the East Wapsipinicon to the latter. In order to bring the city of Waverly within a single township the boundaries of Washington and the townships adjacent are made irregular, although not deviating from section lines.

Bremer county lies for the most part upon the outcrop of the limestones and shales of the Devonian system, a broad belt extending diagonally across the state from Worth and Howard counties on the northwest to Muscatine and Scott counties on the southeast. It occupies a somewhat central position upon the wide sheet of glacial deposits known as the Iowan drift. Furthermore, it stretches across the valleys of three goodly rivers, which extend for many miles beyond its limits. Any description, therefore, of either the geology or the physiography of this restricted area must include features shared with other counties as well as some perhaps peculiar to itself. A large number of the problems presented by the rocks and superficial deposits of the area have been solved elsewhere and many of the phenomena which occur here have been elsewhere described and interpreted.

Hence the student of the local geology may profitably extend his reading to the descriptions of similar areas as given in the annual reports of the Iowa Geological Survey, such as the reports on the geology of Cerro Gordo, Mitchell, Chickasaw and Johnson counties by Calvin, Benton and Fayette counties by Savage, Black Hawk county by Arey, and Linn, Cedar and Scott counties by Norton.

PREVIOUS GEOLOGICAL WORK.

Before the organization of the present Survey Bremer county received little attention from professional geologists. No mention is made of the county in the reports of the Geological Surveys of Iowa conducted by Hall and Whitney and by Chas. A. White. Fossils collected at Waverly either by R. P. Whitfield, or by Orestes H. St. John and examined by Hall led to the mention in the 23d Annual Report of the New York State Cabinet of Natural History, Albany, 1873, of the fact that nearly the same series of fossils occur at Waverly as at Independence.

McGee, in the Pleistocene History of Northeastern Iowa (Eleventh Annual Report, U. S. G. S., Washington, 1891), quotes a description by Shimek of two species of fossils from the loess six miles southeast of Waverly, and mentions an unusually large boulder two and one-half miles north of Sumner.

PHYSIOGRAPHY.

RELIEF.

Bremer county is included in the wide plain of northern Iowa. So slight is the relief that it would be hardly noticeable when represented on section or model drawn without great exaggeration of the vertical scale. The maximum local relief can hardly exceed one hundred and fifty feet. The highest point of the county whose altitude is known, the crest of the prairie upland, about two and one-half miles northwest of Sumner, is 1128 feet above tide, according to the profile of the Chicago Great Western Railway, and stands about 250 feet higher than the lowest point, the Cedar river at Janesville.

Nowhere is the plain of Bremer county entirely level. Shallow sags and low irregular swells diversify the surface even where it most closely approaches horizontality. In places, as

east of Waverly, bold, isolated, rounded hills surmount it. In eastern Jefferson township and the adjacent part of Washington the plain gives way to a sharply dissected upland. Moreover the plain is trenched by the valleys of the streams, and over considerable areas by the systems of numerous and fairly deep lateral ravines.

All the same the prevalent type of the Bremer county landscape is the gently undulating plain. It thus stands in strong contrast with several other typical Iowa landscapes. A few miles to the east lies the maze of deep valleys of eastern Fayette county and of Clayton, and all the mature erosion topography of the driftless area. To the southeast, from Jones and Clinton counties westward, lies the singularly fluted landscape of the ridged drift, where wide belts of undulating lowland, stretching from northwest to southeast parallel with the river courses though often not occupied by the master streams, alternate with long ridges and uplands of well dissected drift. Farther south is found the typical landscape of the Illinoian and Kansan drift of southeastern Iowa, where the dominant topographic form is the tabular divide, flat as a floor, and separated from adjacent similar remnantal levels by the comparatively narrow valleys which streams have carved upon the initial plain. The divides of Bremer county never have the flatness of the Kansan and Illinoian drift of southeastern Iowa, nor do the wide long vistas seen from the crests of the ridged drift of east-central Iowa anywhere here meet the eye.

The slight local relief of the county is indicated by any road map. The straight roads almost everywhere follow the section lines without deviation. In exception we may note the diagonal stretches of the road from Waverly southeast to Denver, following the trend of the peculiar hills at whose base they lie, the short stretches of road in the hilly region of sections 17 and 18, township 91, range XIII, which leave their direct courses to obtain an easier grade, and the diagonal road which follows the side of the Wapsipinicon valley south of Tripoli for a short distance.

TABLE OF ALTITUDES.

The following table gives the elevation above tide water of those points in the county whose altitude has been determined, with the authority for the same.

Bremer.....	1044 feet.	Profiles of C. G. W. Ry.
Denver Junction.....	1015 feet.	Profiles of C. G. W. Ry.
Janesville	891 feet.	Gannett's Dict. of Altitudes.
Plainfield.....	941 feet.	Gannett's Dict. of Altitudes.
Potter's Siding.....	1056 feet.	Profiles of C. G. W. Ry.
Readlyn.....	1042 feet.	Profiles of C. G. W. Ry.
Sumner, C. G. W. Ry.....	1060 feet.	Gannett's Dict. of Altitudes.
Tripoli.....	1025 feet.	Profiles of C. G. W. Ry.
Waverly, I. C. and G. W. Ry.		
crossing	936 feet.	Gannett's Dict. of Altitudes.

DRAINAGE.

Three master streams, the Cedar, the Shell Rock and the Wapsipinicon rivers, pursue a south-southeasterly course across Bremer county. The Shell Rock transects the southwestern corner of the county with a winding course of about seven miles in length, and joins the Cedar a mile or more south of the county line. As in the case of the Iowa and Cedar rivers, so here it is the smaller and shorter stream which aligns itself with the course below the confluence, while the larger and longer stream suddenly diverges from its parallel track to meet the axial stream at a high angle. In nomenclature the two cases cited are quite opposite. In the case of the Iowa and Cedar, the course below the confluence takes the name of the axial stream, to which the larger stream is thus made tributary. In the case of the Cedar and the Shell Rock the smaller stream, though axial, is called the tributary of the larger.

The tributaries of the three rivers named as a rule maintain subparallel courses with their master streams until near the confluence. The interstream area between the Little Wapsipinicon river and Buck creek is from two to four miles wide. Buck creek, rising in the northern tier of sections, flows along side the Wapsipinicon across the county, the divide between the valleys in the southern townships seldom exceeding a mile and a half or two miles in width. The East Wapsipinicon holds its parallel course in northern Leroy township about three miles

distant and then flowing southwest joins its master stream. Crane creek crosses nearly the entire county along a track from three to five miles west of the Wapsipinicon and flows into that river in Black Hawk county. The next two creeks, Quarter Section run and Baskin run, flow side by side about three miles apart and at about the same distance from their trunk stream, the Cedar river, on the west, and from Crane creek on the east.

A glance at the drainage map of the county shows the eccentric behavior of one of the streams just named, Quarter Section run. In the normal development of a river system the affluents are expected to join their trunk stream as twigs their stems, at somewhat less than a right angle, and such are all the other confluences in our area. Quarter Section run, however, suddenly departs from its southeastern course about two miles below Denver and turns abruptly to the northwest. Flowing for five or six miles in a direction opposite to that of all the other streams, it picks up Baskin run and meets the Cedar at the sharp bend where the latter turns to join the Shell Rock. Thus we have here a T whose horizontal bar is made of Quarter Section run on the one side and of the Cedar on the other, flowing from the opposite directions, and whose stem is formed of the Cedar below the confluence. To find explanation of this singular fact we must await the description of the topography of the area.

In summation, Bremer county is drained by a series of sub-parallel streams whose general course is directed somewhat east of south and which are so spaced that their tracks lie seldom more than three or four miles apart. On interstream areas so narrow and, as we are to see later, so immature, no laterals have developed worthy of name upon the county maps.

In anomalous contrast with the south-southeastward courses of the streams is the strong southwestward slope of the country, as Calvin has already shown in his reports on Mitchell and Chickasaw counties. From the high divide which extends from eastern Howard and southwestern Winneshiek counties across Fayette county west of the Volga river, through Strawberry Point and Edgewood, to the vicinity of New Vienna in Dubuque county—to follow it no farther beyond the limits of our field,

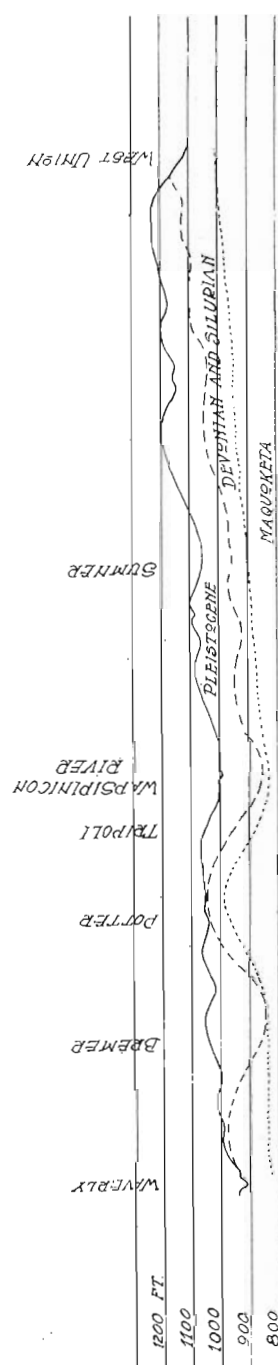


Fig. 38.—Profile from West Union to Waverly showing the southwesterly slope of the surface.

the land slopes everywhere southwestward toward the great trough of the Cedar. This is shown graphically in the accompanying diagram based on the profile of the Waterloo, Cedar Falls and Northern Ry., from Waverly to Sumner, and on the topographic maps of the U. S. Geological Survey thence to West Union. On this northeast-southwest line the upland gradually declines from 1240 feet A. T. on the high prairie overlooking West Union, to 1100 feet at Sumner, to 1065 feet west of Tripoli, to 1045 feet at Bremer, and to 1010 feet on the prairie west of Baskin run,—an average slope of about seven feet to the mile.

The same strong slope appears on a similar profile of the upland south of our area,—from Farley in Dubuque county southwest to Linn Junction in Linn county. The Iowan drift plain stands at 1160 feet A. T. about Farley, at 1040 feet between the Maquoketa and the Wapsipinicon near Prairieburg, while between the Wapsipinicon and the Cedar the same plain has declined from 980 feet near the former river to 840 feet A. T. near the latter,—a gradient from Farley to Linn Junction of seven feet to the mile measured outside the immediate valleys of the rivers.

Contrast this with the comparatively slight fall of the streams whose courses bear to the southeast and with the descent of the

Iowan drift plain in the same direction. According to Gannett, the elevation of Waverly is 936 feet A. T. and that of Cedar Rapids is 732 feet, each being built on the flood plain of the river at about the same height above the stream. The fall of 204 feet gives here a gradient of three feet per mile in a straight line, neglecting the winding course of the river. From Tripoli to Stone City the Wapsipinicon falls 180 feet, a straight line gradient of 2.8 feet per mile. Taking the southeast slope of the Iowan plain from the high prairie near Tripoli, 1065 feet A. T., to the plain southwest of Stone City we have an average slope of two feet per mile. Thus the streams of the Iowan plain east of the Cedar river do not flow with the slope of the country. The major slope of the plain is southwest; the streams flow to the southeast.

In explanation of this exceedingly anomalous behavior several hypotheses suggest themselves. We may conceive that in Iowan times the great depression whose axis is now held by the Cedar river was filled brim-full of glacier ice and that the surface drainage of the stagnant ice was directed to the southeast, the general direction of the glacial flow. Cutting at last through the ice, these surface streams were let down upon a land whose slope was southwest, and on this they entrenched themselves both by corrasion of their channels, and by the deposition of waterlaid drift about their banks.

Again, streams which are younger than the Iowan drift, whose initial courses lay upon its surface on the melting of the Iowan glacier, may have had their tracks determined by long troughs of the drift surface due to phenomena either of modelling or of erosion connected with the southeastward movement of the ice. Deep preglacial buried channels, such as are known to exist throughout eastern Iowa, may have contributed largely to form these troughs upon the surface of the drift either because they were never filled to the level of the land on either side, or because the exceptionally thick drift laid in them settled and formed sags.

These explanations assume that the Cedar depression is preglacial and that the southwestern slope of the country antedates the origin of the present streams. An alternative theory may

also be considered that on the melting of the Iowan ice the slope of the region was to the southeast, thus determining the courses of the initial consequent streams, the present inclination being due to later warping, to which the rivers are not yet adjusted.

THE VALLEY OF THE CEDAR RIVER.

The Cedar river enters the county from the north in a valley three quarters of a mile in width, whose flat floor lies about thirty feet above water level. Rock is exposed in places along the banks of the stream, but we have no knowledge as to whether these are local spurs or a part of a wide rock floor due to planation by the stream when flowing at a somewhat higher level and left covered with a veneer of alluvium. On either side rise hills of drift with moderate slopes eighty feet high or more above the river.

A mile north of Plainfield the lines of bordering hills swing out until they are four miles apart at Horton, which occupies an eastern reentrant of the river-plain where two creeks debouch. The flat fluvial floor continues with a width of about three miles well into Lafayette township. This wide old river-plain stands at the inner margin but about fifteen feet above the present flood plain of the river and rises almost imperceptibly on its outer margin to merge with the gentle slopes of the bases of the bordering hills. These second bottoms are prevailingly sandy. Shallow driven wells secure abundant water everywhere upon them. The shifting banks of the river show nothing here but alluvial deposits. Originally the river plain was well wooded, but much of the forest has been cleared to make room for pastures and plowed fields. Boulders of the Iowan drift are seen out upon the plain in several places, and here the valley of the Cedar and those of the creeks which merge with it on the left bank near Horton are clearly older than this most recent ice invasion of the county.

In Lafayette township the valley constricts to a width of a mile and a half and a mile, while midway the township it narrows to less than half a mile. Rock outcrops in low ledges at a number of places a few feet above the flood plain on the bounding hill sides. Yet nothing like a gorge appears, and the aspect of the valley is still by no means youthful. On the left bank the

hills now rise fifty or sixty feet above the stream, many of them sandy, especially near the river, and underlain with rock at no great distance from the surface. Approaching Waverly one sees on the left groups of the lenticular loess-capped hills called *paha*; the valley narrows until in the north part of the town rocky hills hem it in to a width of about eighty rods. Again the valley opens, leaving beneath the high loess hills with their rocky basements room for the business blocks of east Waverly on an ancient terrace of the river. On the west side the terrace is still more ample, widening to about half a mile, and is occupied by the chief residential portion of the little city. Even this

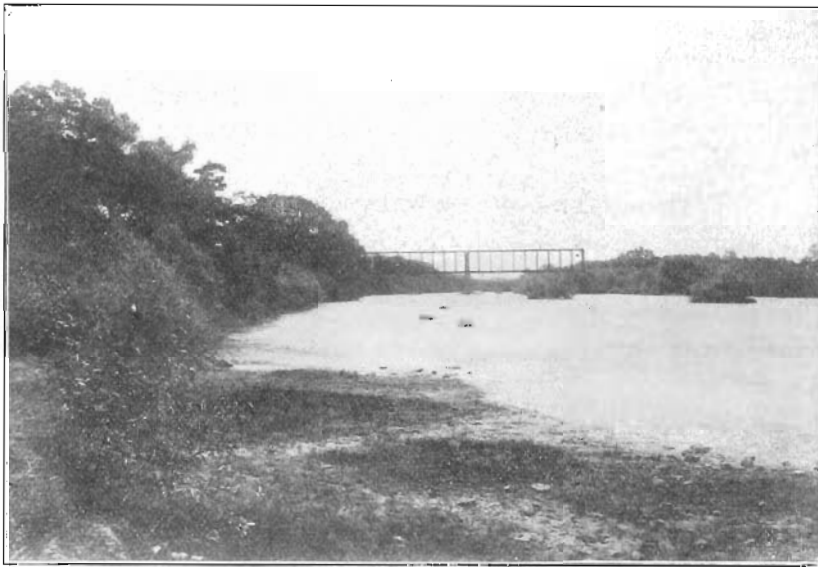


Fig. 39—Looking down the Cedar River at Janesville.

spacious remnant of the ancient flood plain has not been found sufficient, and the growing town has climbed the slightly slopes of the loess hills to the east and the fairly level Iowan drift plain which overlooks the terrace on the west. The terrace is underlain with rock which outcrops along the river banks, though not in cliffs. Here the stream flows swiftly over a rock bottom. If the reports of wells in Waverly are correct, a deeper channel, abandoned and filled, crosses the terrace on the east side of the town, where at the Creamery Supply Factory rock

was found fifty feet below the surface. On the bottom lands southeast of town wells are reported to go nearly one hundred feet through river sands without reaching rock, thus disclosing a buried channel far older than the present course of the river through the city.

South of Waverly the Cedar occupies a comparatively narrow valley, seldom more than a quarter of a mile in width, the Iowan plain of thin drift underlain with the Devonian limestones overlooking it on either side. In the southern part of Washington township the river leaves the lower ground of the Iowan plain and plunges directly into a group of high loess capped hills with nuclei of rock. In Jackson township, leaving this rugged area behind, the river again makes use of a comparatively narrow valley bounded by the rock-basemented Iowan plain until at Janesville it finds on the right bank the wide, gravelly, ancient floodplain terrace which here parts it from the Shell Rock.

THE VALLEY OF THE WAPSIPINICON RIVER.

The Wapsipinicon enters the county from the north in a comparatively narrow valley, about one-half mile in width at Frederika, and bordered by low rocky hills. Immediately below Frederika the valley widens to one and a half and two miles and maintains or slightly exceeds this width during the remainder of its course through the county. The valley is flat-floored, descending however by almost imperceptible degrees toward the thalweg or median stream-line from the base of the gentle slopes of the bordering upland which rises about sixty feet above the river plain.

The valley floor is one of aggradation, not of planation. It is strewn with sand and gravel to a depth of ten or twenty feet, and occasional boulders, apparently of Iowan drift, are found well out upon it, as well as in large number upon the bordering hillsides. These erratics upon the river plain indicate either that the Iowan ice descended to the flood plain perhaps already fashioned at an earlier date, or that the swollen currents from the melting ice carried small bergs or ice cakes which here and there dropped their load of glacial drift. An earlier ice sheet

than the Iowan seems to have found here a valley, and to have aggraded it with its ground moraines. Beneath the surface sands and gravel lies a bed of stony clay, fifty to eighty feet in thickness, the deposit of an ancient ice sheet, probably the Kansan. Underneath this is found a deposit of sand and gravel which may be referred to the Aftonian. These sands and gravels contain an inexhaustable supply of water under artesian pressure, whose head seems to be due to the rise of the aquifer on the sides of the ancient valley. No occasion has been found to drill through these water bearing gravels, so that what lies beneath them and how deep is the rock floor are both quite unknown.

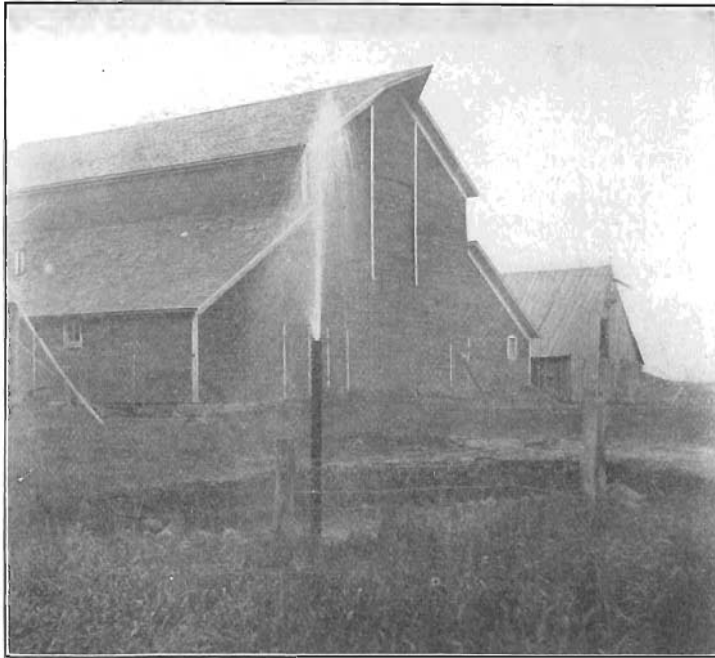


Fig. 40—An artesian well in the Wapsipinicon flood plain.

In this great valley, adequate for a Mississippi, the tiny Wapsipinicon, six or eight rods wide, is as out of place as a mouse in a lion's cage and the misfit is as apparent as a dwarf were in the clothing of a giant. The meanders of the little river, in the few places where it develops these symmetric bends, are hardly

more than 800 or 1000 feet in transverse diameter. For the most part the river rolls its waters through a narrow network of inosculating channels, which wind among low, sandy islands, and new courses in channels excavated by the floods of recent years are not uncommon. In one instance the stream divides about a wooded, sandy elevation to form a low island three-quarters of a mile wide and nearly a mile and a half long, set well out from the borders of the valley on either side.

In one respect the Wapsipinicon valley is in marked contrast with the valley of the Cedar. The latter river has cut its present channel a number of feet below the level of the old valley floor. Its ancient flood plain has been left moderately well drained and dry enough for the growth of forests. These have been cleared away for the cultivated fields and pastures of numerous farmsteads, whose dwellings may stand within a few rods of the river banks. On the other hand the aspect of the Wapsipinicon bottoms is that of a wide savanna whose marshy grass lands are suitable only for pasture. Forests have invaded the area only along the natural levees or drained banks of the immediate vicinity of the stream. Farmsteads have gathered along the slopes of the bordering hills, but are almost wholly wanting over the valley. The roads which cross it are carried on well marked dikes ditched on either hand, and as the traveler looks out from them over the wide expanse of marshy grass-land with occasional ponds bordered with sedge and pickerel weed and covered with the yellow water lilies, he receives a vivid impression of the barrier which the "Wapsie bottoms" must have been to the pioneer before these causeways and their bridges had been built.

No village or town is located on the Wapsipinicon within the limits of the county, or indeed, from Bremer north to the state line, excepting the village of Frederika which has the vantage of the gentle slopes of low rocky hills which lift it out of the general wet.

The valley of the East Wapsipinicon repeats the features of the Wapsipinicon valley on a smaller scale. Its floor is about one mile wide and the valley has been filled with drift

and aggraded with glacial outwash and alluvium to the depth of from eighty-five to more than one hundred feet. Deep lying gravels, referred to the Aftonian, supply artesian water in the lower reach of the valley.

The creeks of the county tributary to the master rivers rise in marshy sags of the Iowan drift plain, winding around low swells in indecisive courses and indistinct valleys, which widen where a basin has been aggraded and narrow where the overflow from slough to slough has cut its way across the intervening rim. From these humble beginnings the larger creeks, such as Crane creek, attain at last aggraded valleys a quarter or a half mile wide as measured across the flat sandy and marshy valley floors, and sunk forty feet or more below the bordering upland. At ordinary stages these sluggish creeks content themselves with channels a rod or so in width, but at flood they widely overflow the adjacent bottoms. An occasional low sand dune occurs upon the flood plains, and gravel terraces fifteen or twenty feet above the streams were noticed in places.

STRATIGRAPHY.

General Relations of the Strata.

The indurated rocks of Bremer county consist of sea-laid limestones and shales belonging to several different natural groups called formations. The lowest, and hence the earliest, of these which come to the rock surface in our area are shales belonging to a stage known as the Maquoketa. In Bremer county the Maquoketa shales are found only in deep drift-filled valleys, where the overlying strata have been removed by long preglacial erosion, and in deep borings beneath the cover of later formations. With the gentle rise of the strata of this region to the northeast the shales outcrop along a belt which stretches from Howard and Winneshiek counties as far south as northern Clinton county. These ancient sea muds testify to a time when our area lay beneath the sea, and when the sea was here clouded with fine waste washed from a not distant land, lying probably to the east and north. Fossils, the remains of ancient organisms, occur in profusion in the Maquoketa shales at many

of their outcrops, as at Elgin in Fayette county, and these fossils show that the shales belong to a system of strata known as the Ordovician, deposited at a time so remote that so far as known no animals then tenanted the land, and fishes of a lowly type were the highest organisms to be found upon the earth.

Resting upon the Maquoketa shales are beds of limestone which prior to this survey were not known to extend into Bremer county. This limestone, as its fossils show, belongs to the Hopkinton stage of the Niagara series and to the Silurian system. Although it comes to the surface at only a few points, on Crane creek, Baskin run and Quarter Section run, it underlies, like the Maquoketa, the entire county. The Niagara limestone records a period of great length when by long denudation the neighboring lands had been worn so low that their sluggish streams now brought into the shallow Silurian sea little except soluble waste, or when the shores had become so remote by a transgression of the sea that little clay and sand was washed out so far from land as was our area. In such clear waters lime secreting animals, such as sea shells and corals, grew in great profusion, and from their remains extensive sheets of limey oozes were produced which are now found consolidated to firm rock. These strata outcrop at Hopkinton in Delaware county, whence they derive their name.

In Linn, Cedar, Scott and other counties lying south of our area, there rests upon the Hopkinton limestone another belonging to the same Niagara series and known as the Gower stage. In Bremer county as in Fayette the Gower limestone does not occur, suggesting that northern Iowa was land in Gower times.

Resting immediately upon the Hopkinton limestone occurs a body of limestone shown by its fossils to belong to the Devonian system. The Devonian limestones form the rock foundation of nearly the entire county, outcropping wherever the streams have cut through the superficial stony clays of later date. According to their lithological differences and included organisms the Devonian limestones have been divided into two stages, the Wapsipinicon and the Cedar Valley.

The Wapsipinicon, the lower of these stages, receives its name from its excellent outcrops on the Wapsipinicon river in Linn county, and there it presents a number of subdivisions,

or sub-stages, not all of which have been discriminated in Bremer county. The Wapsipinicon limestones outcropping south of Waverly on the Cedar river and its tributary creeks, have been extensively broken by earth movements and their cemented angular fragments form what is known as breccia. From its occurrence at Fayette this zone of broken rock has long been known as the Fayette breccia. Since several formations are involved in this brecciation, which sometimes includes even the lower beds of the Cedar Valley stage, it has seemed best to the author to discard the term as a formation-name, notwithstanding its convenience in designating a zone extending from near the northern border of Iowa to Davenport.

The Devonian limestones tell of a shallow sea with shores either remote or so low that little insoluble waste was brought to the limits of our area. The brecciation of the Wapsipinicon records strong lateral pressures, and sudden yieldings to them by these brittle and thin layered rocks, causing, no doubt, great earthquakes to run through the adjacent lands.

The uppermost rocks of the Devonian system and of Bremer county belong to a stage which Iowa geologists have long known as the Cedar Valley, from its extensive outcrops along the Cedar river from near its mouth in Muscatine county to the Minnesota line. The Cedar Valley limestones abound in fossils—corals and allied lowly types, sea shells of many species and the remains of fishes. Our area was in these later times of the Middle Devonian a quiet sea in which, as off the coast of Florida today, great banks of limestone were slowly forming from the remains of the profuse organic life which flourished there.

The Devonian period was succeeded by the Carboniferous, when the coal beds of central Iowa and the eastern states were laid in dense jungles and peat swamps. Outliers of Carboniferous strata occur as far east and north as Linn, Cedar and Jackson counties, but none are known in Bremer, or the adjacent counties. Northeastern Iowa, including Bremer county, seems then to have been land during the entire Carboniferous

period and to have been lifted sufficiently above the sea to avoid imperfect drainage and the formation of coal swamps. We may well imagine it covered with the luxuriant gymnospermous forests which formed the highest vegetal life of the time.

In the Mesozoic era the land of which our county formed a part suffered no doubt various oscillations and passed through successive cycles of erosion. In the Cretaceous period of this era the sea came in widely over the lowlands of the continents and the mediterranean which occupied the site of the Great Plains advanced its eastern margin over western Iowa. We have no evidence to show that this incursion reached Bremer county although in Black Hawk county, adjoining Bremer on the south, the presence of well preserved Cretaceous shells in the drift may possibly point to a local buried Cretaceous outlier instead of to a carriage of these shells from Cretaceous areas in southeastern Minnesota.

The Tertiary period witnessed a broad uplift of eastern Iowa and the carving of wide deep valleys in the upland. The drift-buried valleys of Bremer county record this portion of our history. During the Glacial epoch these channels were choked with glacial outwash of sand and gravel and with the stony clays with which the entire county was mantled. Of the successive ice invasions of which other parts of the state bear testimony only three, the pre-Kansan, or Jerseyan, the Kansan and the Iowan ice sheets, made incursions into our territory. Thrice the area was long buried beneath ice sheets comparable in size to that which now covers Greenland, and during two periods besides the near presence of continental ice fields produced a climate of arctic rigor.

With the retreat of the ice from North America the present geological epoch began, whose records are seen in the peat deposits of the sloughs, the humus of the soils, the silts spread by the rivers on their flood plains, hillocks of wind-blown sand and dust, the erosion done by rain and streams, and the disintegration and decay of the surface rocks under the action of the weather.

The following table presents the succession of all these various deposits ranging in age from those of tens of millions of years ago to those of yesterday.

SYNOPTICAL TABLE.

GROUP.	SYSTEM.	SERIES.	STAGE.	DEPOSITS OR SUB-STAGES.
Cenozoic	Pleistocene	Recent		Alluvial. Aeolian. Organic.
		Glacial	Iowan	Loess. Drift
			Yarmouth	Buchanan gravels
			Kansan	Drift.
			Aftonian	Gravels and sand.
			Jerseyan	Drift.
Paleozoic	Devonian	Middle Devonian	Cedar Valley	Limestone.
			Wapsipinicon	Lower Davenport limestone
				Otis limestone
	Silurian	Niagara	Hopkinton	Limestone or dolomite
	Ordovician	Trenton	Maquoketa	Shale.

ORDOVICIAN SYSTEM.

MAQUOKETA STAGE.

The lowest rock formation which reaches the surface of the indurated rocks is the Maquoketa shale of the Ordovician. Nowhere does it reach the present surface of the ground, being deeply covered by the drift. At Waverly it lies 120 feet below the surface and at Sumner 170 feet as well borings at these places have proved. But in the deep buried ancient river valley which passes through the county between the courses of the Cedar and the Wapsipinicon rivers the rocks overlying the Maquoketa have been removed and here the tools of the well driller find immediately below the glacial drift a shale, known popularly as "soapstone", which can be none other than the Maquoketa. Thus at Clausing's well at Denver the following section is given:

	THICKNESS IN FEET.	DEPTH.
Drift.....	66	66
Gravel and sand.....	10	76
Drift.....	86	162
Shale, dark blue, without gait.....	248	410

This well seems to be located in a tributary of the main old river valley. The abruptness of its banks is indicated by the fact that but a block away from the well just cited the drill found limestone at forty-two feet from the surface. Three blocks away on higher ground another well, Henry Bauman's, found at 124 feet from the surface four feet of limestone, presumably the Niagara, overlying shale. For eight feet below the limestone the shale was red, ocherous, and soft, suggesting unconformity—an interval of long weathering and oxidation of the Maquoketa as a land surface before submergence and the deposition of the Niagara upon it.

The deep well of August Buhr in Maxfield township (north-east quarter of the northwest quarter of section 8, township 91, range XII W.) gives an instructive section according to the driller's log.

	THICKNESS IN FEET.	DEPTH.
Yellow till.....	40	40
Blue till.....	150	190
Limestone (Niagara).....	3	193
Shale (Maquoketa).....	300	493
Limestone (Galena-Plattsville).....	191	684

In Douglas township the following section of a well boring on the farm of C. Zwanziger, (southeast quarter of the southeast quarter of section 6, township 93, range XIII W.) is given by the driller.

	THICKNESS IN FEET.	DEPTH IN FEET.
Blue clay, till.....	200	200
Soft rock and shale, Upper Maquoketa	60	260
Hard rock, Middle Maquoketa.....	6	266

Well of H. Winzenberg (southwest quarter of the southwest quarter of section 27, township 93, range XIII W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
Yellow clay.....	30	30
Blue clay.....	190	220
Limestone.....	10	230
Shale, Upper Maquoketa	87	317
"Sandstone", (limestone of Middle Maquoketa?)	20	337

Special interest attaches to the last well as it is located less than two and one-half miles from an outcrop of the Niagara at about the level of the well curb, thus showing the depth to which

the buried valley was cut in rock. In this well, and that of the preceding record the shale has apparently thinned out from the sections given in townships south. But the Maquoketa itself carries dolomitic layers which would tally with the descriptions, as the hard, glittering sharp-cut sand of dolomite has often been mistaken for that of sandstone.

Much more common than the wells which strike the shale immediately below the drift are those which descend below the level of the upper surface of the Maquoketa without finding rock and end in glacial sands and gravels.

The Maquoketa is found beneath the drift also in a channel apparently tributary to the buried valley of the Wapsipinicon. The following section is of a well on the farm of J. McQuesney (northwest quarter of the northeast quarter of section 18, township 93, range XI W.).

	THICKNESS IN FEET.	DEPTH.
Drift.....	200	200
Shale.....	60	260
Lime rock.....	23	283

In the same section a well, belonging to August Schmidt and situated on the northeast quarter of the northwest quarter, found the shale below the drift.

	THICKNESS.	DEPTH.
Drift clays	135	135
Quicksand.....	60	195
Blue clay.....	25	220
Shale (Maquoketa)....	2	222

It will be noted that the thickness of the shale as given in the above well records varies from 87 to 300 feet, taking only those wells in which shale is found inclosed between both upper and lower limestones. These wide differences are due probably to the fact that, as Savage has shown in Fayette county, the Maquoketa comprises both a lower and an upper shale parted by thick beds of limestone. Where the shale is found of the maximum thickness we may infer that the entire Maquoketa was passed through, the middle Maquoketa not being recognized in the records, while in the minimum thicknesses, we may suppose that the limestone in which the well ended is that of the middle Maquoketa. At Sumner the three members are well

distinguished in the log of the city well, the total thickness of the Maquoketa being 220 feet. At Waverly the deep well section does not show the intercalary limestones, the total thickness being here 150 feet.

SILURIAN SYSTEM.

Niagara Series.

Local upwarps have lifted these limestones which overlie the Maquoketa shale so that they appear upon the surface at several points in the county—about three and a half miles west of Tripoli and, southeast of Waverly, on Baskin run and near the mouth of Quarter Section run.

No doubt the Niagara is concealed over considerable areas about these outcrops by the heavy mantle of glacial drift. In the southeastern portion of the county it is also highly probable that the Niagara immediately underlies the deep drift of the region, as it comes to the surface a few miles to the southeast at Fairbank. As in other counties so here detailed investigations of the present Survey have rectified the frontier between the Devonian and the Silurian largely at the expense of the former as drawn on the geological maps of the earlier surveys. Thus in Buchanan county Calvin found that a strong upfold of the strata had lifted the Niagara above the position which it naturally would occupy. To this upwarp is due the broad triangular salient of the Niagara in northern Buchanan and southern Fayette counties which brings it nearly the width of an entire county west of the general trend of its boundary line. The survey of Bremer county again advances the Niagara to the west by nearly a county breadth, bringing it to the Cedar river below Waverly. Nowhere above this point is the Niagara seen in the immediate valley of the Cedar, nor does it again appear to the south until one reaches the Niagara outcrops of southern Linn county below Cedar Rapids. The outcrop near Tripoli is aligned with the Oelwein-Fairbank anticline and is perhaps an extension of it. No rock outcrops between the Tripoli and Fairbank exposures, the entire country being buried beneath one hundred feet and more of drift.

SECTIONS OF THE NIAGARA.

Outcrop three and one-half miles west of Tripoli (southeast quarter of the southwest quarter of section 36, township 93, range XIII W.). The occurrence of Niagara dolomite so far within the Devonian boundaries as they have hitherto been drawn is of peculiar interest. Fortunately the presence of distinctive Silurian fossils leaves no possibility of doubt as to the age of the outcrop and forbids it to be mistaken for the lithologically similar Devonian dolomite which in northeastern Iowa had been sometimes confounded with it before the present survey. This outcrop lies on the left bank of Crane creek, and is disclosed by the cutting of the road along the south line of section thirty-six of Douglas township. The valley of the creek is here cut but about thirty feet below the nearly level surface of the Iowan upland.

	FEET.
2. Geest, dark red, unctuous residual clay, with much yellow chert and fragments of silicified corals.....	1
1. Dolomite, in weathered masses of buff color with hard subcrystalline gray cores, highly vesicular, in places containing nodules of flint, fossiliferous, with numerous casts and molds of crinoid stems, corals, etc.....	5

The following fossils were found to occur in this dolomite, so far as determinable:

Calymene niagarensis.
Illænus, pygidium.
Halysites catenulatus Linn.
Favosites favosus Goldfuss.
F. hisingeri.
Heliolites subtubulatus.
Stromatopora sp.
Zaphrentis sp.
Streptelasma sp.

A chemical analysis of the rock shows it to be a typical dolomite.

SiO ₂	1.53
Fe ₂ O ₃ ..	.48
CaCO ₃	54.32
MgCO ₃	43.41
H ₂ O ..	.26
	100 00

Section at Old Limekiln quarry (southwest quarter of the southeast quarter of section 17, township 91, range XIII W.).

	FEET.
3. Breccia composed of sharp angular fragments of a drab, laminated limestone, of lithographic fineness of grain, the laminae in places flexed and broken but retaining an approximate parallelism, matrix gray, nonfossiliferous, sparse in amount. Breccia of typical Lower Davenport type.....	1
2. Sandstone filled with small angular fragments of white chert, in two or three layers, resting with apparent conformity on No. 1.....	½
1. Dolomite, light buff, crystalline, vesicular, with cavities up to eight inches in diameter as from the removal of corals; in heavy, irregular, rough surfaced, horizontal beds up to two feet thick; main joints vertical, running North 13° East; fossiliferous with numerous <i>Halysites catenulatus</i> ; general facies of the Hopkinton stage	13

The floor of the quarry lies about thirty feet above the level of Baskin run a few rods east. No. 1 is Niagara, and Nos. 2 and 3 are of the Wapsipinicon stage of the Devonian. This most interesting contact between the Silurian and Devonian will again be mentioned under the Devonian sections.

Section on Quarter Section run (southeast quarter of the southwest quarter of section 20, township 91, range XIII W.).

Here a small branch trenches the side of the valley of Quarter Section run displaying the following:

	FEET.
1. Limestone, greenish yellow, subcrystalline, argillaceous, weathering to irregular, rough-surfaced layers, from one to four inches thick. Dip south, varying in amount, reaching as high as 13°. General facies that of the lower members of Hopkinton stage.....	8

The same beds recur a few rods east along the left bank of Quarter Section run (southeast quarter of the southwest quarter of section 20, township 91, range XIII W.), and in both cases are overlain by an interesting succession of beds of the Wapsipinicon stage of the Devonian:

The fossils of the Niagara here collected are as follows:

Leptaena rhomboidalis
Camerotoechia sp.
Orthoceras unionensis.
Encrinurus nereus.
Halysites catenulatus.
Stromatopora sp.
Favosites sp.

DEVONIAN SYSTEM.

WAPSIPINICON STAGE.

It has already been stated that the Devonian rocks of the county fall into two divisions, the Cedar Valley and the Wapsipinicon. The lower of these stages, the Wapsipinicon, has been subdivided in counties to the south of our area, where it is thickest and its terranes most fully represented, into several substages, the Upper Davenport, the Lower Davenport, the Independence, the Otis, and the Coggon, to name them in their order from the highest downward. The Upper Davenport has not been recognized in Bremer county. The Coggon limestone may be considered as merely a dolomitized or highly magnesian phase of the Otis, since it has been found to carry fossils characteristic of the Otis and known in no other substages of the Devonian of Iowa. Neither in this magnesian phase, nor in the phase of a non-magnesian limestone has the Otis been recognized in Bremer county. The two substages of the Independence and the Lower Davenport occur in some force on the Cedar at Janesville and from near the mouth of Quarter Section run up river to near Waverly and also up the small stream and its tributary ravines.

LOWER DAVENPORT SUB-STAGE.

Along nearly the entire outcrop of the lower strata of the Devonian in Iowa there has been recognized a group of beds of non-fossiliferous limestone of peculiar facies sharply set off from fossiliferous beds above and from shales or impure argillaceous and often cherty limestones beneath. These have been termed by the writer the Lower Davenport beds from their occurrence in their typical form at Davenport. In its commonest lithological type the Lower Davenport is a hard compact and homogeneous limestone, non-crystalline, of almost lithographic fineness of grain, brittle, breaking with smooth conchoidal or splintery fracture. In color it ranges from dark to light drab. It is often finely laminated, the laminae usually being strongly coherent and their edges etched on weathered surfaces. Because of its brittleness this limestone has yielded by fracture in many places to lateral pressure, producing a crush or pressure breccia, consisting usually of a mass

of small fragments set close at all angles without trace of bedding planes. The fragments retain a flint-like sharpness, and the matrix is commonly sparse and of much the same material, though more granular and slightly lighter colored and less resistant to the weather. Where the stresses were most severe, fragments of these beds have been mingled also with earthy yellow limestones beneath, and with fossiliferous limestones of higher stages. Outcrops of the brecciated Lower Davenport beds have been described at Davenport, at various localities in Cedar county, at Solon in Johnson county, at Independence in Buchanan county, at Fayette, between Vinton and Mt. Auburn in Benton county, and at a number of places along the Cedar and Wapsipinicon rivers in Linn county. With these brecciated beds the author has grouped beds of similar facies but slightly or not at all disturbed, such as those of the government reservation of Rock Island, at Gilbertville and Devil's Den near Davenport, and at Rochester in Cedar county. Here also should probably be placed the limestone weathering to thin plates and only slightly flexed which occurs beneath the brecciated beds at Fayette. The Lower Davenport thus includes massive as well as laminated limestones, a lateral alternation between the two occurring sometimes in the same stratum. The formation is bounded beneath by the Independence, and when this locally fails to appear it is difficult or quite impossible to distinguish the unbrecciated Lower Davenport from the Otis, when the latter is unfossiliferous, so like are the two formations lithologically.

INDEPENDENCE SUB-STAGE

In its typical exposure in a miner's shaft near Independence this formation was found to be a fine fissile and highly fossiliferous shale, varying in color from light gray to black. The rich and interesting fauna was described in detail by Calvin and a new formation added to the Devonian of the West. Since their early discovery, shales of the typical fossiliferous or carbonaceous type have been rarely found in the exploration of the Devonian during the progress of the present survey, the only outcrop known being that of a gray clayey shale carrying the typical Independence fauna in the cut of the Chicago, Milwaukee

and St. Paul Railway west of Linn Junction in Linn county, where it is associated immediately with the breccia. The geological report on Linn county cites two instances where the same typical fossiliferous or carbonaceous shale was discovered by wells.* In a large number of localities, however, argillaceous limestones or calcareous shales have been found to underlie the Lower Davenport, or to rest upon the Otis, and these though unfossiliferous have been referred to the same horizon as the shale at Independence. Thus at Kenwood there occurs beneath the brecciated beds some thirty feet of variable clayey limestones and limy shales, and these outcrop in force at a number of places in and about Cedar Rapids. In Scott county rough brown earthy and ferruginous limestones are found resting upon the Otis along Crow Creek.† In Cedar county similar soft brown clayey limestones sometimes associated with shaly beds occur at various localities in the same relations.‡ In Benton county also, in Cedar township, Savage records the occurrence immediately beneath the brecciated Lower Davenport of impure buff magnesian limestone, in places arenaceous, and with two feet of gray calcareous shale.§ Moreover, the lowest phase of the brecciated beds of the Wapsipinicon as defined by the writer has as its abundant matrix an earthy buff or brownish limestone altogether similar to the underlying clayey limestones of the Independence.* * This also has been distinguished widely over the Devonian area, as for example, in Johnson county by Calvin in the vicinity of Solon.† †

A special feature of the Independence beds remains to be mentioned, their siliceous inclusions. These consist of angular siliceous fragments, varying from sand to fragments a few inches in diameter, and lenticular nodules reaching a foot or more in length, and are so common and so constant that they serve as one of the diagnostics of this horizon. With this mention of the characteristics of the lower strata of the Devonian in the areas where they are most fully represented, we are now prepared to consider their occurrence in Bremer county.

*Iowa Geological Survey, Vol. 4, p. 157, Des Moines, 1895.

†Iowa Geological Survey, Vol. 9, p. 442, Des Moines, 1899.

‡Iowa Geological Survey, Vol. 11, pp. 333, 335, Des Moines, 1901.

§Iowa Geological Survey, Vol. 15, p. 159, Des Moines, 1905.

*Iowa Geological Survey, Vol. 4, p. 158, Des Moines, 1895.

†Iowa Geological Survey, Vol. 7, p. 58, Des Moines, 1897.

SECTIONS OF THE WAPSIPINIOON STAGE

No. 1. Southeast quarter of the southwest quarter of section 20, township 91, range XIII W. In ravine tributary to Quarter Section run.

	FEET
6. Limestone, massive, in one undivided layer weathering to scoriaceous surface in places and in other places to smooth surface. Color mottled, prevailing a light brownish drab, weathering to lighter gray, slightly vesicular, fracture uneven.....	4
5. Limestone of same facies as above in layers of about eight inches.....	2
4. Concealed.....	15
3. Limestone of facies of Nos. 5 and 6, but in separable laminæ.....	1
2. Cherty sandstone; in layers from four to six inches thick, chert fragments angular, small, those of an inch and one-half being rare, sand fine, of moderately well rounded grains of clear quartz and of minute angular grains of cryptocrystalline silica, cement calcareous. Not seen in place but scattered in slabs over a slope of	5
1. Niagara limestone, exposed a few rods down stream; described on page 344.....	8

No. 2. Farther to the west the same series outcrops on a bluff on the left bank of Quarter Section run, (southwest quarter of the southwest quarter of section 20, township 91, range XIII W.)

	FEET.
5. Slope of hillside strewn with gray boulders of weathering of facies of No. 6 of preceding section, but generally smooth surfaced.....	38
4. Concealed.....	10
3. Fragments of cherty sandstone, same as No. 2 of preceding section; scattered over slope.....	5
2. Niagara limestone, No. 1 of preceding section but with layers horizontal.....	6
1. Concealed to water's edge.....	2

Limestone of the Lower Davenport is also seen on Baskin run where four feet are exposed four feet above the bed of the creek. (Southwest quarter of the northwest quarter of section 28, township 91, range XIII W.)

No. 3. Section at Janesville on left bank of Cedar river.

2. Limestone, fossiliferous, Cedar Valley stage.
1. Breccia, matrix a soft yellow limestone in which the fragments are set without apposition, orientation or arrangement, fragments sharp-edged, showing no signs of water-wear, usually small, those exceeding an inch in diameter being rare, and many but from one to three millimeters in

diameter; fragments mostly of a hard, dense, drab limestone of finest grain, surfaces often crackled, laminated, but laminae thoroughly coherent. Other fragments of a very different lithological type occur. These are composed of a buff earthy limestone similar to the matrix. Some of these are so arenaceous with sharp sand of chert and rounded grains of clear quartz as to deserve the name of sandstone. These latter are practically identical with the cherty sandstone of the preceding sections. (p. 340).

In places the breccia has weathered to a yellow calcareous clay with residual masses of dingy limestone highly vesicular from the removal by solution of the small angular limestone fragments; total exposure to water's edge. 14 FEET

The above section is not particularly well exposed, and is made out in part from bowlders of weathering, which seem to represent the rock ledge of their horizon. No. 2 is exposed only some rods above the mill dam; No. 1, both there and immediately below the dam.

Up the valley from Janesville there are several exposures of Devonian limestone along the river's banks in section 26, township 91, range XIV W., but all are of the Cedar Valley stage.

The Wapsipinicon stage recurs along the Cedar river north of the mouth of Quarter Section run, in the southwest quarter of the southeast quarter of section 18, township 91, range XIII W. The lowest bed here seen is a ledge five feet thick outcropping along the river at the water's edge and resembles lithologically in some respects Nos. 3, 5 and 6 of section No. 1, page 348. It lies in irregular, rough-surfaced layers, eight and twelve inches thick, composed of coherent laminae, some hard and dense alternating with others of lighter color and either originally vesicular or weathered to this condition. These laminae are irregular, undulating, and in places broken, giving here to the weathered rock a finely fragmental appearance.

A few rods north of this ledge, and apparently succeeding it vertically, is a breccia of the type of that at Janesville, outcropping at about eight feet above the river. A few rods south of the ledge first mentioned and twenty-five feet above water level outcrops a breccia composed of close-set drab fragments of the Lower Davenport type imbedded in a sparse matrix of similar color. This breccia is wholly of the second phase of the Fayette breccia as the author has defined it, while the Janesville

type corresponds with the first phase.* Breccia of the second phase was found also two and one-half miles up river from these exposures (northwest quarter of northeast quarter of section 12, township 91, range XIV W.), below the quarry of the Cedar River Stone Co. Here a ledge about five feet thick outcrops three feet above water level, the breccia being composed of small fragments of hard dense brittle lithographic limestone, drab in color but weathering to lighter gray, set in a gray matrix. In places the long laminated fragments retain an approximate parallelism though detached and flexed fragments were also noted.

North of Waverly the breccia was not recognized, nor is it known to occur in Black Hawk county on the Cedar river. The outcrop of these beds of the Wapsipinicon and that of the Niagara in southern Bremer county is therefore due to an upwarp whose summit seems to lie in the southeastern sections of Washington and the adjacent northeastern sections of Jackson townships.

Comparing these sections of the Wapsipinicon stage in Bremer county with those of the counties along the southeastern outcrop of the Iowa Devonian, where the terrane is thicker and its subdivisions more clearly marked, we note first the strong resemblance of the cherty sandstone which rests immediately on the Niagara of the Limekiln section on p. 344, and that of sections 1 and 2 (p. 348) and the cherty fragments of the Janesville breccia to the cherty and arenaceous beds of the Independence as seen at Kenwood and many other localities. Assuming that these cherty beds in Bremer county are the equivalent of the Independence, all the higher beds of the Wapsipinicon fall into the Lower Davenport substage. If, however, the cherty sandstone in southern Bremer derived its cherts from the Niagara upon which it rests as a basal conglomerate, the above correlation can not be safely made, since the cherts of the Independence seem in all cases to be derived from its own cherty nodules.

The Wapsipinicon limestones of the county are characterized by the slowness of their magnesian content, as are the

*Iowa Geological Survey. vol. 4, p. 158, Des Moines, 1895.

Wapsipinicon limestones of the Otis and Lower Davenport sub-stages in other areas. This is shown by their very ready and brisk effervescence in cold dilute HCl, and still more satisfactorily by the following analysis of No. 6, of section 1, page 348.

Si O ₂71
Fe ₂ O ₃ and }46
Al ₂ O ₃ .. }	
Ca C O ₃	96.57
Mg C O ₃	1.80
H ₂ O51
	<hr/> 100.05

Three wells in sections 20 and 21 of Lafayette township pierced the Independence shale in what appears to be its facies at Independence, if we may judge from the log of the drillers alone.

Well of B. Bennett, (southeast quarter of the southwest quarter of section 20, township 92, range XIV W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
5. Drift, yellow clay.....	10	10
4. Blue clay.....	60	70
3. Limestone.....	44	114
2. Gray shale, Independence.....	10	124
1. Limestone.....	14	138

Well of Wm. M. Colton, (southeast quarter of the northeast quarter of section 20, township 92, range XIV W.).

	THICKNESS IN FEET.	DEPTH IN FEET
4. Drift	20	20
3. Limestone	30	50
2. Shale, black, Independence.....	15	65
1. Limestone.....	27	92

Well of E. Chase, (northwest quarter of the southwest quarter of section 21, township 92, range XIV W.).

	THICKNESS IN FEET	DEPTH IN FEET.
4. Drift.....	30	30
3. Limestone.....	50	50
2. Limestone and shale, several beds of shale four and five feet thick, Independence.....	40	120
1. Limestone.....	10	130

CEDAR VALLEY STAGE.

The limestones of the Cedar Valley stage of the Devonian comprise a number of varieties, some of which are widely separated. Soft, earthy, granular, buff limestones with geodic

cavities are perhaps most common. There are also exceedingly tough granular limestones, soft friable dolomites and dolomites of harder texture. The beds contain considerable magnesia, and are distinguished from the Wapsipinicon limestones which underlie them, by this feature as well as by their higher argillaceous content, by their coarser grain, and by the absence of brecciation.

Still more clearly are they demarked by their fossils. The assemblage of fossils characteristic of the highest Wapsipinicon substage has not been observed in Bremer county; the lowest fossiliferous beds observed carry the fossils associated with *Spirifer pennatus* at the Independence quarries and elsewhere.

SECTIONS OF THE CEDAR VALLEY STAGE.

We may consider first the beds exposed at Waverly, since these give a considerable vertical range, and are well seen in the numerous quarries opened in the vicinity of the town.

The lowest rocks here seen are those of the pit in process of excavation in 1905 for the City Power Plant at the foot of the dam on the left bank of the river, at a level of about eight feet below the water level below the dam. The normal type of this rock is a hard, ringing, yellow limestone containing many fossils. Cores of the stone are in places bluish, and considerable is much weathered and decayed, leaving perfect fossils easily disengaged from the whitish, clayey, rotten stone. *Atrypa aspera occidentalis*, of the coarse-ribbed type is very common, as are the large form of *Atrypa reticularis* and *Spirifer pennatus*. *Orthis iowensis* is not rare and with it occurs the variant of *O. Macfarlanei*. *Cyrtina hamiltonensis* and *Productella subalata* were also collected here. The horizon is clearly that of the *Spirifer pennatus* beds at Independence.

Several quarries have been worked for many years in the north part of Waverly along the left bank of the Cedar river. The following section taken at the quarries of A. S. Mores is typical.

Section No. 1. Mores' quarry, Waverly.

	FEET.
3. Limestone, yellow, fine grained, non-fossiliferous so far as observed, heavily bedded, crossed with close diagonal joints containing numerous geodic cavities up to six inches in diameter lined with dog-tooth spar, and concretionary balls marked with reddish concentric ferruginous stains.....	10

FEET.

2. Limestone, yellow, argillaceous. weathering above to calcareous plates one-half inch and upwards in thickness; below more massive, weathering to irregular chipstone, geodiferous, sparingly fossiliferous, only a small *Atrypa reticularis*, and *A. aspera occidentalis*, and a *Stropheodonta plicata* being noted, besides some unidentified fragments of fish remains..... 8
1. Limestone, yellow, hard, tough, layers up to four feet thick, fossiliferous, in places a coquina, fossils difficult to disengage, among them *Spirifer pennatus*, *Orthis iowensis*, *O. macfarlanei*, *Gypidula comis*, *Productella subalata*, *Atrypa reticularis* and *A. aspera occidentalis*, to flood plain of river..... 10

Section No. 2. G. W. Beebe's quarry.

This quarry had recently been opened at the time of the survey. Though not developed sufficiently for a satisfactory section, it was seen that the rock is identical with No. 2 of Mores quarry. It contains a few flint nodules, besides calc-spar geodes up to eight inches in diameter.

North of Beebe's quarry, which is just outside the corporation limit, are a number of other quarries opened many years ago along the bluffs skirting the river. The following is a generalized section of these quarries:

Section No. 3—Old Quarries North of Waverly.

FEET.

5. Limestone, light yellow, fine grained, obliquely jointed, the master joints running north and south, bedding planes fairly regular and even, lower layers about one foot thick, upper portion weathers to layers of about four inches, geodes common, some a foot in diameter; fossils rare, *Atrypa reticularis*, *A. aspera occidentalis*, *Orthis iowensis*, and a *Productus* the only ones noted. Especially toward the summit of these beds crevices and seams of the rock are lined and filled with calcite (calcium carbonate) and with barite (barium sulphate). These chemical deposits are particularly heavy in places where the rock has been disturbed and fractured. On the sides of enlarged joints and on dislocated masses are found selvages up to a foot wide of interlocking calcite crystals, yellowish brown in color and with a strong odor of petroleum when struck with the hammer. Upon the calcite rests the barite as an inner and later deposit forming often vesicular masses up to one foot thick. On the other hand, geodes occur with a thin lining layer of barite covered with inward pointing crystals of calcite (dog-tooth spar)..... 24
4. Concealed..... 4

	FEET.
3. Limestone, gray or bluish gray, weathered in places to buff, tough, hard, in heavy layers, geodiferous, in places sparingly fossiliferous, in places a coquina, irregular and discontinuous seams filled with calcite, fossils observed, <i>Atrypa reticularis</i> , <i>A. aspera occidentalis</i> and <i>Spirifer pennatus</i>	8
2. Limestone, yellow, breaking into thin irregular laminae on weathering, highly fossiliferous with <i>Spirifer pennatus</i> , <i>Orthis inactarlanei</i> , <i>Atrypa reticularis</i> and <i>Spirifer bimestialis</i> . . .	2
1. Concealed to water's edge in mill pond.....	8

In the southeast part of Waverly adjacent to the tracks of the Chicago Great Western Railway, a quarry was opened in 1905 by Peter Fosselmann at the base of a hill and at the level of the flood plain of the Cedar river. Below about seven feet of spalls there are exposed some ten feet of disturbed limestone dipping southwest 13 degrees. The lower layers are massive, a coquina of gray tough limestone, containing *Orthis iowensis*, *Spirifer pennatus*, and *Atrypa reticularis*.

One of the more important of the Waverly quarries is that of G. R. Dean, situated in the southern part of town on the southwest side of the river. The face of the quarry is fifteen feet. Below a stripping of five feet of sand and sandy humus including also a few inches of geest on top of the rock, the stone is a hard, ringing limestone with sub-conchoidal fracture, dressing to face, and durable. A stone house adjacent to the quarry, built from its surface stone, thirty years ago, shows no signs of weathering either in the way of rock decay or of cracking and breaking of the stone under frost and temperature changes. It is from this quarry that the sills and caps of the high school building were taken. One course near the bottom of the quarry is two feet thick, but the layers run as a rule a foot and less in thickness.

Section No. 4—Nichol's Quarry, Waverly.

	FEET.
6. Soil, sandy.....	1½
5. Sand, brown, somewhat indurated	2
4. Geest, unctuous, fine, reddish and yellowish residual clay, mottled with grav where deoxidized, containing numerous residual fossils in silica, chiefly short fragments of the stems of <i>Diphyphyllum</i> , with <i>Favosites alpenensis</i> , and valves of <i>Pentamerella dubia</i>	1
3. Limestone, weathered to friable rotten stone and loose rock-meal, with cores of harder rock	1¼

- FEET.
2. Limestone, firm as a rule, but in places easily cut down with trowel, containing nodules of white chert..... 3
 1. Limestone, yellow, heavily bedded, in two layers; thin chert nodules occur along horizontal lines; widened joints and pipes filled with geest extend to the quarry floor..... 7

The cuts of the Chicago Great Western Railway, one-half mile east of the station and beyond, show also deeply decayed limestone due probably largely to preglacial weathering. Beneath a sandy humus and brown geest containing flints and some fossils, the limestone is disintegrated to meal for a distance of four feet from the surface. Underlying this is twenty-two feet of soft, buff, massive limestone, whose layers reach seven feet in thickness, with numerous geodes. The dolomitic nature of this stone is indicated in the following analysis:

Fe ₂ O ₃	1.21
Si O ₂	9.07
Al ₂ O ₃	2.16
Ca CO ₃	34.99
Mg CO ₃	51.64
H ₂ O combined.....	.64
H ₂ O uncombined.....	.29
	100.00

The cuts near the quarry of the Cedar River Stone Co. show a firm, hard limestone with the following fossils: *Atrypa reticularis*, *A. aspera occidentalis*, *Spirifer pennatus*, *Stropheodonta demissa*, with *Stromatopora*, *Favosites*, *Cladopora* and *Aulacophyllum* as corals.

Higher horizons than those of the Waverly quarries occur near town. Thus a road cutting near the Harlington cemetery displays the horizon of the *Acervularia profunda* life zone, which, as Calvin has shown in a number of counties, overlies the *Spirifer pennatus* beds. Along with this characteristic coral occur specimens of *Favosites* and *Aulacophyllum* too imperfectly preserved for specific identification.

The same horizon of the *Acervularia profunda* beds was found northeast of Waverly (southeast quarter of the northwest quarter of section 36, township 93, range XIV W.). Here the occurrence was noted also of two species of *Favosites*, *Stromatopora*, *Diphyphyllum*, and a specimen referred with some uncertainty to *Alveolites minima* Davis.

FISH REMAINS FROM WAVERLY.

The quarries north of Waverly have long been known for the well preserved remains of Devonian fishes which they contain. As early as 1875 an item published in a local paper, relating the finding of a *bona fide* fish at Waverly, attracted the writer's attention, and visiting the town he obtained the loan of the interesting object,—not indeed a fish, as its appearance, half imbedded in the stony matrix, suggested, but an immense fish tooth, identified by Newberry, to whom the writer carried it, as belonging to *Ptychtodus calceolus* N. & W. At the time the writer also made quite a collection of fish remains of the Waverly quarries, a collection whose value was greatly increased by generous contributions by Mr. Norris, a veteran quarryman of the town. All these were safely placed in the museum of Cornell college. It is to be regretted that further than the fact that they were obtained from the quarries north of town little is known of the exact horizons of the remains. It is wholly probable however that they belong for the most part to beds 2 and 3 of section 1, and bed 5 of section 3. Through the kindness and skill of Dr. C. R. Eastman of Harvard University, who has made a thorough study of the Devonian fishes of Iowa for the Survey, the Waverly remains have been identified as follows:

Holoptychius, scales, very similar to *H. Flemingi* Ag.

Dinichthys pustulosus Eastman, palato-pterygoid dental plate, or "shear tooth".

Onychodus sp., presymphysial tooth.

Dipnoan tooth, resembling *Synthelodus* from State Quarry beds near Iowa City.

Ptychtodus calceolus N. and W., tritons.

Ptychtodus compressus Eastman, dental plate.

Rhynchodus occidentalis Newberry, dental plate.

Dr. Eastman reports also from the same horizon fin spines of *Heteracanthus politus* and tritons and dental plates of a large species of *Ptychtodus* probably *P. ferox* Eastman, from fossils collected at an early date by St. John.

In explanation of these rather formidable names it may be said of the fishes which thus are known to have inhabited the shallow sea whose limy oozes hardened to the rocks of the Waverly quarries, that *Holoptychius* was a "fringe-finned ganoid" whose body was covered with small overlapping bony enameled scales, and whose paired fins were lobed, with a scaly

axis whose structure suggests that of the limbs of the higher vertebrates. *Dinichthys* was a ferocious monster eighteen feet long, equipped with powerful jaws and protected by heavy armor plate. *Onychodus*, covered with bony scales, reached a length in some of the species of fifteen feet. *Synthetodus* was a genus of lung fish, among whose modern representatives is the *Ceratodus* of Australia. *Ptychodus*, *Rhyncodus* and *Heteracanthus* were sharks.

It is to be hoped that as the quarries are developed local collectors will take special pains to secure the fish remains of the Waverly limestones, and to preserve them for the service of science.

SECTIONS OF THE CEDAR VALLEY STAGE NORTH OF WAVERLY.

Limestones of this stage outcrop at numerous points on both sides of the river from Waverly north to the county line.

Unfossiliferous limestone of the type of the upper beds of the Waverly quarries is seen along the north-south road in the north half of section 26 and the south half of section 23 of Lafayette township.

In the southeast quarter of the northwest quarter of section 22 of the same township a small quarry has been opened in the side of a rocky hill. In the brown and buff thin-layered limestones here exposed no fossils were seen except a rare *Atrypa*.

In the same township the following section is exposed in the road.

Section No. 5. (Southwest quarter of the southeast quarter of section 16, township 92, range XIV W.):

	FEET.
3. Limestone, light brown, weathering to drab, hard, ringing, unfossiliferous, laminated to plates one half inch thick.....	8
2. Magnesian limestone, soft, buff, with casts of large <i>Atrypa reticularis</i>	10
1. Unexposed to flood plain of river	5

Unfossiliferous beds having the general appearance of the upper beds at Waverly occur in the northeast quarter of the northwest quarter of section 21 and in the northwest quarter of the southeast quarter of section 9 of Lafayette township.

North of Plainfield in the extreme northwestern section of Polk township are several interesting exposures. On the right bank of the Cedar river (northwest quarter of the northeast quarter of section 7, township 93, range XIV W.), there have been quarried at water level seven feet of non-fossiliferous,

compact, buff, magnesian limestone, in layers from six to ten inches thick, containing small balls and irregular nodules, some with concentric ferruginous stains, and often fantastically aggregated. The stone becomes thin-layered and argillaceous for a few inches from the top. The dwelling house on this farm is built of stone from this quarry, and its excellent preservation shows the durable nature of the stone.

On the left bank of the river in section 8 of the same township (southwest quarter of the southwest quarter of section 8, township 93, range XIV W.) for five or ten feet above the flood plain of the Cedar, fragments of a fine grained slate-colored and in part brecciated limestone strew the hillside, and are apparently derived from a concealed ledge. These may represent the lithographic beds found well up in the Cedar Valley section by Calvin in Mitchell county. They resemble closely the Wapsipinicon, however, and it is not impossible that we have here a local upwarp which has brought the Lower Davenport to the surface. Somewhat in favor of the latter hypothesis are the beds which appear farther up stream. Here an old quarry (southwest quarter of the northwest quarter of section 8, township 93, range XIV W.), now so filled as to show no clear face, gives indication of a soft buff magnesian limestone or dolomite, and this appears clearly in an old lime kiln in the quarry in the northwest quarter of the northwest quarter of the same section. The numerous casts of fossils found here indicate according to Calvin a horizon just a little above the quarry beds at Independence. As these are near the base of the Cedar Valley stage, it is not difficult to believe that the Wapsipinicon may outcrop a few rods further south. The fossils of the dolomite are *Atrypa reticularis*, (very numerous), *Athyris vittata*, and a species of *Paracyclas*. The following analysis is of the rock quarried for lime in section 8 of Polk township.

Si O ₂	3 28
Fe ₂ O ₃	1.61
Al ₂ O ₃51
CaCO ₃	55 23
MgCO ₃	39.03
H ₂ O combined23
H ₂ O hygroscopic16
	<hr/>
	100.05

SECTIONS OF THE CEDAR VALLEY STAGE ABOUT FREDERIKA.

East of the western tier of townships crossed by the Cedar river, the rock formations of Bremer county are everywhere buried deep beneath the drift excepting in the vicinity of Frederika. In and about the town are a number of outcrops of the Devonian, and little more than four miles to the south occurs the anomalous outcrop of the Niagara already described (page 343). The most important of the quarries about Frederika is the following:

No. 6. Section of Quarry of James Brodie, Frederika.

This quarry on the bank of the Cedar river has a face of eighteen feet, the floor of the quarry standing three feet above water in the mill pond. The stripping of drift is very slight. The upper surface of the rock is fairly even although here and



Fig 41—Brodie's Quarry, Frederika.

there occur drift lined and geest filled pockets a foot or more in depth. The geest resting on the rock is from one to four inches thick and contains numbers of poorly preserved siliceous fossils, *Accervularia profunda* being the most important as it denotes a definite horizon.

	FEET.
3. Limestone, yellow, shattered by the weather to coarse rhombic chipstone.....	9
2. Limestone, hard, yellow, magnesian, in heavy courses up to three feet thick, not laminated; bedding planes quite even and regular; geodes up to six and eight inches in diameter not uncommon.....	6
1. Limestone, bluish weathering to buff; hard, ringing, sub-conchoidal fracture, in two layers, the lower being one foot and the upper two feet thick. Sparingly fossiliferous with <i>Gypidula comis</i> and other species.....	3

The rocks of the quarry have a slight but perceptible dip to the south. Master joints run north 8 degrees east. The rock is strongly magnesian carrying more than 25 per cent of magnesium carbonate.

Several small quarries have been opened near Frederika, as in the northwest quarter of the northeast quarter of section 13, township 93, range XIII W.; in the southwest quarter of the northwest quarter and in the southeast quarter of the southwest quarter of section 18, township 93, range XII W., but their pits are now generally so filled as to make it difficult to get good sections.

The last two sections mentioned are situated on the estate of C. L. Rima. At the first named of these two are exposed six feet of a hard, fine grained rock whose layers run to six inches in thickness and are marked by some chert and varicolored flint concretions arranged linearly. These layers and the rock exposed in the road near by carry a gregarious *Chonetes* of an undescribed species, *Productella subalata*, and *Favosites*. The second of the two named quarries has been abandoned, and now but six feet are exposed of a buff limestone in six inch layers carrying *Atrypa reticularis* to the exclusion, so far as observed, of other species.

Geest.

For countless ages after the Devonian seas retired from our area a land surface was exposed to the disintegrating and dissolving action of the weather. The rock surface was thus everywhere roughened. Wherever roots pried apart the blocks of limestone, or where by any cause a way was made for the downward passage of water, there ground water, charged with carbon dioxide and the humus acids, dissolved the solid rock and

opened pipes and chimneys, pits and cavities of various shapes and dimensions. Weathering also produced a residual clay, called geest, which can be referred to no specific geological age, although doubtless largely Tertiary, so far as it is not interglacial.

Slight though it may be, there is in all limestone an insoluble residue of fine quartzose, argillaceous and ferruginous matter. When the carbonates of lime and of magnesia are dissolved and carried away to the sea something of these insoluble ingredients of the limestone remains as fine unctuous gritless clay. The iron compounds of the decaying rock are at the same time oxidized, and when concentrated in the residue of clay, give to it its deep shade of red or brown. In places these products of preglacial and interglacial rock decay have wholly been removed by glacial scour, but for the most part the rock surface and the geest upon it seem to remain much as they were at the beginning of the last ice invasion. Nichol's quarry and the various railway cuts about Waverly offer excellent examples of this ancient formation.

THE PLEISTOCENE SYSTEM.

PRE-KANSAN STAGE.

The ground moraine of the Jerseyan, or pre-Kansan, the earliest of the great ice sheets which invaded Iowa in Pleistocene times, is buried out of sight in Bremer county by later glacial deposits. In counties of southern Iowa where it is exposed by erosion and its physical characteristics have been noted it has been described as a dark blue or almost black stony clay, or till, fine-grained and friable, not jointed to any marked degree and rich in pebbles of granite. These physical characteristics, due to the lithological materials which compose the till and their relative proportions, obviously depend on the abrasion of the rocks over which the ice sheet passed. This is especially true of the ground moraine of the earliest ice sheet, an ice sheet which everywhere moved over the country rock and not over the ground moraines of previous ice sheets. The Jerseyan

drift may be expected therefore to differ widely in regions so far apart as southwestern and northeastern Iowa where the country rocks of the one are of the Cretaceous and Coal Measures and of the other the systems of the earlier Paleozoic.

In well drillings and well records the Jerseyan can hardly be told from the unweathered Kansan till, which normally succeeds it, unless they are separated by the silts, soils, or vegetal deposits of the intervening interglacial epoch, the Aftonian. A few miles east of our area, in a cut of the Chicago Great Western Railway near Oelwein, the Jerseyan, ten feet thick, is overlain by such an old soil and peat bed four feet thick with its ancient moss perfectly preserved.

The few well sections where the Aftonian and Jerseyan seem to be indicated are the following:

Well of C. F. Schwem, Frederika township, (northwest quarter of the northwest quarter of section 32, township 93, range XII W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
Yellow till	10	10
Blue till, Kansan	24	34
Sand, Aftonian?	16	50
Blue till, Jerseyan?	10	60
Rock	27	87

Well of C. E. Falcher, Leroy township, (northwest quarter of the northeast quarter of section 22, township 93, range XII W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
Yellow till	12	12
Blue till, Kansan	63	75
Old soil, ill smelling, Aftonian?	20	95
Blue till, Jerseyan?	41	136
Rock	10	146

Well of Aug. Schmidt, Leroy township, (northeast quarter of the northwest quarter of section 18, township 93, range XI W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
Drift clays	135	135
Quicksand, Aftonian?	60	195
Blue till, Jerseyan?	25	220
Shale, Maquoketa	2	222

Well of M. Farrington, Jefferson township, (northeast quarter of the southeast quarter of section 35, township 91, range XIII W.).

	THICKNESS IN FEET.	DEPTH IN FEET.
Yellow till and gravel, Kansan and Aftonian?.....	30	30
Sand at		30
Blue till, Jerseyan? to		110
Rock.....	12	122

Well of Fred Schnoeder, Tripoli.

	THICKNESS IN FEET.	DEPTH IN FEET.
Yellow till.....	8	8
Blue till	62	70
Sand and gravel, Aftonian?.....	2	72
Blue till, Jerseyan?	6	78
Gravel.....	1	79
Rock	1	80

From the very few wells in which sand and gravel or old soils have been found intercalated with glacial clays, we may infer that the Aftonian formation is very scantily represented in the county. Even in several of these wells just listed the sands may be local accumulations of stratified Kansan drift.

Nearly all the wells of the county are reported to have found continuous till from the surface of the ground to rock or to the thin sands and gravels often found resting directly upon rock, and the only division in the till noted by the drillers, that of color, may be referred to the weathering to yellow of the blue till of the Kansan.

KANSAN STAGE.

KANSAN DRIFT.

The Kansan drift extends over nearly the whole of Bremer county. Even on the areas mapped as belonging to the later drift sheet, the Iowan, the Kansan is to be found a short distance beneath the surface and is exposed in road and railway cuts and other excavations and along the banks of eroding streams. In the areas referred on the map to the Kansan, it is more deeply buried and for the most part is concealed by loess.

In its normal unweathered aspect the Kansan till is a dense stony clay, jointed, and in color bluish drab. It effervesces freely in acid because of the considerable amount of limestone meal and flour which it contains, ground from the calcareous

rocks which it has overridden. But so deeply has it weathered since the remote epoch of its deposition as the ground moraine of a continental glacier that one rarely finds an exposure deep enough to bring to light its normal unweathered aspect. The common exposures of Kansan till in Bremer county are of thoroughly weathered till. Percolating water has taken into solution the lime carbonate and the magnesium carbonate and carried them down to gather not infrequently in small hollow lime balls. The roots of plants and trees have also consumed these carbonates so that the Kansan till, for a number of feet from the surface, has been well leached of all easily soluble ingredients. Frost and the processes of chemical weathering have so altered the texture of the till that it readily crumbles on the surface to small particles. Still more conspicuous and deeper are the changes wrought by the alteration of the iron compounds of the drift. To a depth usually greater than the section opens for observation the stony clay has been changed in color by the oxidation of its iron compounds. From bright yellow or even a reddish brown at the surface it changes to paler shades until it passes into gray and bluish gray as the unweathered deeper portion of the till is reached. In the weathered zone pebbles of the less resistant rocks, such as the coarser granites, are often thoroughly rotten. The upper limit of the till is often marked by a washed surface on which pebbles are specially abundant, and perhaps correlated with this is the red loam, a reddish clay lying directly in places on the Kansan drift beneath the loess, from which it is distinguished not only by its color but also by its more clayey nature.

Sections of Kansan Drift.

Section in cut of Chicago Great Western Railway, two-thirds of a mile west of Denver Junction.

	FEET.
4. Humus graduating into No. 3.....	2
3. Yellow, sandy clay.....	1
2. Till, yellow, pronounced line of pebble accumulation on upper surface, many of the pebbles being decayed, no ferretto, or zone of ferruginous accumulation, on upper surface; pebbles of till mostly fresh, but many rotted pebbles of granite; pebbles four inches and upwards not rare, with some cobbles and boulders up to three feet in diameter. Till non-calcareous to four feet from its upper surface, graduating into No. 1	8

FEET.

1. Till, blue, dense and tough, breaking into flakes of one inch or less, with many small pebbles. 3

Section by road at pahoid hill, southwest of Waverly.
(Southeast quarter of the southwest quarter of section 17, township 91, range XIII W.)

FEET.

3. Loess, typical floury, yellow, with minute ramifying calcareous tubules. 7
2. Red loam, laminated, loessial in texture, with an occasional small pebble and rare small lime concretion. 1½
1. Till, bluish gray mottled with reddish, predominantly clayey, pebbles small, greenstones abundant, chert and limestones few, many calcareous concretions an inch or less in diameter, round and hollow, most numerous about eight inches from the surface but occur to base. 3

Topography of the Kansan Drift.

The Kansan drift sheet makes its presence felt everywhere in the county as an important or decisive factor in the topography. In places it is more or less masked by the Iowan drift and by the loess, but perhaps in no instance can the relief of this heavy drift sheet be neglected in accounting for the topography of the present. We may recall here the fact that where the later drift sheets are wanting as in southeastern Iowa the Kansan surface presents several distinct topographic types. To mention one of the most important, the divides are tabular areas of considerable breadth, and of a remarkable flatness as though leveled in a body of static water. Such are the level prairies which form the divides between the Des Moines, the Skunk and the Iowa rivers, from Jasper, Poweshiek and Iowa counties southeast to the border of the Illinoian drift near the Mississippi river, to cite examples as near as possible to Bremer county. When the Iowan ice invaded northeast Iowa, these divides, we may infer, were somewhat broader and less worn than now. Nor have we any reason to believe that at this remote time the erosion cycle was more advanced in northeastern Iowa than in the southeastern portion of the state. Indeed, if the drainage of the long interglacial epochs which followed the retreat of the Kansan ice pursued in a general way the courses of our present rivers, the northern area about the headwaters of the trunk streams should have been considerably less dissected than were the areas adjacent to the baselevels of their graded lower courses. We may

infer that at the epoch of the Iowan ice the divides of Bremer county, left by the long erosion which intervened between the Kansan and the Iowan epochs, were broader and less scored than those of southeastern Iowa are today. Whether the Kansan drift in northeastern Iowa was deposited with the monotonously level surface which still is left over much of southern Iowa is another question and one difficult to answer, since the northern Kansan is blanketed with heavy loess or veneered by the Iowan drift. Certainly there is no evidence that the Kansan of our county ever exhibited the marked reliefs of the hummocky moraines of the Wisconsin drift. But any fainter inequalities of surface which may once have marked it could not be expected to afford any evidence of their existence when covered by the deposits from a later, overriding ice sheet. We are at liberty, then, to believe that before the Iowan ice invasion, belts of upland little scored by running water and of very faint relief occupied the wide interstream areas between the rivers of our county. Such areas when covered with the veneer of the Iowan drift result in the gently undulating plains of Douglas, Warren, Fremont, Maxfield and Sumner townships. These plains are interpreted as due to the even surface of the underlying Kansan drift and not to the leveling effect of the Iowan drift in filling any considerable inequalities in the pre-Iowan surface.

A second type is that of the well dissected Kansan drift covered and partly masked by Iowan drift. The narrow interstream area between the Cedar and the Shell Rock rivers seems to have attained topographic maturity before the Iowan ice invasion. This narrow upland skirts the broad flood plain on the west with a sinuous line of projecting hills and deep and broad reentrants. West of Plainfield the hills rise sixty feet and more above the flood plain; west of Waverly they appear still higher. The wide, flat-floored and aggraded valleys which penetrate this upland tell of long continued subaerial erosion made effective by nearness to the main erosion levels of the two trunk streams and they and the undulating crest lines, together with the occasional boulders seen even on the hill tops,

show that here a well dissected Kansan upland has been overridden by a later ice sheet, its valleys partially filled and its summits heaped with drift.

Polk township has been similarly trenched by ravines tributary to the Cedar and to the three creeks which empty into it from the east. Frederika and Leroy townships have been largely reduced to rolling hills by storm waters seeking the Wapsipinicon, the East Wapsipinicon and Leroy creek, and narrow belts of well dissected upland border all the principal valleys. In these areas long and gentle slopes lead down from the upland; the subordinate water ways are all well opened, but show no recent trenching. Iowan boulders and Iowan drift lie on these hillsides and even follow out upon the wide ancient flood plains of the Wapsipinicon and Cedar. Evidently the erosion of the ramifying valleys with which the upland is thus dissected near the major streams is older than the Iowan ice invasion by which they have been partly filled with drift. The immediate streamways have been aggraded notably by outwash. About the heads of the ravines there is a perceptible departure from the normal type as if the valley heads had been somewhat filled subsequent to their carving. The crests of the rolling Kansan-Iowan hills are uneven and the sky line undulating.

Another topographic type is that of the deeply dissected and loess covered Kansan. This common and oft described type occurs in long parallel belts of hilly upland scores of miles in length in the counties lying to the south and east, but in Bremer it occurs in but two isolated areas, one on the left bank of the Cedar at Waverly and one in northeastern Jackson township extending thence to Denver. The latter area of six or seven square miles we will first describe under the name of the

Denver Loess-Kansan Area.—This region touches the Cedar at the sharp bend where it turns from its normal course to join the Shell Rock and continuing the general trend of the river is bounded on the south by Quarter Section run in its anomalous course already mentioned. On the east it extends to Denver and on the northeast its limits are indicated by the diagonal Denver-Waverly road which skirts the bases of its hills. In

contrast with the surrounding prairie this region is heavily wooded with hardwood trees, among which the white oak, the sugar maple and the hickory are most noticeable. It has long been known as the Big Woods.

Any of the roads leading through the Big Woods crosses a succession of deep, steep-sided valleys parted by narrow ridges with gently undulating crests which rise to about one common level. Steep, high and detached as seems the Briden hill, for example, (southeast quarter of section 28, township 91, range XIII W.) one standing on the summit sees the even crests of the hills to the east rise to an accordant level giving an even sky-line. A gigantic ruler laid across the area would touch the tops of practically all the major ridges with the exception of certain high hills at the extreme west. If the initial surface could be restored by filling the valleys with the material which has been washed out of them by running water, there would appear a nearly level upland plain.

The valleys which dissect the upland naturally differ in depth. The main streams have cut their channels to a depth of seventy-five feet and more below the upland level. Their short laterals draining southwest into Quarter Section run are somewhat less deep and the youngest and outmost twigs of this arborescent drainage system, the little gullies which trench the steep sides of the ravines, head on the summits of the divides.

Everywhere the area is heavily blanketed with loess. Just outside the area streams and roads give sections of Kansan till and rock, but within it the yellow roads everywhere climb the hills without disclosing the customary red ferretto of the underlying Kansan; the stream ways which begin within the area are clean of pebbles either of the country rock or of northern drift, and where they sap the valley sides show fresh scarps cut in loess to the water's edge.

To the west the upland narrows and culminates in a high ridge known in the neighborhood as Booth's hill, (northwest quarter of section 20, township 91, range XIII W.). The broad rounded summit rises by barometer 125 feet above the creek at its base and is distinctly higher than the upland to the east. The trend of the ridge is west-northwest by east-southeast, and

is continued to the northwest by high short axised ridges set *en echelon* and parted by high cols. The Cedar river cleaves its way into the midst of these hills in a deep valley whose lower slopes are cut in rock. A narrow ridge of the same west-northwest trend is thus left on the right bank of the river. Instead of continuing on the comparatively low ground of the Iowan plain, the Cedar here goes half a mile out of its way to plunge into the loess-Kansan upland. The depth of the loess on the upland has not been sounded since the well drillers naturally have not discriminated the yellow loess from the yellow weathered Kansan which underlies it. Judging from other areas of like nature in northeastern Iowa, the thickness of the loess here may well reach forty or fifty feet.

The view from Booth's hill is singularly impressive. None in the county is bounded by horizons more remote, and none is filled with objects of greater beauty, or of greater interest to the geologist. To the south the eye ranges far over the Iowan upland plain to discover on the horizon some of the higher towers of the Iowa State Normal School at Cedar Falls, about twelve miles distant. To the southwest, beyond a few wooded hills, lies the low Iowan plain from which rise the white church spires of Janesville. To the west, beyond the maze of high wooded hills of the immediate foreground, the eye catches glimpses of the dissected Iowan upland which forms the divide between the Cedar and Shell Rock. Looking northwest the vision is bounded by the great Waverly hills lifting their long sweeping curves against the sky. The middle distance is here filled with the Iowan plain, much dissected because of the older unefaced Kansan erosion, and also broken by detached boat-shaped hills called paha, too low to intercept the distant view. To the north and northeast the eye looks down the grassy slopes of the bold hill to a tiny pahoid ridge which lies at the base and rises upon its flank, ranges across an upland of Kansan facies strewn with boulders left by the Iowan ice and gashed with numerous sharp valleys, but surrounded by pahoid hills and ridges, and rests in the far distance on the level horizon line of the high Iowan plain. To the east the view is intercepted for the most part by heavy forests, but here and there clearings enable one

to catch glimpses of the even crests of the loess-Kansan upland.

At the time of the settlement of the county the dissected upland, with its paha hills, lying to the north was also covered with the heavy mesophytic forest of the Big Woods as far north, we are told, as the south line of sections 5 and 6 of township 91, range XIII W., while beyond this the smooth Iowan plain was prairie to the limits of the county and far beyond.

The loess-Kansan area at Waverly is much smaller than that west of Denver and is almost wholly comprised within the extended corporation limits. The high wooded hills of the First ward and those about that on which the city reservoir is built are included in this area. Their billowy crests, with little or no systematic arrangement, reach a height by barometer of 145 feet above the Cedar river. The loess lies thick upon them and its basal sections show the interstratified yellow sands characteristic of the loess when bordering the Iowan drift. These hills rest on a foundation or platform of rock which outcrops along the Cedar, but whether the rock rises to any greater height beneath them than on the surrounding Iowan plain is a matter on which no data were secured.

THE BUCHANAN GRAVELS.

Of those deposits of stratified and waterlaid drift associated with the melting of the Kansan ice sheet, Calvin has distinguished in adjacent counties two separate phases,—an upland phase of outwash upon the interstream areas consisting of sand and gravel so well rotted and rusted that an age far greater than that of the surrounding or overlying Iowan drift is indicated, and second, a valley phase of quartzose sand and gravel, the valley trains of the Kansan ice. As an example of the former we may cite a section shown on a road cutting north of Waverly, (southeast quarter of the southwest quarter of section 14, township 92, range XIV W.) on the top of a hill about seventy feet above the adjacent creek. Underneath a foot and a half of sandy humus there are exposed six feet of reddish brown gravel intermixed with sand and partially cemented. Pebbles are small, few reaching the diameter of an inch, and the granite pebbles are thoroughly decayed. Interbedded with the gravels is a lens eight feet long and two feet thick of brownish clayey till containing few pebbles.

A similar deposit occurs a mile northeast of Waverly, (southeast quarter of the northwest quarter of section 36, township 92, range XIV W.) on the slope of a hill. North of Plainfield an interesting exposure of gravel occurs about thirty feet above the tracks of the Illinois Central Railway (northwest quarter of the northeast quarter of section 18, township 93, range XIV W.). Here five feet of gravel are exposed in a road cutting, the upper three feet being the coarser. The pebbles are chiefly of Devonian limestone of the type of the Lower Davenport of the Wapsipinicon, or of the Lithographic beds of the Cedar Valley stage, a dense drab limestone, in part brecciated. Pebbles six inches in size are common. These gravels resemble the Buchanan in that they are rusted and the granite pebbles thoroughly decayed, but the limestone pebbles are entirely sound.

The quartzose gravels which occupy the wide valleys of the Cedar, the Wapsipinicon, Crane creek and other streams are undoubtedly the extensions of the valley trains which Calvin in other counties crossed by these rivers has referred to the melting of the Kansan ice.

IOWAN STAGE.

IOWAN DRIFT.

The wooded loess-covered Kansan areas which we have just described are surrounded like islands by the wide prairie of the Iowan drift sheet which covers all the remainder of the county, excepting the flood plains of the river valleys, and stretches far beyond the limits of the county in all directions. The Iowan drift is very thin, forming as a rule scarcely more than a veneer. Three types of the unstratified drift may be discriminated,—a prevailingly sandy, brownish till with abundant pebbles whose loose texture has allowed it to become well oxidized and leached, second, a light yellow, clayey till unleached of lime to within the grass roots, and third, large boulders superficial and in places apparently the only deposit of the ice.

An instance of the rather rarely recognized second type of Iowan drift was seen in a cut of the Chicago Great Western Railway east of Waverly (southeast quarter of the southwest quarter of section 8, township 91, range XIII W.).

- | | |
|---|-------|
| | FEET. |
| 3. Humus graduating into yellow sandy clay with rare pebbles | 2 |
| 2. Till, upper two feet yellow and non-calcareous, lower three feet gray and calcareous, pebbles fresh and mostly small, limestones under an inch abundant, till massive, neither jointed nor flaky, not continuous throughout cut, being seen chiefly on north side of cut and at top of the low hill | 5 |
| 1. Till, clayey, dense, tough, breaking into small rhombs, oxidized to base, but calcareous to the top where tested, pebbles of limestone not so numerous as in No. 2, cobbles of six inches not rare and some bowlderets a foot in diameter, pebbles generally fresh but some of gray granite rotten, observed | 11 |

Resting on the surface a few feet away lies a pink granite bowlder seven feet long and nearly as broad. No. 1 of this section is apparently Kansan whose decalcified upper surface has been rubbed off by the Iowan ice. No. 2 and the clay of No. 3 are referred to the local deposits of the Iowan.

The bowlders of the Iowan are scattered throughout the county and no special and local aggregations of them were noted, such as bowlder walls or bowlder belts. While a great variety of the igneous and metamorphic rocks are represented, the large majority of the larger bowlders are of granite and gneiss. Thus out of twenty-two large bowlders from four to six feet in diameter in a wall near Horton, twenty are granites. In eighty cords of bowlders which had been hauled in to Janesville from the adjacent prairie, and piled near the mill, it was easily seen that granites and gneisses were far in excess of all other kinds together, diorites and diabases being comparatively few, and schists still fewer. While the majority of these bowlders were firm and undecayed, yet a number of large macrocrystalline granite bowlders were much disintegrated. In this collection it was also noted that a number of the stones showed faceted and scored surfaces. Such must have been dragged by the ice as part of the ground moraine; they were not englacial or superglacial stones deposited on the melting of the ice as part of an englacial or superglacial drift.

Very large bowlders are by no means rare in the county. One seen in the northeast quarter of the northeast quarter of section 35, township 93, range XIV W., measures ten by twelve by twelve feet. That of figure 42 has as its horizontal diameters twelve and fourteen feet, and is ten feet high above ground. A bowlder

in section 1 of Douglas township northwest of Frederika, quadrate in shape, is twenty feet long, twelve feet wide, and eight feet high. A mile and a half southeast of Frederika another was measured whose diameters are twenty-two and fifteen feet and which is only four feet out of the ground. McGee mentions the monster two and one-half miles north of Sumner as the

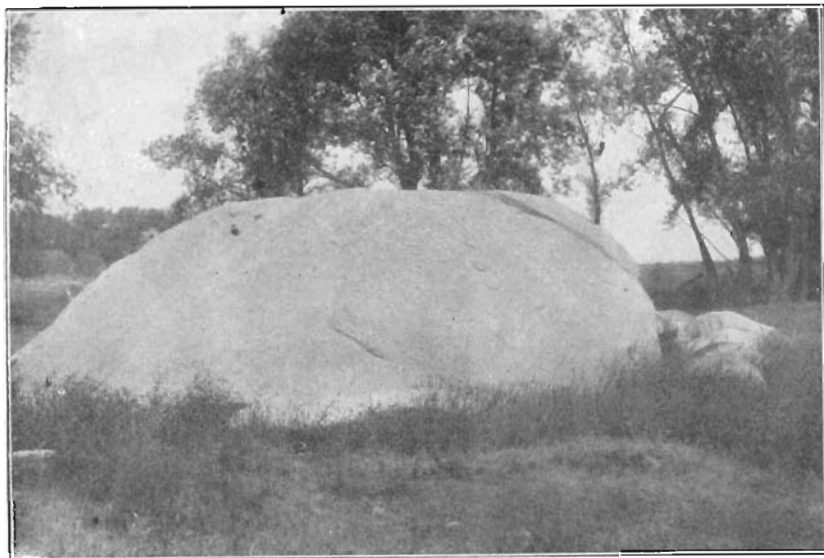


Fig. 42—Rounded Iowan boulder, east of Waverly.

largest seen in Northeastern Iowa. At the time of his measurement—in 1890—its diameters at the surface were twenty-five by forty feet and its height above the surface eleven feet. But enough of it had been quarried to form foundations for two or three houses and the larger portion appeared to be buried in the drift.

Boulders affect the lower ground, the swales and draws, and are less often seen upon the low crests of the gently undulating plain. Many of the stones are well rounded, as for example those of figure 43. This is the shape to which a homogeneous stone is dressed by the long action of the weather, but that this rounding has not occurred since the melting of the Iowan ice is indicated by the fact that many of the boulders of the drift are

*Pleistocene History of Northeastern Iowa, 11th Ann., Rept., U.S. Geological Survey, pt. 1, page 482.

angular although of the same lithological varieties as those well rounded. As a glacier facets instead of rounds when it affects at all the erratics which it carries, we must suppose either that the Iowan boulders were brought from some area not previously overridden by glacier ice, and that they are the product of immensely long preglacial weathering or that the interglacial epoch intervening between the Iowan and the

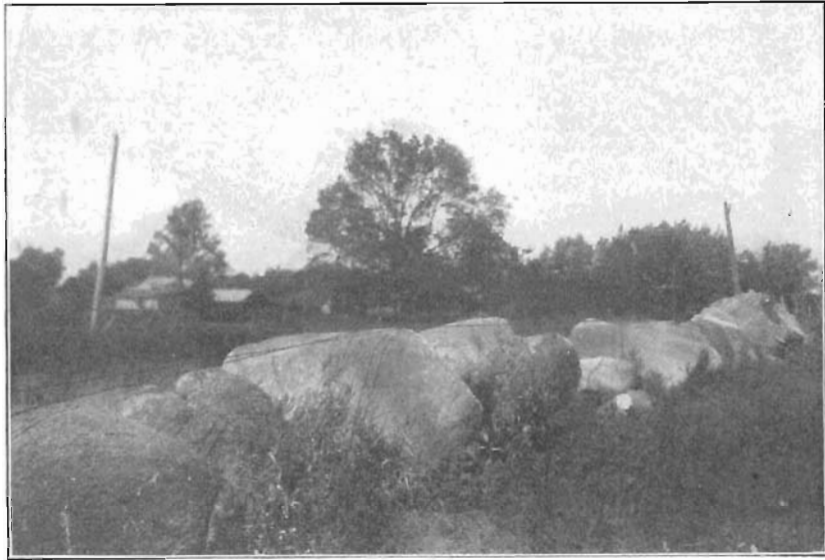


Fig. 43—Iowan boulders set as a fence, Horton.

previous glacial stage whose ice sheet overran the same gathering ground was long enough for boulders of weathering to develop on the rock surface glaciated by the earlier ice. The long time requisite in either case is suggested by the fact that the glaciated rock surfaces of our northern states and Canada are still comparatively fresh, notwithstanding the thousands of years which have elapsed since the final withdrawal of the Pleistocene glaciers.

The boulders of Bremer county, while by no means rare, do not seem by any means as plentiful as those of the areas nearer the eastern margin of the Iowan drift. In very few cases are they thick enough to seriously interfere with agriculture. The views of figures 44 and 45 are quite exceptional. In many

sloughs used for pasture only, bowlders have been left intact. Very many have been moved to the roadside to make way for the mower, the cost for limited areas thus cleared being in one case six dollars per acre.



Fig 44—A swale on the Iowan Drift.

Throughout the county one may see the uses to which farmers have put these excellent building stones quarried by glacier plucking in northern Minnesota and Wisconsin and transported and delivered free of charge at their very doors. Although bowlders are everywhere used for foundations of the farm-houses, barns and granaries, and for abutments of the bridges of the minor streams, the supply is still far from being exhausted.

As unequiauxed bowlders may be expected to take the position of least resistance in the ice and like logs of wood in a stream to be carried for the most part end on and thus set down, their orientation is an index of the line of motion of the ice sheet. The observations of the orientation of the large bowlders of the county are not complete enough to be anything more than merely suggestive, as that of but twenty-three was taken. Of these eight bore west-east, and five north-south; five bore north-west-southeast and as many northeast-southwest.

LOESS.

The fine silico-argillaceous silt known as loess has already been mentioned as blanketing the areas where the Kansan drift is not covered by a later drift sheet. It also occurs upon the Iowan in cumulose deposits capping the peculiar hills called paha as will be shown in their description.

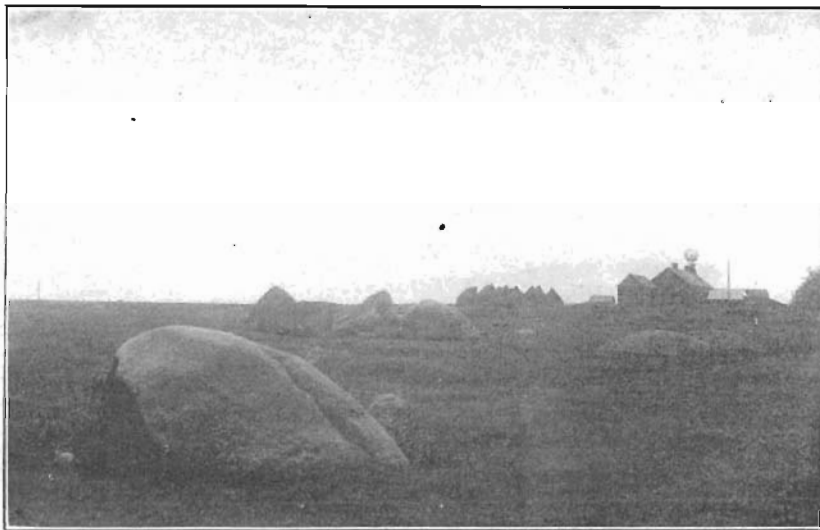


Fig. 45—Iowan boulders, south of Tripoli.

The loess presents several phases, due in part at least to alteration since its deposit. The main body of the formation is a light buff loam, often mottled or streaked with gray, where it has either escaped oxidation or has been deoxidized by the presence of organic matter such as tree roots, which penetrate it deeply. Vertical cleavage is a notable characteristic. Lime carbonate occurs in minute branching tubules, in concretions sometimes called loess kindchen, and in small fossil shells, the latter being more numerous, however, in the ashen loess underneath. Ferruginous nodules are not rare.

The loess is often underlain, as in many places in the Denver area, by a bluish gray or ashen loess sometimes obscurely laminated, more pervious than the loess above and usually more calcareous. In places it graduates into a reddish loess-like

loam, more clayey than the loess, intermediate in nature between the loess and the residual clays of the geest or the weathered clayey and ferruginous surface of the Kansan till, on one or the other of which it rests.

About the Iowan margin the loess usually passes downward into sand by inter-stratified streaks and bands of sand and loess. Superficially the loess weathers into brown, minutely jointed clay, differing from the main body of loess in its higher oxidation and deeper color, in dark narrow bands of ferruginous stain which traverse it parallel with the upper surface, in greater induration, in finer particles due presumably to disintegration, in complete leaching and absence of fossils and in its tendency to break down into a slope of small crumbling fragments.

Paha.—These enigmatic hills, eminently characteristic of the border of the Iowan drift sheet where it meets either the main area of the Kansan drift or the numerous Kansan islands found within the Iowan limits, were first described by McGee in his classic treatise on the Pleistocene history of Northeastern Iowa. Of these lenticular hills, constituted in part or whole of loess and trending with the direction of the ice flow, McGee discriminated three or four types:—"the elongated swell of soft and graceful contour standing apart on the plain, or else connected with its fellows, sometimes in long lines, again in congeries, and locally merging to form broad loess plateaus."*

The last mentioned type in which *paha* merge in broad loess plateaus can hardly be recognized under the definition, and it is perhaps to the long belts of loess-Kansan upland often skirted with *pahoid* hills to which McGee here refers. The *paha* of Bremer county either stand somewhat apart on the Iowan plain, or are much more frequently connected in congeries, but in no case are they far away from the Kansan margin. The Kansan upland of the Denver area is fringed with short-axised, low, elliptical loess hills where it meets the boulder-dotted Iowan plain descending to it from the north. Still more marked and noteworthy are the long strips of loess which trail out from this

*Pleistocene History of Northeastern Iowa, 11th Ann. Report., U. S. G. S., p. 397.3

area across the high Iowan upland lying east of Denver. This upland rises about as high above Quarter Section run as does the Kansan upland on the west. A short distance west of Denver (sections 25 and 26, township 91, range XIII W.) lies a cluster of rather short paha with undulating crests, inosculating with several long narrow swells of loess hardly more than twenty feet in height which stretch straight away across the nearly level Iowan plain, elsewhere destitute of loess, to the edge of the valley of Crane creek in section 33 of Maxfield township, a distance of more than two miles. The compass direction of these interesting banks of loess, 20 degrees south of east, is readily taken with the help of the farmsteads which are located upon them.

North of Waverly a singularly bold and picturesque group of these unique boat-shaped hills rises abruptly from the Iowan plain in sections 25, 26 and 36 of township 92, range XIV W.



Fig. 46—A small Paha, southeast of Waverly.

The largest lift their great rounded backs, bare of forest, to about the height of the forested hills of Waverly. To the northwest they descend to a series of short axised, overlapping paha whose lateral slopes measure about seven degrees. Still lower

and longer pahoid ridges continue the northwesterly trend nearly to the flood plain of the Cedar river. The Iowan plain surrounds this group, separating it from the forested paha which merge with the Waverly loess-Kansan area. To the southeast of this area also, for a distance of about three miles, a number of more or less well defined paha of decreasing height extend their straight courses over the Iowan plain with an inflexible trend of about twenty degrees south of east. Other paha ridges lie still further south connecting the Waverly paha with those north of the Denver loess-Kansan area.

The intimate structure of the paha is not shown in any deep sections in the county nor by any accurate well records. Some of the road sections which may be of slight assistance in elucidating their structure are the following:

Section at northwest end of paha about thirty-five feet high on west line of section 7, township 91, range XIII W.

	FEET.
4. Loess, typical, yellow, pulverulent, with vertical cleavages, containing ramifying calcareous tubules, obscurely laminated, lower portion marked by a few thin discontinuous seams of fine sand	11
3. Loess, ashen in color, sparingly fossiliferous with small molluscan shells, laminated, containing a few vertical ferruginous concretions.....	3
2. Red loam.....	$\frac{1}{2}$
1. Geest, red, containing Devonian cherts and some silicified corals, with a few pebbles of the northern drift, upper surface rising with slope of hill, rock beneath not seen, but inferred to be a few inches beneath.....	$\frac{1}{2}$

The lamination lines of Nos. 3 and 4 and the surface which separates them, are parallel with the surface slope of the hill. No. 4 grows coarser as it approaches the side of the paha on the north. The rock is near the surface in this area, and there may be a low rock nucleus to the hill. Upon this nucleus a considerable body of till may be molded in the center of the paha, as our section was taken at the end. At the southeast end of the paha a reddish sandy till is seen in a shallow road cutting, and the south road along section 7 indicates that the paha has a sandy margin. This ridge is somewhat more than one-half mile long, the long axis bearing between 20 degrees and 25 degrees south of east.

A section of a low pahoid ridge seen in a road cutting between the southeast and the southwest quarters of section 6, township 91, range XIII west, shows a central nucleus of till whose surface slopes with the hill, covered with reddish sand somewhat indurated, and a few feet of a pale calcareous loess beneath a sandy humus. On the margin the loess gives place to the reddish sand.

A section at the end of a paha on the road separating the southwest quarter of the southeast quarter and the southeast quarter of the southwest quarter of section 5, township 91, range XIII W., shows five feet of yellow loess, with small loess kindchen scattered through it, overlying ashen loess of which only two feet were disclosed.

As to the difficult problem of the origin of paha the survey of Bremer county adds little information. The problem resolves itself into two parts, that of the origin of the nucleus of till and of similar pahoid drift hills and ridges on which loess is absent, and second, the origin of the loess cap.

The elliptical profile of paha, their occurrence in groups and the parallelism of their major axes all suggest a close affinity with the lenticular hills of glacial till called drumlins. These hills are extremely abundant on the later drift, in parts of Wisconsin, Michigan, New York and Massachusetts, but have not been recognized in Iowa, nor on the Kansan or Iowan drift sheets, unless the paha are a subspecies of the class,—are drumlins capped with loess. The precise form of the till nucleus is seldom ascertainable. The shapes of some paha suggest that several mounds of drift, which may be far from drumlinoidal in their profiles, are concealed beneath the ample sweeping curves of the loess blanket. On the other hand in Cedar and in Benton counties drift hills have been reported, drumlinoid in axis and in some instances drumlinoid in form and immediately associated with paha. The distribution of paha differs from that of drumlins in other states. The former occur, as the latter are not known to do, in long belts alternated with strips of smooth drift plains. Paha are connected closely also with long parallel ridges of loess-covered drift of such dimensions and complexity

as to remove them wholly from the category of drumlins. The difficult problem of the ridged drift may, when solved, be found to include the lesser problem of the paha. If these ridges are constructional they would seem to belong to some type of sub-lateral moraines, or to find their cause in the presence of underlying ridges of the country rock inherited from preglacial or interglacial times. If erosional these ridges must be regarded as remnants of an earlier drift sheet left in relief by the erosion of the intervening lower plains by the long tongues of glacier ice of a later ice invasion.

If the till nucleus of paha is drumlinoid, it may hypothetically be of either Kansan or Iowan drift, and three possibilities here present themselves,—the paha cores may be loess covered drumlins either accreted out of Kansan drift by Kansan ice, or accreted out of Iowan drift by Iowan ice, or eroded out of Kansan drift by Iowan ice. So far as observed the drift of paha has been referred to the Kansan. But it should be noted that the discrimination between the two drifts is not always easy in a few individual exposures and that the position of the axial drift of these hills relative to the ground water surface promotes a comparatively rapid oxidation and leaching, thus tending to an approach to the Kansan facies in these respects rather than to that of the Iowan till of low lying areas where ground water stands higher and its level fluctuates but little.

If paha cores are Kansan drumlins as the appearance of their till suggests, they can hardly be drumlins of accretion; for we could not possibly explain their restriction to the margin of a later drift sheet. If they are drumlins of erosion carved out of the preexisting Kansan drift sheet by the Iowan ice, we have here also a difficulty to meet, for the implication of any considerable erosion so near the margin of the Iowan ice is opposed not only by what is known of the behavior of ice sheets, which deposit rather than erode in such positions, but also by the current conceptions of the extremely limited amount of the drift deposited by the Iowan ice at any place either as ground or terminal moraine. Certainly a glacier able to erode an earlier drift so markedly should have been able to drag the eroded material a little farther on and leave it in a terminal moraine about its

margin. This theory, however, of paha cores as remnantal masses of Kansan drift accounts for their distribution in connection with Kansan areas and their usual accordant height with the drift of Kansan uplands adjacent.

The problem of the presence of the loess on the paha and its absence on the surrounding Iowan plain from which they rise is entangled with the problem of the origin of the loess. Although the loess may be held to be an aqueous deposit, yet paha can not be called eskers of loess as some have done, for the lenticular paha are quite unlike the winding ridges of sand and gravel laid by subglacial streams and known as eskers. Some peculiar control must be posited in explanation of the parallelism of the paha axes and their constant trend over all of north-eastern Iowa; the control of some single cause operant over this entire area. No such cause is now known to be in operation, but such a cause may be found in the constant direction of movement of an ice sheet covering the entire area, the direction with which the paha are aligned. McGee long since suggested that during the last stages of the ice which latest invaded this territory the glacial flow was checked in the lee of each prominence beneath, and a line of less rapid movement stretched away. Along these lines surface melting was more rapid and the surface was lowered (as in the lee of the nunataks of the Greenland ice cap). Here the courses of superglacial streams became established, here the ice was cut through, and here in ice-walled sluggish streams or ice-bound lakes the finer waste washed from the surface of the stagnant ice was in part laid as loess together with its interstratified and basal sands. In such crevasse-like openings in the stagnant ice which covered Bremer county we may entertain the theory that the paha which trail away so conspicuously in the lee of the loess-Kansan hills of the Waverly and the Denver areas received their cap of loess.

The distribution of the Loess.—The problem of the paha is inextricably entangled with the problem of the origin and distribution of the loess of the upper Mississippi valley. The latter problem presents itself in Bremer county in an unusually simple form and under special conditions. The loess of our area differs in its insularity from that found in counties to the

south and east. It is not spread heavily and continuously over long belts of upland parallel to the rivers, nor does it occur as a comparatively thin sheet mantling all the land as over southern Iowa. Here it is seen only in the completely isolated and restricted areas which we have described. No theory of the origin of the loess can be satisfactory, therefore, which fails to explain the absence of the loess over the larger part of the region as well as its presence in these small islands far removed from any other deposits of loess east, west, north or south.

Except in distribution the loess of the county is entirely typical. It presents the same upper weathered zone, leached of lime, of browner color and more clayey composition, the same body of floury, calcareous, yellow silt, the same interlamination with streaks of fine sand increasing in width and number toward the base, the same fossils of small terrestrial mollusks, the same calcareous and ferruginous concretions, the same gradation beneath into ashen loess, into sand and gravel, or into red loam and geest, the same gradation in places outward also into peripheral sands,—the same phenomena in all respects as the loess of the loess-Kansan ridges and paha of east-central Iowa.

The theories of the loess may be mentioned here, if only to discover to what extent each may be able to explain the distribution of the loess in this region. These theories fall into two divisions as to the processes concerned—the eolian and the fluvio-lacustrine, the former accounting for the loess as a wind deposit, the latter as water-laid in lakes or by the sluggish currents of rivers. Each theory includes a number of different views as to the source of the material, the period of deposit and various modifying conditions. Thus the eolian theory finds the source of the material blown up to form the loess:

1. In the silt of river plains either
 - a—that of present rivers, the loess still being in process of formation or
 - b—that of the valley trains and outwash of glacial streams during the closing stages of an ice invasion.
2. In sheets of drift left exposed by the melting of glacier ice either
 - a—immediately after the recession of the ice sheet or
 - b—during an interglacial epoch of great aridity.
3. In superglacial moraines sheeting the margin of the ice, as that of the Malaspina glacier.

4. In the loose superficial deposits of arid western plains, either
 - a—during the epoch of an ice sheet and deposited in part upon the ice after the manner of the dirt on the margins of the ice cap of Greenland or
 - b—in a period succeeding the withdrawal of the ice.

The fluvio-lacustrine theory is much more limited in period of deposition and in sources of material. By this hypothesis the loess must have been deposited in a period of flooded lakes and rivers attending the closing stages of an ice invasion. The material of the loess can be sought for only in the finer silt washed from glacier drift, including any superficial dust deposits, and laid both in advance of the ice front and over any insular areas within the margin of the ice sheet.

The insularity of the loess in Bremer county is an objection to any one of these theories, as for example a and b of "1" of the eolian theory, which gives no explanation of the absence of the loess over the remainder of the county. For while the loess areas touch upon one of the rivers of the region, they touch upon it at the most narrow portion of its valley, where it has no wide flood plain from which loess could be blown up. And loess is wanting precisely where on this theory it might be most expected, that is, along the wide flood plains of the Cedar above Waverly and of the Wapsipinicon throughout the county. Both of these wide valleys were the channels of the floods attending the melting of the ice sheets of the Glacial epoch, and the Cedar, at least maintains its sandy plains of overflow which should long have been an ideal gathering ground for loess, if its origin were eolian.

If we are to assume that the peculiar distribution of the loess is due to anchorage, the loess being deposited only where the uneven surface of hilly ground caught and held the wind-driven dust, it is difficult to understand why the loess was not deposited on the valleyed uplands east and west of the broad flood plain of the Cedar at Horton as well as on the Kansan areas at Waverly and Denver. Or if the presence of forests be made the determining factor, it might be supposed that the forests of Leroy township between the wide bottom lands of the Wapsipinicon and the East Wapsipinicon rivers would have made as good a catchment area as any in the county. It is true that

the loess areas are mostly forested, a fact usually attributed to the porous and well drained loess soil. The eolian theory, however ingeniously reverses the relation, holding that the forests are the cause of the deposition of the loess by checking the velocity of the dust-laden wind, and by anchoring the dust by means of its mattress of roots.

If the accumulation of such a forest loess were rapid it should include considerable vegetal carbonaceous matter; if slow, the loess should be both decalcified and deoxidized, since by hypothesis it has formed a part of the forest soil rich in decaying organic matter which would act as a reducing agent, and in humous acids and carbon dioxide to aid in the solution of lime carbonate. Moreover, the presence of loess over the prairies of southern Iowa shows that neither forest nor hilly country is a necessary condition to loess accumulation. It would seem that the loess, if of eolian derivation, should be as wide spread over the county as are the channelless currents of the air which laid it, unless it had some local source not yet discovered. The fluvio-lacustrine theory may be able to explain the insularity of the loess tracts by affording ice-barriered water bodies for its deposition and the absence of the loess over other tracts by the presence of overlying ice. We may thus suppose that during the waning of the Iowan ice the stagnant glacier which still lay over the remainder of the county, was removed from the Denver area where, because of the underlying hills of rock and drift its motion had been retarded and its surface lowered. Here the glacial Cedar was diverted from an earlier course and incised a narrow valley in the rock basemented hills. Here it spread its muddy waters in the wide lake-like expansion or embayment, the sluggish current being sufficient to carry away the finer clays and not strong enough to bring in coarser sands and gravels, thus leaving the glacial silt of intermediate texture, too coarse for clay and too fine for sand, and known as loess. The embayment may be conceived as being surrounded by gentle slopes of ice rather than by precipitous ice walls, if this would in any way help to explain the difficult point of why no coarse waste was washed in from the surface of the glacier and deposited with the loess or was dropped from bergs.

This theory of the loess of the Denver area perhaps offers an explanation of the anomalous course of Quarter Section run, which, as we have seen, flows round the border of the loess-Kansan area, diverging at right angles from its normal track. For the stream is seen to follow the eastern and southern edge of the ice barrier, which, by hypothesis, inclosed the area at the time preceding the final withdrawal of glacial ice from northeastern Iowa.

In age, the loess of Bremer county is clearly younger than the Kansan, whose weathered and eroded surface it overlies unconformably. The close association of its basal sands with the Iowan drift points to the Iowan epoch as the time of its formation. The same conclusion is indicated elsewhere in the state, where the loess is seen to be parted from the Illinoian drift by old soil beds, and to be overridden by the margin of the Wisconsin drift sheet, and is thus proven to be younger than the first named drift and older than the second, thus limiting its period to the Iowan and the interglacial stages following and preceding the Iowan.

PRE-GLACIAL TOPOGRAPHY.

It is a matter of common knowledge that the underlying rock surface, which seems to have been little affected by the glacial invasions, does not correspond with the relief of the surface of the ground today. In places in the county the rock basement appears in ledges on the hillsides; in others it is so deeply buried that the drill of the well driller is driven two and more hundred feet through drift before it grinds on solid rock. If the deposits of the ancient glaciers and their glacial waters could be stripped away, what would be the relief of Bremer county? Thanks to the records and the good memories of the well drillers of the county, we are able to sketch some of the outlines of the preglacial topography, although much is vague, some perhaps erroneous and many details are wanting. In a broad way it may be said that the evidence before us presents the northeastern counties of Iowa, such as Allamakee and Clayton, over which no glaciers ever passed, and like eastern Fayette county, where the glaciers left little drift,—a hilly area

trenched deeply with broad valleys and intricately carved with branching gullies and ravines. We know that the floors of the preglacial valleys stand at a lower level than those of today. Not only have they been filled with drift as one might fill a watering trough with mud or sand, but even the preglacial uplands between the streams have been deeply buried. Nearly 300 feet above where a great river once flowed the farmer now drives his plow over gently rolling fields.

Such a deep buried valley crossed the county from northwest to southeast. It passed from Douglas township into Warren between Quarter Section run and Baskin run, passed under the site of Bremer station, then turning eastward followed the valley of Quarter Section run into Jefferson township, and crossing into Maxfield near Maxfield P. O. followed down the west side of Crane creek into Black Hawk county. It will be convenient to designate this as Bremer river.

On the high divide between Crane creek and Quarter Section run in sections 17, 19 and 20 of Maxfield township are a number of wells from 240 to 273 feet in depth and all in drift. The divide here has an altitude of about 1035 feet above tide (taking the grade of the Chicago Great Western Railway one and a half miles north as datum), giving the floor of the buried valley an elevation of not more than 765 feet A. T., or 160 feet below the rock bed of the Cedar river at Waverly. The channel of this ancient stream has been completely obliterated, leaving no trace on the present surface, unless the broad valley of Crane creek occupies the sag due in part to a settling of the unusually thick drift of this belt.

The wide valleys of the Wapsipinicon and the East Wapsipinicon are also deep preglacial or interglacial valleys now filled with drift, though not to the height of that which buries the valley of Bremer river. The depth of the artesian wells drilled on the Wapsipinicon bottoms seldom exceeds 100 feet, but in only a single case is rock reported to have been struck. As the elevation of the Wapsipinicon bottoms is about 970 feet (where crossed by the Chicago Great Western Railway) the rock floor of the ancient valley can not be higher than about 870 feet.

The Cedar valley in its broad reaches north of Waverly is of unknown depth, drive wells furnishing abundant water at a few feet from the surface.

Further south, where the valley is of the same type, it has been sounded by the artesian borings at Vinton, and found to be filled to a depth of 115 feet, its rock floor lying at about 665 feet A. T.

We add some details of the thickness of the drift in the different townships of the county.

Sumner township.—The drift varies here from nearly 200 feet in the northeastern part, and 136 and 150 feet at Sumner, to a little over one hundred feet in the northwestern sections of the township. Little is known of the depth in the southwestern sections; one well (southwest quarter of section 21) ends in drift at 138 feet.

Franklin township.—East of the Wapsipinicon valley rock occurs from 100 and 120 feet from the surface, as at Minkler, to 160 and even 200 feet in the southeastern part of the township. On the west side of the Wapsipinicon, deep wells are reported in section 7, where two wells found rock at 192 and 200 feet and another is listed as ending in drift at 275 feet. At Key the drift was not drilled through by a well 130 feet in depth. These three wells are near the side of the Wapsipinicon valley, but their significance as related to any ancient course of the river is undiscovered.

Dayton township.—The southeastern township of the county is throughout an area of thick drift. On the east of the Wapsipinicon valley wells ending in drift are reported from 150 to 180 feet deep and the only one listed as striking rock discovered it at 190 feet. Rock occurs just east of the Wapsipinicon valley at from ninety to 120 feet.

Leroy township.—The divide between the Wapsipinicon and the East Wapsipinicon rivers rises a little more than 100 feet above the rock surface, and the divide between the latter stream and Leroy creek to nearly the same height. Statements as to the depth of the filling in the valley of the East Wapsipinicon are conflicting, one being that in the valley wells are from 150 to 180 feet deep and strike no rock. On the other hand, two

wells are reported on the bottoms below the confluence of the stream with Leroy creek (sections 23 and 26) which find rock at eighty-five and ninety-five feet. A well in the valley in section 11 is reported to be 100 feet deep and ending in drift or in alluvium. An interesting group of wells is found in section 18 where rock is found at 200 and 220 feet below the surface. We have evidently here an old buried channel, but no deep wells in the vicinity enable us to trace its course.

Frederika township.—In the northeastern part of the township rock is found beneath the upland at a depth of from fifty to eighty feet at the north and farther south at less than 100 feet. The Wapsipinicon valley is filled to at least the depth of sixty and seventy feet, as wells ending in drift attest. Rock appears on the flood plain at Frederika, but west of old Tripoli it has sunk to sixty and 100 feet below the surface.

Douglas township.—The scanty data at hand suggest that two channels of Bremer river or the main valley and a tributary unite in the southern portion of the township, where the buried valley reaches a depth of 220 feet. Less than two miles and a half away in the southeastern part of the township the Niagara comes to the surface, giving the measure of the depth of the rockcut valley at more than 200 feet at this locality. The slight grounds for positing two channels in the north are a deep well reported as 190 feet to rock on the east (in section 2) and wells on the west of the township (sections 6 and 9) sounding rock at 200 and 178 feet, with rock at less depths between in the center of the township. In the southwestern part of the township rock seems to lie about 150 feet below the surface.

Warren township.—In the southwestern part of the township the drift is from sixty to 100 feet in depth. Between Quarter Section run and Crane creek it is 105 feet deep at the Bremer County Poor Farm. But in the buried channel of Bremer river the drift lies at least 236 and 240 feet deep, as several drift wells of these depths attest.

Maxfield township.—Here Bremer river valley reaches a depth of at least 270 feet as several drift wells of this depth, or a little more, testify. East of this well-marked valley the rock rises,

reaching to within eighty feet of the surface at Readlyn. In the southeastern part of the township it lies deeper, since drift wells are reported at from eighty to 100 feet in depth.

Polk township.—Little information was obtained regarding the thickness of the drift in the northwestern township of the county. Rock outcrops in the northwestern section and at Horton it lies but twenty feet below the surface. On the upland south of Horton wells eighty feet deep do not strike rock, and in section 24 a drift well 214 feet deep is reported, probably indicating a tributary valley of Bremer river.

Lafayette township.—On the upland west of the Cedar, drift seems to be about 100 feet thick, and about as thick on the upland east of the river. Rock outcrops at numerous places along the Cedar valley.

Washington township.—Here the rock is disposed much as in Lafayette township, lying from seventy-five to 100 feet below the crests of the hills west of the Cedar and at the same depth over the Iowan paha-dotted plain of the eastern sections, but outcropping along the course of the Cedar river.

Jefferson township.—The only outcrops of rock known are in sections 9, 21 and 28. The rock surface evidently descends toward the east to the valley of Bremer river, where drift wells 214 and 220 feet deep are reported. At Denver a lateral of Bremer river seems to be indicated, for here rock is found 162 feet below the level of the flood plain of Quarter Section run, while a block away rock lies but forty-two feet from the surface, indicating a precipitous slope of 120 feet in this short distance. In the southeastern part of the township rock is found at 110 feet (section 35). On the loess-Kansan area west of Denver wells are reported to find rock at from sixty to ninety feet.

Jackson township.—Rock outcrops along the Cedar river. Between the Cedar and the Shell Rock it lies from forty (section 28) to 100 feet (section 22). In the southeastern sections rock appears to be found from thirty to eighty feet below the surface of the prairie.

ECONOMIC PRODUCTS.

BUILDING STONE.

Small quarries capable of supplying stone suitable for ordinary building purposes are well distributed along the Cedar river from the northern to the southern limits of the county. East of the Cedar valley no rock outcrops except at or near Frederika. All of the building-stone quarries opened are in the Cedar Valley stage of the Devonian limestones. All are worked without the assistance of machinery and in a small way for the supply of the local demands, chiefly for foundations. These quarries have been described in detail under the geological sections of their formations.

CRUSHED STONE.

The Cedar River Stone Company has recently opened an important quarry one and one-half mile southeast of Waverly on the Cedar river connecting with the Chicago Great Western Railway by a short spur. Large contracts are being filled for crushed stone for ballast and macadam over the lines of this railway and in the cities which it reaches. A view of the plant is given in figure 47. Below the stripping, which is easily disposed of by dumping in the river, the stone is unusually tough, dense and unaffected by the weather, being one of the best limestones in the state for the purposes for which it is now used. There is an uniform run of twenty-five feet or more of good rock with no waste of soft stone or disintegrated rock meal. The following section is exposed:

	FEET
5. Stripping, limestone, light gray, soft, broken by the weather into layers from 2 to 4 inches thick, fossils rare.....	9
4. Limestone, dense, hard, tough, yellow-gray, lowest layers about 3 inches thick, divided above by diagonal joints and bedding planes into rhombic blocks 1 to 4 feet in diameter. Occasional geodic cavities an inch or so in diameter lined with drusy calcite; fossiliferous with many firmly imbedded <i>Atrypa reticularis</i> , <i>A. aspera occidentalis</i> and <i>Orthis iowensis</i>	25
3. Concealed.....	12
2. Breccia of Wapsipinicon stage, hard and dense	5
1. Concealed to water's edge.....	3

Lime.

Lime is now burned in the county only at Brodie's quarry, in Frederika, in a small square pot kiln, using wood as fuel. The stone used is the buff magnesian limestone of the Cedar Valley stage of the Devonian, underlying the *Acervularia profunda* beds. The high magnesian content of the stone gives the lime its repute as a slow slacking, slow setting lime of excellent quality. Lime has been burned in the past at a num-

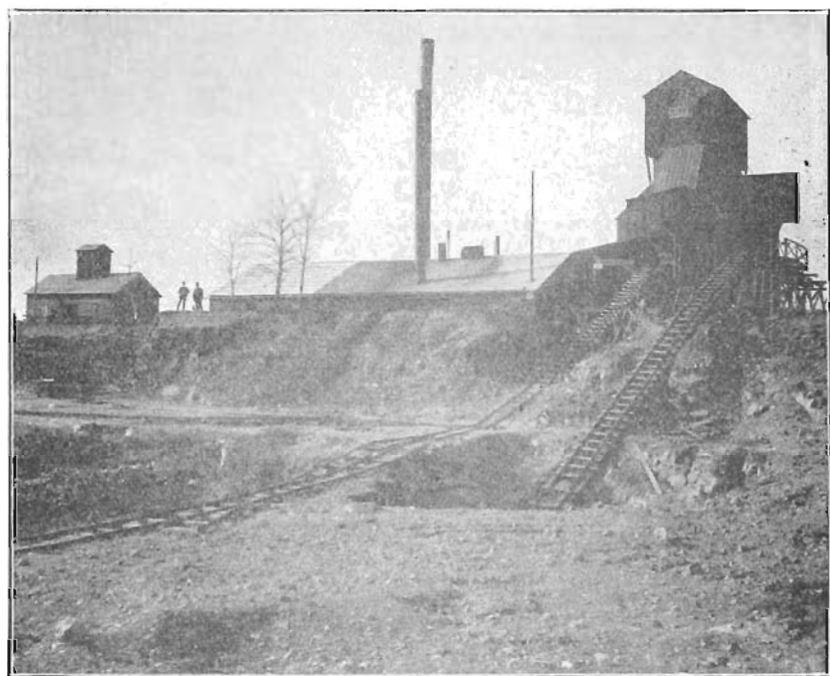


Fig. 47—Plant of the Cedar River Stone Company, Waverly.

ber of small pot kilns, as on the Niagara outcrop southeast of Waverly and on the Devonian northeast of Plainfield. The former site has a stone unexcelled in quality, with little stripping and is also near a large timber supply, but its distance from town is such that it has not been able to meet the close competition in this industry.

Clay.

The loess clay is utilized at Waverly in the manufacture of common brick, for which it is admirably adapted. In 1903, the

two brick kilns in operation, that of the Waverly Brick and Tile Co. and that of Henry Cretzmeyer, reported an output of 273,000 brick valued at \$2193.

Soils.

The soils of Bremer county may be grouped into three general classes, drift soils, loess soils and alluvium. The first class named occupies the areas mapped as Iowan drift. Over much of this area the topography is indecisive and the drainage imperfectly developed. A deep humus rich in nitrogen and carbon taken from the atmosphere has here accumulated in a black soil of unusual fertility. Where the unleached, clayey Iowan till forms the subsoil this contributes various mineral plant foods in a condition such as to make them readily available. Where, as is commonly the case, the upper surface of the drift is sandy, the effect is to produce a light, warm soil, readily drained and easily worked. In places where the Iowan is specially sandy either from glacial outwash or from the working over of the drift by the winds, there results a soil easily affected by drought but quickly responsive to fertilizers and favorable for maturing early crops and special agricultural products.

Loess makes a most admirable subsoil and when well mingled with abundant humus, no soil can yield more generously or with greater endurance. It absorbs like a sponge any excess of storm water and in drought gives it back to the surface by capillarity. Thus it neither drowns out in wet weather nor bakes in dry. Moreover, its mineral ingredients, drawn from an exceedingly large variety of rocks, are in a finely divided condition in which they are easily taken into solution and used by the plants. Owing to its porosity, loess is readily penetrated by plant roots, and it is thus available to greater depth than are most soils. In Bremer county, however, the loess has been laid upon the slopes of the paha and over deeply dissected uplands. Where unadvisedly the forests have been cut down and the loess hills placed under the plow, the humus, the careful savings of the virgin forests for ages past, is washed away and wasted in a few years, leaving the yellow hillside scarcely altered from the normal color of the loess by any carbonaceous admixture. Constant care is now needed to prevent the formation of gullies

which, beginning where the grass has been destroyed by the tread of cattle or in the furrow of the plow, grow in a few years to be great arroyas. One farmer in this area reports that a month of his time is occupied each year in preventing these natural effects of rain and gravity on the soft loess silt of his hillsides. Even when the loess has been stripped of its humus, it still responds generously to fertilizers, but good economy strongly urges that the loess-Kansan areas be left for forests, for orchards, for vineyards and for pastures, for which they are best adapted by nature.

The rivers and creeks of the county are bordered with belts of soil derived from the materials washed down by streams and deposited over the valley floors at times of flood. There is also an extensive creep of the cream of the soil of the adjacent hills forming alluvial slopes which blend with the alluvial plains and whose soil differs but little from that of the flood plain except in the finer grain of its material. On the flood plains river silts are mingled with humus accumulated in place upon the level areas from the growth of vegetation and from that washed off the soils of the country and brought in by muddy floods. Thus to a depth of several feet the alluvial soil may be dark with rich carbonaceous matter and of corresponding fertility. Where the deposit has been laid in what was at the time the channel of the river, and by its rapid currents, the alluvium consists of sands and gravels, with little of intermingled, finer material, and it is far less fertile than are the finer deposits from the shallow and sluggish overflow upon the wide flats of the river bottoms.

Water Power.

The diversion of the rivers by the Pleistocene ice sheets from their ancient channels, setting them to flow over higher courses and rocky beds, gives excellent water power to each of the rivers of the county. The water power at Waverly was substantially improved in 1905 by raising the head, by repairs on the dam, and more especially by the installation of a large cement bulkhead, wheel-house, new wheels, and the excavation of a tail race, the total amount of these repairs being about \$22,000. There are now installed in the wheel-house two wheels

(S. Morgan Smith Co., wicket gate), each furnishing at the normal stage of the water about 170 horse power at the wheel shaft. The normal head of water is from eight and one-half to nine feet. The incorporated town of Waverly owns in fee simple all the water power, having purchased all outstanding leases and water rights. The power is used in the operation of the municipal water works and the municipal electric plant, both owned and operated by the city, and a feed and flour mill owned by the city but leased to a miller. For all these purposes the power supplied by one wheel alone is amply sufficient. The power now available is thus greatly in excess of present demands. It can be largely increased in the future by the completion of the tail race and the installation of additional wheels.

An excellent water power has also been developed on the Cedar river at Janesville, where a large three story flour and feed mill has long stood. The equipment of the mill is now five run of buhr millstones and one set of rollers, with a capacity of 125 barrels in 24 hours. The head is reported as nine feet.

At Frederika, a dam across the Wapsipinicon river gives a head of seven feet, two wheels furnishing to the flour and feed mill there about fifty horse power.

Water Supply.

The rivers of the county afford a permanent and inexhaustible supply of stock water to the farms adjacent to their banks. The creeks are also utilized in this way, although their supply may fail in dry years, especially along their upper courses. Everywhere the wind engine forms a prominent feature of the landscape, thus attesting the prosperity of the farmers, and also the fact that the ground water of the country has lowered since its settlement and permanent and adequate supplies for stock are now to be secured only by deep wells.

Water is seldom found in sufficient quantities beneath the Iowan drift and above the Kansan. Wells are driven until they come upon water bearing sand or gravel either in or between the blue tills of the Kansan and Jerseyan. Water is occasionally found in gravels lying on the rock, but not infrequently the drill finds the drift dry throughout and is compelled to pass

into the country rock. Where this is limestone, water is commonly found in the zone of broken rock within a few feet of the upper rock surface, although where the rock comes near the surface of the ground, the ground water level may lie deep. But over the considerable area of the buried valley of "Bremer river", where the drift is 200 feet thick and more, the drill may pass through the drift only to strike the Maquoketa shale. The boring must then continue through the Upper Maquoketa in order to find water in the limestones of the Middle Maquoketa. In an instance of one farm well even this resource failed, and the well was drilled through the entire Maquoketa, Upper, Middle and Lower, and into the Galena before sufficient water was obtained. In this area of deep drift another difficulty presents itself: in places heavy beds of fine sand are encountered, water-logged indeed, but impossible to sieve out. In this case it is only with much care and skill that the driller forges his way to the underlying gravels.

On the wide flood plain of the Cedar water is obtained by drive wells. Farms on the floor of the valley of the Wapsipinicon, and even some distance up the slopes of the bordering hills, obtain a most copious supply of excellent artesian water at a depth of about 100 feet, from glacial gravels underlying an impervious sheet of till. From Tripoli to the Black Hawk county line nearly every farm in the valley is thus supplied. The original head has been seldom measured, but in one well, located somewhat up from the bottoms, the head was found to be twenty-one feet above the curb. Although the head of the wells, some of which have been flowing for more than twenty years, has lowered considerably, and some on the hillsides have ceased to flow, the discharge is still ample, and is reduced usually to that of a three quarter inch pipe. Unlike some drift artesian, the water of the Wapsipinicon valley is both palatable and healthful. Flowing wells are obtainable also in the valley of the East Wapsipinicon, at least below the confluence of Leroy creek.

A high compliment is paid in recording the fact that each of the large towns of the county has supplied itself with artesian water, thus insuring the health of its citizens against those

diseases of which drinking water is the vehicle. This fact is all the more noteworthy in that the county is removed to a considerable distance from areas where successful artesianians had already been sunk and the sinking of these wells was without near precedents and examples, and no doubt seemed to their promoters something of an experiment.

The artesian well at Waverly, owned by the city, was begun and completed in 1899. It had been the intention of the city council to sink the well several hundred feet deeper in order to obtain the largest possible supply under the greatest possible head. The writer was called in when the well had reached its present depth, and as he advised against drilling deeper, because of the excellent supply already obtained, because of the danger of injuring the quality of the water by tapping veins of highly mineralized waters apt to be found at greater depths, and because the chief aquifers of the artesian field of northern Iowa had already been passed by nearly 500 feet, the boring was stopped at once. The supply was estimated by citizens at 200 gallons a minute. Analysis of the water showed it to belong to the finest class of mineral waters,—the calcic magnesian, containing about 37 grains to the gallon of calcium and magnesium carbonates. The small amounts of sulphate and carbonate of soda present are not unhealthful, and the little iron in the water has a distinct therapeutic value. No sulphate of lime is present, and the water ranks among the best drinking waters in the state.

The first water vein reported was encountered in the St. Peter at 730 feet. In the Upper Oneota from 840 to a little over 900 feet strong veins were found, giving an overflow at 840 feet. Other flows were found in the Jordan sandstone from 1120 to 1200 feet, below which the boring seems to have encountered no more water.

The supply has remained entirely adequate to the growing needs of the town. In the summer of 1905 the well was found to be leaking badly. When the cistern, 19 feet deep, into which the well discharges from a pipe seven feet from the curb was pumped down, a strong flow came in through the rock bottom of the cistern and the well ceased its discharge, resuming when

on the cessation of pumping the cistern filled to near the level of the discharge pipe of the well. It was suggested that the well should be recased to near the Maquoketa shale. The temperature of the water, taken with some difficulty and possibility of error from the water discharging into the cistern was found in 1905 to be 53 degrees Fahr. Samples of the drillings were carefully saved as the work progressed and on their analysis the following geological section is based:

(GEOLOGICAL SECTION OF THE WAVERLY ARTESIAN WELL.

DESCRIPTION OF THE DRILLINGS.	DEPTH IN FEET.
48. Limestone, buff, earthy, facies of Cedar Valley stage....	20
47. Limestone, light buff, earthy.....	30
46. Limestone, dense, hard, brittle, brownish drab and light buff, of finest grain and conchoidal fracture; rapidity of effervescence in cold dilute HCl indicates a very slight percentage of magnesium carbonate; facies of Wapsipinicon stage of the Devonian.....	40
45. Limestone as No. 46, with a few chips of flint and some of light yellow arenaceous limestone.....	50
44. Limestone, light buff, earthy, rapid effervescence.....	60
43. Dolomite, or magnesian limestone, gray, earthy luster... ..	70
42. Dolomite or magnesian limestone, in coarse chips, with flakes of bluish-white, subtranslucent, cryptocrystalline quartz.....	80
41. Dolomite or magnesian limestone, yellow gray, in fine sand.....	90
40. Dolomite in large chips, gray, luster earthy, with cryptocrystalline silica as No. 42... ..	100
39. Dolomite, or magnesian limestone, soft, blue, subcrystalline.....	110
38. Shale, blue, with small nodules of pyrite, and fine sand of bluish limestone chippings.....	120
37. Limestone, soft, blue, saccharoidal, of brisk effervescence, pyritiferous.....	130
36. Shale, calcareous, bluish or greenish in color; samples at 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, and.....	260
35. Limestone, mottled light and dark drab, fine saccharoidal, magnesian.....	270
34. Flint, light drab, in large chips, with limestone, blue-gray, of rapid effervescence.....	280
33. Limestone, blue-gray, rapid effervescence, soft, argillaceous, with considerable flint; samples at 290, 300 and	320
32. Limestone, white, light gray, and cream colored, often in thin flakes, rather soft, and often argillaceous, luster earthy, effervescence rapid; samples at 360, 390, 400, 410, 420, 430, 470, 480, 490, 500, 510, 540, 550, 560, 580, and...	590

DESCRIPTION OF THE DRILLING.	DEPTH IN FEET.
31. Shale, green, with some fine chips of limestone	600
30. Limestone, soft, earthy, non-magnesian, light gray, fossiliferous	610
29. Limestone and shale, the latter green, (two samples for this depth, one of limestone of Trenton facies and one of Trenton shale as No. 31, may represent the interval between 610 and 630 feet)	620
28. Shale, green, in angular chips, with some chips of light gray limestone as above	630
27. Limestone, soft, earthy, with much green shale; samples at 640, 650 and	660
26. Shale, green, bright, plastic, in large pieces of dried clay cleaned from drill; samples at 670 and	680
25. Sandstone, white, soft, grains of pure quartz, moderately well rounded and rather fine; samples at 690, 700 and ...	710
24. Dolomite, gray, cherty, with chips of white saccharoidal sandstone and much quartz sand	720
23. Dolomite, hard, crystalline, light gray or cream colored, in chips with much quartz sand; samples at 740, 760 and ...	780
22. Dolomite, light yellow-gray, in chips mingled with much white sand; samples said to represent drillings from 790 to	920
(Another statement that here drillings washed away because of overflow at 840 feet).	
21. Dolomite, white, crystalline, cherty, with much moderately fine quartz sand in sample of drillings; 930 and	940
20. Dolomite, cream colored	950
19. Sandstone, white, fine grained, calcareous cement, in small chips with some of pink dolomite and grains of sand	960
18. Dolomite, light gray, cherty, arenaceous	970
17. Dolomite, mostly in clean sand and chips, often vesicular, white, gray, pink, often cherty; samples at 980, 990, 1000, 1010, 1020, 1030, 1040, 1050, 1060, 1070, 1100, 1110 and	1120
16. Sandstone, white, soft, of clear quartz, grains rounded, general size of grains of last sample about $\frac{1}{2}$ millimeter in diameter; samples at 1130, 1140, and	1150
15. Sandstone, drillings consist in part of angular sand of what appears to the naked eye as a light yellow dolomite, effervescing freely in hot HCl. Under the microscope it is seen to consist of minute angular grains of limpid crystalline quartz with calcareous cement; much of the drillings consists of rounded grains of white sand; samples at 1160 and ...	1170
14. Sandstone, quartz, moderately fine and well rounded, with chippings of gray dolomite	1180
13. Sandstone, calciferous as No. 15; samples at 1190 and	1200

DESCRIPTION OF THE DRILLING.	DEPTH IN FEET
12. Sandstone, fine grained, white.....	1210
11. Sandstone, calciferous as No. 15 with some flakes of dolomite; 1220 and.....	1230
10. Dolomite, highly siliceous, with finely divided quartzose matter of angular particles and somewhat arenaceous, with bright green grains of chlorite; samples at 1240, 1250, 1260 and.....	1270
9. Chert and dolomite and siliceo-calcareous shale	1280
8. Dolomite, highly argillaceous and siliceous.....	1290
7. Dolomite, gray, siliceous, silica in form of minute angular crystalline particles constituting a large part of the rock; with some green grains of chlorite, samples at 1300, 1310, 1320, 1330 and.....	1340
6. Shale, bluish green, feebly calcareous; samples at 1410, 1420, 1430 and.....	1440
5. Shale, pink, buff and green, non-calcareous.....	1450
4. Shale, blue-green; somewhat indurated, non-calcareous; samples at 1460, 1470, 1480, 1490, 1500, 1510, 1520 and....	1530
3. Sandstone, rather coarse grains, drillings contain clayey admixture, and dolomite chips; sample said to represent drillings from 1540 to	1580
2. Shale of various colors; yellow; a bright dark green set thickly with grains of chlorite; red, arenaceous, with small partially rounded quartz grains.....	1590
1. Shale, blue-green, with considerable red shale probably from above; samples at 1600, 1610, 1620, 1640, 1670, 1690, 1700, 1710 and.....	1720

ASSIGNMENT OF STRATA.

FORMATIONS.	NUMBERS.	THICKNESS IN FEET.	DEPTH IN FEET.	ELEVATION A T.
Devonian, Cedar Valley	48-47	40	40	890
Devonian, Wapsipinicon.....	46-44	30	70	860
Niagara.....	43-39	50	120	810
Maquoketa.....	38-36	150	270	660
Galena and Platteville.....	35-26	420	690	240
St. Peter	25	30	720	210
Upper Oneota or Shakopee	24-20	240	960	-30
New Richmond.....	19-18	20	980	-50
Lower Oneota	17	150	1130	-200
Jordan.....	16-11	110	1240	-310
St. Lawrence dolomites and calciferous sandstones.....	10-7	170	1410	-480
St. Lawrence shales.....	6-1	310	1720	-790

It is not improbable that the magnesian limestone of No. 35 and the cherty limestones of Nos. 34 and 33 represent the limestones of the Middle Maquoketa seen in the Sumner well and outcropping in Fayette county as fully described by Savage.*

*Iowa Geological Survey, Vol. 15, p. 464.

In this case the Lower Maquoketa shales are either unrepresented in the samples of the Waverly well drillings, which unfortunately do not completely cover this horizon, or have thinned out to the west and are wanting in the western part of the county. The assignment of these strata to the Galena is, however, more in accordance with the thickness and dip of the formations.

Comparing the elevations above tide of the best distinguished horizons at Waverly and Sumner we may estimate the dip of the strata to the southwest in 20 miles.

	WAVERLY. FEET.	SUMNER FEET.	DIFFERENCES IN ELEVATION. FEET.
Summit of the Maquoketa.....	810	904	94
Summit of the St. Peter.....	240	340	100
Summit of Jordan.....	-200	-106	94
Summit of St. Lawrence Shales.....	-480	-376	104

These results indicate a general dip of the Paleozoic strata in this area to the amount of about five feet to the mile to the southwest.

The deep well at Sumner was begun in early August 1899, but owing to the loss of tools in the well at 1770 feet which the contractors were not able to remove, the well was not accepted until January of 1902. Water was found in the Middle Maquoketa at 260 feet, with a temperature of 51 degrees Fahr., and a head of 1036 A. T. rising to within eighteen feet of the surface. Other veins were struck in the Galena from 420 to 660 feet. The head of eighteen feet below the curb was retained until the well was sunk to 1086 feet, in the Lower Oneota, when the water fell to the present height of -144 feet, owing to a strong inflow here at the low head of 910 feet A. T. The capacity of the pump installed is 200 gallons a minute, and continuous pumping for five days has not lowered the water below the cylinder, which is set 204 feet below the curb. The temperature of the water as taken from the pump is 50 degrees Fahr. The water has a slight sulphurous odor when first drawn, due no doubt to the presence of sulphureted hydrogen. But the rapid escape of the gas soon renders the water entirely free from any disagreeable taste or odor. The water ranks among the best artesian waters in the state.

It will be noted from the geological section of the well that here, as at Waverly, the boring was continued several hundred feet below the chief water bearing stratum or aquifer, the Jordan sandstone. In each case about one thousand dollars might have been saved by stopping the boring at the base of the Jordan, below which lay the dry dolomites and shales of the St. Lawrence, penetrated to a depth of between 450 and 480 feet. In case new wells are drilled at either Waverly or Sumner, the depth need not exceed 1240 feet at the former and 1280 at the latter town.

DESCRIPTION OF DRILLINGS, CITY WELL, SUMNER.

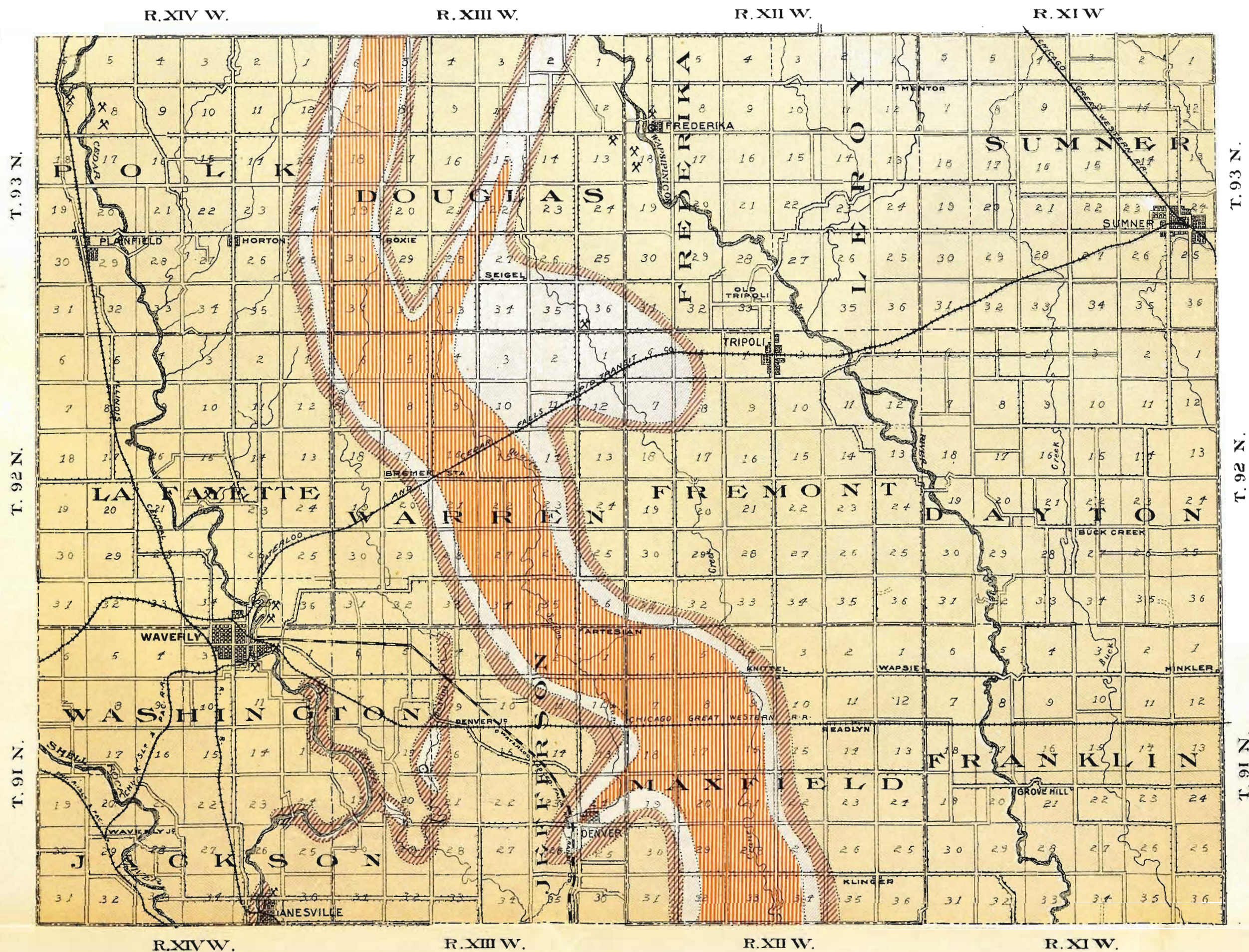
NO.	CHARACTER OF DRILLINGS.	DEPTH IN FEET.
44.	Sand and gravel, yellow	40
43.	Gravel, coarse, pebbles in sample up to three inches diameter	41
42.	Till, glacial stony clay, drab; samples at 50, 57, 70, 90 (sandy), 100, 110, and	120
41.	Limestone, largely drab, fine-grained, of Wapsipicon type	128
40.	Limestone, hard, light buff, of rapid effervescence, samples at 135 and	140
39.	Limestone and shale; limestone light buff, of rapid effervescence, shale drab; samples at 150 and	160
38.	Shale, blue-green, plastic, calcareous; samples at 170, 190, 200, 210 and	220
	"hard rock" in driller's log at	230
	(Samples of drillings consist of drift, sand and gravel)	235
37.	Limestone, light blue-gray, earthy luster, mottled, of rapid effervescence in cold dilute HCl, with much chert of same color; samples at 250, 260, 270 and ...	280
36.	Limestone, soft, semi-crystalline, gray, rapid effervescence, cherty, one sample containing crinoid stem; samples at 290, 300 and	310
35.	Shale, light blue-green, calcareous; samples at 320, 330, 340, 350 and	360
34.	Limestone, blue-gray, of rapid effervescence; samples at 370, 380 and	390
33.	Shale, calcareous, drab; samples at 400 and	410
32.	Limestone, cream colored, soft, in thin flakes	410-420
31.	Limestone, light and dark gray, soft, earthy luster, rapid effervescence; samples every ten feet from 430 inclusive to	630
30.	Limestone, dark blue, highly fossiliferous; 640 and	650
29.	Shale, bright green, plastic, slightly calcareous; samples at 660, 665 and	668

NO.	DEPTH IN FEET.
28. Limestone, mottled gray, fossiliferous, rapid effervescence; samples at 678, 683, 690, 700 and.....	710
27. Shale, bright green.....	710-714
(These shales at 665 and 710 are highly fossiliferous and fragments of them with bits of their characteristic fossil brachiopods, etc., occur in almost all the drillings below this.)	
26. Sandstone, of clean white quartz sand, grains well rounded, rather fine, at 720 some limestone chippings in the drillings; samples at 720, 730, 750, 760 and.....	770
25. Dolomite, white, gray and light buff. in places cherty, crystalline; samples at 780, 790, 800, 820, 830, 840 and..	850
24. Dolomite, cream colored, with much quartz sand in drillings.....	860
23. Dolomite, pink, arenaceous, with minute rounded grains of crystalline quartz; samples at 870 and.....	880
22. Dolomite, light buff and pinkish; samples at 890, 900 and	910
21. Sandstone, and dolomite, drillings chiefly or largely fine grains of quartz sand, but with chips of light gray dolomite; 920 and.....	930
20. Sandstone, fine grained, white, grains well rounded.....	940
19. Sandstone, white, and dolomite, gray.....	950
18. Dolomite, white or light gray, in places saccharoidal, in places with white chert, at 980 drillings contain considerable sand; samples at 960, 970, 980, 990, 1000, 1010, 1015, 1020, 1030, 1050, 1060, 1070 and.....	1080
17. Sandstone, of white clean quartz grains well rounded, moderately fine.....	1090
16. Dolomite, white and light gray and buff, with siliceous residues of finely divided quartzose matter, and at 1150 finely arenaceous; samples at 1120, 1140 and.....	1150
15. Sandstone, fine grained, white, grains of clear quartz, well rounded; 1160 and.....	1170
14. Sandstone, as above, but coarser, some grains reaching one mm. in diameter.....	1180
13. Sandstone as No. 15; 1190, 1200 and.....	1210
Drillings from 1230, 1236 and 1240 are indecisive, consisting at 1236 of highly calcareous shale resembling the Maquoketa, and at the two other depths of limestone clearly Trenton and fallen in the boring. Considerable quartz sand is mingled with the drillings, and while this may have fallen from above, it is the only material in the samples in which the drill apparently could have worked at 1230 and.....	
12. Sandstone, fine, white, with Trenton limestone in the drillings; 1260 and.....	1270

NO.	DEPTH IN FEET.
11. Dolomite, highly siliceous, with minute angular particles of crystalline quartz, in places with green grains of chlorite; samples at 1280, 1290, 1300, 1310, 1330, 1340, 1360, 1368, 1370, 1380, 1390, 1420 and.....	1425
10. Shale, reddish, feebly calcareous	1430
9. Shale, green, feebly calcareous; 1440, 1450 and.....	1460
8. Shale, green, fossiliferous, practically non-calcareous, minutely quartzose; 1480, 1490, 1500, 1510 and.....	1520
7. Shale, bright and light green, highly arenaceous with minute grains of quartz, chloritic.....	1530-1550
6. Sandstone, gray, fine grained, with chlorite grains.....	1560
(Drillings only a few water worn fragments of shale)....	1570
(Drillings chiefly rusted chips of iron, from a fallen slush bucket, cut up by the drill)	1580
5. Sandstone, gray, fine grained	1600
4. Shale, dark and bright green, minutely arenaceous and chloritic; 1610 and.....	1620
3. Sandstone, fine grained, mingled with some greenish argillaceous material; dried blocks set after pouring from slush bucket are readily friable.....	1630
2. Shale, light green, finely arenaceous, feebly calcareous, plastic.....	1640
1. Marl, green, greenish yellow or greenish gray, highly arenaceous with almost impalpable quartz grains, calcareous and argillaceous, chlorite present in round grains of dark green color, some samples easily friable when dried, others more clayey and somewhat tenaceous; samples at 1660, 1670, 1680, 1690, 1700, 1710, 1720, 1730, and	1740

ASSIGNMENT OF STATA.

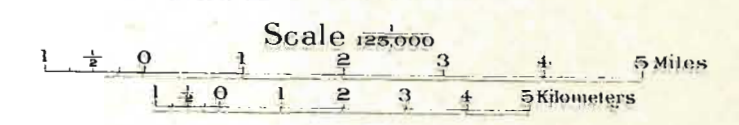
NOS.	FORMATIONS.	THICKNESS IN FEET.	DEPTH IN FEET	ELEVATION A T. FEET.
44-13	Alluvial sands and gravels.....	41	4	1013
42	Glacial till.....	87	128	926
41-40	Devonian or Silurian.....	22	150	904
39-38	Upper Maquoketa.....	80	230	824
37-36	Middle Maquoketa.....	90	320	734
35	Lower Maquoketa.....	50	370	684
34-27	Galena and Plattsville	344	714	340
26	St. Peter.....	66	780	274
25-22	Upper Oneota or Shakopee	140	920	134
21-19	New Richmond.....	40	960	94
18	Lower Oneota.....	200	1160	-106
17-12	Jordan.	120	1280	-226
11	St. Lawrence dolomites.....	150	1430	-376
10 1	St. Lawrence shales.....	310	1740	-686



IOWA GEOLOGICAL SURVEY

GEOLOGICAL
MAP OF
BREMER
COUNTY,
IOWA.

BY
W.H. NORTON
1906



LEGEND
GEOLOGICAL FORMATIONS

Cedar Valley		} Devonian
Wapsipinicon		
Niagara		Silurian
Maquoketa		Ordovician

INDUSTRIES

QUARRIES	X
LIME KILNS.	⊙

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