PHYSICAL FEATURES AND GEOLOGIC HISTORY OF DES MOINES VALLEY

BY

JAMES H. LEES

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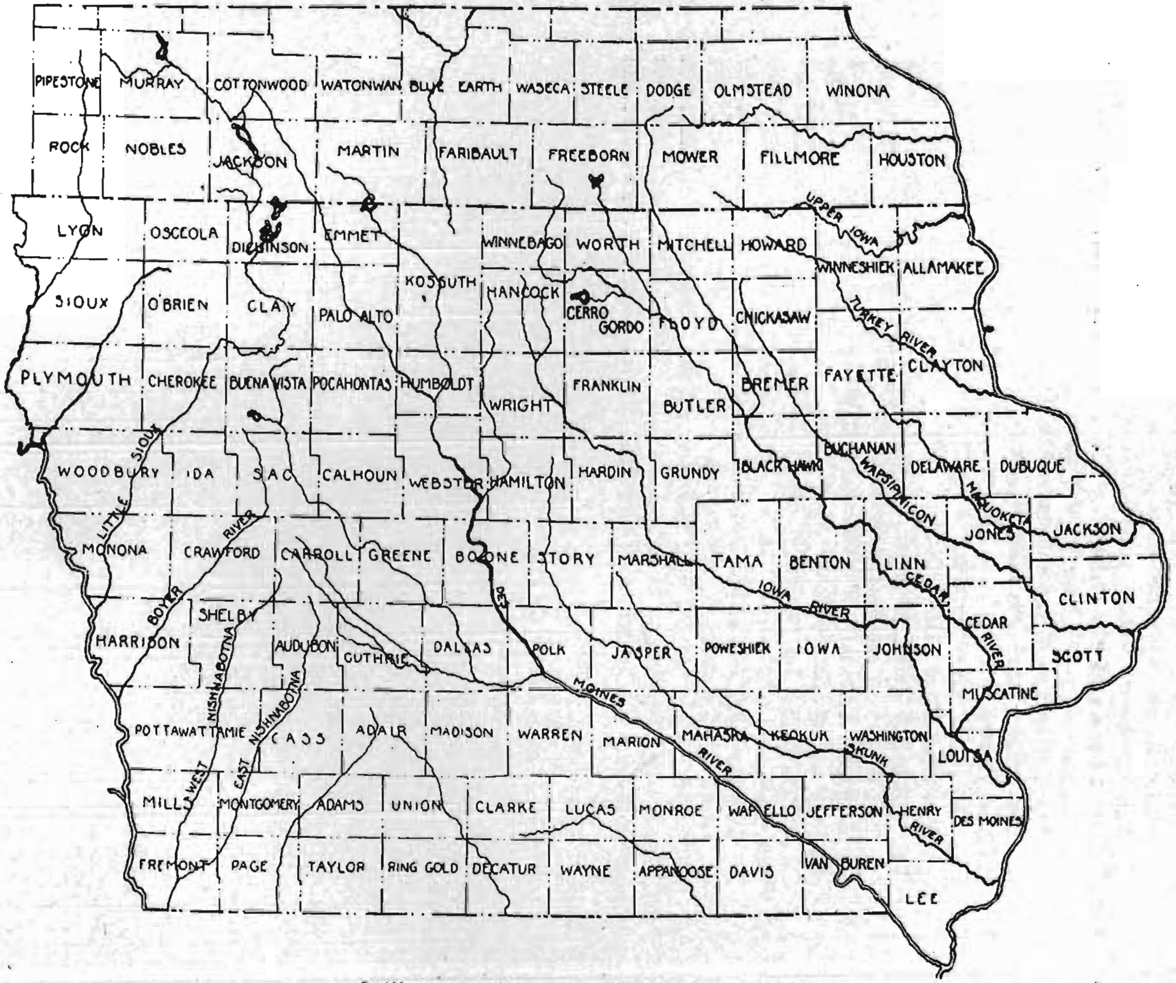


Outline map of southern Minnesota and Iowa.

PHYSICAL FEATURES AND GEOLOGIC HISTORY OF DES MOINES VALLEY

CHAPTER I.

Introductory.

Purpose of this Report.—The aim of this report is to describe the important features of the valley of Des Moines river and to discuss as well the geologic history and structure of the region in which the valley is situated.

The motive in undertaking this work has been to make available for study and general use a simple and yet comprehensive outline of the characteristics of a typical Iowa river and its valley. A study of this kind should be of value and interest in widening and intensifying the knowledge of Iowa geography and geology, especially among Iowa people.

Area Included.—This study is not intended to be carried far beyond the immediate valley of the river, nor is it the intent to include the entire drainage basin, but rather the valley in its more restricted sense. Only the lower courses of tributary streams are considered. The broader view is left for a later, more inclusive survey. Plate XXVII will show the general relations of Des Moines valley and the region which it crosses.

Des Moines river aids in the drainage of three states. Its two forks, the East and the West, rise in the lakes and prairies of southwestern Minnesota and unite their waters below the town of Humboldt, Iowa. In the last few miles of its course it divides Iowa from Missouri and the irregular triangle included between the Des Moines and the Mississippi is the southernmost land of Iowa.

The Des Moines river system drains an area of 12,500 square miles in Iowa together with about 1,525 square miles in Minnesota and about 75 in Missouri. This gives to the entire basin an area of about 14,100 square miles. The basin is nowhere very wide and below the mouth of the Boone the divide between Des Moines and Skunk rivers is scarcely over ten to fifteen miles from the former stream.

History of Des Moines Valley.—The early settlers of Iowa sought the river valleys, both as lines of travel and in locating their homes. Railroads were unknown or so few as to be but slightly available and the river courses offered easy and certain lines of communication. The valleys furnished shelter for the homesteads and their supplies of timber yielded material for building as well as for fuel. The difficulty of winning the farm lands from the forest was supposed to be more than counterbalanced by the superiority of the valley soils over those of the prairie. These hardy pioneers had not come to realize that instead of marking the richest soils the forest indicated the poorer ones; that the barren open uplands carried a soil which would far surpass in its yield of crops the tree-covered soils of the valley sides. Many of the flat bottom-lands, it is true, bear a rich alluvial soil of great fertility. But the wider areas of forest-covered slopes can not hold rank with the prairies, as is shown abundantly by comparison of present day farms in the two regions. Nevertheless the forest-filled valleys served their purpose in offering indispensible timber and water for the standard bearers of civilization, and, leading as they did into the heart of the unknown, they were a perpetual incitement to further effort toward the solution of the mystery of the lands beyond.

For an early view of the prairies the following clipping from the Saint Louis Enquirer, written in 1819, is interesting. "After you get forty or fifty miles west of the Mississippi the arid plains set in. The country is uninhabitable except upon the borders of the rivers and creeks."

Apparently, the first white men to visit the Des Moines valley were Pere Jacques Marquette and Sieur Louis Joliet, who came westward from the Great Lakes country down the Wisconsin to its confluence with the Mississippi, which they reached on June 17, 1673. They descended the Father of Waters as far as the mouth of the Arkansas river and on their journey spent a few days on Des Moines river with a band of Illinois Indians. They reached the river on the 25th of June and were welcomed most hospitably by the Indians living on its banks. These natives called their village Mon-in-go-na, (meaning "at the road"), which name was shortened to Moingona by the map makers. Nicolet states that the French abbreviated the name still more, and, applying it to the river, called it "la riviere des Moins," whence the modern name. It was not until a later day that this name was associated with that of the Trappist monks (Moines de la Trappe), who lived with the Indians.

Other Indian tribes lived in the Des Moines valley, among them the Iowas, of whom Ma-has-kah was one of the noted chiefs. His home was near the present site of Eldon. The famous Black Hawk, chief of the Sacs and Foxes, spent his last years on the banks of the Des Moines near Iowaville, a village in Van Buren county near Selma, and he was buried near the northeast corner of Davis county, not far from his home. Keokuk, Appanoose and Wapello, chiefs of the Sacs and Foxes, lived near Agency and Ottumwa.

By treaties made in 1832 and 1842 the Sacs and Foxes ceded their lands, including the Des Moines valley below the junction of the two forks, to the United States. This was the Black Hawk Purchase. The upper stretches of the valley were owned by the Sioux and other tribes of the Dakota group, who ceded their lands to the Federal Government by various treaties between 1825 and 1846.

White men were pressing westward, government troops were stationed at army posts to preserve peace and order and it was not long until settlements were springing up all along the river, as well as elsewhere over the state. In 1820, Dr. Samuel Muir, an army surgeon stationed at Warsaw, Illinois, crossed the river and built a cabin and located a farm where Keokuk now stands. He and his Indian wife lived here until his death in 1832. A station of the American Fur Company was afterwards established here. The organization of a city was undertaken in September, 1834, and it was agreed to name the town for the Sac chief, Keokuk.

The Appanoose Rapids Company laid out a town site in May, 1843, and named it Ottumwa, an Indian word signifying "rapids" or "tumbling water," and in the same year J. P. Eddy, a trader, plotted a town at the location of his store and named it Eddyville. In 1859 the Burlington and Missouri River Railroad, now the Chicago, Burlington and Quincy Railroad, extended its line to Ottumwa and the next year the Des Moines Valley Railroad, since acquired by the Chicago, Rock Island and Pacific Railway, was built through Eddyville and Ottumwa and soon was extended through Oskaloosa to Des Moines.

In order to prevent disturbances among hostile Indian tribes and also to check the activities of a band of outlaws in the vicinity the Federal Government issued orders in 1842 for the establishment of a fort at the junction of the Des Moines and Raccoon. Captain James Allen ascended the river in November of this year to select a site and in March of the next year he returned and built the post, which General Scott named "Fort Des Moines." It was built on the west bank of the river near the present line of Second Street. The Government maintained the post until 1846, a year after the Indian reservation had been opened to settlers. The town was platted in 1846, and the Capitol of the State was located here in 1857. The first railroad to reach the town was the Des Moines Valley, in 1866. The Rock Island was built in a year later.

In 1835 Captain Nathan Boone was sent out in charge of a party of United States cavalry from a temporary post at the Raccoon forks. He explored the Des Moines and Boone river valleys and a few years later some of his party made settlements along the river. When these settlements were organized into a county, in 1849, it was named in honor of its first explorer, Boone.

Another of the outposts of the early days was located on the upper Des Moines by the Federal Government in 1850 and named Fort Dodge. This post was occupied by the army for three years and upon its abandonment the land was sold and a town site was platted and given the name of the army post. The town thrived and was soon made the county seat. It was not until 1869 that the Iowa Falls and Sioux City Railroad reached Fort Dodge and in this same year the town attained notoriety in another way—through the Cardiff Giant. This was a gigantic statue unearthed near the village of Cardiff, near Syracuse, New York. After being heralded far and wide as a "petrified giant" and a "Phœnecian idol" this statue was proven to have been carried from the gypsum beds of Fort Dodge, carved into its existent form in Chicago and taken to Cardiff and buried, soon to be dug up and exhibited as a marvel of antiquity. Even at the Pan-American Exposition in Buffalo in 1901 this statue was the center of such interest that many visitors paid admission to witness the great Cardiff Giant.

For many years gypsum had been used as a building material and in 1871 plans were perfected for making stucco and plaster from it. One of the first public buildings in which Iowa stucco was used was the new State House at Des Moines. Since then the industry has grown until Iowa ranks first among the states in the manufacture of gypsum products.

Coal mining began in Iowa in the year 1840 near Farmington. Some of the product of these early mines was hauled to Keokuk by team and some was used by the steamboats which came up the Des Moines. Coal retailed at $4.50 to $5.00 per ton. By 1843 the blacksmiths were using Mahaska county coal and within ten years several mines were opened in the county. During the fifties the village of Coalport in Marion county was the most important coaling station for river steamers between Eddyville and Des Moines. Today Coalport is wiped off the maps. In 1843 Captain Allen dug coal from the vein still exposed near the dam at Des Moines, but wood was so plentiful that coal could not compete very successfully. Its chief use was in the army blacksmiths' forges. After 1865 the industry grew rapidly and Polk county always has held a leading position as a coal producer. It was about the same time that mining in Boone county received great impetus by the advent of the Chicago and North Western Railroad. In 1870 the first shipping mine of Webster county was opened and since then coal has been mined continuously on a large scale. The fact that the Des Moines traverses the entire length of the Coal Measures in Iowa has made exploitation of the coal deposits relatively easy and has directed the growth of the industry along the valley. Here also is seen the influence of the river valley in the development of the state. Previous to the advent of railroads the river furnished a waterway leading to the heart of the state. One of the first railroads to be built in Iowa was pushed up the valley as far as Eddyville. At the present time two other railroads follow the valley more or less closely from Des Moines to Harvey.

The importance of the rivers for navigation was early realized by the people of Iowa and in 1846 Congress was persuaded to cede to the state upon its admission into the Union a grant of land for the improvement of the Des Moines. This grant included every alternate section on each side the river and within five miles of its banks. It was estimated in 1848 to amount to nearly 1,000,000 acres. Work was at once undertaken by the state for improving the channel of the river by the building of canals, dams and locks and the Legislature lent every aid in its power. The land was sold to settlers for $1.25 per acre. But the work proceeded slowly and by 1854 it was seen that river navigation could not be so successful as had been hoped and that railroads must be depended on very largely for transportation. By 1857 nearly $800,000 had been spent and but three dams completed. In this year the legislature authorized the payment of claims against the work and the sale of lands, tolls and water rents to any company who would give good security for the completion of the work. In 1858 a portion of the original land grant was given to the Keokuk, Des Moines and Minnesota Railroad Company for the purpose of helping the construction of a road up the valley of Des Moines river, and final settlement with the Des Moines Navigation Company, which had assumed the work, was provided for by granting to it another part of the land. This company claimed all the land included in the grant north of the Raccoon forks and from this claim arose one of the most expensive and disgraceful series of litigation in the history of the United States. There is not space here for recounting this episode but a full review will be found in Hon.

B. F. Gue's History of Iowa, from which the facts here given are gathered. Much of the land included in the grant still lies idle and useless as a result of the avarice of the eastern speculators who obtained title, however falsely, to the property.

General Character of the Valley. A. Geologic.—Throughout its entire course Des Moines river, including both its east and west forks, flows across a region which in past ages was covered by continental glaciers. The mantle-rock in this region therefore, is composed of loose material—clay, sand, gravel, bowlders—carried by these glaciers and left as sheets of glacial drift when the glaciers melted away. Overlying the drift sheet found south of Des Moines is a very fine-textured, yellow or gray, siltlike material known as loess. Beneath these superficial glacial deposits there is universally present the bedrock, which consists of layers of various classes of stone—limestone, sandstone or shale—and is for the most part in nearly horizontal position. In the upper stretches of the valley these rocks are concealed entirely by the mantle-rock and it is only near Humboldt that any outcrops of bedrock are to be seen on either branch. Below here to the Mississippi they are common features. The bottom of the valley is covered throughout most of its extent in Iowa with a layer of alluvium, which consists of black soil mingled with more or less coarser matter. In places great bodies of sand and gravel cover the valley floor or form terraces on its sides.

B. Topographic.—The topography of the region bordering the valley is determined chiefly by the glacial deposits, but in part by the bedrock. It is to be understood, of course, that the effects of these factors have been more or less modified by erosion. Below Des Moines the changes due to this agent are of large importance but they become less important in the upper portions of the valley. For this reason the valley itself below Des Moines is wide and mature, while most of the portion above the capital city is narrower and has the appearance of youth. It is true that in Kossuth, Palo Alto and Emmet counties, as well as in Minnesota, some parts of the valley are very wide, but at the same time they are very shallow and do not show evidences of much erosion. Their topographic features are of glacial origin, practically unmodified by the work of the modern stream.

It may be remarked that the statements regarding the topography of the valley hold true for the entire region drained by the Des Moines. Below the junction with the Raccoon, streams are abundant and have done much to modify the ancient land forms. North of the Raccoon the surface is much more level and streams and valleys are relatively rare while the prairies are dotted with sloughs and lakes, direct evidences of topographic immaturity.

CHAPTER II.

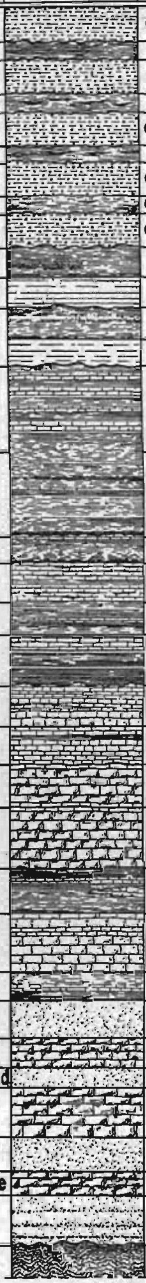
THE GEOLOGY OF THE REGION.

THE BEDROCK.

Rock Deposition and Erosion.—The geologic history of the Des Moines valley begins long before the formation of the oldest rocks exposed therein, but it will be understood that a knowledge of the underlying rocks and the history of their formation is necessary to a thorough comprehension of the later stages of the development of this region as revealed in the strata in which the valley itself is cut. The rocks which lie below the floor of the valley are similar in many respects to most of those which are exposed along its walls and from the very fact that they do underlie the valley we need to know something of their original character. Because of these facts and because there are several breaks in the record as found in the valley we must go outside our immediate region if we would learn the complete sequence of events.

Geologic time has been separated, for convenience, into divisions known in descending rank as eras, periods, epochs and ages. The rocks deposited during these time divisions are classed as groups, systems, series and stages (formations). In general the same names are applied to time divisions and to the corresponding rock strata. In order that the succession of these divisions may be clear the following table is inserted.

Era	Period	Epoch
Cenozoic	Quaternary	Recent Pleistocene
	Tertiary	Pliocene Miocene Oligocene Eocene
Mesozoic	Cretaceous	Upper Lower
	Jurassic	
	Triassic	
Paleozoic	Permian	
	Carboniferous	Pennsylvanian Mississippian
	Devonian	Upper Middle Lower
	Silurian	Cayugan Niagaran
	Ordovician	Cincinnatian Mohawkian Canadian
	Cambrian	Potsdamian Acadian Georgian
Proterozoic (Algonkian)	Keweenawan	
	Huronian	Upper (Animikee) Middle Lower
Archeozoic (Archean)	Great Schist Series	
	Great Granite Series	(granite intruded into Great Schist Series)

SYSTEM	SERIES	FORMATION NAME	COLUMNAR SECTION	THICKNESS IN FEET.	CHARACTER OF ROCKS
QUATERNARY	PLEISTOCENE	Wisconsin		0-30+	BOWLDER CLAY, PALE YELLOW VERY CALCAREOUS.
		Peorian			SOIL BAND
		Iowan		0-30+	BOWLDER CLAY. YELLOW, WITH VERY LARGE BOWLDERS.
		Sangamon			SOIL, PEAT AND FOREST BEDS.
		Illinoian		0-100+	BOWLDER CLAY, YELLOW.
		Yarmouth			SOIL, PEAT AND FOREST BEDS.
		Kansan		0-400+	BOWLDER CLAY, BLUE, JOINTED, WITH INTERCALATED STREAKS AND POCKETS OF SAND AND GRAVEL.
		Aftonian		0-40+	PEAT & FOREST BEDS, SOIL BANDS, AQUEOUS GRAVELS.
		Nebraskan		0-30+	BOWLDER CLAYS, DARK, FRIABLE.
CRETACEOUS	UPPER CRETACEOUS	Colorado		150	SHALES WITH SOFT LIMESTONES, IN PLACES CHALKY.
		Dakota		100	SANDSTONES.
PERMIAN		Fort Dodge		20	RED SHALES AND SANDSTONES.
				20	GYPSUM.
CARBONIFEROUS	PENNSYLVANIAN	Missouri		600	SHALES AND LIMESTONES.
		Des Moines		750	SHALES AND SANDSTONES WITH SOME BEDS OF LIMESTONE.
	MISSISSIPPIAN	St. Louis		100	LIMESTONE, SANDSTONE & MARLY SHALES.
		Osage or Augusta		265	LARGELY CRINOIDAL LIMESTONE, WITH HEAVY BANDS OF CHERT, SOME SHALE.
		Kinderhook		120	SHALE, SANDSTONE AND LIMESTONE, LIMESTONE IN PLACES OOLITIC.
DEVONIAN	UPPER DEVONIAN	State Quarry Lime Creek Sweetland Creek		(40) (120) (20)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA MOSTLY SHALES SHALE (LOCALLY DEVELOPED FEATURES EACH LYING UNCOMFORMABLY ON THE MIDDLE DEVONIAN.)
	MIDDLE DEVONIAN	Cedar Valley		100	LIMESTONES, SHALY LIMESTONES, SOME DOLOMITE IN THE NORTHERN COUNTIES.
		Wapsipinicon		60-75	LIMESTONES, SHALES. AND SHALY LIMESTONES.
SILURIAN	NIAGARAN	Gower		120	DOLOMITE, NOT VERY FOSSILIFEROUS, LE CLAIRE PHASE EXTENSIVELY CROSS-BEDDED.
		Hopkinton		220	DOLOMITE, VERY FOSSILIFEROUS IN PLACES.
ORDOVICIAN	CINCINNATIAN	Maquoketa		200	SHALE, SHALY LIMESTONES, AND, LOCALLY, BEDS OF DOLOMITE.
	MOHAWKIAN	Galena		340	DOLOMITE IN PLACES; IN PLACES UNALTERED LIMESTONES
		Platteville		90	MARLY SHALES AND LIMESTONES.
	CANADIAN	St. Peter		100	SANDSTONE.
		Prairie du Chien — Shakopee		80	DOLOMITE
		Prairie du Chien — New Richmond		20	SANDSTONE.
		Prairie du Chien — Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN	St. Croix — Jordan		100	COARSE SANDSTONE
		St. Croix — St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
		St. Croix — Dresbach		150	SANDSTONE, WITH BANDS OF GLAUCONITE.
ALGONKIAN	HURONIAN	Sioux Quartzite		25	QUARTZITE.

General Geological Section of Iowa.

If this table be compared with the general section of the rocks of Iowa, as shown in Plate XXVIII, or with figure 39, their relationships will become evident. It will be seen that the oldest rock exposed anywhere in the state, the Sioux quartzite, (compare also Plate XXIX) is evidence of the effectiveness in those early days of the processes of rock weathering, transportation and deposition—the processes by which sedimentation always has been carried on. For unknown ages the agencies of weathering had been attacking the rocks, and immense quantities of sand grains were accumulating as the residue of rock wastage and were being carried into the sea or piled upon the land. In time these grains were cemented and recemented until they became an extremely hard rock—the Sioux quartzite. While not over twenty-five feet of this quartzite are exposed in Iowa the total thickness is known to be many hundreds of feet. The rock outcrops in Iowa only in the northwest corner of the state but it underlies the entire state, probably, and reappears at the surface in south-central Wisconsin.

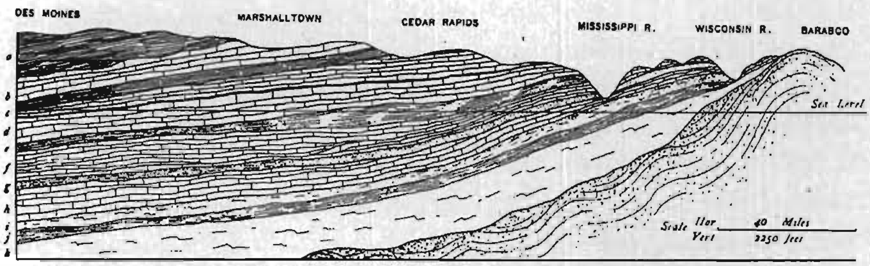


FIG. 39—Geological section from Baraboo, Wisconsin, to Des Moines, Iowa, showing the general stratigraphy of the region. The drift is not shown. The line of juncture of the Dresbach sandstone and the Huronian is hypothetical. *a* Des Moines; *b* Mississippian; *c* Devonian; *d* Niagaran; *e* Maquoketa; *f* Galena-Platteville; *g* Saint Peter; *h* Prairie du Chien; *i* Jordan sandstone; *j* Saint Lawrence; *k* Dresbach.

Immediately beyond the margins of the Des Moines basin in southwestern Minnesota the Sioux quartzite outcrops in widely separated areas around Pipestone and a few miles north of Windom. This formation also immediately underlies the drift in a somewhat limited area between those just mentioned, and within the confines of the valley; but the rock nowhere rises nearer the surface than 100 feet, and it has not been reached by post-Pleistocene erosion. It is not at all probable that it exerts any influence on the position or character of the present valley.

We have been accustomed to think, perhaps, that during the formation of the continents they have changed places many times with the oceans as we now know them, that there have been going on during geologic times great oscillations between these two grand divisions of the crust. But it seems probable, indeed, it is almost certain, that the oceans have occupied substantially their present basins from the beginning of their existence; likewise, that the continental masses always have retained about the shapes and positions they now occupy. They have been often more or less covered with water, it is true, but the same condition exists today along the continental borders, and the presence of waters over the continents in times past was due merely to the action of the same forces which today are elevating or depressing parts of the land masses. These continental oceans or epicontinental seas always were relatively shallow, and the deposits formed in them wherever they are known, are all characteristic of shallow seas; none of them are at all like those found in the deep ocean basins. Thus near the shores, where rivers brought down their loads and dropped them, or where waves and currents carried them about, were formed the beds of sand which we know as the sandstones of the geologic section. The ocean waters carried a little farther out, the finer sands and the muds and silts but these soon were dropped and accumulated on the bottom, to be consolidated into beds of shale. Still farther from the shores and below the disturbing effects of the waves were formed banks of limy ooze, mingled with shells of marine animals, and out here would grow up coral reefs and banks. All of these united in forming the beds of limestone which are so common over the state. Some of the limestones were altered by the partial replacement of the lime by magnesia and became dolomites. In many cases the different classes of deposits grade into each other and we have sandy or limy shales, sandy or shaly limestones, limy or clayey sandstones. These beds have hardened into rock by cementation, by pressure of overlying rocks and by removal of the water contained therein.

It was under such conditions as these, then, that the sands which now form the Sioux quartzite were accumulated and that ages afterward the sands of the next member of the geologic column of Iowa—the Saint Croix—piled up on the sea bottom. This sea bottom must have been subsiding slowly through a long period to allow the building up of such an immense thickness—1500 feet— of fine material as the Saint Croix sandstones. Only about one-fifth of this total is exposed in Iowa.

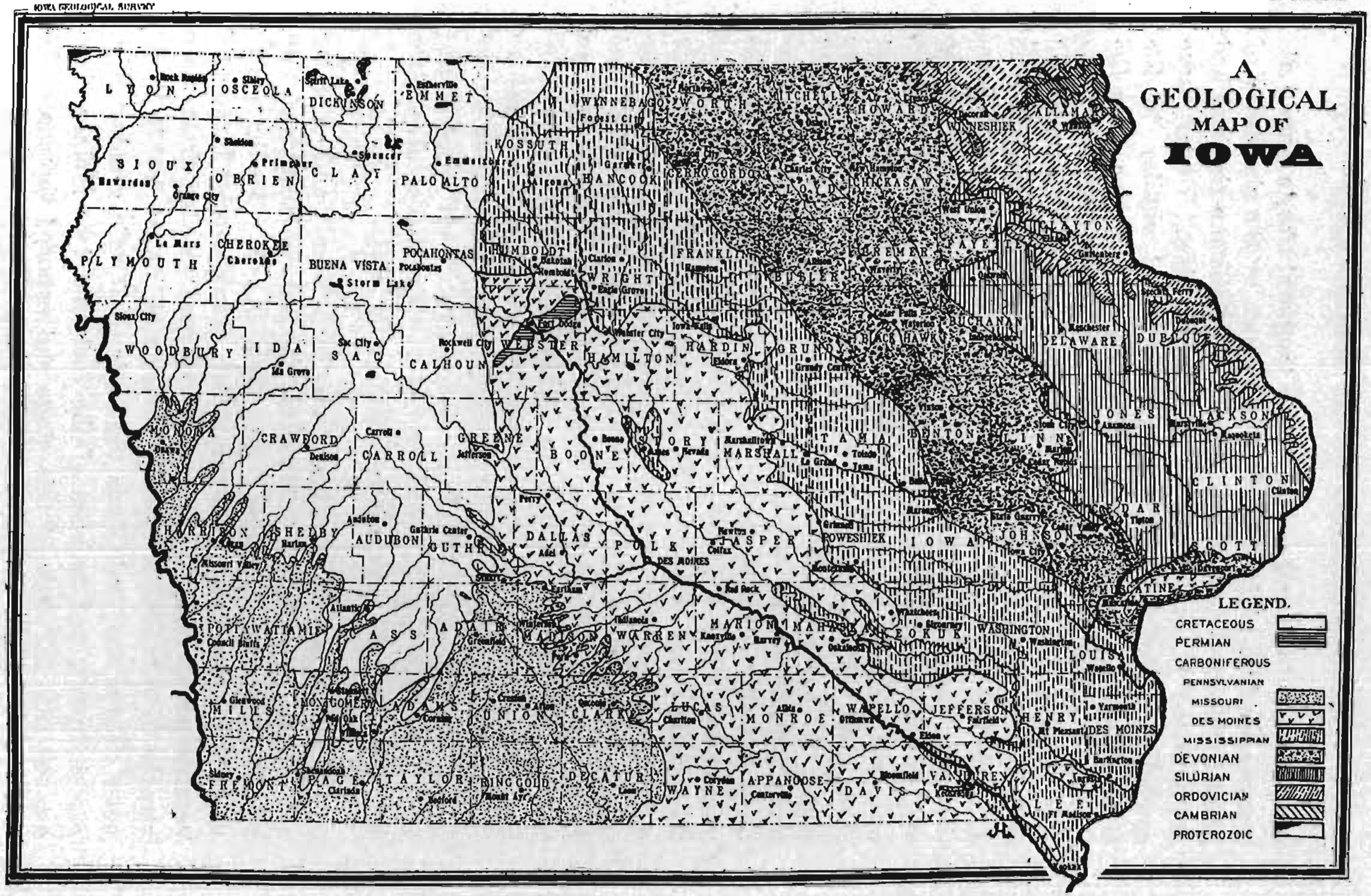
Above the sandstones of the Saint Croix were laid the varied types of rock of the Ordovician, Silurian and Devonian series, whose characters as indicated in the section (Plate XXVIII) bespeak the changing conditions attending their deposition. As these rocks are exposed nowhere within the area of our study we may pass them with this word. Since northeastern Iowa was being elevated slowly, though with many oscillations, during these epochs, the rocks now outcrop in parallel bands to the southwest of the ancient land mass, as may be seen by inspection of the geologic map, Plate XXIX.

The oldest rocks which are found at the surface in the Des Moines valley are those of Mississippian age and so it is with the beginning of the Mississippian epoch that the immediate history of the valley may be said to begin. Lest there be any misunderstanding it should be explained that the valley did not originate until long after this time, not until the epicontinental seas had left Iowa for the last time as will be described farther on. But the history of the Mississippian and later rocks becomes a part of the history of the Des Moines valley because it is through these rocks that the valley has been sunk. Therefore the course of events from this time forward acquires a special significance in our study.

A study of the geological map, Plate XXIX, will show that Mississippian strata form the country rock under a considerable area in north-central Iowa, as well as under a wide band southeast to the Mississippi. North of the latitude of Des Moines these country rocks belong chiefly to the Kinderhook stage (Plate XXVIII). In the valley of the Des Moines these strata outcrop only as very small patches along the river in central Humboldt county along the West Fork. The strata of the Osage stage (Plate XXVIII) are found in the valley of the Mississippi below Fort Madison and appear along the Des Moines as a narrow belt extending up to the Keosauqua oxbow. Above this point the Saint Louis limestones outcrop (Plate XXVIII) as long narrow patches extending up the valley into central Marion county, and again appearing as isolated areas in the bottom of the valley, or more rarely out on the prairies in Webster and Humboldt counties. The most northerly outcrops of this rock to be found along the West Fork are small exposures east of Bradgate. Similar outcrops are found at Dakota on the East Fork, but north of these points the indurated rocks are covered deeply with glacial drift.

Following the deposition of the Saint Louis strata the sea receded from Iowa and there followed a period of prolonged erosion, including the Kaskaskia (uppermost Mississippian) and the early part of the succeeding stage, during which valleys scores and hundreds of feet in depth were carved in the once level surface of the limestones. How irregular this surface became is shown by the fact that in the Greenwood Park well at Des Moines the top of the St. Louis limestone is 373 feet above sea level, at Commerce, a few miles to the west, it is 300 feet, at Valley Junction, intermediate in position, it is about 600 feet, at Carbondale, a village at the southeast margin of Des Moines, the surface of the rock is about 600 feet above sea level, and at Mitchellville, about twelve miles to the northeast, it rises to 760 feet above sea.

This period of erosion had brought much of the country to the condition of a low plain and as another periodic incursion of the sea began at the opening of Des Moines times (Plate XXVIII) great areas were reduced nearly to sea level. Climatic conditions now favored the development of a vegetation exceeding in luxuriance anything the earth had yet seen. These con-


A
GEOLOGICAL
MAP OF
IOWA
LEGEND.
CRETACEOUS
PERMIAN
CARBONIFEROUS
PENNSYLVANIAN
MISSOURI
DES MOINES
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
CHICKASAW
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
FAYETTE
WOODBURY
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SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
DES MOINES

ditions seem to have been moderate temperatures, a humid atmosphere and a uniform climate, as shown by the similarity of plant life from Greenland to Brazil. In addition a rich soil had accumulated through ages of rock weathering. Under these conditions great coastal swamps developed similar to the Great Dismal Swamp of Virginia. In these swamps grew the moisture-loving plants of the times, such as great tree ferns and clubmosses. These flourished, died and fell, were buried in the water and succeeding generations followed them. In time a thick bed of vegetal matter accumulated, preserved from decay by the water. A slight change of level brought in the sea, or enabled the streams to carry in detritus from the lands, and this bed was covered by sediments, usually mud, in some cases sand. When this layer approached the surface or another slight earth movement occurred, vegetation would take hold again and the process would be repeated. Meanwhile the underlying bed of vegetal matter was being compressed, some of the gases were driven off, and a bed of coal was being evolved. If the swamps had continued for a long time the coal bed was correspondingly thick, or on the other hand, it might be a mere film between layers of mud. In this way bed above bed of coal formed in the coal swamps until in places in the Des Moines valley there were ten or twelve. Meanwhile the sea was creeping northward until it had covered the Saint Louis limestone in Webster county, and had overspread the older beds as far as Linn and Jackson counties. Later it retreated to the southwest and, following the deposition of the Missouri strata (Plate XXVIII), passed beyond the limits of the state.

The Des Moines beds extend today in a broad band on either side of the Des Moines valley from the eastern border of Van Buren county to Humboldt. See Plate XXIX. To the southwest they pass under younger rocks. They consist largely of sandstones and shales, with seams of coal varying from mere streaks to beds four or five and rarely eight or ten feet in thickness. These coal beds form the basis of Iowa's greatest mineral industry, and because of the fact that Des Moines river has cut into the beds of this stage and exposed the coals, the mining industry of the state has always centered along the valley. The value at the mines of the coal produced in Iowa in 1915 amounted to $13,577,600. The shales of the Des Moines beds, or Lower Coal Measures, make high grade brick, drain tile, sewer pipe and other ware.

It is very difficult to determine the relations of different beds in the Coal Measures because of the lack of continuity between them. The coal swamps seem to have been limited in extent and the same is true of most of the other beds. However, those in southeastern Iowa doubtless are the oldest of those exposed at the surface, while those seen between Des Moines and Fort Dodge probably belong about in the middle of the stage. These may correspond to the Cherokee shales of Kansas. The younger layers occur in the counties west of the river from Appanoose to Guthrie. Some of these latter are quite constant over wide areas. Probably they are to be classed with the Henrietta and Pleasanton formations.

In Webster county there is a series of rocks of Permian age, laid down in a basin cut in the beds of the Des Moines and Saint Louis stages (Plates XXVIII and XXIX). The basin extends across the county from northeast to southwest, and in it are found the bed of pure gray gypsum for which Webster county is noted, and about twenty feet of overlying red shales and sandstones. The gypsum is extensively mined and quarried for manufacture into wall plaster, plaster of Paris and other products. In 1915 the output of these articles was valued at $1,278,128. The river has cut its valley right across the old basin and through the gypsum, through the Coal Measures in many places, down into the Saint Louis limestone. Whether there are elsewhere in the state other beds of Permian age now covered by later deposits is not certainly known. Probably there were such at one time but doubtless they were removed by erosion during the long interval preceding Upper Cretaceous times, and doubtless the wastage was continued in some localities until the indurated rocks were covered by the deposits of the Pleistocene.

The Permian ocean came from the southwest and on its floor were formed the salt beds of Kansas and the gypsum of Iowa, Kansas, Texas and Oklahoma. These gypsum and salt beds are indicative of an arid climate and they tell us that during the Permian the interior sea was more or less cut off from communication with the oceanic waters. In this restricted sea evaporation proceeded until gypsum was precipitated, and in some cases the process went on until salt was deposited. In Webster county the bed of gypsum thus formed has a maximum thickness of thirty feet. A few thin interstratified clay bands speak of the admission of new supplies of ocean waters from which again precipitation took place. Then there came a more extensive inundation attended, probably, by uplift of the lands, and the red shales and sandstones overlying the gypsum were brought in. They were the terrestrial remnants of erosion under arid conditions as the gypsum was the marine representative of these conditions. In places the shales are interbedded with thin layers of gypsum. No fossils have been found in these beds.

There had been similar periods of aridity in past times, for the record of the deep well at Des Moines shows layers of gypsum in the Silurian, and during 1911 a bed of pure gypsum eighteen feet thick was found in the upper part of the Saint Louis limestone at Centerville in Appanoose county. These facts emphasize the recurrence of similar conditions during geologic history and they also show conclusively that the earth could not have been swathed in a dense blanket of hot vapors and heavy gases during Paleozoic times, as was long supposed. The presence of glacial deposits in the Permian of India, South Africa and South America also points to the same conclusions.

All through the Triassic and Jurassic and Comanchean (Lower Cretaceous) periods the Des Moines valley, in common with all the upper Mississippi valley, was land, and was subjected to all the degradational processes of Nature. Just how much was accomplished by these processes is difficult of reckoning. If we could gain an estimate of the differential erosion in areas not covered by Upper Cretaceous sediments over those which have been so protected, we might have a fair basis for judging of this pre-Dakota erosion. But the entire country affected is overlain by drift and the region covered by Cretaceous deposits (Plate XXIX) is especially deeply buried, so that it is almost impossible to judge of what was done during this long period.

With the opening of the Upper Cretaceous (Plate XXVIII) there was ushered in the formation, as a lake and river deposit, of the Dakota sandstone, a very widespread stratum whose eastern fringe is found in western Iowa. Following this there occurred one of the greatest incursions of the sea known in geologic history and in this sea were deposited the chalks and other beds of the Colorado stage (Plate XXIX). While Cretaceous strata probably underlie the valley of the upper Des Moines they are exposed nowhere in this region and are of no practical consequence as a topographic factor.

A series of great crustal and mountain-making movements marked the close of the Mesozoic and the beginning of the Cenozoic eras. See the table on page 437. Throughout most of the Cenozoic the Des Moines valley was affected almost entirely by the degradational forces of Nature. The rocks have been weathered and carried away by the waters, the topography has advanced through the different stages of development and in addition there have been progressing certain diastrophic movements which eventually have raised northwestern Iowa from a position below (Cretaceous) sea level to one which gives it the highest altitudes within the state. The culmination of these movements probably came after the close of the Pleistocene. By the close of the Mesozoic, too, northeastern Iowa had been cut down to a low, level plain and subsequently shared in the elevating movements mentioned above. These various uplifts while very slow, gave the drainage systems new energy and enabled them to cut deep valleys into the surface. Some of the rivers of eastern Iowa probably owe their origin to this quickening and the same doubtless is true of the two great rivers bordering the state. The Des Moines basin probably owes its location to these different warpings of the surface, although the present valley differs widely from the original.

It will be seen that the geologic range of the bedrock exposed in the Des Moines valley is quite limited. From the Kinderhook of Humboldt county, and the Osage, as seen near Keokuk, through the Saint Louis, the Des Moines and the Fort Dodge stages (Plate XXVIII) is only a small portion of the geologic section of the entire state. Not over twenty feet of Kinderhook limestone are exposed near Humboldt and Rutland, but nearly the entire thickness of the Osage and all of the Saint Louis and Coal Measure beds are cut through by the river in its lower course. Within this limited span are compassed some of the most characteristic and vital elements of the geologic record.

Structure.—A number of years ago a well was drilled in Des Moines to a depth of 3000 feet. The section of this well, when compared with the geologic map, shows the important fact that all of the strata which appear at the surface in eastern Iowa as roughly parallel belts are present beneath the site of Des Moines. Now the Saint Croix sandstone at Lansing, Allamakee county, rises 300 feet above Mississippi river or 930 feet above sea level. But this sandstone is reached in the well at Des Moines 1547 feet below sea level. In other words it has descended about 2475 feet in the 175 miles between the two towns. The same condition holds true for the strata above the Saint Croix, and this is the dominant factor in the structure of the strata underlying the Des Moines valley. These rocks are not warped or twisted or folded to any great extent but all have an inclination to the southwest of a few feet to the mile. This does not apply, of course, to the deposits of Pleistocene age, as these were laid down indiscriminately upon the beveled edges of the older formations. It is true also that there are a few warpings of the strata, such as one, an upbending or anticline, in the Saint Louis strata of Story county, just beyond the limits of our present study. But these are only minor exceptions to the general rule.

In northwestern Iowa, conditions are reversed. Here the Sioux quartzite formed an island in the ancient seas, just as did the Cambrian sandstones in northeastern Iowa, and so the strata rise to the north and northwest, so that at Sioux City the top of the Saint Croix sandstone lies about 300 feet above sea level.

Thus it happens that, in northern Iowa at least, and probably as far south as Des Moines, the river valley lies near the axis of a great trough, or syncline, which embraces the whole state and extends beyond its borders. It is scarcely likely, however, that this trough determines the position of the river, as the depression had been filled up before the river began to cut the valley.

A feature which cannot fail to interest the student is the apparent discontinuity of the beds as they are exposed along the walls of the river valley. Thus at several points north of Fort Dodge the river has cut into beds of sandstone, shale and coal belonging to the Des Moines stage, while between these exposures there are outcrops of limestone of Saint Louis age. The same is true below Fort Dodge, where gypsum of Permian age, shales or sandstone of the Coal Measures and limestone of the Saint Louis stage alternate in the valley walls. This phenomenon is not due to breaking up or displacement of the strata, as might be suspected, but to the fact that the younger strata are in each case laid down in channels or basins cut into the older rocks. Small bendings of the strata also may cause similar appearances, though these probably are not so common as are the features due to erosion.

THE PLEISTOCENE SERIES.

General.—Some scattered beds of sand assigned with some uncertainty to the Pliocene are the only known representatives of the Tertiary system in Iowa. The climate of the Tertiary period was mild and pleasant, with gradual development of temperature zones. But by the end of the Pliocene the climate of North America had become much cooler and with the opening of the Pleistocene (Plate XXVIII) there was initiated the most remarkable series of glacial invasions of which present day science has knowledge. What the ultimate causes are which lead to the formation of a continental ice-sheet is not positively known, but whatever the causes were they resulted in the formation in Canada of several great snow-fields from the excess of snowfall over summer melting. It will be seen that this condition would tend to be self-perpetuating and so the snow-fields increased and the snow became ice. Then under the pressure of its own weight the ice began to move away from the center of accumulation and became a glacier. The glaciers from the different centers spread until at their maximum they covered Canada and extended into the United States as far as Long Island and Ohio and Missouri rivers. About 4,000,000 square miles of North America were buried under this frigid mantle. Following a period of glaciation came one of more genial climate when the ice was melted partly or wholly away. This succession took place several times and so the Pleistocene consists of a series of glacial ages alternating with a similar series of interglacial ages.

The Work and Movement of an Ice Sheet.—The progress of a glacier is accomplished by the forward movement of the ice, caused by the pressure at the center of the ice-field, aided more or less by the slope of the ground. But when the front of the glacier retreats there is no backward motion. The ice either continues to advance or remains stationary. The recession is caused by the excess of wastage through melting or evaporation over advance by forward push of the ice. There also will be times when the ice front will remain stationary, when the two factors of forward push and wastage balance more or less exactly.

In its advance the glacier tended to plow up the superficial covering of the rocks and because of its own weight and force and with the aid of the loose material it had thus accumulated it scored and scraped the rock surface and plucked off such masses as it could move. In this way the glacier gathered a great load of rock-flour, clay, sand, gravel and bowlders, which was carried or pushed toward the margin. At the ice-front where melting was in progress, the material brought down was dumped in great heaps and ridges or was carried away by the streams flowing from the ice. When the front retreated the glacier's load was spread blanket-like over the ground. If the margin remained stationary for an interval during its retreat another series of heaps and mounds would be piled up. The ridges thus formed at the limit of the ice-sheet are known as a terminal moraine, those marking stages of rest in the retreat form recessional moraines and the great sheet of detritus spread over the ground is the ground moraine, the glacial drift, the till. The content of the moraines naturally will depend upon the character of the rocks over which the glacier passed. Thus the Kansan drift of western Iowa contains large numbers of Sioux quartzite bowlders, gathered from the ledges of quartzite outcropping in the area centering about Sioux Falls. The Iowan drift of eastern Iowa carries many immense granite bowlders picked up or plucked from the parent beds in Minnesota or Canada. While most of the material of the till is local in origin, some has been transported for scores and hundreds of miles.

Types of Deposits.—The deposits of the Pleistocene series belong to two classes—first, bowldery clays, with associated sands and gravels and in some areas numerous surface bowlders; and second, soil bands, peat beds, forest remains, and silts, sands and gravels. The deposits of the first class owe their origin and position to the work of glaciers and glacial waters while the beds of the second class in part are the remnants of the vegetable life of the interglacial ages and in part represent the work of the interglacial streams.

In addition to these two classes mention must be made of a peculiar type known as the loess, which is intermediate in its relations to the other two groups. It may be stated that the bed rock series are largely of submarine origin. They were laid down under the sea. On the other hand, the Pleistocene deposits were all made after the lands had been raised above the sea. They are subaerial or subglacial according as they were formed in the air or under the glaciers.

History of Glacial Invasions in Des Moines Valley.—When the first continental glacier of the Pleistocene, the Nebraskan (Plate XXVIII), entered Iowa it found a deep layer of residual material, which it plowed up and again spread out, together with some foreign material, as the Nebraskan drift sheet. This sheet is covered commonly by later beds and so is known chiefly by exposures along river banks and in artificial excavations.

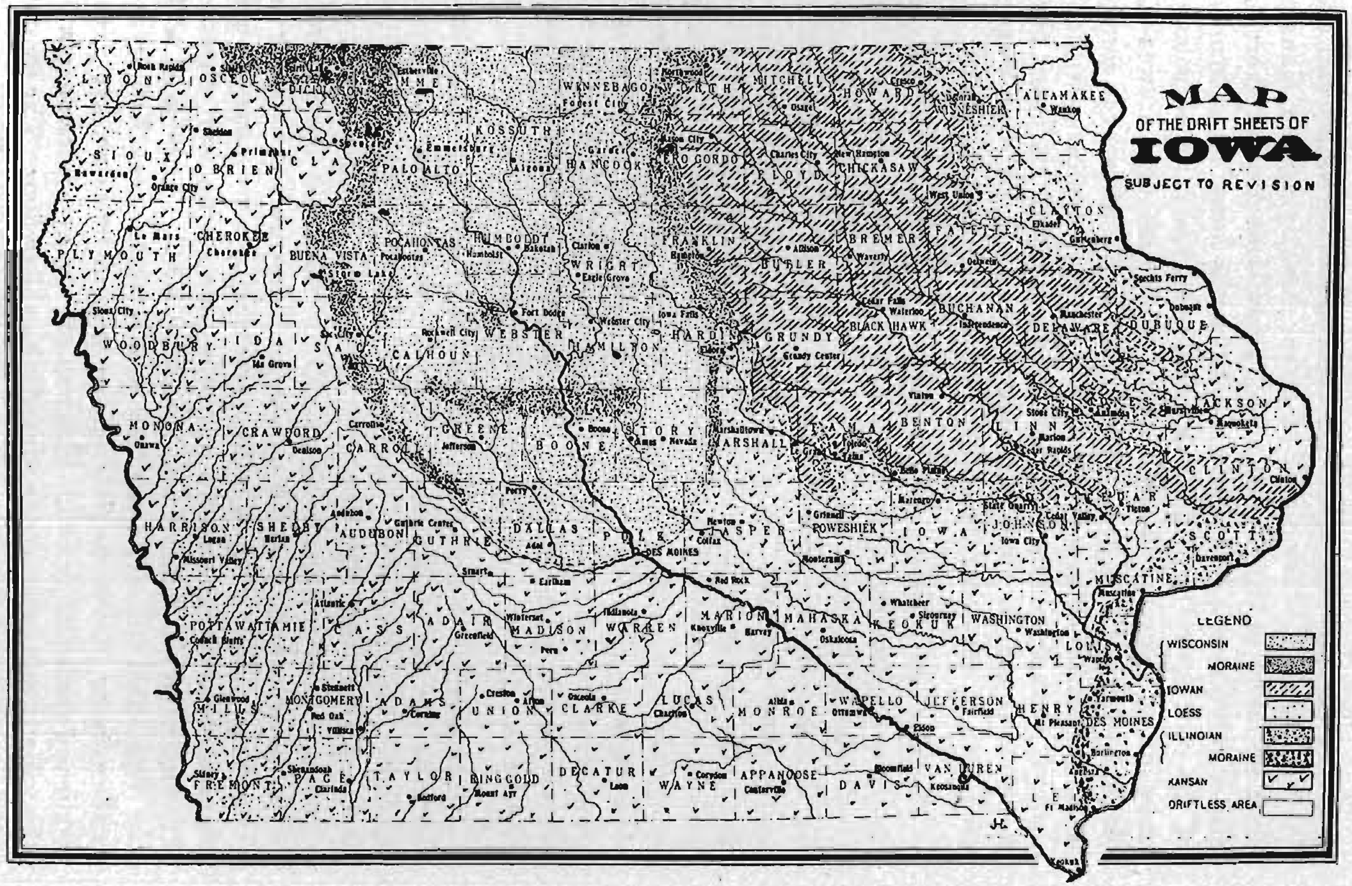
It has been found at different localities in the valley and over the state, for example, in Fayette, Polk, Union and Harrison counties, but its exact extent is not known. Where it is unweathered it is a very dark gray, almost black clay, containing some pebbles. When dry it breaks into small blocks like starch but when wet it is very gummy and sticky. How long this glacier covered the state is not known but its occupancy probably is to be reckoned in thousands of years.

During the Aftonian interglacial age the climate became so mild that such animals as the horse, camel, elephant, deer, bear, sloth and many others flourished on the plains and in the forests. During this time, too, great floods carried down immense quantities of sand and gravel, which filled many of the stream valleys.

The Aftonian is thought to have been the longest of the interglacial ages, and there seems to have been a progressive shortening of these from the earliest and longest to the latest and shortest.

After many years, however, the conditions favoring the formation of the continental ice-sheet recurred and again the glacier crept down from the north and spread over Iowa and as far south as Missouri river. This is known as the Kansan glacier and its work was similar to that of the Nebraskan except that some of the material which it found and worked over was drift from the older sheet which had escaped erosion during the long Aftonian interval. The Kansan is the surface drift of the Des Moines valley south of the city of Des Moines and over probably half the state (Plate XXX). It is typically a bluish pebbly clay becoming yellow and even reddish on exposure. Many outcrops may be seen on the valley sides bordering the Des Moines and at some localities Aftonian and Nebraskan materials are found between the bedrock and the Kansan drift. However, for the most part the latter rests directly on the bedrock, and the same condition holds true in the case of the later drift sheets.

Associated with the Kansan drift sheet in different parts of Iowa are large bodies of gravel, some of them rusty and weathered, known as the Buchanan gravels and belonging to the Yarmouth interglacial stage (Plate XXVIII). These are ex-


MAP
OF THE DRIFT SHEETS OF
IOWA
SUBJECT TO REVISION
LEGEND
WISCONSIN
MORAINE
IOWAN
LOESS
ILLINOIAN
MORAINE
KANSAN
DRIFTLESS AREA
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
MITCHELL
HOWARD
WINNESHIEK
ALLAMAKEE
SIOUX
O'BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
CERRO GORDO
FLOYD
CHICKASAW
CLAYTON
FAYETTE
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
CEDAR
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
DES MOINES

posed at several localities along the Des Moines valley and are very common in other parts of Iowa. Overlying the Kansan drift at many points in the valley below Des Moines there is also a fine blue-gray or yellow silt known as loess. It is formed of the rock-flour from the glacial mill and seems to be related in origin of material to the Kansan drift, although it owes its present position to deposition by winds which brought it chiefly from the valley flats near by. The loess is typically without pebbles, though locally it is sandy, especially in its basal portions. It is usually more or less calcareous, except when weathered, and is noted for its ability to maintain vertical walls.

The third or Illinoian glacier failed to affect Des Moines valley except indirectly, since at its closest approach—in Lee county—it was still several miles from the river, and the upper valley is much farther distant, as will be seen from examination of the map opposite. It seems probable that these conditions were true of the Iowan ice-sheet also, although the general direction of the southwestern margin of the Iowan drift-sheet is such that if it were continued to the northwest it would bring that margain near, if not into, Des Moines valley. Further discussion of the effect of a possible invasion of the valley by the Iowan ice can be given best in connection with the detailed outline of the history of the valley. See page 548.

Stretching as a broad lobe southward from Minnesota into Iowa as far as Des Moines, is the drift sheet of the Wisconsin glacier. This, the most recent of the glacial drift sheets of the state, differs from the others in presenting along parts of its eastern and western margins ranges of knobs and mounds scattered promiscuously about or grouped compactly together in long series. This is the Altamont moraine, and a similar, though smaller, recessional series within the area of the drift sheet is known as the Gary moraine. See Plate XXX. Associated with the Wisconsin till, as in the Des Moines valley near Estherville and in many of the mounds on the ground moraine, are great bodies of sand and gravel. Those of the valley are remnants of the valley train, which once covered the valley floor. The mound gravels are *kame* deposits.

The valley of the Des Moines crosses two of these drift sheets—leaving the buried tills out of consideration—namely the Wisconsin and the Kansan. The upper valley, down to Des Moines, is parallel with the axis of the Wisconsin lobe and in northern Boone county cuts directly through the Gary moraine. Below Des Moines the river turns a little more to the east and flows across the Kansan plain to the Mississippi.

The glacial forces seem to have exerted their greatest efforts in the early invasions, for the last two failed by many miles to reach the limits of the earlier ones. In Iowa the Iowan and Wisconsin glaciers are represented merely by lobes covering a few counties each.

Physiographic History.—There are now no well-defined terminal or recessional moraines belonging to the Kansan drift. Such as may have been left by the ice long since ceased to exert any visible effect on the topography. On the contrary, streams have been long at work upon and have cut deep trenches into the Kansan till. While the skyline is almost everywhere level, the surface is deeply scarred and gashed by rivers, creeks and ravines. The Kansan ice-sheet, without doubt, left the surface with a topography not far from even and very similar to that of the Wisconsin drift sheet today. The amount of erosion which has taken place and the amount of time required for the work will be realized by anyone who travels over these two areas or compares topographic maps of the different sheets. The character of the topography of the younger and older drift sheets is an accurate index of their relative ages. The Wisconsin still has a typical glacial topography. It has been but little modified by erosion, comparatively few streams cross its surface and the terminal and recessional moraines doubtless are nearly as distinct as when first formed, while the ground moraine still retains its original features. Wide expanses of prairie stretch to the horizon, broken only by a shallow slough or deeper lake, or perhaps by a rare sag through which flows more or less intermittently a small stream carrying off the surplus rainfall.

Length of Time Involved.—Geologists have estimated the length of time since the climax of Late Wisconsin glaciation at 20,000 to 60,000 years. The interval since the final retreat of the ice would, of course, be many years less. Doctor Calvin, a number of years since, suggested 6,000 to 10,000 years for this period. The smaller figure, especially, seems low in view of the advanced civilizations flourishing on the earth at that time. If we adopt as unity the period which has elapsed since the Late Wisconsin drift-sheet began to suffer erosion, the ages of similar stages in the history of the Early Wisconsin, Iowan, Illinoian and Kansan are thought to be roughly represented by the series 2, 4, 8, 16. (The Late Wisconsin is the sheet found in Iowa; the Early Wisconsin occurs east of the Mississippi.) To these estimates we must add the time while the Kansan ice covered Iowa, the length of the Aftonian interval and that of the Nebraskan age in order to get the full sweep of the Pleistocene epoch. For the duration or antiquity of this first invasion, especially, we have no adequate data upon which to base any estimate. Although not too much confidence must be placed on the figures given they will serve to indicate the order of magnitude in which Pleistocene time must be computed.

It has seemed probable that the Pleistocene is one of the shorter geologic time divisions. If this is the case we may begin to gain some conception of the immensity of the periods of earth life. There are no means for a close measure of the duration of the geologic periods, but since an intelligible record was first made, with the beginning of Cambrian deposition, 100,000 feet of strata, at least, have been laid down by the extremely slow methods of erosion and reaccumulation. The length of time required for this has been computed variously at 50,000,000 to 100,000,000 years, with both higher and lower figures. Before the Cambrian lie the uncounted ages of the Proterozoic, which probably exceeded in length the duration of all Paleozoic and post-Paleozoic time. Again the Proterozoic was preceded by the illimitable eons of the Archeozoic, which is considered to have been longer than all succeeding time and preceding which were incalculable years of development and growth. Since life had attained probably three-fourths of its present development at the beginning of Cambrian time we may see how long must have been the antecedent ages of the earth.

POST-PLEISTOCENE EVENTS.

Down the full length of the Wisconsin drift lobe in Iowa extends the valley of Des Moines river (Plate XXX). In their upper reaches the two forks occupy shallow trenches in wide sags in the plain. As the junction point is approached, the sags grade into definite valleys and in Webster and Boone counties the river flows through a deep though not wide gorge. The sags show no evidence of being erosional but rather are constructional, in their present form at least; but where the river occupies a well defined gorge, as mentioned above, it has been very active and the gorge shows the large amount of post-Wisconsin cutting which has been accomplished within its limits. For it will be understood that whatever the development of a valley preceding any glacial age, the advancing glacier would fill the valley with drift as much as it was able and so would put an end to the life of the river. Many large streams have thus been blotted out. But others have been able to resurrect their valleys, as it were, and this is the case, in part, with the Des Moines, which has resurrected the lower part of that portion of its valley which was buried by the Wisconsin ice-sheet. But all the energies of the river have been devoted to the excavation or reëxcavation of its valley, and very little has been done toward carving any relief forms in the level prairies.

Below its exit from the Wisconsin plain at Des Moines the river has been long at work and in contrast to the very slight influence which it has exerted on the younger topography, its effect on the vastly more mature landscape of the Kansan is very noticeable. It has not only widened its valley but side wash has assisted it in smoothing down the valley slopes and its many tributaries have penetrated nearly all the surrounding prairies, which have been transformed into more or less flat-topped ridges and divides separating wide valleys.

During the glacial occupations those parts of the state not covered by ice were still subject to arctic conditions and plant and animal life must have been modified accordingly. With the passing of the glaciers, vegetation again spread its mantle of green over the desolate landscape and forests resumed their footing along the valleys. When the white man settled in these valleys they were covered with timber, which served as a protection against the wash of the slopes and bottom lands. The settlers' needs and their successors' greed and thoughtlessness have transformed many of these beautiful and useful timber tracts into barren wastes gashed by rains and trenched by ravines. In contrast with these tracts are those spots where judicious cutting and proper care have resulted not only in immediate financial returns, but also in assurances for the future by way of increase in economic and esthetic value.

With the clearing and cultivation of the hills and slopes there has come inevitably an increased wastage of the soil. Many of the hillslopes bordering the Des Moines in southern Iowa now show, instead of that covering of rich black loam which had accumulated during ages of plant growth, yellow patches which show where the top soil has been washed away, leaving exposed the unmodified and therefore less fertile loess or drift, which in turn is following the overlying loam into the valley.

Parallel with the erosive, down-cutting work of the rivers there is going on a process of up-building. The smaller streams may deliver to their mains the loads they have received, but in the case of the Des Moines, as with other large streams, deposition is taking place in the valley. Since the finer materials on the valley floor represent surface wash from fields and hillsides they are often rich in plant food. Hence when the bottom lands, covered with their veneer of fine black alluvial silts, are brought under cultivation, they yield bountiful returns for the labor expended on them.

The terraces of sand or gravel found along the river are not to be classed as postglacial, but are remnants of glacial valley trains and old flood plains which covered the valley floor, and the deposition of this material was associated with the closing stages of the ice-sheet. This is true also of the great bed of gravel filling the valley between Estherville and Emmetsburg. The sands of Van Buren and Lee counties also are to be assigned to a glacial age.

Upon the generally level surface of the Wisconsin drift are numerous depressions, some of which are filled with water and form lakes and ponds. Others have been partly filled, during the years, with the remains of water-loving plants and now contain beds of peat of varying thickness. Some of these lakelets or peat swamps may be found almost at the margin of the Des Moines valley and testify to the slight extent to which the river, as yet, has affected the topography left by the last ice-sheet.

It is probable that the elevation of western Iowa mentioned on page 447 has been in progress since the close of the Pleistocene. The east and west margins of the Wisconsin drift differ in height by several hundred feet and this seems best accounted for by the theory that in Wisconsin time western Iowa was lower than now by the larger part of this difference and has been elevated as a part of the general uplift of the continent closing the Pleistocene epoch. This tilting of the surface must have influenced the location of the Des Moines valley, whose position was being determined also by several other factors, among them the broad sags in the Wisconsin plain, the pre-Wisconsin valley—more or less drift filled, and the activities of that part of the antecedent river which had not been destroyed by Wisconsin glaciation.

CHAPTER III.

THE WORK OF RUNNING WATER.

THE GROWTH OF VALLEYS.

The Beginnings of a Valley.—Whenever a land area emerges from the sea or is uncovered by the retreat of a continental glacier its surface is somewhat irregular. Elevations alternate with depressions. If the depressions are without outlets—are basin-shaped—water from rainfall will fill the basins and they become lakes. If, however, the depressions have outlets the waters which fall upon their slopes are gathered into the lowest part—the axes—of the troughs and run off as streams. Even clear water running over loose material has some cutting power and so the water running down the slopes will cut for itself a channel in the axis of the hollow. The material which thus is cut away will assist in further cutting and so *gullies—infant valleys*—are made. Each succeeding rainfall aids in deepening and widening and lengthening the gullies until they develop into ravines and with further growth into valleys.

Why do some gullies remain small and insignificant while others grow into valleys hundreds of miles long and carry the waters of great rivers? Several factors influence the problem. Assuming an equal rainfall the size of the basin supplying the gully with water (the catchment basin) will affect the rate of growth of the gully. A gully carrying the run-off from a large basin will increase faster than one serving a smaller basin, since the greater the supply of water the greater the erosive power. Thus a gully may grow into a ravine and gradually rob its neighbors of their gathering grounds. The slope of the depressions acts in a similar manner. That stream which has a greater slope, or gradient, than its neighbor flows more swiftly, cuts more energetically and enlarges its channel in every direction more rapidly than do its weaker competitors. The law of the struggle for existence and the survival of the fittest is inexorable.

Stages in the Development of a Valley.—During the early part of its growth a valley is enlarged chiefly by cutting at the bottom because erosion is most active along this line. The valley is steep-sided and V-shaped. If it is being cut in unconsolidated material the walls will be no steeper than the angle at which such material can lie (the angle of rest). This usually is not much more than 30°. If the walls are of solid rock they may be precipitous or vertical. The valley is now in its youthful stage of development. It is well to call to mind here that the development of topographies follows that of valleys and hence the area which is affected by a series of young gullies or valleys is itself youthful.

With progress of time the valley lengthens by head erosion and at the same time, while deepening is still in progress above, the valley begins to widen in its lower part. The rains wash down the loose soil and stones from the sides and the stream may undercut its banks. The material thus thrown into the water is carried off and so the valley grows broader and at the same time the areas separating it from its neighbors on either hand (the divides) grow narrower. During the growth of the valley tributaries develop on either side just as the main valley grew on the original surface. These aid and indeed are the principal agents in cutting up the divides and also in wearing down their surfaces, which is one part of the development of topography. When the valley has acquired gentle slopes and a broad bottom it has reached the stage of maturity. The divides, by this time, have been reduced to rounded ridges with few or no flat tops.

By the time a valley has reached the point when flats have been developed to a notable extent the most active down-cutting has ceased. In other words it has, for the area where flats exist, practically reached its base-level.

This base-level always is reached first at the mouth and is here the level of the main valley, or of the sea if the valley opens into the sea. Back from the mouth of the valley the base-level rises somewhat, since a stream can not cut its channel down to a horizontal line, but always the channel assumes the form of a concave curve.

From this time on, then, the activities of the stream are devoted to side-cutting, and the valley grows wider and flatter while the divides become narrower and lower. The stream meanders across its valley from side to side, undercutting its banks and building up flats from the material thus gained as well as from that brought in by tributaries. In this way the valley passes through the later stages of maturity and arrives at old age. It will be seen that the different parts of a valley may show several or even all of these stages at the same time. Thus at the headwaters of the Des Moines the valley is still in its infancy and farther down the stages of youth and maturity are reached. In the last few miles of its course the valley has arrived at late maturity and long ago reached base-level—the level of the Mississippi bottom-lands.

It will be understood also that a given stage will travel up the valley from its mouth as development proceeds and that a given locality will pass through the stages from infancy to old age and possibly death, provided there is no interference. When erosion has reduced a surface to old age, when the divides are low and narrow, the land is said to be a peneplain (an "almost-plain"). If erosion proceeds further and the whole land becomes practically level it is called a base-leveled plain. None of our Iowa topography is at present in so advanced a state as a peneplain. The oldest part of the state, topographically as well as geologically, the Driftless Area (Plate XXX), is in its maturity.

The progression which has been outlined is known as a cycle of erosion, and every normal valley and normal topography passes through this cycle in greater or less degree. If the region remains stationary long enough the entire cycle will be enacted. But we have seen that in Iowa there have been many depressions and elevations and tiltings of great areas, and these have interfered with the histories of the streams. The lowering of the surface through crustal movements has drowned the lower reaches of the valleys and lessened or terminated the work of the upper parts and it is easy to see how the mature portion of a valley in this way may have had premature old age or death forced upon it. On the other hand, when the land has been elevated, the drainage systems have been quickened, their fall has been increased and the mature part of a valley, for instance, may have been rejuvenated by the increased erosive power of the stream, which has cut deeper into its bed and caused greater activity among its tributaries. If an area is tilted unequally the streams of the elevated portion will increase their activity and will deepen and enlarge their valleys, hastening the cycle along, while the streams and parts of streams in the unaffected land may not receive any quickening, or on the contrary may be unable to care for the increased loads of detritus brought down by the upper waters. In such a case their lower valleys will be filled up, will be aggraded, by this excess of sediments. There is no doubt that all of these accidents have affected the successive drainage systems of our state.

In our special region, the valley of Des Moines river, there is another complication. This lies in the fact that the upper part of the valley has been obliterated, or practically so, by the Wisconsin glacier, as discussed in Chapter II. Because of this we have the unique phenomenon of a young valley being attached to a mature valley. Of course the valley advanced northward from Des Moines as the ice melted back, keeping pace with the retreat of the margin, and so the lower part of this newer section is a little older in years as well as in development, than the stretches farther north. But in spite of this the statement as to the inequality of development of the two parts is essentially true.

THE WORK OF STREAMS.

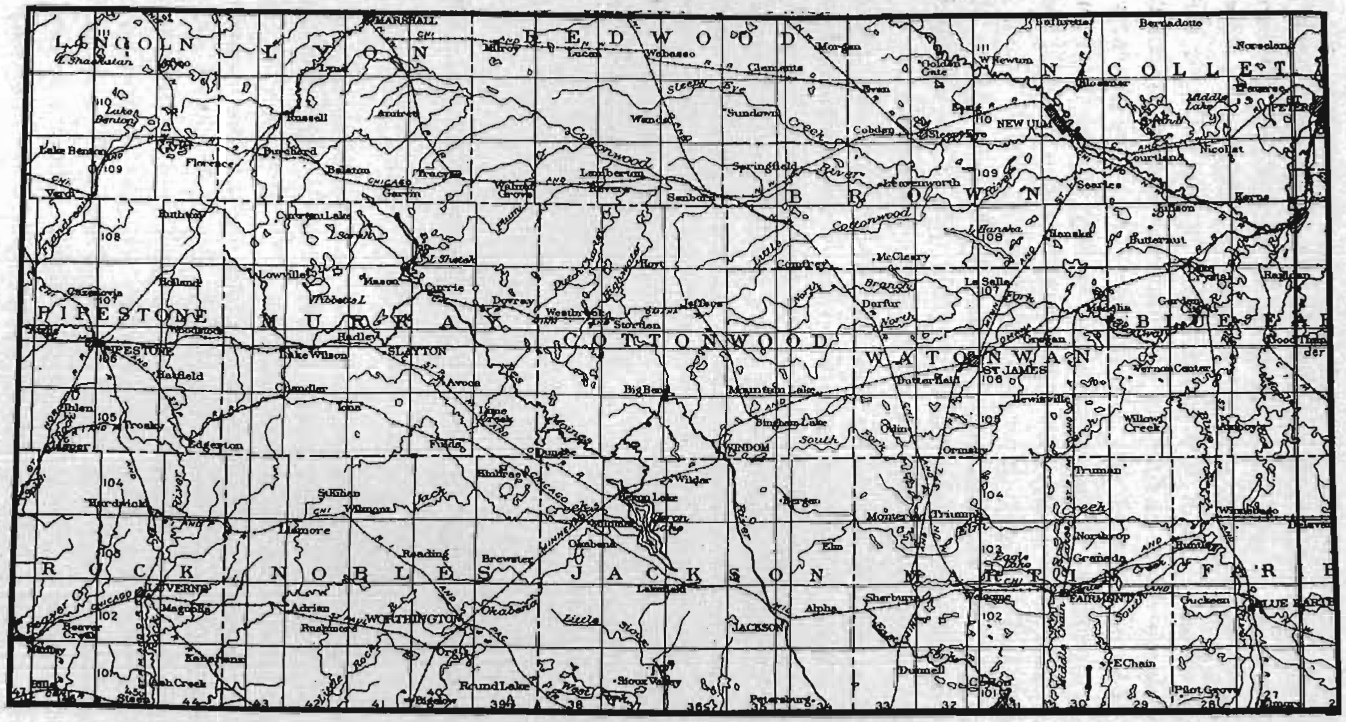
Growth of the Stream.—In the preceding paragraphs attention has been devoted chiefly to valleys, but it has been made plain that these owe their origin and development to running water, or streams. Normally valleys begin by the work of wet weather torrents and are dry between rains or rainy periods. But by and by, as these torrents cut deeper valleys, water stands in these valleys or flows through them during a greater portion of the year, and with the continued growth of the valleys they come to have permanent streams. How is this brought about?

We know that if we dig a well water will fill it to a certain level. If other wells be sunk near by through similar material water will rise in them to a similar level. This level is known as the ground-water level or water table. The surface of the water table partakes somewhat of the irregularities of the topography, rising under the uplands and sinking beneath the valleys. But it is not so near to the surface under the hills and may rise to the surface of depressions, creating swamps and lakes, or if the depressions have outlets, allowing the ground waters to flow away as streams. The ground-water level rises in wet weather and sinks in dry seasons as is known to anyone who has had experience with wells. Now when a valley is cut down to the ground-water level the valley will have a stream which is permanent so long as the water table maintains its level. If during the summer months the water level sinks below the valley the stream dries up until the water level rises again.

Below the water-table the rocks are saturated to unknown depths. It has been estimated that the ground water in the upper 100 feet of the earth's crust in the humid regions is equal to one-fourth of the volume of the subsoil and rock and that it represents six or seven years' rainfall. It is equivalent, therefore, to a reservoir twenty-five feet deep and having an area equal to that of the humid regions. Since the annual rainfall in Iowa is about thirty-one inches, this reservoir represents ten years' rainfall. The ground water is supplied by rains and represents that portion of the rainfall which soaks into the soil. Another part is evaporated while a third portion flows away at once into the streams as the run-off.

The different parts of a large valley will show various stages in the development of the stream. Des Moines river, for instance, is permanent in the driest seasons from its mouth to the forks at Humboldt and both branches flow continually many miles above here. So at Algona on the East Fork the valley contains a permanent stream but at Armstrong during the dry summer of 1911 only disconnected pools occupied the lowest hollows of the channel. Similarly, on the West Fork there is a never failing stream at Estherville but at Windom, Minnesota, the channel was dry except for isolated pools during the dry season mentioned, while in the extreme upper reaches of the valley above Lake Wilson, in Murray county, there were scarcely any pools and the tiny channels of the river's feeders are occupied only by wet weather rivulets.

Work of the Stream.—The great work of streams is the cutting down of the land and carrying it to the sea. The manner in which streams work during the stages of their development has been indicated in the discussion of Valleys. The ability of flowing water to push or carry solid material is shown by every stream. This ability varies with the slope or gradient of the bed and with the volume of water, both of which factors affect the velocity. Hence the working power of the stream's tools—the materials it is carrying in suspension—is enormously increased with added velocity. In addition to carrying matter in suspension the stream also carries much in solution. Des



Map of southwestern Minnesota.

Moines river is estimated to carry to the Mississippi each year 5,130,000 tons of solids in suspension and 2,480,000 tons in solution. This indicates that its basin is being worn down at the rate of one inch in 370 years. This is much faster than is true of some other basins, as for instance that of Iowa river, which is being lowered one inch in 980 years. The average rate for the lowering of the Mississippi valley is one inch in 510 years. Of course much the larger part of the river's load is gathered and brought in by the tributaries, which reach back into all parts of the drainage basin. While some parts of the basin are being cut down rather rapidly others are affected but slightly; hence the general level is altered but little.

Weathering.—Weathering aids the direct work of streams in several ways. Freezing and thawing of the contained water expand and loosen soil and rock and this process is aided also by roots of plants. Rains wash down the loosened material into the streams and it is carried away. Rain and ground water also dissolve out a portion of the rock through which they pass and this finds its way to the sea. All these agencies, and others, help in cutting valleys and in reducing the whole land surface towards base level.

CHAPTER IV.

PHYSIOGRAPHIC FEATURES OF DES MOINES VALLEY

The East Fork.

The Upper Valley.—The East Fork of Des Moines river rises in the prairies of southwestern Martin county, Minnesota, at an altitude about 1350 feet above sea level (Plate XXXI). It is a typical prairie stream of the Wisconsin drift area, meandering across a flat sag, five or ten feet below the prairie level and one-fourth mile wide near its mouth. The gradient of the stream is so gentle that it has been necessary to straighten the channel to increase its capacity. After a course of about fifteen miles the valley opens into Alton lake, a picturesque sheet one and one-half miles long. Alton lake is connected by a short stream with Tuttle lake which is crossed by the state line. It covers about

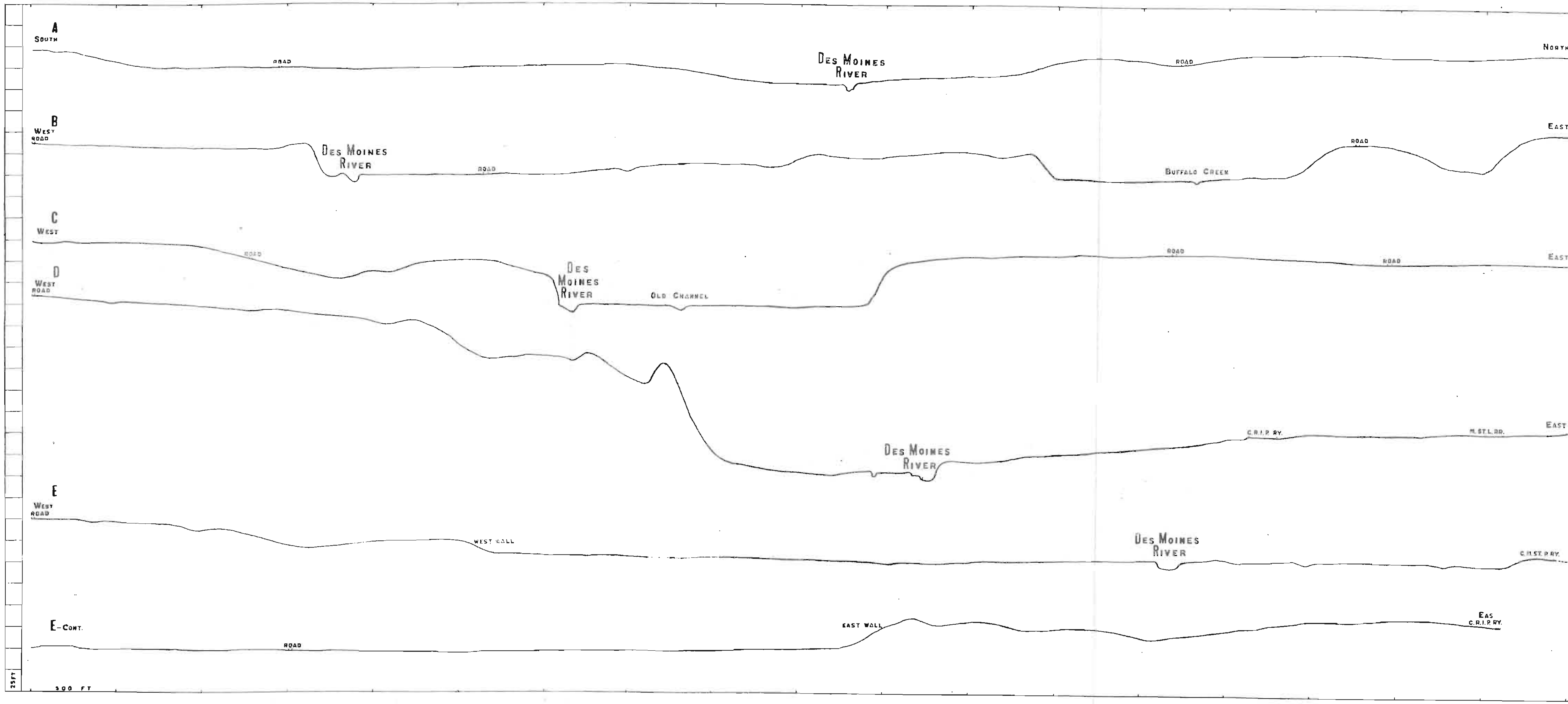
Map of Des Moines valley from Minnesota line to Fort Dodge, Iowa.

four square miles and like Alton lake is bounded here by gentle slopes; there by steep though not high bluffs. The shores are wooded and form attractive spots for summer camp-grounds. See Plate XXXIV, A.

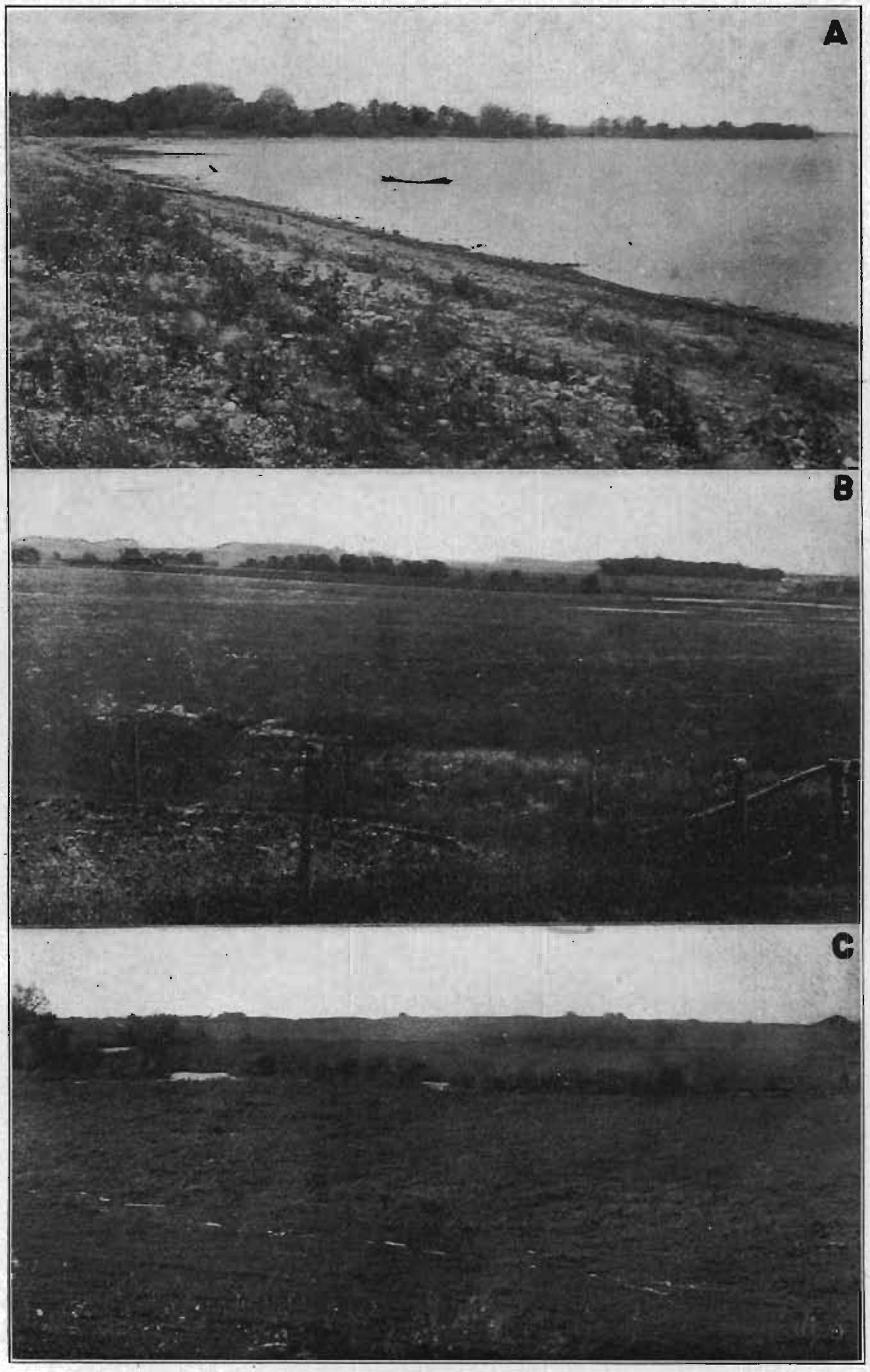
The outlet of Tuttle lake has been cut in the bottom of a broad sag which stretches southward from the southeast corner of the lake. During the very dry weather of the summer of 1911, however, the lake level was two feet below the bottom of the channel. The sag confining the stream—when there is a stream—is one-fourth mile wide and in wet weather is swampy, although the shallow channel is well defined. Where the valley cuts through a range of morainic hills, in southeastern Lincoln township, Emmet county, it is deeper, twenty to forty feet below the hill-tops, and shows fairly steep walls. It is everywhere quite wide and flat-bottomed, much too large and well-developed to have been made by the present stream. Soldier creek, which drains Tremont lake in northwest Lincoln township, shows similar features—an insignificant stream in a broad flat sag, except where a morainic knob juts into the valley and forms a steep slope ten or fifteen feet high.

It seems to be a characteristic feature of the upper course of the East Fork that on one side the valley is bounded by a rather steep bluff which faces a long gentle slope reaching back half a mile, a mile, or even two miles to the prairie level. For instance, just southwest of Armstrong the north bluff is fifty feet high and very precipitous, while the south wall slopes back a mile before it reaches this level. Where the road leading south from Armstrong crosses the river the flood plain is forty feet below the station. In many places, however, the bluff is absent and there are present merely the two long gentle slopes, so that the stream occupies a depression a mile or two miles wide.

In several places, notably in the central and southeastern parts of township 99, range 31 (see Plate XXXII), the morainic knobs flank the stream on both sides and so form a rather steep-walled valley. The stream here makes several wide detours as if it were forced to wind about among the hills to find an outlet for its waters. After the stream emerges from these morainic



A. Profile of the valley of East Fork of Des Moines river about two miles south of Bancroft, Kossuth county. B. Profile of the valley of East Fork of Des Moines river and of Buffalo creek just above their union, east of Burt, Kossuth county. C. Profile of the valley of East Fork below the mouth of Buffalo creek, one mile south of B. From the east end of the profile the surface drops 5 feet in 1000 feet, then rises 10 feet in 3000 feet. From the west end of the profile the surface drops ten feet in one-half mile, then rises five feet in one-half mile, thence is level to Burt, one-half mile. D. Profile of the valley of West Fork at Estherville. East of the profile the surface rises 27.5 feet in 6950 feet, then sinks to Brown creek. E. Profile of the valley of West Fork at Emmetsburg.



A. Tuttle lake, on the state line. B. Des Moines valley two miles south of Bancroft. The railroad bridge at the left crosses the river. C. Buffalo creek valley opposite the junction with Des Moines river.

hills its valley shows, in western Kossuth county, features similar to those seen in the more level portions of Emmet county, namely, very long gentle slopes, with here and there a steep bluff caused by the inroads of the stream upon a morainic ridge or knoll. These latter features, however, are less conspicuous than farther west and are rarely more than twenty or thirty feet high. The cross section profile of the valley just south of Bancroft, Plate XXXIII, A, and the view shown in Plate XXXIV, B, will show how exceedingly gentle the slopes are. South of Bancroft as far as the mouth of Buffalo creek similar conditions prevail, although the valley becomes somewhat deeper, as the profiles taken east of Burt indicate (Plate XXXIII, B and C).

Gravel beds.—Gravel deposits of large extent are quite common in the wide valley, such as the bed opposite Armstrong, one filling the long plain in the eastern part of township 98, range 30, Kossuth county, and an especially noticeable bed two miles southwest of Bancroft. This extends south for one-fourth mile from the river and its probable limit is marked by a slight rise to the prairie level. At the west line of township 98, range 29, a recent straightening of the channel has revealed gravel above yellowish Wisconsin till, and one-fourth mile up stream a pit shows the same succession of materials. Again, a gully close to the railroad bridge crossing the river west of Armstrong shows gravel overlying till, which in turn rests upon rusty gravel which perhaps is to be correlated with the Buchanan gravels (page 452, Plate XXVIII), although it may be interbedded Wisconsin gravel. These exposures indicate that after the Wisconsin glacier had spread out its sheet of till and had melted back until its edge stood a little north of our immediate region, floods from the melting ice brought down great quantities of gravel and dropped them on top of the drift in this sag, which served as an outlet for these glacial waters.

Origin of the Valley.—It seems evident that the upper portion of the East Fork, and its tributaries also, (1) have done much more erosive work in the past than they seem capable of doing now, or (2) the valleys in which they flow are constructional in origin, or else (3) the streams have sought out courses or parts of courses of pre-Wisconsin streams which were not entirely obliterated by the till of the last ice-sheet, and are utilizing these for their present valleys.

With regard to the first of these hypotheses, it will be seen that whatever erosion might be accomplished in late Wisconsin time by flood-waters from the melting ice-sheet would be more than counteracted by gradation through deposition of the vast loads of silt, sand and gravel carried by these waters. We might attribute to this gradational process, perhaps, in some cases, the excessive width and very gentle side slopes which these valleys present today, but this leaves no room for the effective erosion of young valleys which must have preceded gradation.

As to the second theory, it will be understood that the ground moraine had a more or less irregular topography. Drift was heaped up here, while depressions were left there. The drainage waters from the Wisconsin glacier during the retreat of the ice margin naturally sought out the easiest path and so made use of depressions. Thus in the morainic region of Emmet and Kossuth counties the new-born Des Moines wandered about among the hills, and the path thus originated has been slightly better defined and more accentuated during subsequent time. Elsewhere, in the more level regions, the escaping waters found the broad shallow sags which lie between the low swells of the prairie, and put them to use. The question may be raised as to the sufficiency of such sags, in number and arrangement, to form a continuous valley. It is not necessary to suppose that they were entirely continuous. The early streams as they sought their way from one swale to another may be assumed to have cut away some obstacles to a clear channel.

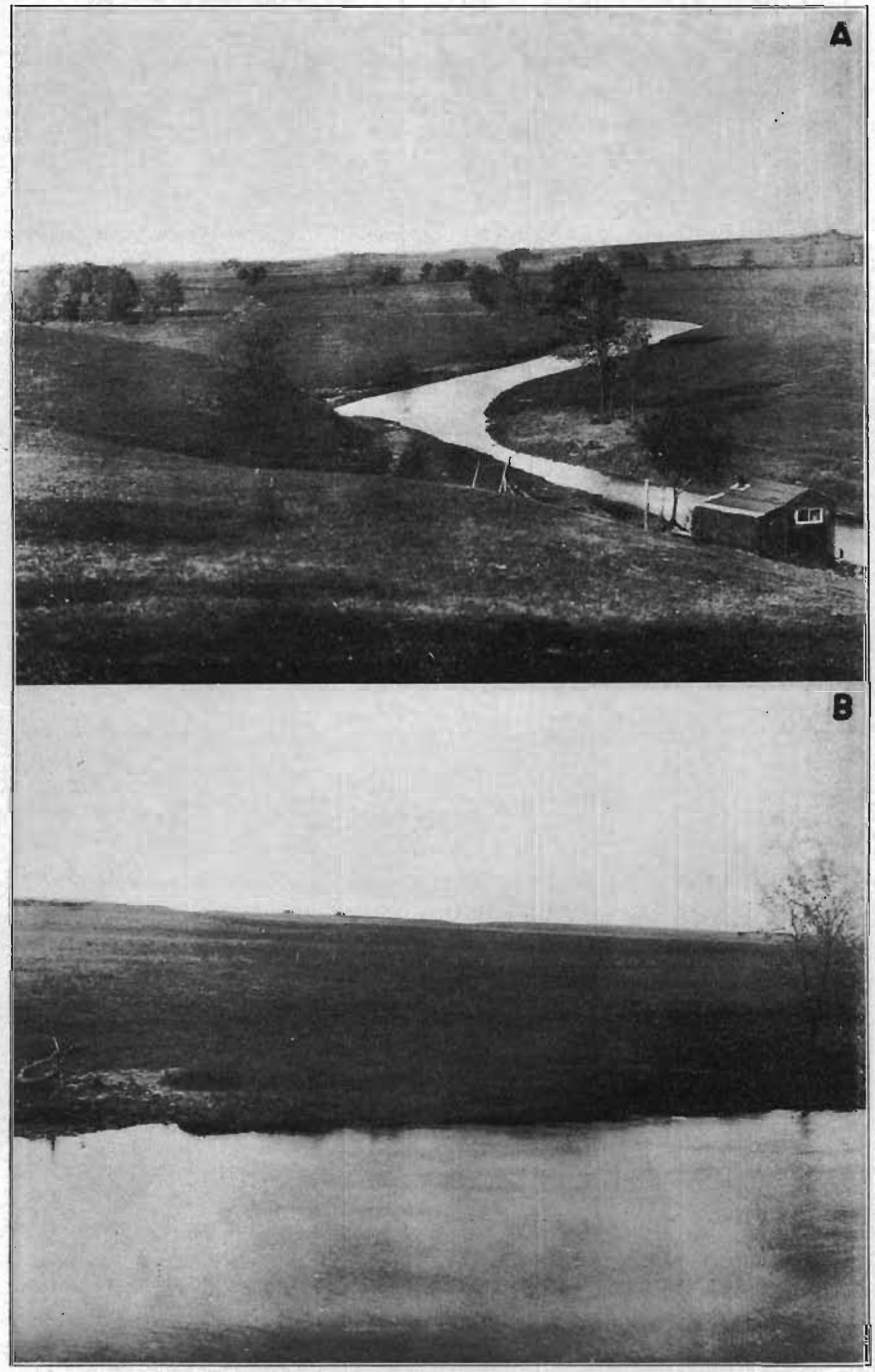
It is quite possible that the condition to be outlined in the third hypothesis may have aided in the formation of valleys; that is, some of the older stream courses were again made serviceable through their incomplete filling with drift and also to a less extent, perhaps, through the greater settling of drift in the valleys than over the upland owing to its greater thickness in the valleys. How important these factors have been can not, of course, be told without a thorough knowledge of the relations of the different drift-sheets and the underlying rock. For reasons which will be explained later (see page 477) it does not seem likely that these conditions held to any great extent.

Considering all the evidence available it seems probable that by far the most important factor in the initiation and development of the upper valley of the river and the valleys of its tributaries has been the use of constructional valleys. The streams from the ice-front took advantage of depressions in the drift-sheet, scoured these out to some extent and then in many cases filled them up again, as shown by the bodies of gravel bordering the streams. Macbride repeatedly has emphasized the fact that in this part of Iowa drainage—or the lack of it—is determined by topography, rather than the opposite, and this is nowhere better shown than in the valley of the East Fork. The streams have not formed the topography but have been imposed upon one that had been created before they came into being. Hence the valleys are variable, they change in character from point to point and are not definite, fixed features of the landscape as is true lower down the course of the Des Moines.

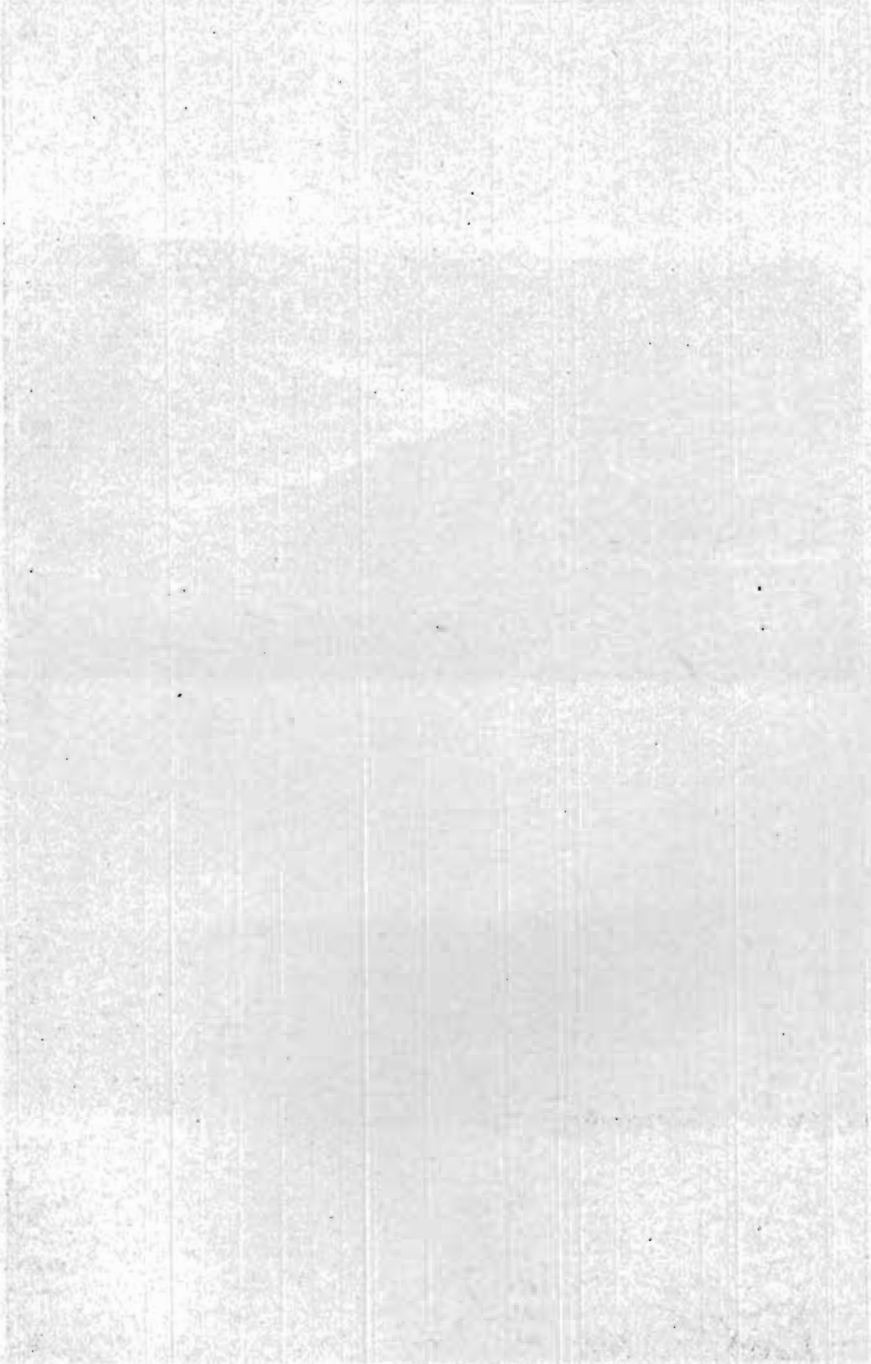
But below the mouth of Buffalo creek (Plate XXXII) there is a marked change in the character of the valley. The broad shallow sags give way to a wide, flat-bottomed valley bounded by fairly steep, well-defined slopes rising at angles as high as 20° or more. See the profile of the valley east of Burt, Plate XXXIII, C. These slopes are not merely the result of the undercutting of morainic hills, but they represent the actual depth of the valley below the general upland level. This is now a normal mature valley, albeit incised in a plain still in its early youth, and as such it continues as far as Algona.

Buffalo Creek and Union Slough.—In order to understand this very significant change in the valley we must examine the lower course of Buffalo creek. The profile taken across Des Moines and Buffalo valleys above their union, Plate XXXIII, B, and the views shown in C of Plate XXXIV, page 469, and A and B of Plate XXXV show that the valley of the creek is as wide as that of the master stream, and much better defined. The stream itself, while not large, is nearly as important as the East Fork before the two unite. This condition remains true as far as a point two miles above the mouth of the creek, where it makes an abrupt turn from the east to the south. See Plate XXXII. At this point there opens into the creek valley a long flat depression one-eighth to one-fourth mile wide, and limited laterally by clearly defined, rather gentle to fairly steep walls twenty to thirty feet high. See Plate XXXV, A. In fact it is an almost exact duplication of the lower valley of Buffalo creek, except that here it contains no stream channel. This is Union slough, and in its northern stretches rise the headwaters of one of the forks of Blue Earth river, which drains into Minnesota river. The slough retains similar characters as far as the state line except that here the walls are somewhat lower and the floor is better drained by Blue Earth river. The width is fully as great at the state line as at the junction with Des Moines river and the bottom is practically as level.

Above the mouth of the slough the valley of Buffalo creek is narrower and it rises until within a few miles it is not over ten to fifteen feet below the general level of the plain. It is a typical prairie stream, like the upper reaches of the other creeks of the region. Union slough on the other hand, is not a typical prairie slough. It is far too deep and too well defined. It is very evident that Union slough, Buffalo creek below the mouth of the slough, and Des Moines river below the mouth of the creek are occupying an ancient valley, one which they found ready to hand when their careers began, after the region was uncovered by the melting of the Wisconsin ice. But this valley differed from those now used by the Des Moines and its feeders above the mouth of Buffalo creek in being an erosional valley rather than constructional. The fact that no stream at all has yet formed in the southern part of the slough, coupled with the great discrepancy between Buffalo creek valley below the slough and the insignificant streamlet which now occupies it, shows that post-Wisconsin drainage can not be held responsible for the



A. Looking up Union slough from its mouth. Buffalo creek crosses along the line of trees. B. The long gentle wall of Des Moines valley a mile above its union with Buffalo valley.

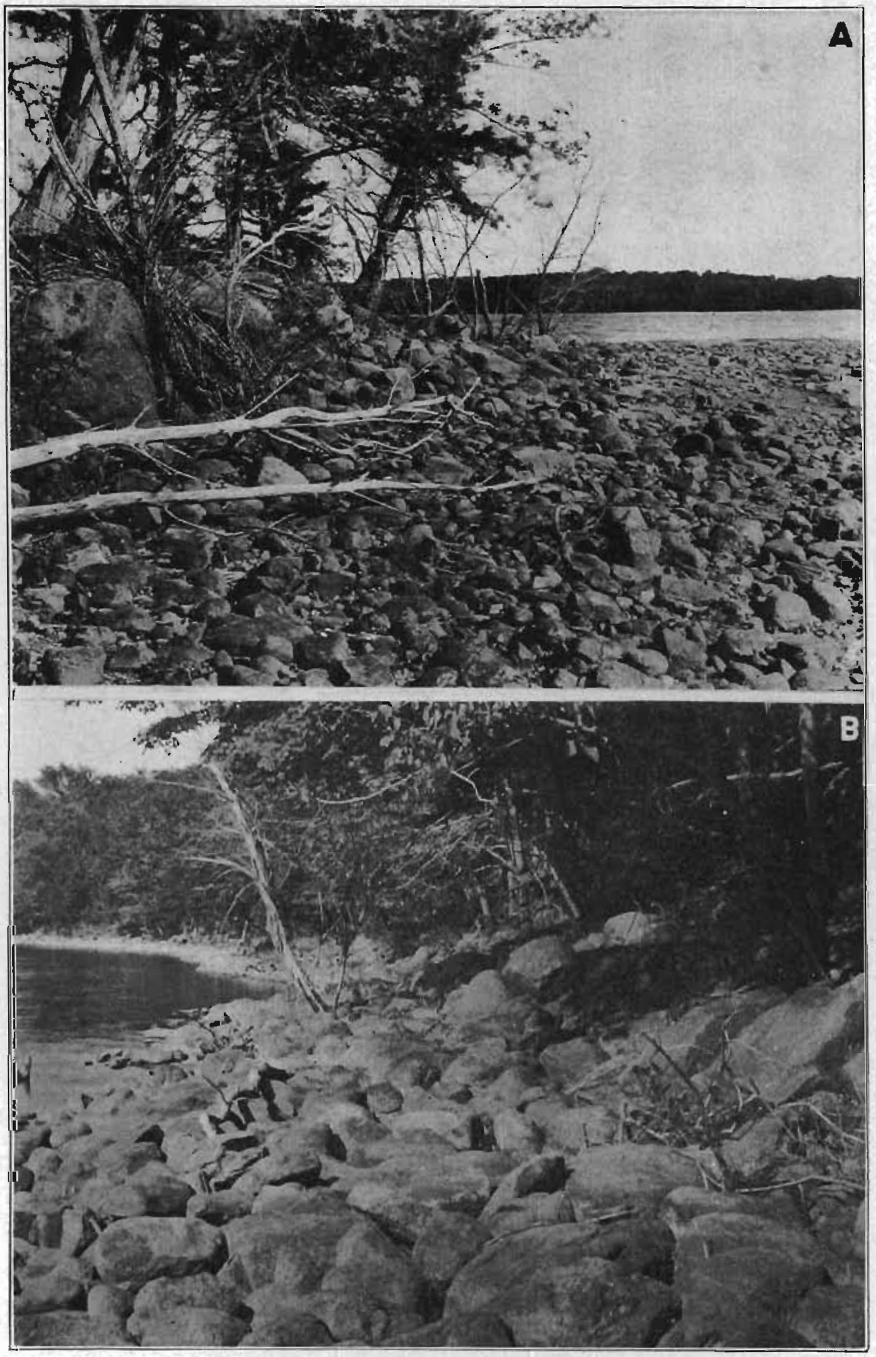


very mature features of the valley, and the same is true in practically the same degree of the Des Moines and its valley below the junction.

It was stated above that the use of old valleys probably was not responsible to any extent for the features characterizing the Des Moines and its tributaries above the union with Buffalo creek. If we assume that such use does account for the really remarkable features of Union slough, Buffalo creek south of the slough, and the East Fork below the junction, and we are seemingly driven to that assumption, it is easy to see why the same condition could not have held good for the upper part of the main valley. Post-Wisconsin stream erosion, sidewash and weathering have not been sufficient to develop an erosion topography on the Wisconsin plain and could not have produced either type of valley we have before us—the broad sag or the well-defined flat-bottomed valley. Furthermore, the differences between the two types are so great that they can not be the result of the same forces acting during a similar period of time, and we can not think that two regions so close together were subjected to different conditions. The one agent to whose work we can assign such a valley as Union slough is erosion during the long post-Kansan or possibly post-Iowan epochs, preceding the Wisconsin invasion. When the last ice-sheet covered north-central Iowa, it was unable to fill all of the valleys and this one, then as now one of the largest, was left with only a veneer of Wisconsin till over its slopes and upon its bottom-lands, to be alternately filled and scoured by the rushing waters from the melting ice.

After studying the Wisconsin moraines and till sheet in Iowa and Minnesota, Mr. Warren Upham decided that Union slough marks the outlet of a glacial lake which covered parts of Faribault and adjacent counties in Minnesota during the retreat of the Wisconsin ice, and which later found a lower outlet to the northeast by way of Cannon and Minnesota rivers.

The Chain Lakes.—A similar case, but one in which Wisconsin filling proceeded somewhat further, is found in the Chain lakes of Martin county, Minnesota (Plate XXXI). Three diverging series of lakes extend from the Iowa line in Emmet county northward and northwestward across Martin county. The East and Center Chains are well connected for the most part and drain into creeks flowing east or northeast into Blue Earth river. The West Chain, of which Tuttle lake is the southernmost and largest, is not so well connected. The Center Chain is the most remarkable. See Plate XXXVI. It extends in an almost perfectly straight line for more than twenty miles and includes twenty lakes. These lakes are bordered by undulating expanses of till which rise thirty to fifty feet above their shores, and while the depression in which they lie has not a uniformly level floor its valley-like shape is too prominent to escape even casual observation. Mr. Upham concluded that these three converging chains, the western one with a branch on either side, occupy the valleys of interglacial rivers whose waters flowed southward into the East Fork of Des Moines river. The convergence of the chains southward seems to indicate that the interglacial streams flowed in that direction. One of the strange results of glaciation is shown in the fact that the present drainage of Martin county is to the north and east, except for that part which drains into the East Fork, and southward through Tuttle lake. Possibly, however, the uplift of northwestern Iowa referred to on page 459 is partly responsible for this change. In any event the traces of this pre-Wisconsin drainage in Iowa have been wiped out entirely, unless it be for the present system of the Des Moines. For reasons before given it is not thought that the upper part of this system dates back of the last ice invasion. Hence the pre-Wisconsin drainage course extending southward from the Chain lakes could not have followed the same lines as those now followed by the East Fork. There is a possibility that the West Fork of Des Moines river, in some part of its extent, is utilizing a fragment of this pre-Wisconsin water-course. With this hypothesis in mind the most attractive point at which to locate the union of the post-Wisconsin Des Moines valley with the pre-Wisconsin Chain lakes valley is near the northeastern corner of Pocahontas county. The discussion of the evidence can be given best in connection with the description of the West Fork. See page 509.



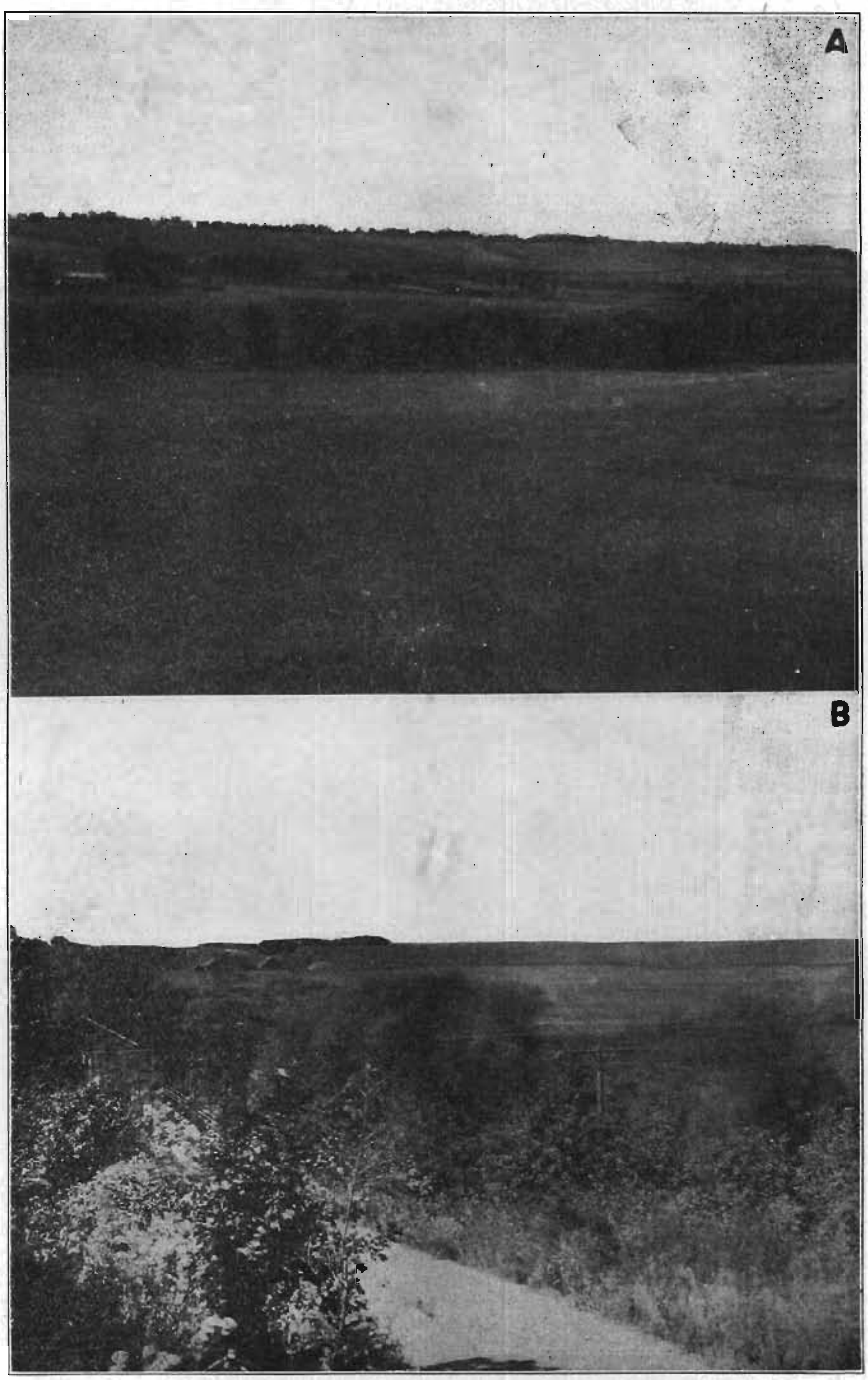
A. The natural riprap on Silver lake, one of the Middle Chain, a mile north of the Iowa line. B. The "wall" of Silver lake. The views show the effect of ice-push and erosion of the banks.

While we may accept Upham's statements regarding the mode of origin of the Chain lakes and the Wisconsin history of Union slough, there seems no sufficient reason for regarding them to be of different age and development, as is held by Mr. Upham. Their characteristics and similarities of form are so striking as to point to the conclusion that they are both of pre-Wisconsin age, but that during Wisconsin time Union slough was kept open by serving as the outlet of a glacial lake while those valleys which now are occupied by the Chain lakes, being in a region of greater deposition, were so far choked with drift as to render them useless as waterways, at least so far as southward drainage was concerned.

The Valley Below Buffalo Creek.—The valley of the East Fork presents some rather peculiar features between the mouth of Buffalo creek and the Kossuth-Humboldt county line. Below the mouth of the creek the river swings to the southwest as far as Algona, where it suddenly turns upon itself and pursues a southeastward course to Irvington. At this village there is a sharp bend to the west, followed by an equally abrupt one to the south two miles farther west, whence the course is direct to the county line. Above Algona the valley is wide, with much alluvium covering its flood plain. In places the walls are rather steep, elsewhere they are fairly gentle. In the vicinity of Algona the east wall especially is cut by ravines into a series of ridges and is choppy and rough. The valley is still quite wide, however, nearly one-half mile, but narrows somewhat toward Irvington. All along here the sides are rather steep and the flood plain is well defined. At Irvington the bluff where the river impinges upon it is fifty or sixty feet high. Embraced in the bend of the stream opposite the village is a long, gently sloping plain built up of sand and gravel, and facing the river from the east after it turns southward a long, rather high terrace of the same material separates the valley wall from the present channel. The wall is very distinctly outlined, by a bluff-face along much of its extent, and the terrace is lower near this face than near its free edge. Several large oxbow lakes fill remnants of old channels in the wide valley.

Here, then, are several features which require explanation. Doctor Macbride, in his study of this region, assumed, as is done here, that the valley above Algona is pre-Wisconsin. But he states that "at Algona the channel seems to have been pushed west by the drift," and cites as evidence the fact that the valley, on the east side, "is flanked by narrow choppy ravines." However, the ice-movements were from the north as shown by Macbride's map of Kossuth county, and hence would have affected the valley uniformly rather than have tended to push it to one side locally. If the pre-Wisconsin valley swung westward here there might have been some increase in the deflection, though this should be manifested in the immature character of the west wall, a condition which does not exist. The long smooth slopes of this wall are shown in Plate XXXVII. The fact that the river here flows near the east wall probably has influenced the formation of ravines along that side. The statement that "the valley is here new and narrow" does not seem to the writer exactly to fit the facts, since his own repeated observations led him to conclude that the appearance of the valley here is as mature as those parts above or below the city, and the width of the flood plain—nearly one-half mile—is as great as that above the town and greater than that above Irvington. The profile of the Chicago, Milwaukee and Saint Paul railroad gives a width of three miles for the depression west of Algona, though this exaggerates the actual width of the valley a little on account of the oblique direction in which the railroad crosses it.

On his map of Kossuth county Macbride has drawn a line from Saint Benedict through Irvington to Whittemore, which marks the "border of a glacial advance not characterized by conspicuous morainic deposits." This border is shown in the field by a low terrace forming the edge of the *coteau,* which faces the south and crosses the river just above Irvington. When the edge of the ice-field lay here, the valley must have been taxed to its utmost to contain the floods which issued from the glacier and we may readily ascribe to these floods the great amounts of sand which fill the elbow in the valley at Irvington.



A. The valley of the East Fork three miles north of Algona. B. The valley of the East Fork at Algona. These show the wide valley with fairly gentle walls.

The great terrace occupying the eastern edge of the valley southwest of Irvington doubtless had the same origin. These floods with their loads were not able to obliterate the old valley but they did make some important changes. The bend of the river at Irvington was pushed to the southeast by partial filling of the valley, or other obstruction, so that the stream now impinges on its east wall, while the bend to the west was forced farther westward and the stream which had flowed in an almost straight direction between the site of Algona and the county line, was forced to adopt a sinuous course to escape being overwhelmed altogether.

Very possibly the narrowness of the valley for some distance above Irvington is to be attributed to the effect of this minor glacial advance. There are no deposits of sand or gravel above the line of the coteau, the valley is cut in drift, and even if it was not drift-filled by the secondary advance it may have been narrowed materially.

At the county line the flood plain is one-half mile wide, but below here it narrows somewhat though it is still one-fourth mile wide at Livermore, and maintains this as its normal width along the remainder of its course. The river meanders across its flood plain, and here and there it undercuts and forms steep banks, such as those just northeast of Livermore and those southeast of Dakota, but elsewhere it leaves the valley walls rather long and gently sloping. For the most part these lie at angles not higher than 10°. All along its course the valley sides are covered by patches of timber which alternate with bare, grass-covered stretches of prairie. In places along the lower course of the river the flood plain bears upon its surface ponds which probably are remnants of old channels abandoned through the swinging of the river from side to side. Very abundant in the lower course also are bowlders, some of which are four to six feet in diameter, and which locally are so numerous as to form reefs across the channel.

Tributaries.—There are very few tributaries entering the East Fork, not only in its upper course, but along its entire extent. See Plate XXXII. Mud creek is one of the few, and it is typical of those which join the main valley above Buffalo creek. It enters the larger valley south of Bancroft and presents phenomena common among these tributaries—a minor stream in a widely expanded shallow sag-valley; an infant in adult dress, as it were.

The few important creeks which enter the valley below the mouth of Buffalo creek—Lindner and Plum creeks from the east and Black Cat, Fourmile and Lotts creeks from the west—share in the change of character which the valley of the East Fork has undergone. The lower courses of their valleys possess wide bottom lands bounded by mature side slopes, although farther back they are typical shallow prairie water-courses. The lower courses of even the minor tributaries have mature valleys showing flat bottoms and very broadly arcuate cross sections. It will be clear that no matter how small a tributary stream may be the tendency is for it to keep pace in the development of its valley with that of its master stream, so long as the latter passes through only the normal stages in valley-making. Therefore we would expect the valleys of these creeks to present mature features in their lower parts, though they are but very young prairie swales in their upper parts. If, however, an accident happens to a master stream, such as the passage of a glacier down its valley, this may be cut down so rapidly that the tributaries can not keep pace with it and are left as "hanging valleys." This is what has happened to the Yosemite Valley and what has given it such charming grandeur and picturesqueness.

During dry summers the smaller streams disappear, except for the underflow as revealed by the waterholes, and even the larger valleys are dry except near their mouths. Where the walls of the East Fork are steep they are cut by numerous ravines which generally are short and steep-sided, with very high gradients, and which carry no water except in time of rain. Many of these ravines are wooded and all of the tributary valleys have more or less forest filling for some distance above their mouths.

Like their master stream, those tributaries which join the main valley below its union with Buffalo creek, seem to have found remnants of pre-Wisconsin drainage courses, at least so far as their lower reaches are concerned. Their valleys are far too mature to belong to the same erosion cycle as the undrained Wisconsin plain surrounding them. It is not uncommon upon ascending a road leading out of one of these valleys and before one is fairly upon the plain to see an undrained kettle hole or marsh by the roadside. If these valleys had arrived at such a degree of maturity by post-Wisconsin erosion alone they should have developed also a well-defined system of lateral drainage—the dendritic form should have been assumed by this time. But this is far from being the case. The upland immediately adjacent to the river shows all the characters of the unmodified Wisconsin plain and is practically as high as that farther back from the valley's edge. Hence it is possible to look across the valley from a short distance and see no signs of its presence. The hills and plain along the horizon seem continuous with those in the nearer distance. The long gentle slopes reaching back from the stream a mile or two miles or even three miles which characterize some parts of Kansan drift areas, are here conspicuously absent. Evidently the Wisconsin ice, while failing to fill the major valley, succeeded in obliterating the minor drainage lines except the lower portions of a favored few. Therefore, when stream work began anew the main valley already was well developed, but lateral drainage had to start from the beginning, or nearly so. Hence its present immaturity.

Rock Outcrops.—South of Humboldt and Dakota the East and West Forks run nearly parallel, separated by a high tableland about a mile wide, as completely uneroded as if the rivers were miles away. In several places along the river's edge near Dakota there are outcrops of limestone, identified by Macbride as Saint Louis, and lower down, notably at the Minneapolis and St. Louis railroad bridge, there are shales and sandstones of Des Moines age. These are considered by Macbride as filling a valley eroded in Saint Louis limestone. No outcrops of rock *in situ* are known along the East Fork north of Dakota. Three miles south of Dakota the valleys unite, and the two forks mingle their waters in the common flood. The nose of the table-land slopes down to the valley and a great bed of sand and gravel fills the flood plain between the two streams.

The West Fork

The Upper Valley.—The West Fork of Des Moines river rises in upland meadows among the morainic knobs of the crest of the *Coteau des Prairies* on the border between Pipestone and Murray counties, Minnesota (Plate XXXI). The *Coteau des Prairies,* so called by the early French explorers, is the high rough land representing the outer terminal (Altamont) moraine which marks the western edge of the Wisconsin glacial lobe in South Dakota, Minnesota and to a less extent in Iowa. Several small creeks which rise in springs and tiny lakelets unite in northwestern Murray county to form the headwaters of the river. The meadows in which these take their origin lie at altitudes of 1800 to 1850 feet above sea while the crests of the hills and ridges about them rise 50 to 100 feet higher.

After winding about among the hills for three or four miles the branches emerge from the moraine and enter a broad sag which extends along its inner edge. On the east this sag rises very gently to the fairly level upland plain, but on the west it is bordered by the knobby region of the moraine.

In its southward extent the sag widens until in the vicinity of Lake Wilson it has a breadth of three to four miles from crest to crest. This swale, and also a continuation of it which stretches north to Redwood river, is similar except for its larger size to those described in connection with the East Fork, and like them doubtless is to be attributed to the irregular deposition of Wisconsin drift, aided in some measure, perhaps, by drainage from the ice. The drainage of this region is still immature as is shown by the presence of the headwaters of three drainage systems—Des Moines river flowing to the Mississippi, Redwood river to the Minnesota and Rock river to the Missouri—all within a small area upon the crest of the Coteau des Prairies, while there is undrained territory between and around them. In fact the topography of all the region east of the moraine is quite youthful. Very little drainage has been developed. On the west of the Des Moines sag-valley is the moraine with its constructional knobs and undrained marshes, while to the east stretches the great plain of Wisconsin drift with very few streams and with very little erosion yet accomplished. An instance of this immaturity is given by Lake Wilson, near the town of the same name. This lake is on the very margin of the great swale in which lies Des Moines river, it lies at a similar level and is separated from it by a ridge less than ten feet high. Nevertheless it is drained to the south into Chanarambi creek and thence into Rock river.

A short distance east of Lake Wilson the valley, if such it may be called, is diverted by a curve in the moraine from its southeasterly course into a northeasterly one. It extends in this general direction past Hadley and Slayton until near Currie it approaches the inner (Gary) moraine of the Wisconsin drift, by which it is deflected southeast again. It retains its width and shallowness between Lake Wilson and Slayton, north of which town it makes a minor loop to the southeast. While above Slayton the valley is several miles wide, where it again turns northeast it narrows suddenly until it is not much over one-fourth mile from crest to crest. It also becomes quite deep and steep-sided. Beyond the crests the river is of very little force topographically. There are almost no secondary valleys, only a few short steep ravines which run up into the prairies 200 to 300 yards and there terminate.

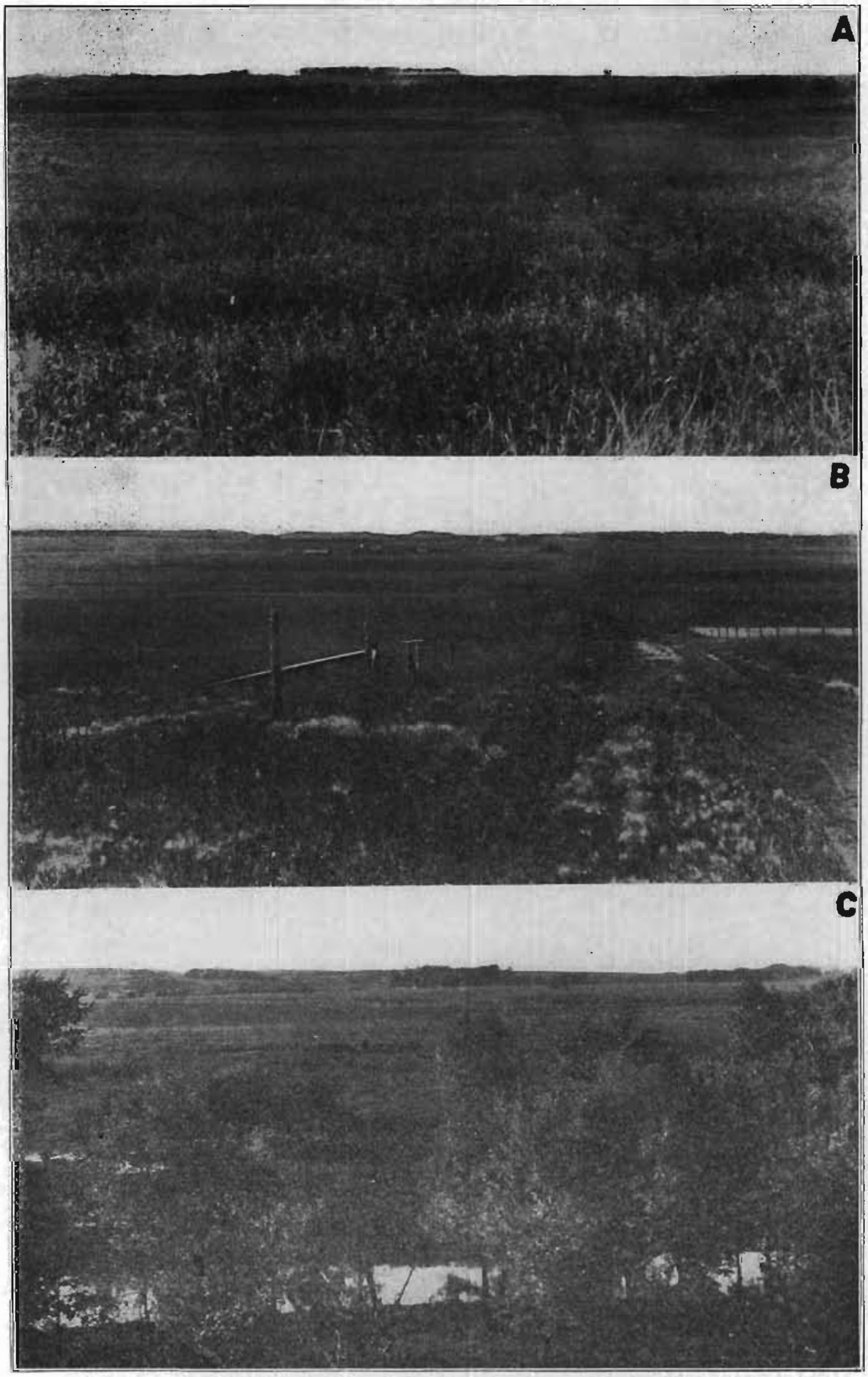
What the cause of this change in the character of the valley may be is not clear. It may be due to topographic causes as there is, near Mason (see Plate XXXI), three or four miles north of the valley, quite a prominent elevation due to drift accumulation. This may be represented southeasterly by a less conspicuous swell which has been cut through by the river. Evidently this part of the valley owes its present condition to erosional activity, in part, at least.

The narrow valley continues within two miles of Lake Shetek, where it begins to widen out, first by the flattening and lengthening of the north wall and then by the same change on the south side. Lake Shetek lies in the outer part of the Gary moraine and its lower end and outlet lie in a broad flat swale with very low, gently rising sides. The upper end of the lake is continued as a long narrow arm known as The Inlet. The lake seems to occupy a depression which is continued to the southeast as the valley of Des Moines river. It empties into the river, when the water level is high enough, by a short channel less than a mile long. Above this outlet the main stream is known as Oksida or Beaver creek; below, it is Des Moines river.

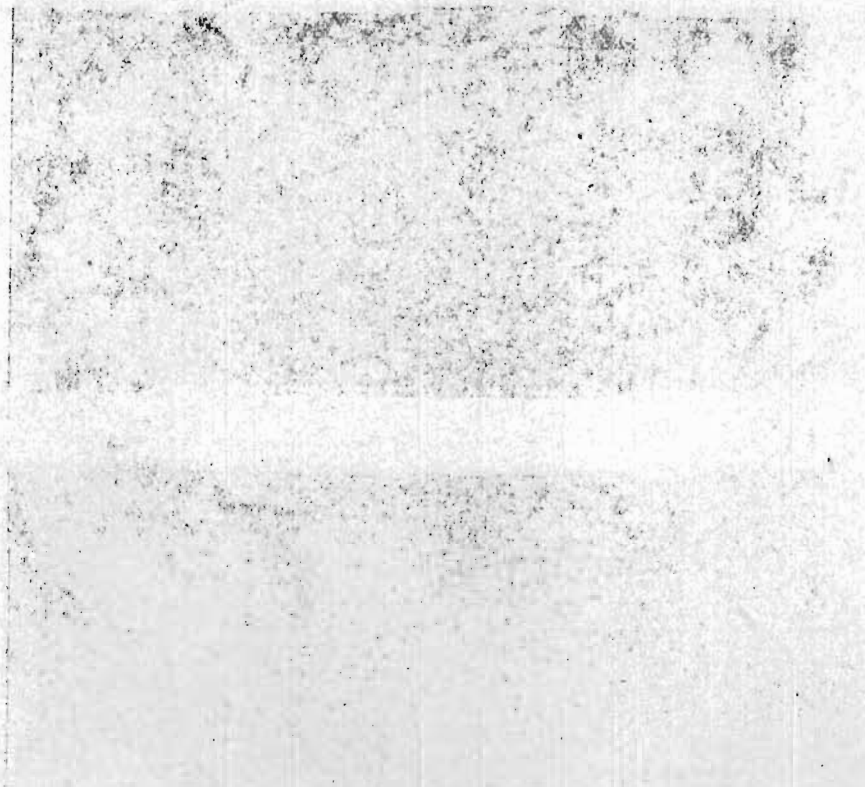
The wide, shallow depression continues past Currie (Plate XXXVIII, A) and across this valley the stream wanders aimlessly back and forth in a shallow channel. In southeastern Murray county the broad sag is so poorly defined along parts of its extent as to render the stream almost devoid of any true valley. This is well shown on Plate XXXVIII, B. In places it is two, three or four miles wide, although not over fifteen or twenty feet deep. Here and there are low, steep embankments, the result of side-cutting, but the sag is the predominating feature as far as the southern line of Cottonwood county. Its floor in places is over a mile wide and practically flat except for occasional low mounds which apparently are built of gravel. Wherever the road is cut into the valley floor, gravel is revealed. It is not very coarse, but is in immense quantities, sufficient for every conceivable purpose for years to come.

In the southwestern township of Cottonwood county several long flat swales open into the valley and some of these are occupied by shallow lakes. Such are Talcott lake, Oaks lake and Clear lake.

The Valley in the Moraine.—Beyond the point where the river turns northeast from the county line its valley changes character. On the north the wall is fairly steep and high, although the southern slopes still are rather gentle. The valley here is clearly marked and well confined, much more so than it is farther west. The stage of sag-valleys is past until the river passes Estherville. This change in character is due partly, at least, to the fact that the river is approaching, and near Big Bend cuts through, the Gary moraine.



A. The wide sag-valley of the West Fork below Currie, Minnesota. B. The wide valley of the West Fork in southeastern Murray county, Minnesota. C. The valley train at Estherville, showing how the wall is buried by gravel.



Immediately upon accomplishing this it turns southeast again, skirts the inner edge of the moraine, except where it cuts through a branch which strikes northward from Windom, and so continues past Jackson, into Iowa and beyond Estherville.

Where the moraine is bordered by the river, south of Big Bend, the ridge rises into great knolls, the Blue Mounds, which appear in profile to be piled upon the otherwise almost level surface. This is especially well shown from the top of the valley wall at the head of the bend, where the Mounds seem to stand out from the plain like western buttes. The valley is about fifty feet below the prairie, and these morainic knobs rise fifty to one hundred feet higher than the upland.

Control of Tributaries.—The control of the character of secondary valleys by the major stream is well illustrated in this general region. Thus Lime creek in southeastern Murray county (where the Des Moines valley is of the wide sag type), lies in a narrow, rather shallow valley even to its debouchure. On the other hand the South Branch of Des Moines river—the outlet of Heron lake—enters the Des Moines (which now is constricted and deepened as it approaches the moraine) by a deep, rather narrow, forest-filled trench. The upper part of the valley is merely a typical broad, very shallow flat swale, opening out of the greater though otherwise similar depression which contains Heron lake. The fact that Little Sioux river rises in a swamp only a mile or two south of the lake shows how imperfect has been the drainage of the Wisconsin plain.

Characterizing the morainic belt where the river crosses it are several rather deep, flat-bottomed swales whose floors are more or less covered with water in wet weather. One of these swales is almost closed near its mouth by the hills, through which it breaks by a mere gap, and beyond which it again widens toward the river. Somewhat resembling these swales, although larger and of different origin, is a great depression which opens into the river valley at Big Bend. It is fully half a mile wide at its mouth and extends northwestwardly about six miles to Lake Augusta, whose surplus waters it carries away by means of a channel known as Honey creek. The valley is well de-limited, its side walls slope up at angles of 10° to 20°, and it is much better defined than is the river valley in southwestern Cottonwood county. Probably it was a pre-Wisconsin channel which served to carry the waters from the retreating glacier, as is evidenced by the filling of gravels in its mouth, and the well developed gravel terraces in the river valley just below the junction. No gravels were observed in the narrow main valley above Big Bend.

Relation to Interglacial Valleys.—The action of the Des Moines in turning abruptly northeast at the north line of Jackson county and cutting directly across the moraine seems, at first sight, quite inexplicable. It would have seemed so much more reasonable had the river continued its course southeast through Heron lake and so to the southward. Mr. Upham, of the Minnesota Geological Survey, formulated a theory by which to explain this anomalous situation. Briefly stated the theory is this: The basin of Lake Shetek, Des Moines valley from the lake to the south line of Cottonwood county, and the basins of Heron, Spirit and Okoboji lakes form parts of a river valley excavated during post-Kansan times and extending along the present valley of the Little Sioux as far south as Spencer and thence eastward to Emmetsburg, where it entered the present valley. This ancient valley was partly filled by Wisconsin drift and the drainage of Spirit and Okoboji lakes and Little Sioux river was diverted to the Missouri. The waters of the more northerly part of this system found an outlet through the newly formed Gary moraine, and being there held in check by the ice front they flowed southward along the inner margin of the moraine.

While it is quite probable that the valley of the Des Moines in Minnesota originated in a manner similar to that suggested in the preceding sentence, it does not seem to the writer that there is sufficient evidence for postulating such a pre-Wisconsin valley as that outlined by Mr. Upham. Every existing element of this hypothetically reconstructed valley, with the exception of West Okoboji lake, is merely a shallow depression in the Wisconsin plain or among the mounds of the moraine. For reasons outlined in connection with the discussion of the East

Fork (pages 471 to 473), these depressions are not thought to antedate the Wisconsin ice invasion. Certainly, there seems to be no basis for tying an ancient river to the Des Moines at Emmetsburg, as there is no change in the character of the valley above and below the city except that due to the divergence of the moraine and the valley as they proceed southward from Estherville. Indeed there does not appear to be any necessity for supposing that the Little Sioux must have joined the Des Moines in pre-Wisconsin times, as is done by several authors. From such study as the writer has given to the valley of the Little Sioux in northern Iowa, he is disposed to assign it a history entirely independent of that of Des Moines river. Professor Macbride has suggested that Beaver creek valley in northeastern Pocahontas county may represent a pre-Wisconsin valley which at one time connected with the Little Sioux in Clay county. It is true that in this general region the Des Moines assumes features which seem to be of pre-Wisconsin age, and this fact apparently lends strength to the hypothesis regarding the age of the creek valley. But the present character of this valley offers no support to the idea that it once connected with the Little Sioux. In its lower part it is simply a fairly wide, flat-bottomed trench cut in drift, and in its upper part it becomes a shallow prairie sag.

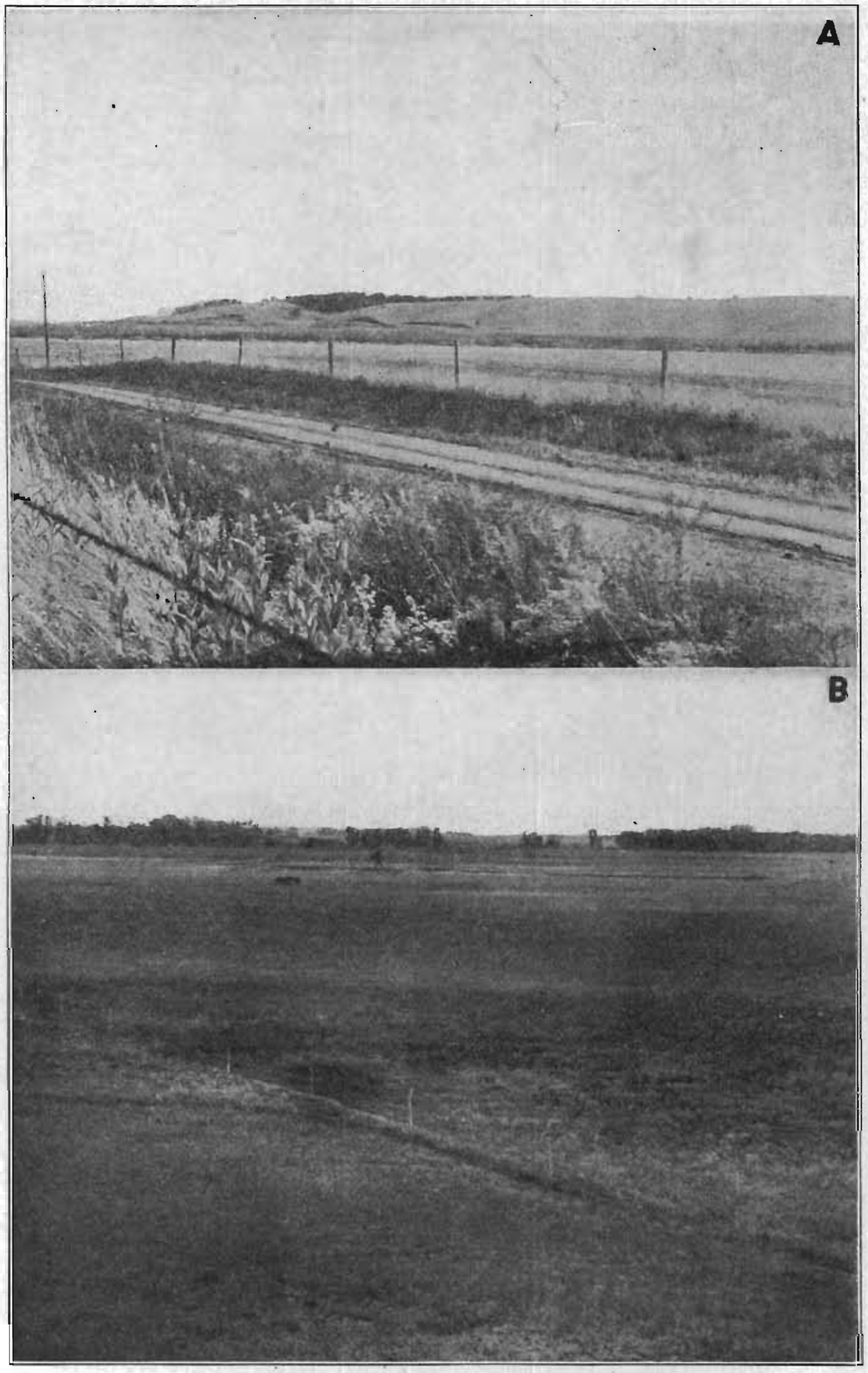
Before leaving this point it may be suggested that very possibly the passage of the river through the moraine north of Windom was helped by the use of one of those deep swales which are still so common here and some of which are low enough and capacious enough to carry the waters of the Des Moines very easily. Once the obstruction was passed the flood waters found the wide sag described on page 493, and utilized it as far as Windom at least. Possibly, too, the slow post-Pleistocene elevation of this region later made it possible for the stream to deepen its channel and to hold its course and avoid ponding. This would account for the depth and narrowness of the valley in the vicinity of Jackson.

Where the valley crosses an arm of the moraine near Windom it is steep sided and narrow. Here lakes are abundant and the topography is quite rough. In this region, too, the valley becomes quite heavily timbered. About six miles above Jackson some ravines on the east side of the river show steep sides and flat bottoms in the lower mile or two of their extent although they are shallow and much less steep-walled above. It is probable that they acquired their size and depth while the Wisconsin ice lay in their upper courses and the waters from the ice passed down them to the river. They may have been partly filled later, when the floods had less carrying force.

Near Jackson the valley has a depth of 100 feet or more and is quite steep-sided. Its floor is less than one-fourth mile wide and the town is built on a series of gravel terraces which reach back to the west for another quarter of a mile. Above the town, similar gravels bank the east wall for fifty feet above the valley floor. The ravines which enter the valley here are deep and narrow and have steep grades but within short distances they become shallow and of low gradient—mere prairie stream-courses. While much of the west wall of the main valley is wooded the east side is for the most part bare, due in part at least to its exposure to the afternoon sun.

Five miles below Jackson the walls begin to diverge and to flatten so that the valley becomes a mile or so in width from crest to crest and at the same time is much shallower. It is only fifty or sixty feet deep instead of one hundred as at Jackson. This condition persists as far as the state line. Between this point and Estherville the country bordering the valley, and especially that on the western side, is morainic, and consequently the river is walled in by a deep valley whose western slopes in particular are rather steep. Just above Estherville the valley contains some prominent gravel terraces, which rise forty feet or so above the stream and have buried the walls to that extent (Plate XXXVIII, C, page 491).

The Valley Below Estherville.—The Des Moines breaks through the morainic belt a little north of Estherville and thenceforward flows along its eastern margin. On this account it is bordered to the Palo Alto county line and beyond by a bold steep wall which is constructional rather than erosional, built of piled-up mounds of drift, knobby and rolling as far as



A. The high morainic west wall a mile below Estherville. B. The wide sag-valley near Ottosen.

the eye can reach (Plate XXXIX, A). The east side of the valley, however, is a long gentle slope, reaching back for a mile or even two miles, and on this slope the town of Estherville is built. The cross section profile, Plate XXXIII, D, will show this feature clearly.

Below Graettinger the hills to the west of the valley become lower and the topography is less knobby and rolling, although a clearly marked moraine, the Ruthven moraine, is present in western Palo Alto county. See the map, Plate XXXII, page 467. On the east side also the rise to the upland is less and in places there is no demarcation between valley and upland, so gentle

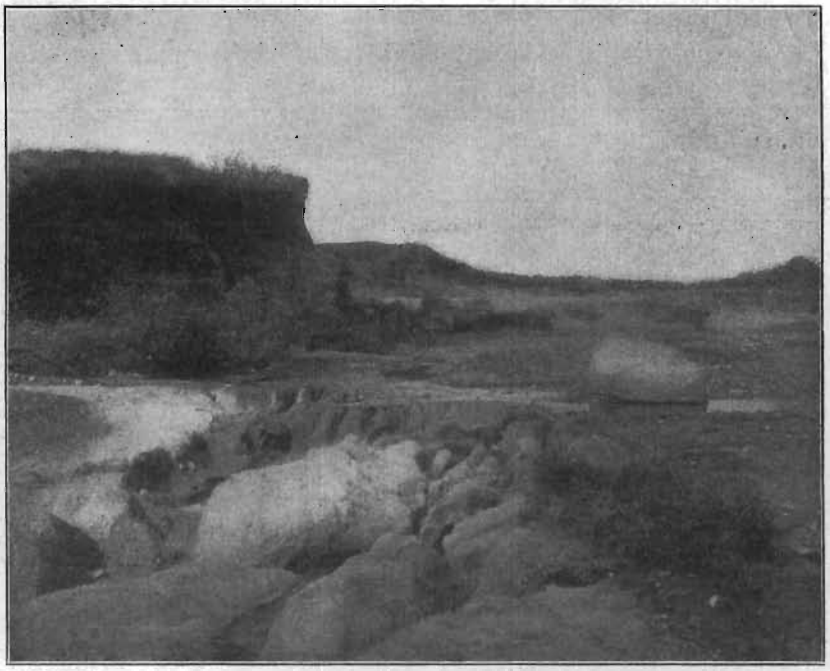


FIG. 49—Kansan blue clay beneath the gravels at Estherville. Pit of Minneapolis and St. Louis Railroad Company.

is the rise. Near Emmetsburg the valley widens to such an extent that its floor is a mile and a half to two miles wide. See the profile of the valley at Emmetsburg, Plate XXXIII, E. See also Plate XL, A, page 502, for the narrow flood plain in the vicinity of Graettinger.

Beginning with the terraces above Estherville and continuing to Emmetsburg and beyond is an immense gravel train which covers, or once did cover, the entire valley floor and whose constituents grow progressively finer from the bowlder besprinkled coarse gravel of the Estherville pits to the fine sands and alluvium which border the river in central Palo Alto county. The Minneapolis and Saint Louis Railroad Company formerly operated a great pit in these gravels on the south edge of Estherville and the drainage streams from the pit have uncovered the Kansan blue clay which underlies these Wisconsin gravels. See figure 40. At Graettinger also a large pit is opened in the gravels, which have been penetrated for twenty-two feet, until water forbade further digging. They show all the characteristics of water-laid materials, such as cross-

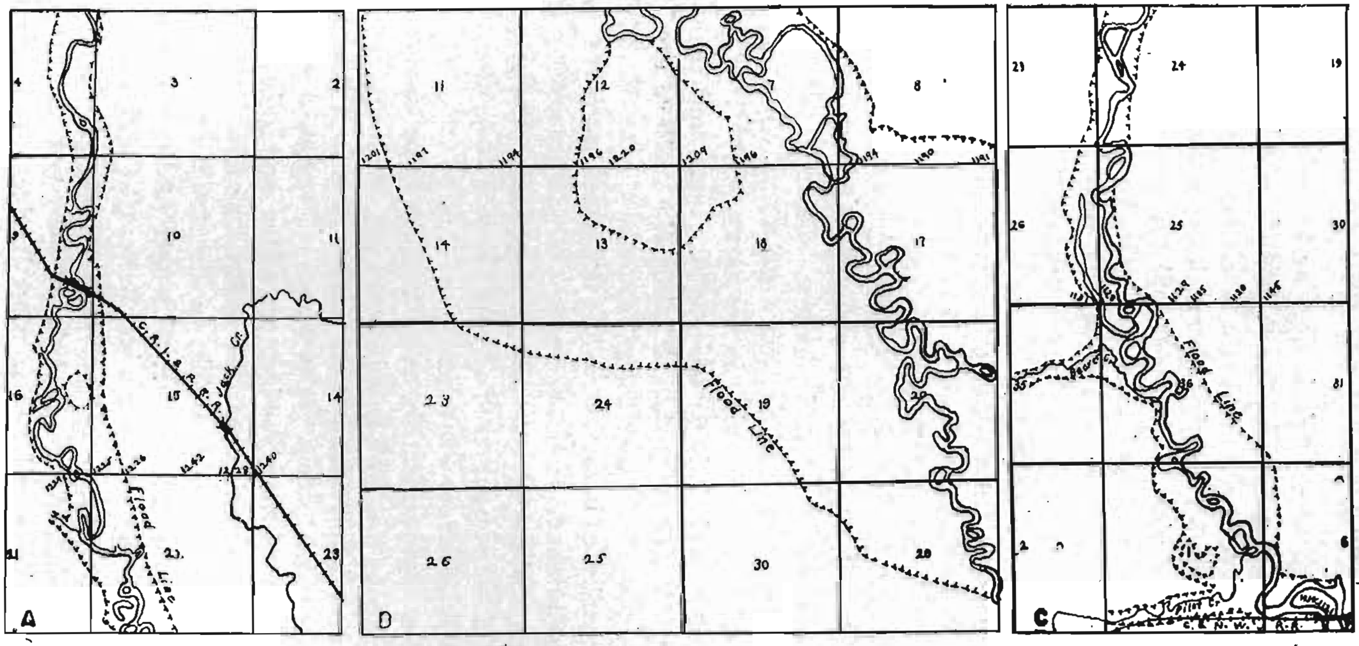
FIG. 41—View of the gravel pit in the valley train at Graettinger, Palo Alto county.

bedding, contemporaneous erosion and those irregularities of deposition which one might expect from shifting, hurrying floods. See figure 41.

The origin of these gravels is not far to seek. We may picture to ourselves the edge of the Wisconsin glacier as lying at one time just above the present site of Estherville, for example, with torrents of water passing down the great hollow between the high rolling region to the west and the more level plain to the east. All the mud and sand and gravel and bowlders that the stream could carry or push were brought down this channel and when the water could no longer transport them they were dropped over the valley bottom.

The Valley from Emmetsburg to Humboldt.—Between Emmetsburg and Rodman the valley is remarkably wide and flat. For distances of two to three miles one may look across the bottom-lands and see scarcely a change in level, excepting here a low mound and there an old abandoned channel. Most of these channels are short and shallow, although one south of Emmetsburg is several miles long. Another remarkable feature of the valley in this region is the extreme gentleness of the bounding slopes and their great length. Here and there is a rather steep though low rise defining the valley, especially where, as south of Emmetsburg, the valley is bordered by a group of morainic knobs. But for the most part the valley margins are ill-defined or not defined at all. They merely grade back through a slope of one mile to three miles to the ground moraine. This is equally true of both sides of the valley; there seems to be little or no difference.

The maps accompanying the report of the Iowa Conservation Commission show how widely separated the floodlines are below Emmetsburg and how shallow the valley is. See Plate XL, B, which is reproduced from these maps. They also show how exceedingly crooked the river is in its minor wanderings. There are a few great swings across the valley, but more conspicuous are the smaller meanders which, in the southern part of the county especially, double the actual length of the stream. The low gradient of the valley across Palo Alto and Pocahontas counties—less than three feet per mile—renders a deflection of the stream by relatively small obstacles very easy and hence its course is bent hither and yon in most intricate and marvelous fashion.



A. Map showing narrow flood plain of Des Moines valley at Graettinger, Palo Alto county. B. The wide flood plain just south of Emmetsburg. C. The narrow flood plain west of Bradgate, in Palo Alto county. Reproduced from maps of Iowa State Drainage Waterways and Conservation Commission, 1910. Altitudes above sea level.

The valley train fades out in this latitude and only the finer materials were carried beyond. These finer materials are covered by several feet of alluvium—rich black silt mingled with more or less sand—a gift which is renewed by each recurring flood. The valley gravels no longer form a conspicuous feature of the landscape.

The only tributaries in this region worthy of note are Jack creek, which drains Swan lake in central Emmet county, Willow creek, the outlet of Silver lake, which reaches the main stream west of Emmetsburg, and Cylinder creek, which winds its tortuous way across the prairie from Medium lake near Emmetsburg to yield its contribution to its master southwest of Rodman. Jack and Cylinder creeks in their lower reaches occupy valleys of some width but of slight depth and probably largely constructional. Willow creek finds its way among the low knobs of the Ruthven moraine until it leaves these to enter the broad sag which contains Des Moines river. Beaver creek, in northeastern Pocahontas county, has been mentioned on page 495, and Pilot creek is practically identical with it, except for its somewhat smaller dimensions.

Below Rodman the valley begins to narrow somewhat, although many of the slopes still are long and gradual, stretching away a mile or even two miles, such as those shown in Plate XXXIX, B, page 497, west of Ottosen. However, in places the bounding walls are well defined, and locally are steep. Here and there groups of low knobs at the valley's margin accentuate the division between lowland and upland. Such are a group south of Rodman and another three miles east of Bradgate, which latter sends the stream off to the south. Much of the valley between Bradgate and Rutland, however, is bounded by rather gentle slopes which rise thirty to forty feet to the prairie levels. See Plate XL, C, for the narrow flood plain above Bradgate.

The valley near Bradgate is underlain by alluvium and sand to a depth of fifteen to twenty feet. Below this yellow Wisconsin till fifteen to twenty-five feet thick is reported and beneath this a layer of very fine sand ten to twenty feet in thickness often causes serious trouble in wells. This sand may be of Buchanan age, although more probably it is Wisconsin outwash material. Beneath it Kansan blue clay is reported, and this has been penetrated sixty feet.

Rock Outcrops.—Professor Macbride maps a small exposure of Saint Louis limestone opposite Bradgate but this could not be found by the writer, even with careful search. However, there were seen near river level two small outcrops of the bright colored, variegated, finely sandy clay shales which are characteristic of both the Des Moines and the Fort Dodge beds, and which are readily distinguished from Pleistocene clays by the vividness of their coloration. These clays apparently form the first outcropping of the preglacial rocks along the West Fork. In the vicinity of Rutland Kinderhook limestone underlies the

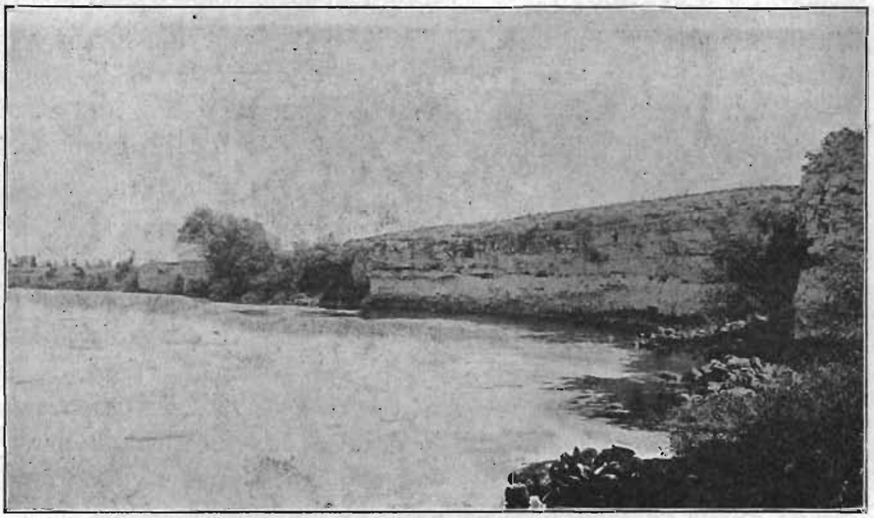
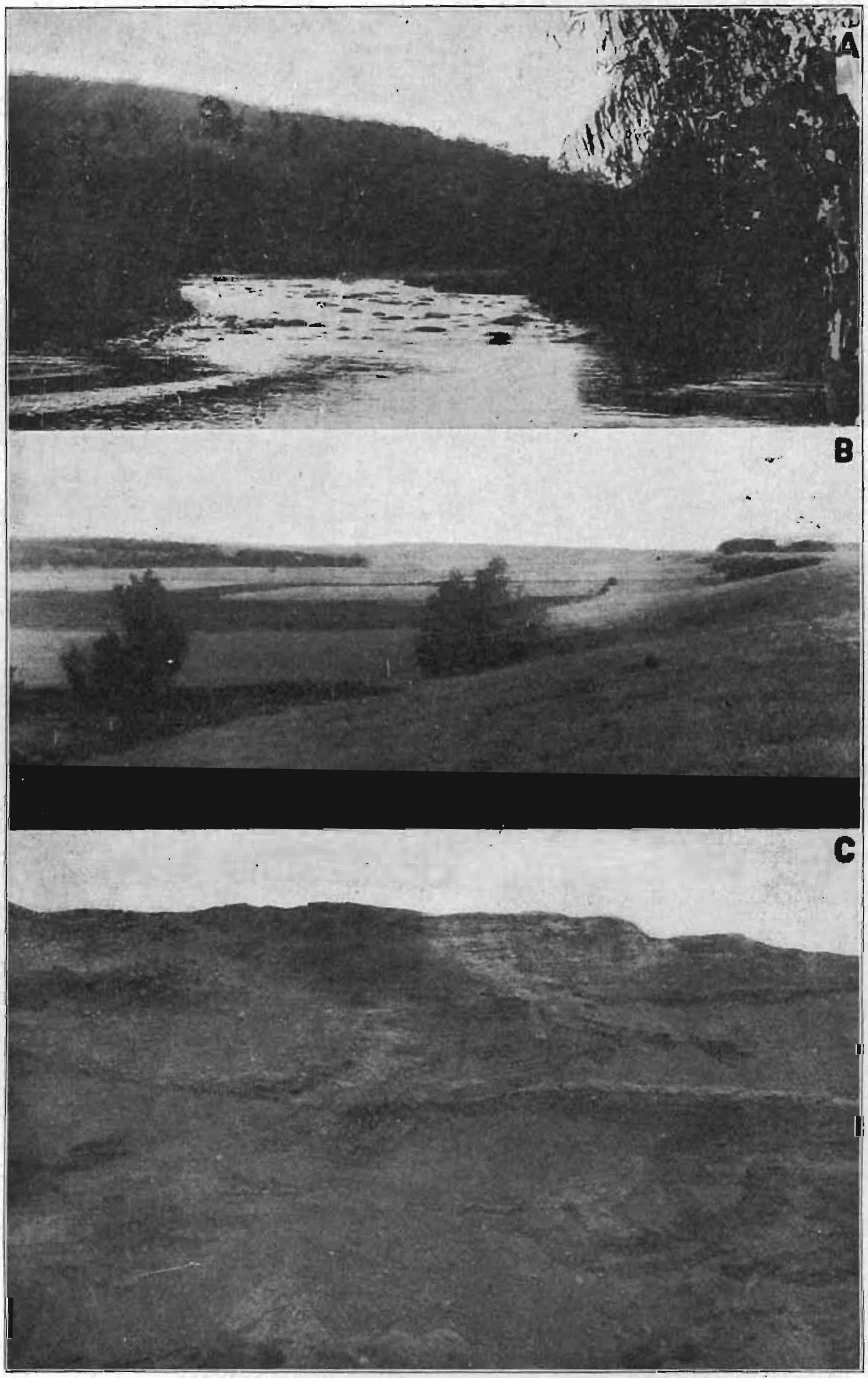


FIG. 42—The escarpment of Kinderhook limestone at the Rutland bridge, Humboldt county.

valley plain and at the village it outcrops abundantly. A vertical scarp of the limestone twelve feet high forms the south wall of the channel at the Rutland bridge. A view of this escarpment is shown in figure 42.

Below Rutland the valley becomes quite narrow, so that the flood plain is not over one-fourth mile in width and in some



A. The bowlder sprinkled channel at Humboldt. B. The wide valley of the West Fork just below Humboldt. C. Crossbedded gravels near Humboldt.

places even less. The valley also becomes deeper and where the river cuts against the banks, as is the case above Humboldt, the bluff is high and steep, and heavily wooded. The narrowing no doubt is due to the presence of the limestone, which, being so much more resistant than the unconsolidated drift, has confined the activity of the stream to a narrower zone. The channel from Bradgate eastward is strewn with bowlders, which in places are so abundant, to use Macbride's phrase, as to suggest some New England mountain channel, rather than the quiet, creeping river of the level prairie. This is especially true at Bradgate and at Humboldt as Plate XLI, A, shows. Below the exposures of Kinderhook limestone the chips and blocks of this stone litter the floor and banks of the valley.

Humboldt is built upon a rock platform which stands twenty feet or more above the narrow flood plain and has been swept almost clear of drift for a width of a mile. It is covered with a thin veneer of soil through which in numerous places the rock projects as small mounds rising about six feet above the surrounding level. This plain seems to be a remnant of the post-Kansan valley which was not filled with Wisconsin detritus to the same extent as adjacent portions. Its width is about the same as that of the valley just above Bradgate and probably represents fairly well the size of the older watercourse.

At Humboldt the steep, timber covered slopes of the west wall rise sixty to eighty feet above the water's edge and are indented by numerous short, steep ravines and gullies which cut into the upland for a short distance but fail to effect much in the way of drainage. The east wall also is quite steep for two miles below Humboldt. South of the town the walls approach each other within one-half mile or less and retain this relation for many miles below the union with the East Fork. See Plate XLI, B.

Three miles below Humboldt the West Fork swings to the east, bounded by the rather steep, wooded slopes of its west wall, and passing the nose of the dividing ridge, meets its fellow, the East Fork, at a right angle, two miles north of the county line.

Age of the Valley.—There seems to be no evidence to prove that the valley of the Des Moines in Minnesota and across Emmet and Palo Alto counties is older than the retreat of the Wisconsin glacier, if we make a possible exception of the stretch between Big Bend and Windom, Minnesota. If the depression above Big Bend is pre-Wisconsin, it would seem probable that a portion of the main valley below would be of the same age. For the most part, however, the valley is simply a great, broad sag, chiefly constructional, partly erosional, although the present river is entirely inadequate to determine the form of its valley except to a very minor extent.

Because of the outcrops of limestone in the valley below Bradgate Professor Macbride has suggested that in this locality the modern stream enters a rock-walled channel of Pre-Wisconsin age. In northeastern Pocahontas county as well as near Bradgate the valley floor is a mile wide, the walls are perfectly defined and their slopes are fairly steep, in places precipitous. At the bridge crossing the river a mile south of Bradgate, undercutting and road grading have exposed twenty feet of yellow, very pebbly Wisconsin till, five feet of rather fine, fresh gravel and twenty feet of drab, sparsely pebbly Kansan drift to water level. It was here also that the exposures of pre-Pleistocene clay shales were observed. The succession below river level already has been described. On the other hand wells on the uplands are reported as reaching rock at depths varying from a few feet to twenty, forty or sixty feet or occasionally at even greater depths. These facts are cited to show that above the mouth of Beaver creek as well as below, the river evidently is occupying a valley cut wide and deep before the Wisconsin glacier brought down its load of clays and sands. There is no such abrupt change in character here as one might expect to find, did Beaver creek represent a pre-Wisconsin watercourse. It was stated above that beyond Rutland the valley floor is not more than one-fourth of a mile wide. But this narrowing is the natural result of the gradual sinking of the valley into the resistant limestone of the Mississippian, rather than of a sudden change in the age of the valley. It is evident that somewhere in this region there occurs the passage from the wide, immature, constructional, modern sag to the narrower, better defined, erosional, interglacial valley. But Beaver valley does not bear the evidence of being at the critical point or of marking the continuation of the older channel. But wherever the change in age may occur, the assumption of an interglacial valley seems necessary to account for the depth and definiteness of the present course across Humboldt county, as well as for the rock cuts at Rutland and Humboldt.

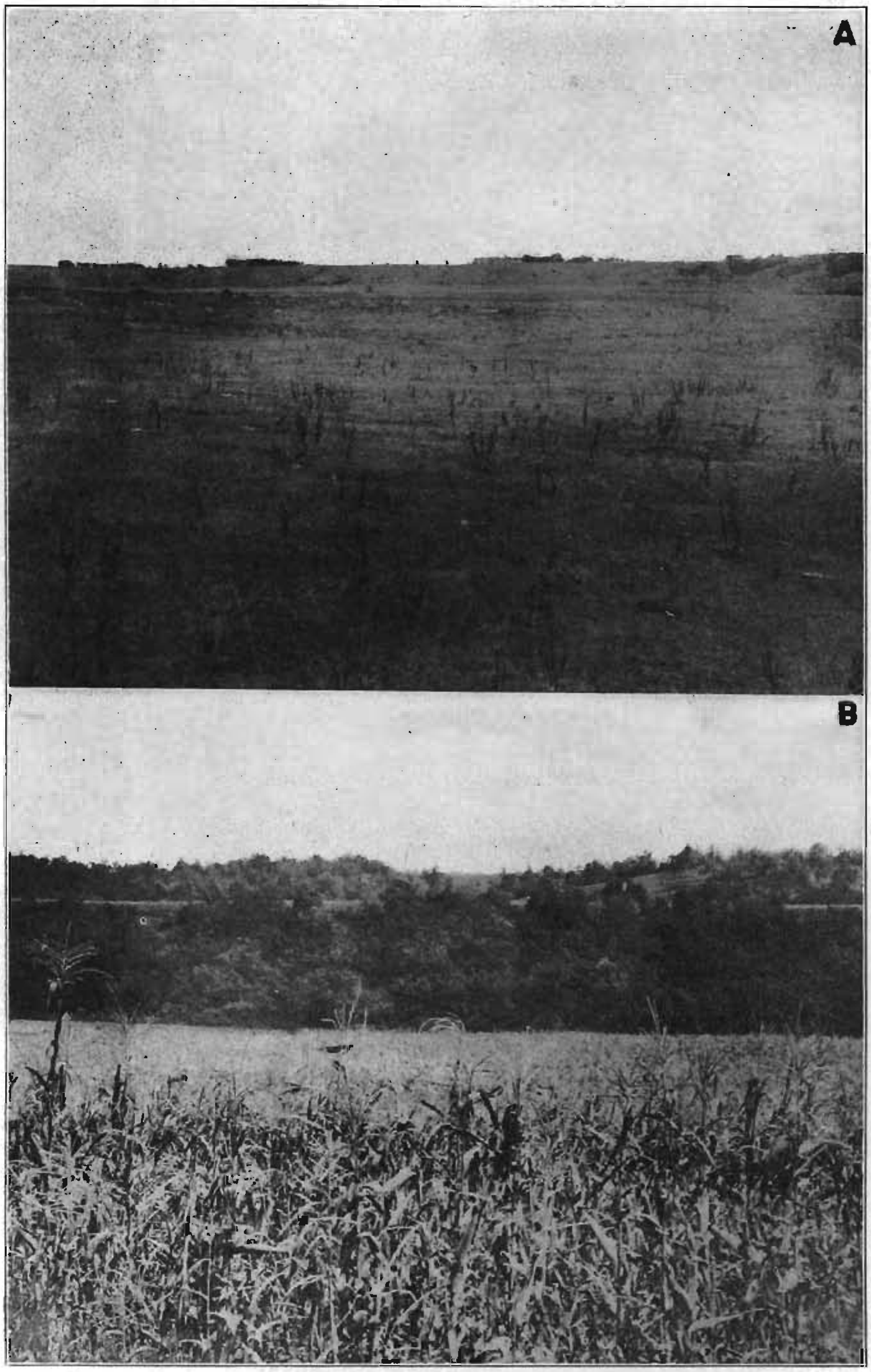
Outlet of the Chain Lakes.—In connection with the discussion of the origin of the valley of the East Fork the possibility was suggested (page 478) that the pre-Wisconsin drainage line now represented by the Chain lakes in Martin county, Minnesota, might be continued southward by the lower part of the West Fork valley and that a possible point of juncture was near the northeastern corner of Pocahontas county. Since here the younger valley seems to join the older, this locality affords the logical point for the attachment of the buried Chain lakes river to the pre-Wisconsin Des Moines. At least this theory has the advantage of accounting for the pre-Wisconsin valley in Pocahontas and Humboldt counties and of suggesting as well the outlet of the ancient river which once occupied the Chain lakes valley.

Age of the Gravels near Humboldt.—There are large amounts of gravel in a low terrace along the West Fork below Humboldt. Plate XLI, C, shows their character well. Where the long upland ridge between the two forks slopes down to the south its face is banked by a broad terrace of sand and gravel which also fills the entire valley and forces the West Fork against its south wall. Professor Macbride assigned this latter deposit to the Buchanan and the same is done by Beyer and Wright in a recent publication. The bed near Humboldt is assigned by these writers to the Wisconsin, as are also beds on the East Fork. The materials banked on the nose of the ridge are slightly rusted, the sands are stained a little yellow, the gravels a little red, but they are far less weathered than typical Buchanan gravels of eastern Iowa. Furthermore they contain a strikingly large proportion of fresh limestone pebbles of all sizes up to several inches in diameter. Those beds which lie down in the valley bottoms are very similar in composition and in showing streaks of iron rust and stain, especially in their coarser parts. The same is true of the terrace materials near Humboldt; while they are essentially fresh they show streaks of iron and manganese stain. There seems to be no sufficient basis for separating these various deposits as to their age. Between the low terrace near the city and the bank at the foot of the ridge dividing the forks there is no distinguishing criterion, and as between these latter and the materials somewhat higher up the slopes there can be no doubt of their equivalency and continuity. It seems scarcely reasonable to consider the valley as pre-Pleistocene or even pre-Kansan in age, but the gravels can not be Buchanan if the valley is post-Kansan. Considering then the character and age of the valley and the character and physical condition of the gravels it seems necessary to assign them to a period later than the Kansan, in other words to the close of the Wisconsin. There is, of course, the alternative of an Iowan age for the gravels, but judging from conditions where the Iowan is better known, this does not seem an attractive hypothesis. The Iowan does not seem to have been a period of extensive gravel deposition.

Des Moines Valley Below the Forks.

Within a few miles below the junction of the forks the valley becomes much deeper. Near the mouth of Deer creek, the bluff is ninety feet high and at Fort Dodge the river is 160 feet below the upland level. This notable deepening is continued into Boone county and is due not merely to the natural processes of erosion but chiefly to the ridges of drift material which are piled across its course in ever increasing height, from northern Webster county to their culmination as the Gary moraine of Boone county.

Near the county line Saint Louis limestone comes into view in the bed of the river and continues intermittently as far as



A. The wide flat valley above Fort Dodge, near Deer creek. B. A high bench a mile below Kalo.

Fort Dodge. A mile south of the line a terrace rises fifty feet above the flood plain and has a width of one-fourth mile. It is seen clearly to be a rock platform and upon it lie great numbers of Wisconsin bowlders, and probably there is Wisconsin till beneath the soil. It is evident that the erosion of the valley in the limestone was pre-Wisconsin as the slope to the flood plain is covered with Wisconsin bowlders. In places the rock has been cut out for a width of a quarter of a mile, and, as is the case opposite this terrace, through a thickness of fifty feet, too great a task for the present stream to have accomplished during its brief history. The high platform, like the inner gorge, may be the result of interglacial erosion.

Three miles north of Fort Dodge a broad expansion of the valley covers about a square mile. For the most part it lies above the reach of modern floods and evidently is an ancient flood plain. The surface, where the road traverses it, is covered with sand which may have been swept in by Wisconsin floods. Opposite this plain the river is cutting into Coal Measures clays and coal, although above and below here the Saint Louis limestone is exposed. The presence of the softer Coal Measures doubtless accounts for the expansion of the valley at this place. Plate XLII, A, shows well the character of the valley between Humboldt and Deer creek in northern Webster county.

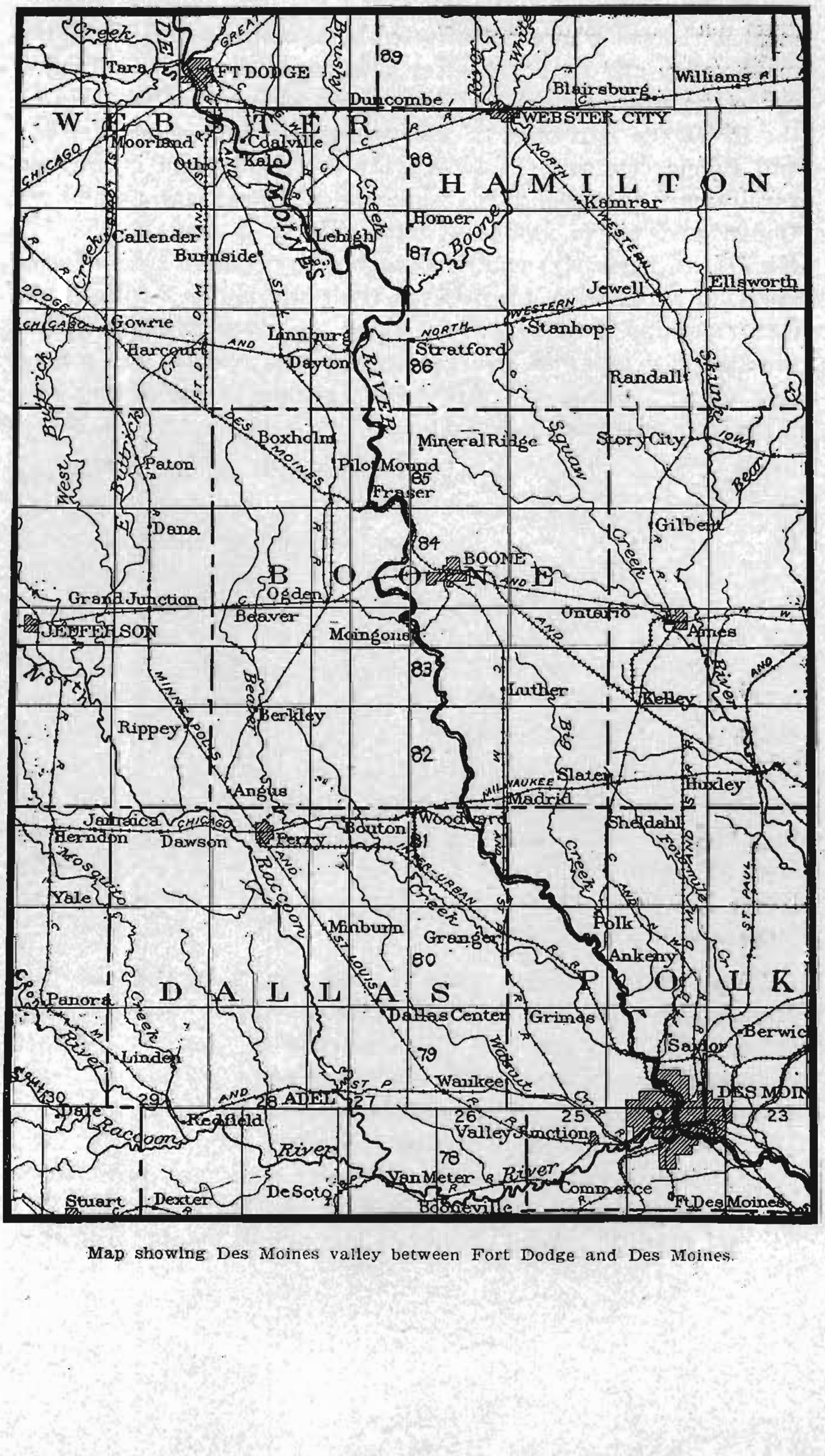
Tributaries.—The tributaries of the Des Moines in Humboldt county are of little consequence. In Webster several laterals enter the master stream but these are typical prairie creeks, with the exception of the Lizard Forks, until within a mile or two of the main valley. In their lower courses they have been obliged to cut deep trenches into the rock to keep in topographic accord with the great valley. North Lizard is the most important creek of the county (Plate XXXII, page 467). Where it opens into the Des Moines valley it has cut a deep gorge in which it has developed a moderately wide flood plain. For some distance above the mouth the north wall is lower than the south wall, owing to the presence of a prominent range of morainic knobs which extends across this township and which here bounds the valley closely. The south wall is accordingly rugged and well timbered while the north slope is less rough and rather bare. Above the junction of the forks the North Lizard has a rather wide valley, but this shallows rapidly. Followed back a few miles it is only a few feet below the prairie level, and is quite a typical valley of the drift plain.

Where the South Lizard cuts through or abuts against the knobby drift region it develops steep bluffs but elsewhere its valley is shallow until within two or three miles of the junction with the North Fork. In the lower stretches several remnants of old levels appear as terraces on the steep walls and some low hills of circumdenudation are seen in the narrow valley. Apparently the stream occupied a somewhat different course when it flowed at a higher level but the process of adjustment to changing conditions in the Des Moines valley caused it to seek new channels as it deepened its valley.

The secondary streams exert practically no influence on the topography of the region aside from their immediate valleys, and the same is true to a large degree of the master stream itself. One no sooner ascends from the deep gorge than the unchanged Wisconsin plain stretches away before him, mile after mile. Swamps and sloughs remain undrained on the very border of the valley and bear witness to the immaturity of the drainage.

A small creek valley in southern Webster county, west of Stratford, down which the Chicago and North Western railroad runs for a short distance, is typical of the secondary drainage of the Des Moines system in this region. It begins as an insignificant swale or shallow sag in the drift plain about two miles from the river but deepens rapidly and within a mile has attained a depth of ninety feet. It is narrow, however, down to its junction with the main valley, for, although its depth at the mouth is 180 feet, even here there is a space of only thirty to forty feet between the bases of the bluffs.

The Valley Below Fort Dodge.—Below Fort Dodge for many miles the high walls of the valley are relatively steep for the

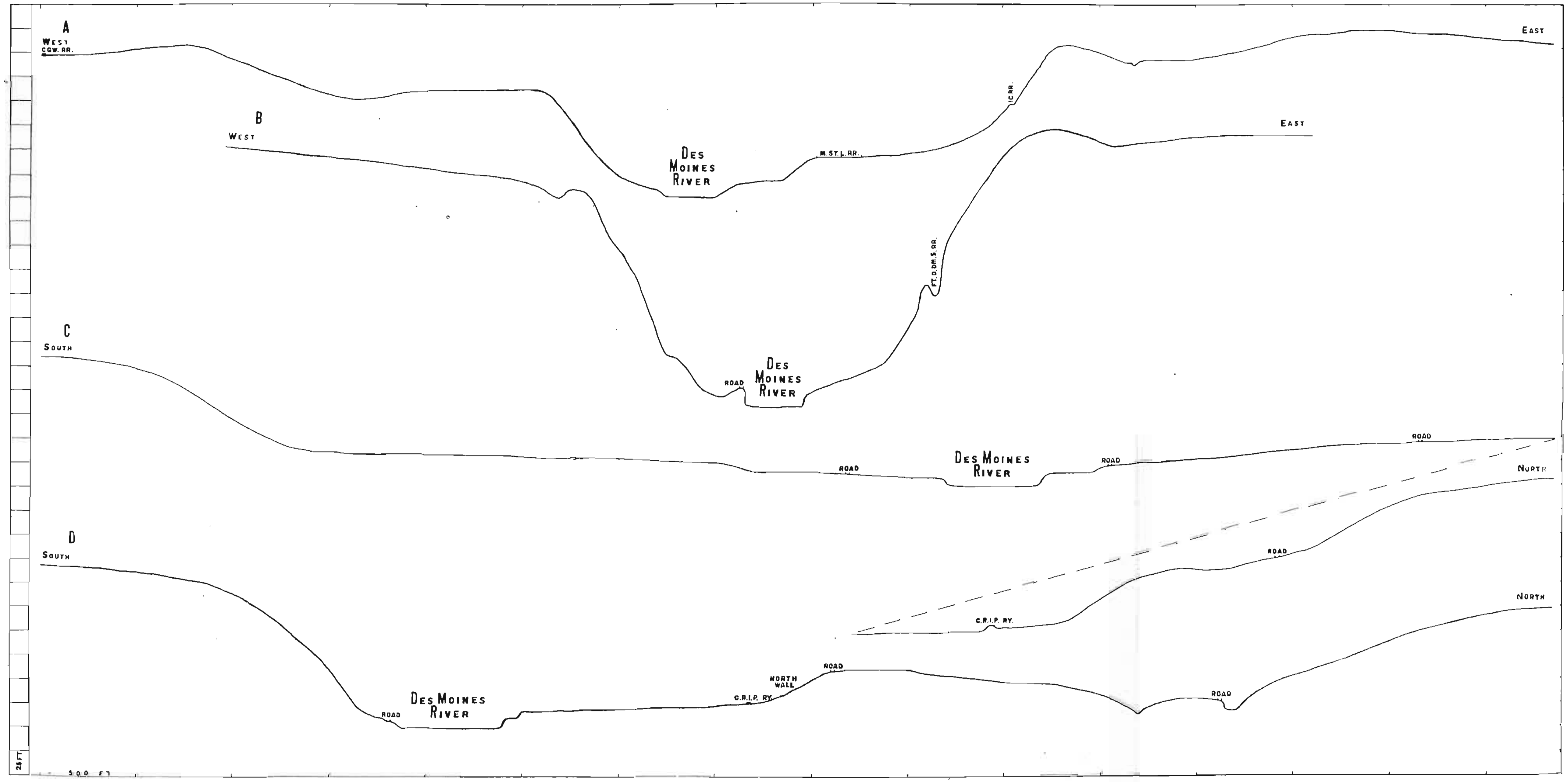


Map showing Des Moines valley between Fort Dodge and Des Moines.

most part even where not affected by recent erosion. Both the main valley and its short, steep tributaries are heavily wooded up to the prairie level and form most picturesque features of the landscape. In most of the valley's extent across Webster and Boone counties (Plate XLIII) the flood plain is narrow, rarely more than 200 yards wide, and in places less, as at Fort Dodge and above Boone (Plates XLIV, A and B; XLVI; XLVII, A, page 521) and at Fraser where a mere strip of lowland 100 yards wide lies between river and bluff. South of the Gary moraine, however, from which the river emerges within the last few miles of its course in Boone county (see Plates XLVI and XLIX), the valley widens until at the county line it is a full mile from rim to rim.

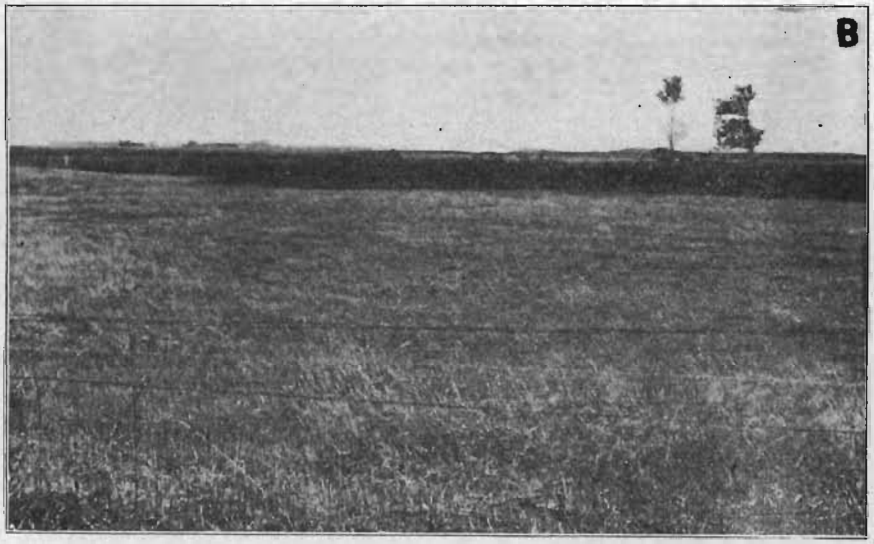
Below Fort Dodge exposures of shales are very frequent along the banks as far south as Kalo. In the vicinity of Fort Dodge gypsum also may be seen outcropping along the main valley and in its tributaries. Below Kalo massive, yellow, cross-bedded sandstone forms the walls as far as Lehigh, though covered along much of this distance with a veneer of drift. The bare rocky walls of the master gorge, presenting occasional vertical cliffs forty to fifty feet in height, are exceedingly picturesque and make delightfully attractive spots when framed in the verdant mantle which clothes much of the floor and slopes of the valley. With the increasing depth of the gorge the picture becomes more charming and where, as at Lehigh, the bluff rises at one sweep 190 feet from the water's edge to the upland levels it is one which will be excelled with difficulty in the landscape of central Iowa.

Boone River.—Boone river enters the valley of the Des Moines just within the limits of Webster county. The river has cut a gorge fully one-half mile from rim to rim and 180 feet deep in its lower reaches. This valley possesses all the characters of the master valley and in but slightly smaller degree. The rather insignificant stream meanders idly over its flood plain, which is flat and sandy. The side walls are quite steep, just as are those of the major valley. Angles of 12°, 15°, 20°, 22° and even 26°, were measured at various points. About a



A. Profile of Des Moines river at Fort Dodge. Beyond the east end of the profile the surface is practically level. On the west are gently rolling uplands. B. Profile of Des Moines valley across middle of section 12, Yell township, and section 7, Des Moines township, Boone county, about two miles north of Boone. See Plate XLIX. Slightly rolling uplands west of profile; level land east of profile. C. Profile of Des Moines valley one mile west of Selma, Van Buren county, showing the wide valley. D. Profile of Des Moines valley one-half mile east of Selma, showing the narrow valley.

A



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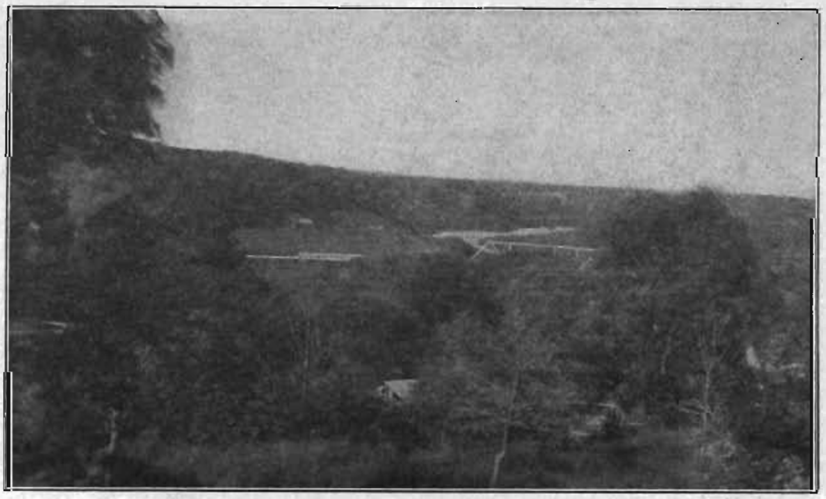


C

A. Boone valley about a mile above its mouth. B. The flat Wisconsin plain stretching away from the edge of the valley. Taken from the same point as A. C. Boone valley at the first bridge above Stratford, about two miles above its mouth.

Topographic map of northern part of Boone quadrangle, including parts of Webster, Hamilton and Boone counties.

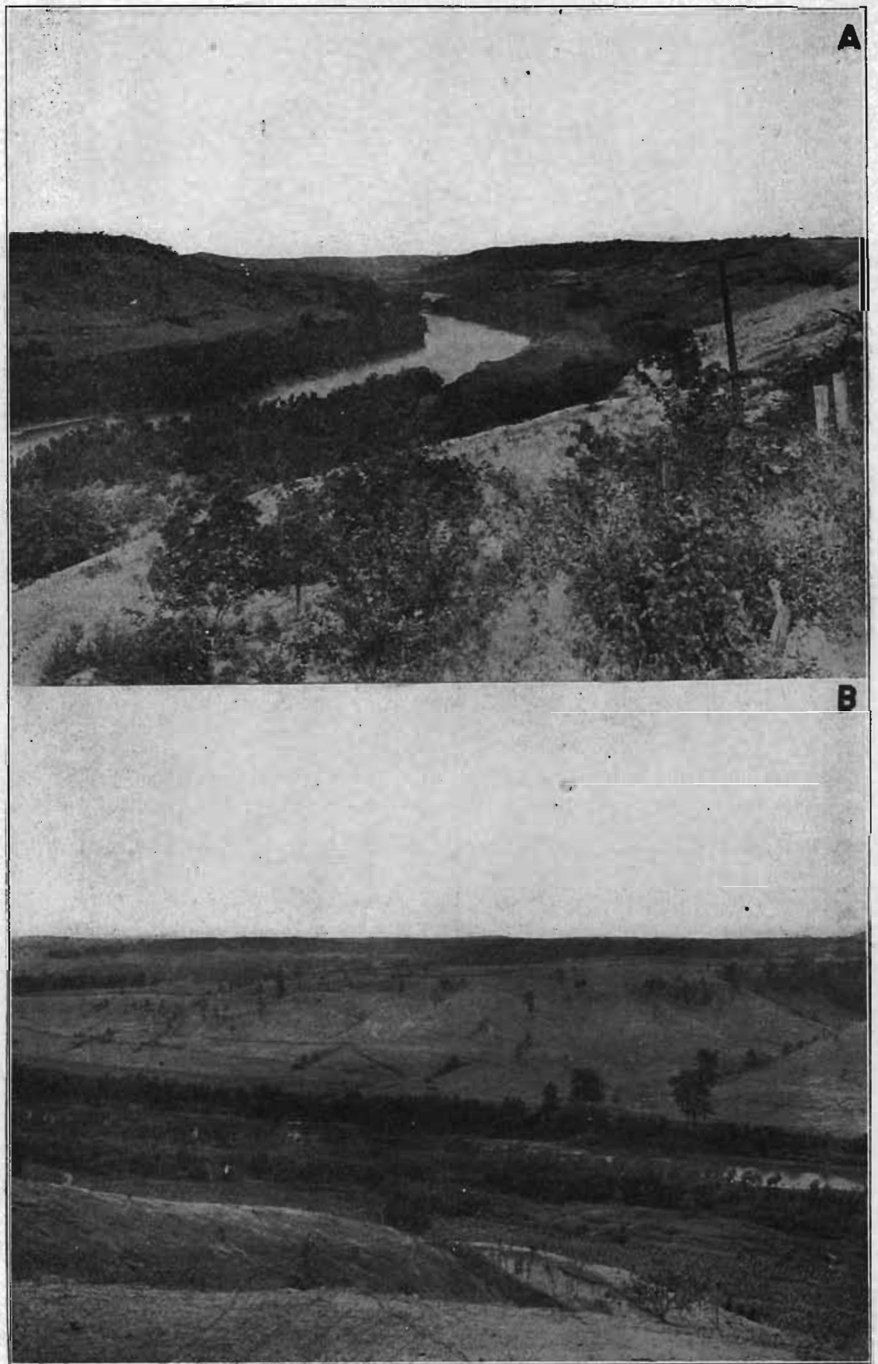
mile above the mouth of the stream is a bench ninety feet high which doubtless is related in origin to those in the major valley. See Plate XLV, A, B and C.

Terraces.—A mile below Kalo there is a high bench on the south side of the river, representing a former level of the valley. It is underlain by Des Moines shales and doubtless is to be correlated with the high benches noted in the north part of the county, both in age and in method of formation. See Plate XLII, B, page 511.

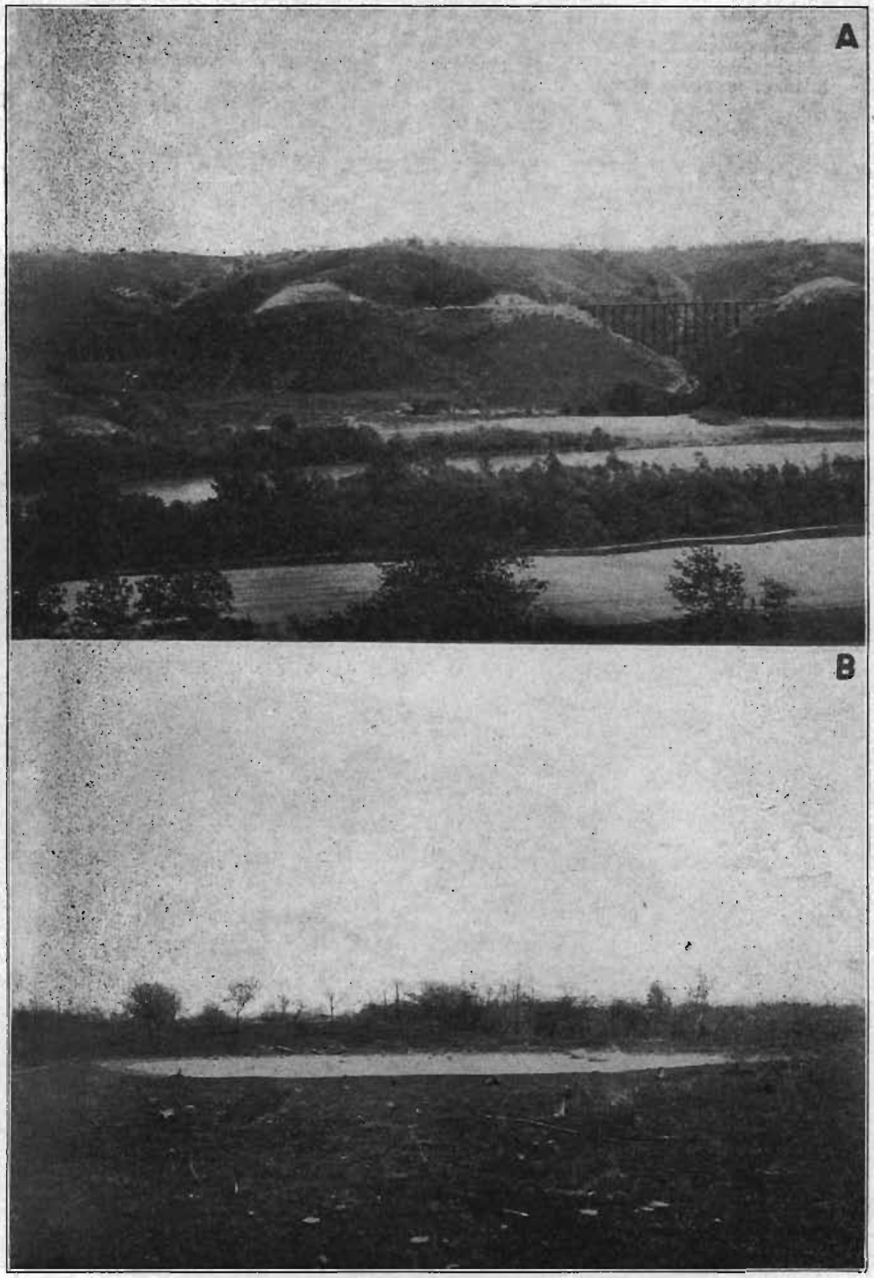
Opposite the mouth of Boone river is a bench which is nearly 100 feet high, and in its course across southern Webster, Boone and northern Polk counties the river is bordered almost continuously by benches and terraces. Just south of the Webster-Boone line, for example, a low terrace 300 yards wide rises ten feet above the flood plain, and a mile down the valley a high bench lies seventy feet above the stream. Its rough surface rises to meet the bluffs, at whose bases it is one hundred feet high. This bench covers one-fourth of a square mile and so far as can be seen in cuts it is built of waterlaid sand and gravel. It seems to fill a recess in the ancient valley. The village of Fraser is built upon another of these high benches and still another fills the hollow across the river from the village.

A similar bench fills the north part of the bend east of Fraser (Plate XLVI) and, in common with many others, consists of sand, gravel and cobblestones. To the south it slopes down to a lower terrace, built of detrital material, which fills the mile-wide recess between the river and the bluffs. The upper bench is perhaps sixty feet high and the lower one is about thirty feet above water level. The bayou in which these are built is one of the largest along the river. Plate XLVII, B, shows a similar group of terraces in sections 1 and 12, Yell township.

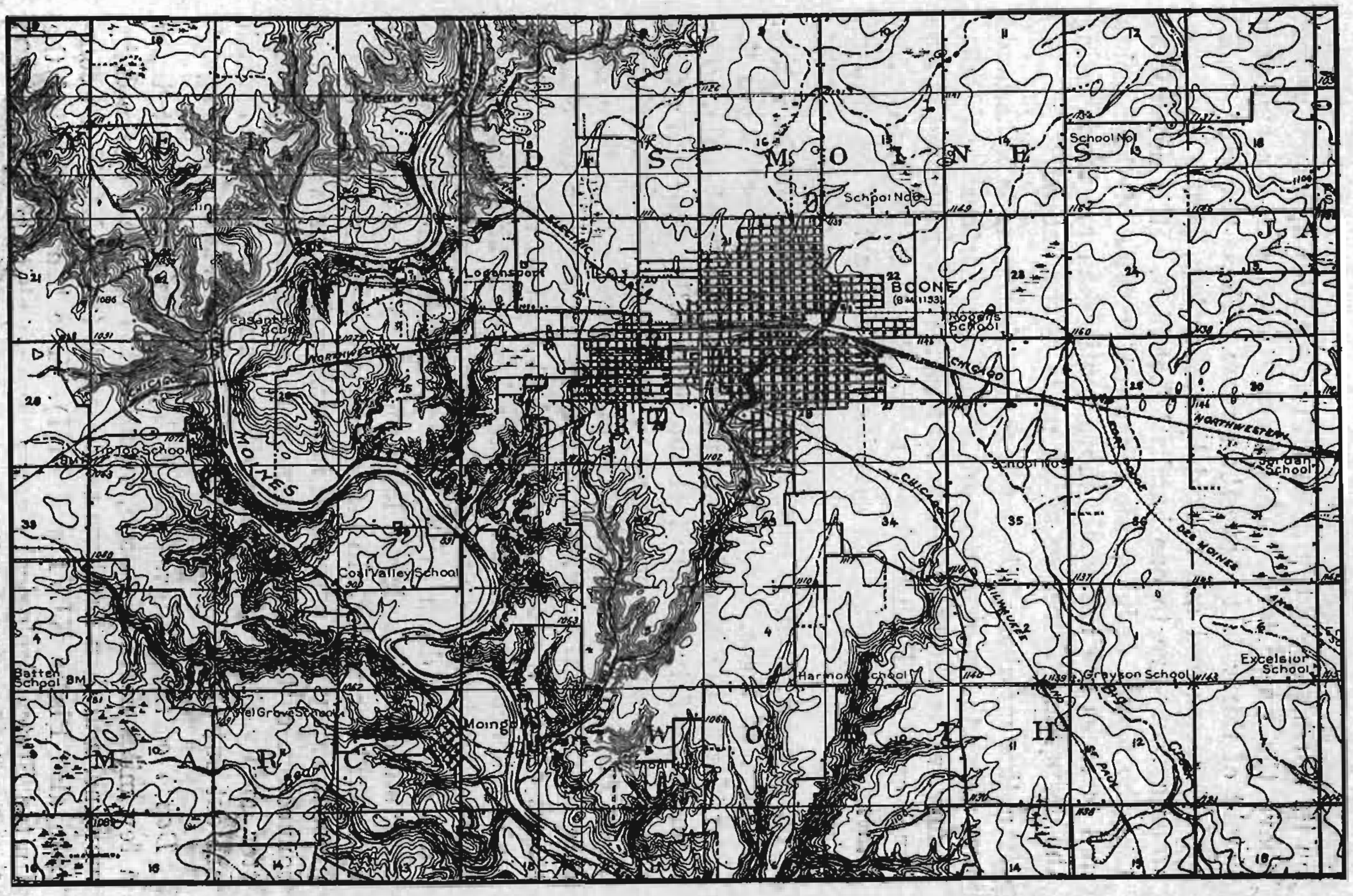
The series of terraces to which the upper one just mentioned may belong, is represented by that on which Moingona is built and other representatives of this series are to be seen near the north and south lines of Douglas township. See Plate LII, page 531. The former of these shows gravel and waterlaid sands



A. The narrow gorge of Des Moines river, midway between Boone and Fraser.
B. High terraces on the west side of the valley above Boone. The upper edge of the higher terrace is shown in A at the left. Note the even skyline.



A. Short steep ravines in the east wall above Boone. They are only about two hundred yards long and are two hundred feet deep. B. A pond on the unaltered Wisconsin plain, between the ravines shown in A. The beginnings of a third ravine approaching from the rear may be seen to the right of the center background.



Topographic map of southern part of Boone quadrangle, in Boone county.

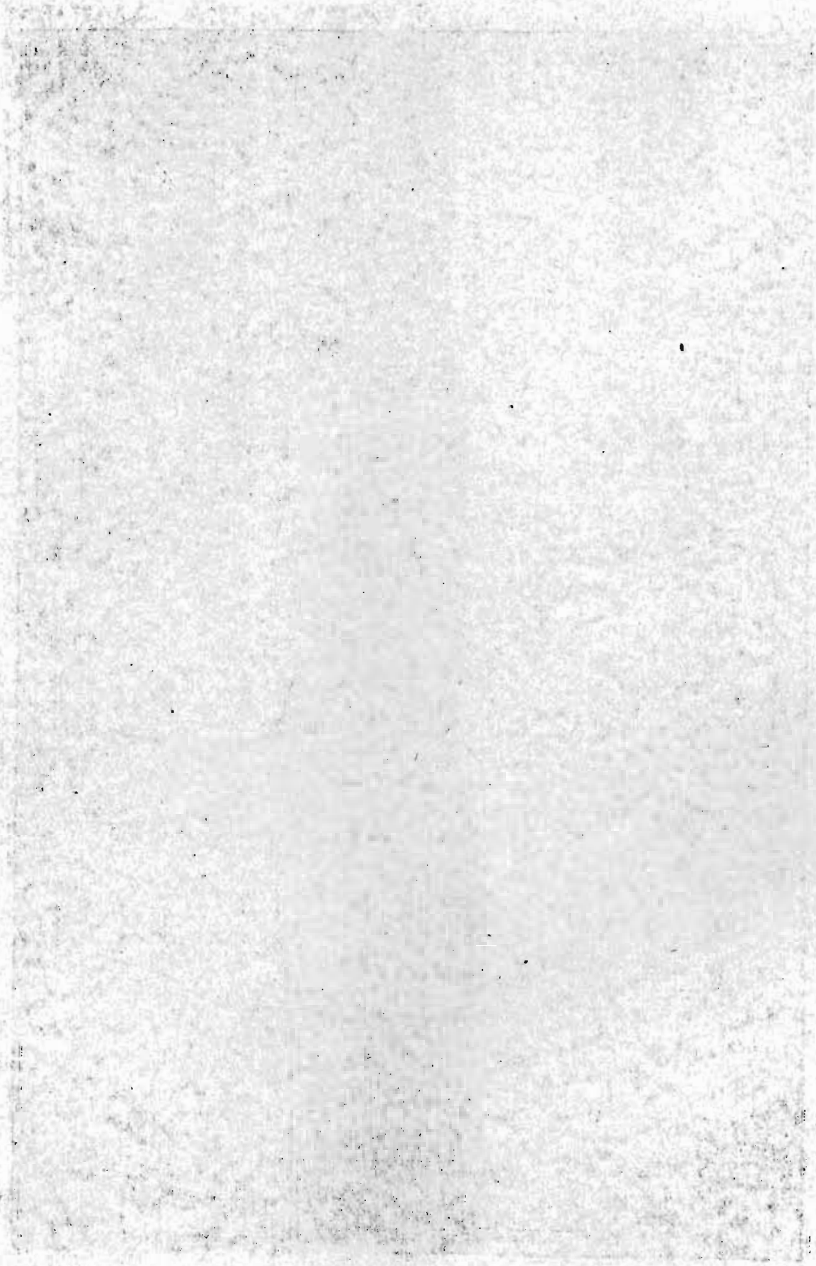
on its north side, but on the south side shales appear fifty feet above the water level. This terrace faces a lower one at a height of thirty feet above the stream. These two seem to fill an old recess and are backed by rather low, gentle bounding walls seventy-five to one hundred feet high. It is noteworthy that the slopes defining the rearward margins of the benches and terraces are uniformly more gentle than are those facing the deeper and therefore newer parts of the valley.

Another member of the lower series of terraces is to be found just above the mining camp of Scandia, in northeastern Dallas county, while the seventy-five foot series is represented by the bench on which High Bridge is built. See Plate LIII, page 533. Others of these series are plentiful in this part of the valley's extent.

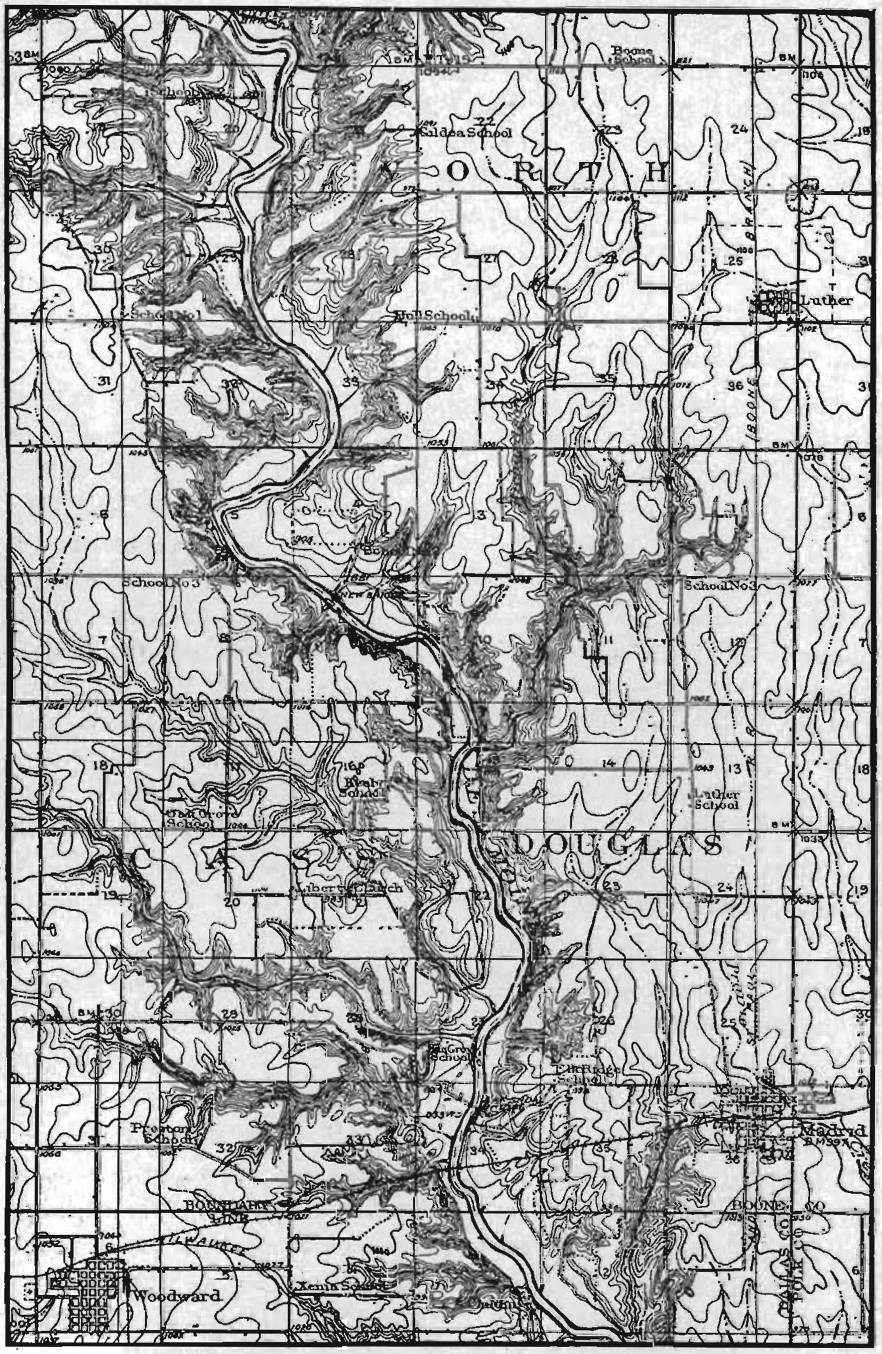
There seem, then, to be three series of benches in the valley. The first of these, ranging from ten to thirty feet above the river, forms the immediate boundary of the flood plain. The second rises fifty to sixty feet above the valley floor and a third series is seventy to one hundred feet from the bottom-lands. In so far as these terraces are of sand and gravel they indicate that the valley was at one time, probably in the closing stages of the Wisconsin age, filled at least to the level of the highest bench, and that the filling has been since largely cut away. The two lower series of gravel terraces, as well as terraces cut in or down to the indurated strata, indicate that the river stood at those levels long enough to widen out its valley by lateral corrasion. In other words the down-cutting of the present valley has proceeded intermittently. As was stated in connection with the rock terraces near the north line of Webster county those of Webster, Boone and Polk counties which are cut out of Coal Measures must be pre-Wisconsin in age.

Depth of the Valley.—The valley attains its greatest depth a few miles north of Boone, owing to the presence of the Gary moraine, and then shallows to the south (Plate XLIV, B; compare also Plates XLVI and LIII). The bench marks of the United States Geological Survey give an altitude of about 890 feet for the river two miles north of Fraser while the uplands

The Gary moraine in Boone county, and a Wisconsin bowlder.



The Ledges, Des Moines valley, Boone county.



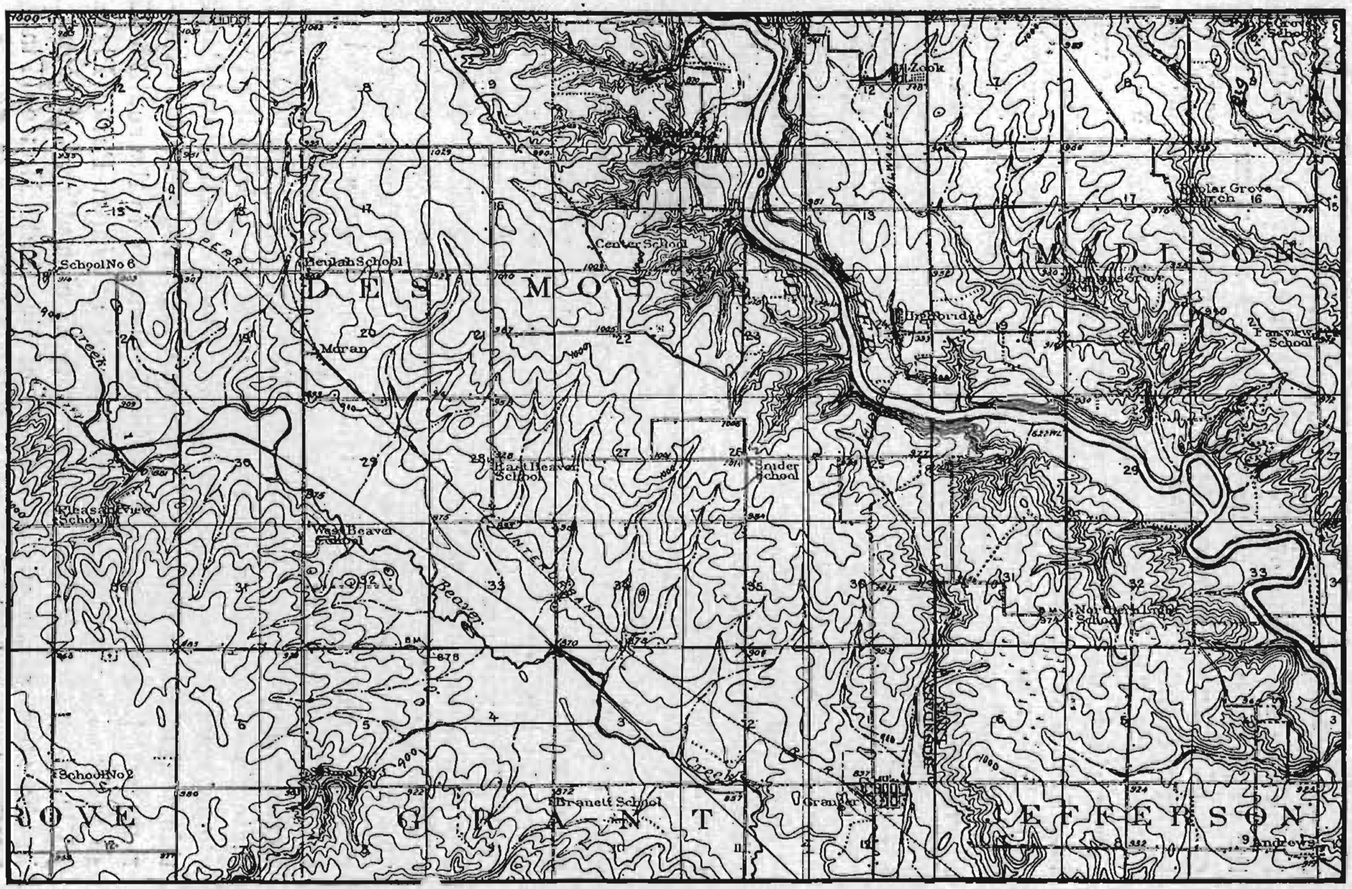
Topographic map of northwestern part of Madrid quadrangle, including parts of Boone, Dallas and Polk counties.

on either side rise to elevations of 1120 to 1160 feet, and Mineral Ridge, the crest of the Gary moraine, reaches a height of 1240 feet above sea level. See Plates XLVI and L. This means a maximum depth of over 260 feet, although the immediate rise to the crests of the bluffs is generally about fifty feet less. Where Mineral Ridge approaches the valley the bluffs rise fully 250 feet at a single sweep. However, where the valley is crossed by the Dallas-Polk county boundary its depth does not exceed 160 feet, and the prairies scarcely are 1000 feet above sea. See Plate LIII.

The Ledges.—There are numerous ravines along the valley walls but many of these extend back only a short distance and are very steep. So in many cases they are only 200 to 300 yards long but are 200 feet deep. The ravines shown in Plate XLVIII, A, are excellent examples, while B of the same plate shows how little they have affected the topography. The creeks which enter the valley also have deep timber-filled gorges. Bear creek is one of the best examples. One of the most picturesque scenes along any part of the valley is The Ledges, near the mouth of Pease creek in section 16, Worth township (Plates XLIX and LII). Massive sandstone forms high mural escarpments between which lies a charming valley with its little stream. See Plate LI. Trees and grass and rocks combine to form one of the most attractive spots of the region and one whose charm is greatly appreciated and utilized by visitors from far and near.

Doctor Beyer ascribes the formation of the Ledge sandstone to rapid sedimentation during Pennsylvanian times, apparently in a valley of limited area eroded in older Coal Measures. The present valley has been formed by erosion and differential weathering in this heavy bedded sandstone.

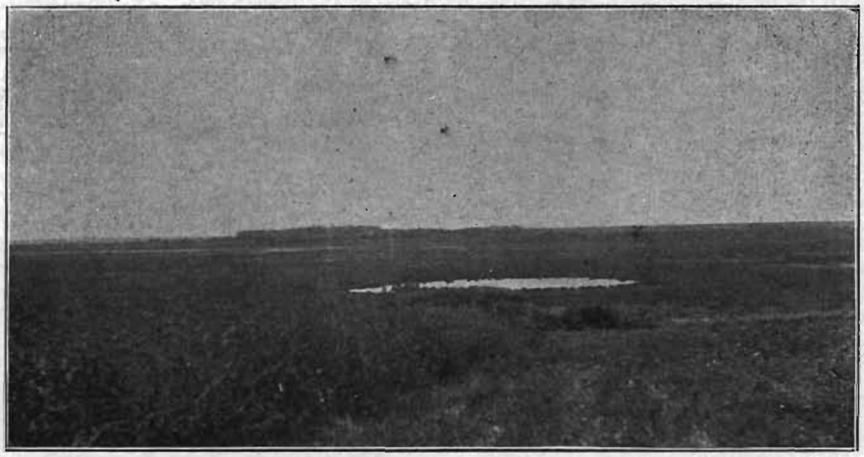
Moraines.—Below the Boone county line the valley shows on its western side a marked tendency toward long gentle slopes after the crest of the bluffs has been passed. On this account the highest land is not reached for a mile or more back from the first sharp rise. This feature is accentuated by a high morainic swell extending from northeastern Dallas county past Woodward and Granger into Polk county. This swell is capped



Topographic map of southern part of Madrid quadrangle, including parts of Dallas and Polk counties.

by knobs and kamelike ridges which rise eighty to one hundred feet above the crests of the river bluffs to the west. Among the most conspicuous of these ridges are the mounds a mile east of Granger (Plate LIII), one two miles northeast of Granger (Plate LIV, B) and another three miles further west (Plate LIV, C). Southward this swell is continued by a narrower ridge, which separates the Des Moines and Beaver valleys (Plate LV). This ridge is only a mile to two miles wide at its base, and its crest is in many places broad enough merely for the road which follows it. The highest points are 200 feet above the river and twenty feet less above Beaver creek. Although capped by aeolian sands it is built up of yellow Wisconsin till, blue, fossiliferous loess, perhaps overlying Kansan till, and a core of Coal Measures, which rises in places 100 feet above the river. Its eastern slope, facing the river, is almost everywhere steep and rugged and gashed by many short ravines, but the westward slope is much more gentle. The ridge descends by a long easy grade to the mouth of Beaver valley.

The Valley in Polk County.—From the Polk county line to the south line of Crocker township the Des Moines valley is gradually widening until the flood plain is fully a mile wide and the entire valley is practically three times that width if we consider the long gentle slopes back of the steeper walls (Plate LV). The wall overlooking the valley from the east becomes less rugged and dissected in Crocker township and south of the township line this transition suddenly becomes very marked. The gentle, mature slope swings off to the southeast, down to a point opposite Saylorville (Plate LV), where a mile and a half of level flood plain intervenes between it and the stream. Between Saylor and Des Moines city limits (Plate LV) this plain rises by a rather steep wall twenty to forty feet high to an almost equally level plain beyond. Just north of Highland Park this wall meets at right angles a steep, high, rugged bluff which runs west to the river. Here it bends abruptly to the south and so makes its way with a local descent at Union Park (Plate LVI), past Capitol Hill, to terminate as abruptly as it began, in the steep sandstone cliff south of the State House (Plate LVIII, A, page 553).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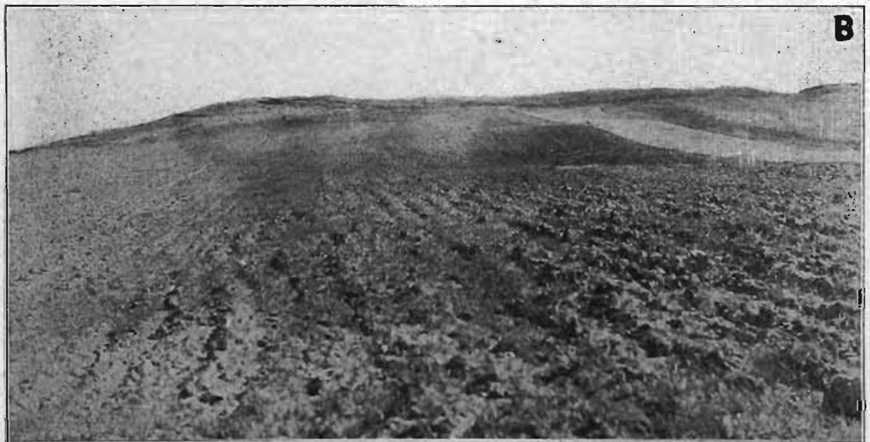
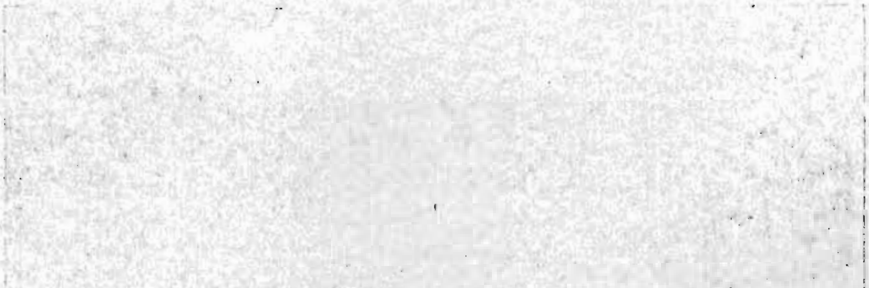
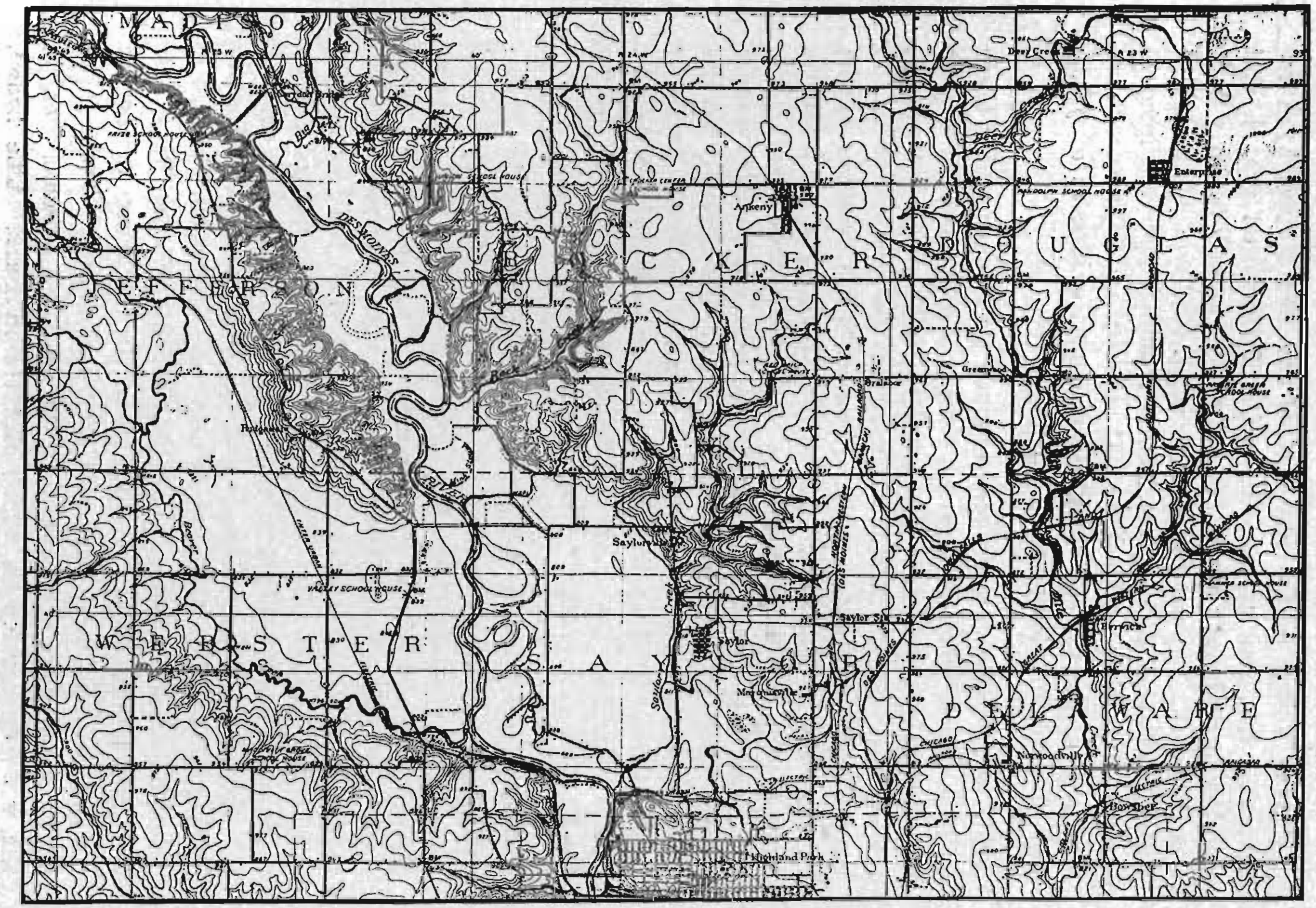

B


C

A. A pond near the kame shown in B. B. A kame in section 31, Madison township, Polk county. View from the west. C. A kame in section 34, Des Moines township, Dallas county. View from the east.



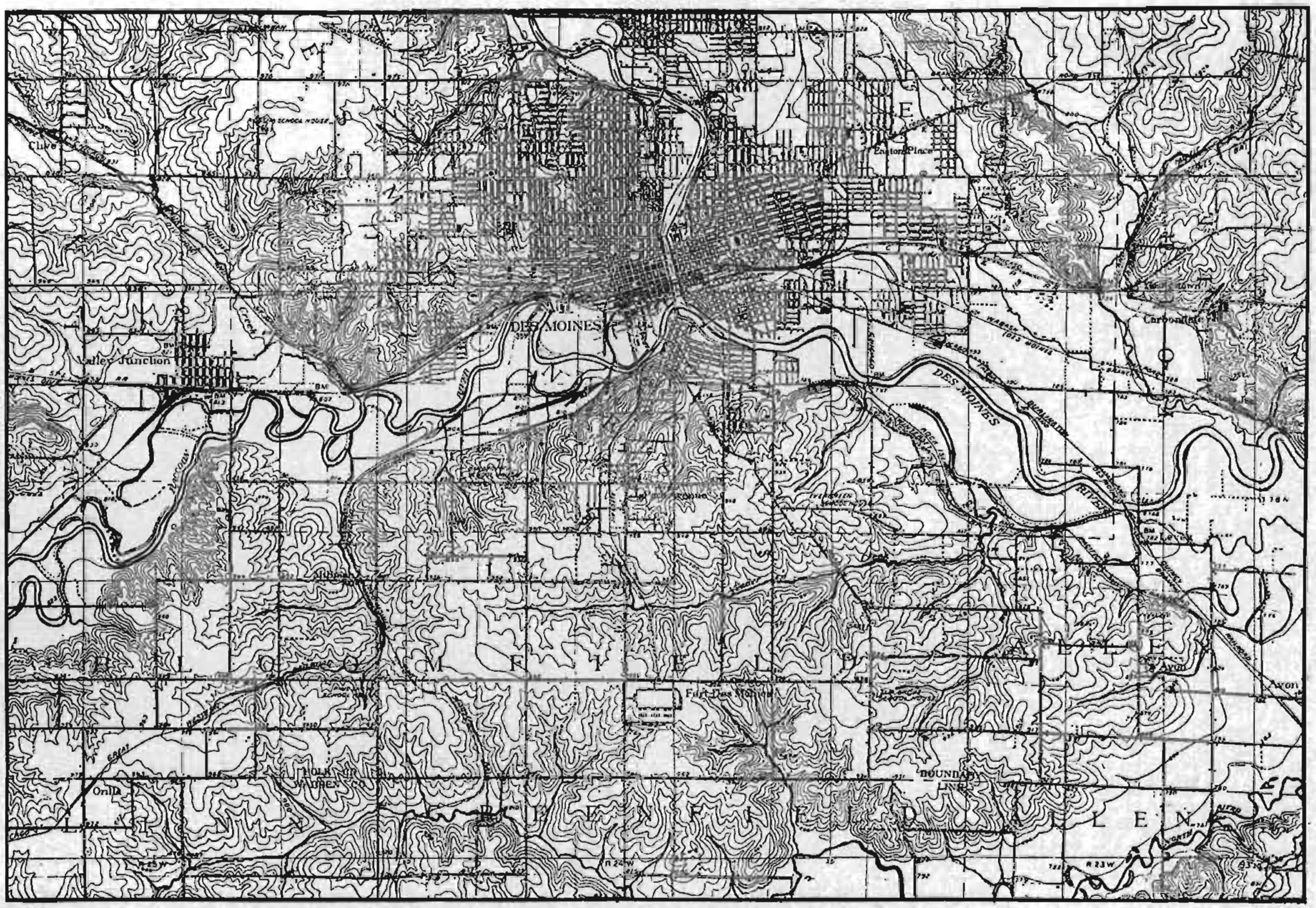


Topographic map of northern part of Des Moines quadrangle, in Polk county.

Beaver Valley opens into that of the Des Moines by a remarkable flat, two miles wide, built of sand and gravel, and varying in its height above the river from twenty to forty feet. See Plate LV. Beyond this flat the steep west wall of the major valley, as described on page 532, is resumed and continued to the junction with the Raccoon. It is trenched by numerous ravines, and, like the opposing slope, shows evidences of youth and immaturity along nearly all its extent.

The wide flat just mentioned extends up Beaver valley three to four miles. But far beyond, along all of its extent in Polk and Dallas counties, as well as across southern Boone county, the creek occupies a broad shallow sag, many, many times too large for the present stream. It reminds the observer of the great swales in Minnesota and in Palo Alto county, for instance, along which the sluggish stream winds its aimless way. The sag rises to the east to the range of morainic hills previously mentioned as extending past Granger and Woodward. To the southwest stand knobs and high ridges like sentinels guarding the broad and fertile plains beneath. The valley of the Beaver, like the Plain of the Jordan of the ancient writer, is "fair as the Garden of Jehovah." See Plates LIII and LV.

Now it is to be noted that immediately opposite the mouth of Beaver valley lies the wide plain which has been spoken of already as reaching from Saylorville almost to the limits of Des Moines and which occupies the west half of Saylor township—the plain popularly known as Saylor Bottoms. The relations of these are well shown on the map of the Des Moines quadrangle (Plate LV). Beyond the low wall south of Saylor there stretches southeast a wide plain limited on the east by the upland on which stand Saylor and Marquisville, and south of this by the more strongly rolling ridge known as Four Mile ridge, on whose slopes are Grandview Park and the State Fair Grounds (Plate LVI). On the west lie the lower eminences crowned by Highland Park and East Des Moines. From these latter, the slope is very gently to the east, and between them is the wide depression in which lies Union Park. The broad,



Topographic map of southern part of Des Moines quadrangle, including parts of Polk and Warren counties.

smooth slopes of these walls give an aspect of considerable maturity and offer a strong contrast to the choppy topography of the valley slopes to the west.

The sag or plain which lies between these walls is very level in general, except for scattered mounds which dot its surface, and which seem to be dunelike in origin and nature. It sinks to the south from elevations of 840 and locally 860 feet to an altitude of 800 feet or less where it opens into the great valley of the Des Moines between Capitol Hill and the Fair Grounds. Like the mouth of Beaver valley it is underlain very largely with sands, as has been learned to their cost by some of the coal mining companies which have run entries into it. It is obviously the continuation of the broad depression through which Beaver creek meanders, and must be connected with it in origin. The two are merely separated, or we may say united, by the now somewhat lower expansion of the Des Moines valley which lies between them.

DISCUSSION OF CONDITIONS.

We have now reached the point where Des Moines river emerges from the Wisconsin plain and passes into the much older topography of the Kansan drift area. Hence it is well to consider the reasons for some of the features that have been studied.

In Boone County.—Doctor Beyer, in his study of Boone county geology, indicated certain facts which he considered to point toward the youthfulness of Des Moines river in that county. These are: "(1) The extreme shortness of the tributaries, taken in conjunction with their high grades, is indicative of brief careers. (2) The river itself has done comparatively little lateral corrasion. Only in rare instances does it impinge on the limiting walls of the valley. (3) According to data derived from coal mines and well sections the position of the stream appears to be out of harmony with the topographic features of the older formations; i. e., the Des Moines is a superimposed stream, younger than the glacial deposits." The accompanying diagram, figure 43, adapted from Professor Beyer's report, shows the relations of the present and pre-Pleistocene surfaces.

In Webster County.—For Webster county, Doctor Wilder brings forward similar topographic evidence to show that the present valley is very young, but demonstrates from geologic facts that the river is "reworking a pre-Wisconsin, perhaps pre-Kansan valley."

Relations of the Valley.—It is very probable that the statements of these two writers, while seemingly contradictory, are entirely in harmony. It is true that the valley in both counties has every appearance of youthfulness and that the system appears to be out of harmony with the underlying topography. But the first of these conditions may be ascribed to the Wisconsin glaciation of a post-Kansan valley, while the second is accounted for by the probable fact that the post-Kansan river was imposed upon a drift sheet so thick that the underlying topography was entirely ineffective as a controlling agent. It is certain that the detritus of the Gary moraine in Boone and Webster counties would so conceal any pre-Wisconsin drainage lines that the survival of even the master valley is a marvel, and its immaturity and youthful appearance are quite to be expected. Nevertheless, it seems to be a fact that the modern valley holds its present position by inheritance, by virtue of necessity. The presence in the valley of terraces, in-so-far as these are built of glacial materials, indicates that when the Wisconsin ice covered central Iowa, the Des Moines valley had attained practically its present dimensions, that while the

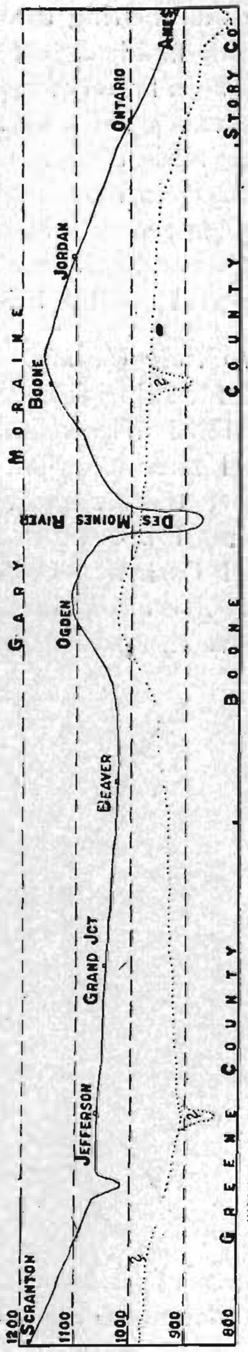


FIG. 43—Section across Boone and Greene counties, showing the relation of the present surface to the pre-Pleistocene surface. The latter is shown by dotted line. The relation of Des Moines river to the Gary moraine is well shown.

ice was melting the valley was filled to a depth of seventy-five to one hundred feet with waste from the glacier, and that this has been largely swept away since, leaving mere remnants along the valley sides as terraces and benches. If all that has been done since the end of Wisconsin time is the excavation, almost entirely in loose materials, of the inner, and narrower, valley, we can scarcely attribute the making of the great gorge in its entirety with its rock walls scores of feet in height, to the closing years of the briefest of the glacial ages.

In Polk County.—Within Polk county Doctor Bain learned the following facts: The bottom of Beaver valley is filled with modified Wisconsin drift to depths exceeding fifty feet. The Coal Measures rise in the side slopes to heights considerably above the stream, and undisturbed Kansan drift is found at points low down in the valley. In the low plain east of Highland Park and Capitol Hill, wells and mines go through seventy-five to one hundred feet of filling, although rock rises well above the present floor in the hills on both sides. The valley

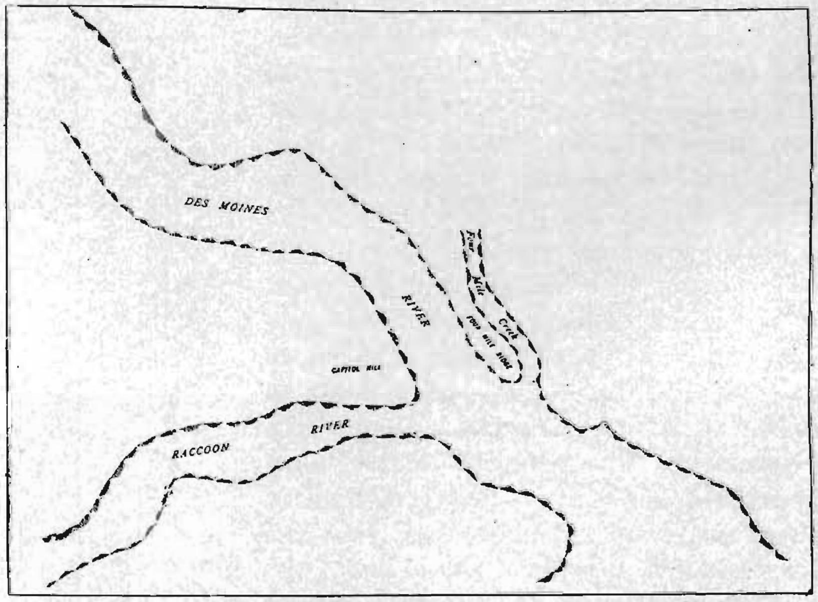


FIG. 44—Preglacial drainage at Des Moines. (After Bain.) The present site of Des Moines is indicated by Capitol Hill.

filling is in part Kansan drift. Below Des Moines the present river valley has been filled with many feet of drift—between fifty and one hundred.

Bain's hypothesis.—From these and similar facts Bain has constructed the following history for Des Moines river. The valley probably was excavated in the period immediately preceding the advent of the first ice sheet, as was that of the Raccoon, and their aspect near Des Moines was somewhat as represented in figure 44. The Kansan ice of course buried these valleys (the Nebraskan was not considered, as little was known of it when Bain made his studies), but did not fill them completely, and they were found by the post-Kansan streams—the valleys were resurrected. A system of drainage represented in figure 45 developed in the long post-Kansan interval, and among the minor streams those marked A and B played a most important role. The advance of the Wisconsin ice blocked the main valley opposite the stream B before the upper portion of the river was thrown entirely out of its valley. The swollen

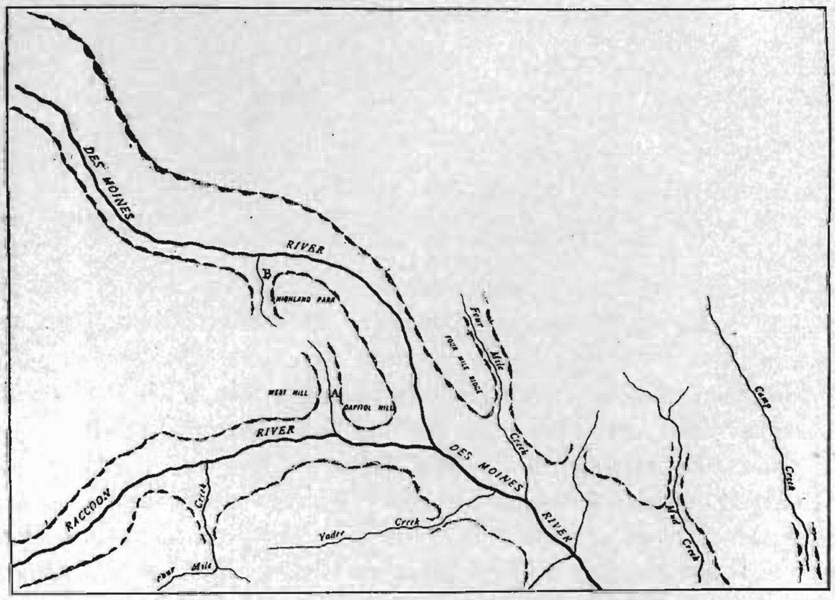


FIG. 45—Pre-Wisconsin drainage at Des Moines; illustrating Bain's theory of development of present drainage. The present site of Des Moines is indicated by Capitol and West Hills.

waters of the upper course flowed up the stream B, across the divide, and down A into the Raccoon. As the ice did not advance much farther the stream may have held its course under the ice. When the glacier melted back, the river held to the new course and abandoned the old one. It also abandoned the upper valley, now occupied by the Beaver, and cut the newer and narrower one in which it now flows. Present day conditions are shown in figure 46.

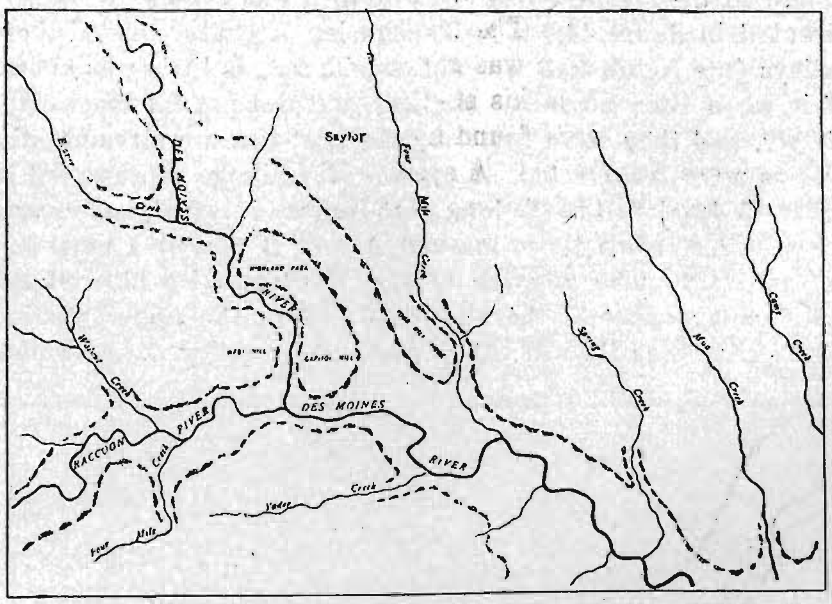


FIG. 46—Postglacial drainage at Des Moines. (From Bain.) Saylor Bottoms are located immediately north of Highland Park.

Objections to Bain's Hypothesis.—According to this theory the valley above Saylor Bottoms was excavated during the retreat of the Wisconsin ice. During the same period the portion between Beaver creek and the Raccoon was being deepened. Since terraces are found in the valley above Saylor Bottoms we must assume that the newly made valley was partly filled with sand, much of which has been carried away since. This sequence of events does not agree with the course outlined on page 541, but implies a very different history and necessitates a very much more rapid downcutting than is there postulated. Incidentally it may be questioned whether a glacier moving from west of north—which is also the general direction of the valley —would block the valley opposite B of figure 45 before the upper part of the river was overwhelmed or thrown out of its course.

That part of the valley within the city limits (see Plate LVI) is narrower than the upper reaches, although a somewhat greater age is assigned the former. And yet, rock outcrops are as common north of Beaver valley as in the city, the strata are similar, and rock rises fully as high above stream level, so there is no difference in this respect on which to rely for interpretation.

The assignment of the valley-cutting to the Wisconsin ice epoch might accord with Beyer's outline of conditions in Boone county but it fails to harmonize with the statements of Wilder as to the situation in Webster. If the Des Moines in Webster county is re-excavating a pre-Wisconsin valley while the Des Moines in Polk and Boone counties occupies a valley dating back only to the close of the Wisconsin epoch there should be topographic unconformity between the parts and there should be somewhere in the valley a topographic break which would record this fact. However, there is no such break and so the difference must be one of interpretation rather than of fact.

A NEW HYPOTHESIS REGARDING THE AGE OF THE VALLEY.

In order to harmonize these apparent discrepancies and to obviate certain difficulties which seem to be inherent in the theories heretofore presented, the following working hypothesis is offered.

Date of Origin.—It will be shown later from the relation of Des Moines river to the Mississippi, that the initiation of the Des Moines valley cannot antedate the beginning of the Pleistocene. The earliest date to which we can assign its formation is the close of Nebraskan glaciation. The post-Nebraskan Des Moines followed the course of the present river below Des Moines, but across the site of the city it occupied the wide depression described on page 540, and to the northwest, across Polk and Dallas and southwestern Boone counties at least, it cut out the wide sag through which Beaver creek now flows. The

Aftonian interval must have been of great duration to give time for the cutting of such a large valley even though it was sunk entirely in the soft strata of the Coal Measures for many miles above and below Des Moines. Raccoon river also probably originated at the same time, since its features are much more like those of the older than of the younger parts of the master valley.

Effect of Kansan Glaciation.—The oncoming Kansan ice filled the valleys, blotted out the drainage systems and so forced the waters, after its retreat, to seek new courses for themselves. Owing to their not being entirely filled with drift, as well as to the greater thickness of drift in them, the pre-Kansan valleys would be made manifest by the presence of sags over their former courses. In this way the old valley of the Des Moines was revealed and was used by the resurrected stream as far up as the junction with the Raccoon which also had been revived. But above this point the stream course suffered profound changes.

Width of the Valley.—North of Saylor Bottoms the present valley floor has a width varying from three-fourths of a mile to more than one mile. West and south of Highland Park the width is a little less, but is still from five-eights to three-quarters of a mile. At Union Park, which is opposite the bend in

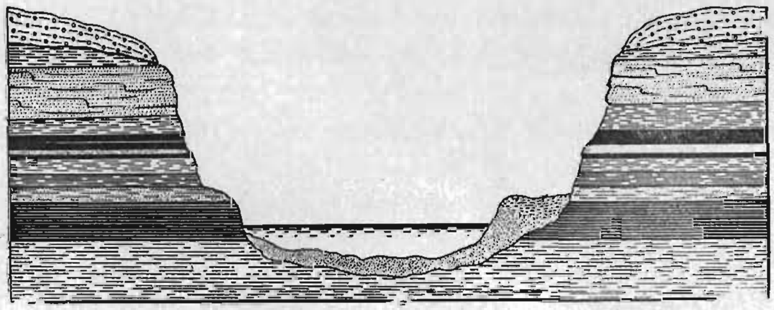


FIG. 47—Gorge of Des Moines river at Des Moines above the dam. (After Keyes.)

the valley, the rock wall is cut away below river level, as is shown by wells and drill holes in the vicinity, and the depression is filled with silts and sands. The sag here is on the same level as the pre-Kansan valley to the east, and the two are continuous.

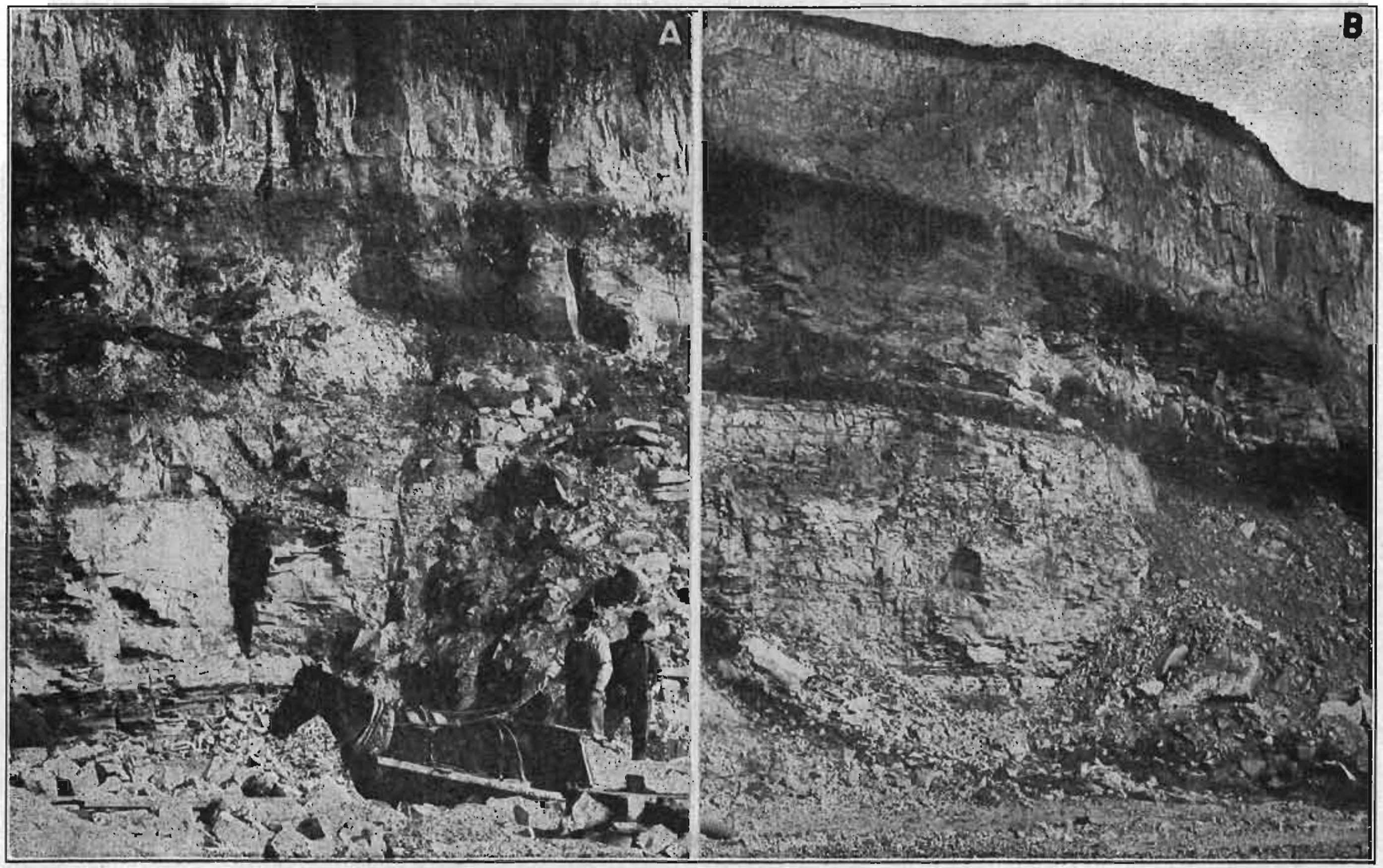
See Plate LVI. South of Union Park the valley again narrows until it is not more than one-fourth of a mile wide and the bottom is almost entirely covered by the river, as is shown in figure 47. This notable difference in the size of the valley immediately above and below Union Park seems to point definitely to a difference in age.

The Post-Kansan Valley.—Despite the difference in the width of the valley immediately above and below Saylor Bottoms both sections may be of the same age. From the evidence given on previous pages we may assume that the post-Kansan Des Moines established the course now followed by the river across Humboldt, Webster, Boone, Dallas and northern Polk counties (Plate XLIII), but instead of following the pre-Kansan course below the intersection at Saylor Bottoms it cut a new valley west of Highland Park as far south as the present site of Union Park. The absence of the rock wall at Union Park, and the extremely narrow gorge south of this locality seem to indicate that the post-Kansan stream, instead of making the abrupt southward bend which exists at present below Highland Park (Plate LVI), flowed across Union Park, down the pre-Kansan valley east of Capitol Hill and so into the valley at present occupied by the river below Des Moines. The fact that the old valley is wider between Capitol Hill and Four Mile ridge than east of Highland Park seems to lend additional support to this view.

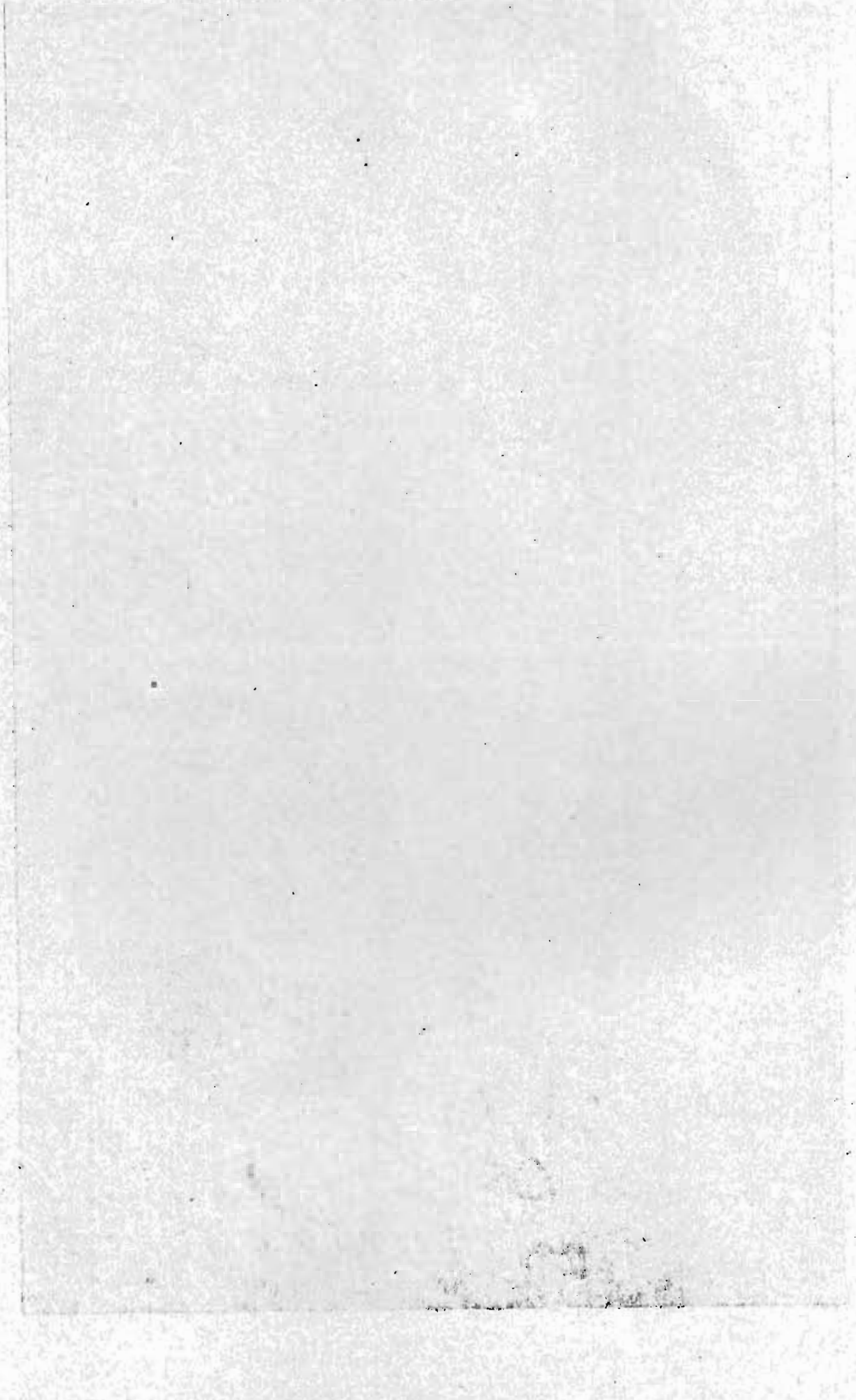
Just why the river chose the course it did after the retreat of the Kansan ice can not be told. Perhaps it was because the pre-Kansan valley was filled to a level higher than the course taken by the post-Kansan river. Perhaps it followed the valley of a tributary of the post-Nebraskan Des Moines, or it may have been guided by swales similar to those which today are so abundant on the Wisconsin drift plain of northern Iowa. Its action is paralleled by that of the Mississippi near Rock Island and Keokuk.

Effect of Iowan Glaciation.—During the long ages following the Kansan glaciation the river was cutting its valley through the drift and into the Coal Measures until interrupted by the advance of the Wisconsin glacier. The Illinoian glacier could affect this region only indirectly, of course. See the Pleistocene map of Iowa, Plate XXX. If the Iowan glacier entered the territory tributary to Des Moines river its effect would be twofold. The upper valley would be buried, while beyond the reach of the glacier the depositional work of the stream would be somewhat accelerated. It does not seem probable that any of the significant changes which the Des Moines has undergone are due to Iowan glaciation. The Iowan ice seems to have been so ineffective as a topographic agent that at many places within its borders in eastern Iowa the pre-Iowan topography was not much obscured, but was merely mantled. The slopes were toned down and the irregularities were smoothed out somewhat, but there still remain areas which retain the contours of pre-Iowan time. Then, too, the entire valley within the region which would have been crossed by the Iowan margin is a unit, and at present shows no evidences of having been subjected to influences which would affect one part more than another. The changes which are evident, those near Des Moines, are so far beyond the probable extent of the Iowan glacier that it is difficult to see how they could have been caused through its agency. If the Iowan ice had found Des Moines river occupying its post-Nebraskan course, the ice-free section of this great valley would have served as a channel for the outlet of glacial waters, and the blocking and abandonment of this channel must have been postponed until Wisconsin time, conditions which are directly contrary to what the evidence shown in the present valley above Des Moines seems to the writer to prove.

Origin of the Gorge below Union Park.—With the development of the Des Moines-Raccoon drainage system there may have been cut out two ravines, one heading south from the locality of Union Park (rather than from west of Highland Park, as Bain supposed, see figure 45) and another working north from near the present mouth of Raccoon river. These ravines grew and enlarged until their heads met and ultimately they formed a broad low sag where the river now flows through the city. The present form of the valley here seems to agree bet-



The clay pit of the Iowa Pipe and Tile Company, Des Moines, showing Coal Measures shales, overlain by loess, which extends within two feet of the surface and is capped by a thin layer of Wisconsin till which appears as the dark band in B. The dark upper part in A is the loess modified by vegetation.



ter with the theory of two ravines than with that of but one which cut across the point from one side. This sag was well developed when the loess was spread out over this region, since loess, in places covered by Wisconsin drift, is found as low as fifty feet above the present river level. See Plate LVII. The sag evidently was so broad and low at the time of loess deposition that later the waters from the Wisconsin ice did not need to scour away the veneering materials from the rock walls. The facts that the loess was spread over a well developed erosion topography and that the Kansan drift beneath it is locally much weathered and leached, or even absent, or present merely as a residual band of ferretto, are facts which point to a date for the loess formation much later than the close of the Kansan epoch and suggest that the buff and blue-gray loess of the Des Moines valley and adjacent regions may be the equivalent in age of the Iowan loess of the counties farther east, although it is of local derivation and not related genetically to the Iowan loess. Exposures recently made on Capitol Hill in connection with enlargement of the State House grounds give additional evidence of the same sort.

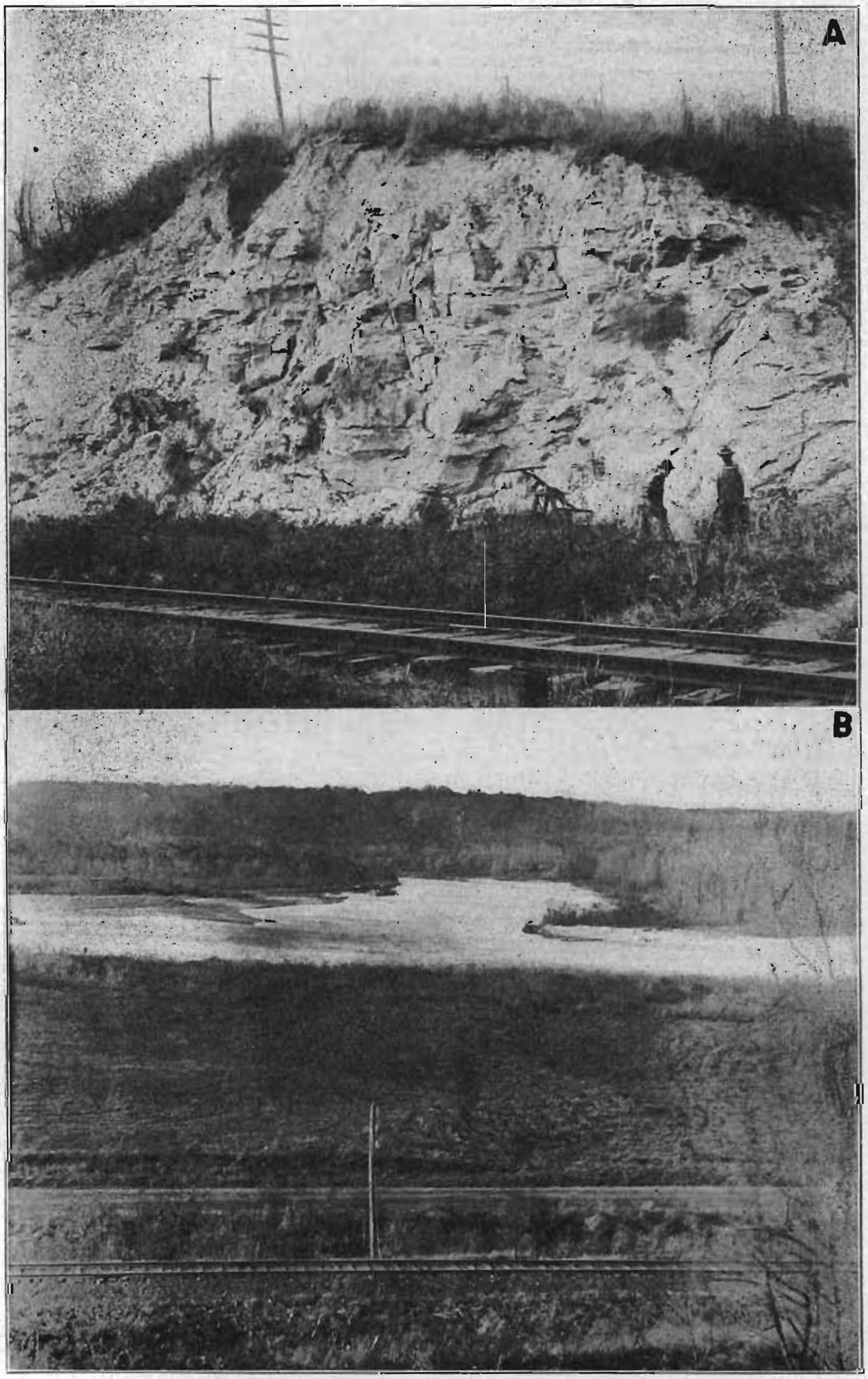
Effect of Wisconsin Glaciation.—While the Wisconsin glacier occupied the Des Moines drainage basin, the great valley east of Capitol Hill was filled with detrital material, the passage of the river by that channel was obstructed and so the younger and much narrower sag cut out west of Capitol Hill was utilized and deepened to gorgelike proportions, though possibly not until the later stages of Wisconsin occupation. That portion of the present Des Moines valley immediately south of Capitol Hill is so evidently related to the Raccoon valley in size and direction (see Plate LVI), rather than to the Des Moines valley below it, that it seems plain that here is a case of stream shifting. This fragment of the Raccoon valley was cut off and added to the valley of Des Moines river.

The Wisconsin glacier reached only as far as Des Moines and its attenuated border in this vicinity did not effect serious topographic changes by direct erosion or deposition. Its chief work was accomplished by means of the waters arising from the melting of the ice. Probably the lower Des Moines and Raccoon valleys were not modified to any notable extent, and the smaller drainage lines covered by the ice were not effaced, but resumed their functions after the retreat of the glacier. Above Saylor Bottoms the valley sides are covered with Wisconsin drift, in places to the bases of the bluffs, and are flanked here and there by terraces of Wisconsin gravels. Both of these demonstrate the pre-Wisconsin age of the valley, as has been emphasized before.

Relation of the Gary Moraine.—Another, though perhaps indirect, proof of the pre-Wisconsin age of the valley above Des Moines is the fact that it cuts directly across the Gary moraine, the area of highest altitudes and of deepest drift in this immediate region. Compare Plates XLVI and LVI. See also figure 43. It is, to say the least, more reasonable to assume that the valley was formed before such a barrier was thrown across its course, and that the river maintained or resumed its path through the moraine after this was formed than to suppose that the post-Wisconsin river cut a new channel along the most difficult course which it could have found.

An Alternative Hypothesis.—As an alternative hypothesis we may assume, as was done on page 547, that the valley above Des Moines is of immediate post-Kansan age but that originally it united with the pre-Kansan valley at Saylor Bottoms rather than at Union Park, as was assumed in the first hypothesis. The present valley through the city, by this hypothesis, originated somewhat as described by Bain—by the junction during pre-Wisconsin time of a series of ravines, probably four, which were cut practically to the present dimensions of the valley when the loess blanketed their slopes. This hypothesis, it will be seen, calls for only one episode of valley cutting to form the present course of Des Moines river across the city, but it is open to the objection of the difference in size of the valley above and below Union Park.

The smooth gentle slope of the west bank opposite Union Park bespeaks a mature stage of development, but this rather anomalous feature may be explained as follows. If the modern



A. The massive sandstone at the foot of Capitol Hill. B. The valley of Raccoon river three miles above its mouth. Note the sand spit at the left. The north wall, here shown, is the limit of the Wisconsin glacier.

valley from Saylor Bottoms to Raccoon river all dates from the same period, the sag at Union Park must have been an embayment of the old valley to the east, and the smooth slope just described probably formed its west bank. In this case it was necessary for only the sections of the valley west of the now isolated eminences of Highland Park and Capitol Hill to be cut out by ravines between the Kansan and the Wisconsin ice invasions. When the Wisconsin ice came down and filled the older valley of the Des Moines with glacial and fluvio-glacial material the waters found a way of escape through these ravines and abandoned the old channel in favor of the newer one to the west.

Character of the Strata.—The variations in the strata cut through by the river do not seem to be of such character as to account for the differences in the valley, or to help in solving the problems it offers. Above Beaver valley and west of Highland Park these strata are shales with two to three intercalated bands of hard limestone six to ten inches thick. These limestones rise toward the north from at or near river level, to eighty feet above that datum at Corydon bridge. On the south bank of the river opposite Highland Park a soft sandstone fifteen feet thick replaces the shales below the limestone beds and west of Capitol Hill ten feet of this sandstone are exposed. On the south front of Capitol Hill the bed of sandstone attains a thickness of twenty-five feet. See Plate LVIII, A. Another bit of evidence is the fact that the valley here, which, as explained above, originally belonged to Raccoon river, is as wide as the valley of that stream above its present mouth, where the sandstone lens is absent or thins down to a few feet. It seems then that the Des Moines cut its valley through sandstone or through shale with no apparent difference in the result.

Summary.—According to the hypotheses here proposed the Des Moines valley originated after the Nebraskan glaciation. Below Des Moines the river still occupies its post-Nebraskan valley, but north of the city it found a new course after the retreat of the Kansan glacier. The first hypothesis considered gives reason for believing that the present valley between Saylor Bottoms and Union Park also is of immediate post-Kansan age, but that the gorge between Union Park and the Raccoon was not occupied by the river until Wisconsin time. By the second hypothesis the modern valley from Saylor Bottoms to the mouth of Raccoon river is all of the same age and was used first by the river when the Wisconsin glacier covered the region. Aside from assigning the date of origin of the valley to post-Nebraskan rather than to pre-Pleistocene time these hypotheses differ from that of Bain chiefly in calling for a post-Kansan instead of a post-Wisconsin age for the valley north of Des Moines. The first hypothesis, in addition, differs in postulating diverse ages for the two parts of the valley west of Highland Park and of Capitol Hill respectively, while the second hypothesis demands more than two ravines to form the valley within the city. As Bain did not take into consideration the sag at Union Park he assumed only two ravines to mark out the future course. The first hypothesis is preferred to the second because it accounts better for the difference in the size of the valley opposite Highland Park and opposite Capitol Hill (see Plate LVI), since the evidence seems to strengthen the theory of diverse times of origin for the valley within the city rather than that of a single date.

The foregoing interpretation of conditions in Polk county will allow us to tie the valley in the northern part of this county to the parts in Boone and Webster counties without a break in topographic continuity. In its essentials the valley is similar in all these counties, and there seems to be every reason to think that the different portions have had a similar history. Naturally the valley, if of pre-Wisconsin age, would be at least partly filled with Wisconsin drift and valley train, and the river has not yet had time to clear out this material completely. Hence it presents an appearance of youth and immaturity very commonly above Des Moines. In contrast with this appearance, however, the size of the valley and its evident maturity in some parts of its course in central Iowa are more consistent with the view of its post-Kansan age adopted here than with that of its extreme youthfulness advocated by Beyer and by Bain.

TODD'S PREGLACIAL NIOBRARA RIVER.

In his vice-presidential address, "The Pleistocene History of the Missouri," delivered before Section E of the American Association for the Advancement of Science, at the Atlanta meeting, Professor Todd suggested that Niobrara river of northern Nebraska, during pre-Pleistocene time joined James river northeast of Yankton, thence "turned south and followed the courses of the James and Missouri to the vicinity of Onawa, Iowa, thence east and northeast through Ida and Sac counties past Wall Lake and thence southeast along the Raccoon river." The map accompanying the paper seems to locate this preglacial channel along the course of Beaver creek, just north of Des Moines.

This hypothesis is attractive as proposing a solution for the question regarding the continuation northward of the old valley of the Des Moines. It might also serve to explain the enormous width of the Missouri valley between Sioux City and Onawa—fifteen to eighteen miles on the Iowa side. It is based admittedly on rather slender evidence—"a few apparently reliable reports from wells which show that the pre-glacial surface indicates a valley whose bottom is less than 900 A. T., in some cases less than 850"; past and present supposed drainage conditions of Wall lake; the anomalous course of Boyer river. The two last named features clearly are due to post-Kansan causes, while Professor Todd is discussing preglacial conditions, and the first is not supported by any evidence available to the writer. At present it seems best not to place too much confidence in this hypothesis so far as it concerns Des Moines river.

RACCOON RIVER.

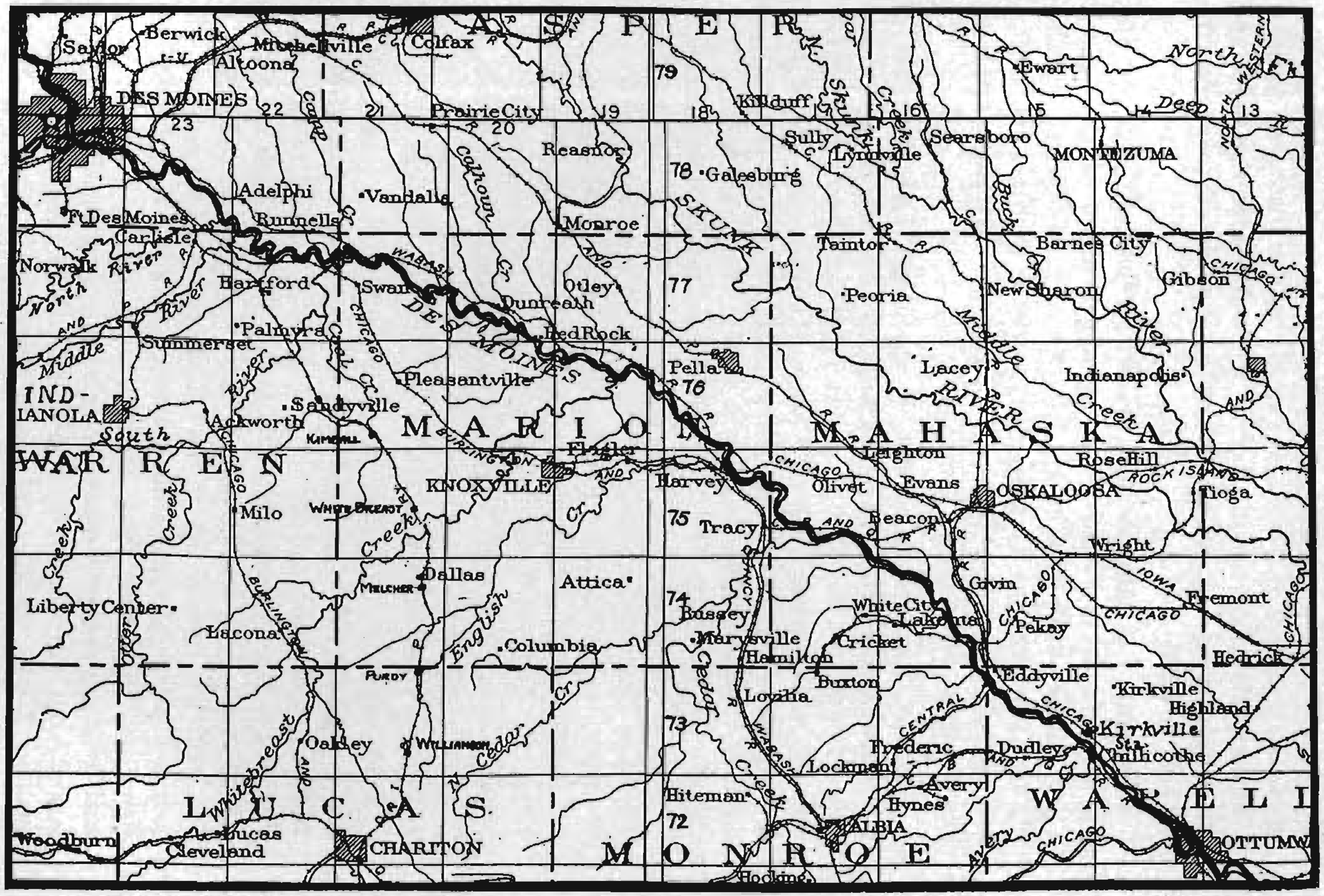
As previously mentioned, Raccoon river is utilizing a post-Nebraskan valley. The valley is wide and flat—its floor is at least a mile across—and it contains immense quantities of sand (Plate LVIII, B, page 553). The walls below Valley Junction are very different in character. The north wall is high and rugged. Short, steep ravines cut up this wall and the neighboring upland and give them a rough and rolling aspect. The opposite wall, on the contrary, is for the most part rather gentle, the ravines are not so steep, the bluffs are less bold. The last mile or so above the junction with the Des Moines is quite abrupt as here the river has been undercutting within recent times. The valley of the Raccoon marks the limit of advance of the Wisconsin ice and probably this accounts for the difference in the valley slopes. The north wall was covered with ice and a mantle of drift was left upon it, while the south bank still retains its pre-Wisconsin features unaffected by the glacier's work. See Plate LVI.

Walnut creek has a broad saglike valley, which may represent an interglacial line of drainage and which served also to carry the waters from the ice front.

The Valley Below the Raccoon Forks.

Direction.—Below its union with the Raccoon, the valley of the Des Moines changes abruptly and markedly in both character and direction. Compare Plates XLIII and LIX. The river has now left the narrow, steep-sided valley in which it flowed through the city of Des Moines and, after traversing the short fragment once attached to the Raccoon, it enters a broad plain two to three miles across (Plate LVI). Instead of running a few degrees east of south, its general direction from the Minnesota line, the valley now follows a course a few degrees south of east to the Mississippi. The abandoned preglacial valley opens into its modern continuation with a two mile mouth stretching between Capitol Hill and the Fair Grounds and lying about twenty feet above the river. The nose of Four Mile ridge is high and steep and beyond it is the narrow mouth of Four Mile valley. This valley has been restricted here by the piling up of Wisconsin drift, no doubt, for above the mouth it widens out, and the restraining slopes become less steep.

General Character.—In general, the broad valley of the river shows all the phenomena of maturity. The excessively flat, broad flood plain across which the river winds is bordered by slopes which for the most part rise gently to the uplands, although the line between flood plain and slope is well marked.



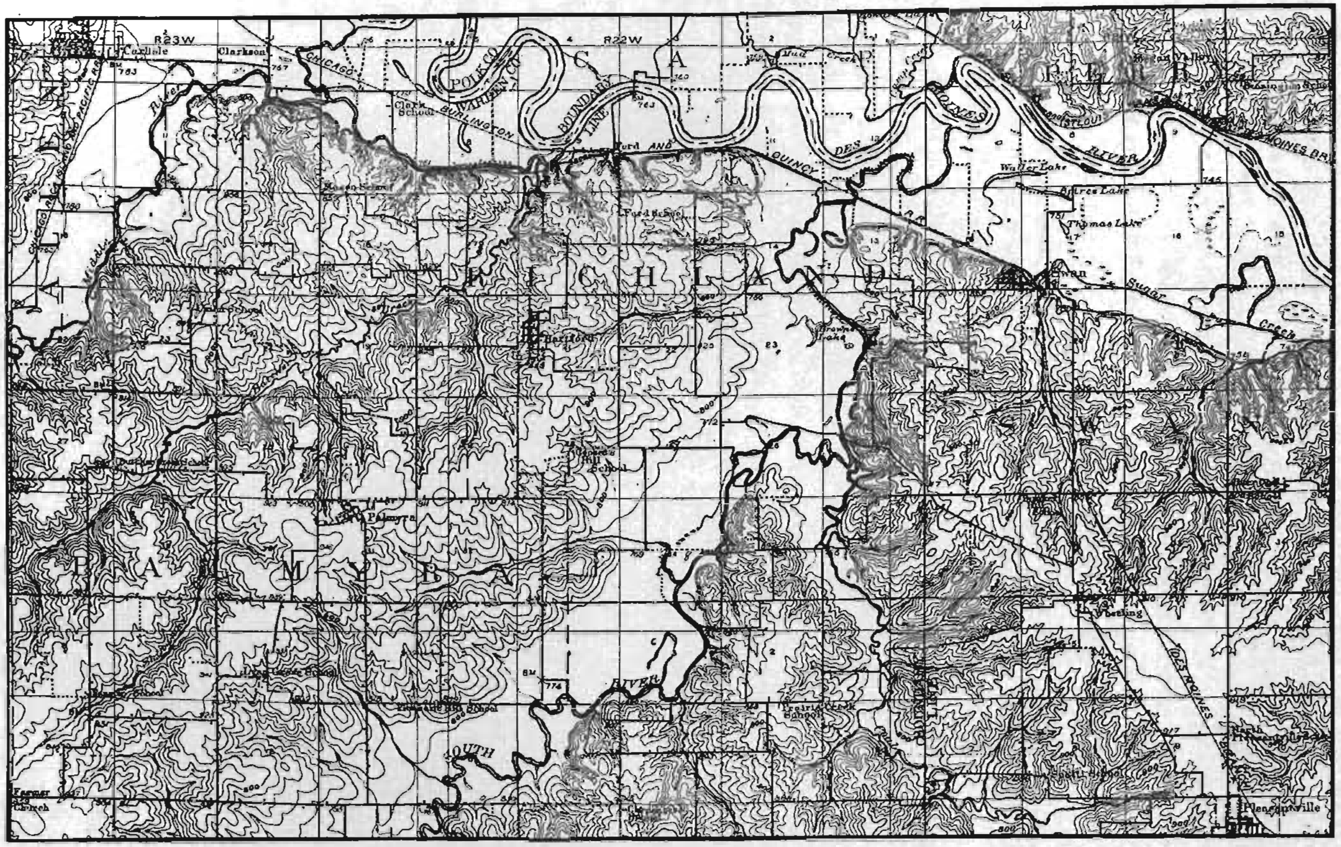
Map showing Des Moines valley from Des Moines to Ottumwa.

In places the wall is steep and rugged as, for instance, between Clarkson and Swan (Plate LX). In such places the walls and the neighboring region are much cut up by ravines and are heavily wooded.

There is no relation here between the character of opposing slopes such as is found in the younger parts of the valley. There steep bluffs face long gentle slopes; here the slopes facing one another may be both steep or both gentle or of differing angle. The valley is now too wide for any close relationship to exist between its walls.

There is a notable difference in the height and character of the walls above and below Des Moines. The depth and steepness of wall of the valley in Boone county have been given already. In contrast, the elevation of Fifield, at the edge of the valley, is 727 feet. See Plate LXI. The immediate slope rises to about 840 feet within one-fourth to one-half mile. The uplands lie at 900 feet about Otley and Knoxville, at a maximum of 880 feet at Pella, but these heights are reached only at distances of three to five miles from the crest of the inner walls. In other words, the valley here has an actual width of six to ten miles. Contrast this with the equally deep gorge near Boone where the distance from upland to upland is compassed within a mile or little more! Certainly such proportions bespeak a long and busy life, as time counts with features so ephemeral as rivers. Compare Plate XLVI with Plates LX and LXI.

Topography of the Region.—Contrasts in the character of the topography of the bordering region and of the tributary valleys are no less marked, as may be seen readily from inspection of the topographic maps. Compare again Plates XLVI and XLIX with Plates LX, LXI or LXIV, page 571. Instead of flat prairies incised by a few short steep-sided ravines, the entire country is gently rolling, except near the steep bluffs, and there are numerous long ravines and valleys, most of them with gentle gradients, and with slopes rising easily to the uplands from very wide bottom lands. The larger tributaries, such as North, Middle and South rivers, flow in valleys of remarkable width, with very low gradients and gentle side walls.



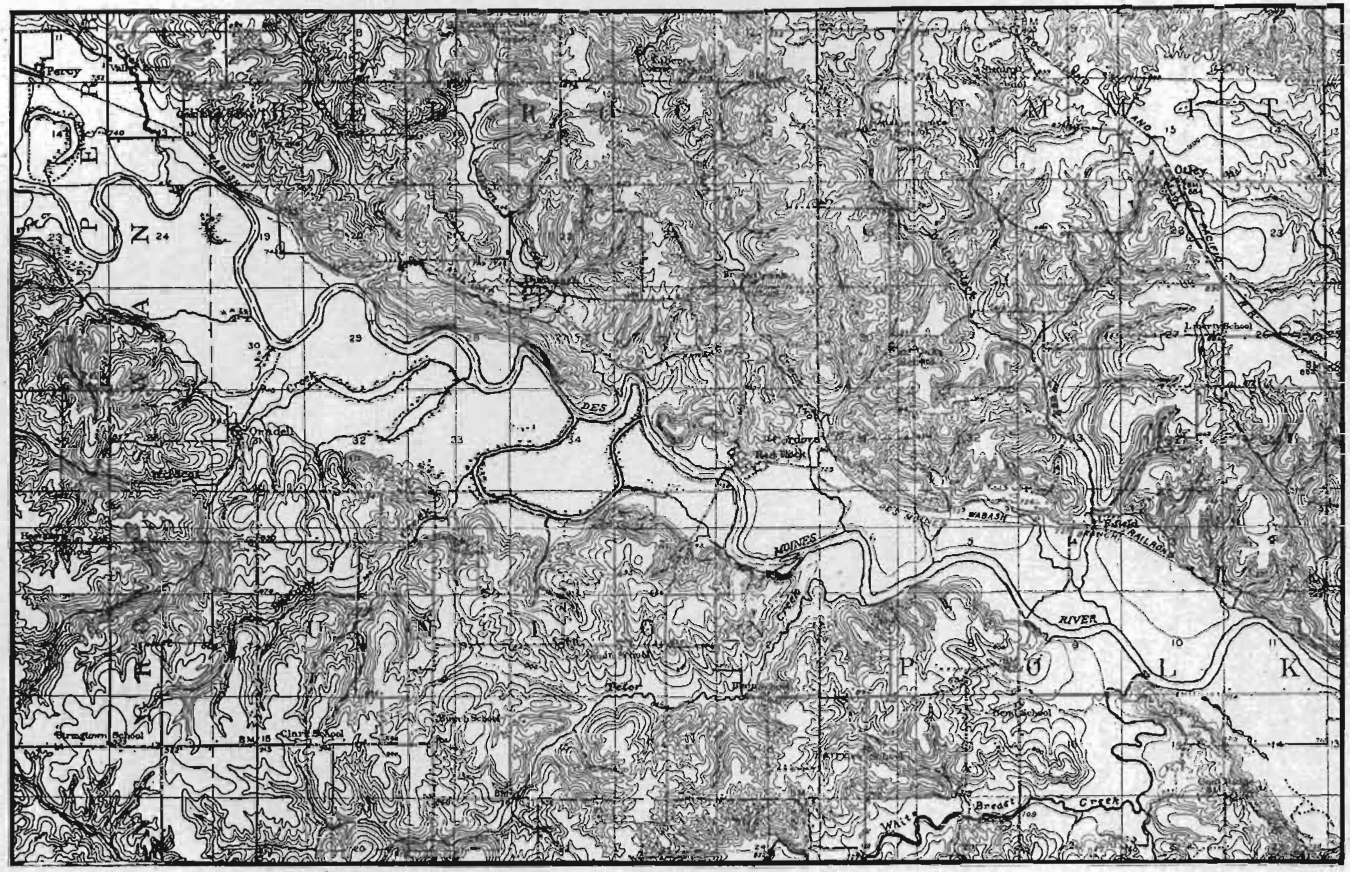
Topographic map of northern part of Milo quadrangle, including parts of Polk, Warren and Marion counties.

But the student cannot fail to observe that the south walls of many of these valleys, and especially of the three mentioned, are much more steep than are the opposite slopes (Plate LX). These south walls are generally well timbered while those opposite are bare of trees and grade imperceptibly into the uplands, owing to their greater exposure to sun and wind with attendant desiccation and degradation.

A further word regarding differential weathering of valley slopes may be in place. Freezing and thawing together with lesser alternations of temperature are the great aids of streams in widening valleys and toning down their slopes. A north-facing slope does not undergo these alternations very much, hence is not broken down a great deal during the winter season. A south face, however, may be repeatedly frozen and thawed and a great deal of material thus be loosened for the spring and summer rains to wash down to the stream. Again, during the warm season evaporation from the north-fronting walls is less than from those facing the sun and the south winds; hence trees gain a better foothold on the north-facing slopes and assist in retaining soil, rock and other material against wastage.

Another feature which will not be overlooked is that while the lateral streams on the Wisconsin plain approach the master valley between parallel walls, the side valleys on the Kansan area show widely diverging walls where they open into the main valley. This is illustrated very well by the debouchure of Mud creek valley a mile west of Runnells. This has the appearance of a wide, alluvium-filled embayment bounded by very gently sloping walls which are a mile apart where they join those of the main valley but converge rapidly upstream. The same feature is well developed by the valley of Brush creek at Cordova (Plate LXI).

The Kansan Drift.—Everywhere below Des Moines the difference in the character of the drift exposed as compared with that north of the city, is plainly marked. The Kansan drift is reddened by the oxidation of its iron content, the contained pebbles are mostly of dark color, and the surface material is in nearly all cases loess, except where this has been washed



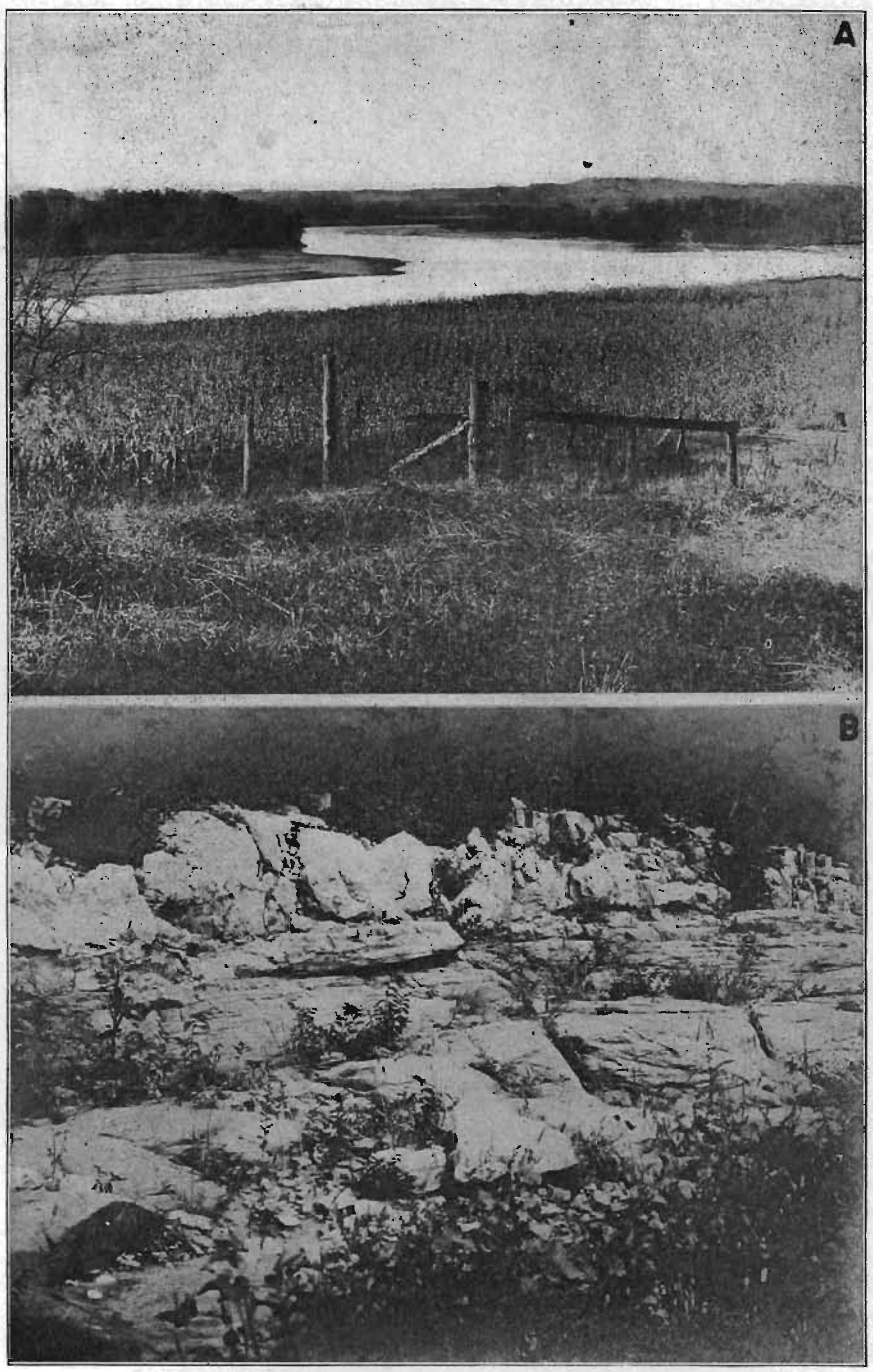
Topographic map of central part of Knoxville quadrangle, in Marion county.

away from the steep slopes. The contrast with the yellow Wisconsin drift with its abundance of limestone pebbles and absence of loess covering, is very striking.

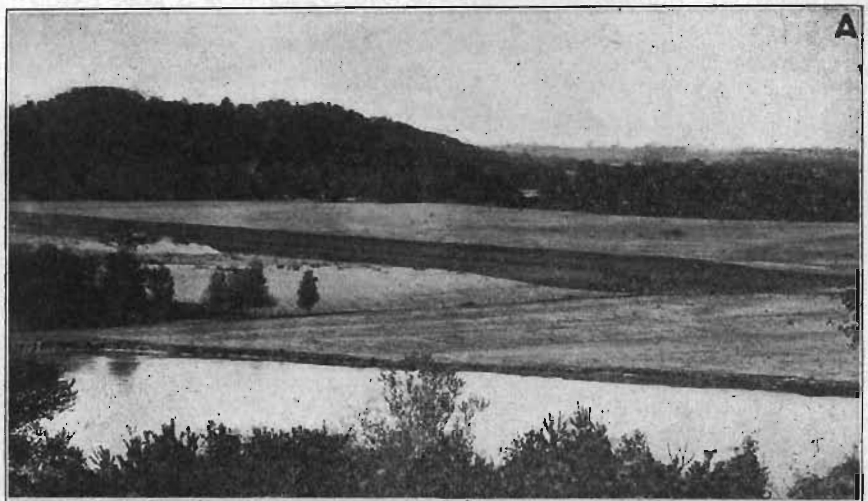
Sand Beds.—The valley below Des Moines shows none of the high gravel benches which are so common in Webster and Boone counties. There are, it is true, abundant deposits of sand in the valley, as within the limits of Des Moines, at Avon, Eddyville and elsewhere, but they are down on the flood plain or form low terraces at its margin. A common characteristic is a gentle backward slope from the river bank to the edge of the valley. Thus a United States Geological Survey bench mark at the southeast corner of Runnells reads 750 feet above tide, while the flood plain near the river, a mile south and southwest rises to 758 and 760 feet (Plate LX). This is due to the building up of a natural levee during times of flood where the swiftly flowing current of the main channel meets the sluggish waters covering the flood plain.

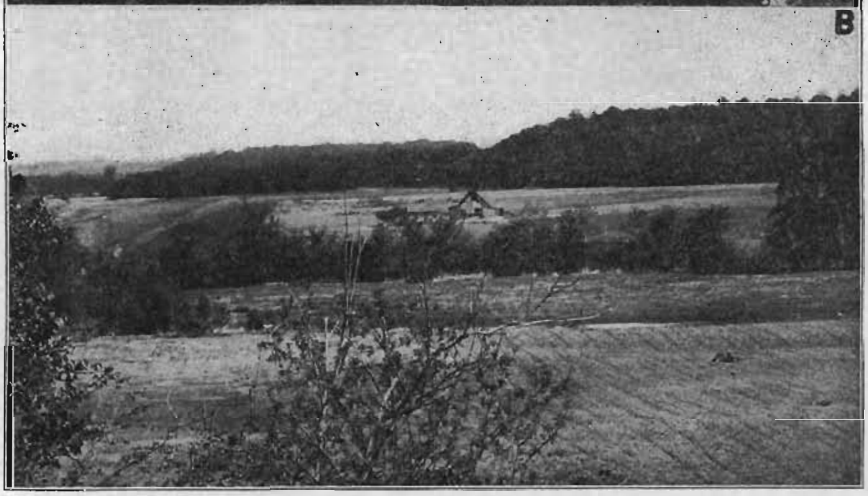
Numerous oxbows scattered over the flood plain mark old meanders of the channel and show that the stream is practically at grade. It long ago ceased cutting downward and has since been devoting its energies to side cutting and widening its valley. See Plate LXII, A, for illustration of this phenomenon.

Red Rock Sandstone.—Between Des Moines and Red Rock the valley walls are cut in Coal Measures, chiefly soft, easily eroded shales, with a capping of Kansan drift and loess. Here the valley is wide, its flat is two to three miles across, and, as before mentioned, most of the slopes are rather gentle. About a mile above Red Rock, however, the valley narrows suddenly to a width of a mile or even less. See Plates LXI and LXIII. The bluffs are high and steep, and present bold scarps of bright red sandstone, which has given its name to the nearby village. These features continue down the valley for several miles, at least to Fifield and the mouth of Whitebreast creek. Below this creek the Red Rock sandstone gives place to shales, and the valley widens somewhat, although it nowhere attains the width it has above Red Rock, owing to the fact that within a



A. Des Moines valley two miles above Dunreath. Shows its mature character and the meandering stream. B. Alternating sandy and limy beds of the St. Louis east of Tracy.





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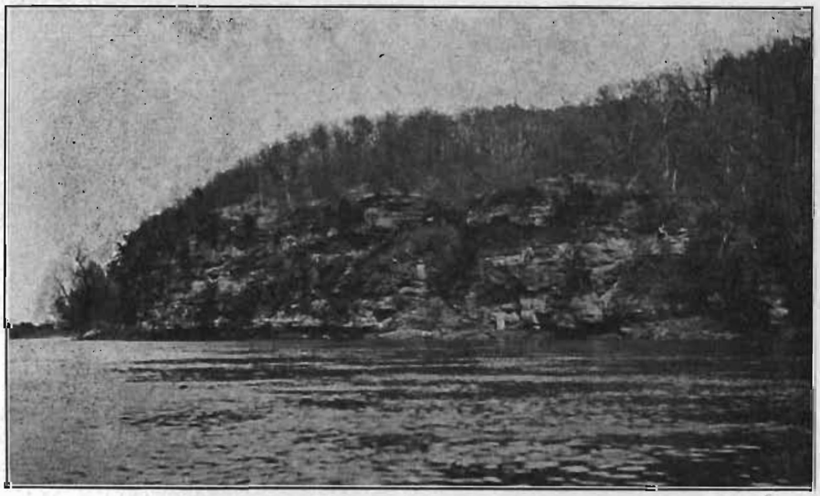


A. Where the valley narrows at Red Rock. Note the wide valley at the right. The bluff at the left is Red Rock sandstone. View looking southwest from Red Rock bluff. B. Looking north from the bluff shown in A to Red Rock bluff, which appears at the right. C. Elk cliff, two miles below Red Rock.

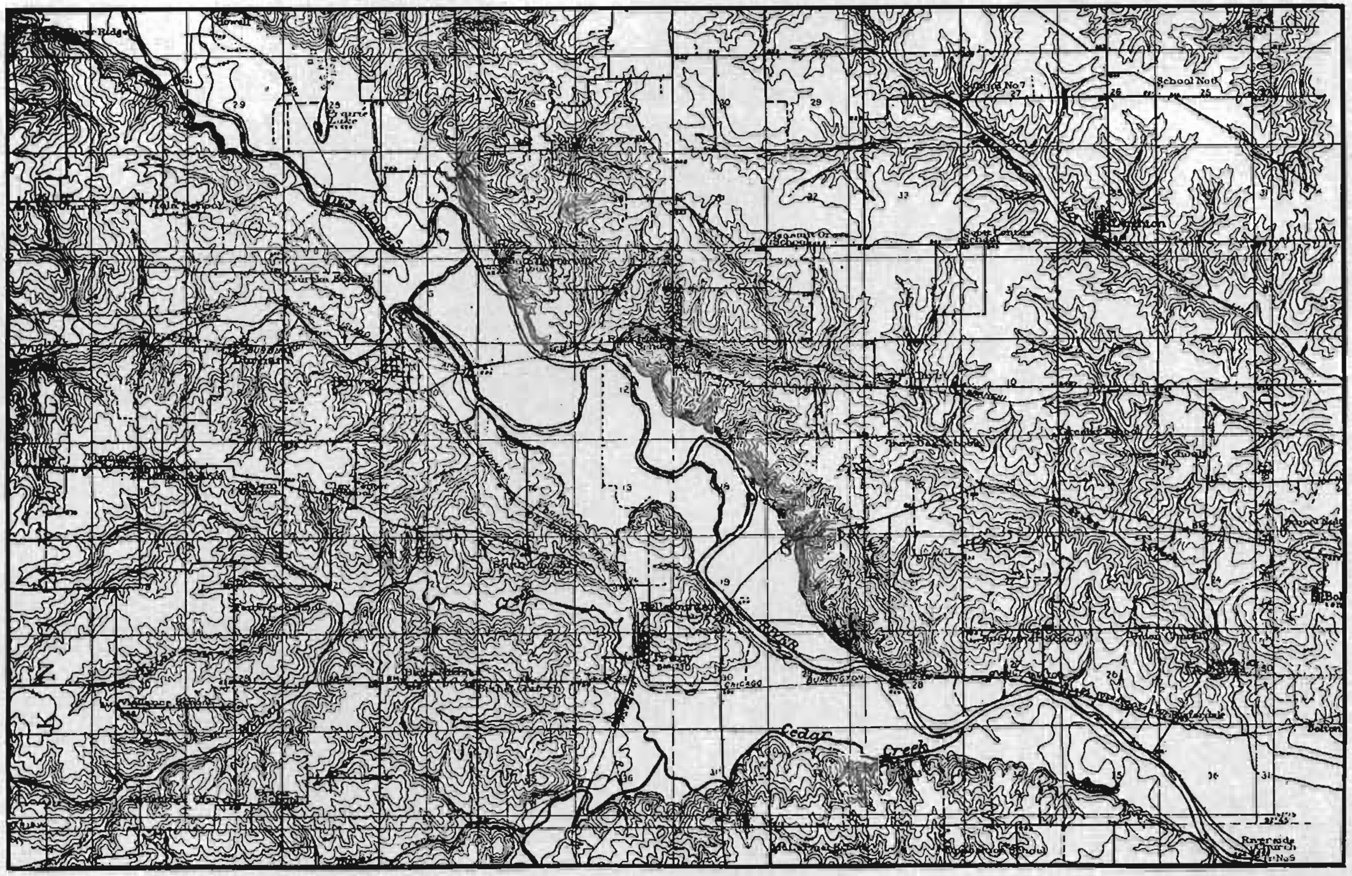
few miles the river cuts into the somewhat resistant arenaceo-calcareous beds of the St. Louis stage, as shown on Plate LXII, B.

The Dunreath Ridge.—A peculiar feature of the valley in central Marion county is the presence opposite Dunreath of a long ridge rising steeply above the plain and extending parallel to the valley for nearly three miles. The character and boundaries of this ridge are well shown on the map of the Knoxville quadrangle, Plate LXI. Possibly it is the result of the diversion of Prairie creek at a time when both it and the river flowed at a much higher level than now. More likely, however, it is not a case of stream diversion at all, but rather of the simple growth of a valley parallel to the main valley instead of in the more customary transverse direction. The recess into which the valley opens, and which is now invaded by a swing of the river, is another example of the type of valley mouth described on page 562. The ridge has been isolated still more by the cutting down of the col at the north end, through headward erosion of a ravine working back from the main valley.

Ridges Near Harvey.—Another conspicuous feature of the topography in this region is the presence between Harvey and Tracy of a series of isolated ridges and hills set off by wide swales and gaps. These are shown on the Pella topographic sheet and need but brief description (Plate LXIV). The first and second members of the series are long ridges rising rather steeply 100 and sixty feet respectively above the broad swale which lies behind them. The third and fourth members are high rounded knobs, the third rising 140 feet above the river. The gaps between these eminences and the swales which lie behind them are broad and for the most part are bounded by gentle slopes. The northern ridge, at least, has a core of Coal Measures rock, and a clay pit is operated in it. Walnut creek turns from its northeasterly and easterly course to flow south past the southern hill to join Cedar creek just beyond. The remarkable flat across which the lower part of Cedar creek finds its way to the river is worthy of note.

Here, then, are four isolated hills cut off from the uplands by long swales, only one of which is occupied by a stream of any consequence—Walnut creek. How are these phenomena to be accounted for? We can see that if the ridges were made continuous we would have behind them a valley extending from English creek to Cedar creek, and lying but little above the level of the Des Moines flood plain. Now it is to be noted that opposite the northernmost swale, English creek is diverted from its southeast course and turns northeast, in which direction it enters the main valley. It seems quite possible that at a time when it ran at a little higher level the creek may have continued southeast down the swale, perhaps to unite its waters with those of Walnut and Cedar creeks. Or possibly it may have entered the Des Moines through one of the gaps between the hills. Perhaps, too, the Des Moines once washed the western slopes of the two southern hills and utilized the spacious valley of Cedar creek. The sudden narrowing of the main valley opposite the two southern knolls may be significant in this connection, although this may be due to stratigraphic reasons. Some of the gaps between the hills may be due to lateral erosion by ravines whose lower parts have been cut away by the widening of the main valley by side cutting. The embayment at the second gap undoubtedly is the result of an incursion of the river, which has cut into what was once a gentle slope like the other gaps. These changes in the courses of the valleys may be attributed (1) to the effect of the Kansan glacier or its deposits, if the tributary valleys are pre-Kansan in age, or, as seems rather more probable, they may be due (2) entirely to the erosive work of running water, including the capture of English creek by a short tributary of the Des Moines, the possible diversion of a fragment of the Des Moines and consequent changes in lower Cedar creek.

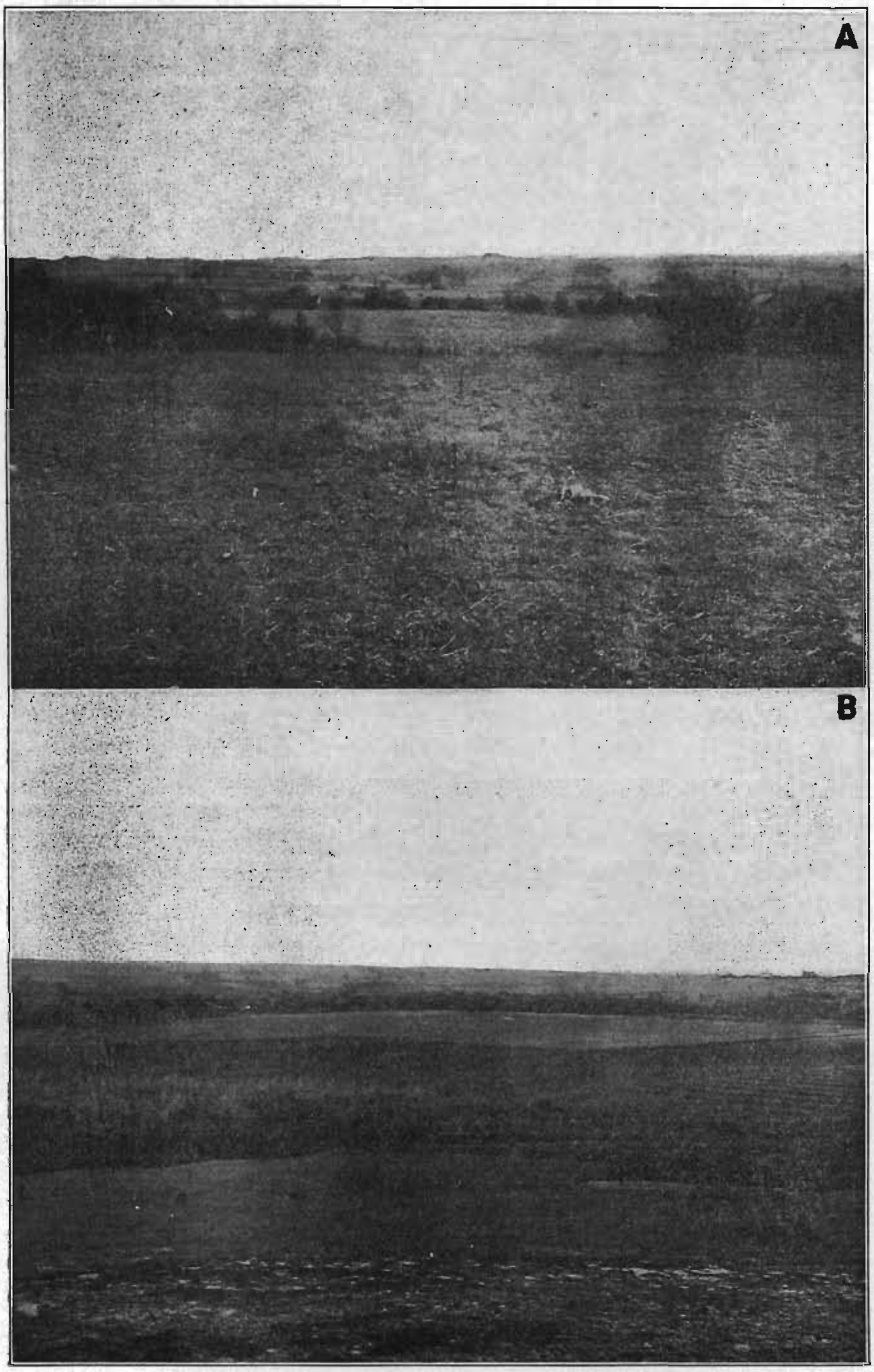
A Pre-Pennsylvanian Valley.—The depth to which the valley of the Des Moines has been filled is revealed by a sand-pumping station located at the Chicago, Burlington and Quincy railroad bridge over the river east of Tracy. This has taken out sand to a depth of thirty-five feet below the level of the flood plain. The sand was said to rest on "slate," which probably repre-



Topographic map of southern part of Pella quadrangle, including parts of Marion and Mahaska counties sents the Coal Measures shales. Bain, in his report on Mahaska county, maps Coal Measures here, although St. Louis beds are found up the river and below. It is interesting to note that east of Oskaloosa, on both North and South Skunk rivers, the same phenomenon occurs—the Saint Louis beds evidently have been cut away and the depressions filled with Coal Measures shales. These depressions seem to represent a pre-Pennsylvanian line of drainage, leading to the southwest and extending under Cedar creek valley. The comparative ease of erosion of the Coal Measures strata no doubt accounts for the width of the lower part of this valley.

Benches and Terraces.—The steep bluffs which border Cedar creek on the south and blend with those of the main valley soon lose their steepness and are separated from the valley by a series of wide, fairly level benches lying seventy-five feet above the river and sloping down at angles of 10° to 20° to a rather narrow flat which rises about twenty-five feet above water level. Behind the benches a long gentle slope rises a hundred feet to the uplands, which here lie at about 840 feet above sea level.

On the east side of the river there is a broad plain extending from the railroad bridge above the mouth of Cedar creek southeast for several miles (Plate LXIV). It is about twenty feet above the water at the free edge and has a very gentle, almost imperceptible rise to the north of ten to fifteen feet per mile. Along the railroad track the plain, or terrace, as probably it should be called, is bounded by a gentle slope and its eastern margin is marked by high steep bluffs which are followed closely by Saint Joseph creek. These bluffs rise 150 to 175 feet above the river and form the west slope of a long, narrow ridge whose east face overlooks Muchakinock valley. The southern part of this ridge is buried beneath hills of sand and it terminates in a sandy point a mile north of Eddyville. Opposite this point Muchakinock creek cuts the wall of the main valley by an opening which has been so restricted by sand hills that it is not over 400 feet wide. Above the opening, however, the creek presents the characters typical of Kansan streams—a broad valley, easy gradient and gentle slopes, although not much flood plain has



A. Looking northeast across Muchakinock creek two miles below Given. B. Looking west across Des Moines valley from the ridge north of Eddyville. These views show the great width of the valleys and the fairly gentle slopes of the walls.

been developed. Below Given the valley is between two and three miles wide from ridge to ridge (Plate LXV, A) and even in its upper reaches above Beacon and Evans it already has assumed mature proportions. A road grading over the valley wall in the eastern edge of Eddyville shows, near the brow of the hill, six feet of deep red and yellow sand, overlying which is a heavy body of loess, gray at the top of the hill, but buff lower down, which caps the hill top to a depth of twenty feet. The sand evidently is to be correlated with the Buchanan gravels.

Below Eddyville conditions on the east side of the valley are somewhat reversed, for with the exception of the bluffs near the town, which are fairly steep, the valley wall is long and gently sloping all the way to Ottumwa. In places this wall is broken by benches which rise seventy-five feet above the river. These are separated at Kirkville Station by a terrace thirty feet high, backed by a long rise to the prairie. At Ottumwa the gentle slopes are succeeded by high bluffs which are crowned by many of the best residences of the city.

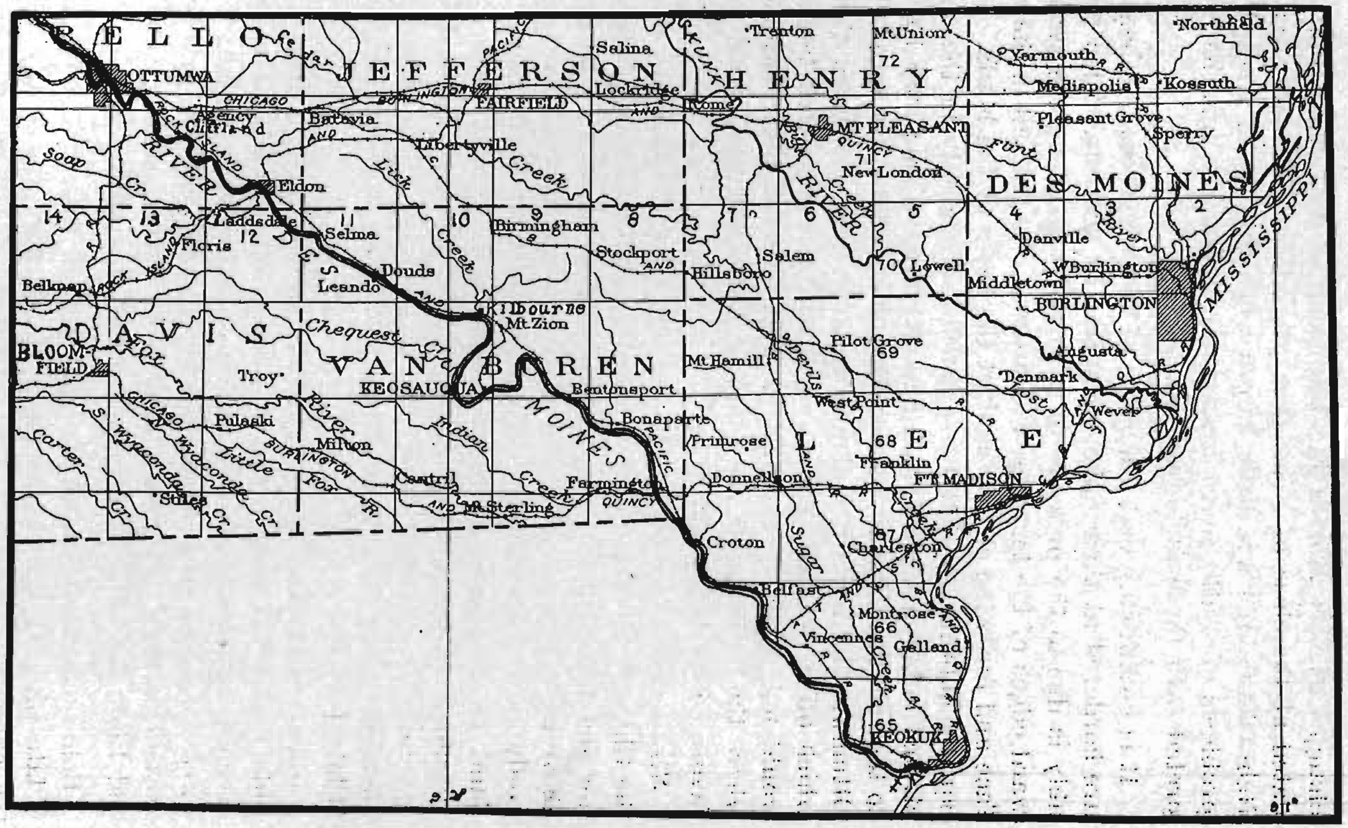
Much of the west slope is fairly steep, descending 100 to 150 feet within a short distance. There is not much evidence of benches on this side, except in the vicinity of Chillicothe, between North and South Avery creeks, where one lies thirty feet above the river, at the same level as the terrace opposite Kirkville Station. Evidently these date from the same period and are due to the same causes.

The bottom lands of the Des Moines in most of this region are limited to a width of one-half or even one-fourth of a mile. The entire valley, however, is much wider. Opposite the narrow ridge mentioned on page 572, where bluffs bound its east margin, the valley still is three miles from rim to rim and above and below here, where the high benches and terraces increase its width, there must be a distance of three and four to six miles from upland to upland. See Plate LXV, B. The lower part of the valley is cut in limestone, of which numerous exposures occur, especially between Eddyville and Ottumwa. The uplands are underlain by Coal Measures and are dotted with the top-works of coal mines.

Origin of the Benches and Terraces.—The terraces at the lower levels may well be of river origin, as their free margins are built entirely of sand and alluvium. The slopes at the back may be due to wash from above. Near the east end of the low wide plain described on page 572 there are some well-defined oxbows which lie near the edge of the terrace. They indicate that the river ran at this level at a date not so very far removed and that therefore the river, in reaching its present level, must have cut this terrace during recent, post-Wisconsin time. Eddyville is built on a low terrace which is continuous with the sand hills mentioned on page 572. This terrace like the others at a similar level is due, doubtless, to river work, while the sand hills owe their form to wind action.

The high benches must be of different origin. Where steep bluffs face the river they are seen to be composed of rock, but where the slopes are gentle, only drift or loess is seen. Hence it is not certain whether rock underlies all the high benches, although it seems probable that it does for the most part. The benches are covered with Kansan drift and loess. The drift is weathered and reddened and appears in strong contrast with the loess, which generally is grayish at the surface and buff at depth. In places, however, a gray, iron-stained type appears beneath the buff variety. Locally there is a pebble band between drift and loess, indicative of the greatly superior age of the drift.

The presence of drift on these benches shows that they represent pre-Kansan erosion by the ancestor of the modern Des Moines. Probably the Coal Measures were cut away by the meandering stream, but when hard limestones of Saint Louis age were reached, the river, unable to erode these so readily, narrowed its valley as it sank into the more resistant strata. Bain evidently has mapped the superficial distribution of the Saint Louis in Mahaska county according to this theory, although the same is not true of Leonard's map of Wapello county. It was assumed by the earlier students of the region—Gordon, Bain, Leonard and others—that the present features of the valley are preglacial in age, but as stated in connection with



Map showing Des Moines valley between Des Moines and Keokuk.

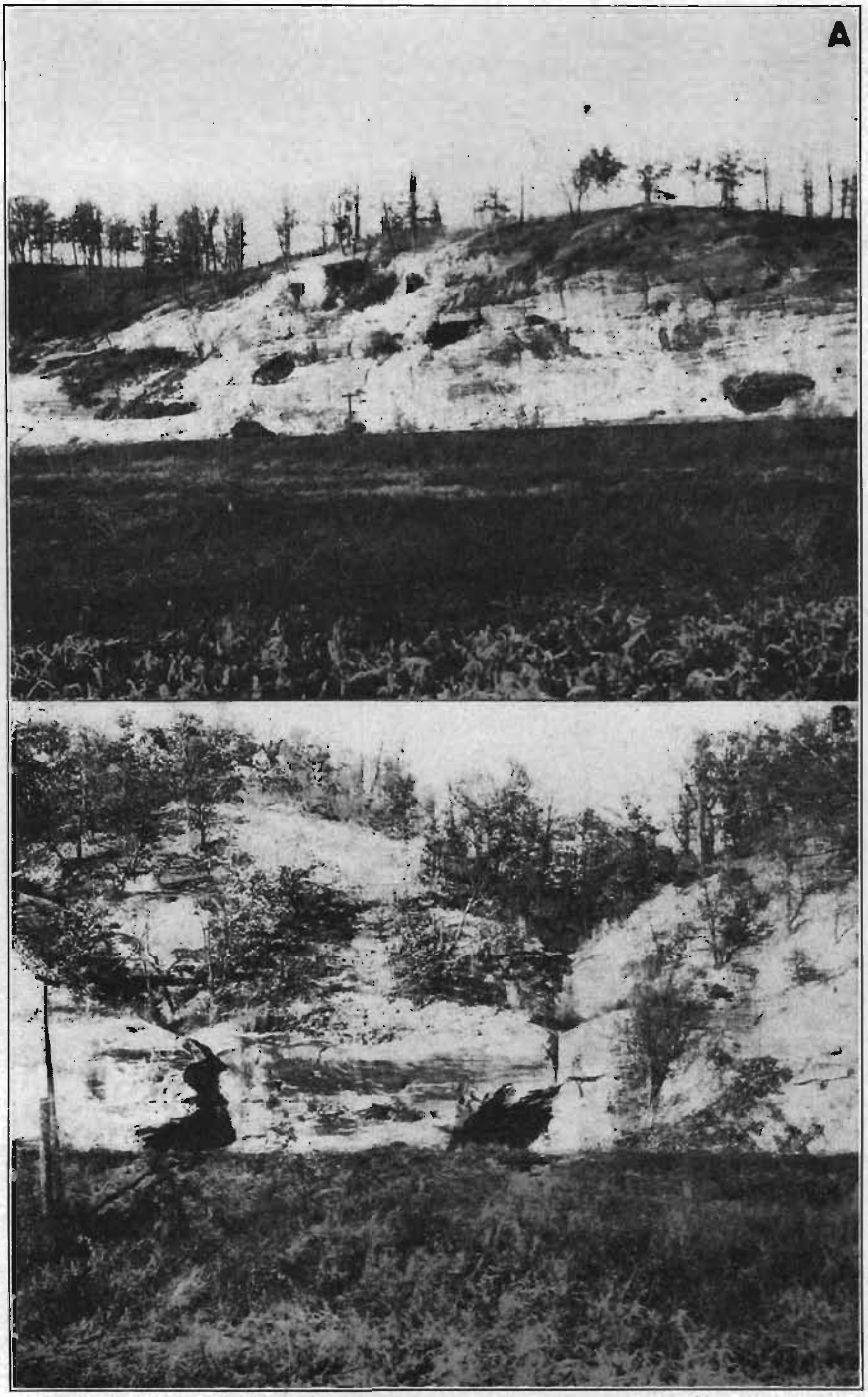
changes at Des Moines the beginning of the valley must be dated at the close of Nebraskan glaciation. Moreover, as the Nebraskan stage was little known when these men studied the problems of southeastern Iowa, their statements must be interpreted with these facts in mind.

It is noteworthy that a number of these terraces and benches are bordered at their upland margins by streams. This probably is due to the presence of natural levees along the streamward edges of the terraces, which cause a slight fall in the surface and force the stream against the bases of the bluffs. It is equally noteworthy that these benches occur only in the short stretch between Cedar creek and Ottumwa. This may be due to the fact that above Cedar creek and also for a distance below Ottumwa, the walls are almost entirely Coal Measures strata, which offer so nearly equal resistance to erosion that terraces would not be likely to develop. But between these localities, where the Saint Louis rises high in the bluffs, conditions were favorable for terracing.

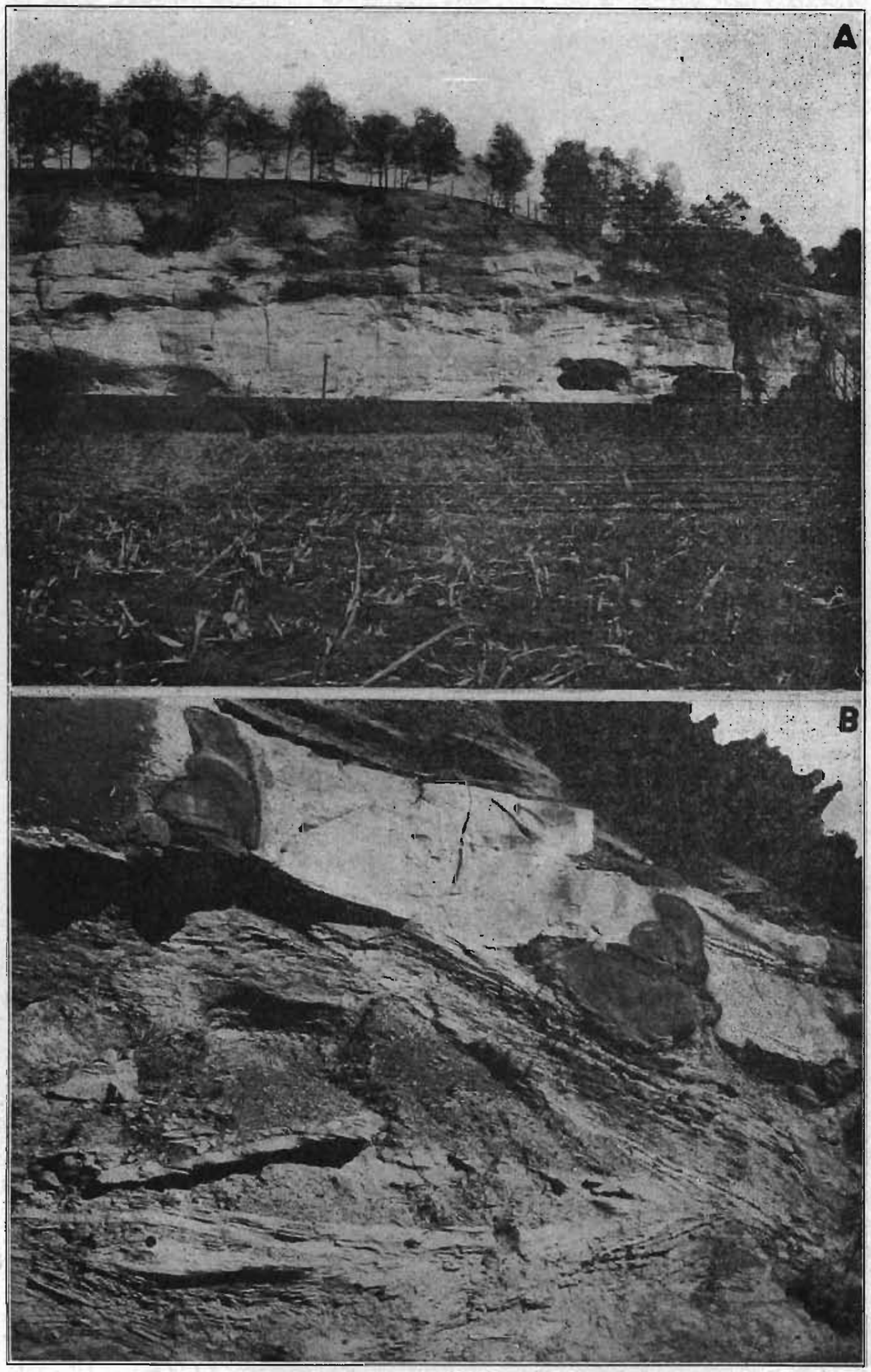
Strata below Ottumwa.—At the east edge of Ottumwa, where the Chicago, Rock Island and Pacific and the Chicago, Burlington and Quincy railroads cross, the bluff is seen to be built, above black shales of the Des Moines stage, of sands, silts and sandy silts of Pleistocene age. In the vicinity of Ottumwa the Saint Louis strata dip below water level, so that black Coal Measures shales outcrop in the bluffs, although Saint Louis limestone is quarried in the northern part of the city. The limestone reappears in the bed of the river as Eldon is neared (Plate LXVI).

Beyond Ottumwa the eastern wall of the valley swings in a wide curve and soon becomes a steep bluff which presents a precipitous sandstone scarp fifty to seventy-five feet high. This scarp continues with occasional breaks, to Cliffland, where it presents a very picturesque view. See Plate LXVII, A and B, and Plate LXVIII, A, for portions of this cliff.

Below Cliffland, shales are interbedded with the sandstones (Plate LXVIII, B) and gradually form more and finally all of the exposure. Here the wall is somewhat less steep. About



A. The sandstone bluff at Cliffland. B. Valley and caves in the bluff.



A. The continuation of the bluff at Cliffland. B. Shales and interbedded sandstone one-half mile below Cliffland. Note the crossbedding and concretions.

two miles below Cliffland a high wall of sandstone locally replaces the shales above the level of the railroad. It seems to fill a valley in the shales— a valley, perhaps, of contemporaneous erosion. From these exposures to Eldon the rocks are not exposed and the slopes are quite gentle. On the outskirts of Eldon is a bluff fifty feet or more in height composed entirely of a buff loesslike silt with sandy streaks in the lower part.

Along the west side of the valley the wall is quite steep nearly all the way from Ottumwa to Eldon. These steep slopes give way, however, as Soap creek is approached and grade down to the wide valley of the tributary. Beyond the space of half a mile occupied by the flood plain of the creek, the high slope is resumed.

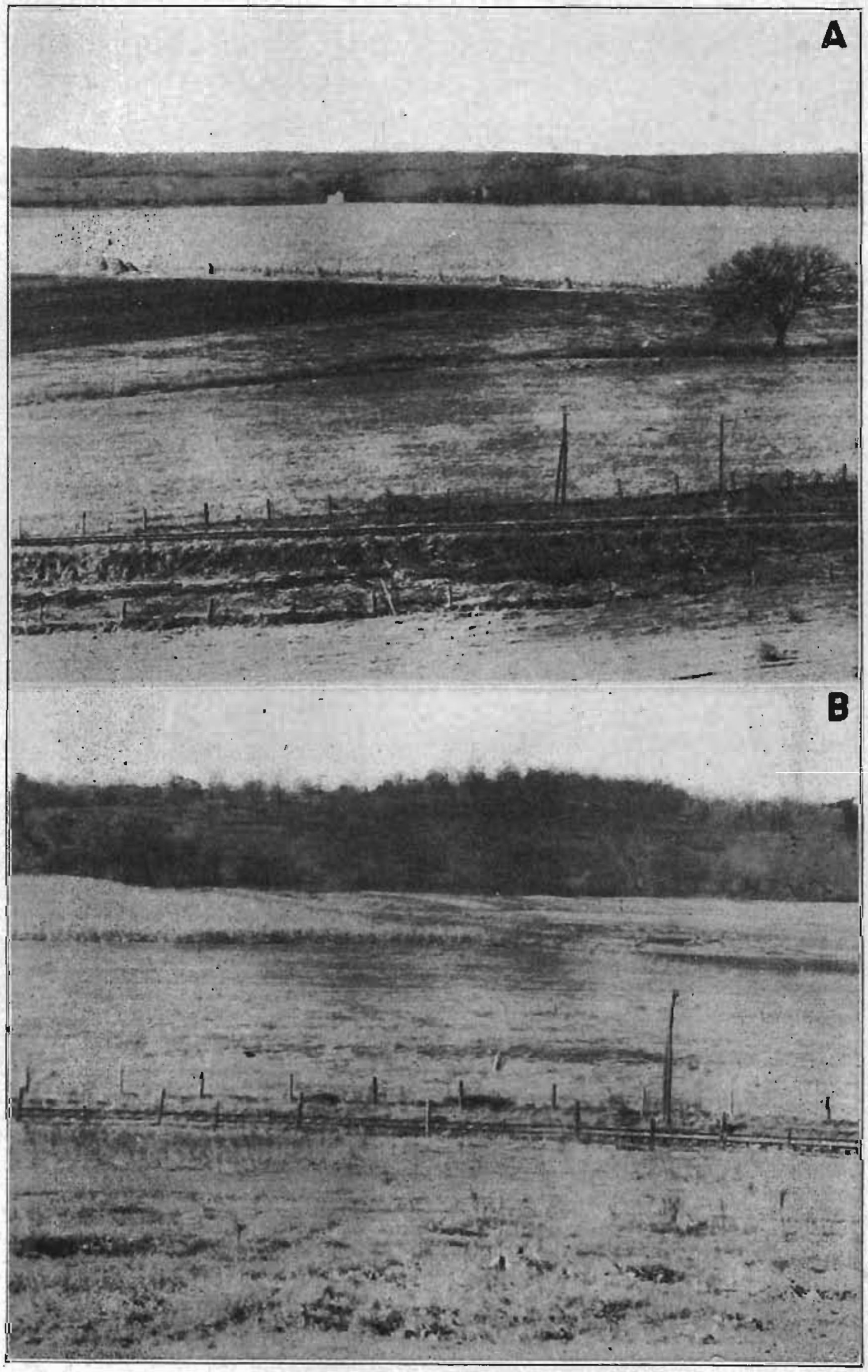
FIG. 48—The wide valley of the Des Moines between Cliffland and Eldon.

Between Eldon and Kilbourne the east side of the valley rises with gentle slopes of 2° to 5° inclination from the flood plain to the uplands. These gentle slopes are interrupted only at Selma and Douds, where for a brief space, steeper, rougher walls intervene. The gentle slopes reach back one-fourth to one-half of a mile to the uplands. The west wall, contrariwise, is quite steep all the way from Soap creek to Kilbourne. Here it assumes a gentle grade, while the opposite wall rises to a bold steep bluff, owing to the abrupt change in direction at this point.

The fact that the soft strata of the Des Moines stage dip below river level between Ottumwa and Eldon explains why the flood plain here is one and one-half to two miles in width instead of one-half to three-fourths of a mile, as above Ottumwa. See figure 48. Below Eldon the Mississippian limestones rise above water level and, as a result, at Selma the valley suffers a remarkable constriction, as here the flood plain is narrowed quite abruptly to a width of about one-fourth of a mile. Plate LXIX, A and B, show the character of the valley in this vicinity and the profiles taken near Selma will show how abrupt and how great this change is (Plate XLIV, C and D). As the resistant limestones of the Mississippian stage rise higher and higher above the valley floor, they become more and more a determining factor in the development of the topography, and hence the river is straitened in its course and compelled to flow in a singularly direct path, in strong contrast to its meandering progress between Des Moines and Eldon.

At Douds Leando there is a terrace extending one-half mile or more along the west side of the valley. It is fifty to sixty feet above the flood plain and back of it the uplands rise by about the same amount. It runs out to the south and is succeeded by a narrow flood plain not over one-fourth of a mile wide. Three miles farther down the valley another ill-defined terrace cuts out the flood plain and beyond it the steep bluffs rise from the water's edge to the prairie levels. Across the river a strip of bottom land perhaps 200 yards wide separates the channel from the slopes and extends down the valley as far as Kilbourne.

Below Selma, limestone outcrops are abundant in the bed and walls of the master valley as well as in those of its tributaries. On both sides of the Davis-Van Buren county line quarries have been opened in Saint Louis strata well up on the hillsides. On the other hand, in a creek valley on the Davis county side of



A. The wide valley a mile north of Selma. B. The narrow valley just below the village.

the line, Des Moines sandstones are found at the base of the bluffs. This is one of many illustrations of the irregularity of the old Saint Louis surface.

The Keosauqua Oxbow.—Below Kilbourne the valley presents what is probably the most singular phenomenon of its entire course—the Keosauqua oxbow. Plate LXVI shows the relations of this oxbow to the valley and figure 49 presents a topo-

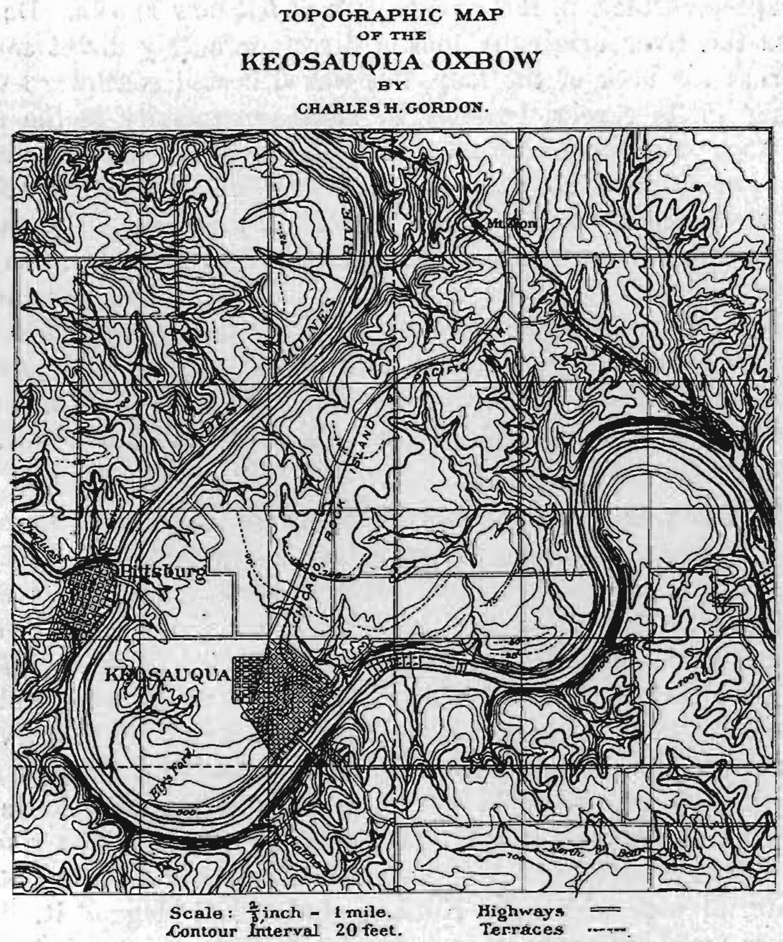


FIG. 49—Topographic map of the Keosauqua oxbow, Van Buren county.

graphic map of the oxbow. In this great bend the valley leaves its direct course, swings six miles to the southwest, then bends on itself and after coming back into line with its upper course continues in the southeasterly direction common to the valley below Des Moines. This oxbow illustrates beautifully the tendency of rivers to develop steep bluffs on the outer side of their curves while long gentle slopes are formed on the inner side.

It seems difficult to account satisfactorily for this great detour of the river. There is no material difference in the rock strata of the region, but whether there was at any time a topographic obstacle in the river's path is not now known. Doubtless the river originally took a direct or nearly direct course across the neck of the loop, but was deflected southward very early in its career, possibly by some irregularity in the rock surface or in the glacial deposits. The level of the ridge within the loop is about the same as that of the land outside the valley, to the northeast (760 feet above sea) so that this early course could not have affected the topography very seriously. In accordance with the laws of stream work the river constantly increased its curvature. When the hard limestones below the Coal Measures were reached, this lateral erosion was carried on at the expense of the deepening of the channel and so there was planed out the broad terrace on which the upper part of Keosauqua is built.

Terraces in the Oxbow.—A number of sand terraces have been developed on the valley sides as remnants of old flood plains, marking stages in the river's history, and these were mapped by Gordon at the following levels above low water at Keosauqua: 145 feet, 120 feet, 90 feet, 75 feet, 50 feet, 25 feet, 15 feet and 10 feet. See figure 49. The most prominent of these are those lying at the 50 foot, 90 foot and 145 foot levels. Since the oxbow must date from early Aftonian time these terraces may represent in part the great Aftonian gravels of western Iowa, and in part they are the result of the river's efforts to clear its valley of the accumulations of drift and other material with which the Kansan glacier had clogged it. The lower members probably represent a similar activity following the Wisconsin stage, since sand and silt would be carried down the valley by the floods while the Wisconsin ice was melting.

Topographic map [illegible] he [illegible]hoka quadrangle, including part of Lee county, Iowa, and of northeastern Missouri.

The Narrow Valley near Keosauqua.—The river valley is narrow and rock-bound in this region and every tributary flows on a floor of rock, limestone for the most part, although shales are found at numerous points. The uplands are covered with a heavy blanket of loess which in general is light gray with iron stains and with local changes to bluish color. The drift also is quite thick and is very pebbly.

The Bentonsport Ridge and Terrace.—Three miles above Bentonsport a high steep ridge half a mile long flanks the river closely on the east side. Behind it is a narrow, rather shallow swale which opens into the river valley to the north, into a creek valley at its lower end. There is no stream of any consequence in the swale, and the reason for its existence is not clear. It must be due to some drainage element not now evident, or to some change necessitated by glaciation.

Beyond this ridge gentle slopes border the river as far as Bentonsport, while across the valley these are faced by steep walls. At Vernon, however, across the river from Bentonsport, these walls give way to a terrace sixty to eighty feet high and varying in width from one-third to one-half of a mile. There seems to be no clear reason for this terrace nor for those between Douds Leando and Kilbourne, since in both of these localities the river is flowing in a straight course. But evidently they date from a period when the river, flowing at a higher level, was swinging from side to side in its valley and was cutting away its walls. As it sank to lower levels the stream pursued a straighter and narrower path.

The Valley near Farmington.—Below Bentonsport the valley is increasingly narrow until at Bonaparte there is practically no flood plain. The walls, more or less steep, come in quite close to the river banks. The alternation of steep and gentle slopes, with the reversal of the succession across the valley, is even more pronounced than above Bentonsport. The character of the walls changes every mile or two. Two miles above Farmington the valley widens a little and a sand flat occupies the bottom lands east of the stream. This flat is twenty to thirty feet above the water, and at Farmington attains a width of half a mile. On its landward side it is bounded by gently rising hills which are built of Coal Measures and faced with sand which in places is overlain by a light gray loess. At the south edge of town a large pit has been sunk thirty feet below the level of the flat into cross-bedded, waterlaid sands and gravels.

It may be noted that from the Keosauqua oxbow southward within two miles of Farmington limestone outcrops abundantly in the floors and lower walls of tributary valleys. A mile below Farmington, too, a ravine shows Mississippian limestones in its floor, while the Des Moines shales and sandstones are found higher up the valley. At the village, as is shown by coal mines

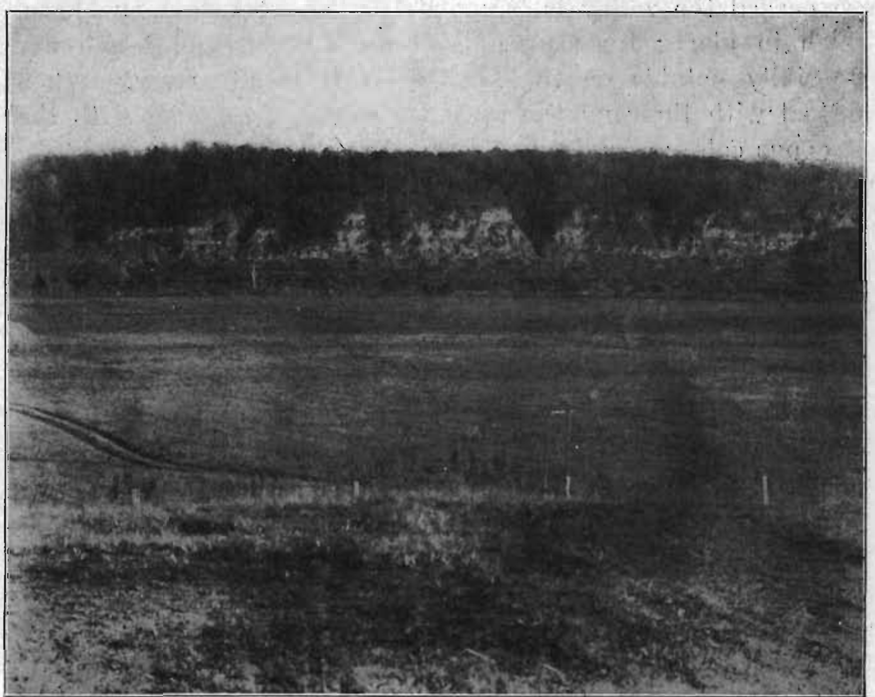


FIG. 50—The narrow flood plain just below Croton. View taken from the edge of the terrace on the Missouri side.

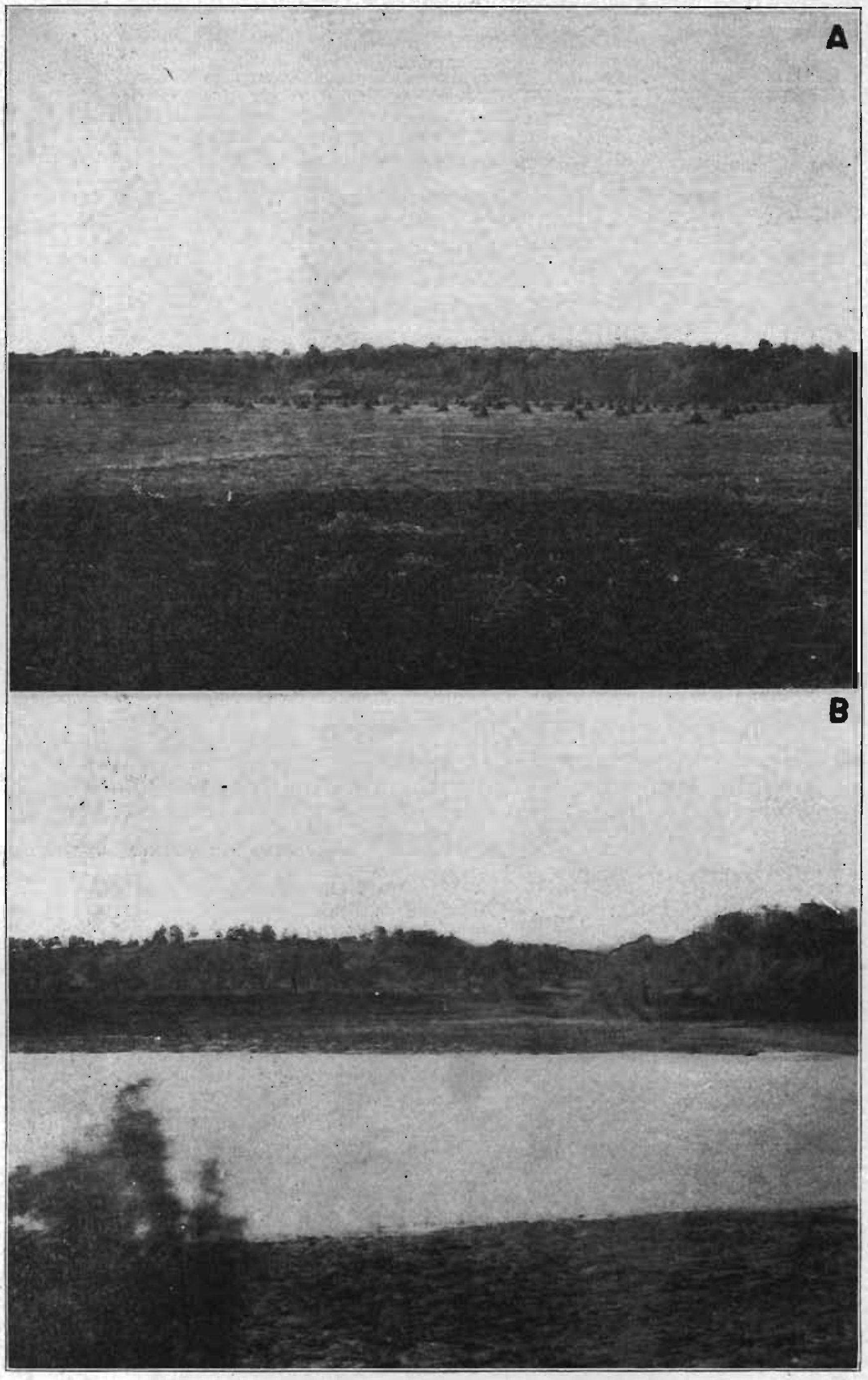
and prospects, Coal Measures strata lie in an ancient basin cut in the limestones. In the light of these facts we can understand how the valley was cut wide and deep across the strip of soft

Coal Measures and since then, following the close of one or more of the glacial periods, was partly filled with sand and gravel. From this source came the sand veneer which now mantles the hills to the east of the valley.

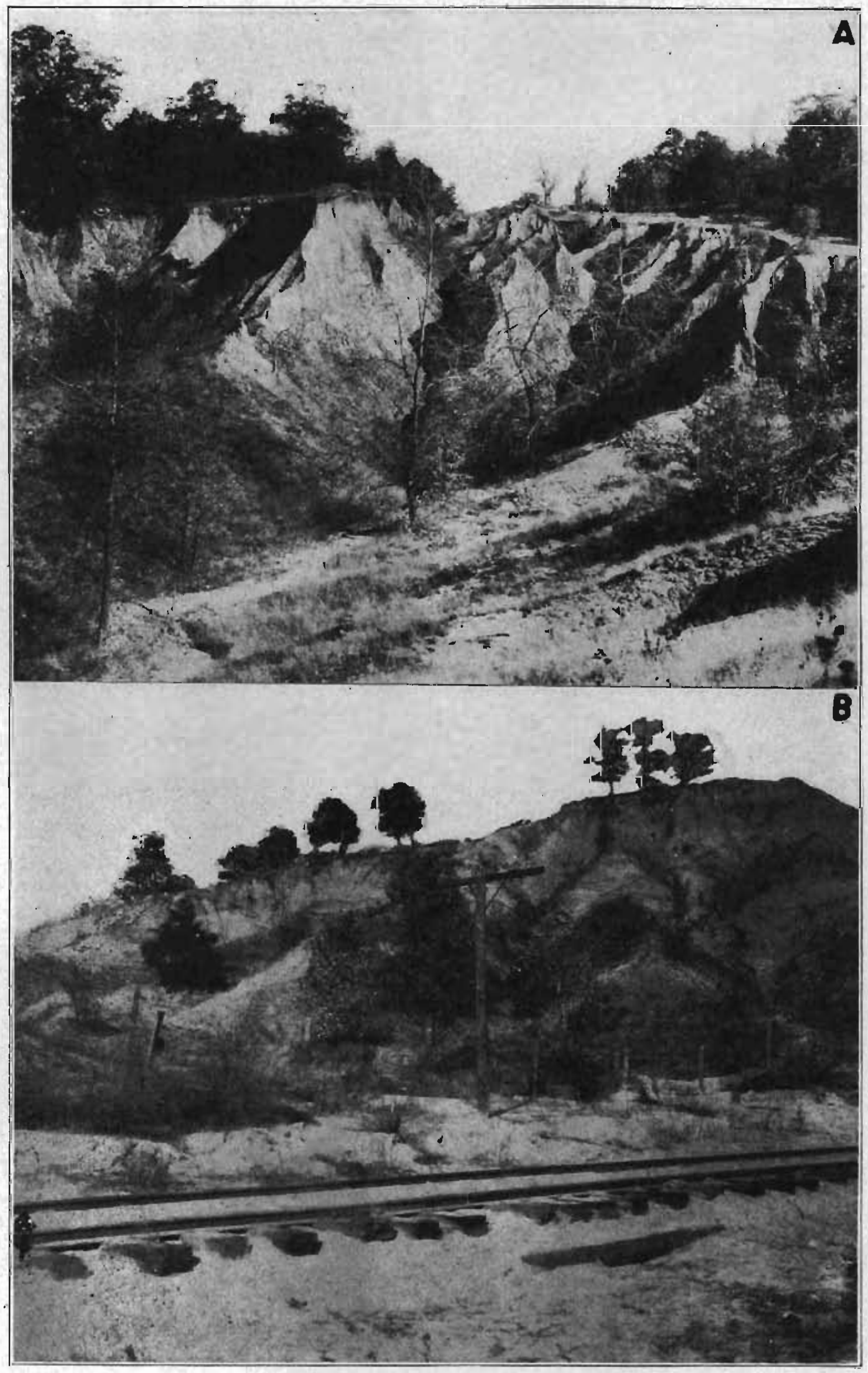
Below Farmington the sand flat shrinks to a mere strip and thenceforward a narrow sandy flood plain lies between river and bluffs, now on one side of the stream, now on the other. South of Croton this flood plain is less than one-fourth mile wide (figure 50) and at Belfast it narrows to 300 yards, a width which it retains beyond Hinsdale, just below the bridge of the Atchison, Topeka and Santa Fe Railway over the river. Everywhere the valley is filled with sand to the practical exclusion of the customary fine alluvium. After the Farmington sand hills are passed the valley is bounded for the most part by bluffs, which in places form precipitous rock cliffs, and which are especially notable on the Missouri side of the river. When clothed with their mantle of green or when glowing with the gorgeous colors of autumn foliage these bluffs and scarps make most charming and delightful scenes.

Just above Hinsdale, where the Atchison, Topeka and Santa Fe railroad skirts the hills, these are built up to a height of seventy-five feet of yellow sand. However, the rock basement rises to the level of the flood plain, as it is seen in the creek beds. A little farther along, too, the bluffs show rock to their summits, so that this sand probably is banked against rock walls. The sand hills are capped with the gray loess which is so abundant along the valley.

The Vincennes Plain.—In the vicinity of Sand Prairie, or Vincennes, the bluffs bend away from the river and leave a wide sandy plain twenty to forty feet high, stretching from their bases one to three miles south to the stream (Plate LXX). Here also the rock walls are replaced by hills of sand and between Vincennes and a point two miles east of Sugar creek (Plate LXVI) no more rock is seen; only sand and silt, which rise in steep embankments a hundred feet or more above the plain below. The wide sandy flat opposite Vincennes in general is quite level save for minor irregularities which perhaps



A. The wide valley two miles below Vincennes. The valley is cut in the filling of the buried Mississippi gorge. B. Where the west wall of Des Moines valley unites with the wall of the Mississippi valley and swings away to the south. View at Saint Francisville.



A. Badland topography eroded in the old valley filling at Connables. B. Erosion in the valley filling two miles below Connables.

are dunes. Plate LXXI, A, shows the character of this plain. A typical example of the material of the valley wall is seen a mile and a half east of Sugar creek. Here blue gravelly clay, probably Kansan drift, rises six feet above the railroad tracks. This is overlain by red and yellow sand seventy feet or more thick, and this is capped by fifteen feet of gray silt. From the edge of the escarpment the uplands slope gently up to the divides. A similar exposure is found two miles southeast of Vincennes, at a little station known as Connables, where the road climbs the hills. See Plate LXX and Plate LXXII, A. The material here is a yellow gravelly clay. Plate LXXII, B, shows a bluff of sand about one hundred feet high which is located two miles south of Connables.

The Valley near Keokuk.—Just where rock begins to reappear in the wall, about a mile above the Chicago, Burlington and Quincy railroad bridge crossing the Des Moines, a hill of circumdenudation stands at the edge of the valley, cut off from the rock plateau by a sag one-fourth of a mile wide. This sag may represent an abandoned fragment of the Des Moines valley, or it may be a remnant of some pre-Pleistocene drainage line or of some tributary of the Mississippi. The hill consists of limestone and from here to Keokuk the valley on the north side is rock-bound with but little bottom land between wall and stream. This wall, however, really marks the valley of the Mississippi since at Keokuk this river swings westward about three miles to meet the Des Moines. See Plate LXVI and figure 51, page 598. This part of the valley near Keokuk bears evidences of immaturity in the steepness of its walls and their bare rocky character. Time and the elements have not yet been able to smooth out its roughness and cover its nakedness with a protection of soil and vegetation.

The Mississippi Plain.—It is to be noted that the steep bluff which has faced Des Moines river on the Missouri side, where it reaches the village of Saint Francisville, opposite Vincennes, bends abruptly and swings off to the south, far away from either the Des Moines or the Mississippi. See Plate LXX and Plate LXXI, B. And yet the wide stretch of plain sloping gently to the east now constitutes the immediate valley of the Mississippi, and to a less extent of the Des Moines also. This plain is rather high near the bluffs, but soon runs down to a lower level—the great flood plain of the Father of Waters. Oxbows and lakelets in its northern part show that here it has been occupied by the Des Moines within recent time.

The Mississippi Valley Between Burlington and Keokuk.

In order better to understand the phenomena we have just been describing let us note the character of the Mississippi

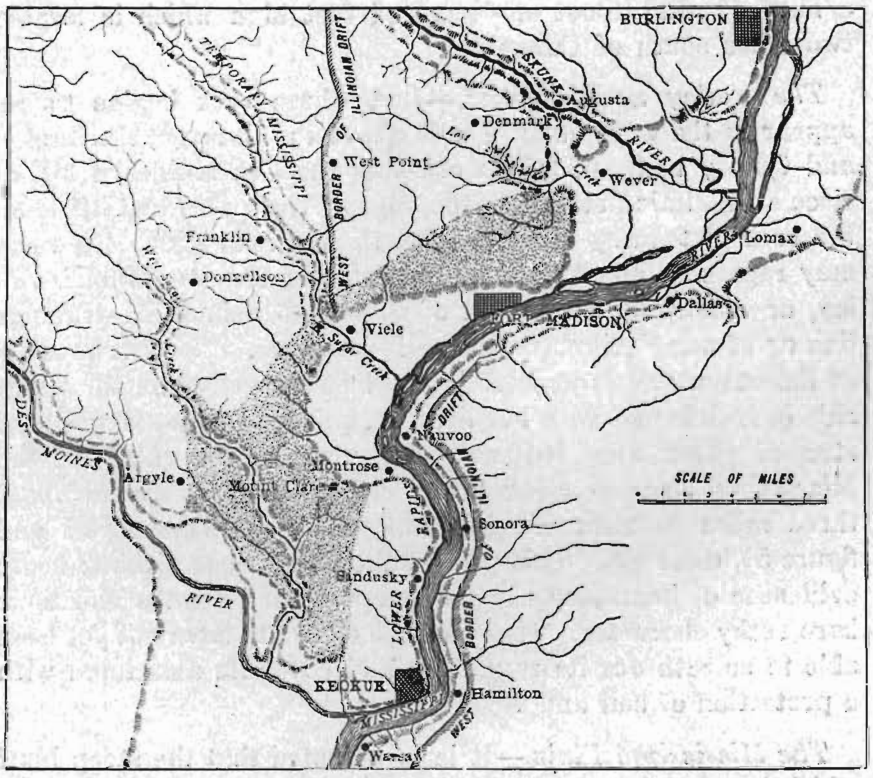


FIG. 51—Map showing drainage changes in southeastern Iowa. The buried valley of Mississippi river is dotted. Present valleys are indicated by hachures. From Leverett.

valley between Keokuk and Burlington (figure 51). Between Keokuk and Montrose the great river flows between steep, rocky, closely restraining walls. There is hardly any room for a flood plain. Between Montrose and Fort Madison the east wall bounds the river almost as closely, but on the Iowa side the bluffs recede far to the west and leave a crescentic, sandy flat four or five miles wide. Moreover, these bluffs, unlike those below Montrose, but just like those facing the Des Moines valley at Vincennes only a few miles southwest, are composed entirely

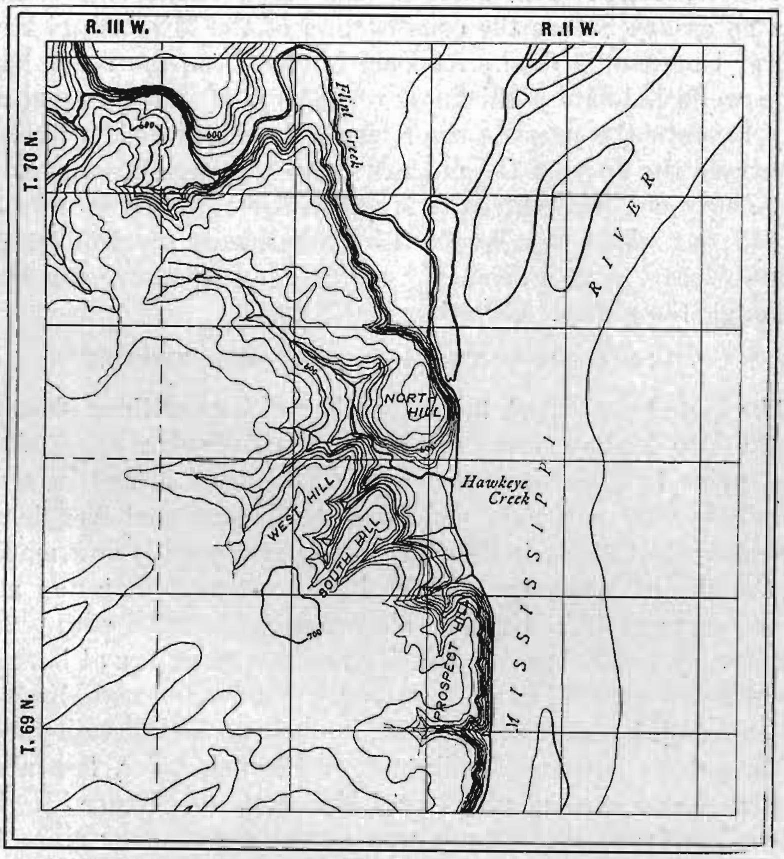


FIG. 52—Topographic map of vicinity of Burlington, showing the high rock bluffs on the Iowa side of the valley.

of loose detrital material—sand and silt. Even where they sweep in to reach the river at Fort Madison the same is true, and one exposure on the east edge of the city shows a face 150 feet high composed entirely of bedded sands and silts. These sand hills continue past Wever three or four miles north of

Skunk river, where they are replaced by rock walls which extend to Burlington and beyond (figure 52). They look down upon a low plain which is crossed by Skunk river and which is similar to the plain above Montrose except for its larger size. See figure 51.

Between Keokuk and Montrose the river is flowing over rock and the channel is obstructed by rapids, so that a ship channel was necessary before the construction of the Mississippi River Power Company's dam. At Fort Madison, on the other hand, deep wells indicate a thickness of 125 to 140 feet of sand and clay beneath the present river level. In other words, while at Montrose the floor of the modern rock-cut channel is about 495 feet above sea level, at Fort Madison the rock bed is only 380 to 365 feet above sea level. Two miles west of Montrose, at Mount Clare, a well reached rock at 374 feet above sea level, although the surface elevation is 679 feet.

THE HISTORY OF THE MISSISSIPPI NEAR KEOKUK.

The facts here stated, taken together with conditions observed in the Des Moines valley, point to the following conclusions: Just prior to Pleistocene time the Mississippi flowed in a valley whose west wall extended from Burlington past Argyle and Vincennes to Canton in Missouri. The east wall is now marked by the site of Montrose and the hill of circumdenudation mentioned on page 597. But this old channel was filled with glacial detritus by the Nebraskan glacier and the river found it easier to cut a new channel in part. Between Burlington and Montrose it succeeded, by lateral corrasion, in clearing its old valley more or less, more between Burlington and Skunk river, less above Montrose and least of all at Fort Madison. See figure 51. But below Montrose the stream was diverted and ever since has been excavating a passage in the hard rocks of the Mississippian. This new course extends past Keokuk to the mouth of Des Moines river, where the Mississippi again found its old valley. It will be seen from Plate LXX and figure 51 that the bluffs south of Saint Francisville mark the ancient as well as the modern western bounds of the valley, while on the east the river hugs the high wall stretching past Hamilton and Warsaw which bounded its valley on this side in preglacial as in postglacial times. South of the Des Moines the two rivers together have succeeded in clearing out the upper 150 or 175 feet of the valley filling, and a little has been accomplished north of the Des Moines, as witness the flat at Vincennes and one east of West Sugar creek (figure 51). This great buried valley had a width of six miles, and a depth which must have approached 300 feet—dimensions which indicate the vast amount of work performed by the ancient river (figure 53).

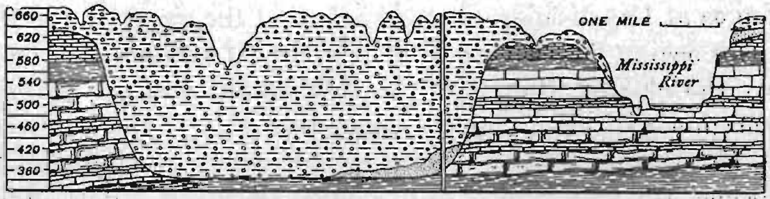


FIG. 53—Section across present and former valleys of Mississippi river in Lee county between Sonora and Argyle. From Gordon.

A BURIED TRIBUTARY OF MISSISSIPPI RIVER.

A number of years ago Gordon described the buried valley of the Mississippi, and also made mention of a smaller buried channel which lies beneath the valley of West Sugar creek and opens into the larger valley north of Vincennes, as shown in figure 51. The smaller valley he interpreted as being a former channel of the Des Moines. However, water level in Des Moines river at Saint Francisville, 500 feet above sea level, is 130 feet above the rock floor of the old valley. Moreover, Des Moines river is rockbound for many miles above Saint Francisville, and flows over rock at numerous localities, as for instance Bentonsport, Selma, Eldon and Ottumwa. The physiographic evidence shows that the valley from Des Moines to Keokuk is a unit, and so far as rock structure permits, is in the same stage of development. There is no point at which the valley could be divided on a physiographic basis and a part joined to this ancient channel, and besides, it is impossible for the present valley to join the ancient one without assuming an abnormal gradient. This buried channel must have contained some minor tributary of the former Mississippi, not Des Moines river.

The Age of Des Moines River Valley.

It must be clear from the above statements that the Des Moines valley can have no relationship with any pre-Pleistocene Mississippi valley, that it must be of the same age as the valley at present occupied by the Mississippi between Montrose and Keokuk, unless we conceive of an interglacial Mississippi as partly re-excavating and occupying the older valley between Montrose and Vincennes, and that is a needless assumption. It was stated in connection with the discussion of drainage changes at Des Moines, on page 545, that the greatest age which we can assign to the Des Moines is the Aftonian epoch or possibly the closing stages of the Nebraskan, and the preceding discussion will have made it plain that this is the case. If it can be proven that the Mississippi valley is younger than Pliocene, the Des Moines valley must be given a date of later origin than Nebraskan, and conversely the establishment of a Kansan or of a Nebraskan date for the origin of the lower Des Moines valley would place the beginning of the oldest Mississippi channel at an earlier time. The drainage changes which have taken place at Des Moines seem to be critical if the view adopted in this paper be the correct one and they required so much time and so many geological events that they necessitate a pre-Pleistocene Mississippi to cut out the great buried valley west of Keokuk and the still greater one to the south now partly cleared of its Quaternary filling. This valley, as was stated above, was cut out and filled again before the Des Moines came into being.

Filling of Des Moines Valley.—Above Ottumwa the Des Moines valley has been filled to varying depths above its original rock floor. Thus at Eddyville rock lies twenty-five feet below the bottoms, east of Tracy it is thirty-five feet below the present valley floor, and below Des Moines the valley filling is at least fifty or sixty feet thick. The valley for many miles below Des Moines is cut entirely in the soft, easily eroded strata of the Coal Measures, and where the sandy limestone layers of the Saint Louis appear in central Marion county and eastward, they are exposed only intermittently and for a few feet above water level. These softer strata have not been able to limit the activities of the river either horizontally or vertically to the same extent as is the case farther down the stream where limestones form a greater part of the restraining walls. These statements apply also to the situation at Farmington as described on page 591. It will be clear then that the depth of the rock floor below the flood plains represents scouring by the river in past time, and has no relation to the question of the unity of the valley. That is, it does not mean that the valley above Ottumwa is of different age from that below that city, or that below Farmington it extended across southwestern Lee county instead of along the course which it now occupies.

SUMMARY.

Provinces of the Valley.—By way of review it may be noted that the valley is divided topographically into two provinces, which correspond with the areas of Wisconsin and of Kansan drift. The differences in the character of the valley in these two areas are strongly marked, as is to be expected in regions which differ so greatly in their topographic development. In the first province, the river is relatively small and inefficient as a physiographic agent and the valley bears all the marks of youth and immaturity. In the second province on the other hand, the signs of the long activity of the river and of the maturity of the valley are on every hand. Moreover, as is to be expected, the transition between the two areas is abrupt and decisive.

As regards the age of the drainage lines the present valley may be divided into two parts, interglacial and postglacial, although it is not always possible to distinguish clearly between them. On the East Fork of the Des Moines the part above the mouth of Buffalo creek is clearly postglacial while the lower part is interglacial. The West Fork is postglacial in Minnesota and across Emmet and Palo Alto counties, if we make exception of a short stretch above Windom as explained on page 508. Between Bradgate and Des Moines the river occupies a post-Kansan valley, while below the latter city the valley is Aftonian (post-Nebraskan) in age.

If we consider the dependence of the topography of the valley upon the underlying rock, the distinctness of the two topographic provinces is very plain. It is largely true that within the area of Wisconsin drift the present relation of topography and bed rock is not very close. In the postglacial stretches of the valley there is no relation whatever between them, and lower down where the river flows in an older, but still post-Kansan, valley, it has been occupied during recent time in clearing out the obstructions and has come in contact with the rock foundations but little. In its pre-Kansan portions, however, where the river crosses the Kansan drift, the character of its valley is influenced very strongly by the underlying strata, and in places is determined by them.

Area and Declivity of the Valley.—The valley of the Des Moines, using the term in its larger sense, includes an area of 12,500 square miles in Iowa, besides 1,525 miles in Minnesota and 75 miles in Missouri, making a total area of about 14,100 square miles. Of this, 1,200 miles belong to the East Fork, 2,420 miles to the West Fork and the balance, 10,475 miles, to the combined valley. Of course the area actually considered in this report is very much less, as was stated in the introductory paragraphs.

The sources of the West Fork lie at altitudes of about 1,850 feet and where it crosses the state line the river is about 1,250 feet above sea. In the 100 miles of its course in Minnesota, therefore, the river falls practically 600 feet. However, the first 200 feet of this are accomplished within ten miles from the heads of the stream and the outlet of Lake Shetek, not over 35 miles from the sources, is practically 400 feet below the headwaters. Between the state line and Fort Dodge, 100 miles, the valley drops to 975 feet, or nearly three feet per mile. Through Palo Alto and Pocahontas counties the slope is from two and one-half to three feet per mile, although the fall of the stream is only one-half this amount. In Humboldt county the valley declines about eight and one-half feet per mile near its outlet. From Fort Dodge to Des Moines the river falls practically 200 feet in 100 miles, and between Des Moines and the mouth—175 miles—the fall is 301 feet, or less than two feet per mile. Low water at Keokuk is 477 feet above sea level, hence the total fall of the river in its extent of 475 miles is about 1,375 feet.

The elevation of the sources of the East Fork is about 1,350 feet and Tuttle lake, on the state line, lies practically 100 feet lower. The Minneapolis and Saint Louis railroad bridge over the river at its mouth stands 1,067 feet above tide and so the river is at about 1,050 feet or 300 feet below its source 100 miles to the northwest.

Physiographic Principles Illustrated by the Valley.—Perhaps the physiographic principle which is most strikingly illustrated in this valley is that of the close relation which exists between the age of a stream and the direction in which its energies are being expended, and the consequent character of its valley. Another point which is well shown is the relation which the materials wherein a valley is cut bear to its size and proportions. Thus above Des Moines, where the river dates only from the Wisconsin ice epoch, it is engaged in down-cutting; its valley, where this is erosional, is narrow; it is bounded by steep walls. Below the edge of the Wisconsin drift the stream is much older; it has been long widening its valley by side-cutting; to a larger extent the limiting slopes are rather gentle. Again, between Des Moines and Eldon the greater part of the valley is cut in Des Moines shales and it is very wide, although where it crosses the more resistant Red Rock sandstone it is temporarily narrowed very decidedly. After the valley enters the region of the Saint Louis limestone below Eldon it once more becomes narrow and steep-sided, and retains these characters until it unites with the valley of the Mississippi.

Another principle which is well illustrated is the close connection between the character of the valley and the topographic development of the surrounding region. That these two go hand in hand and progress simultaneously is shown clearly in the two provinces of the valley. In the upper province, both are young and incompletely developed. In the lower province the reverse is true. In the younger province the topography is glacial and chiefly constructional. In the older area the topographic forms are erosional, and are the result chiefly of down-cutting activity.

The development of tributaries in harmony with that of their master also is well shown. Where the main valley is young its tributaries are of a similar stage of development. Where it is mature the secondaries have progressed to the same stage.

Bibliography of Des Moines Valley.

In order to avoid distracting the attention of the reader with footnotes, references to literature have been omitted from the text. The region through which the Des Moines flows has all been covered by geological surveys, however, and a list of the published reports dealing with the area will be found below. These reports have been in constant use in the preparation of this paper and the writer wishes at this time to acknowledge his indebtedness to the authors for many suggestions which have come from their writings in the course of his work. Even where he had reason to differ in details these suggestions have served as an inspiration in formulating his own thoughts.

In addition to the reports on county geology of Minnesota and Iowa several other reports and text-books on geology have been used and are cited here on account of their usefulness. Any reliable text-book will give discussions in more or less detail of the physiographic principles which are illustrated in the Des Moines valley, and the geologic history outlined in this paper will be found described in more expanded and complete form in the references here given. Liberal use should be made of the works mentioned in this bibliography, and of any others which have any bearing in connection with this report.

The most complete and elaborate exposition of principles and of earth history is found in **Chamberlin and Salisbury's** Geology, a three volume work. A more condensed statement is given in College Geology, by the same authors, and in the second edition of An Introduction to Geology, by **W. B. Scott.**

The pre-Pleistocene elevation of Iowa is discussed by **Samuel Calvin** in Iowa Geol. Survey, Vol. XIII, pp. 297-299. A possible postglacial elevation is described by **T. C. Chamberlin** in Third Ann. Rept., U. S. Geol. Survey, p. 390.

Data regarding time relations of the Pleistocene are based upon **Chamberlin and Salisbury:** Geology, Vol. III, pp. 414, 420; also upon **Calvin:** Introduction to County Geology, a brief summary of Iowa geology bound with the separate reports on counties of the state. In this connection see also **T. C. Chamberlin**, The Future Habitability of the Earth: Ann. Rept. Smithsonian Institution, 1910, pp. 371-389.

In connection with valley development see **J. E. Carman,** The Mississippi Valley Between Savanna and Davenport: Bull. Illinois Geol. Survey, No. 13, pp. 22-27. This report also discusses several other features which are connected with the development of Des Moines valley.

Another clear and concise discussion of valley development and stream work is given by **Salisbury and Atwood,** Geography of Region About Devil's Lake, Wisconsin: Bull. Wisconsin Geol. and Nat. Hist. Survey, No. V, pp. 36-59.

The figures for the denudation of the Des Moines Valley are taken from Papers on the Conservation of Water Resources: Denudation, by **R. B. Dole and H. Stabler,** Water Supply Papers, U. S. Geol. Survey No. 234, pp. 89, 90.

The data concerning the amount of water in the earth's crust are given by **W J McGee,** Principles of Water-Power Development: Science, N. S., Vol. XXXIV, Dec. 15, 1911, p. 814.

The section on the history of the valley has been abstracted from History of Iowa, by **B. F. Gue,** and from the chapter on Geographical Exploration of Iowa-Land in Vol. XXII, Iowa Geol. Survey, Bibliography, 1912, by **Charles Keyes.**

Among the early workers on the geology of the state the members of the Hall survey make brief mention of the Des Moines valley. See **J. D. Whitney,** Geology of Iowa, Vol. I, Part I, 1858, p. 10; also **A. H. Worthen,** Ibid, pp. 219, 248. On pages 186 to 188 **Mr. Worthen** discusses the bluffs and terraces between Montrose and Fort Madison which are described on pages 598 to 600 of this paper. While Mr. Worthen did not realize the extent of the preglacial erosion between these points and did not know of the old valley extending south to the present Des Moines, he understood that a great basin had been scooped out of the limestones in this region.

Professor **C. A. White** in Geology of Iowa, Vol. I, 1870, pp. 57-60, gives an excellent summary of the general features of Des Moines valley. Mr. White, however, considers the East Fork as rising in Union slough, which is now considered to be of merely subsidiary importance as a source of supply.

The geological sections across Iowa which are given by **W. H. Norton**, Artesian Wells of Iowa: Iowa Geol. Survey, Vol. VI; and Underground Waters of Iowa: Op. Cit., Vol. XXI, will give a good idea of the strata underlying the valley. A good conception of the topography of southern Minnesota and its relations to drainage may be had by studying the maps accompanying a report on Geology and Underground Waters of Southern Minnesota, by **Hall, Meinzer and Fuller**, Water Supply Papers, U. S. Geol. Survey No. 256.

For a theory regarding the preglacial Des Moines Valley see **J. E. Todd**, The Pleistocene History of the Missouri River: Science, N. S., Vol. XXXIX, Feb. 20, 1914, pp. 263-274.

Some valuable data on the river are given by **The Iowa State Drainage, Waterways and Conservation Commission**, The Des Moines River Valley: Biennial Report, 1909-1910, pp. 67-69, 123. See also maps of West Fork.

The Report of the Secretary of War regarding an examination and survey of Des Moines river contains maps and profiles of the river which will be of interest in this study. The report was printed as House of Representatives Document No. 1063, 62d Congress, 3d Session.

See also for information concerning gravel deposits **S. W. Beyer and H. F. Wright**, Road and Concrete Materials of Iowa: Iowa Geol. Survey, Vol. XXIV, 1913. The gravels of Humboldt county are discussed on pages 339 to 342. Each county of the state receives treatment.

An excellent discussion of the Pleistocene is given by **O. P. Hay**, The Pleistocene Period in Iowa: Iowa Geol. Survey, Vol. XXIII, pp. 9-99.

For detailed descriptions of the valley in the different counties across which it extends see the following reports:

The East Fork of Des Moines river:

Warren Upham, Geology of Watonwan and Martin Counties: Final Report, Geol. and Nat. Hist. Survey of Minnesota, Vol. I, 1872-1882, pp. 473, 479-485. The chain lakes are described and their origin explained.

Warren Upham, Geology of Faribault County: Op. Cit., Vol. I, pp. 460-461. Describes a glacial lake in the basin of Blue Earth river, and its outlet through Union slough. A briefer description also is given in 9th Ann. Rept. State Geologist, Minnesota, 1880, p. 341, pl. VI.

T. H. Macbride, Geology of Emmet, Palo Alto and Pocahontas Counties: Iowa Geol. Survey, Vol. XV, 1904, p. 243.

T. H. Macbride, Geology of Kossuth, Hancock and Winnebago Counties: Op. Cit., Vol. XIII, 1902, pp. 93-96, 104.

T. H. Macbride, Geology of Humboldt County: Op. Cit., Vol. IX, 1898, pp. 117-119.

The West Fork of Des Moines river:

Warren Upham, Geology of Murray and Nobles Counties: Final Report, Geol. and Nat. Hist. Survey of Minnesota, Vol. I, pp. 518 and 519.

Warren Upham, Geology of Cottonwood and Jackson Counties: Op. Cit., Vol. I, pp. 492-496, 507-509. A supposed interglacial line of drainage is described in this report. See also the description of the Coteau des Prairies on pages 68 and 494.

T. H. Macbride, Geology of Emmet, Palo Alto and Pocahontas Counties: Iowa Geol. Survey, Vol. XV, 1904, pp. 238-242, 245-250.

T. H. Macbride, Geology of Humboldt County: Op. Cit., Vol. IX, 1898, pp. 118, 119, 138.

F. A. Wilder, Geology of Webster County: Op. Cit., Vol. XII, 1901, pp. 70-75, 136-138.

S. W. Beyer, Geology of Boone County: Op. Cit., Vol. V, 1895, pp. 182, 183, 202.

A. G. Leonard, Geology of Dallas County: Op. Cit., Vol. VIII, 1897, pp. 61, 62, 90.

H. F. Bain, Geology of Polk County: Op. Cit., Vol. VII, 1896, pp. 273-284, 348-352. Describes drainage changes.

J. L. Tilton, Geology of Warren County: Op. Cit., Vol. V, 1895, pp. 306-314.

B. L. Miller, Geology of Marion County: Op. Cit., Vol. XI, 1900, pp. 132-140.

H. F. Bain, Geology of Mahaska County; Op. Cit., Vol. IV, 1894, pp. 318, 319, 321.

S. W. Beyer and L. E. Young, Geology of Monroe County: Op. Cit., Vol. XIII, 1902, pp. 361, 362, 380.

A. G. Leonard, Geology of Wapello County: Op. Cit., Vol. XII, 1901, pp. 444-448, 460, 475.

C. H. Gordon, Geology of Van Buren County: Op. Cit., Vol. IV, 1894, pp. 201, 203, 234-236.

C. H. Gordon, Buried River Channels in Southeastern Iowa: Op. Cit., Vol. III, 1893, pp. 239-255.

C. R. Keyes, Geology of Lee County: Op. Cit., Vol. III, 1893, pp. 312, 314-316, 366-369. Discusses old gorge of Mississippi River.

J. E. Todd, Formation of the Quaternary Deposits of Missouri: Missouri Geol. Survey, Vol. X, pp. 173-176. Discusses the old gorge of Mississippi river in Clarke county.

James H. Lees, The Pleistocene of Capitol Hill: Iowa Acad. Science, Vol. XXIII, 1916. Discusses the loess and the Wisconsin drift.

Topographic Maps of Des Moines Valley.

There are a number of the topographic maps published by the Iowa Geological Survey, in coöperation with the United States Geological Survey, which cover portions of the valley of

Des Moines river. These include the Boone, Madrid, Slater, Des Moines, Milo, Knoxville and Pella quadrangles in central Iowa, and the Kahoka quadrangle in the southeastern corner of the state. These maps will be found of great service in connection with the descriptions and discussions in this paper as they show so plainly the various features described herein and will enable the reader in many cases to follow more closely the arguments set forth than would be possible otherwise. The Boone and Madrid sheets show splendidly the young, narrow, immature valley crossing the Wisconsin plain; the broad, flat-bottomed, well-developed valley of the Kansan area is well illustrated by the Milo, Knoxville and Pella sheets; and the transition from young valley to old is shown upon the Des Moines sheet. This sheet also shows the abandoned and partly buried valley of the river in the vicinity of Des Moines, and the lower course of Raccoon river. The Kahoka sheet covers a few miles of the lower course of Des Moines river and shows the effect upon the topography of the valley of the soft materials filling the buried valley of Mississippi river. A portion of the wide old plain of the Mississippi also is included in this quadrangle.

These maps will furthermore serve the purpose of showing the character of the topographies developed upon the Wisconsin and Kansan drift sheets, the drainage incised on them and the varying efficiency of Des Moines river in controlling and modifying these features.

The outline maps of the valley in Minnesota and Iowa are reproduced from base maps of these states compiled and published by the United States Geological Survey. Acknowledgment is here gladly made of the kind permission of the Director of that organization to publish these and the topographic maps in this report.

Addendum.

When the foregoing paper was written it represented the state of knowledge at that time with reference to the Pleistocene epoch, its duration and its deposits. However, since then notable work has been done on the problems of the Pleistocene, and as some of these definitely affect the geologic history of Des Moines valley it seems well that note should be made of them here. One of these problems related to the gumbos of southern Iowa which have been the source of so much discussion among geologists, not alone in Iowa, but of other states as well. At the Washington, D. C., meeting of the Geological Society of America, December, 1915, Dr. George F. Kay, the Director of the Iowa Geological Survey, presented an outline of the results of his studies of this problem up to that time, and with Doctor Kay's permission this statement is reprinted here in full.

SOME FEATURES OF THE KANSAN DRIFT IN SOUTHERN IOWA.

In county reports issued by the Iowa Geological Survey and in other publications many of the features of the Kansan drift of southern Iowa have been described, including the original Kansan drift plain, the present topography of the Kansan drift, the tabular divides, the characteristics of the weathered and unweathered zones of the Kansan drift, the gumbo, which is closely related to the Kansan drift, and the fine loesslike clay overlying the Kansan drift surface, and which has been interpreted by several investigators to be material of eolian origin deposited after a mature topography had been developed on the Kansan drift. The origin of the gumbo has been interpreted differently by different authors, the most recently published view being that of Tilton, who considers the material to have been formed, in the main, during the retreating stages of the Kansan ice. To this gumbo and other materials which he considers to be related in age to the gumbo he has given the name Dallas deposits.

Detailed field studies which are still in progress in southern Iowa seem to warrant the author in making a preliminary statement involving some interpretations which differ from those previously advanced.

(1) The surface of the Kansan drift, after the Kansan ice withdrew, was, according to present evidence, a ground moraine plain, which from the main divide between the Mississippi and Missouri rivers, sloped gently to the southeast and south toward the Mississippi and to the southwestward toward the Missouri. This drift plain was so situated topographically that weathering agents were very effective, but erosion was slight. As a result of the weathering during an exceedingly long time a grayish, tenacious, thoroughly leached and non-laminated joint clay, which has been named gumbo, was developed to a maximum thickness of more than 20 feet. This gumbo contains only a few pebbles, which are almost wholly siliceous, and grades downward into yellowish and chocolate-colored Kansan drift from 3 to 7 feet in thickness, in many places with numerous pebbles, few, if any, of which are calcareous. This oxidized but non-calcareous drift, in turn, merges into unleached drift, oxidized yellowish for several feet, below which is the normal unleached and unoxidized dark-grayish to bluish-black Kansan drift. The gumbo is believed, therefore, to be essentially the result of the thorough chemical weathering of the Kansan drift; but, subordinately, other factors, such as the wind, freezing and thawing, burrowing of animals, slope wash, etcetera, have undoubtedly contributed to its formation. The Kansan drift which has been changed to gumbo may have differed somewhat from the normal Kansan drift that lies below the gumbo.

(2) After the gumbo plain had been developed by weathering processes on the Kansan drift plain, diastrophic movements seem to have occurred, the plain having been elevated to such an extent that erosion became effective and valleys began to be cut into the gumbo plain. Erosion of the gumbo plain progressed to such an extent that some valleys were cut to a depth of more than 150 feet before grade was reached and

a mature topography was developed. Only remnants of the original gumbo plain remain, the most conspicuous of these being flat, poorly drained areas, known as tabular divides. Where creep and slumping have occurred the gumbo, in places, may be found on slopes at an elevation several feet below the level of the gumbo plain. The tabular divides are more prevalent east of a line drawn north and south through south-central Iowa than west of such a line. In the southwestern part of the State the Kansan gumbo which is *in situ,* is found only where the divides, which are no longer distinctly tabular, retain the level of the former gumbo plain.

(3) While there is, in places, loess of eolian origin on the Kansan drift of southern Iowa, much of the material which has been described as loess is thought to be not of eolian origin, but to be related more or less closely to the gumbo. The upper few feet of the Kansan gumbo, which is now limited to the tabular divides, is a fine-grained, loesslike, joint clay, in which, if diligent search is made, it is possible to find a few very small siliceous pebbles similar to those in the normal gumbo, and it is thought that this loesslike clay is the result of changes that have been going on at and near the surface of the gumbo during the great length of time since the normal gumbo was formed. The loesslike clay which is now found as a mantle on the Kansan drift on the slopes and divides that have been brought by erosion considerably below the level of the original gumbo plain is believed to be the product not primarily of wind action, although wind may have been a factor, but chiefly the product of the weathering and concentration of the gumbo and to some extent of the underlying Kansan drift, where erosion has not kept pace with the weathering.

(4) The evidence indicates that the time taken to develop the present topography from the gumbo plain stage, although it represents a great length of time, is short when compared with the time taken to develop the gumbo plain from the Kansan drift. It is thought that the formation of the main part of the gumbo and the development of the present mature topography of the Kansan drift were effected between the close of

the Kansan epoch and the advance of the Illinoian ice into Iowa; in other words, during the Yarmouth inter-Glacial epoch. All the evidence indicates that the Yarmouth epoch was an exceedingly long interval of time.

(5) Detailed chemical analyses of gumbo, loesslike clay, etcetera, are now being made in the chemical laboratory of the University of Iowa by Dr. J. N. Pearce. The results of these analyses will go far to strengthen or weaken the interpretations given above from the field evidence.

Many of the chemical analyses mentioned in (5) have been completed and they serve to strengthen the interpretations given in Doctor Kay's paper. Continued field work gives results which are consistent with those of earlier studies. What then would be the effect of the events outlined in the paper quoted upon the history of Des Moines valley as sketched in foregoing pages? It does not seem to the writer that that history would be materially modified by the development of the Kansan gumbo plain as discussed by Doctor Kay, except that the active work of the river in cutting its post-Kansan valley would be postponed largely until after the Kansan gumbo plain had developed and diastrophism had elevated the stream valleys above grade. While the gumbo was forming the river was a sluggish, inactive stream flowing across the top of a ground moraine plain. When elevation set in the river sank into the underlying formations and widened its valley to its present proportions until it reached grade again.

The newer view emphasizes the great length of time required for the formation of the thick layer of Kansan gumbo and corroborates other lines of field evidence which point to the great age of the older portions of the valley; and probably all of these features taken together indicate a much greater duration of Pleistocene time than we have been accustomed to consider.