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STATE GEOLOGICAL SURVEY

BULLETIN NO. 11

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Physical Features of the Des Plaines Valley

BY

James Walter Goldthwait

Urbana
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State Geological Survey,
University of Illinois,
Urbana, March 22, 1909.

Governor C. S. Deneen, Chairman, and Members of the Geological Commission:

Gentlemen—I submit herewith a report on the Physical Features of the Des Plaines Valley with the recommendation that it be published as Bulletin 11 of the Survey. This forms the second of the "Educational Bulletins" of the Survey being prepared under the general direction of R. D. Salisbury, Consulting Geologist of the Survey. The author, Dr. J. W. Goldthwait, now of Dartmouth College, prepared this while connected with Northwestern University. Into it he has put the accumulated experience of several years' teaching during which the Des Plaines Valley was explored and studied as a field for illustration of the common principles of physiography. While, therefore, the report will be of particular interest to people living in the vicinity, it will afford excellent illustrative material wherever rivers and their valleys are being studied. The large demand for the preceding bulletin of this series (Bulletin 7) indicates a very widespread and live interest in the subject of physical geography among teachers and laymen. An intelligent insight into one's environment is the desire of every normal person and it is felt that these little bulletins serve a very real need even of those not concerned with teaching. Dr. Goldthwait's studies of the development and history of this, a typical stream of our region, with his special notes on its floods, have also a very direct and practical value in view of the area of land subject to overflow and the need for regulation of the stream.

In the preparation of the text and illustrations free use has been made of earlier publications and the author desires that acknowledgments be made especially to Messrs. Frank Leverett and W. C. Allen of the U. S. Geological Survey, and Mr. Lyman E. Cooley, Civil Engineer, of Chicago. A copy of the well executed map of Cook county, drawn for the Sanitary District of Chicago, was furnished the author, through the courtesy of the Chief Engineer, Mr. Isham Randolph, and has been of great value. Small portions of this map have been copied in reduced form in Figs. 17 and 19. Mr. J. W. Ferris of Joliet contributed useful information concerning the fossils of that vicitnity. To Mr. J. M. Large, instructor in physical geography in the Joliet township high school, the writer is indebted for a contour map of the ravine in Reed's woods. This map was extended and redrawn to form Plate 7 by Mr. D. F. Higgins, who also prepared a contour map of the gorge of Sugar creek (Plate 6) and aided greatly in the preparing of other illustrations. Special acknowledgment is due to Mr. Charles E. Decker for efficient help in the field, and to Professor R. D. Salisbury for kindly yet most thorough criticism.

The Survey is under great obligations to these gentlemen, and to Dr. Goldthwait for the preparation of the report, all of which it is a pleasure to acknowledge.

Very respectfully,
H. FOSTER BAIN,
Director.

PHYSICAL FEATURES OF THE DES PLAINES VALLEY.

(By James Walter Goldthwait.)

CHAPTER I.

GEOGRAPHY AND HISTORY OF THE DES PLAINES RIVER.

INTRODUCTION.

The Des Plaines valley is one of peculiar interest geologically and historically. The lower portion of the valley, southwest of Chicago, was once occupied by a great river, the outlet of an early Lake Michigan. The divide over which the lake once spilled to the Des Plaines, now the continental divide between the Laurentian lakes and the gulf, is only about ten feet above the present lake. So low and flat is this divide that before the construction of the Illinois-Michigan canal it was covered by the spring freshets of the upper Des Plaines, and afforded the early French explorers an easy and continuous canoe route from the lakes to the Mississippi. The Chicago pass is fully 175 feet lower than the next lowest pass in the St. Lawrence-Mississippi divide, at Ft. Wayne, Indiana. No wonder that the idea of an artificial channel near Chicago, to join the lakes with the Mississippi, was conceived by Louis Joliet, one of the first men to cross the divide. The plan thus early suggested was at length realized in 1848, when, after years of delay, the Illinois-Michigan canal was completed and opened to traffic. Again, when the city of Chicago had outgrown its drainage facilities, the valley was resorted to for the great sanitary canal of Chicago. Rich in historic associations, and inevitably connected with the great metropolis, the Des Plaines valley is destined to become of the highest commercial importance; for it now awaits the construction of a deep waterway that shall conduct lake vessels across Illinois to the Mississippi.

Thus the valley of the lower Des Plaines possesses in a peculiar sense elements of a strictly geographic value. In its physical features lie the reasons for its early discovery and exploration, its present industrial advantages, and its future development.

It is not within the province of this report to dwell upon the geography of the valley—the relationships between the physical features and the historical and industrial conditions—however interesting such a

FIG. 1. Map of the Des Plaines basin and vicinity. The distribution of glacial drift is taken from Leverett's map in Monograph 38, U. S. Geol. Surv. (in Illinois), and from Alden's map in Prof. Paper 34, U. S. Geol. Surv. (in Wisconsin).

story may be. Rather is it the purpose here to describe the physical features and to explain the manner in which they have been developed. The valley abounds in phenomena which would be of interest to many persons living near by, and of especial use to students of physical geography and geology in the schools. Before presenting this material, it will not be out of place to take a general view of the river basin and the Des Plaines river, and to outline briefly its history.

THE DES PLAINES BASIN.

The long narrow basin of the Des Plaines river (see Fig. 1.) lies only a few miles west of Lake Michigan, in the northeast corner of Illinois. From northern Kenosha county in Wisconsin southward through Lake, Cook, DuPage and Will counties in Illinois, the basin has a length of ninety miles. Its width, however, is never over twenty-five miles, and for a large part of the distance is less than fifteen. Its area is about 1,400 square miles.

The northern portion of this basin is narrow, and is drained almost wholly by the trunk river and a single tributary, Salt creek. Its area (above Summit) is about 634 square miles. The southern portion is wider and more complex, for it includes the north-south basin of the Du Page river, the largest tributary of the Des Plaines, and several rather long creeks from the east. A few miles below the mouth of the DuPage, the Des Plaines unites with the Kankakee to form the Illinois river.

The elongated form of the Des Plaines basin is largely, if not wholly dependent on the disposition of glacial drift. At the close of the glacial period, when the district finally emerged from beneath the waning ice sheet, the bed rock had been concealed by an irregular blanket of loose earthy material or "drift," deposited in part by the glacier itself and in part by the waters that came from it. Conspicuous among the newly built surface features was a broad U-shaped belt of rolling ground, standing a little above its surroundings, and encircling the south end of Lake Michigan through Illinois, Indiana and Michigan. This belt is known as the Valparaiso moraine. The manner in which it was built up around the edge of a lobe or tongue of ice which lingered in the lake basin will be explained in a later chapter. It is enough here to note that the great moraine is crossed obliquely by the Des Plaines river between Summit and Joliet, and that from its slopes comes a large part of the water discharged by the river. The Valparaiso morainic belt is, in fact, a system of parallel ridges; (1) a central ridge which makes up the main body of the moraine; (2) an outer ridge, lower or narrower, which divides the Du Page basin from the Des Plaines proper, north of Joliet, and which for several miles southwest of Joliet is separated from the main moraine by a crescent-shaped plain and (3) an inner ridge, lying east of the central belt, and separated from it by the basin of Salt Creek.

Just outside the Valparaiso morainic system is another border moraine, known as the Minooka till ridge, which forms the west boundary of the Du Page basin, and ends interruptedly near the junction of the

Des Plaines and Kankakee. On the inside of the Valparaiso moraine, near Lake Michigan, is a group of till ridges called the "lake-border morainic system." Southwest of Chicago these are absent; but near Oak Park one of them appears, and runs northward into Wisconsin, being joined on the way by others of the system whose south ends are at Winnetka and Northfield. Since these till ridges both branch and coalesce as they run northward, the number of distinct morainic lines at different points is variable. In northern Cook county it is three, in Lake county two, and in Kenosha county, Wisconsin five.

Surrounding the city of Chicago, between the curving Valparaiso moraine and the lake, is the crescent-shaped Chicago plain. It is the smooth floor of an extinct Lake Chicago, which for a long time occupied the space between the morainic ridge and the melting ice lobe. Its former border is marked by abandoned beach ridges and wave-cut banks, and its surface is somewhat diversified by similar shore forms built at lower levels as the lake fell from its original height down to the present stage. On its north side the lake plain finds extension in a flat depression which separates the Valparaiso moraine from the west till ridge, and constitutes the present valley of the upper Des Plaines.

Let us now follow the Des Plaines from its source among the till ridges of Wisconsin southward along the shallow inter-morainic depressions across a corner of the Chicago plain, and on through the Valparaiso moraine by way of the old outlet.

THE DES PLAINES RIVER.

The Des Plaines issues from a flat swamp, or slough, near the boundary of Racine and Kenosha counties, Wisconsin, where drainage is so imperfect that in wet weather part of the marsh discharges northward to Root river and part southward to the Des Plaines. From this ill-defined divide the little stream runs south along the depression which separates the two westernmost of the lake-border till ridges, gathering drainage from other creeks among the morainic hollows, turning to run eastward for a few miles in Kenosha county, then resuming a southerly course and entering Illinois between the two till ridges which at that point compose the whole lake-border system. West of Waukegan (near Gurnee station) the river passes through the west ridge; and thence southward past Libertyville, Wheeling, Franklin Park and Maywood, it follows the broad inter-morainic basin immediately east of the Valparaiso moraine. Entering the Chicago plain by way of this broad pass, which is in itself an arm of the lake-plain nearly shut off by a long sand spit at Oak Park, the river winds around a beach ridge at Riverside, swinging again eastward around a rock elevation at Lyons.

In the distance of sixty miles from the head of the Des Plaines to the Riverside dam, the river falls ninety feet, or at an average rate of 1½ feet per mile. The portion in Lake county has a moderately uneven grade, for the river flows through a series of flat, marshy stretches separated by more pronounced slopes. Through Cook county its fall is much more uniform, since it has entrenched itself in a valley, and built a well-graded flood plain. From Riverside down-stream for three miles, the Des Plaines descends fourteen feet on the exposed ledges, or about five feet per mile, to the Ogden dam. At this point it lies within ten miles of Lake Michigan, and is less than twelve feet above it. For a detailed map of this vicinity, see Fig. 19.

Here, then, near Summit, is the divide between the lakes and the Gulf, the St. Lawrence and the Mississippi. In time of flood a large portion of the Desplaines discharges over the dam and through a ditch to the Chicago river and the lake, while the remainder follows the lower Des Plaines down to the Illinois and Mississippi rivers. This double discharge was operative under natural conditions before the Ogden dam was built. The natural divide was five miles farther east, near Kedzie avenue, at the east end of a great swampy tract, known as Mud lake. So flat is the plain at this point that the escape of the Des Plaines from the lake plain westward through the deep notch in the moraine seems highly accidental.

From Summit it makes for the head of the abandoned channel of the "Chicago outlet" where the waters of Lake Chicago once poured across the moraine toward the Illinois valley. With uncertain course, the river runs for a long distance on the flat channel floor. This stretch between Summit and Lemont is known as the "12-mile level." Since the construction of the sanitary canal, the Des Plaines is confined to an artificial channel by earthworks. Approaching Lemont, the river finds bed rock rising to the level of the valley floor, and still higher on either side in rock bluffs. Near the left bank of the Des Plaines and parallel to it down the outlet, run the Illinois-Michigan canal and the Chicago drainage canal. Both of them are largely cut in solid limestone.

Beyond Lemont the rock declines again to about the level of the valley floor, and the channel is cut through the thick till structure of the moraine. Bending southward, the river runs past Romeo; and now there appear at the top of its bluffs, terrace remnants of an old outwash plain or valley train—the original filling of the valley, deeply trenched by the outlet. At Romeo the Des Plaines begins to descend a long series of shallow rapids, which lower it eighty feet in the ten miles to Joliet pool. At Lockport, on the old canal, and farther down, near Joliet, are three locks, made necessary by the rapids. One of them is pictured in Plate 2. Here the bed rock rises some thirty or forty feet above the floor in bluffs on both sides of the valley, forming a flat rock terrace twenty feet lower than the fragments of the outwash plain. These two terraces, the one of gravel and sand of the outwash, and the other of rock, mark important steps in the history of the river, and of lake Chicago of which it was the outlet. At Joliet, the river is confined artificially, passing through the west side of the city. A single dam crosses it at Jackson street. Below Joliet the descent of the river is steep for two or three miles to Brandon's bridge, where it broadens, forming Joliet pool.

This pool, otherwise known as "Lake Joliet," occupies a broad, shallow depression (ranging to ten feet in depth) in the floor of the old outlet. It extends five miles down the valley, below Brandon's bridge, allowing the river no perceptible fall in that distance. The level of the river here is about seventy-six feet below Lake Michigan. The pool is probably due to a deepening of the floor of the ancient river, where it passed from the hard Niagara limestone out on to the weaker limestones and shales of the Cincinnati formation.

Below Joliet pool, the slope of the river is again moderate for three miles. Just beyond the mouth of the Du Page river another pool—"Lake Du Page"—is entered. This is ninety feet below Lake Michigan, and extends three miles down the valley. Half a mile below it, the Des Plaines joins the Kankakee, at the head of the Illinois river.

HISTORY OF THE CHICAGO PORTAGE AND THE CANALS.

The divide between the Des Plaines river and Lake Michigan stands only 592 feet above the sea—less than twelve feet above the present lake. It is a part of the floor of the extinct Lake Chicago which is so flat as to show no slope to the eye. Before the natural drainage of the district was disturbed by trenches and canals, the divide was a broad, swampy tract, called Mud lake; a long slough west of Kedzie avenue which in time of flood led a part of the water from the Des Plaines river eastward to the west branch of the Chicago river and Lake Michigan. Indeed, this slough may at no very remote time have carried the entire discharge of the Des Plaines river. It was evidently a familiar path for the Indians, who in time of flood might paddle their canoes continuously from the Chicago to the Des Plaines.

An entertaining and instructive account of the early exploration of this region by the French traders and missionaries is to be found in Parkman's "LaSalle and the Discovery of the Great West." In 1671, LaSalle started out in search of the Mississippi. Sailing through Lakes Erie and Huron, and entering Lake Michigan, he proceeded southward past the head of Green bay. Turning towards the west at a "trés-beau-havre," which Parkman thinks may have been the mouth of the Chicago river, he crossed to a river that flows westward—doubtless the Illinois. The fact that LaSalle chose the Chicago portage on a later expedition, in 1682, lends strength to the belief that this was his route in 1671. If so, he was the first white man to cross the divide at Chicago.

In 1673, the intrepid explorer Joliet and his Jesuit companion Marquette, returning from their successful voyage of discovery on the Mississippi, followed up the Des Plaines and across the portage. In August, 1674, Joliet, in a letter to Father Dablon,[1] states that "by cutting half of a league of prairie" between the "Lake of Illinois" (Lake Michigan) and the "Saint Louis river" (the Illinois) an easy boat route would be made between the lakes and Florida. In 1673-4, Marquette, on his way from Green Bay to the Mississippi, where he hoped to found a new mission, was forced by illness to spend the winter at Chicago. With his two French comrades, he built a cabin beside the west fork of the south branch of Chicago river, near the present Robey street. On the last day of March he was driven away by a spring freshet and ice

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[1] Quoted by L. E. Cooley, in "The Lakes and Gulf Waterway"—report by the Internal Improvement Commission of Illinois to the Governor, Feb. 1907, p. 3.

gorges on the Des Plaines, which flooded the low ground in that vicinity. He crossed the divide on March 31st, in canoes, and went down the Illinois river as far as Utica. Compelled by broken health to return just as his hopes were being realized, Marquette died on his way up the east side of Lake Michigan.

In the winter of 1679-1680, LaSalle crossed the neighboring divide at the St. Joseph river, and went down the Kankakee and Illinois rivers to Peoria. Returning a few months later, he followed up the Des Plaines as far as Joliet, but chose thence an overland route eastward—a more direct course for Fort Miami. Again in January, 1682, LaSalle, accompanied by Friar Hennepin, by Tonty, his Italian lieutenant, and by some fifty Frenchmen and Indians, journeyed from "Checaugou" across the divide and down the frozen Des Plaines on sledges, to Peoria. There they found open water, and, launching their canoes, floated down the Illinois and Mississippi nearly to the Gulf. Returning late the same year, LaSalle established Fort Saint Louis at Starved Rock, opposite Utica, remaining in that vicinity a year and then returning to France.

LaSalle's attempt to find the Mississippi from the Gulf of Mexico in 1687 failed. He was assassinated in Texas by members of his party. The fugitives, together with Tonty (who had been in charge of Fort Saint Louis) made their way across the Chicago portage in 1688, en route to France.

Messrs. R. Graham and Joseph Phillips are quoted by Mr. Cooley in his recent report[1] to have written in 1819 the following: "The route by Chicago as followed by the French since their discovery of the Illinois presents at one season of the year an uninterrupted boat communication of six to eight tons burden between the Mississippi and the Michigan lake; at another season a portage of two miles; at another a portage of seven miles, from the bend of the Plein (Des Plaines) to the arm of the lake; and at another a portage of fifty miles from the mouth of the Plein to the lake, over which there is a well beaten wagon road. Boats and other loads are hauled by oxen and vehicles kept for that purpose by French settlers at Chicago."

Since the opening of the Illinois-Michigan canal, in 1848, when the Mud lake slough was first tapped and drained by a ditch, several similar trenches have been excavated, at public and private expense, and a dam erected west of the slough, close to the Des Plaines, as a substitute for the ridge of the divide. (See Fig. 19). Still, in time of flood, the Des Plaines overflows the Ogden dam, and the slough is filled with water.

The project of a ship canal across the Chicago portage was laid before congress by Albert Gallatin, in his famous report of 1808, on means of internal communication. A few years later it was recommended to congress in a bill along with the Erie canal. While the latter, thanks to the perseverance of DeWitt Clinton, was soon undertaken, and finished in 1825—a "ditch" running 360 miles across New York state—the Illinois-Michigan canal was long delayed. Although it was commenced

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[1] Op. cit., p. 5.

in 1836, it was not until 1848, when railways were already replacing canals elsewhere, that the Illinois-Michigan canal was finished, with the summit level across the Chicago divide eight feet above low water mark of the lake. Water was supplied by "the feeder" through the "sag" (a broad valley tributary to the Des Plaines above Lemont), and in times of low water by lift wheels at Bridgeport. Its length, down to its termination at LaSalle, was nearly a hundred miles; its vertical descent almost 150 feet. Two locks were required near Lockport, and two at Joliet. The canal was made six feet deep, sixty feet wide at the surface and thirty-six feet at the bottom in earth, and forty-eight feet wide in rock. It cost the State and the city of Chicago about $10,000,000.00, only one-tenth the cost of the Erie canal; and two-thirds of this was paid by a land grant.[1]

The failure of the government to properly dredge the Illinois river below LaSalle greatly limited the development of the canal. While the Erie canal, profiting by the improvement of the Hudson, was a vitalizing artery of commerce for the city of New York, the Illinois canal, too small for lake boats and leading to a barely navigable river, contributed only in a moderate degree to the growth of Chicago. In 1885 it was estimated that the canal had saved the people of Illinois $180,000,000.00 in freight charges.[2]

The plan of supplying the canal from Lake Michigan—restoring in miniature the ancient outlet of Lake Chicago, was not carried out until 1871, when the city of Chicago cut down the summit level for sanitary purposes. For the first time in probably several thousand years, waters flowed out from Lake Michigan to the Mississippi. Meanwhile, the federal and State governments spent a considerable amount of money in constructing locks and dams along the lower Illinois. Agitation of plans for a deep waterway from the lakes to the gulf, continually recurring, availed little against conservative reports and recommendations of the United States army engineers.

The extraordinarily rapid growth of Chicago soon made the Illinois-Michigan canal inadequate for the discharge of its sewage. Early in August, 1885, a heavy flood on the Des Plaines swept the sewage of the city out into the lake; and the pollution of the city water supply was so intolerable that steps were at once taken to remedy the drainage conditions. Plans were gradually formed for a new sanitary canal. The construction and operation of this channel was delegated to a "Sanitary District of Chicago," under an act adopted at the November election, 1889, the district being organized the following January.

The work of excavating the drainage canal was begun in September, 1892, and finished in January, 1900. Its length from the west fork of the Chicago river at Robey street to the controlling works at Lockport was twenty-eight miles. Of this a little more than half (the fifteen miles between Willow springs and Lockport) was cut through rock. Above Willow springs the channel was sunk wholly in unconsoli-

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[1] Statement by L. E. Cooley. "The Lakes and Gulf Waterway, as Related to the Chicago Sanitary Problem," pp. 4 and 7. 1891.

[2] L. E. Cooley's report of 1907, p. 8.

dated beds, mainly glacial drift. The depth of the canal is twenty-four feet, its bottom width, where in earth, 202 feet, and where in rock, 160 feet. The declivity is 1 to 40,000 in the section above Willow springs, and 1 to 20,000 below, giving a total fall from the head at Bridgeport to the controlling works at Lockport of about 5½ feet. The Des Plaines river was diverted from its natural channel by embankments between Summit and Lockport. Several large bridges were built, and necessary improvements made on the river below the controlling works. The discharge of sewage down the new channel and eventually out to the Mississippi past St. Louis aroused bitter feeling in that city. On the same day that the canal was formally opened a bill of complaint was filed in the U. S. Supreme Court in the case of "State of Missouri against State of Illinois and Sanitary District of Chicago," asking that the discharge of sewage be stopped. After six years of expensive legal battles and investigations by experts, the complaint was dismissed.

Now that the sanitary canal is again nearly outgrown by the great city, repeated efforts are being made to obtain the privilege to enlarge it and to divert a larger volume of water from Lake Michigan, thus insuring the proper dilution of the sewage. The extension of the channel to Joliet and LaSalle, and the improvement of the Illinois river so as to give a deep waterway across the State to the Mississippi and thus to the gulf, even if not immediately possible, is none-the-less inevitable. Such an attainment will fittingly express the enterprise and foresight of the twentieth century. The project of Louis Joliet of an unbroken path for boats from the lakes to Florida will at length be fully realized, and the Des Plaines valley will become one of the great avenues of inland navigation.

CHAPTER II.

THE STRUCTURE OF THE BED ROCK.

DEPOSITION OF PALEOZOIC SEDIMENTS.

Nature and Age of the Rocks.—Beneath the loose, unconsolidated deposits, chiefly glacial "drift," which cover most of the surface of the ground in this region, is a firm rock foundation. This bed-rock struc-

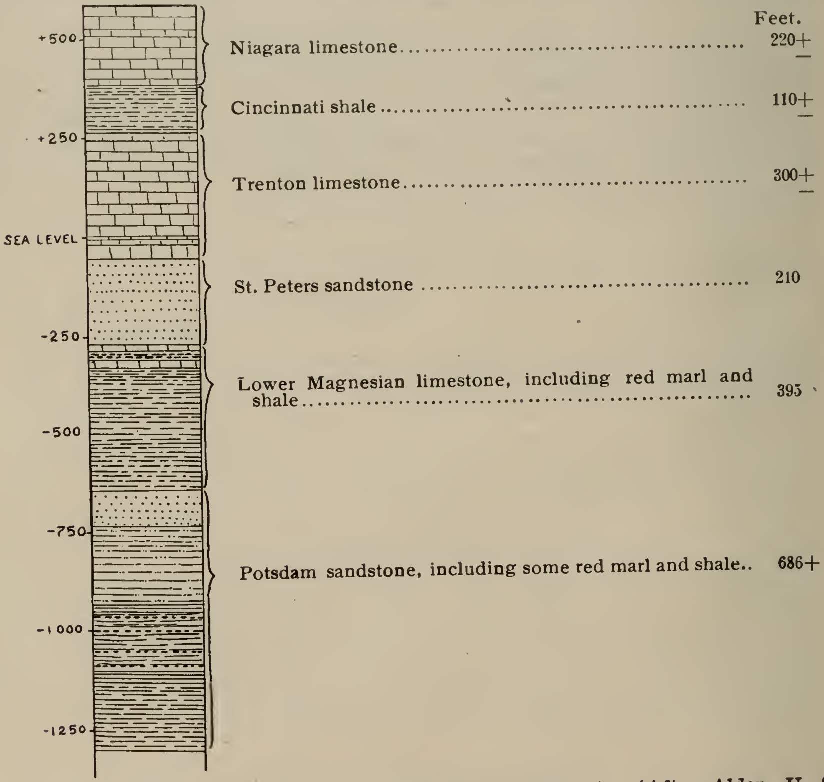

FIG. 2. Section of rocks in a deep well at Lockport. (After Alden, U. S. Geol. Surv.)

ture consists of an unknown thickness of great stratified formations—limestones, shales and sandstones of comparatively remote age. The formations are nearly horizontal in position, resting one upon the other. Their bedded or "stratified" structure, fragmental composition (in part), and the marine shells which are fossilized in them, indicate clearly that the rocks accumulated as successive sheets of sediment on the sea floor, spread out in the order of their position, the oldest at the bottom. The consolidation of the original clays, sands, and calcareous muds into firm, compact rock is due largely to the cementing action of percolating waters, which deposited mineral substances in the interstices of the strata. Consolidation is favored, if not actually affected, also, by the pressure of overlying sediments, including great thicknesses of strata which formerly buried these but have been wholly removed from the region by erosion. From their relation to overlying and underlying rocks in other regions, as well as from the relics of animal life they contain, these formations are known to belong to early geologic periods, the Cambrian, Ordovician and Silurian. These constitute the first three divisions of the Paleozoic era.

The Cambrian Period.—During these early periods, the central part of North America, including the Great Lake region, was occupied by an interior epicontinental (on the continent) sea. The depth and extent of this sea fluctuated repeatedly. The rising of it, at certain times, with respect to the neighboring lands, is believed to have been due largely to the fact that the lands, exposed to the disintegrating and denuding forces of the atmosphere and running water, were being reduced to lowlands, while the rock waste thus stripped from them was being deposited in the sea, partly filling the ocean basins. The waters thus displaced would rise, and even though the actual change of level might be slight, it would be enough to cause the sea to transgress far over the lands, because of their greatly reduced condition. Changes in relation of land and sea were doubtless inspired also by warpings and dislocations of portions of the earth's "crust." While it is clear that such warpings have occurred, in abundance, inasmuch as rocks which must once have been essentially horizontal on the sea floor are now found far and wide over the lands, in a great variety of warped and folded attitudes, we cannot tell with certainty the reason for the deformations. It may be that gravity, or the tendency of the earth's mass to crowd radially toward the center, finds temporary and partial relief in the sinking in or caving of portions of the earth which are excessively heavy (the ocean floors) or less firmly supported from beneath than the surrounding structure. It may be, also, that the earth has been cooling off for ages, and while cooling, contracting; that along with this contraction it has been shrinking, and the more rigid outer portion or "shell" has accommodated itself to the shrinking "nucleus" by warping or wrinkling.

Some such processes as these caused the epicontinental sea, during the Cambrian period, to creep gradually up over the low interior of North America, expanding on all sides, until by the end of the period, all the central portion of the continent and most of the western and northwestern portions were submerged. (See Fig. 3). An extensive highland belt, "Appalachia," separated this interior sea from the Atlantic on the east, and long, discontinuous mountain belts in the far west and northwest, separated it from the Pacific. On the north, a great V-shaped land area in Canada, "Laurentia," formed at that time the main part of the land of the North American continent. Two large highlands, outliers of the Laurentia land, perhaps escaped submergence; one in the Adirondack region of northern New York, and the other in the highlands of northern Wisconsin. Around their subsiding borders were spread out in late Cambrian time extensive deposits of sand. From the Wisconsin highland region the sand reached southward on the sea floor well into Illinois, and now constitutes the Potsdam sandstone, which is penetrated by a few deep wells in and about Chicago (See Fig. 2).

The Ordovician Period.—During the next geologic period, the Ordovician, the interior sea continued to expand, though local and temporary oscillations of its floor and its shores kept changing its outline. In northern Illinois, a change from sandy sediments to sandy limestones and finally to pure, fine-grained limestones as the Ordovician period progressed indicates that the surrounding land areas suffered great reduction under the destructive action of atmosphere and erosion, so that during middle and late Ordovician the waters of the interior sea were no longer clouded by river-borne sediment, and the deposits made were limited almost wholly to shells, corals, and other organic remains. The early Ordovician sediments are the Lower Magnesian limestone and the St. Peter's sandstone. Both are encountered by wells (See Fig. 2). Above them is the Trenton limestone, containing an abundance of fossils, which indicate that the water, while relatively clear, was shallow and rather warm. The sea floor was peopled by colonies of lime-secreting animals, such as corals, brachipods, trilobites, and others whose peculiarities may properly be left for fuller consideration in connection with the Niagara limestone, since that is the only rock exposed to any extent in the Des Plaines valley district.

Toward the close of the Ordovician period, the Trenton limestone deposits were buried by a great sheet of mud, over one hundred feet thick, which has since been consolidated into the Hudson river or Cincinnati shale. By the time the mud of this formation was deposited the interior sea had begun to shrink, and the surrounding land to emerge, exposing broad coastal plains, from which and across which sediment was washed into the sea.

Geographic changes of large extent now occurred. Intense deformations in eastern New York added to the width of the Appalachian mountain belt, while in the Mississippi valley region there was a very extensive emergence of land, with, however, little or no deformation of the rocks. The interior sea shrank to small proportions and marine life became seriously restricted. Many species of animals were forced to migrate to deeper parts of the seas, and many were exterminated. These parallel changes of the geography and the fauna are the reasons for separating the Ordovician period from the succeeding Silurian.

Down the Des Plaines valley, about four miles below Joliet, and opposite Flathead mound, are a few exposures of limestone near the old canal, which may be a part of the Cincinnati formation. The rock is

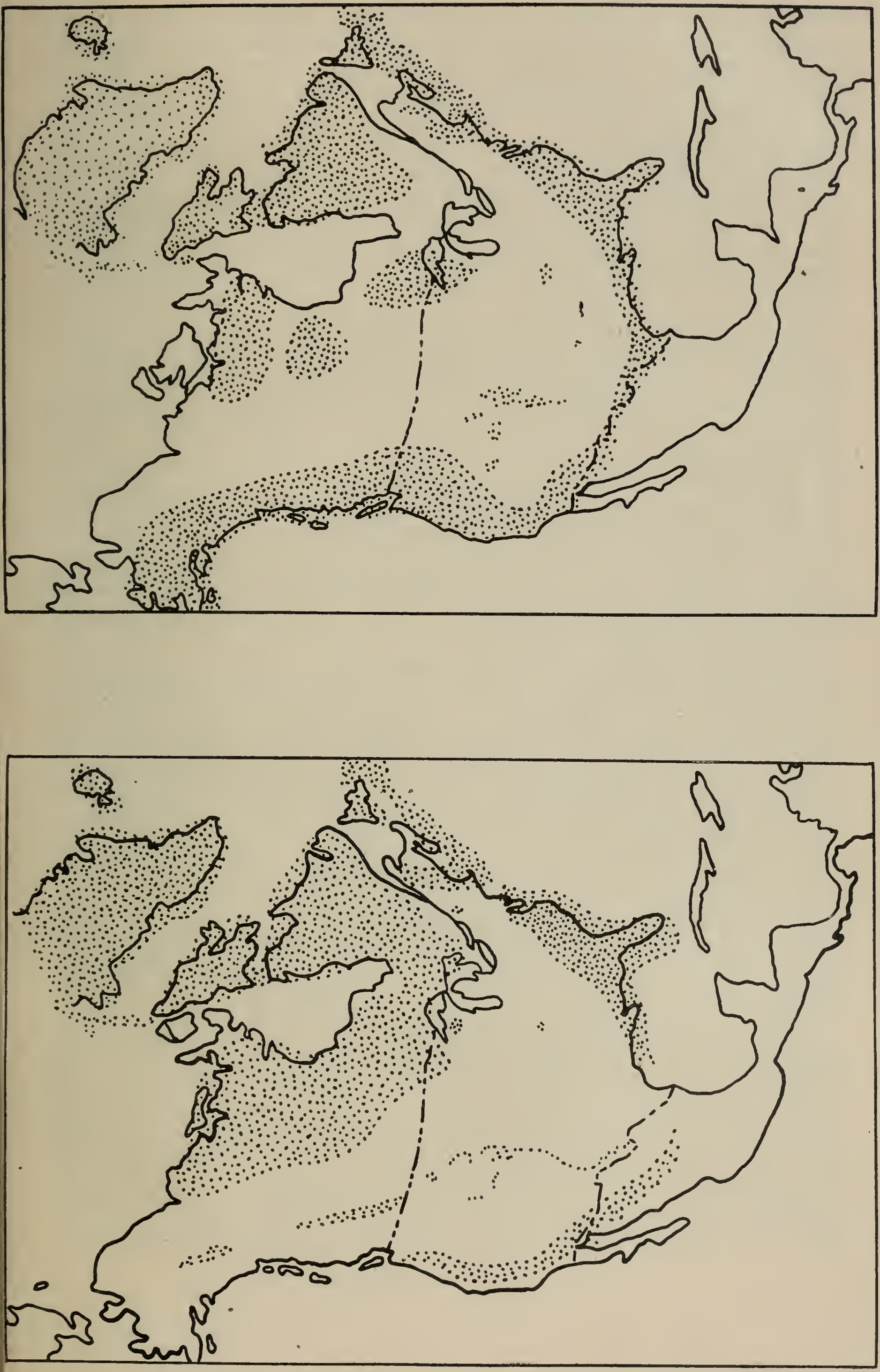

FIG. 3. North America during (a) Potsdam, or later Cambrian, and (b) Trenton, or middle Ordovician time. The unshaded areas were probably wholly submerged, the shaded areas were probably land.

composed partly or argillaceous (clay-bearing) limestone, of dull greenish or bluish color (weathering buff), and partly of dense cherty beds. It is an exceptionally rich field for collecting fossils. Two of the siliceous layers are full of coiled gastropod shells (somewhat like No. 7, Plate 1) and cup corals (zaphrentis, No. 3, Plate 1). The latter are sometimes an inch long, and stand out from the weathered surface of the rock because they have been completely replaced by insoluble silica. In other beds of the limestone are to be found fragments of trilobites and brachiopods and many pteropods (tentaculties). This rock and its fossil contents are quite different from the Niagara limestone, as exposed about Chicago and Joliet; and it is probably a part of the Cincinnati formation.

An abandoned quarry at the lower end of "Flathead" gives a good exposure of blue shales and shaly limestones typical of the Cincinnati formation. Certain layers here, notably two or three thin shaly layers on the floor of the quarry, are full of fossils, especially strophomena (See No. 9, Plate 1), which are silicified, and show plainly on the weathered surface. Traces of trilobites (See No. 5, Plate 1) are evident, but not sufficiently well preserved to make them of value for collection. In some of these a film of marcasite (iron sulphide) has replaced the original shell structure, and has since turned black, under exposure to the air. Orthoceras (a straight shelled cephalopod, (See No. 4, Plate 1) is also plentiful. No traces of crinoids, however, have been found. Other exposures of the Cincinnati formation are to be seen at the mouth of Rock run, and near Channahon.

The Silurian Period.—With the changes which closed the Ordovician period, most of the interior of the continent became dry land, but as the Silurian period advanced, the epicontinental sea once more emcroached upon a part of the interior, perhaps creeping southward from Hudson bay (See Fig 4). It expanded over Illinois and Michigan, and southward and southwestward to Arkansas and Missouri, where it was presumably bordered by a land area. In this area a great limestone formation, the Niagara limestone, was laid down. This formation outcrops continuously for more than a thousand miles, from central New York to northeastern Iowa, and is widely exposed about the Great Lakes, forming the surface rock of the northeastern corner of Illinois. It takes its name from the falls of Niagara, for which the hard limestone is chiefly responsible. Since this is the only rock exposed in the Des Plaines valley, it deserves more than brief mention here.

Where it has been penetrated by artesian wells in the vicinity of Chicago, the Niagara limestone has a thickness of from 250 to 400 feet. Its original thickness was probably still greater, for we cannot say how much was worn away from the top of it in the long interval of exposure and erosion between the Silurian and the glacial periods, when the rock surface was finally buried by glacial drift. Like most limestones, the Niagara limestones was originally an organic deposit—that it, an accumulation of calcareous skeletons and shells of marine animals, worked over by the waves and currents, and ground to a fine calcareous mud.

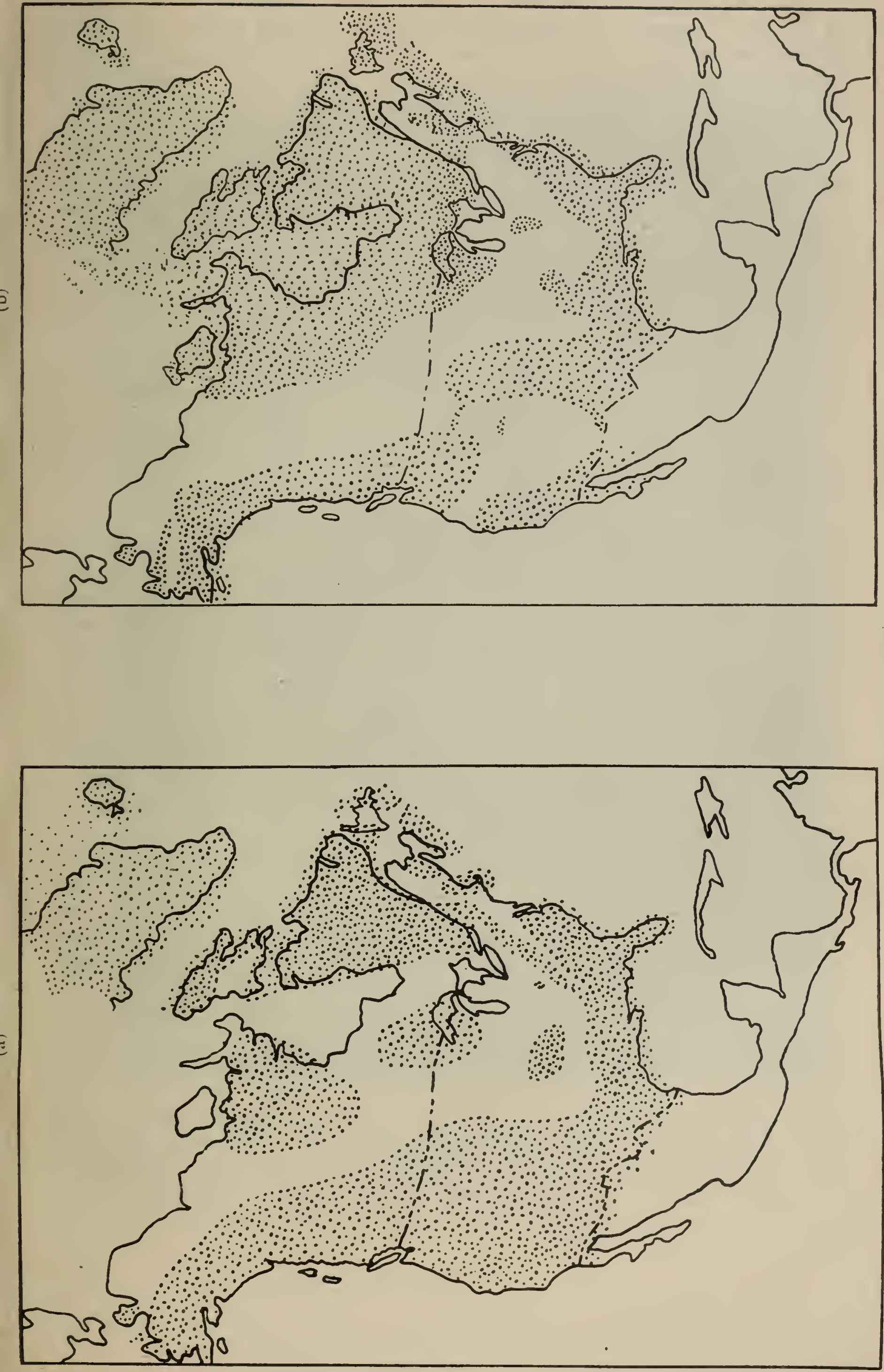

FIG. 4. North America during (a) Niagara (later Silurian) and (b) later Devonian time.

One of the distinctive features of the Niagara limestone is the wealth of fossils it contains. Evidently the interior sea was nearly free from river-borne sediment in many places. Hence it is believed the surrounding lands were low, and the rivers sluggish. The water apparently was warm and of slight depth—perhaps not over 150 feet; for several species of corals grew in great profusion and built extensive reefs like those of tropical seas today. In eastern Wisconsin, especially, the reef building habit was well developed, and there it appears that the coral reefs were tenanted by hosts of animals of other orders such as brachiopods and molluscs, all of which have contributed to the rock mass. Under the attack of the waves these reefs suffered continual grinding and reconstruction. The blocks and smaller fragments were piled up in embankments, while the sand and finely ground clay was spread out in broad sheets on the sea floor. Animal life, so profuse near the reefs, was more scanty on the broad smooth flats of white calcareous mud about them. These calcareous muds now constitute layers of compact, fine-grained gray limestone, nearly barren of fossils.

Some idea of the variety of the marine animals of the Niagaran group may be gathered from Plate 1, in which a few of the most characteristic types of fossils of the Des Plaines valley and Chicago district are to be seen. The resemblance between the fauna of northeastern Illinois and that of rocks about Hudson bay, Grinell land, north Greenland, and northern Europe, when contrasted with the markedly different fauna of the Appalachian district, warrants the belief that the interior sea extended northward from the Mississippi valley across Canada and north Greenland, and thence eastward and southeastward across Iceland to Scandinavia and England. In no other way can we satisfactorily explain the inter-migration of animals, whose habitat was the shallow shore zone. It is evident, too, that the climate in the northern hemisphere at this time was much more equable than now, to enable the same corals to thrive in Arctic regions and in the lower Mississippi valley.

The Niagara limestone, so far as known, is the bed rock beneath all but the extreme southwest portion of the Des Plaines valley. Not far below Joliet, as previously stated, the Cincinnati makes its appearance on the valley floor. Natural exposures of the Niagara occur on the bed of the Des Plaines near Lyons, on the floor and in the side bluffs near Lemont and from Lockport down to Joliet. On the tributary streams small exposures occur frequently near the main valley, where the side valleys have been cut most deeply, e. g., on Long run, Fraction run and Sugar creek. The limestone appears in the bed of Hickory creek at New Lenox, forming small rapids. A broad elevation of rock at Lyons, about which the Des Plaines river runs, between Riverside and the Santa Fé bridge, is only thinly covered by drift. In many places here, the rock is within a foot or two of the surface, and is exposed in shallow pits and trenches in the fields. Stone walls built of the fragments, in a field east of Joliet avenue, contain an abundance of fossils, chiefly crinoids.

A good field for collecting fossils of the Niagara limestone is the great pile of refuse along the side of the drainage canal near Lemont.

Fossils from the Niagara formation. Corals—Halycites (chain coral), (2) Favosites (honeycomb coral), (3) Zaphrentis (cup coral). Cephalopod—(4) Orthoceras. Trilobites—(5) Calymene, in foreground, two specimens; Dalmanites, in background. Brachiopods—(6) and (9). Gastropod—7. Crinoid—Roots (8).

The recently quarried blocks of rock, representing a vertical range of twenty-five feet where the canal has cut wholly in rock, frequently afford a wide variety of fossils. Trilobites (*Calymene Niagarensis* No. 5, Plate I) may be collected, for instance, in the waste bank beside the canal just northeast of quarry No. 1, a mile and a half above Lemont.

Perhaps the best known fossil in the Niagara is the orthoceras, a long, straight, cephalopod shell (No. 4, Plate I.) While as a rule it is only one or two feet long, it attains sometimes a length of several feet. Naturally enough, it invariably lies with its long axis parallel to the bedding planes—a position which it would assume when it fell upon the sea floor. In this respect, it merely illustrates a rule that would apply to all fossils which have a marked flatness or length. They all tend to be deposited flat side down, or with their length in a horizontal position. Since the bedding planes are planes of easy separation when the rock is quarried, the surfaces of flagstones frequently show casts of the long chambered orthoceras shells. One can hardly walk three blocks in Joliet on a sidewalk of limestone slabs, without seeing at least one of these big shells. In the quarries about Joliet, crinoids, trilobites, brachiopods, etc. may be collected, but usually with difficulty, since the massive gray beds which are so extensively used as building stone are as a rule barren. Fossils are more plentiful in the thin-bedded portions, which are not so often quarried. The abundance of nodules or lumps of chert, and of cherty layers in the limestone (recognized by its compact flinty texture and splintery fracture, as well as by its superior hardness) is due in part, at least, to the burial of quantities of siliceous sponges on the ancient sea floor. Traces of the structure of these sponges have been found in the chert, under the microscope.

The Devonian Period.—At the close of the Silurian period, the emergence of large portions of the interior of the continent greatly restricted the inland sea. Subsidences of the land and expansions of the epicontinental sea were renewed in the Devonian. By the middle of the Devonian period (Hamilton epoch), the northeast part of Illinois (at least near Chicago) was again below the sea (See Fig. 4). The evidence of this is not found in broad exposures of Devonian rocks (like the belts of Niagara and Cincinnati) for the Devonian strata were stripped off by erosion long ago. All that remains to mark the former existence of Devonian sediments about Chicago are small pockets of clay, containing fish teeth and other fragments of Devonian species, in the cracks, here and there, in the Niagara limestone. The first discovery of this interesting feature was at a quarry near Elmhurst. Since then, similar Devonian exposures have been found in Fred Schultz's quarry, at Lyons. Stuart Weller's description of the Elmhurst locality is quoted below in somewhat abbreviated form.[1] "At this locality the limestone is much fractured by two sets of gentle folds whose axes have a general northwest, southeast and northeast, southwest direction, joint cracks being well developed. Some of these cracks are several inches in width, and are

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[1] "A peculiar Devonian deposit in Northeastern Illinois;" Journ. Geol., vol. 7, pp. 483-488, 1899.

in general filled with a black or blue clay. At one point, in the southeast face of the quarry, about eighteen feet below the glaciated surface of the rock, one of these joints is somewhat enlarged, to form a narrow triangular opening about six inches in width at the base and about sixteen inches in height. This opening, instead of being filled with clay, as are all the other larger joints in the quarry, is filled with a breccia composed of angular fragments of the adjacent limestone, imbedded in a dark brown arenaceous matrix. This matrix is abundantly fossiliferous, containing immense numbers of fish teeth and a smaller number of lingula shells and other brachiopods, which indicate its Devonian age." The fish teeth represent a species *ptyctodus calceolus* and two new species of diplodus. Of these the teeth of ptyctodus are extremely abundant. The most plentiful brachiopod, *lingula ligea,* is known to occur in the Devonian of New York and Nevada. One of the others, of which only one specimen was found, and the teeth of diplodus had previous been known only in carboniferous strata. Apparently, then, the deposit is of very late Devonian age.

The nearest place where the Devonian is the surface rock is probably northwestern Indiana; but there it is almost wholly concealed by glacial drift. "The nearest actual outcrop of Devonian is at Milwaukee, Wisconsin, eighty miles north of Elmhurst; and the nearest outcrop to the west is near Rock Island, Illinois, one hundred and thirty miles away. At both of these localities *ptyctodus calceolus* occurs, but the strata are believed to be somewhat older than the material from Elmhurst.

"The presence of this Upper Devonian fauna at Elmhurst, buried as it is deep down in the Niagara limestone, indicates with certainty that during the greater part of Devonian time the region now known as northern Illinois was above sea level. It was part of what was probably a large land surface, stretching from the Wisconsin land on the north to the Ozark land of Missouri on the south. The waters which collected upon this land surface in part percolated through the underlying rock strata and by solution increased the size of many joint cracks. At a later period, near the close of the Devonian, when the sea again occupied the region, sand was sifted down into these open joints and with it the teeth of fishes which inhabited the sea thereabout. It is perhaps possible that the opening which has in recent time been uncovered at Elmhurst was during this late Devonian time large enough for the entrance of some of these fish, and that they sought this opening for shelter, much as fish at the present time enter similar openings.

"The manner of communication between this opening and the surface is not clearly shown in the field, but arenaceous material with fragments of fish teeth is seen clinging to the quarry face to the left of and above the opening. This rock face is one side of a joint whose opposite side has been removed, through which there may have been communication between the buried opening and the sea bottom above."

The similar exposure in the Lyons quarry was first observed and examined about a year ago, by Messrs. C. E. Peet and Stuart Weller. The following brief description of it is written by Mr. Charles E. Decker, who visited the locality in May, 1907, after much of the rock had been quarried away:

> The fish teeth occur in a tension crack near the axis of a large fold in the south face of the quarry (described later). When examined a recent blast had torn away several feet of rock along the crevice, and some fragments of teeth were found in the debris among the loose rocks. The crevice is narrow, varying from one to two and a half inches in width, and extends downward about ten feet from the top of the quarry. It is filled with a dark, compact clay, in which there are many angular fragments of limestone. The fossil teeth are black. The largest one found is about three-sixteenths of an inch in cross section and three-fourths of an inch long. A small water-worn brachiopod was found in the same crevice, and near the edge of the crevice, a large fragment of a blunt tooth or tusk.

The close of sedimentation.—At the close of the Devonian period, northern Illinois seems to have emerged again from the sea. Whether in succeeding periods it sank again to receive new sheets of sediments cannot well be determined, since later exposure to weathering and stream erosion has stripped off everything down to the Niagara limestone. It is possible that during the Mississippian and Pennsylvanian periods, when thick limestone and the coal measures were being deposited in the central and southern parts of the State, the sea covered the northeast corner of Illinois; but, if so, not a scrap of these rocks remains, so far as known, in the Des Plaines valley. Even the Devonian sediments were weathered and eroded except where they had penetrated deep cracks in the underlying limestone. By the close of the Paleozoic era at least, when the Appalachian ranges were elevated, and the whole eastern part of the continent emerged, the district in which the Des Plaines now lies became dry land. Its rock structure was thus practically completed. The constructive process of deposition ceased, and the destructive process of denudation took its place.

WARPING, JOINTING AND FAULTING OF THE ROCKS.

The uplifting of the rock foundation in a region is never accomplished without local warpings of the strata, extensive fracturing of a systematic sort, and more or less definite dislocation of the rock along certain fractures. So, in the quarries and other exposures in the Des Plaines valley the Niagara limestone exhibits signs of having been subjected to great strains, and of having yielded in a measure by the development of folds, joints and faults.

Folds.—The elevation of the Silurian strata in this district—or, more accurately, the elevators, as there have doubtless been several movements—seem to have been pretty uniform in amount, for the bedding of the rocks as a rule remains nearly horizontal, or in about the attitude in which the sediments were laid down on the sea floor. In places, however, the strata lie in an inclined position, with a dip of 10°, 20°, or 30° from the horizontal. In the quarries near Cass and Grinton streets, on the east side of Joliet, dips of moderate amount can be measured. In Dellwood park, the rock shows a general dip 10° to 20° toward the southwest, but there are local undulations in the bedding. A good view of this can be had just below the upper dam on the north wall of the gorge. It is possible that some of the small folds or undulations are not deformations formed when the rock was uplifted after Devonian time, but that they are of earlier date. Folds of a puzzling nature and in part at least of Silurian age occur in the quarry of Fred Shultz at Lyons.

The chief structural feature of the Lyons quarry is a gentle arch, or anticlinal fold, the axis of which runs north and south. Cross sections of it appear in the quarry walls on both the north and south sides. Superposed upon this major fold are domes and folds of minor importance, with axes running in various directions. They are best seen along the south side of the quarry, as the strata on the west side are approximately horizontal. The nature of these folds presents an interesting problem. It might indeed be questioned whether they are folds or constructional elevations formed at the time of deposition of the sediment which makes the limestone. In some cases the folds affect only a certain zone, the strata above and below being nearly horizontal. In one fold on the south side and still more notably on the west side, the beds thicken markedly towards the center of the fold. The fold itself is flanked by nearly horizontal layers, which thin out against the limbs of the fold and are overlain conformably by continuous horizontal beds. If corals were present in sufficient numbers, the arched structures might be taken for reefs. The strata underlying the arch seem to be crumpled, at the level of the quarry floor, as if there had been an actual deformation. If so, it seems almost necessary to suppose that the folding occured while the limestone was being deposited, because the arched beds are overlapped by horizontal beds without any intervening surface of erosion. If we can imagine earth movements to have folded the surface sediments without raising them above the sea, while deposition continued, we satisfy both the peculiar overlapping and the thickening of the beds. Soft plastic muds or ooze might be squeezed or thickened by compression in the arches.

Another puzzling relation of beds is seen at the southeast side of the Lyons quarry, where an anticlinal bend at the surface is directly over a synclinal bend, there being a lens-shaped mass between, with ill-defined bedding planes.

A certain amount of warping is going on here at the present time where the rock floor of the quarry, under long exposure has expanded. One of these recent folds may be seen on the bottom of the quarry where two layers have been arched up so as to leave several inches of space between them. The same phenomenon has been observed in the quarry near Crystal run, north of Joliet, and doubtless occurs elsewhere.

Joints.—The same warpings which accompanied the elevation of the strata to their present positions involved tensions and strains which led to a wide-spread and systematic cracking and jointing of the rocks. These joints may be plainly seen in any quarry in the Niagara limestone. They are vertical cracks by which the rock mass is divided into rectangular blocks (Plate 2). The cracks are by no means haphazard, but run in sets or systems. Each set includes a large number of parallel or nearly parallel joints. Usually two sets are more conspicuous than the others, and these are perpendicular to each other. They run down to considerable depths, but just how far is unknown. In width they range from closed fractures to gaping fissures. The difference does not date back to their origin, but is due almost wholly to subsequent solution and weathering, accomplished by the penetration of air and water. Because of this enlargement of cracks, the jointing is much more conspicuous near the surface than near the bottom of the quarry. Joints appear to be much more numerous above than below. In a measure this is a real as well as an apparent truth. At the surface the tensions due to deformation are stronger than they are far below ground, and more cracks result. The photograph of the wall of Sugar creek gorge (Plate 2, B) shows a natural exposure of joint surfaces.

Faults.—Signs of dislocation or faulting along joint fractures may be seen rarely in the Des Plaines valley. Where a set of stratified rocks is faulted, the relative motion on the two sides will be shown by the way the strata fail to match. Those on the (relatively) lifted side lie above those on the downthrown side. Such faultings have been very common in the past. They are known to have occurred in recent times and to be the chief cause of earthquake shocks. The recent earthquake of San Francisco[1] was caused by a dislocation resulting in a horizontal shift of from eight to twenty feet, with but little vertical displacement. As a result the surface of the ground was broken, fences and car tracks offset, and in some places a low fault "scarp" formed. Even after erosion has obliterated the surficial indications of a fault, its existence can be told from the dislocated structure. Indeed, in most cases faults are discovered in this way, for as compared with the rapidly changing form of the surface, underground structure is permanent. In the district about the Des Plaines valley faults are relatively rare and of small measure. Occasionally on the wall of a quarry one may see a joint crack at which there is a break in the continuity of strata. This seldom amounts to more than a few inches.

The fault best shown in this district is near Joliet. It crosses a little gorge out by Sugar run between the Alton railway and the slaughter house road. The walls of this gorge are vertical joint faces, developed by the tearing off of blocks. As usual, two joint systems, nearly at right angles, are dominant. On the map of this district (Plate 6) the joint systems are indicated by two crosses. It is worthy of notice here that where the limestone contains hard nodules of chert or flint the joint cracks cut through them like a knife, rather than pass around them irregularly. Obviously, the cracks occurred after the rock became thoroughly compact and hard. Scarcely one hundred feet above the bridge at the slaughter house road, the fault shows in cross section on the southeast wall of the gorge (Plate 2, B.) Three cherty bands in the limestone mark out the stratification, and serve to distinguish the offset on the right and left side of the fault plane, which is one of the master

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[1] See Salisbury, "Physiography," pp. 419-426. 1907.

joints running northwest-southeast. The block on the right (southwest) side has risen fully a foot with reference to that on the left. On the northwest side of the gorge the continuation of this fault is somewhat concealed, but careful search will discover the extension of the same joint plane, which is here accompanied by a zone of crushed or "brecciated" rock between the dislocated sides. The rock, though decayed, has not wholly lost the half polished, half shredded surface produced by the slipping, a surface known to miners and geologists as "slickensides." It is not sufficiently well preserved, however, to show the exact direction of the dislocation.

A. Lock on the Illinois-Michigan Canal, above Joliet.

B. Fault in the Wall of Sugar Creek Gorge. The fault fracture cuts the large rectangular opening. The block on the right is a foot above that on the left.

CHAPTER III.

THE CONCEALED SURFACE OF THE BED ROCK.

SIGNIFICANCE OF THE BURIED TOPOGRAPHY.

Except in a few places, as in the bluffs which overlook the Des Plaines valley at Lemont, Lockport and Joliet, and where quarries have been opened, the bed rock of this region is concealed beneath a sheet of glacial drift or of recent alluvial material. So few are the exposures of rock and so limited in extent, that it is difficult from them to form a distinct picture of the buried bed rock topography. Some information can be gained from records of wells where the thickness of the drift cover has been measured, yet these data are very limited, and show little more than the fact that the bed rock surface is uneven, having a relief of 75 or 100 feet in short distances. The surface of the rock, it appears, is much more irregular than the old lake plain, and fully as uneven as the Valparaiso moraine; yet the bed rock topography bears no relation whatever to the topography of the overlying drift. We can form no correct idea of the concealed rock surface from the location and extent of the moraine ridges or the lake plain.

It is of deep significance that we have in this region the Niagara limestone of Silurian age overlain immediately by glacial drift. Evidence has already been presented, in the remnants of Devonian sediments preserved in deep cracks of the underlying limestone, that a considerable period of time elapsed after the Silurian period, during which a shale formation was deposited on the sea floor, and subsequently, after emergence, was stripped off by erosion. It remains for us now to extend this conception of the long interval of erosion which succeeded the Devonian period and antedated the deposition of the glacial drift, by realizing that the Devonian formation belongs far back in geologic time while the glacial drift is of very recent date. The time interval registered by the sharply defined surface which separates the eroded bed rock from the unconsolidated drift is enormously long. This is shown conclusively by the occurrence elsewhere of a great series of formations younger than the Devonian and older than the glacial drift. These formations are absent from northern Illinois, either because this region stood above the sea and so received no sediments, or because if once deposited they were subsequently removed by erosion. In either case, the time required for the deposition of the formations which elsewhere lie between the Devonian and the drift was immeasurably long.

With this brief mention of the importance of the bed rock surface as a record of a great interval of erosion we may turn to the history of it.

The bed rock topography has been moulded by two agencies; (a) by running water and the various processes of weathering, and (b) by the great ice sheet, which, by erosion and by the deposition of drift, modified to a considerable extent the form of the surface.

PRE-GLACIAL DENUDATION.

Deductions from the "Driftless Area."—The pre-glacial condition of the topography can be judged best by the topography of the driftless area of northwestern Illinois and southwestern Wisconsin. The rock structure of that district and the history through which it has passed are comparable to the district surrounding the Des Plaines valley, but the driftless area, unlike the surrounding region, was never covered by the ice sheet, so that its pre-glacial surface is preserved, though modified to some extent by the erosion of later time.

With the emergence of northern Illinois from the interior sea, probably at the close of the Devonian, the rocks which had been deposited were exposed to agencies of decay and of valley excavation. In the long periods of time which followed, while the Coal Measures of Illinois and other states were accumulating; while the Alleghany mountains were folded, worn down to a plain, and again uplifted and deeply dissected by erosion; and while the broad Coastal Plain of the Atlantic seaboard and the gulf were being built; during all this time, the surface of the rock structure of northern Illinois was being lowered by erosion. Once at least it was worn down to an almost featureless plain, a "peneplain," a condition reached only when the land stands still for an almost inconceivably long period of time, and river systems are enabled to complete their work of reducing the entire systems of their basins to a lowland near sea level. At length this base leveled plain was lifted up by a broad warping movement, while the revived rivers sank their channels below the rising plain and a new set of valleys was worked out. Gradually these valley systems were extended as well as deepened, until today the region is an upland of rolling prairie, a great sea of hills and valleys with smooth flowing outlines. The hill tops rise to nearly the same level, and the main divides or ridges between the valley systems are remarkably flat topped, representing the remnants of a once continuous peneplain. Here and there a higher knob or "mound" rises the upland level, a residual hill which escaped base-leveling. But, for the most part, the relief is one of monotonous regularity. Long continued decay of the rocks has produced a residual soil several feet thick, which passes downwards by unbroken transition into the firm unweathered rock.

The pre-glacial topography.—A surface similar to that of the driftless area was developed before the glacial period in northeastern Illinois. At the same time, it is altogether probable that a broad lowland had been developed where Lake Michigan now lies, for the rock formations which underlie the lake are a series of soft Devonian shales and sandstones which would be reduced much faster than the hard Niagara limestones farther west. Possibly also, there was a somewhat distinct escarpment running from north to south in the western part of our district, owing to the greater reduction of the Cincinnati shales, which lie west of the Niagara limestones. The hills carved out of the hard limestones at Joliet may have descended rather abruptly a few miles west of the city to a lower, flatter district occupied by the shales.

The development of underground drainage.—The limestone of this region not only suffered decay and erosion at the surface, but was attacked by ground water. Any rock structure so extensively affected by joints permits water to work its way downward at a rather rapid rate. This water, charged with a small amount of certain acids, the carbon dioxide from the air, the humus acids from the soil, can slowly dissolve certain rock constituents, especially limestone, which is very largely composed of soluble lime carbonate. Thus it comes about that material is dissolved from the two faces of every joint crack in limestone, and the joint is slowly enlarged. Under favorable conditions definite underground stream channels may be eaten out in time. These may grow into large passages and caverns. It is in fact in just this way that the great limestone caverns of Indiana, Kentucky and Virginia were made. If a cavern is not far underground and is so greatly enlarged that the roof falls in, a "sink" or "sink hole" results. These sink holes are saucer shaped depressions in the ground. While in some cases they originate after the fashion just described, it is probable that most sink holes are developed by local enlargement of innumerable small passageways through which water drains downward from the surface, and without the development of any great cavern immediately beneath. Surface drainage flowing into sinks increases their size, and eventually almost the whole drainage of a district may enter sinks and follow underground channels. This condition has been reached in the interior of Florida.

While no such wholesale development of sinks and subterranean streams occurred in northern Illinois before the ice age, sinks are known to exist there, in spite of the fact that the drift so generally conceals them. Two or three good sized hollows, leading to caves of unknown extent, could formerly be seen in the west part of Joliet, near Jasper street and Raynor boulevard. They have been more or less filled up with rubbish in recent years, so that they cannot satisfactorily be examined. In places, small tunnels or openings in the limestone may be seen in the quarries about Joliet, though none of them are of striking proportions. One appears in the northeast corner of the quarry near Grinton and Jackson streets. It is a thin horizontal opening worked out along a bedding plane in the limestone, close to the present quarry floor. The steady flow of water through these openings renders them most unwelcome to the quarrymen, necessitating the constant use of pumps. It is said that a spring issuing from the limestone near here, was formerly a regular stopping place for the stage, as it passed down the Des Plaines valley through Joliet.

GLACIATION.

The Glacial Period.—The rolling upland with its maturely developed valley systems and its residual soil was destined not to remain. An extraordinary change of climate led to the development of a great ice field over much of the northern part of North America. The extent of the ice sheet (shown in Fig. 5) was some 4,000,000 square miles, fully the size of the ice sheet which now covers the Antartic continent. Why such an enormous ice sheet grew up in North America, with its centers of accumulation nearly thirty-five degrees away from the pole, has never been satisfactorily explained. It has been ascribed, in turn, to

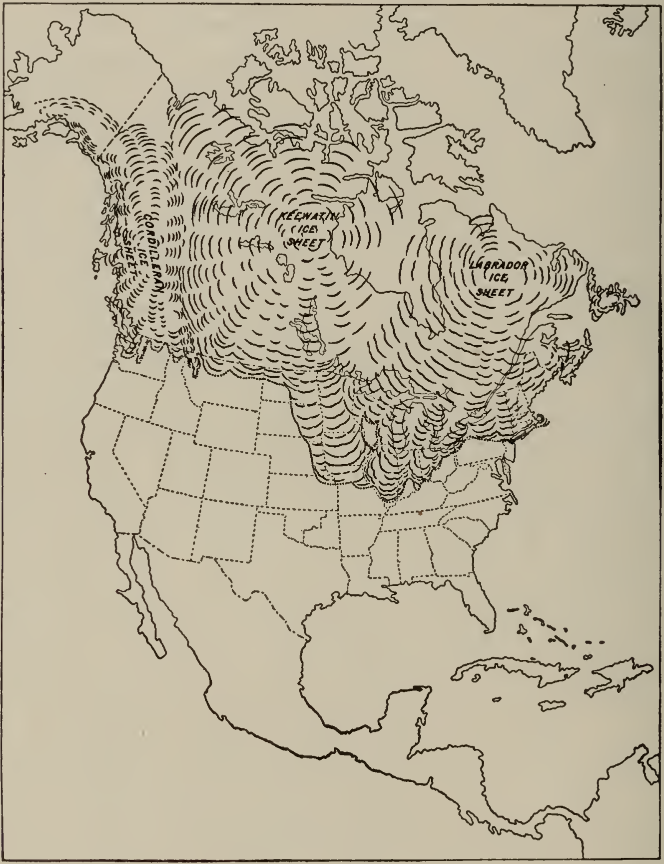

FIG. 5. Map of area covered by the North American ice sheet of the glacial epoch at its maximum extension, showing the approximate southern limit of glaciation, the three main centers of ice accumulation, and the driftless area within the border of the glaciated region. (*Courtesy of U. S. Geological Survey.*)

a general uplifting of the continent to an altitude above the snow line; to a shifting of ocean currents by up-warpings of the sea floor; to certain changes in the earth's planetary relations (eccentricity of the orbit and precession of the equinoxes) which might rarely combine to give a series of ice caps, alternately at the north and south pole; to a shifting of the poles themselves, with respect to the crust or outer shell of the earth; and to changes in constitution of the atmosphere, wherein slight enrichment in carbon dioxide gas, accomplished by certain geologic and geographic changes, might bring about a cool moist climate. All these except the last have met serious objection, and while this cannot be said to have been demonstrated it seems the most satisfactory yet suggested.

The North American ice sheet, as the map (Fig. 5) indicates, probably extended as far north as the continent itself. Greenland is believed to have been covered by its own separate ice cap. A similar ice sheet, with its center on the Scandinavian peninsula, covered all of northwestern Europe and most of the British Isles. On the Alps there was a smaller, isolated ice field, from which great tongues of ice moved down the main valleys.

It must not be thought, however, that the North American ice sheet was a group of narrow glaciers moving out from an elevated mountainous center. While the Canadian highlands, from which it spread, stand somewhat above the general level of the upper Mississippi valley, the motion of the ice was not controlled by the topography. Rather was it a vast sheet, radiating out from three (possibly four) centers, with the ice from at least two of them coalescing to form a single great ice cap. The ice in the western mountains appears to have remained measurably distinct.

The history of the glacial period was complex. It was made up of several glacial and interglacial epochs. In the former the ice sheets grew larger; in the latter they dwindled, or disappeared altogether. The glacial epochs evidently represent periods of severer climate, while the interglacial epochs mark times of milder climate. The glacial period was therefore a period of climatic changes. We seem now to be living in a post-glacial epoch, but if another glacial epoch should follow, the present would prove to have been an interglacial epoch. It may be said, in this connection, that some of the interglacial epochs seem to have been much longer than the time since the ice last withdrew.

The ice sheet was thick enough to cover the hill tops everywhere within reach, and even to bury the mountains of northern New York and of New England. We may get some idea of its thickness over the Des Plaines basin by measuring the distances out to the border of the glaciated area and assuming a surface slope in this distance, equal to that of the Greenland ice cap. When the ice had its greatest extent in Illinois (in the "Illinoian" epoch) its outer edge was more than 300 miles south of the Des Plaines district (see Fig. 6). If the average slope of its surface at that time was thirty feet per mile, i. e., about the same as that of the interior of the Greenland glacier, the thickness of ice over the Des Plaines basin was some 9,000 feet. It seems unlikely, however, that such a steep slope as that would continue so far from the ice margin. Nansen, in his trip across Greenland, found that on the west side (where the slope was gentler than on the east) the surface of the ice cap rose to 6,600 feet in the first seventy-six miles, and after that at

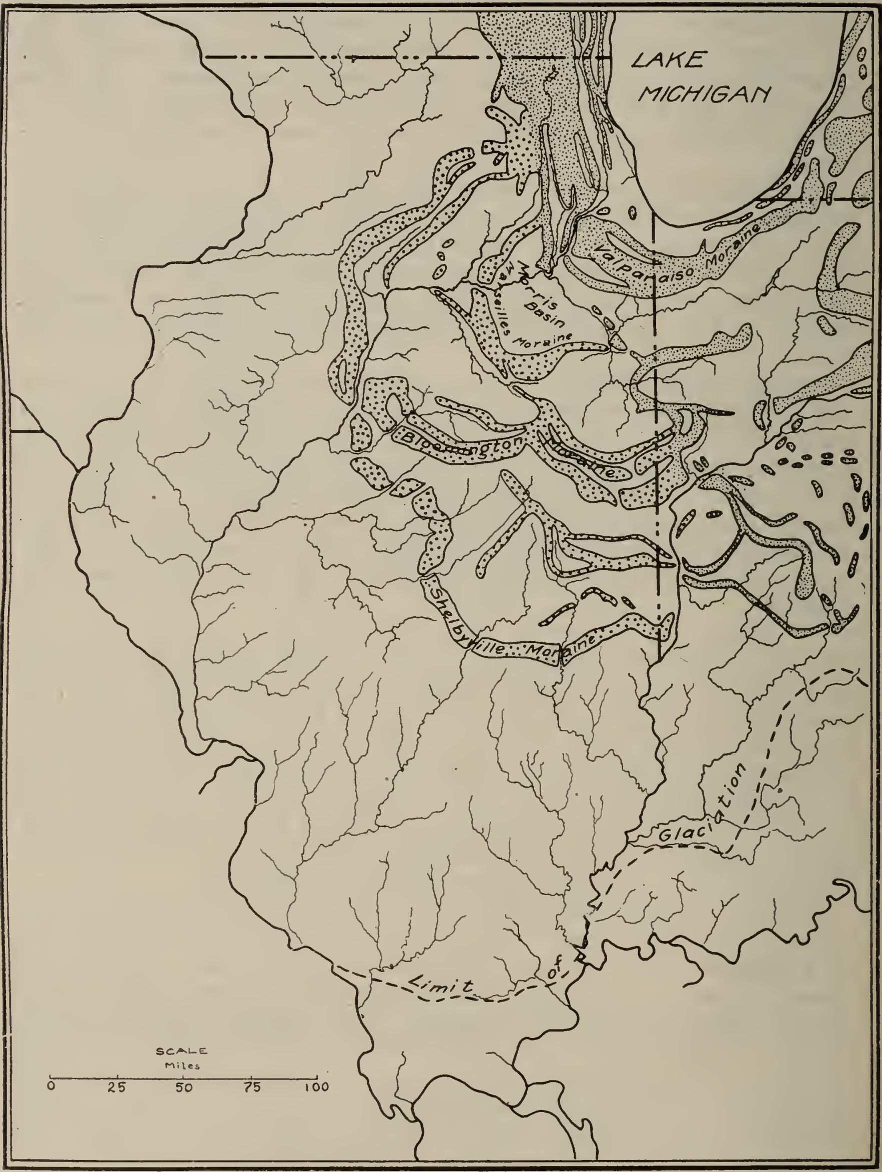

FIG. 6. Moraines and other limit of drift in Illinois. After Leverett, U. S. Geol. Surv.)

an average rate (constantly decreasing) of twenty-six feet per mile. If we assume the same rate for Illinois, we get 6,600 feet for the first seventy-six miles back from the ice border, and 5,850 feet for the 225 miles following, or a total thickness over Joliet and Chicago of over 12,000 feet. There is reason to believe, however, that the Greenland ice sheet covers a high mountainous region from which there is a rather steep descent to the sea: and that the slope of the surface of the ice sheet is steeper on that account than it would be over a flat region like Illinois. So far as this is true it should lead us to reduce the estimate of thickness accordingly. We may reasonably believe, however, that during the Illinoian ice invasion the ice sheet was several thousand feet thick over northeastern Illinois. During the last glacial epoch, however, the ice advanced only a short distance southwest of the Des Plaines valley, and its thickness over that area was probably not more than a very few thousand feet.

For a long period, probably a hundred thousand years, this great cap of ice was a powerful agency in modifying and reshaping the surface features of this district. When it finally melted away, on the establishment of the present climate, a wholly new topography appeared. In two distinct ways the ice sheet had changed the topography of the surface. It had carried away the residual soils and most of the loose rock within the zone of surface decay and disintegration, and as a rule it ground, scraped, and scoured the firm rock below until its surface was reduced, in many places at least, several feet below its former position (See Fig. 7).

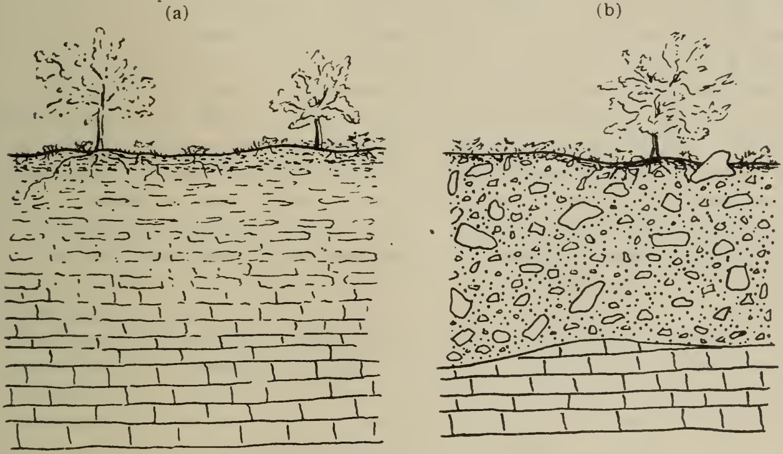

FIG. 7. Section showing (a) residual soil, passing downward into rock, and (b) glacial drift overlying a glaciated rock surface unconformably.

The smoothing and striating of the rock surface.—The appearance of a strongly glaciated surface of rock is so characteristic that it deserves more than mention. The drift-shod ice, moving slowly along over the rock floor and pressing down upon it with tremendous weight, rasps and scours it. The finely comminuted clay or "rock flour" which makes up a large part of the drift, probably lubricated with water, smooths and even polishes the rock surface. Coarser particles in the ice such as sharp cornered bits of rock, are held firmly against the bed rock like engraving tools, scratching the surface more or less deeply in the direction of glacier motion, until the cutting edge is blunted or the pebble turns around. These scratches or "striæ," where best formed (on rock of fine grain, dense texture, but of relatively slight hardness, like certain layers of the Niagara limestone) begin abruptly and gradually narrow or tail out in the direction in which the glacier advanced. They vary in size from scratches of a hair's breadth to grooves several inches in cross section. Large bowlders were probably the carving tools in the case of the larger grooves. In length the fine scratches are to be measured by inches rather than feet. With a little practice, striae can be distinguished readily from cracks. The scratches are mere surface markings, and can be seen only on well smoothed surfaces of freshly exposed rock. Cracks, of course penetrate the rock and may occur on any surface. As a rule the scratches at a given point follow a single direction, which is that of ice motion when the rock surface was last covered by ice. Occasionally, however, two or more sets of scratches cross one another, testifying to the local shifting of the direction of ice movement.

Striated rock surfaces are to be looked for where the drift has been only recently stripped away, as around the borders of freshly worked quarries. Where a rock surface has been exposed even for a few years the decay of the limestone has usually obliterated them. Moreover no striae are likely to remain where the rock surface was washed by streams during the retirement of the ice sheet, and was buried by gravels. For these reasons chiefly, striated surfaces are rarely seen near Joliet. The rock floor of the valley was cut down by an ancient river (the outlet of extinct Lake Chicago) and the rock up to the height of some fifty feet on either side of the valley was washed by gravel-bearing streams. A smoothed rock surface has been recently exposed beside the track of the Coal City branch of the Chicago & Alton railway, just southeast of the switch house on South Chicago street. No scratches can be seen on it, however, and the gravelly and bouldery drift which has been stripped away seems to indicate that the surface, if ever scratched by the ice, was subsequently eroded by running water.

The burial of the rock surface with drift.—Over the glaciated surface of the bed rock the glacier spread a sheet of rock debris or "drift," which it had collected on its way southward, and which it was unable to carry farther out to the position of its extreme border in southern Illinois. So the residual soils of pre-glacial time were taken off, the underlying rock worn down to some extent, and then buried by a sheet of drift of variable thickness. The contact of the rock and the drift is therefore a true "unconformity," the record of an interval of erosion between two widely separated periods of deposition. Too much emphasis can not be placed on this feature, so characteristic of the glaciated region.

The buried topography.—The rolling upland of pre-glacial time was probably modified only slightly by glacial erosion. There is no evidence that any profound erosion took place. The pre-glacial valleys were probably somewhat deepened and widened, and the hill tops were somewhat reduced, but the undulatory character of the bed rock surface remained, with probably little change in the amount of unevenness. This fact is suggested by data from wells and by the exposures in quarries, and along the valleys where the drift has been removed. Take, for example, the profile of rock along the Des Plaines valley from Lemont to Willow Springs. At Lemont the Niagara limestone appears on either side of the valley in the bluffs, to a height of about fifty feet above the valley floor, or sixty feet above Lake Michigan. As exposed in the wall of the quarry west of the village the surface of the rock declines gradually to the level of the valley floor in two miles. East of Lemont, likewise, the surface of the bed rock descends, reaching the level of the river within a mile and a half. Opposite the mouth of the "Sag" the bed rock (by measurements along the drainage canal) ranges from fifteen to thirty-five feet below the valley floor, or five to twenty-five feet below Lake Michigan, indicating a change of altitude of the rock surface of eighty-five feet between the highest point, at Lemont, and the lowest, near Sag bridge. That the bed rock surface rises and falls as much as eighty-five feet, even, in comparatively short distances is indicated by the presence of a rock outcrop on Saw Mill creek, about a mile northwest of Sag bridge, and at a height of nearly seventy-five feet above Lake Michigan. This means for that vicinity at least a vertical range of 100 feet in a mile. It is not likely that these measurements (the highest and the lowest) are extreme; rather does it appear that the rock surface rises and falls with moderate slopes in innumerable hills and valleys of about the size and height of the morainic hills on Mt. Forest island.

In places the surface of the bed rock after glaciation had really precipitous slopes. Such was the case, apparently, near Lemont, where sharp rock bluffs overlook the valley floor. At first sight these bluffs might be thought to be the work of the Des Plaines river or its ancestor, the outlet of glacial Lake Chicago, which once poured through the valley, and which might easily have cut a deep notch through the bed rock had there been a rock barrier athwart its course at Lemont. Such an explanation for the bluffs and the rocky floor of the valley has in fact been entertained.

The contrary belief, i. e., that the valley, with its rocky floor and sides, was already in existence when the ice sheet last covered the district, and that no rock barrier crossed the Chicago outlet at Lemont, is based on the distinctly glaciated character of the bed-rock floor of the valley at several points between the opposed bluffs. At the quarries on the north side of the valley about Lemont, near where the Santa Fé railway turns obliquely across the river and the drainage canal, the bed rock floor of the valley at the base of the bluffs is smoothed and polished and distinctly scratched. The striae run about south 50° west, parallel to the axis of the valley. The best exposure noted is at the northeast end of the quarries, where a thin covering of glacial drift in April, 1907, had just been stripped from the rock floor. Clearly this spot in the valley, at least, was once scoured by the glacier. Similar exposures a few hundred yards away confirm this view, and suggest that the whole valley was once filled and buried by glacier ice. Such glacial markings on the valley floor have been noted before at Lemont. A strongly glaciated surface, exposed in the bed of the Chicago drainage canal at this place, was described and pictured by Leverett in his monograph on "The Illinois Glacial Lobe."[1] It is, of course, not safe to insist that no rock barrier could have crossed the valley somewhere just above or below Lemont, until it is known that the floor of the valley shows marks of glaciation as far down-stream as it is bordered by rock bluffs—a matter as yet undetermined. But the evidence just reviewed strongly favors that view. The valley at Lemont seems to be a glaciated valley, and not a post-glacial valley of river excavation. Besides throwing light on this question of a rock barrier at Lemont, the striated surfaces at the base of the bluffs illustrate the local steepness of bed-rock slopes which were covered and scrubbed by the ice.

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[1] U. S. Geol. Surv., Monograph 38, p. 416.

CHAPTER IV.

THE GLACIAL AND INTER-GLACIAL DEPOSITS.

The nature and history of the extinct North American ice sheet has been outlined in the preceding chapter. The manner in which it eroded the surface of the underlying rock has also been briefly told. We have now to consider in some detail the deposits which the ice left on its retreat, and those laid down in inter-glacial periods. To the deposits of glacial drift we owe all the main features of the present topography and indeed most of the details of the surface.

DISTRIBUTION AND SURFACE FORM OF THE DRIFT.

The map of the Des Plaines district (Plate 1) and an introductory sketch of the leading features of relief on pages 3 and 4 indicate the massing of the drift into parallel belts of upland, known as terminal moraines. Each of these moraines marks a stage in the recession of the ice border, when the rate of melting was temporarily checked and the edge of the ice became nearly stationary. At such times the drift which was being moved forward to the melting border and deposited there, accumulated to great thickness. When the ice border receded a relatively smooth lowland was laid bare behind the belt of thick drift. This extended to the time when another halt of the ice caused the making of another ridge of drift.

It is characteristic of these terminal moraines to have a very uneven surface. The unevennesses consist of depressions and swells, more or less like upright and inverted saucers, yet too irregular in outline to be described accurately in those terms. The range of undulation and the angle of slope vary in the different moraines. They are greatest on the largest one, the Valparaiso moraine, reaching on Mt. Forest Island a relief of over fifty feet between hill top and valley bottom. At Hinsdale the relief is somewhat less marked, with a range of about thirty feet, and around Elmhurst the eastern portion of the moraine has very wide flattish sags and swells. On the smaller moraines, the Minooka till ridge, the west ridge of the Valparaiso morainic system north of Joliet, and the lake border moraines, the undulations of the surface are very faint comprising long gentle slopes which rise and fall no more than fifteen to twenty feet in long distances. The size of the hills is also variable.

They are commonly half a mile to a mile in longest diameter. The hollows are often enclosed basins, in which surface water collects to form swamps or little ponds in wet weather. This is favored by the impermeability of the compact clay of which moraines are largely composed. There seems to be little regularity in the trend of swells and sags, for in some places they appear to run roughly parallel to the former border of the ice and in other places they are prevailingly perpendicular to it.

The cause of the marked irregularity of the surface of moraines is to be found in the variability of conditions under which the moraines grew up. In the first place, the drift was not evenly scattered through the ice, so that much more reached the melting border of the ice at some points than at others. Low mounds and hollows on the surface of the deposit naturally resulted. Secondly, the ice edge was oscillating backward and forward locally at different rates, so that the drift was spread out more in some places than in others, and deposits once made were frequently overridden by local re-advances of the ice. In some cases, moreover, blocks of ice were left behind as the ice retreated. If these were surrounded or buried with gravel their melting may have led to the formation of hollows in the surface of the drift.

The deposit left beneath the ice, between the morainic ridges, is known as the "ground moraine." This too has its swells and hollows, but in this region they are much less pronounced than those of the terminal moraines. The belts of ground moraine have the appearance of rather smooth plains. The broad shallow valley followed by the upper Des Plaines river, above Riverside, is one of these plains. Its lower portion, as well as the adjoining Chicago plain, was afterwards covered by the glacial Lake Chicago, and the initial smoothness was increased by the leveling action of waves and currents, which tended to cut down the elevations and to build up the depressions. The lake plain in many places appears to be absolutely flat for miles. This is its appearance at the city limits of Chicago, near Archer avenue, and west of Harlem, around "Broadview."

THICKNESS OF THE DRIFT.

The undulating surface of the bed rock, and the equally irregular surface of the drift, with no correspondence in position between the two, combine to give the drift a very irregular thickness. Locally, as already remarked, the drift is almost or quite absent. There are other places where well borings show it to be more than 200 feet thick. As a rule, however, in the neighborhood of the Valparaiso moraine, where we may expect the maximum thickness for the Des Plaines valley district, it is 100 to 150 feet thick. At five localities in our district well records collected by Leverett[1] show thicknesses as follows:

Arlington Heights (about 150 feet below crest of moraine)	128
North of Arlington Heights (20 to 30 feet above station)	190
Elmhurst	98
Crest of moraine northwest of Lemont	150
Crest of moraine east of Lockport	115+

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[1] "The Illinois Glacial Lobe." U. S. Geol. Surv., Monograph 38, p. 354, 1899.

This gives an average of 136 feet along the axis of the moraine. The greatest thickness in the table is by no means a maximum, but it is not likely that the drift is much over 250 feet thick anywhere in the Des Plaines basin, since out of 68 well records cited by Leverett on the Valparaiso moraine between northern Illinois and southwestern Michigan, only four are certainly over 250 feet, and only one is over 300 feet. The deepest visible section through the drift in our district is two or three miles west of Lemont, where the broad valley crosses the axis of the great Valparaiso moraine, and the extensive stripping of the rock in the bluff on the south side of the valley has freshly exposed the drift to a depth of some 75 feet.

COMPLEXITY OF THE DRIFT.

Because of the complexity of the ice age, the series of advances and retreats of the ice, the drift does not consist merely of a single sheet, but of several overlapping sheets, deposited by the successive glaciers. It is through the study of these several drift sheets that investigators of glacial geology, during the past twenty-five years have worked out the fact of successive glaciations. In Illinois and the adjoining states, the later ice advances as a rule fell short of the earlier, so that each of the five drift sheets is to be found locally as a surface deposit south of the outer border of the next younger sheet. Even where an earlier sheet was run over by a later advance of the ice, the old drift, buried beneath the later drift sheet, may sometimes be found where streams have excavated valleys through the deposits, or some other section, natural or artificial, has been made. An older drift sheet is often separated from a younger one above either by an old surface with its evidences of erosion, soil decay, and vegetation (in the form of peat beds, tree trunks, etc.), or by stratified deposits of sand and gravel which indicate deposition by rivers or lakes during the inter-glacial epoch. Often, however, the older drift sheet was wholly destroyed before the deposition of the newer drift, either by surface erosion or by the later ice advance. Consequently one rarely finds in any single exposure more than two or three glacial and inter-glacial deposits, and in most cases there is only the last drift sheet over the bed rock. The five drift sheets recognized in the upper Mississippi valley as marking five distinct advances of the ice have been named in the order of their age (1) sub-Aftonian, or Jerseyan, (2) Kansan, (3) Illinoian, (4) Iowan, (5) Wisconsin. The last has in turn been subdivided into the early and the late Wisconsin stages.

THE TWO KINDS OF DRIFT.

The fragmental rock material which was transported by the ice sheet and sooner or later deposited in a new locality is known as the "drift." The greater part of it was deposited directly by the ice. This is known as "till." But much of the drift was worked over by running water as the ice sheet melted away, and was laid down in beds or strata. This is known as "stratified drift." It resembles till in one respect, in being composed of fragments of rocks of very many different sorts; but it differs from till very markedly in physical structure, possessing stratification, which is unknown in ice-laid drift. The distinction is a fundamental one, and will be emphasized in the following discussion of the till and of the stratified drift.

The ice-laid drift or "till".—The most striking character of the till is the great range in size of the fragments which compose it, and the entire absence of separation of coarse from fine. Large bowlders, cobbles, pebbles, sand, clay, and the finest "rock flour" are mingled in absolute confusion. This arises from the fact that a glacier has great power as a transporting agency; the heaviest bowlder can be carried on its surface or within its frozen mass almost as easily as a particle of clay. Where the strength of the ice movement is locally diminished, deposition affects coarse and fine alike. There results a heterogeneous mixture known sometimes as "bowlder clay" (synonymous with "till".) Not so with deposits which are laid down by running water or by wind. These two agencies are very limited in their carrying power. Each variation in the strength of a current of water means a variation in the size of the particles which it may carry or deposit. Accordingly, at one time fine sand may be deposited, and later, if the current becomes stronger, coarse sand or gravel may be deposited at the same place. With wind a similar change leads to successive layers or beds in the deposit, although wind is of course not strong enough to transport gravel. Ice-laid deposits, then, are peculiar in their absence of stratification.

Another criterion of ice deposits is the shape of the stony ingredient. Although many of the bits of rock in bowlder clay are rounded like river or beach pebbles (and it is significant in this connection that the diabase and granite pebbles and bowlders which have come far are usually rounder than the limestone fragments of local derivation) a large number are angular or sub-angular, with snubbed ends, rounded edges, and smoothed and striated sides. (See Plate 3, No. 2). The striae resemble those of a glaciated bed rock surface, and are made in just the same way, only the stones of the drift are in motion, and scratch against one another as well as against the bed rock. If a stone in the till is decidedly longer in one direction than in others, its striae as a rule run parallel to its length, because the stone tends to orient itself in the position in which it will offer least resistance to the abrading force. This feature is illustrated in the glacial stone in Plate 3.

As regards the composition of its rock particles, the till exhibits a very remarkable variety. The pebbles and bowlders show a lithological heterogeneity far greater than any lot of pebbles that a river or a lake alone would be likely to collect. While most of the pebbles resemble the underlying rock, many of them correspond to rock formations which occur not nearer than 50, 100, or even several hundred miles. Such, for instance, are the granites, diabases, quartz-porphyries and amygdaloids, which came from northern Wisconsin or beyond, and the quartzites which came from the same region or perhaps from certain small areas of quartzite in south central Wisconsin. No agency except ice is known, by which rock material would be collected from such widely separated

Pebbles from the drift. (1) glacial gravel, (2) till, (3) gravel pebbles partly cemented by carbonate of lime.

sources and transported to a single place hundreds of miles away. Especially is this true when we remember that coarse and fine are intimately commingled, and that the material came from various river basins.

LIST OF ROCKS FOUND IN THE TILL.

A list of several kinds of rock, represented by pebbles, bowlders and other fragments in the drift, together with simple means of identifying them, is given below:

Igneous Rocks.

(Rocks solidified by cooling from a hot, molten condition.)

Granite.—Crystalline, usually coarse-grained, speckled appearance due to presence of many separate crystals of three or more kinds of minerals, chief among which are: Quartz (white or sugary, and very hard); Feldspar (whitish or reddish, according to impurities and decayed condition, in part with somewhat rectangular outline, and "cleavage" surfaces which reflect the light, hard); Hornblende (black, or greenish black if decayed, often in small irregular bunches); Mica (white or black, cleaves in thin flakes which reflect the light brilliantly, soft enough to be cut easily with the knife). Granite is sometimes hard to distinguish from Gneiss.

Diabase or Trap.—Crystalline, coarse to fine, dark gray or black. Among the crystals, black minerals such as Hornblende predominate. Feldspar, light colored, is in small quantity. Often so fine grained that separate crystals cannot be distinguished without lens.

Quartz-Porphyry.—Dark gray, reddish, or pinkish "ground mass," in which scattered crystals of Quartz or Feldspar may be distinguished (Quartz, colorless or whitish; Feldspar, usually straw colored or flesh-colored, latter with rectangular outline, former, usually irregular).

Amygdaloid.—Dark colored, often black, and fine grained, with "almond-shaped" bunches of light colored substances (usually the minerals Quartz and Calcite). An old lava, in which steam-bubble cavities have been filled up by deposits from percolating waters.

Sedimentary Rocks.

(Originally deposits of sediment, or organic substances, or chemical precipitates, under water, hardened by pressure of overlying sediments, or by heat, or by some natural cementing substance.)

Limestone or Dolomite.—Gray or buff-colored, varies from coarse crystalline texture to very compact fine grain. Limestone is largely lime carbonate, and unless very impure will effervesce when dilute hydrochloric acid is applied. In Dolomite there is some carbonate of magnesium, and other impurities, and it does not commonly respond readily to this chemical test. It is not very hard, and will scratch with a knife. Formed chiefly by the deposition of ground-up shells and skeletons of marine animals, together with some mud or ooze, frequently rich in fossils.

Chert.—Harder than steel, flinty; where freshly broken it has a sharp fracture and dull greasy luster, dull yellow, gray, or brown, common in limestone both as irregular lumps or "nodules" and in thin beds. In part, at least, derived from siliceous sponges which were buried by sediments on the sea floor.

Sandstone.—Grains of sand bound together into a gritty, often crumbly mass; color depends largely upon the cementing substance; red, yellow, or brown, if the cement is iron oxide; white if it is silica; grains largely Quartz; sometimes flakes of Mica.

Shale.—Hardened clay or mud; greenish gray, dark brown, or black; soft, easily scratched with a knife; yields odor of clay when breathed upon, because of presence of kaolin.

Quartz.—White, except as stained by impurities; too hard to scratch with steel; glassy where broken. Pebbles are fragments of Quartz veins, or fillings of fissures in other rocks by deposits of silica from solution.

METAMORPHIC ROCKS.

(Originally either Igneous or Sedimentary rocks, greatly altered by effects of compression or deep burial in the earths' crust, or in some cases by the extent of the cementation.)

Quartzite.—Very hard, fine crystalline, sugary texture; white, pinkish, purplish, or dull grayish; formerly a sandstone; re-crystallized by addition of silica deposited from solution.

Slate.—Formed from Shale by compression. Harder than Shale, with well defined plane of splitting or cleavage.

Marble.—Like Limestone, but distinctly crystalline, and somewhat harder. A re-crystallized Limestone.

Gneiss.—A banded, crystallized rock, often coarse grained; separate crystals of such minerals as Quartz, Feldspar, Hornblende, and Mica, arranged in more or less definite bands, and thus distinguished from Igneous rocks. Lighter varieties, with much Quartz and Feldspar, resemble Granite; darker ones often largely composed of pinkish Feldspar and black Hornblende and Mica. Most Gneisses seem to have been formed from Igneous rocks, under great pressure.

In the following table is the number of pebbles of various kinds of rock identified from a hundred bits of rock that were taken indiscriminately from a cubic foot or so of bowlder clay or ice-laid drift at two different places, both of them in an exposure of till at the east end of McEnty street, in Joliet:*

	First collection.	Second collection.
Limestone	77	78
Sandstone	8	10
Shale	2	1
Quartzite	1	....
Diabase	9	5
Granite	3	6

Evidently the limestone, most of which has presumably come from close at hand, forms about three-quarters of the stony material. The sandstone and shale probably came from the Potsdam and Cincinnati formations, to the north and northwest, though some may have come from the Devonian rocks which underlie Lake Michigan. The diabases and granites, and some of the quartzites, came from northern Wisconsin or beyond, a distance of at least 250 or 300 miles.

The stratified drift.—As regards the variety of rocks represented among its constitutent bowlders, pebbles and smaller particles, the stratified drift resembles the till. The material that composes the two classes of drift were picked by the ice from a common collecting ground, and because of the vast extent of this collecting ground they show the remarkable variety indicated in the last few pages. The features peculiar to stratified drift which distinguish it from till, are those which have

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* Pebbles identified and counted by Mr. Charles E. Decker.

been effected by the wearing and sorting action of water. While the ice sheet melted, some of the rock waste upon and within it found its way into outflowing streams, which washed the debris along, sifting out the finer and depositing the coarser particles in such places and at such times as the strength of the currents was over-taxed. Such deposits, therefore, are in layers, because of the repeated changes in the strength of the currents. Coarse gravel, fine gravel and sand occur in successive beds, in the order of their deposition. The pebbles have been more or less completely rounded, and are as a rule arranged flat side down, although where coarse gravel deposits have been hurriedly made the constitutents are sometimes poorly arranged, and the stratification may be obscure. The bedding is usually nearly horizontal—the attitude of a stream bed, but separate layers in a single horizontal stratum may be strongly inclined—a condition known as "cross bedding." (See Plate 4, A.) This peculiar stratification, in many instances, marks the forward growth of a sand bar or a delta. The slanting layers represent successive positions of the sloping front of the deposit, as it was advancing. After a large mass of these inclined beds has been laid down, the currents may shift in direction or increase in strength, in such a way that the upper part of the deposit may be cut away as if bevelled and a new layer may be formed above the horizontal surface of planation, with its beds inclined in another direction. Where currents are very erratic or tumultuous, as was evidently the case near the border of the ice sheet, the cross bedding is still more irregular. No horizontal planes of bedding appear, but the deposit is a mass of lens-shaped pockets of gravel and sand, dipping in various directions—This condition is known as "flow and plunge" structure. Examples of both sorts of cross bedding can be seen in Overholster's gravel pit, near the south end of Logan avenue in Joliet (See Plate 4, A.)

Stratified drift is, for the most part, distributed along lines of initial depression, for the waters discharging from the ice sheet seek the lowest ground; hence it happens that the thickest deposits of glacial gravels in this district (if we except older deposits which were buried by the last advance of the ice) are to be found along the Des Plaines valley and the valleys of the larger tributaries, and around the low Chicago plain, which was formerly covered by a great lake.

Large deposits of stratified drift occur about Joliet. On the southeast side of the city a high ridge of gravel starts in at the bend of the Michigan Central railroad near Hickory creek, and runs south and southwest across Rowell avenue. On its southeast side the gravel deposit formerly extended off with gentle slope to the base of the moraine; but the gravels have been widely excavated for railway ballast. Fresh cuts near Rowell avenue show exceedingly coarse gravel with occasional bowlders. This greater coarseness of gravel, together with the steepness of slope on the northwest side of the deposit, in contrast to the gentle slope towards the east, suggests that the gravels were washed out from a tongue of ice which lingered in the valley while the main border of the ice was on the Valparaiso moraine to the east, and which at length melted away, allowing the gravels in contact with it to slip down, forming a steep slope. The form of the ridge varies greatly as it runs south, gaining at times a steep slope on both sides. In places, however, the steepness of the slopes seems clearly due to lateral erosion of Hickory creek on the one side or of the old outlet on the other; for the Des Plaines valley for a time was occupied by a large river which discharged from Lake Chicago. It may be that all these steep slopes are to be accounted for thus, by erosion, rather than by previous contact with the ice edge and the removal of that support.

At Overholser's pit, near Linden heights, is a fresh forty foot section of cross-bedded sands and gravels, which here form the outer border of the main Valparaiso moraine. The cross-bedded layers (as seen in Plate 4, A) show a rather persistent dip towards the west, indicating that the growth of the deposit was to the westward. The relations to the Valparaiso moraine suggest that this is part of a smooth fan-like deposit or "frontal apron," washed forward from the ice while it lay against the moraine. The plain which separates the main ridge from the west ridge of the Valparaiso morainic system south of Joliet may be the surface of a part of the same frontal apron. The deposit is of special interest because it resembles in structure a much older gravel deposit, the Joliet conglomerate described later.

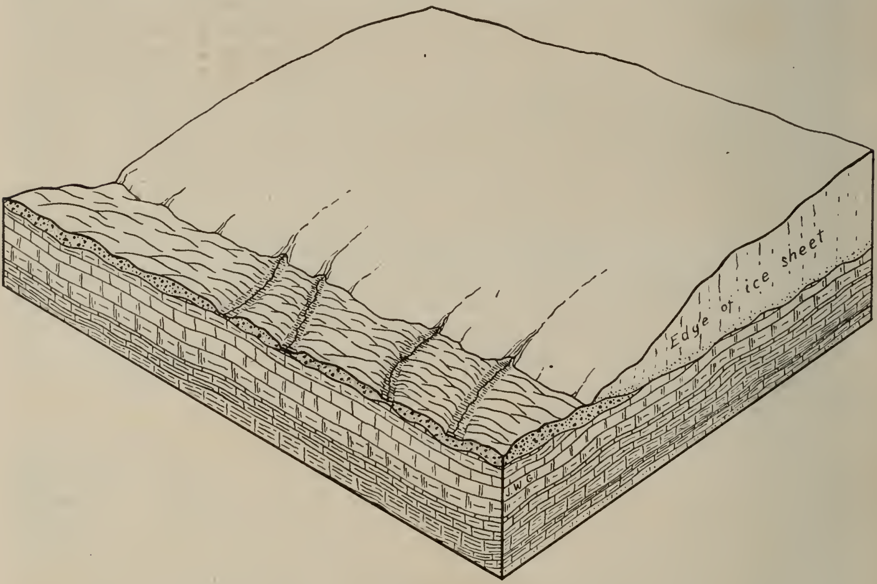

FIG. 8. Diagram showing the border of the ice resting against the outer morainic ridge of the Valparaiso system, near Joliet, Lockport, and Romeo. Four transverse passages are occupied by glacier-fed streams, and are being aggraded with gravel. The passage nearest the foreground later became the course of the Chicago outlet, and finally of the Des Plaines river. The one next to the left is the "big slough" north of Joliet.

A. Stratified drift at Overholser's pit, Joliet.

B. Exposure of Joliet conglomerate near Spring creek.

The chief deposits of gravel, which took place in the valleys which were the main lines of drainage while the ice was melting, are called "valley trains." The Des Plaines valley from Lemont down past Joliet to Channahon, evidently received a thick deposit of this outwash, for it was the main line of escape for the glacial waters with their over-burden of rock waste. The original valley floor was built up by these deposits locally some fifty feet. At the same time, tributary streams built branch valley trains. This was the case in the valleys of Long run, Fraction run, Spring creek and Hickory creek (See Plate 5, A.) This process is illustrated in Figs. 8 and 9. At a later time, when the ice sheet had withdrawn from the Valparaiso moraine, the over-loaded ice-fed stream in the Des Plaines valley was replaced by a river which issued from a great ice-front lake, and which, free to gather up a load for itself, excavated a deep, wide trench in the valley filling, carrying away most of the deposits. Only a few scraps of the old valley train were left as terraces, e. g., opposite Lockport, and three miles west of Joliet, or as flat-topped, island-like mounds in mid-channel, like Flathead mound between Joliet and Channahon. These are mentioned more particularly on later pages. It is of interest, however, to note here that in certain places (e. g., in the outwash terrace opposite Lockport) the pebbles in the gravel have been coated over with a white crust of carbonate of lime, left by percolating water. Sometimes this film of lime carbonate is an eighth of an inch thick, and serves to bind a few pebbles together (See No. 3, Plate 3); but in no place has cementation progressed far.

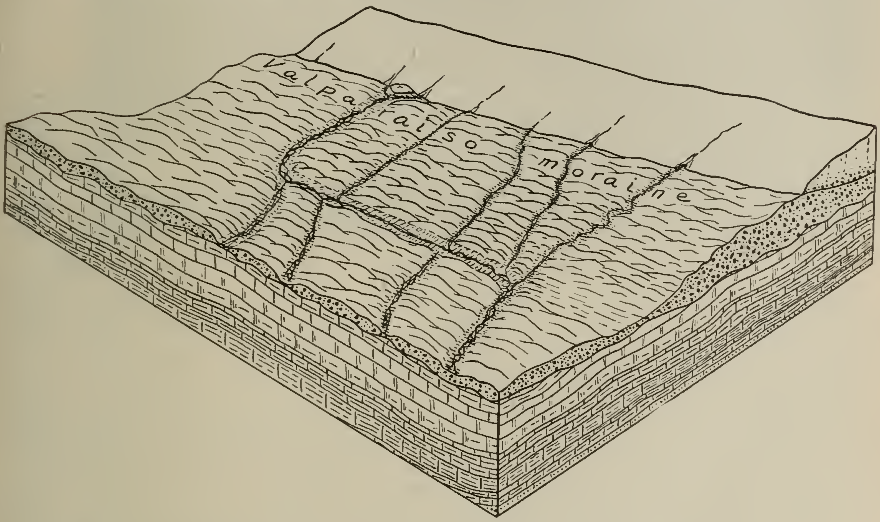

FIG. 9. A later stage than that of Fig. 8. The ice border has receded to the east side of the Valparaiso moraine. Aggrading rivers from it pass down the valleys of Hickory creek, Spring creek, Fraction run, Long run, the "Sag," and the Des Plaines valley. Distributaries occupy the transverse passages in the outer ridge, in the foreground.

Along each side of the Des Plaines valley above Lemont, gravels are to be found where artificial cuttings have been made. At Kellar's brickyards, a mile north of Willow Springs, a freshly cut bank sixty feet high shows stratified gravels and sands beneath ten to twenty feet of till. The gravels there may belong to a distinctly older interval than that which followed the last stage of glaciation.

The stratified gravels exposed in the upper part of the Des Plaines basin, on and near the Chicago plain, are chiefly in the form of beach ridges, spits, and other shore deposits of the extinct glacial, Lake Chicago. While to some extent they may be regarded as stratified drift, they were formed for the most part long after the ice had withdrawn from our district, and its influence on them was quite indirect. Like the gravels in aprons and deltas, they often show cross bedding.

THE JOLIET CONGLOMERATE.

At several places in the vicinity of Joliet, there are exposures of gravel firmly cemented by carbonate of lime into a conglomerate. Judging from its composition and its relations to the overlying Wisconsin till, this conglomerate represents one of the earlier interglacial epochs. The largest and most instructive exposure so far observed is at the east end of McEnty avenue, near the old wire mill, and on the north side of Spring creek (Plate 4, B.) The cemented gravels here are immediately overlain by late Wisconsin till. Another outcrop, better known, but of less significance, since it is buried by outwash gravels rather than till, and thus looks at first sight like a locally cemented mass of the late Wisconsin gravel deposits, occurs at the bend of the Michigan Central railway, a short distance west of the pumping station in Joliet. The rock also outcrops nearby on Cass street. A large amount of the conglomerate was excavated at this place a number of years ago. The ledge that remains, close beside the tracks, is some ten feet high. In the bed of Bush creek, in Reed's woods, the surface of the conglomerate is seen where the stream is trimming back a spur at the side of its ravine. On the map, Plate 7, "Cg." indicates this outcrop of the conglomerate. It looks as if the rock belonged under the till of which the bank is composed. The conglomerate here is of finer texture than usual, but in other respects seems to be like that at other exposures. As only a thin layer is exposed here, one cannot judge either of the extent or of the average structure of the entire mass that may underlie the bowlder clay in the bank. This exposure is about three and a half miles southeast of the one near Spring creek. In a railway cut on the Elgin, Joliet and Eastern railway, near Rowell avenue, in the extreme southeast part of Joliet, ten feet of till covers a coarse gravel deposit which is in places well cemented with carbonate of lime and limonite (hydrous oxide of iron). Nowhere else has a limonite cement been noted. This rock is doubtless the same formation as those mentioned elsewhere.

Another outcrop appears in the bluff on the east side of the outlet valley just north of Lockport, close beside the Chicago and Joliet trolley line.

A. Outwash terrace on Spring creek.

B. Fraction run above Dellwood Park.

This shows eight feet of the rock, with the lower limit not exposed. This exposure is about seven miles north-northeast of the Bush creek outcrop, and four miles north of the one at Spring creek. Talus, which appears in the bluff still farther north, near Romeo, looks suspiciously like the cemented conglomerate. Reports of a "hardpan" underlying the till along the line of the Chicago drainage canal, a mile or so east of Summit[1] suggest that the conglomerate covers even a wider area than that marked by the outcrops just mentioned. Doubtless as further search is made the known extent of the formation will be greatly increased, as well as the understanding of its origin. The following data concerning the Spring creek exposure was collected by Mr. C. E. Decker.

The conglomerate outcrops in a large artificial exposure beneath the till of the Valparaiso moraine (See Plate 4, B.) From the base of the till to the bottom of the excavation the exposure of cemented gravels is about eighteen feet. The overlying till is very compact, and chiefly composed of fine rock flour, with a moderate supply of small stones, some of which are striated and most of which are subangular. The stones of the till, classified according to composition and given in percentages, has already been given. The till is separated from the underlying conglomerate by a well defined plane of unconformity. The till immediately above the unconformity shows no signs of cementation. The surface of the conglomerate is smooth, though locally marked by semi-parallel ridges an inch or two across and rather faint in expression, yet distinct enough to convey the impression that they may be marks of the late Wisconsin ice sheet. They trend northeast-southwest. The surface does not appear to have been striated, however, nor do there appear to be any ridges of the shaly matrix of the conglomerate in the lee of projecting pebbles, where such ridges might be expected to develop. At the top of the cemented section is a dense shaly layer of rock, buff colored and thinly laminated in a horizontal plane. It seems never to be more than an inch or two thick. Beneath it come about six feet of horizontally bedded gravels, fine at the very top and moderately coarse below. The uppermost three inches are well cemented; below that is a zone of about a foot and a half of loosely bound gravels, and then again the firmly cemented material. Most of the pebbles in these horizontal beds are well rounded, although many are sub-angular. Below this six foot stratum come four feet of cross-bedded gravels of much coarser texture; more than one-half the pebbles in this are sub-angular to angular, and all are arranged flat side down on the inclined beds, which dip 25 degrees toward the southwest. They may be seen in the photograph, Pl. 4, B. Beneath this is a confused mass of angular blocks, cobbles and coarse gravel, containing bowlders two feet in diameter. The interstices are not all filled, leaving the gravel with an open-work structure. No bedding could be discovered. A large majority of the fragments of rock are angular, but none were found with striated sur-

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[1] Geological Atlas of the United States, U. S. Geol. Surv., Chicago Folio No. 81, p. 7.

faces. It should be said, also, that the degree of cementation varies locally in a horizontal direction as well as in a vertical. This gives rise to irregular projections and re-entrants in the cliff exposure.

A careful study was made of the pebbles in the conglomerate in order to determine the variety of rocks represented and the proportion of each. Without any choice as to size, one hundred pebbles were selected at random from a small space on the face of the cliff, and the pebbles were identified and counted. This was done at three places, with the results which follow. Since each set includes 100 pebbles, the figures for each kind of rock represent percentages.

Position.	Limestone	Chert.	Sandstone.	Granite.	Diabase.
Half way up cliff	83	7	3	4	3
At same level, within 10 feet of No. 1	87	6	3	2	2
Near top of cliff, and 50 feet away...	88	2	5	4	1

The table shows a pretty close agreement in the three counts, in making the limestone content about 86 per cent of the whole. The limestone and the chert are probably almost wholly derived from the Niagara limestone, the bed rock. Apparently, then, about 80 or 90 per cent of the gravels are of local derivation. The percentage of crystallines (chiefly granites and diabases, although some are probably to be regarded rather as gneisses) is very small, less than five per cent. But their igeneous character indicates a remote source for at least a part of the deposit. The crystallines probably do not exist in place nearer than the highlands of northern Wisconsin, some 300 miles away. All the large cobbles, bowlders and angular blocks seemed to be of limestone. The granites and diabases were well rounded pebbles of medium and small size, as would be expected from their having journeyed many times as far as the others.

The outcrop of the Joliet conglomerate at Lockport shows about the same proportions of different sorts of rock, with perhaps a slightly larger number of granite and diabase pebbles, say 5 to 10 per cent. No coarse, angular material is exposed there at the base. The rock is cemented just as firmly as at Spring creek.

It may be said that the percentage of local fragments (limestone and chert) in the cemented gravels is about the same as in the late Wisconsin till at the same locality for the latter shows about 78 per cent, as against the 86 per cent in the older material. The till was found to contain about 12 per cent of crystalline pebbles—a somewhat larger number than were found in the conglomerate at Spring creek.

On the basis of these facts, some conjectures may be formed concerning the origin of the Joliet conglomerate. That it is a glacial gravel deposit seems clear from the variety of rocks represented in the pebbles. No such collection would be at all likely to be made by any conceivable river or lake in this district. That it is older than the late Wisconsin drift is indicated by the fact that it is unconformably covered by the till of the Valparaiso moraine. It is of some significance also that the bedding of the conglomerate, close to the surface, shows no sign of folding or other disturbance. One would be inclined to infer that the gravels were already cemented when they were over-ridden by the ice, else their stratification would have been disturbed by pressure. The glaciated appearance of the surface of the conglomerate and the unaltered condition of the overlying till argues likewise for pre-Wisconsin cementation. Judging from the advanced state of cementation in which a well-nigh solid rock has been formed out of gravels, a time interval of very considerable length must have elapsed after the gravels were deposited and before the late Wisconsin glaciation. If the conglomerate is compared with the more recent outwash gravels, even those for instance in the outwash terrace opposite Lockport which show more than the usual amount of cementation, the alteration of the former obviously represents several times the amount of alteration of the latter, and we may infer that it is several times as old. Turning now to the conjectured time relation for the several glacial epochs,[1] we find that the interval since the early Wisconsin is estimated to be about twice the post-glacial interval, the one since the Iowan four times, since the Illinoian eight times, since the Kansan sixteen times, and since the Jerseyan a very much longer time. It seems probable, then, from the extent of cementation (and all that, perhaps, before the overlying till was deposited) that the Joliet conglomerate is at least as old as the Illinoian drift.

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[1] See Chamberlin and Salisbury, "Geology," vol. 3, pp. 413-414.

CHAPTER V.

PHYSIOGRAPHIC HISTORY OF THE LOWER DES PLAINES RIVER.

GENERAL DESCRIPTION.

The lower Des Plaines river follows a flat-floored, steep-sided valley, which was cut down across the broad Valparaiso morainic system by the large river that drained the Great Lakes during the closing stages of the glacial period. This valley, inherited by the Des Plaines from the ancestral river, the outlet of Lake Chicago, far exceeds the dimensions appropriate to the streams present size and sculpturing ability. With a somewhat devious course, the channel of the old outlet leads from the lake plain near Summit (See Fig 10) westward and southeastward through the broad upland belt of the Valparaiso moraine, uniting just beyond its outer border with the Kankakee river, on the broad, low plain of the "Morris basin." Between Summit and Lemont the river flows by a directly transverse course through the main moraine, and gathers scarcely any drainage except the direct run-off from the high bluffs on either side of the valley. But beyond Lemont its course is southward along the outer border of the main moraine, from which it receives a large number of tributary creeks. Of these, Long run, Spring creek and Hickory creek drain considerable areas in the interior of the moraine, and widen the drainage basin of the Des Plaines over ten miles on the east side. Beyond Joliet the outlet valley opens on the broad plain which surrounds the junction of the Des Plaines, Du Page and Kankakee rivers. The Du Page joins the Des Plaines so close to its mouth that physiographically it might as well be considered a direct tributary of the Illinois. Its basin is enclosed by the Minooka till ridge, on the west, and an outlying ridge of the Valparaiso morainic system on the east.

In addition to these larger features, certain details of geologic structure and physiographic form along the lower Des Plaines demand explanation—Among these may be mentioned: The relation of the extinct outlet to the bed rock, which rises to a considerable height in the bluffs at two places (Lemont and Lockport); the high level terraces of gravel, conspicuous at several points below Romeo, and terminating near the head of the Illinois at Channahon; a lower terrace of rock on both sides of the valley near Lockport, and the terraces of tributary streams.

In order to understand the physical features of the valley, we shall follow the development of successive moraines and outwash deposits along the retreating ice-border, the formation and the gradual extinction of ice-dammed lakes, and the steps in the cutting down of the great Chicago outlet.

DEPOSITION OF THE EARLY WISCONSIN DRIFT.

The early Wisconsin moraines.—The outline of the border of the Wisconsin ice-sheet in Illinois at the time of its greatest extent is

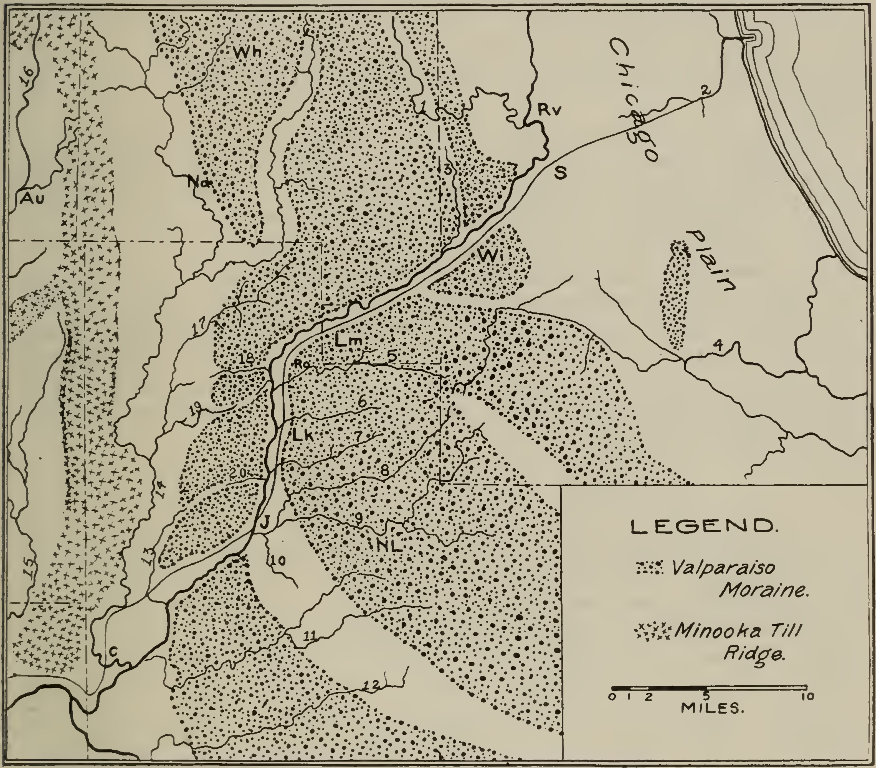

FIG. 10. Map of the lower Des Plaines river, showing towns, tributaries, and distribution of drift. Rv, Riverside; S, Summit; Wi, Willow Springs; Lm, Lemont; Ro, Romeo; Lk, Lockport; J, Joliet; N. L, New Lenox; C. Channahon; Wh, Wheaton; Na, Naperville; Au, Aurora; 1, Salt creek; 2, Chicago river; 3, Flag creek; 4, Calumet river; 5, Long run; 7, Fraction run; 8, Spring creek; 9, Hickory creek; 10, Sugar creek; 11, Jackson creek; 12, Prairie creek; 13, Rock creek; 14, Dupage river; 15, Ausable creek; 16, Fox river; 17, Buffalo creek; 18, Isle la Cache creek; 19, Mink creek; 20, Crystal run. Drift plotted from U. S. Geol. Surv., Monog. 38, by Leverett, with minor changes.

shown on the sketch map (Figure 6). Its position is marked out by the broad Shelbyville moraine, a continuous belt of drift built up along the ice margin, when, for a considerable time, the backward melting of the ice was more or less evenly balanced by forward motion, and the ice border remained almost stationary. When, through the influence of climatic change, the melting of the ice-front came to exceed its advance, the ice border was shifted northeastward. The Illinois lobe of the ice sheet contracted to fit the Lake Michigan basin. The withdrawal was slow and frequently interrupted by short returns of severer climate, during which the ice border became stationary, or even re-advanced slightly. Each time it halted it built a new morainic ridge, whose size is roughly proportional to the duration of the period of re-advance. Between the moraines the drift was spread out in gently undulating plains of till.

One of the most conspicuous of these crescentic moraines, the Marseilles moraine, lying just east of the Fox and Vermilion rivers, forms the semi-circular rim of the Morris basin—a broad, flat plain on whose eastern border the Des Plaines and Kankakee rivers unite to form the Illinois.

The lake in the Morris basin.—The retreat of the ice border from this moraine seems to have left a lake of considerable size in the Morris basin, which found its discharge over the lowest point on the morainic rim, near Marseilles. Beaches built along its shores indicate that its level was fully sixty feet above the river, or 650 feet above the sea. As the outflow cut its channel down through the moraine, it encountered the underlying bed rock at an altitude of about 560 feet. This probably explains the fact that the lake level remained stationary long enough for distinct beaches to be formed. Indeed, as will presently be explained, there is good reason to suppose that the lake was still in existence at the 560-foot level when the ice was making the Valparaiso moraine, ten or fifteen miles farther east.

DEPOSITION OF THE LATE WISCONSIN DRIFT.

The Minooka till ridge.—Following the development of the lake in the Morris basin, and before the construction of the next system of moraines occurred a shifting of the ice lobes in northwestern Indiana, as a result of which the late Wisconsin moraines overlap the earlier moraines in transverse position (See Figure 6). There was evidently a sudden growth of the Erie and Saginaw lobes of the continental glacier, a growth which pushed them westward over the territory which had formerly been occupied by the Lake Michigan lobe. The discordant relation of the two sets of moraines and the somewhat subdued topography of the earlier set have led to the separation of the Wisconsin epoch into an early and a late Wisconsin stage. In the district we have to consider, the Marseilles moraine is the last of the early Wisconsin moraines, and the Minooka till ridge; a small morainic ridge forming the east side of the Morris basin, is the first of the late Wisconsin moraines.

The Minooka till ridge, from the head of the Illinois river, where it is from 100 to 110 feet high, northward for fifteen to twenty miles, is "a single smooth ridge on whose crest and slopes there are few swells exceeding ten feet in height." It is scarcely two miles wide. "The ridge is crossed by two valley-like depressions, which unite near its western edge, in Sec. 13, T. 36, R. 8 E., and drain west into Au Sable creek. These are cut down to the level of the plain on the east side of the ridge. They apparently were formed by the discharge of water from the ice margin or ponded between the ridge and the receding ice front."[1]

South of the river only a few low, broken mounds and ridges of drift mark the continuation of the ice border at this stage.

The Valparaiso morainic system and its outwash.—The next stationary position of the ice border was one of long duration, resulting in the building of the highest and broadest of the morainic belts with which we are here concerned—the Valparaiso morainic system. This is a great U-shaped belt of drift that encircles the south end of Lake Michigan, with its course about twenty miles back from the lake. It is not a single ridge like the moraines just described, but a belt in which, in our district three parallel belts of morainic hills, separated by two narrow plains of drift may be distinguished. The other ridge separates the Du Page and Des Plaines valleys north of Joliet. It is itself separated from the middle morainic belt southeast of Joliet by a fainting undulating plain, which narrows as it approaches the State line, allowing the outer and middle belts to merge into one.

The outer ridge, north of Joliet, is cut transversely by three well defined channels, or scour-ways (as shown in Figure 10). One of these, crossed by the Plainfield road three m iles northwest of Joliet, is a broad, flat-floored sag nearly half a mile wide and four miles long. It is occupied by a marsh, which drains eastward through Crystal run and westward through Rock run. Moderate slopes on either side lead to the morainic upland. The floor is immediately underlain by bed rock, which is shown in small quarry diggings a mile east of the Plainfield road. At its eastern end, the floor of the sag finds continuation in a rock terrace of the Des Plaines valley above Joliet, near the Sprague school house. A few feet above the marshy floor, on either side, is a faintly defined sheet of gravel, which passes into a distinct terrace at the Des Plaines valley to the eastward. From these gravels and similar deposits in the Des Plaines valley at several points below Romeo it appears that the three sloughs north of Joliet, and the Des Plaines valley just below Joliet, were lines of discharge of glacial drainage while the ice rested against the outer belt of the Valparaiso moraine. Figure 8 illustrates this condition of things. As the ice withdrew to the position of the middle belt, the inter-morainic depression between Joliet and Romeo gathered the discharge of heavily loaded streams from the outer slope of the new moraine (See Fig. 9). Long continued aggrading with coarse gravels raised the level of the inter-morainic valley up to and above that of the transverse sloughs. Water from the ice then flowed through them and deposited trains of gravel or "outwash." At a still later time, after the ice had withdrawn from the Valparaiso

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[1] Leverett. Monograph 38, U. S. Geol. Surv., p. 319.

moraine and the outlet of a newly formed Lake Chicago found its way down the line of outwash, aggradation gave way to degradation. The floors of the transverse sloughs were reduced by the overflow from the main valley. The three sloughs north of Joliet were only slightly lowered before the streams encountered bed rock. The one in which the rock lay deepest below the surface (that south of Joliet) was degraded so much the more rapidly that it became the sole line of discharge of the outlet river, while the three rock-floored passageways north of Joliet became sloughs. During the lapse of several thousand years marsh growth has built up the floors of these sloughs and running water has somewhat smoothed down their side slopes.

The surface of the main belt of the Valparaiso moraine is more typically morainic than the one which passes west of Joliet, although its irregularity is nowhere so pronounced as to exhibit steep slopes comparable to the "kettle moraine" of Wisconsin or the terminal moraines of many other places. It is composed of numberless knolls and basins. So subdued are they that the eye hardly appreciates the range of undulation, which often amounts to 25 feet. Over the greater part of the moraine the knolls show a tendency to elongation parallel to the morainic belts, but on the inner border they seem rather to be elongated in the direction of ice motion. On account of the compactness of the bowlder clay of which the moraine is largely composed, little ponds and marshes are of frequent occurrence in the depressions of the moraine, and peat bogs of considerable thickness have formed in the deeper depressions. The cause of the rolling surface of the moraines has been explained on previous pages.

Between the middle and the east belt of the Valparaiso morainic system, is a rather well defined plain. Several large streams which join the Des Plaines between Romeo and Joliet head here in broad marshes: Long run and Spring creek in the township of Orland, and Hickory creek near Tinley park. The lower courses of these tributary valleys, from the points where they cross the middle of the morainic belt down to their junctions with the Des Plaines, were lines of aggradation for glacial streams during the whole time the middle moraine was being deposited (See Fig. 9). Together with the inter-morainic depression into which they ran, they were heavily aggraded with coarse outwash gravels. Patches of the old valley train of Hickory creek occur all the way from New Lenox down to Joliet, and patches of the valley train of Spring creek occur below Hadley. Where the valley trains head on the moraine, they partake of the rolling surface which characterizes the ice-laid drift, for these gravel deposits at the immediate border of the ice were subject to just the same causes of irregular concentration and re-arrangement as the moraine itself. But down the valleys their surfaces become as smooth as the flood plains of the present streams. East of Joliet a remnant of the valley train of Hickory creek forms a conspicuous terrace near the old red mill. Its gravelly constitution may be seen below the iron bridge, where the river is freshly trimming the terrace, or at the gravel pits beside the Rock Island railway, just west of Shaw's brick yards. On Spring creek, above the old wire mill, fine terraces of the valley train stand 35 feet above the present flood plain (Plate 5, A.) On the north side of the valley fresh cuttings show well stratified gravel, frequently cross-bedded, the constituents varying in size from cobblestones to fine sand. A natural section occurs a few hundred yards east of the wire mill, where the creek is trimming away the bluff. At the base of this section the compact, blue bowlder clay may be seen beneath the gravels.

The upper portion of the broad valley now followed by the Des Plaines between Mount Forest and Romeo, as well as the "Sag," which joins it above Lemont, were doubtless transverse depressions, like the valleys of Hickory creek and Spring creek, and were deeply aggraded with outwash gravels. They were the head of a system of valley trains, as indicated in Fig. 10. A main line of discharge, to which they were tributary, was the longitudinal depression between the middle and west morainic belts. The floor of this depression was evidently built up so high with gravels that the aggrading stream overflowed all four passes through the west ridge. At the upper end of the pass, near the Sprague school, a mile north of the end of the Hickory street car line, the outwash gravels form a flat terrace on the west side of the main valley. This is but a small scrap of the flat-topped valley train which once filled the entire valley. The heavy cobbly constitution is revealed in a pit north of Frank Sprague's house, where the road to Coyne's station rises from a rocky bench up to the outwash terrace. Another flat-topped remnant of the valley filling is on the west side of the valley, opposite Lockport, where the road to Plainfield leaves the valley floor. The flat surface of the terrace stretches westward several hundred yards, to the gently undulating slope of the moraine. A cut by the roadside shows the gravels to be locally coated and cemented with carbonate of lime. The incrustation on the pebbles attains a thickness of over a tenth of an inch (See Plate 3, No. 3).

The height (above sea level) of the outwash terrace at Lockport is 620 feet; near the Sprague school, 603 feet. The valley filling extended south and west past Joliet to Channahon, where it took the form of delta-like flats at the border of the lake which still occupied the Morris basin. Most of the filling was removed when Lake Chicago came into existence, and its great out-flow following the main line of glacial drainage, excavated for itself the present deep valley. Only occasional scraps were left, usually as terraces on the valley sides, like those described above.

On the north side of the Des Plaines valley, a few miles below Joliet, the outwash terrace is broad and conspicuous. The upper road to Channahon follows it for a few miles. Out in the middle of the valley is a great island-like mound known as "Flathead," which marks the former extension of the outwash terrace over the whole valley. This, the largest remnant of the valley train, rises about eighty feet above the water. It may have escaped erosion by the outlet river because of a protecting ledge of bed rock; for the rock rises in places nearly to the top of the mound. Joliet mound, near Rockdale, was also an isolated patch of the valley train, but it has been artifically destroyed.

It may be remarked here that the four transverse sags, or passages, across the outer ridge of the Valparaiso moraine lie about in line with four important valley trains from the middle morainic belt (Figs. 9 and 10). The slough between Isle la Cache creek and Plainfield lies opposite the transverse valley of the outlet at Lemont. The slough at the head of Mink creek is nearly in line with Long run at Romeo. The slough above Crystal run lies opposite Fraction run, and the tranverse valley of the Des Plaines at Brandon's bridge is a sort of continuation of the united Hickory and Spring creeks. While this relation of valleys may be purely accidental, it suggests that the position of the main rivers at the ice border was not much changed during the melting back of the ice front from the west belt to the middle belt of the moraine.

The east belt of the morainic system is separated from the middle belt north of the "outlet" by the valley of Flag creek and Salt creek. At Mt. Forest island and farther south its relation to the middle belt is more intimate; yet in places, especiallly near Tinley park, the two upland belts are divided by a smooth plain of considerable width. The contrast between the plain and the rolling morainic belts is well seen along the Rock Island railway. On Mt. Forest island, east of Willow Springs, the topography of the moraine is unusually rough. The knobs and hollows have a range of over fifty feet, and ponds are abundant.

EXCAVATION BY THE OUTLET OF LAKE CHICAGO.

Glenwood stage—Excavation of a trench in the valley train.—As the great lobe of the ice sheet melted back from the Valparaiso moraine there slowly opened up between the moraine and the ice a crescent-shaped lake, known as Lake Chicago (Fig. 11). The waters of this ice-dammed lake found their escape across the moraine through the converging arms of a V-shaped depression which led westward past Lemont and down the broad longitudinal valley between the main ridge and the outer ridge of the Valparaiso morainic system. No precise reason can be given for the presence of the two initial sags in the moraine which determined the two forks at the upper end of the outlet, on either side of Mt. Forest island. It should be recognized, of course, that accumulation of drift along the ice border was quite irregular, that the moraine was locally very weak, and that occasional transverse breaks in the moraines would probably be maintained by the escape of rivers fed from the melting ice. It is clear that the lower part of this valley, below Lemont, had for some time been occupied by a large and much overloaded glacial river. While the ice lingered at the moraine, the valley had been deeply aggraded with gravels, to the altitude of about 630 feet above sea level, at Lemont (Lm. in Fig. 10). The terraced remnants of this old valley train at certain places between Lemont and Joliet have just been described. While the valley train may have had its head near Lemont, in a sag in the main ridge of the Valparaiso moraine, it more probably extended eastward to the vicinity of Mt. Forest, where, during the last stand of the ice against the moraine, the escaping

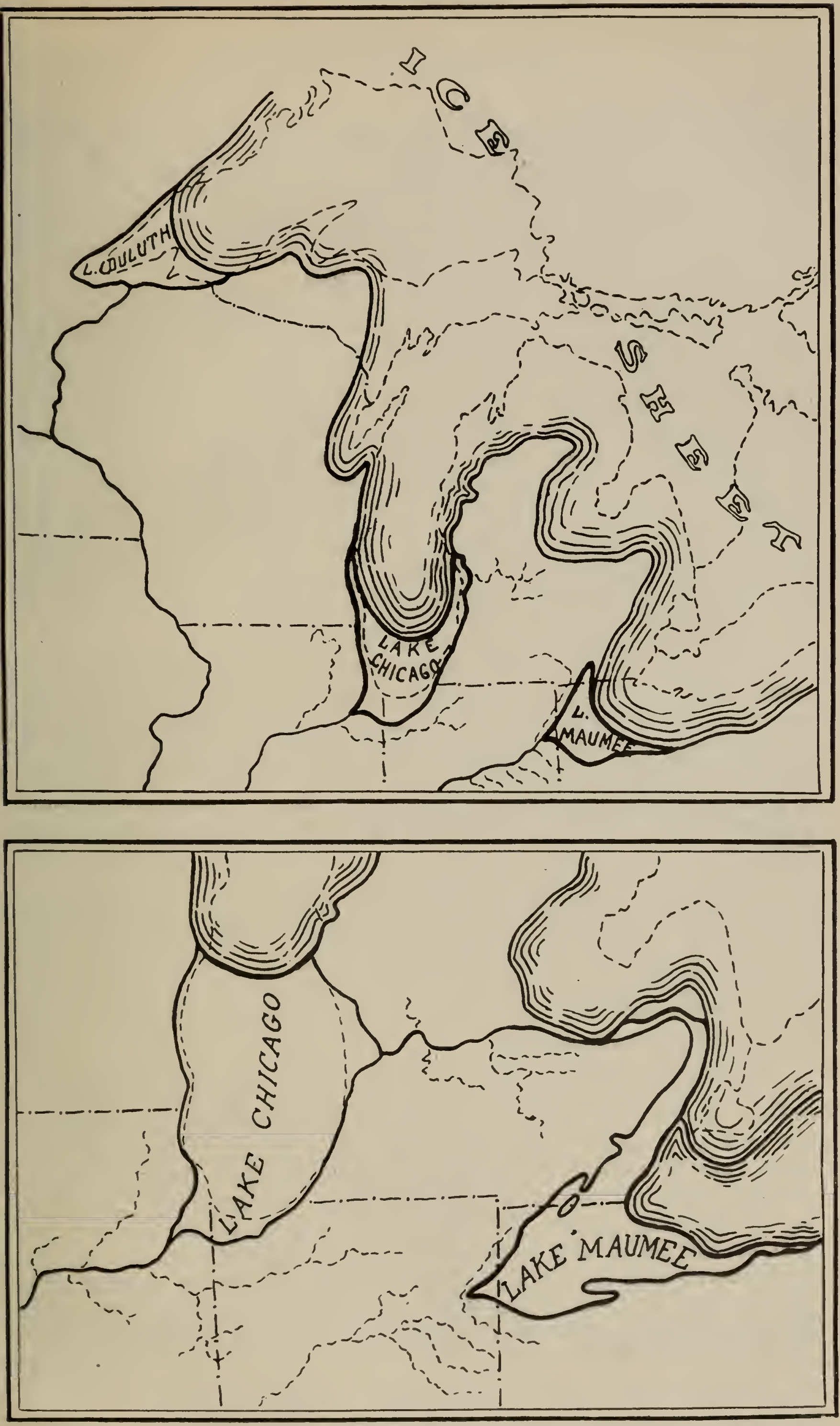

FIG. 11. Two stages of the glacial lakes Chicago and Maumee. (Leverett and Taylor.) The first might represent conditions in the Glenwood stage; the second in the Calumet stage. Notice the expansion of the lakes northward as the border of the ice receded, and the shifting of the outlet of Lake Maumee from Fort Wayne to the Grand river, as the lower pass was uncovered by the ice.

waters would be likely to maintain a flat-floored valley. With the development of Lake Chicago at the head of this valley, the character of the river was completely changed. The over-abundant supply of waste from the melting ice was now carried into the lake and left there. The river was thus relieved of its load, while suffering no diminution of volume, so it at once began to gather up the gravels it had previously laid down and thus to re-excavate the valley.

While Lake Chicago was extending itself northward, as the edge of the ice retreated (Fig 11) its outlet was cutting a wide trench in the valley train, and so slowly lowering the level of the lake. (This is shown in profile, in Fig. 12). Along the shore of the lake at this time waves and currents were busily cutting terraces and building beaches like those of the present shore, at a height which indicates that the water stood about fifty-five feet above the present Lake Michigan. The common occurrence of a set of parallel beaches whose crest altitudes range from 55 down to 50 feet above the present lake doubtless shows that the lake level was not exactly stationary, but was falling slowly as the outflowing river deepened its channel. This earliest and highest stage of Lake Chicago has been named the "Glenwood" stage, because its shoreline is very conspicuous near Glenwood, Illinois.

Calumet stage—The Lockport sill.—We may get further light on the history of the outlet from the lower beaches of this extinct lake. About twenty feet lower than the Glenwood shoreline, in the Chicago district, is a strongly developed beach called the "Calumet" shoreline. It marks a stage when the lake stood for a considerable time at the height of 30 or 35 feet above its present level. Below the Calumet beach is a group of shorelines, called the Toleston shorelines (from the town of Toleston, Indiana.) This includes a well defined beach, 20-25 feet above Lake Michigan, and a series of closely set ridges from 16 feet above the lake down to its level, which represents stages when the lake was falling from the Toleston level to that of the present Lake Michigan. Evidently the surface of Lake Chicago was not lowered steadily and uniformly from the 55-foot mark to the level of Lake Michigan, but went on interruptedly, halting for a considerable time at the 35-foot level, then falling rather suddenly to 20 feet, and then by several successive lowerings gaining its present level.

Reasons for these spasmodic changes in level seem to exist in the way the Chicago outlet was deepened. As the river cut down farther and farther through the gravels, it seems to have encountered a ledge of bed rock at Lockport, (Fig. 12, *a b c*), at a height of hardly 30 feet above Lake Michigan. Downward cutting of the valley floor was at once arrested, while the surface of the rock was widely stripped of its covering of drift and gravels. What seem to be remnants of this old rock floor or sill, which was formerly continuous across the valley, are flat topped terraces of rock in the village of Lockport and at a corresponding height on the west side of the valley near the Sprague school house. The surface of the rock terrace at Lockport is 30 feet above Lake Michigan. While the lake stood at the 35-foot level, therefore, the depth of the ancient river, close to its left bank, at Lockport, was not more than five feet. It seems probable that the surface of the rock sill (if one existed there) was lower than this near the center of the valley, and the river deeper than five feet there. On the basis of this supposed sill it is not hard to explain the manner in which it was worn through so as to cause a sudden drop in level of Lake Chicago. It would be natural for rapids to be established on the down-valley side of the sill, (at *a* in Fig. 12) perhaps near the head of Joliet pool, where the river passed from the hard Niagara limestone to the softer limestones and shales of the Cincinnati formation. Meanwhile on the up-valley side of the sill at Lockport, the river would be unable to cut its drift floor below the 30-foot level, and the lake would consequently be held at a level a few feet above the channel floor, or about 35 feet, while the rapids on the lower side of the sill would be wearing backward past Joliet (towards *b* and *c* in Fig. 12.) Had the Niagara limestone been less massive and uniform in structure, falls instead of rapids might have been developed, leaving, by their recession, a sharply defined gorge like that below Niagara Falls; but the structure of the rock at Joliet and Lockport probably did not permit this. Where the rapids were swift, a steep, straight bluff of rock was left facing the valley. This seems to have been the origin of the high bluff on the west side of the river at Joliet, between Exchange street and Theiler's park, and on the east side at Lockport, from Dellwood park to the north end of the village. For the greater part of the course, however, no striking gorge was produced. As the rapids receded up the valley towards Lockport, the distance across the sill became shorter and shorter. A sudden change followed when the rapids arrived at the very head of the sill (*c* in Fig. 12) and the last of the controlling ledge was removed. The drift floor above Lockport was degraded at once some 15 feet, down to the lower rock floor, and the surface of Lake Chicago fell correspondingly to the "Toleston" level. While the removal of the barrier and the fall of the lake should of course not be thought of as instantaneous, it would be sudden compared to the long time it would take for the rapids to eat back through the sill (from *a* to *c*) a distance of perhaps four or five times. It might well have caused the lake to drop so promptly from the level 35 feet above the present lake to a level 20 feet above it that no beaches were built between the Calumet and the Toleston.

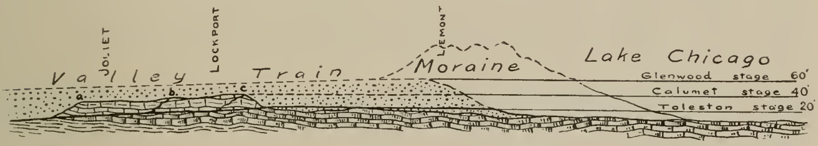

FIG. 12. Diagram showing how the removal of a sill of bed rock in the Chicago outlet, by "stoping," may have caused the sudden drop in level of the lake from the Calumet to the Toleston.

Toleston and later stages—Abandonment of the outlet, and substitution of the Des Plaines river.—In the course of time the border of the ice withdrew northward past the low region at the head of Little Traverse bay and past the Straits of Mackinaw, and Lake Chicago merged with a larger lake, Lake Algonquin, which then occupied the Huron basin. Although the history of this lake has not been fully worked out, it seems probable that at the time the waters of the Michigan basin became a part of it, Lake Algonquin stood at a very low level, discharging eastward through the valley of the Trent river near Kirkfield, Ontario. That region then stood much lower than now, and the surface of Lake Algonquin at that stage was probably considerably below the present level of Lake Huron and Lake Michigan. This low water stage was only a short one, however, for the northern part of the Great Lake region, including the Trent outlet, was soon raised, until the discharge of Lake Algonquin had been shifted to the St. Clair river at Port Huron. This brought the surface of the waters in the Lake Michigan basin up to about 12 feet above the present level. The series of changes which beset Lake Algonquin after this, as the ice receded and as earth movements warped the northern part of the surrounding region, are complex, and have not yet been fully worked out. It is enough here to remark that the waters in the Michigan basin remained long at the 12-foot level, returning to it after a second stage of low water that was probably even lower than the first had been. This was brought about by the uncovering of the "Nipissing" pass, east of North Bay, Ontario, which at that time stood very close to sea level, and by the subsequent uplift of that region and re-establishment of the outlet at Port Huron. At some time during these recurrent 12-foot stages of Lake Algonquin and the Nipissing great lakes, the shallow Chicago outlet was shut off by a long reef of sand which can be traced through the Chicago district from Lincoln park to South Englewood. The discharge of Lake Algonquin and of its successors, the Nipissing great lakes, came in this way to be concentrated at Port Huron, where the outflow was across glacial drift instead of across hard rock.

Thus the Chicago outlet was abandoned. In place of the great river whose volume was perhaps comparable to that of the St. Clair river today, was left the little Des Plaines, a stranger in the district, which straggled into the great valley as if by accident. Extending its mouth out on the flat plain south of Riverside as the lake fell and its shore moved eastward, the Des Plaines seems almost to have had a free choice between a course to the Mississippi or to the St. Lawrence. During floods, if not at ordinary stages, the river used to discharge a part of its volume eastward to the south branch of the Chicago river. The slough, "Mud lake," (See Fig. 19), which marks the old channel, may for a time have carried the entire river out towards Lake Michigan. What caused the channel to silt up and the river to turn westward near Summit is not known. Perhaps, as Mr. L. E. Cooley, consulting engineer of the Internal Improvement Commission, has suggested, a small colony of industrious beavers, building a beaver-dam, were responsible. Whatever the reason, the Des Plaines finally found its way westward; and as a result the valley of the extinct outlet has not been left wholly unoccupied by drainage, but serves as a valley for a river several sizes too small for it. At Romeo, large pot-holes in the rock floor of the valley near the Des Plaines river tell the story of the deeper and more powerful river of ancient times.

The amount of erosion that the Des Plaines has accomplished in its straggling course on the valley floor is very slight. Even between Romeo and Joliet, where the steeper grade of the rock floor produces rapids in the river, its channel is low and ill-defined. Expanding and contracting as it enters and leaves shallow hollows on the outlet of the floor, branching and uniting about low islands which are not bars of its own construction, turning to right and left in its course down the valley, yet at no place (above Joliet) approaching near enough to undercut the bluffs as they must once have been undercut, and occupying usually less than one-tenth of the width of the valley, the Des Plaines is manifestly an incompetent river. The valley it follows is not its own, but one which it inherited.

EROSION BY TRIBUTARIES.

Fraction run.—It is interesting to see what the tributary streams were accomplishing while the great outlet was being excavated. As an example of tributaries which enter the outlet midway of the supposed rock sill, we may take Fraction run, which joins the Des Plaines between Lockport and Joliet. Like the main valley, this tributary was aggraded with gravels while the ice lay against the Valparaiso moraine. Remnants of a smooth-topped valley train remain in terraces on either side of Fraction run, in and above Dellwood park. The Chautauqua building stands on this terrace. Beyond the park fence, a short distance up-stream, broader and better remnants of the outwash terrace, with gravelly constitution, are to be seen on both sides of the run, at a height of 15 feet above the present valley floor.

During the Glenwood stage of Lake Chicago, while the ancestral river lowered its channel in the gravels down to the surface of the rock sill, its little tributary did the same. Fragments of the outwash were left as terraces standing above the rock floor of the run. While the rapids on the down-valley side of the Lockport sill were receding northward from Joliet towards Fraction run, the small side stream was adjusted to the level of the sill at its mouth; but as the rapids migrated up the main valley past the mouth of the tributary the side stream suddenly found itself tumbling over the face of a gorge, the perpendicular wall of rock which overlooks the old canal near the entrance to Dellwood park. The diagram, Fig 13, illustrates this process. The waterfall thus given to Fraction run must soon have been reduced to a series of rapids, for limestone of so uniform a structure, would not permit falls to be long maintained. By the recession of the rapids up the run, a steep-walled gorge was cut in the rock. At its mouth the gorge is equal in depth to the cliff cut by the main river in the sill, but toward the head of the gorge its depth decreases. Where so coarse a load is gathered and must be carried by the stream, it is forced to maintain a steeper slope than that of the old bed rock surface. In the park the bed of the stream has been obscured by the construction of two dams to form artificial ponds. Near the high cement bridge the gorge is cut about 20 feet deep in rock. The limestone there is thin-bedded, cherty, and very much cracked by joint planes. Just above the bridge, near the upper dam and the trestle of the scenic railway, is a fine natural exposure of the limestone, coated with lichens. The overhanging cliff is due to a slightly inclined joint crack. The strata dip 10° to 15° toward the southwest, with local warpings. One may see here the way in which the much jointed rock on the cliff face is wedged and loosened by frost and decay, falling, piece by piece, into the stream. Should the process seem too slow to account for the sculpturing of the gorge, we must remember that the age of the gorge is to be measured, not in tens, but in thousands of years.

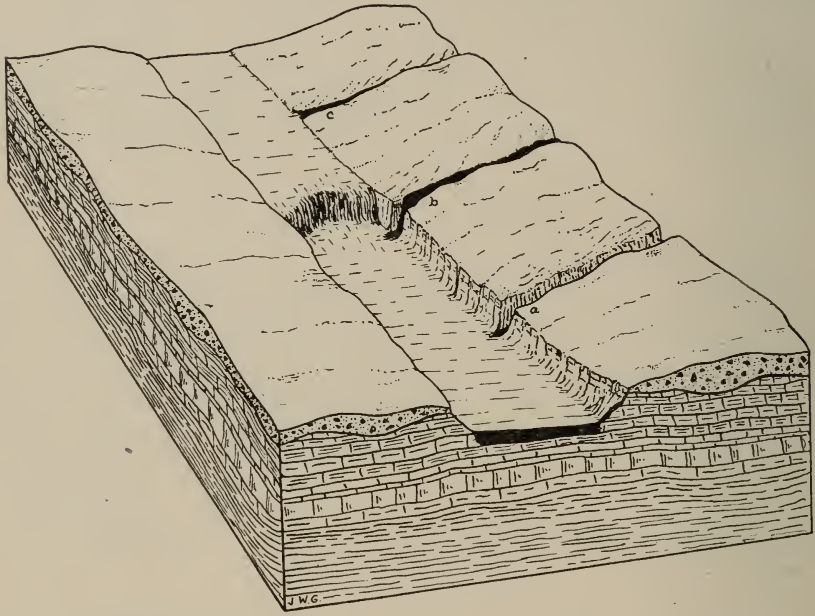

FIG. 13. Diagram illustrating the way in which the up-river valley migration of falls or rapids on a river affects its tributaries. The falls have been worn back from near the front of the diagram past tributaries *a* and *b*, and are now approaching *c*. When they pass *c*, the mouth of the side stream will be suddenly lowered from the level of the crest of the falls to that of the base, forming a fall or rapids there. This has just occurred at *b*. These falls or rapids will then recede up the side valley, forming a branch gorge. This stage in the process has just been reached at *b*, but has been passed at *a*.

Farther up the run, beyond the park fence, one may see in its natural condition the rocky channel of the stream at the shallow head of its gorge. A long string of riffles and pools formed by the step-like bedding planes illustrates remarkably well, though on a small scale, the ungraded condition of a young stream. Here also is a precipitous 60-foot bluff, where the run has swung against the north side of its valley, destroying the outwash terrace and trimming back the moraine and the underlying rock (See Plate 5, B.) The valley floor above the park is broad and flat, built of loose rubble which the stream has torn from its banks. It appear to have been the flood plain of the creek when it was adjusted to the level of the rock sill, and to have been only slightly trenched by the channel since the development and headward extension of the rapids up the run. Opposite the high bluff, on the south side of the valley, a broad flat remnant of the outwash terrace, 15 feet above the present valley floor, runs from the northeast corner of the park upstream several hundred yards, and there finds continuation in a broader terrace on the north side of the valley.

Long run and other tributaries above the sill.—Two sets of terraces occur along the run. The higher is an outwash or valley-train terrace, to be correlated with the Glenwood stage of Lake Chicago, and the lower one is a terrace adjusted to the rock sill at Lockport, contemporaneous with the Calumet stage of the lake. Where Long run enters the main valley, a mile south of Romeo, the two terraces alluded to may be seen from the trolley car. The outwash terrace is about 30 and the lower terrace, 12 feet above the creek.

Other tributary ravines which enter the upper portion of the outlet between Willow Springs and Lemont, sometimes show two terraces. One of these is a large ravine a mile and a half east of Lemont (in sections 22 and 27, Lemont township). The two terraces appear near the mouth of the ravine, in plain sight of the road that runs south from the school house. The higher stands about 30 feet above the present flood plain and the lower 15 feet above it. Only a few remnants of the higher one remain, but the lower one may be followed interruptedly far up the valley, where the present flood plain gradually rises to meet it. Judging from the interval between the old flood plain remnants and the present floor of the ravine, near the main outlet, the higher terrace corresponds with the Glenwood and the lower with the Calumet stage.

Ravines cut by streams which entered Lake Chicago along the north shore at Glencoe, Waukegan, and Zion City, show terraces at the same height as the ravines which entered the outlet above Lockport. They obviously mark repeated lowerings of the lake, which correspond with repeated deepenings of the river.[1]

Spring creek and Hickory creek.—Both Spring creek and Hickory creek were aggraded with valley trains, like Long run; and since they are larger streams they have even more conspicuous outwash terraces than it has. The lower terrace seems to be absent here, however, this suggests that these creeks may have joined the main river below the Lockport sill, so did not have to adjust their floors to a temporary rock barrier.

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[1] For a description of these ravines, and a discussion of their significance, see Bull. 7 of the Ill. Geol. Surv., on the "Physiography of the Evanston-Waukegan District," by W. W. Atwood and J. W. Goldthwait, pp. 69-84. 1908.

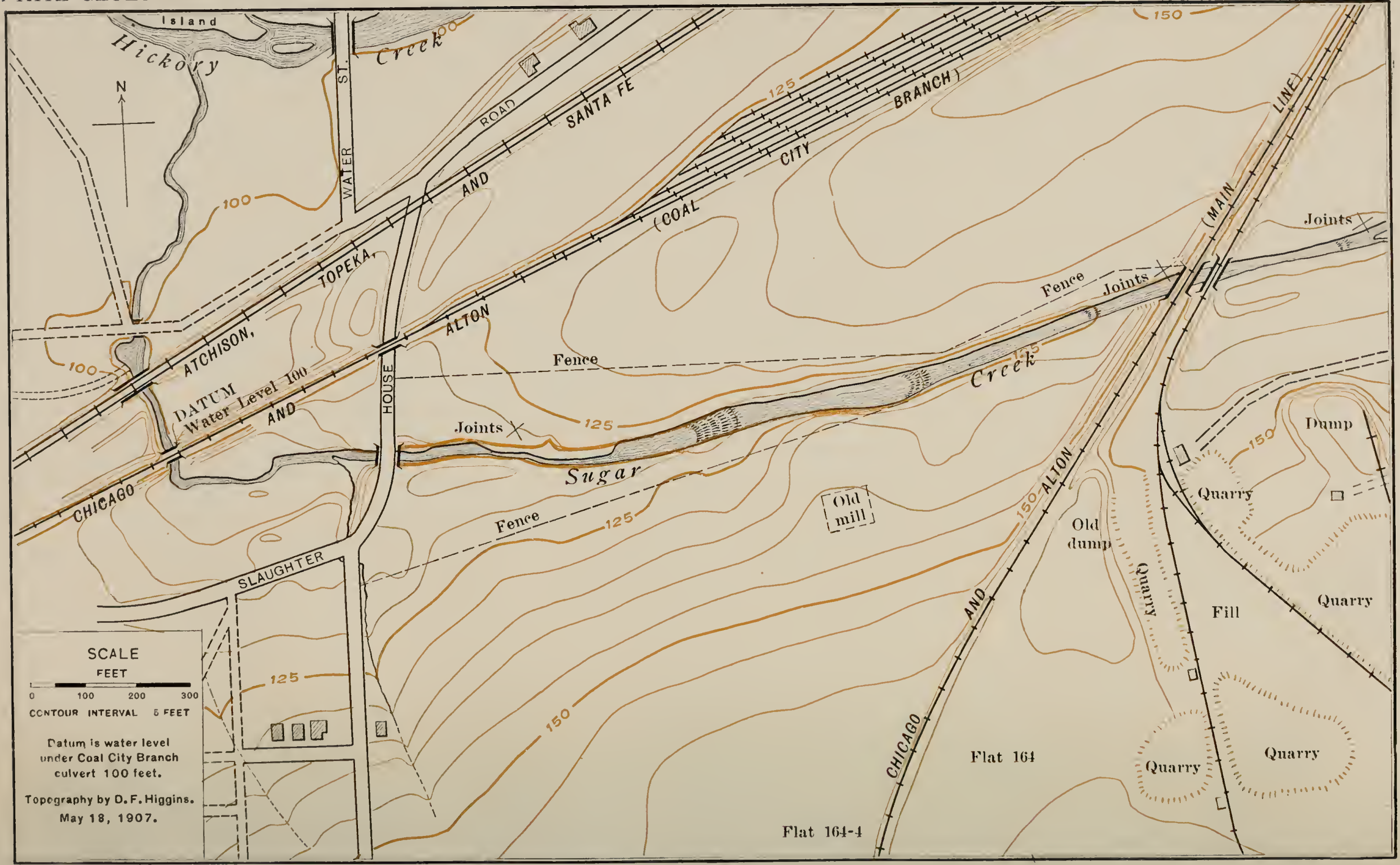
Sugar creek.—Unlike the other tributaries near Joliet, Sugar creek has had to cut down its channel in bed rock; for the Niagara limestone there rises higher than on Hickory creek.

Accordingly, it has worn out a narrow gorge in the flat-bedded limestone from the Chicago & Alton railway bridge down to the slaughter house road, near the old tin-plate mill (See the map of this gorge, Plate 6.) The gorge is nearly 15 feet deep, with vertical cliffs cut out along joint cracks and a rock floor broken by a long succession of little rapids, where the edges of the harder, cherty beds offer greater resistance to erosion. These little water-falls (for such they are, except when the stream is flooded) frequently cross the gorge; not in a straight line, but in a curve, which is concave down stream on account of the more rapid recession in the middle, where the current is faster than at the sides. In this regard they imitate the great Horeshoe falls of Niagara, which, as it happens, plunge over the very same limestone formation. In the pools between the rapids, one may see in low water the chipstone waste that is being swept down stream during each flood. The discoidal or tabular blocks and pebbles (even the larger slabs which have been banked up by the boys to form a swimming pool, and then moved by the creek, in floods) lie packed like the overlapping shingles on a roof, slanting up stream. The shingle structure is even more impressively shown on Hickory creek, below the old red mill, where the freshet of February, 1907, scattered large tabular slabs and chips of rock far and wide over the flood-plain.

The jointed walls of the gorge of Sugar creek offer favorable opportunity to study the manner in which joints aid or direct stream erosion along definite lines. The bare walls, faced by joints, permit no doubt as to the advantage taken by the stream to tear away the limestone, block by block, as the workman does in quarrying. At the same time, it is clear from the course of the creek, which runs oblique to the two master systems of joints in such a way that the walls of the gorge have a zigzag, rather than a straight course, that while joints aid the stream they may not direct its work along definite lines. Instead of running parallel to either of the two prominent sets of joints, the gorge of Sugar creek bisects the angle between them. On the map, where the direction of the joints near the gorge is shown by a symbol, the discordance between the joints and the trend of the stream comes out plainly.

Reed's woods ravine.—One of the prettiest and most instructive examples of excavation by a tributary in the glacial drift is the ravine in Reed's woods, above Bush park (See Plate 7). There are several features to be observed here which, taken together, cannot fail to convince one that this deep ravine and its tributaries have been carved out wholly by the activity of rain and running water.

In the first place, the behavior of the creek and its little tributaries during wet weather is significant. The main channel at such times may be filled brim full or even to overflowing, so that the little flood-plain which forms the floor of the valley is under water. In its swollen condition the stream may be seen to carry fine sediment in suspension and to roll sand and fine gravel along the bed of the channel. Around the



Map of the Gorge of Sugar Creek.

outside of every sharp curve—and there are many such—the stream has cut away its bank. At points where the channel swings against one side of the valley, bare slopes of glacial drift may be seen, several feet high and very steep. After a rain it is not unusual to find little pillars of clay, capped by pebbles or other protective objects, around which the rain has excavated the fine clay. Obviously, with the washing away of soil from exposed side slopes and from the channel bank the ravine is changing form, be it ever so slowly.

Material thus obtained is washed into the stream and swept down-valley (except such large pebbles and bowlders as cannot be moved), to be deposited sooner or later in the channel on the inside of some curve, often directly opposite a place where cutting of the outer bank is going on. It is by this "cut-and-fill" process that the flood-plain has been built, for even now it is being broadened by the extension of deposits on the one side and by lateral erosion on the other, at those points where the channel swings to the extreme border of the floor. In the freshly exposed channel in dry weather may be seen the stratified structure of the flood-plain, due to its having been built up under water by sediment transported by the stream. Each variation in volume of the stream means a variation in its carrying power; hence it is repeatedly depositing a layer of different texture from the preceding layers. The surface of the flood-plain is, indeed, merely a part of the waste material that is gathered up by the creek and its wet weather branches and is just now on its way down to the valley of the Des Plaines. Not only will the stream gather sediment from either side, but it will pick up material from the bed of its channel during each flood, and the channel floor will be lowered thereby. Judging from the rate at which the waste is moving down the fllood-plain-path—a slow rate, to be sure, operative only in wet weather, yet a perceptible one—we may believe that in the thousands or tens of thousands of years during which the drift has been exposed to running water, a ravine as large as this has been excavated. The process of transportation must needs involve excavation. The ravine, then, is constantly growing deeper as the stream cuts downward along its bed, and wider as the stream planes away the border of its flood-plain, and rain washes down the side slopes.

In this connection it is worth while to consider the effect which excavation has at the head of a ravine. Examine, for instance, the extreme upper end of some little side ravine or gully (selecting, of course, one in which the natural conditions have not been upset by artificial drains or rubbish heaps.) The one in Plate 8, A, for instance, is a straight, steep-sided gully, usually without sod, exhibiting the sharp outlines of a recently rain-cut surface. When it rains, the water which falls in this gully and that which is shed into it cuts down its steeply inclined bed and thereby cuts back its head. The deepening and the headward growth of such a gully are inseparable. Thus, while the water is running from the head toward the mouth of a stream, the stream valley and, consequently, the stream itself, wear headward, or, as it might seem, backward. The exact direction in which the gully works back is determined partly by inequalities of surface slope—for a depression which concentrates the run-off and delivers it to the gully will cause the gully to lengthen in that direction; and partly by inequalities in structure of the ground, for if hard and soft materials lie side by side, the running water will select a path along the soft belt. Even foreign obstruction like tree roots or large bowlders serve to turn a young valley to one side, and perhaps wholly change its future course of growth. Here then, at the extreme head of a ravine, we may see the work of excavation in its infantile stages. The difference between the head-water gully and the full grown main ravine, is one not of kind, but of size. This stream has only recently worked back to the gully head, and there its volume is exceedingly small; consequently very little excavation has been accomplished. The main ravine, however, began long ago to be cut out by the growing stream, and with its growth the size and power of the stream has been increased at a more and more rapid rate.

Another feature that demands attention is the straightness of the young gully. It is a matter of easy observation that an enlarged gully

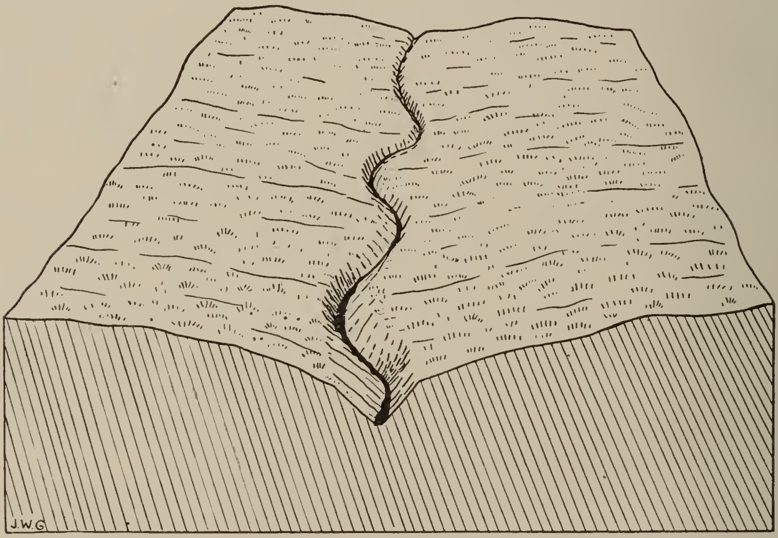


FIG. 14. A crooked gully in an early stage of development.

or small ravine like the one which enters Rush creek from the north in the center of Reed's woods (See Plate 7), follows a crooked path on its way down to the main ravine, bending back and forth between a series of projecting spurs. Where developed under favorable conditions, these bends may be exceedingly symmetrical and evenly spaced. Careful inspection and legitimate reasoning show that they represent irregularities or crooks in the incipient gully which have been enlarged and modified until they approach conventional curves as small accidental obstructions become less and less effective and the minor crooks

Map of the Ravine in Reed's Woods.

are eliminated (See Figures 14 and 15.) While the curves which survive in this growth are slowly enlarged by outward cutting, they begin to shift distinctly down-valley. The explanation of this lies in the fact that wherever a stream winds around a spur it cuts a little more strongly against the up-valley side of that spur than on the down-valley side of the spur next above. Thus, while the stream curves push their way slowly down-valley, and the spurs are slowly consumed by the trimming away of their up-valley sides, the valley itself is widened, and soon the beginnings of a flood-plain may be seen. The main ravine (that of Bush creek on the map, Plate 7) has passed through exactly these stages of growth. It has not only been deepened 25 feet below the upland level, but by the lateral swinging of the creek it has been widened about 150 feet. At the same time, by the down-valley shifting of its curves, the original spurs have been half trimmed away. The map shows plainly the manner in which the creek is attacking the up-valley side of three half-consumed spurs in Reed's woods. Obviously this is not an accidental but a systematic relation. At these points the steep bank of the ravine is bare where the stream has recently been undermining it. Perhaps a tree leaning over the creek at a precarious angle tells the same story of the continued activity. What better explanation for these phenomena than that the ravine is being and has been cut out by the creek? How else, indeed, can such a group of facts be accounted for? If there should still be doubt regarding the ability of so small a creek to excavate so large a ravine, we must consider the

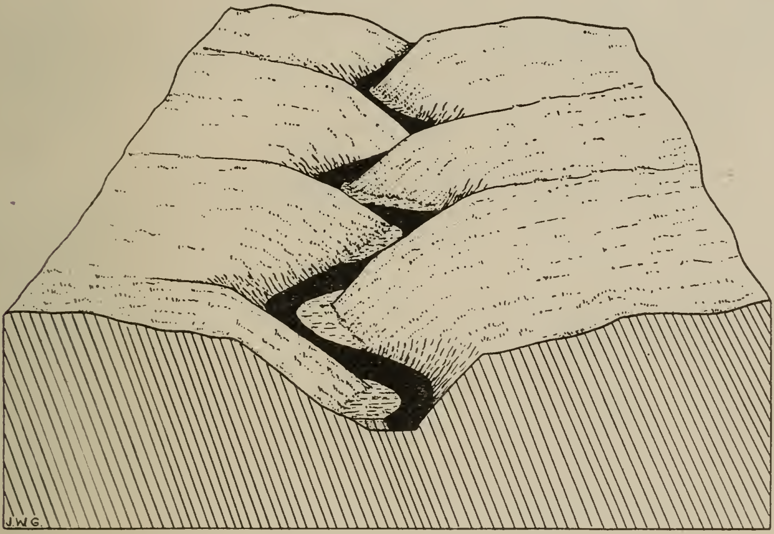


FIG. 15. Same gully as in Fig. 14, in a later stage. As the gully has been deepened by the growing stream, the crooks and bends have become larger and more conventional. A series of overlapping spurs has been formed. On the outside of each curve and the up-valley side of each spur the stream is actively trimming its bank. On the inside of each curve and the down-valley side of each spur it is building a flood plain.

statement of an old-time Scotch geologist, John Playfair, who. calling attention to the manner in which side valleys of a river system join the main valley, declared, in 1802, that side valleys have "such a nice adjustment of their declivities that none of them join the principal valley either on two high or too low a level; á circumstance which would be infinitely improbable if each of these vallies were not the work of the stream that flows in it."[1]

This feature, as well as the others, is illustrated in the Bush creek ravine. They are not "ready made" valleys; fashioned for the streams: they have been slowly and laboriously cut out by the streams themselves, and testify to the changes which can be wrought out in long periods of time. This creek, it might be remarked, is probably some thousands or tens of thousands of years old. [2]

Before leaving this ravine a few minor points should not be overlooked. The process of downward excavation seems to have been arrested at least once; for there are fragments of the old valley floor now in the form of terraces, on the down-valley side of spurs, at a height of about eight feet above the present flood-plain. Whether this terrace corresponds to the stage when the Des Plaines valley was aggraded with the valley train or to some subsequent stage of temporary interruption of the process of excavation cannot confidently be told. The amount of work accomplished by the creek in cutting down to the level of the terrace seems to indicate a later stage than that of the outwash filling. If so, either the Lockport sill extended down-valley as far as the mouth of the creek, or there was some other obstruction in the valley to hold the tributary for a time near a local base level. The presence of terraces at various levels around the base of Flathead mound, a few miles farther down the Des Plaines valley, suggests that even down beyond the Lockport sill the old outlet of Lake Chicago reduced its channel by successive stages. Another small feature of the basin in the Bush creek ravine is an outcrop of cemented gravel, or conglomerate, in the bed of the creek, where it is cutting against a long spur ("Cg." on map). Probably this conglomerate underlies the glacial drift all about here, as it does in the northeast part of Joliet and elsewhere.

ALLUVIAL FANS AND CONES.

Since the outlet of Lake Chicago stopped flowing and its valley floor is all but abandoned, the excess of detritus brought down by the tributary streams has in many places built up distinct fans and cones. One of these, near Joliet, a broad, flattish fan of sand, may be seen at the mouth of a small ravine which issued from the high bluff, half a mile northeast of the penitentiary. Were the old outlet restored, it would collect all this waste and carry it down the valley; but without a full sized river to receive and transport the ma-

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[1] "Illustrations of the Huttonian theory of the earth," p. 102, 1802.

[2] The post-glacial interval during which the surface of the "Wisconsin" drift has ben exposed to stream development seems to be somewhere between 20.000 and 60.000 years long. (Chamberlin and Salisbury's "Geology," Vol. III. p. 420.) This portion of Illinois was uncovered by the ice sheet soon after it began to retreat, for the terminal moraine of the last great ice advance lies only a few miles west of Joliet. Hence the drift surface here may have been uncovered 50,000, or at least nearly 20,000 years ago.

terial, the tributary, when swollen by floods, is forced to drop its load where it debouches on the flat valley floor; and in so doing it is choked and split into innumerable distributaries, after the fashion of fan-building streams. If we knew just how much sediment was being brought down by this little tributary each year (probably almost wholly during severe floods, and knew the total volume of the fan, we might obtain from it a rough measure of the number of years since the outlet stopped running—rough, because the rate of growth of the fan has probably varied much from time to time.

A group of three well marked cones may be seen along the base of the steep 80-foot bluff beside the trolley road half a mile southwest of Willow Springs. They rise with moderately steep slopes thirty feet above the road, where each has its apex in a steep, narrow ravine. The longest of the cones is some fifteen rods from apex to base.

These cones and fans exemplify on a small scale the alluvial deposits which border the great valley of California, where, with a rich soil and ideal facilities for irrigation, the fans have been transformed into great fruit orchards.

CHAPTER VI.

PHYSIOGRAPHIC HISTORY OF THE UPPER DES PLAINES RIVER.

DEPOSITION OF THE TILL RIDGES.

In the preceding chapter it has been explained how the great U-shaped belt of upland which encircles the south end of Lake Michigan—the Valparaiso moraine—was built up under the edge of a tongue of ice which occupied the lake basin. So long as the melting of the ice, at the border of this tongue or lobe, was only fast enough to balance the forward movement of the ice mass, the ice border was nearly stationary; and all the rock debris, or "drift," that was carried forward to the edge of the glacier was banked up to form the moraine. At length the climate moderated somewhat, and melting came to exceed advance. The Lake Michigan ice lobe shrank back toward the center of the lake basin—not steadily, however, but spasmodically. Several times the ice front halted in its retreat, and each time it built beneath its edge a broad ridge of till, lower and smoother than the Valparaiso moraine but like it in origin. Thus there grew up in Cook and Lake counties three successive till ridges of the "lake-border morainic system," between the Valparaiso moraine and Lake Michigan. Between them were lowlands of exceedingly faint relief.

In Racine and Kenosha counties (Wisconsin) the lake border ridges are five in number, but passing southward into Illinois they merge to form three (See Fig. 1.) They do not continue around the south end of the lake, but terminate in Cook county, as shown on the map; the inner, or east ridge, at Winnetka; the outer, or west ridge, north of Oak park. In Indiana and Michigan, however, they reappear inside the Valparaiso moraine. The outermost of the lowland belts between the west ridge and the Valparaiso moraine forms the basin of the Des Plaines river, above Oak Park. There the ending of the west ridge allows the Des Plaines till plain to open upon the broad Chicago plain.

In detail of relief, these border ridges are very weak. Instead of the marked knob-and-kettle topography of typical terminal moraine, their surfaces present low, undulating swells and sags, faint knolls and shallow sloughs. Only when followed for a long distance or plotted on a map is the ridgelike character appreciated, so gentle are the lateral slopes. At Park Ridge, for instance, the outer moraine is about two miles broad, and its crest only twenty-five feet higher than the till-plain of the Des Plaines valley. The west slopes of the till ridges are somewhat more pronounced than the east ones. As the ice border receded and these till ridges, with their intervening lowlands, appeared, a new drainage system began to develop. At first, doubtless, the streams which flowed through the depressions were burdened by outwash from the ice, and started to form alluvial plains or valley trains like those of the lower Des Plaines valley, described in Chapter V, and Figs. 8 and 9. The depression between the east and middle belts of the Valparaiso moraine, now followed by Salt creek, above Fullersburg, and by Flag creek below, was doubtless occupied thus early by streams. Probably the singular bend of Salt creek at Fullersburg (See Fig. 10) was gained at this time, through an initial depression which ran transverse to the east ridge and had been an avenue of glacial discharge like the sag in the west ridge north of Joliet (See Fig. 8), or like those above Lemont, though less marked.

The right-angled turn at Fullersburg, by which Salt creek leaves the inter-morainic depression close to the head of Flag creek has drawn the attention of writers on the geology of the district, at various times. The relation of the two streams resembles that which frequently results from "river piracy," the capture of the upper portion of a stream by the headward extension of a more rapidly growing and more deeply entrenched neighboring stream. The more rapid growth of the "pirate" is usually attributed to advantage from a shorter, steeper course, or of a weaker rock structure to encounter, or of a larger volume (perhaps because of heavier rainfall.) In the present case, it might seem that the upper part of an ancestral "Flat creek," which followed the lowland southward past Fullersburg, was captured by the headward growth of a transverse stream which had begun its growth on the east slope of the moraine, (i. e., the present lower course of Salt creek). The upper part of this ancient Flag creek, above Fullersburg, would thus become a part of Salt Creek, and would be diverted into the Des Plaines at Riverside, while the lower part of it would be left in a beheaded condition, the Flag creek of today. No positive evidence, however, of river capture at this place has been found; nor does there seem to have been any reason for piracy. Salt creek, below Fullersburg, seems to have had no advantage over Flag creek, either as to the length of its course or as to the structure it encountered. So the rather singular escape of Salt creek from the broad valley seems to be best explained merely as one of the freaks of glacier-made drainage, inspired by an irregularity of the newly exposed surface of drift.

LAKE CHICAGO.

GLENWOOD STAGE.

While the ice sheet was withdrawing from the Valparaiso moraine to its next position, waters gathering along its border in the Chicago district began to assume the outline of a crescentic lake, glacial Lake Chicago (Fig. 11.) The overflow of this lake escaped across the Valparaiso moraine along the line of the lower Des Plaines valley.

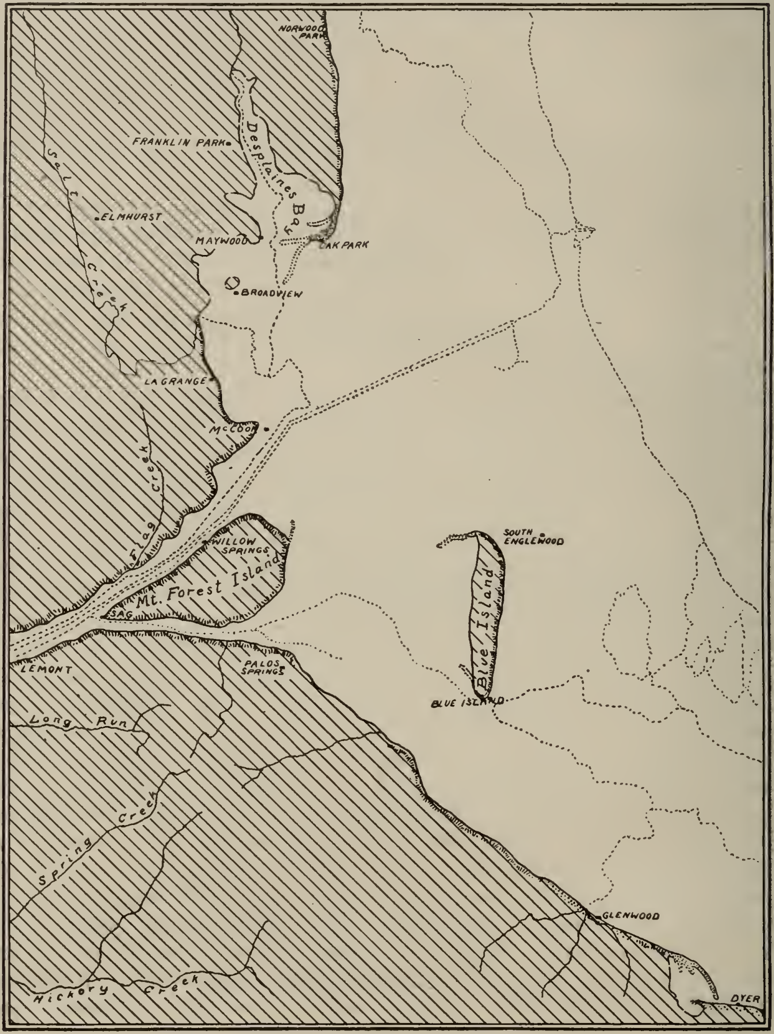

FIG. 16. Part of Lake Chicago during the Glenwood stage (copied, with some modification, from Alden). Outline of Des Plaines bay inferred from the 50-foot contour on the map of the Sanitary district. Hachures show wave-cut and river-cut bluffs; dots show beaches and spits.

A long shallow arm of the lake, two or three miles wide, reached northward from Oak Park up the depression between the west ridge and the Valparaiso moraine to the vicinity of Franklin park (Fig. 16). Further north the inter-morainic depression was probably a long slough, on which the upper Des Plaines, fed largely by the melting of the ice to the north, and subject to overloading with waste, followed an ill-defined, "braided" course. As the ice border melted back, leaving this long bay or slough, outwash gravels accumulated on its floor to a depth of several feet. These deposits of stratified gravel are from 10 to 12 feet thick near the village of Des Plaines. A thin overlying sheet of brown sand, used as moulding sand at the iron foundry, may record the change from the overloaded, glacier-fed stream to the normal stream of diminished volume and load, which followed the withdrawal of the ice from the vicinity. Although the shallowness of the bay prevented the development of recognizable shore topography, its boundary may be considered to follow the contour which is fifty feet above Lake Michigan, for that is about the altitude of Lake Chicago at its earliest stage, judging from the altitude of well defined beaches in the Chicago district.

The largest stream tributary to the bay at this highest, or "Glenwood" stage was doubtless the upper Des Plaines, which seems to have entered it not far above Franklin park. The smaller creeks which head west of the valley on the Valparaiso moraine and are now tributary to the main river between Des Plaines village and Maywood could have brought no significant amount of sediment into the bay, though their courses above the 50-foot level were no doubt already established.

The Oak Park Spit.—Across the mouth of Des Plaines bay a long spit, or bar, was constructed by the waves and shore currents of the lake as they swept their supply of beach gravel and sand southward in the direction of the prevailing drift (See Figure 17). From the beginning of the spit, where it extends out from the end of the west till ridge north of Oak Park, to its termination near the Twelfth street bridge, the distance is about three and a half miles. As far south as the point where it crosses the Chicago and North-Western railway at Oak Park its form and height make it appear to have been a visible reef, rising above the lake during the Glenwood stage and separating the lake from the bay. Its southern half, however, is lower and flatter, and probably was submerged. Spits and bars like this one grow up only along irregular shores. They express a more or less successful attempt on the part of the waves and currents to replace the re-entrants of a shoreline with straight or gently curved beaches. In order to see how the Oak Park spit was constructed, we must understand the conditions under which beach material moves along shore.

Ordinarily during a storm the waves run ashore obliquely rather than straight on; for it does not often happen that the wind is blowing perpendicular to the shore. When the shore line is irregular, the chances for a straight on-shore wind at any place are still smaller. At most places the wind strikes the shore at an angle, and the waves run up more or less obliquely. So there comes about an along-shore translation of water in the form of a definite current. The more oblique the wind and the greater its force, the swifter is this current. Only during storms is the shore current sufficiently strong to transport sand and gravel as it is danced up and down by the breakers.

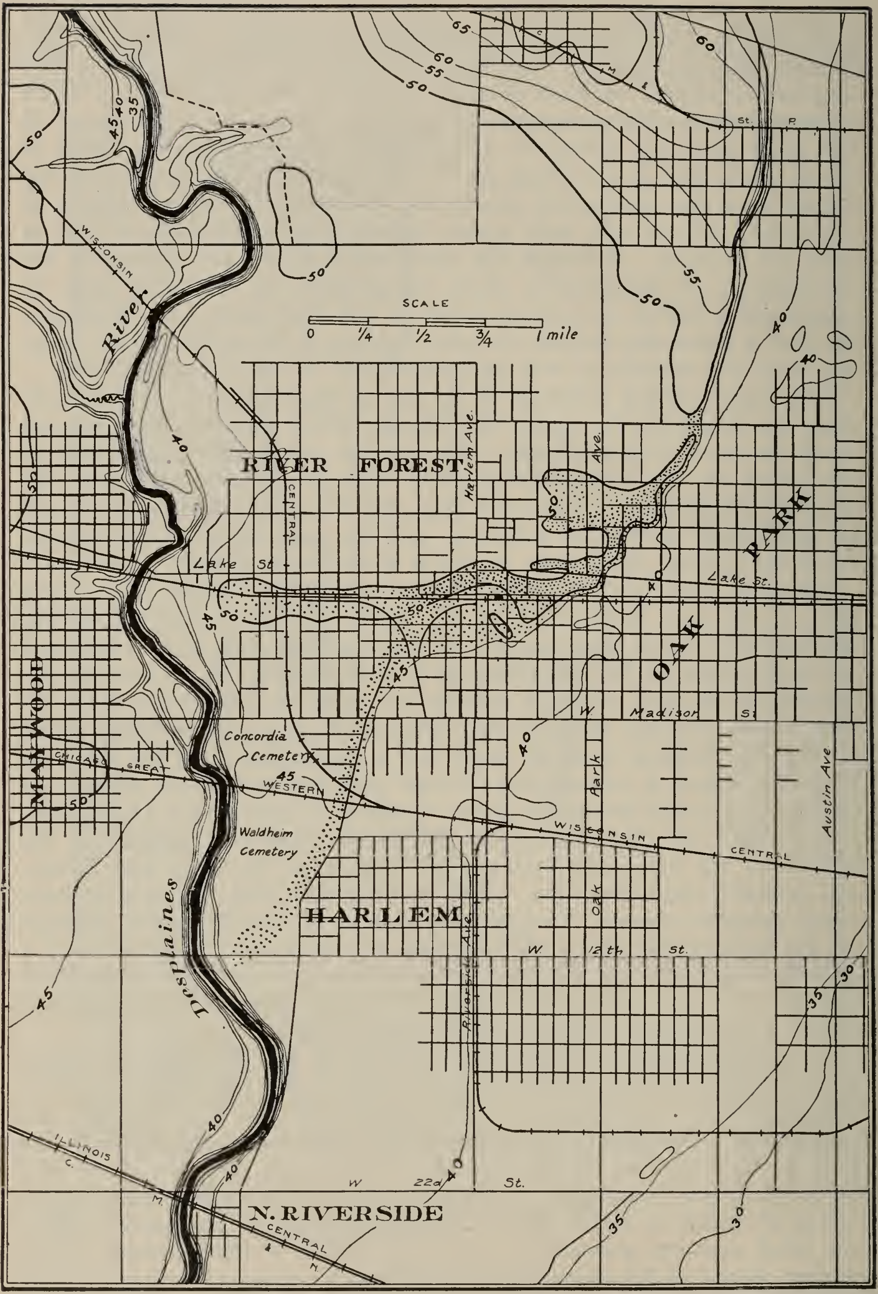

Fig. 17. Map of the district about Oak Park and Maywood (from map of the Sanitary district). Contour interval, 5 feet above Chicago datum. Oak Park spit indicated by dotted pattern; form of Des Plaines valley, by contours.

At a given place on the coast the shore current may be reversed from time to time as the storms bring waves from different quarters. As a rule, however, the wind from one direction is the dominant wind. It may almost invariably be the strongest, or it may last longer than any other storm wind, or it may have a greater "fetch" across the lake or bay; or these elements may be combined. In any case, the wind from one direction, usually sweeps so much stronger waves that it controls the movement of beach material along shore. On the southwest shore of Lake Michigan the dominant strong wind (i. e., storm-wind) comes from the north and northeast. Sweeping some 200 miles lengthwise of the lake, it developes stronger waves than the winds from other directions. It matters little that southeast storms are more frequent than "northeasters," and the southeast winds fully as strong as those from the northeast. Our shores at the southwest corner of the lake are relatively sheltered from the south and exposed to the north; hence, the dominant shore current along the Illinois border of the lake runs from north to south, and has done so ever since glacial Lake Chicago first took shape.

Waves and shore currents always act together. On shelving shores, where the waves in time of storm break in a long line some distance off-shore, the agitation of sand and gravel beneath the breakers offers a chance for the shore currents to shift the particles along the line inch by inch. Relatively large pebbles, while thus raised in momentary suspension beneath a breaking wave, may be worked along by a current which would be too weak to move them unaided. The abundance of gravel in the Oak Park spit, with pebbles even two inches in diameter, ceases to be surprising when it is remembered that the drift of debris along a spit is accomplished by the combined forces of waves and currents.

Supplementing the shore currents, the advance and retreat of the waves up and down the beach when the surf is running in obliquely causes a drift of beach material along shore at the water's edge. The wave dashes diagonally up the beach, sweeping sand and gravel with it; then receding the water pulls back some of the waste, either straight down the slope or still somewhat obliquely along the beach. Thus a pebble or grain of sand journeys along the shore in a zig-zag path, stopping from time to time, to be soon picked up by other waves and carried farther on. When an off-shore reef of sand has grown up to water-level, it will be built up farther into a barrier by material shifted along shore by the waves.

So, during the Glenwood stage of Lake Chicago, the strong shore current which swept southward along the cliff border of the till ridge from Norwood Park past Dunning and Montclair, and out across the mouth of Des Plaines bay found its velocity somewhat checked by the increasing depth of water (its energy becoming diffused) and weakening, deposited its load of sand and gravel in spit-like form. Once started, the spit grew southward and westward by continued addition to its free end, much as a railway embankment is extended by a train of cars which carry gravel out to a dumping place at its extremity. Thus the accumulation not only rose above lake level, but grew in length. As the spit reached out into the bay it turned somewhat toward the west, following the bend which the shore current made in its delayed attempt to enter the reentrant. The most pronounced part of the curve comes at Oak Park avenue and Ontario streets, where the spit bends rather sharply, crossing the grounds of Scoville Institute, and takes nearly westerly course along Lake street. This curving of the spit was not accomplished by a simple continuous growth along the line of deflected current. Several times the growing end of the spit was temporarily deflected as if by the waves of a series of unusually severe storms, which turned the shore current farther into the bay. Later, the normal direction of the shore current was restored, however, and the spit grew southward as before, the temporary hook being left behind the new outer beach ridge. The most distinct hook of this sort lies just north of Lake street, between Kenilworth avenue and Marion street. Another, nearly obliterated by street grading, may be traced from Euclid and Superior avenues westward to Elizabeth court; and a fragment of a third appears in the yards on the north side of Lathrop avenue west of Harlem avenue. This hooked extension of the Oak Park spit seems formerly to have reached nearly a mile west, to River Forest; but the extreme faintness of its slope, and the destructive grading of the railway and the streets have left little trace of it. The 50-foot contour on the carefully prepared map of the Sanitary District (Figure 17), however, as well as the 360-foot contour of the less detailed Riverside Sheet of the U. S. Geological Survey (where altitudes refer to sea level) indicate its trend.

In the vacant block between Linden and Euclid avenues, Oak Park, and north of Superior, the spit has the form of a very pronounced ridge, and, like most of the old beaches, is clothed with a belt of oaks. Its crest rises more than 15 feet above the former lake floor to the southeast, and nearly 10 feet above the old bay floor to the northwest. The back slope is somewhat steeper than the outer or lakeward side. The gravelly condition is revealed in shallow cuts near the sidewalks. This north part of the Oak Park spit, with its characteristic beach profile, from its beginning at the south end of the till ridge (north of Division street and Ridgeland avenue) to the railroad station, probably rose above the water, separating the bay from the lake.

South of the railroad the spit finds extension in a lower and much flatter ridge of gravels, which is followed by Des Plaines avenue for over a mile, or nearly to Twelfth street. This portion of the spit rises less than 10 feet above the lake floor, with faint slopes, and so seems very probable to have been a subaqueous reef along which beach material was drifting, but which never rose as high as lake level. It is composed very largely of fine gravel with pebbles less than 1 inch in diameter, as can be seen in the cuts beside the Great Western railway; but near the south end of the spit, in Waldheim cemetery, artificial pits near Twelfth street show an abundance of coarse gravel in which the pebbles are 2 inches in diameter. The strata here dip steeply toward the south, the direction in which the end of the spit was being extended.

The reason for the southerly direction of this half of the Oak Park spit is somewhat in doubt. It has been explained as "probably due to the combined action of the northeast winds and the current of outward flow from the estuary. The wind turned the spit westward until the outlet of the estuary was somewhat constricted, when the outward flow of water became sufficiently strong to deflect the spit-building current again southward."[1] In a bay of such length and width, with a tributary stream, the Des Plaines, to maintain an outward flow of water, this explanation may fairly be questioned. It seems much more probable that *wave action* in the bay with wind from the north, producing a current on the bay side of the spit, would be competent to prevent its extension in a westerly direction, and, in conjunction with the dominant southwestward drift in the lake, would direct the spit southward.

While the Oak Park spit did not wholly shut in the Des Plaines bay, its construction went far toward replacing the initial irregular shoreline with a gentle curve, such as characterized the more advanced stages of shore development.

Shoreline between Maywood and Mt. Forest.—That part of the Glenwood shoreline which lies west of the Des Plaines river is neither so characteristic nor so interesting as the portion near Oak Park. Across the mouth of the Des Plaines bay west of the end of the Oak Park spit, a hardly perceptible beach was built at the border of the shallow water south of Maywood. A small tract of land here, around Broadview, was probably a swampy island close to lake level. North of LaGrange, however, the gentle east slope of the Valparaiso moraine is bordered by a rather sloping bank 15 to 20 feet high, which faces the lake floor. This seems to have been a low lake cliff rising from the water's edge like the bluffs along the present lake shore north of Evanston. The height of the lake floor at the base of the cliff is approximately 50 feet above Lake Michigan, the altitude of the extinct lake so far as can be judged from the best developed terraces and beaches. This cut bluff may be traced northward from La Grange more than two miles to Salt creek, where it fades away. Just east of the Butterfield road the crest of the bluff is crowned with a ridge of gravels for a distance of over a quarter of a mile. It is plainly seen in the cemetery and in the gravel pits a few rods north. Since the crest of the ridge stands 10 feet or more above the base of the bluff, it seems necessary to regard it as the beach of a somewhat earlier period, probably the very beginning of the Glenwood stage, when the lake stood for a while as high perhaps as 60 feet above Lake Michigan. This beach ridge controls the course of Salt creek for a considerable distance, as far north as Twenty-second street, where the creek turns and enters upon the lake floor. This northward deflection indicates that the direction of shore currents near La Grange, in the Glenwood stage, was towards the north. That is to be expected, because La Grange stands near the mouth of the old bay, where exposure to east and southeast winds was great, while exposure to the north was much reduced by the protection of the Oak Park spit.

South of La Grange, as far as McCook, the same cut bluff may be followed; but it is not always plainly defined, for cultivation of fields

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[1] Alden, U. S. Geol. Surv., Chicago Folio No. 81, p. 8. 1907.

seems to have greatly softened its outlines. Rounding the rocky hillside at McCook, it loses distinctness and passes along the uneven border of the moraine to the head of the outlet near Mt. Forest.

Around the northeast end of Mt. Forest island, imperfect traces of a Glenwood bluff may be seen here and there. Near Archer road the terrace at the base of the bluff is somewhat inclined, and stands a little lower than the Glenwood level. Further east, near Hartman avenue and Eigthty-seventh street, two distinct beach ridges mark the Glenwood shoreline.

CALUMET STAGE.

Emergence of the floor of Des Plaines bay.—As the outlet of Lake Chicago was deepened by erosion, the level of the lake fell rather gradually from 50 feet to about 35 feet above Lake Michigan, where for a time it remained nearly constant. The conditions which seem to have determined this halt at the 35-foot level have already been set forth. As the lake fell, large areas formerly under shallow water became land. The floor of Des Plaines bay emerged to form a broad marshy plain, which stretched south to the new "Calumet" shore at Riverside. (See Figure 18.) Down the ill-defined slope of the bay plain, the Des Plaines river extended its course, with many crooks and bends, while the few creeks which headed on the Valparaiso moraine and were formerly tributary to the bay were now joined or "engrafted" to the trunk stream. Salt creek found a devious path eastward and southward on the new plain, almost failing to reach the Des Plaines, but connecting with it at the lake shore behind a beach at Riverside.

This engrafting of independent streams to form a single system on the emerging of the Des Plaines plain, is comparable in a general way to the growth of the lower Mississippi system. During early Tertiary time a long arm of the Gulf of Mexico reached up the Mississippi valley as far as Cairo. Tributary to the bay were several large rivers; the upper Mississippi and the Ohio at its head, the Tennessee on its east side, and the White, Arkansas, and Red rivers on the west side. Near the close of the Tertiary period warpings of the earth's crust were accompanied by a withdrawal of the sea from the land. The valley of the lower Mississippi emerged, and the several rivers united on the plain to form the single great river system, whose drainage area is a million and a quarter square miles. The Amazon system of Brazil, with twice as great a drainage basin, has been made in a similar way.

The crooked path of the Des Plaines river, which was determined thus early by original inequalities of slope on the newly exposed bay floor, accounts in large measure for its present course and the width of the valley which it has excavated. While the lake stood at the Calumet level, the river began its work of excavating a channel along its course, gradually entrenching itself below the bay plain. Later, as the lake waters fell and the base level of erosion for the river was lowered, the entrenchment of the river progressed to greater depth. The consideration of this matter is left for a later section.

The Calumet shoreline.—The margin of the lake at this stage crossed the plain of the Des Plaines bay obliquely from Austin to Riverside. This portion of the lake shore is marked in some places by a beach slope of moderate definition. South of Twelfth street (where it crosses Austin avenue near the McKinley school) the ridge-like form of the beach becomes more and more marked.

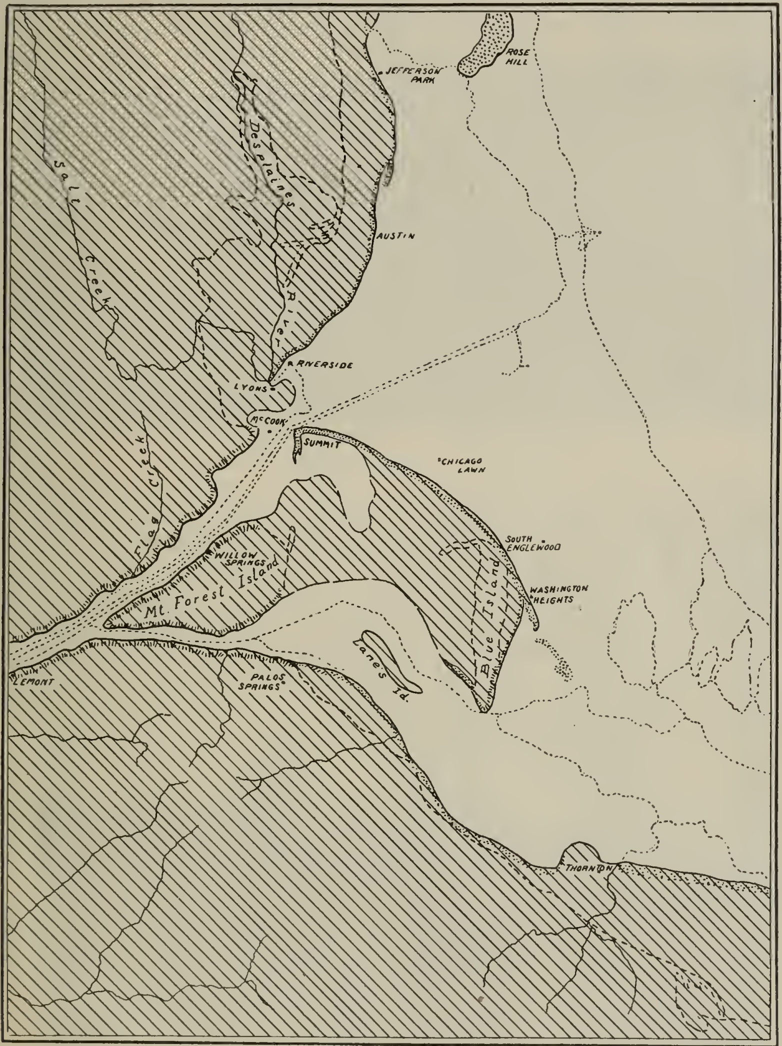

FIG. 18. Part of Lake Chicago during the Calumet stage. (Modified from Alden.)

An interesting geographic response to the shore topography of this old lake stage is seen in the many old farm houses and barns along the crest of the ridge. The early settlers on this poorly drained Chicago plain located their homesteads on the dry, sandy beach ridges. A characteristic old-time farm house, now almost in ruins, stands at the corner of Austin avenue and Twelfth street. Numberless examples of this sort might be given.

At Charles Becker's picnic grove (Twenty-second street), where the La Grange trolley car crosses the beach, the characteristic profile—a long, gentle front slope and a short, moderately steep back slope, is plainly seen. Here, as is frequently the case, the ridge is lined with old oak trees, and was formerly followed by a highway. From this point south for a mile or more a road follows the beach (See Fig. 19). Near the Illinois Central railway the ridge is double. A second crest, on the west side of the road, stands a few feet lower than the main beach. It suggests, of course, that the plain northwest of the beach was formerly a shallow bay, and that the inner crest of the ridge is a low beach built by waves from the bay side of the bar; but as this plain seems to be somewhat above the 35-foot level it seems unlikely that it was submerged during the Calumet stage.

Through the east part of Riverside the beach, if ever strongly developed, has been effaced by artificial grading. It reappears distinctly west of the Chicago, Burlington & Quincy railway station, running southwest as shown in Figure 19. Close behind it, the Des Plaines river follows a deflected course from the railway bridge to the mouth of Salt creek. There, turning abruptly eastward around the end of the ridge and again sharply northward, it runs back to Riverside. The deflected path of the river above Salt creek is doubtless due to the southwestward drift of waste along the beach. Probably the Calumet beach ridge stretched along the lakeward border of a marsh near the mouth of the Des Plaines river and Salt creek. The southwestward movement of material on the beach prevented the river from running directly out to the lake, and pushed it farther and farther toward the southwest. The return couse of the river on the lakeward side of the beach ridge is, of course, of later origin, and will presently be discussed. At one place not far south of the railway bridge the river cuts obliquely across a branch crest or spur of the beach ridge. Beyond that point, however, to the mouth of Salt creek, its course is parallel to the old beach. One should realize, of course, that during later stages the river has deepened its course some 15 feet below the bay plain and the swamp of the Calumet times. The beach ridge which deflected the river was not the high, conspicuous ridge of to-day, but the relatively low beach which now forms its crest.

Across the river, between Lyons and McCook, there is no clear indication of the shore of the extinct lake. The position of the Calumet shore may be inferred from the 35-foot contour of the Sanitary District's map (Figure 19), which indicates that it bent eastward from Lyons in a long curve, passing around the gently sloping rock elevation east of Joliet avenue and returning west and southwest to the base of the long hill west of McCook. There it lies just down the slope from the Glenwood shoreline.

A. Young Gulley near Reed's Woods.

B. Calumet Beach Ridge at Summit.

On the south side of Lake Chicago the shore of the Calumet stage runs northwest from Blue island several miles to Summit, at the head of the outlet. As one approaches Summit along Archer road (the route of the trolley cars from Chicago city limits to Joliet, shown on the

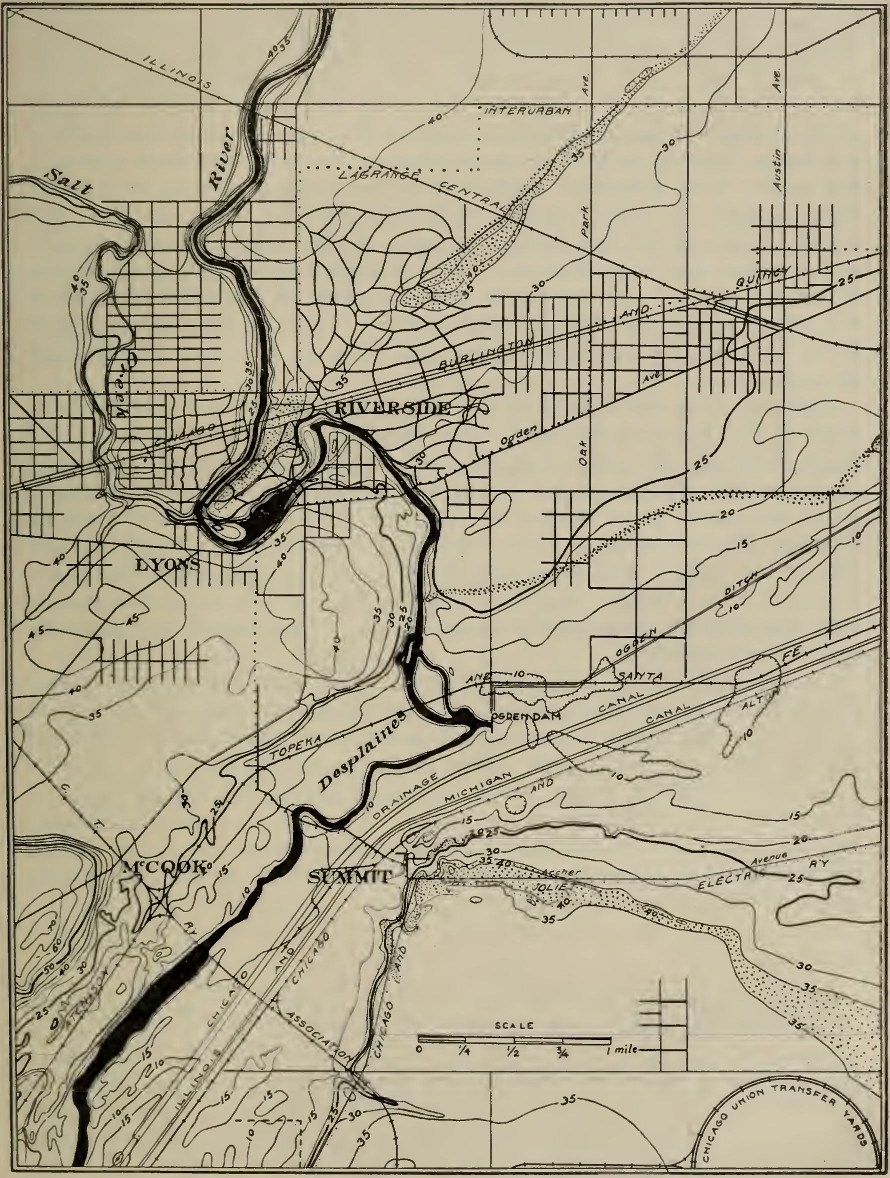

FIG. 19. Map of the district about Riverside and Summit (from map of the Sanitary district). Contour interval, 5 feet above Chicago datum. Beach ridges indicated by dotted pattern.

map, Figure 19) the beach ridge is seen not far to the south, rising with pronounced slope 15 or 20 feet above the lake plain. Its crest is higher than the 40-foot contour. About a mile east of Summit, where the road ascends the ridge, it is double-crested; the south, or inner crest, standing a few feet lower than the outer one. From here westward the ridge widens considerably, showing three distinct crest lines, and at Summit it hooks sharply around to the south, forming the gateway to the outlet of Lake Chicago. There seem to have been been three closely set hooks here at Summit, one overlapping the other; but the subsequent widening of the outlet during the Toleston stage of the lake cut away the bends of the hooks, leaving only their main stem to the east and their points to the south. The innermost extends from the turn of Archer road southward beyond the school house, with characteristic beach profile. The middle ridge, much less distinct, crosses Archer road just opposite the school house and soon dies out. Two hundred yards farther south, the truncated edge of the outermost ridge appears on the channel bank of the outlet, at the west side of Archer road. Crossing diagonally, it runs southward several hundred yards, and flattens out near the railway crossing.

Judging from the height of the ridge, its hooked form and the contours of the Sanitary District's map, this was a bar during the Calumet stage, shutting off a broad lagoon and marsh that stretched southward as far as Mt. Forest island. There was probably a depth of 10 feet of water for a mile or so behind the bar, and extending southwest past the Chicago Union Transfer yards, affording some wave action on the bay side of the ridge. Not far southwest of this, the plain rises almost imperceptibly to a height slightly above the level of the Calumet stage, so that this district immediately north of Mt. Forest island was undoubtedly a great marsh.

On the east side of Archer road, near Mt. Forest island, may be seen a low beach ridge which stretches from Bethania cemetery northeastward across the fields. It is marked by a line of great gnarled oak trees and an old brick farm house. This beach during the Calumet stage ran along the southwest corner of the marsh, marking off the long narrow arm of the lake which led to the outlet. The gateway between Summit and McCook might in one sense be taken as the head of the outlet, though the actual river began more properly at Mt. Forest, at the head of the notch in the Valparaiso moraine.

TOLESTON STAGE.

Extension of the Des Plaines river near Riverside.—As the Chicago outlet once more cut down its floor, the waters of Lake Chicago again dropped 15 feet, to a level of 20 feet above Lake Michigan. The shoreline withdrew somewhat towards the present shore, and the mouth of the Des Plaines river was extended from behind the end of the Riverside bar to a point near the spill-way above the Santa Fé railway bridge (Fig. 19). In this extension the Des Plaines was led far out of its way by the irregularities of the shallow lake floor. From the end of the

Riverside beach ridge, where a broad belt of slightly higher ground bordered the lake on the south, the river turned sharply northwest along the outer side of the beach to Riverside, where it again turned east and south down the slope to the plain to its new mouth above the Ogden dam. The board elevation at Lyons which prevented the extension of the river straight towards Summit, causing the return course to Riverside, is a rocky elevation only thinly covered with till. The limestone quarries of Fred Schultz are located here, near the bend of the Des Plaines. As no bed rock is exposed in the river bank, however, it is altogether probable that the recurving of the river to Riverside was brought about not by the resistance of rock encountered in the river bed, but rather by the initial slope of the old lake floor around the elevation. Thus the earlier deflection of the river behind the Calumet beach was supplemented at the beginning of the Toleston stage by an opposite deflection on the lake plain along the outer side of the beach, producing the peculiar hairpin-like curve which is shown on the map (Figure 19). Salt creek, formerly entering the lake behind the Riverside beach in a swamp close to the mouth of the Des Plaines river, now became a real tributary of it. The volume thus added to the Des Plains system was very considerable. Salt creek drains an area of 110 square miles, or one-fifth as large a basin as the main river above Lyons. It gathers its volume from a long belt of low ground within the Valparaiso moraine. The current of Salt creek where it enters the Des Plaines at the beginning of the sharp bend strongly influences the direction of current of the trunk stream at that point, holding it off from the outer bank, which it would otherwise be actively trimming, and thus tending to maintain the bend in a fixed position.

Renewed trenching of the valley.—The lowering of the lake to the Toleston stage was equivalent to a lowering of base-level for the Des Plaines river about 15 feet. So, with steepened slope, the river was inspired to sink its channel below the grade already established during the Calumet stage, and deepened its trench to a level not far above that of the present valley floor. A more detailed account of the trenching and the associated shifting of the crooks and bends in the river will presently be given.

The Toleston shoreline.—The shoreline of the Toleston stage is marked, between Hawthorne and the river, by a low but distinct beach ridge which rises seldom more than 10 feet above the low lake plain. On the west side of the river a distinct bluff not over 10 feet high appears along the base of the gently sloping hillside south of Lyons. Fading away as it nears Joliet avenue, the shoreline is almost lost on the old lake floor near McCook, and does not again appear at all plainly on the west side of the old outlet.

A short distance east of Summit the outer slope of the great Calumet beach ridge was cut away by the lake to form a low cliff, in the Toleston stage. Just northeast of the village of Summit this is replaced by a broad, flattish beach ridge of gravelly constitution, which stands only a few rods north of the higher Calumet ridge, where the latter is extensively opened at a gravel pit (See Fig. 19). Here is a particularly good place to see the beaches of the 35-foot and 20-foot stages close together, and to study the contrasted features of beach ridge and shore cliff. The stratification of the beach gravels of the Calumet ridge is especially well shown in the gravel pit.

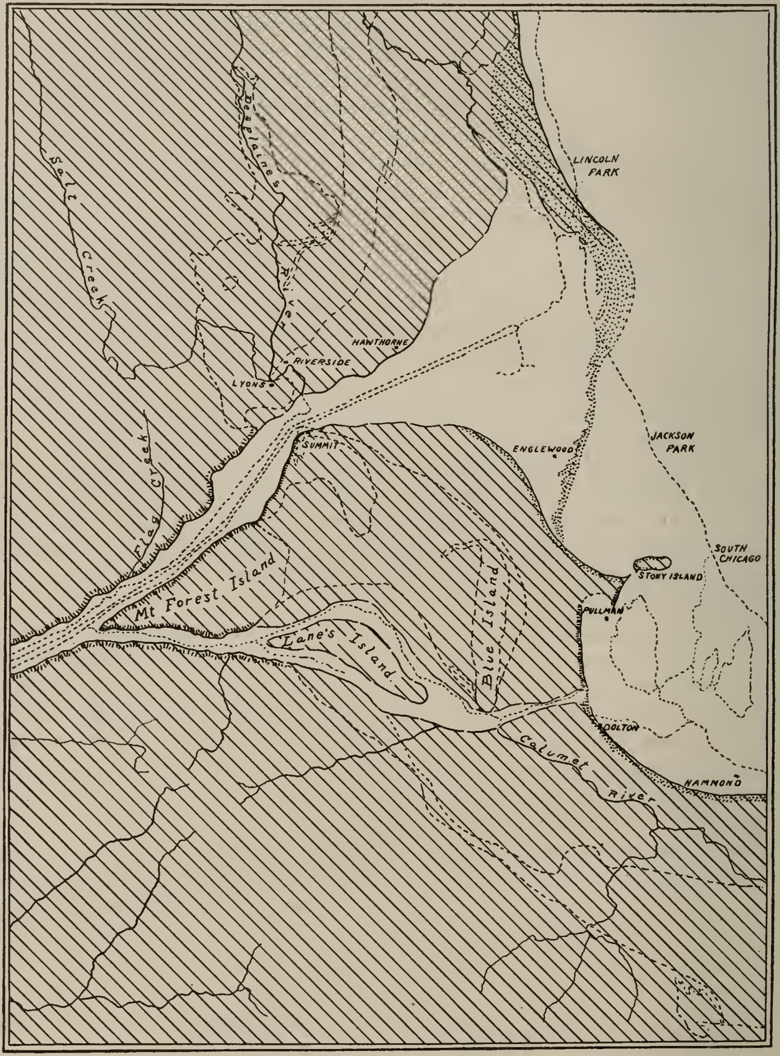

FIG. 20. Part of Lake Chicago during the Toleston stage. (Modified from Alden.)

From Summit southward the east side of the outlet is marked for several miles by a steep straight bluff, which lies just west of Archer road and is plainly seen from the car window most of the way to Willow Springs. The bluff is about 15 feet high, rising from the 20-foot contour to the level of the Calumet lake floor. It was cut by the outflowing river, probably at the time when the removal of the sill of bed rock at Lockport caused the river to saw down its bed along its entire course above Lockport.

SUBSEQUENT CHANGES LEADING TO FORMATION OF LAKE MICHIGAN.

The manner in which the lake fell from the Toleston or 20-foot level to a level below the present Lake Michigan, and then rose to a level about 12 feet above it has already been told. It was while the lake stood at the 12-foot level that the broad reef of sand was constructed between Lincoln park and South Englewood, shutting off the Chicago outlet. Because of this, the district east of Summit, including the greater part of the city of Chicago, was probably a great shallow marsh, with only slight and sluggish drainage westward through the abandoned outlet.

The series of changes which led to the disappearance of Lake Algonquin, to the complex history of the Nipissing great lakes, and finally to the present chain of lakes with the single outlet through the St. Clair river, has been given in the preceding chapter, just referred to. So far as the history of the Des Plaines river is concerned, we may ignore the details of these changes and consider simply how the lowering of the lake from the 12-foot level to the present one affected the river. As the lake fell, the slope of its floor, now newly exposed near Summit, was hardly sufficient to direct the Des Plaines river southwestward into the head of the old outlet. At the bend which the river now makes there, near Ogden dam (See Fig. 19), a well defined slough, formerly known as Mud lake, leads eastward to the south branch of the Chicago river. It marks a line of escape which has been used time and time again by the Des Plaines during floods. Here was the old Indian portage, where Marquette and other early explorers, at the time of a spring freshet, could paddle their canoes from Lake Michigan to the headwaters of the Illinois. It is not at all improbable that at one time the Des Plaines river discharged wholly through this slough, into Lake Michigan. If so, its southwestward course (which we have called the "lower Des Plaines)" is a very recent one. The natural divide, east of Mud lake, on the smooth plain near Kedzie avenue, may have been built, as Mr. Lyman E. Cooley suggests, by silts from the river, collected behind a beaver dam.

EXCAVATION OF THE VALLEY.

It has already been explained how the emergence of the smooth floor of Des Plaines bay when the lake fell from the 50-foot to the 35-foot level was accompanied by the extension of the river from near Franklin Park southward to Riverside. Many crooks and bends were caused by faint irregularities of slope of the newly exposed surface. The slope of the bay plain from the 50-foot contour near Franklin Park down to the 35-foot level at Riverside is exceedingly gentle, a fall of 15 feet in 12 miles. This is somewhat steeper, however, than the present slope of the Des Plaines river, which falls only 5 or 6 feet in the same distance.

During the Calumet stage, then, with an initial slope of about 1½ feet per mile, the river may have reduced its slope to as low a grade as it now possesses—half a foot to the mile, by sinking its channel a few feet below the bay plain. The river, then, during the Calumet stage, might have deepened its trench several feet below the level of its broad valley floor. The subsequent drop from Calumet to Toleston level, while it extended the mouth of the river only a short distance, reduced its base-level 15 feet, i. e., made it possible for the river to cut 15 feet lower, by steepening its slope and increasing its velocity and its efficiency for deepening its bed. Again, when the lake waters fell from the 20-foot mark to essentially the present level, laying bare the plain between Riverside and Summit and allowing the Des Plaines to turn southwest down the floor of the abandoned outlet channel, the local base-level was lowered; erosion was revived, and this revival was transmitted upstream, causing a deepening of the channel. In the subsequent interval, the river has cut its valley about 10 feet below the Toleston level, near where its mouth lay during the Toleston stage. Farther up, however, the deepening has been much less, because it has cut down to bed rock, revealing the surface of the ledges at three places—(1) a few rods below the Ogden avenue bridge, (2) just below the Riverside dam, and (3) on Salt creek just above its junction with the Des Plaines. Since the sill of limestone at Riverside stands almost as high as Toleston level, it seems to have prevented the full amount of deepening above Riverside after the Toleston stage.

If such is the case, there have been three steps in the excavation of the trench-like valley above Riverside. (1) During the Calumet stage of Lake Chicago a shallow, winding trench was cut below the bay plain, with low grade appropriate to Calumet base-level. (2) With the drop of the Toleston stage, a second period of deepening began, which probably reduced the floor of the trench to Toleston base-level. (3) Since the lowering of the lake from the Toleston to the present level there has been a further deepening of the channel, amounting probably to only a few feet; for the process has ben effectively checked by the ledges at Riverside.

Bearing in mind these points of erosional history of the upper valley, we may now seek to explain the peculiar details of the valley that has been excavated. It should be remarked in the first place that the contour map of this district published by the U. S. Geological Survey (Riverside quadrangle), with its rather small scale of one mile to the inch, lacks details; so the expression of the trench-like valley on this map is quite misleading. It is shown as a narrow, winding trench which follows closely every crook and turn of the river. On the larger and more detailed contour map drawn by the Sanitary District (and copied in part in Figures 17 and 19) the true form of the valley comes out distinctly. It is a trench of considerable width, not infrequently ten times as broad as the channel which swings across its floor from side to side in imperfect meandering fashion. Compared with the crooked river channel the trench of the valley is relatively straight, its two banks constricting the turns and sharply defining its meander belt. Where the river impinges against one of its bluffs there is a steep bare-faced exposure of glacial drift and frequently toppling trees, which testify to the lateral sawing of the river and the constant widening of its trench.

Perhaps the most instructive view of this lateral cutting is to be had at the Madison street bridge, near Harlem. (See Fig. 17.) On the north side of the bridge the river is rapidly trimming back its left bank, exposing the compact glacial drift in a steep 15-foot bluff. As fast as the river saws at the base of the bank, the bowlder clay, loosened by frost or by percolating water and its own weight, slides into the river, and is carried down stream. Thus a nearly perpendicular bank is maintained, as steep as the unsupported clay will stand. Just across the street, at Concordia cemetery, the same bank has been protected from lateral erosion by a high fence of posts and planks and walls of loose rock. While, because of this protection, the river has not cut outward on its bend at the cemetery, it has trimmed away fully 25 feet just above the bridge.

Even at those points where the bluff is removed from the river, on the opposite side of its valley, the slope is as a rule steep and straight, and the valley floor at its base is often marked by a shallow slough, formerly occupied by the river when it trimmed and steepened the bluff. (See contour on Fig. 17.)

A very little study makes it clear how the trench has been cut so much wider than the river channel and everywhere just as wide as the meander belt. When the river first found its way across the bay plain, a surface exhibiting frequent inequalities of slope, it followed many crooks and bends much like those of the present course. It is a well known principle that at each bend in a crooked channel the current of river swings toward the outside of the curve and in consequence there is a tendency for the river in time of high water to trim away its outer bank. This process is known as "lateral planation." At the same time, the river deposits sediment on the inside of the curve where the current is weak. The combined process is known as "cut and fill." Now, it follows from this deflection of the current from side to side that in rounding a bend or loop the river does most of its cutting on its down-valley side and most of its filling on the up-valley side. The result of this progressive growth is the constant migration of the bends down-valley. Figure 21 illustrates the effect of this migration on the outline and width of the valley. As the bend thus shifts its position, the point of attack against the bank likewise shifts down valley, so that a straight bluff is trimmed one one side and a pointed spur developed on the opposite side. (Fig. 21 II.) Slowly this spur is worn away as the upper bend encroaches on it (Fig. 21, II, III and IV), and by the time this second bend has passed the starting point of its predecessor both sides of the valley have been trimmed back. There remains a flat-floored, straight-walled trench, whose width corresponds to the meander belt of the river. It necessarily follows, also, from the deflection of the current toward the outer bank, that as the river cuts downward and outward the bends will increase in size, and to that extent the meander belt will be widened. While the bends are shifting and banks are being trimmed, the filling process on the inner bank covers the floor of the valley with stratified sediments and a flood-plain is formed—a flat valley bottom, usually above the river level but submerged whenever the river is swollen by rains sufficiently to fill its channel to the brim.

During low-water stages the river does very little work. It is too weak to carry any significant amount of sediment. Even at ordinary stages the river works slowly and laboriously: but during floods, when the volume of the stream is considerably increased, its power as a carrier is enormously increased, and it is then that the cut-and-fill process is effective and flood-plains are constructed. It may be demonstrated that the transporting power of a river varies as the sixth power of its velocity and that its velocity varies as the cube root of the volume, if the shape of the channel be disregarded. In other words, the carrying power varies as the square of the volume. If, then, the flood volume of a river is eight times its normal volume, its velocity is twice as great, and it is able to move fragments sixty-four times as large as at the ordinary stage. The extreme low water volume on the Des Plaines, as measured at Riverside, in 1887 was 4 cubic feet per second; the flood volume of the same year, 10,324 cubic feet. What an enormous difference, therefore, exists in the carrying power and sculpturing power of the river between these extreme stages! We may well believe, then, that just as the

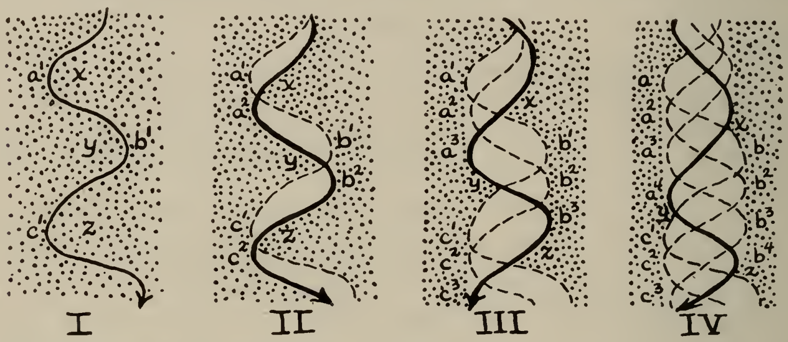

FIG. 21. Diagrams showing the development of a straight walled, flat floored valley, by the trimming away of spurs as the bends of the stream migrate down-valley. The river is flowing in the direction of the arrow. Four stages are shown. In I $a1$, $b1$, $c1$, are three bends, which lie between three alternating spurs, x, y, z. The valley bottom is narrow—no wider than the stream. In II the tendency of the stream to cut on the down-valley side of each bend has shifted $a1$, $b1$, and $c1$ to the positions $a2$, $b2$, $c2$, leaving stretches of straight valley walls, $a1$-$a2$, $b1$-$b2$, $c1$-$c2$. Across the river at each bend a portion of the up-valley side of each spur, x, y, z, has been trimmed away, sharpening these spurs. A flat floor, of variable width (un-shaded) has thus been produced. In III the process has continued. The bends have migrated down-valley to $a3$, $b3$, $c3$. The stretches of straight valley wall have been lengthened, $a1$-$a3$, $b1$-$b3$, $c1$-$c3$. The spurs x, y, z, have been half consumed by the trimming away of their up-valley sides. The valley floor has been much widened. In IV a still later stage has been reached The bend a has shifted down-valley nearly to the position c, extending the straight wall $a1$-$a4$ nearly far enough to consume the spur y. This spur is now very blunt, and will be wholly consumed by the time bend a has migrated down-valley to the very position which the next bend below it, c, originally had. The other spurs, x and z, have been similarly blunted, and will soon be consumed. The valley will then be straight sided, flat floored, and as broad as the swing of the bends, i. e., as the meander belt of the river.

average yearly flood greatly *exceeds* the ordinary river stages in its working capacity, the *occasional extreme* flood *greatly exceeds* the normal flood in its destructive and constructive work. Although extreme floods commonly occur only once in several years, and at irregular intervals, the flood-plains which they build are usually very prominent features of the valley. During the interval between extreme floods (usually 5 to 10 years in the case of the Des Plaines), the normal yearly floods permit the partial destruction of the high-level flood-plain and the development of a lower floor at the level of ordinary high water. The erosion of the river along the banks of its channel aids somewhat in tearing down the high-level plain; but before the upper flood-plain has been wholly destroyed by lateral planation, another flood of unusual proportions occurs, and the high flat is reconstructed. One of the most striking features of the Des Plaines trench is a terrace which stands several feet above ordinary high water and is covered only by extreme floods once in several years. The infrequency of submergence of this terrace is shown by the fact that many picnic groves with their small buildings, and a group of cottages at the Methodist camp grounds at Des Plaines are located upon it. Rarely do the spring freshets rise high enough to cover it, but when they do much damage is done. Stretches of bottom land a few feet lower than the terrace and always between it and the river mark the level of ordinary annual floods.

The Des Plaines river illustrates remarkably well the features just described and figured. Migrating bends, straight-trimmed bluffs and broad flood-plain are exhibited especially well between Maywood and Riverside. (Figure 17.) The bends of the Des Plaines are as a rule obtuse rather than acute, hence the trench formed as they have sunk and moved down valley is rather narrow when compared with the few places where the bends are more circular (e. g. the S-shaped bend two miles above Maywood and a series of curves above Des Plaines village). There the more rapid enlargement of the curves together with their down-valley migration has formed a trench 400 to 500 yards wide.

When studied in connection with a large river like the Missouri or Mississippi, the Des Plaines is found to be deficient in the regularity and symmetry of its bends. Close study will also show that its valley is not wide enough in proportion to its channel to compare with rivers which have reached an advanced or mature stage of development. The widening of a river valley continues as a rule until the meander belt is at least sixteen times as wide as the river channel. By that time the crooks have turned into loops of great beauty and symmetry, and the trimming of the bank no longer occurs at every bend. The meander becomes more and more looped, the inclosed lobes of flood-plain matching together in dove-tailed fashion. The necks of the pear-shaped spurs grow narrower and narrower by the cut-and-fill process, until at last (usually in time of flood) the river cuts through the neck, gaining a shorter course, and the long loop is abandoned, becoming either a slough or an ox-bow lake. These old "meander scars" are gradually effaced by deposits of sediment during subsequent floods.

As regards its stage of development, therefore, the Des Plaines may be called a youthful river. In its infancy a crooked stream, running along the newly exposed bay plain, it was enabled to lower its channel, and in so doing sent a succession of loops moving down valley. By them its valley floor has been widened and its valley walls trimmed back. It is still at work at these tasks, broadening its valley by lateral planation, seeking to gain a floor sufficiently wide on which to turn and twist in closed loops like the larger and older "father of rivers" to which it is tributary. No longer exactly "young," it is still "youthful." Another interval of time, as long probably as that already elapsed in the river's history, will be required for the river to reach full maturity.

DEVELOPMENT OF TRIBUTARIES.

The development of tributaries to the upper river has already been partly discussed. The larger tributaries, like Salt creek and Higgins creek, which head on the Valparaiso moraine and cross the old floor of Des Plaines bay to reach the main river, have already been spoken of. They are consequent upon the drift surface, having followed the guidance of initial slopes. Along their lower courses the tributaries south of Franklin Park were extended and engrafted on the Des Plaines as the bay plain emerged, at the close of the Glenwood stage of Lake Chicago. As previously remarked, these tributaries are confined almost wholly to the west side of the Des Plaines. The low till ridge that forms the eastern side of the valley does not gather and shed enough water to support permanent streams of any considerable length.

Some of the larger of these tributary creeks, near where they join the Des Plaines, have a remarkably mature aspect; for they meander broadly, with horse-shoe shaped loops. One of the most accessible, as well as one of the prettiest examples is the creek which enters the river north of Maywood, opposite Theiler's park. (See Figure 17.) Its valley floor, unlike that of the Des Plaines, is much wider than the meander belt, and the meanders approach in shape those of the Mississippi. In these respects, the tributary looks more mature than the trunk river. Such a condition is quite abnormal and demands explanation; for we should expect the trunk stream to have reached a more advanced stage of development than any of its tributaries. The explanation seems to be found in the influence which strong floods of the main river have on the flood plain of the branch stream. It is very apparent that when the Des Plaines, gathering a large volume from its long basin during a spring thaw or a heavy rain, is swollen and overtops its flood plain, it invades the lower end of the tributary valley, backing the waters up. In this bay-like extension of the trunk valley, during the flood, silts, chiefly from the main river, may be laid down and a flood plain built up to the back-water level. A flood-plain constructed under such conditions would be flatter than one formed by the tributary itself, flowing downgrade into the main river; and on such an over-flattened plain, after the flood subsided, the tributary would be apt to meander more widely than on the sloping floor of its upper course. The fact that the "mature" loops seem to be restricted to the lower courses of the tributaries favors the idea that they are due to back-water influence.

This class of tributaries might be called "original," to distinguish them from another, newer group of "secondary" origin.

The manner in which the second class of tributaries start to grow may be studied to advantage wherever the main river is bordered by a freshly trimmed bank; as, for instance, at the Madison street bridge. It will be observed here that the clay slope is carved by innumerable little gullies, the work of recent rains. Such of the gullies as chance to find an advantageous place for headward growth, either because of softer ground structure than their neighbors or because of an initial depression near their heads, from which they may receive more than an equal share of the run-off, will grow more rapidly than those on either side. In the incipient stages, such differences in rate of growth are slight; the advantages are small, and largely accidental. The presence of a tree root that will turn the rain wash away from one gully and towards its neighbor may be of prime importance in determining which shall grow. With growth, both lateral and headward, the favored gullies rapidly swallow up or dwarf their neighbors. Natural selection operates as truly here as in the realm of life. Of the hundreds of gullies on a newly rain-carved bank, only one or two are destined to grow to conspicuous size; and but one out of many thousand will develop into a large ravine. It should further be said that of the gullies carved by side wash down a river bank there is wholesale destruction at the hands of the river itself; for it as a rule trims away its bank faster than most of its side gullies wear back their heads. This, together with the competition among the gullies themselves, explains the delay in the development of tributary ravines.

North of the Madison street bridge, in the picnic grove and woods, may be found gullies of "secondary" tributaries in various stages of growth. Short, steep, V-shaped gullies with bare sides occur close to the bridge, where the freshly trimmed river bank is being scoured by rains. About an eighth of a mile north of Madison street is a small ravine, which is some 300 yards long and at its mouth is about 20 feet deep. It has no branches, and is remarkably straight, yet towards its mouth it bends back and forth between a set of interlocking spurs, similar to those described on pages 83-84. Besides the examples near Madison street, there are well developed "secondary" tributaries in the northeast part of Maywood, two of which are shown by contours on the map, Fig. 18.

These "secondary" tributaries, formed by the headward growth of lateral gullies, are few, short, and exceedingly simple in plan. They have few or no branches. Like other features of the valley they are marks of the youthful condition of the Des Plaines system.

CHAPTER VII.

FLOODS ON THE DES PLAINES RIVER.

THE UPPER RIVER.

The Des Plaines river is subject to floods of unusually long duration, as compared with other rivers of its size. Each spring, as the snow melts rapidly out of its basin, the river is swollen by the additional volume, and rises several feet above its normal level. A portion of the valley floor is thus flooded for days or even weeks.

In his paper on "The Illinois river basin in its relations to sanitary engineering,"[1] Mr. L. E. Cooley expresses the view that the peculiar shape of the basin—narrow from east to west, and sixty miles long from north to south above Riverside (See Fig. 1) makes the floods on the Des Plaines last longer and rise less than they would in an equally large basin of different shape. When a warm spell comes in the spring, attended perhaps by rains, the snow and ice are rapidly melted from the frozen ground, and on all sides water runs down the slopes into the river. The melting begins a little sooner at the south end of the basin and advances northward up the valley to the head-waters. Accordingly, "after heavy precipitation the maximum flow comes from the immediate body of the watershed, while the flow from the head-waters will come in to sustain the volume and to prolong the flood. The melting of the snow in the north portion of the basin will maintain the flow for several days after it has melted and run away from the south portion."

In this respect the Des Plaines river is the antithesis, on a small scale, of the Red river of Minnesota and Dakota, which runs towards the north for several hundred miles, and chiefly on that account is subject to very high and destructive floods.[2]

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[1] Appendix to a report on "Water Supplies of Illinois." Preliminary report to the Illinois State Board of Health, pp. 49-81, 1889.

[2] One of these occurred in the spring of 1897. During the preceding winter several feet of snow had accumulated on the ground, around the headwaters of Red river. Early in April, in the course of only two or three days, all this snow was melted off by a warm wave. The immense volume of water thus let loose quickly found its way over the frozen ground into the river, swelling it beyond all proportions. Farther down the river, i. e., farther north, where the arrival of the warm wave was somewhat delayed, the ice had only begun to break up when the flood and floating ice from the headwaters were precipitated upon it. Ice jams were formed, and the Red river was dammed back, at Fargo and Morehead, until it was 12 miles wide.

While the meridional length of the Des Plaines basin is an interesting fact, when seen in this light, and while it may operate to some extent in prolonging floods, it seems hardly likely that because of the difference of latitude alone the snow would melt sooner at its south end than at its north end. The sun's rays are hardly one degree higher at the former than at the latter. Certainly the difference would not cause a delay of several days in the melting process. The explanation of the delay in the northern portion of the basin, about the headwaters, is probably to be found in the greater acreage of forest there and the greater diversity of surface, affording more frequent shaded slopes.

Mention has been made of the spring freshet of 1674, in which the Des Plaines discharged so much water eastward towards Chicago that Marquette and his two companions were forced to abandon their hut beside the Chicago river, and were enabled to cross the divide in canoes a few days later. Another flood of this sort, accentuated by ice jams near Summit, caused much damage to shipping and bridges on the Chicago river in 1849.

One of the most extraordinary floods of which there are accurate measurements was in April, 1881. Mr. Cooley tells of it in these words.[1] "The flood maintained its height for nearly four days, and lasted about twenty-one days. The ground was practically saturated when winter set in, and about one foot of water in the shape of ice and show accumulated, and all ran out or melted during three weeks, at a temperature a little above freezing point and without material rain. The southern portion of the watershed was entirely bare before the northern snows began to melt. For this reason, the flood volume held measurably constant even toward the sources of the stream, until the snow at headquarters began to be exhausted. The conditions presented in this flood are of extraordinary occurrence only." On April 21st the flood reached its maximum height at Riverside, the discharge over the dam amounting to 13,500 cubic feet per second. The river here was nearly six feet above its low-water level. At the Ogden dam the river rose more than seven feet above its low-water mark, giving an overflow there 3½ feet in depth, so that a considerable part of the flood waters found their way to the Mud Lake district and Lake Michigan instead of down the lower Des Plaines. The proportion of water which turned eastward was abnormally great on April 9th and 10th, because of an ice gorge on the river. Nearly all the water that passed Riverside on these two days was diverted towards Lake Michigan. At Kedzie avenue the volume flowing through the Ogden ditch, from the flooded slough into the Chicago river, was as follows:

Feb. 10th	7,800 cu. ft. per second.
(cf. with the 8,00 feet at Riverside.)	
Feb. 11th	4,636 cu. ft. per second.
Feb. 14th	1,625 cu. ft. per second.
Feb. 18th	4,000 cu. ft. per second.
Feb. 9th	3,042 cu. ft. per second.

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[1] Op. cit., p. 74.

The figures determined at three stations show that the flood was double, decreasing between the 10th and 16th and rising again on the 19th. Regarding the effect of the overflow across Ogden dam in diminishing and regulating the flood along the lower Des Plaines, Mr. Cooley says:[1] "When the water in the Des Plaines stands at the crest of the dam, the flow down the Des Plaines is 800 to 1,000 feet per second, depending upon whether the water is falling or rising, or on the condition of vegetation in the '12-mile level.' Above this volume, the proportion escaping to Chicago increases rapidly with the height of flood, and for this reason the floods passing Joliet are more uniform in volume, one year with another, than at Riverside." In large floods fully half the water goes over the dam of Lake Michigan. The crest of the dam is 11.7 feet above the lake (Chicago datum for Lake Michigan, 580 feet above the sea.) In low water the river is 3.7 feet below the dam.

Another unusual flood occurred early in February, 1887, reaching a maximum height at Riverside on the 9th.[2] The volume of discharge as measured at Riverside and Joliet on different days is as follows:

	Riverside. Cu. ft. per sec.	Joliet. Cu. ft. per sec.
Feb. 9th	10,324	.....
Feb. 10th	8,000	.....
Feb. 11th	7,000	5,775
Feb. 16th	2,000	1,460
Feb. 19th	5,374	5,385

Comparing figures at the two stations for the 11th and the 16th, it is seen that a large fraction of the volume which passed Riverside escaped over the Ogden dam to Lake Michigan, diminishing the flood at Joliet very materially.

According to Mr. Cooley, an extraordinary flood, with discharge of upwards of 10,000 cubic feet per second at Riverside, occurred every five or six years between 1840 and 1890. Of the fifty-three floods that occurred between 1834 and 1890, thirty-eight were in February, March, or April, and the majority associated with the spring breakup. "The ordinary yearly flood as deduced from marks on the Lyons dam is 6,000 to 7,000 cubic feet per second."[3]

At the Fullersburg dam on Salt creek several extraordinary floods have given a discharge of about 2,800 cubic feet per second. On February 10th, 1887, the volume was 2,860 cubic feet. If the volumes of floods on Salt creek, compared with those on the Des Plaines, were in direct proportion to the areas of the respective basins, the flood at Riverside on February 10th should have been over 16,000 cubic feet instead of 10,324. The failure of the flooded Des Plaines to attain a volume proportional to that of Salt creek is thought by Mr. Cooley to be due to the greater meridional length of the main basin, in which the melting of snow advances northward day by day, prolonging and equalizing the flood.

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[1] Op. cit., p. 73.

[2] The source of the information here presented, on the floods of 1881 and 1887, is Mr. Cooley's report, previously cited.

[3] Op. cit., p. 73.

The dry-weather volume of the Des Plaines is extremely small; for the river has not cut down its bed sufficiently below permanent groundwater level, and must get its supply almost wholly from surface run-off. In 1887 the discharge at Riverside was diminished to four cubic feet per second, as contrasted with 10,324 feet in the February flood of the same year. For five months the discharge did not exceed seventeen feet per second. Although the river has been known to be even lower than this it has never run dry. Salt creek, however, was dry at Fullersburg in 1887.

The effects of settlement of the basin in changing the height and direction of the floods from their original and natural condition has been pointed out by Mr. Cooley. During the settlement of the valley, the clearing away of timber and the draining out of the bogs and marshes by systematic trenches largely destroyed the natural reservoirs and regulators of floods, allowing a more immediate run-off; consequently the floods now are higher and of shorter duration. The flow of the river during the year is less uniform, and low-water lasts much longer than formerly. These effects are even more strongly felt on the Kankakee river, where broad marsh lands have been reclaimed.

THE LOWER RIVER.

On account of the usual diversion of a large fraction of the flood waters by the Ogden dam at Summit, the floods which are conspicuous above Summit are usually of minor concern to the property owners on the lower course of the river. As the flood rises higher and higher above the Ogden dam, a larger and larger fraction of it overflows toward Lake Michigan. So, at Lemont, Lockport, and Joliet the floods as a rule are lower than at Riverside, and more uniform from year to year. The normal extreme flood at Riverside (as computed by Mr. Cooley) is nearly twice that at Joliet (12,000 and 6,300 cubic feet respectively.)

Measurements on the dam at Joliet determine discharges during extraordinary floods as follows:

1877 (April 7th)	6,410 cu. ft. per second.
1881 (April 21st)	6,550 cu. ft. per second.
1883 (Feb. 16th)	6,370 cu. ft. per second.
1887 (Feb. 11th)	5,775 cu. ft. per second.

In the flood of April, 1881, the highest for thirty-three years (up to 1890), the water was 3.75 feet high on the Jackson street dam at Joliet. This city, however, does not always escape floods. Local cloudbursts, flooding the tributaries east and north of the city on the Valparaiso moraine, occasionally cause much destruction of property in Joliet. One of these occurred on August 10, 1867, which flooded a part of the city and in a few hours caused much damage.

The worst flood within the memory of the townspeople occurred at about midnight June 2nd and 3rd, 1902. A storm began about 9:00 o'clock in the evening, increasing to a heavy downpour which was accompanied by hail. Motormen were driven from the fronts of their cars by the hailstones. By midnight the water in the drainage canal had risen several feet. The old slough which lies between Eastern avenue and the Alton railway (in the heart of the city) was a raging torrent. The northeast portion of the city north of Columbia street became a temporary lake. The greatest inundations, however, were along Hickory creek, in the section known as Brooklyn. The water poured over the Hickory creek dam at the red mill three or four feet deep, and a portion of the dam at last gave way. The Union elevator was surrounded by a lake, and its lower portion flooded; but no grain was destroyed. A bridge near by, on the Michigan Central spur track, was washed out. On Brooklyn, Iowa, and Mississippi avenues, the waters flooded the sidewalks and poured through basement windows, filling cellars and in some cases invading even the living rooms on the ground floor. Houses were partially wrecked as their foundations were undermined. One small house was swept along several blocks and lodged against the Second avenue bridge. The darkness of the night magnified the confusion and horror of the scenes. People turned out long before daylight with boats, ladders, and rigs for the relief of the imprisoned ones, and the fire and police departments responded to the emergency. On McDonough street a horse and wagon carrying six people to some place of refuge was overwhelmed by the current, and two of the passengers were drowned. Many others had narrow escapes from drowning. It was feared that the big dam at Jackson street would go out, but it did not.

The railways were among the heaviest losers from this flood. The Rock Island railway bridge over the Des Plaines swung 17 inches out of position, a supporting pier being washed out. On the Michigan Central the transfer yards were destroyed. The car sheds of the street car company were flooded, and the motors of many cars ruined by water. Stove works and mills suffered likewise from inundation. Merchants within the lower portion of the city lost heavily of goods stored in basements. A local newspaper estimated the damage at over $500,000. For several hours Joliet was cut off from the outside world. No trains passed through the city until the following morning.

At Lockport the small creeks which drain the bluffs were veritable torrents, tearing away fences, bridges, and even stone walls; destroying gardens and sweeping the debris into the Illinois-Michigan canal so fast that it was choked up and overflowed its banks. In this way the west side of the town was flooded and the colored people driven from their homes. The Barrows Lock company suffered damages of about $2,000. At Romeo the quarries were filled to the brim, and the farmers lost crops and young stock. The Santa Fé tracks were blocked until the following evening, delaying the mails.

There were two washouts on the Rock Island railway above Joliet, on Hickory creek. At New Lennox, bridges and culverts were damaged to the extent of $1,500. At a washout on the track just east of the depot the night train on the Rock Island barely escaped a wreck. The flood of 1902, the highest for many years, was quite abnormal, occurring, as it did, in June, in response to a local cloud-burst.

Effects of a Recent Flood on Hickory Creek.

A more typical flood took place on January 19, 1907, when, during a temporary thaw and rain, Hickory creek overflowed its banks through the city and the water on the Des Plaines rose within a few inches of the top of the embankment. Weak points on the retaining wall above the Economy plant were hastily reinforced, and the dam at the controlling works was raised to lessen the flow. Brooklyn was again under water; cellars were flooded, furnace fires extinguished, and fuel rendered useless. The storm was accompanied by high winds that wrecked the houses where foundations had been loosened by the floods. Furniture and personal property was hurriedly moved to places of safety. The climax of the flood was reached about 8 p. m., when a cold wave began to check the discharge. The waters slowly fell as the little headwaters and side-slopes of the Hickory creek system were gradually frozen. At the same time the occupants of many houses found their cellars filled with 3 to 5 feet of water and their fuel inaccessible. Suffering from cold supplemented the direct injury from floods. All the railways were blocked. At several places between Joliet and New Lennox, the Rock Island tracks were under water.

After such a flood as this there are many interesting things to observe on the recently submerged flood-plain. Some of the drift-wood and rubbish which was swept down the valley has been caught by bushes and trees that grow on the flood-plain, forming great bunches of floatsam as high as the flood level. On Hickory creek below New Lennox, where the photographs (Plate 9) were taken, two months after the flood of January, 1907, the rubbish heaps indicated a rise of the water 7 feet above ordinary level. In the lee of each of these rubbish-laden bushes the turf on the floor-plain had been gullied out by the eddying currents. A lofty elm tree a little below New Lennox had been swept down stream, its branches trailing along behind it and ripping long grooves in the flood-plain surface. (See Plate 9, A.) Close to New Lennox station a smaller type, stranded in the bed of Hickory creek, had within two months after the flood caused the construction of a considerable bar of sand in mid-channel. The scattering of fresh shingle over large tracts of the grassy floor-plain in some places and the tearing away of the old structures in others, after floods like this, shows how far from stable is the course of the river channel.

Recent ditching of marshy areas at the head waters of Hickory creek, near Tinley park and elsewhere, in order to make them available for farming, may be expected to affect the height and duration of floods as already discussed in the preceding section. The more extensively swampy conditions are replaced by dĕfinite lines of drainage the faster will the run-off occur. Floods will rise higher but they will not last so long.

APPENDIX.

SUGGESTIONS FOR FIELD TRIPS.

The object of this appendix is to suggest some of the more accessible and more interesting localities in the Des Plaines valley where physical features may be studied to advantage by the amateur or by the teacher with a class. The catalog is by no means an exhaustible one. Every locality has its features of peculiar interest, and the amateur or the teacher will naturally find and study those which are nearest at hand. The localities listed here, however, are representative, and any one of them might form the subject of an instructive field trip. For details and for descriptions of the localities and the features noted here, reference should be made to the text or illustrations, as indicated in parenthesis. Although the localities are classified under certain subjects, such as "river erosion," "old shorelines of Lake Chicago," etc., it is needless to say that a great variety of features may be studied at any locality, and only the most conspicuous or most interesting of these features are suggested in the list.

RIVER EROSION.

Certain fundamental studies, such as the observation and measurement of velocity of the current (in feet per mile) during low water and during a flood, the transportation of sediment, etc., might be conveniently made at several of the following localities. These are not mentioned among the features cataloged below:

Maywood.—Northwest part of town. Meandering and lateral planation of the Des Plaines river; broad flood plain; development of tributary ravines; a peculiar case of mature condition of a tributary, with broad open valley and several well developed meanders of the true looped form. (pp. 83-86 and Fig. 17.)

Harlem.—Madison street bridge. Broad valley of the Des Plaines; flood plain; channel close to left bank; destructive lateral planation opposite Concordia cemetery; development of gullies along bank of main river; young ravine. (p. 83 and Fig. 17.)

Riverside.—Peculiar bend of the Des Plaines river around the Calumet beach ridge; ledges in its bed near the mouth of Salt creek; Lyons dam, for development of water power. (pp. 4 and 5; Fig. 19.)

Joliet.—(*a*) *Reed's woods.* Young ravine; narrow flood plain; trimming spurs; behavior of river on meanders; development of tributary ravines and gullies; their headward growth. (pp. 60, 83-86; Fig. 21; Pl. 7.)

(*b*) *Sugar creek.* Gorge in rock; effect of joint planes on shape of walls; waterfalls and pools. (pp. 59, 60; Pl. 2 B, and 6.)

(*c*) *Hickory creek,* below old red mill; and *Spring creek* above old wire mill. Outwash terrace; its gravelly constitution and stratified structure; amount of excavation since the ice sheet withdrew from the moraine and excavation commenced; arrangement of blocks and pebbles in bed of river, like overlapping shingles on a roof; effects of recent floods on pastures, trees, fences, houses, etc. (pp. 59, 60; Pls. 5 A, and 9.)

GLACIAL MORAINE.

Elmhurst, or Hinsdale.—Characteristic swell-and-sag topography; frequent undrained depressions. (p. 33.)

Joliet.—(*a*) West ridge, crossed on the Plainfield road, a mile north west of town. Swell-and-sag topography; transverse slough. (p. 49.)

(*b*) *East end of McEnty street,* a half mile east of the penitentiary. Swell-and-sag topography; pond in an enclosed depression; section of the moraine, showing bowlder clay overlying the Joliet conglomerate.

Mt. Forest island.—At Willow Springs or Mt. Forest. Strong "knob-and-basin" topography; peat bogs in basins.

Lockport.—East of village, on upland. Swell-and-sag topography; moraine trenched here and there by ravines, near the Des Plaines valley.

OLD SHORELINES OF LAKE CHICAGO.

Oak Park.—Hooked spit, built at mouth of Des Plaines bay in the Glenwood stage. (pp. 69-72; Fig. 17.)

Berwyn.—Calumet beach is well shown where La Grange interurban trolley car crosses it, near Oak Park avenue. Flat lake plain; beach ridge; highway, line of old oak trees, and old farm houses on the beach.

Riverside.—Calumet beach ridge; deflection of the Des Plaines river; the beach is not so well shown here as at Berwyn.

Summit.—Double-crested barrier beach of the Calumet stage, along Archer avenue, east of the village; flat lake plain on the north; floor of old lagoon on the south; stratified beach gravels shown in pit in northeast part of village; hooked end of the barrier in southeast part of village, near school house; middle portions of hooks cut off in west part of village; Toleston beach in northeast part, at base of slope of Calumet beach; turns into a cut bluff in west of village, where outlet begins, and continues thus to Mt. Forest island. (pp. 76-80; Fig. 19.)

CHICAGO OUTLET.

A very good general view of this may be had on the interurban trolley car that runs from Chicago to Joliet.

Summit.—Entrance to the outlet during the Calumet and Toleston stage on the west side of Archer road. (pp. 74-80; Fig. 19; Pl. 8b.)

Willow Springs.—Just beyond entrance to outlet at Glenwood stage. Outlet cut deeply in moraine; step bluff on both sides; canals.

Sag Bridge.—The "sag," the more easterly of the two entrances of the old outlet.

Lemont.—Rock exposed in bluffs on both sides, and on floor; at quarries on north side of valley, striæ may be seen on the floor of the outlet; west of village, quarries cut far back into the bluffs, exposing a thick section of the moraine and underlying glaciated rock.

Lockport.—(*a*) At village, rock terrace, remnant of sill; locks on old canal; controlling works and power plant.

(*b*) On west side of valley, opposite village. High terrace of gravels, remnant of outwash deposit which formerly filled whole valley and controlled level of Glenwood stage of the lake; gravels partly cemented with lime carbonate. (p. 51; Fig. 9; Pl. 3, No. 3.)

Joliet.—Flathead mound, 4 miles west of the city. Remnant of outwash deposit or valley train, like that at Lockport, but in the middle of the valley. (pp. 51, 52.)

BED ROCK STRUCTURE.

There are many quarries in the Niagara limestone, in the Des Plaines valley, near Summit, Lyons, Lemont, Romeo, Lockport, and Joliet. At all of these, features of structure such as stratification, variation in composition (including cherty layers), jointing, and inclined or even folded stratification may be seen. The following quarries, however, exhibit features of special interest:

Elmhurst.—Quarry a mile west of the station, on the north side of the Northwestern railway. Joint cracks and fissures containing fossiliferous clays of Devonian age. (pp. 17, 18.)

Lyons.—Fred Schultz's quarry, in west part of village. Devonian sediments in fissures, as at Elmhurst; peculiar folds in the limestone.

Lockport.—Ravine at Dellwood park. On the walls of the gorge gentle folds in the limestone are clearly shown.

Joliet.—(*a*) *Gorge of Sugar creek.* Dislocation along a fault is shown on the southeast wall, near the slaughter house road. (pp. 21, 22; Pl. 2 B.)

(*b*) *Abandoned pits and quarries* in the Cincinnati formation, affording many fossils, may be found close to the north bank of the old Illinois-Michigan canal, four miles west of the city, and at the west end of Flathead mound, further down the valley. (p. 14.)

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