DESCRIPTION OF THE CHICAGO DISTRICT.

By William C. Alden.

TOPOGRAPHY.

Position and area.—The area covered by the sheets of the Chicago folio embraces not only the immediate site of the city but adjacent parts of Cook, Dupage, and Will counties, Illinois. It is bounded by parallels 41° 30′ and 42° north and by meridians 87° 30′ and 88° west. It thus covers one-quarter of a square degree of the earth's surface, or about 892 square miles. Of this area about 785 square miles are land surface and the remaining 107 square miles are covered by the waters of Lake Michigan. The four sheets included in the folio are the Chicago sheet on the northeast, the Riverside sheet on the northwest, the Calumet sheet on the southeast, and the Desplaines sheet on the southwest.

Perhaps the points of most special geologic interest in the district lie in the beaches and other deposits of the ancestral Lake Michigan and in the contribution to the history of the Great Lakes furnished by their study.

The Chicago Plain, the site of the city.

Relief.—To an interested observer the topography is at once significant. The city of Chicago is situated on a low, strikingly flat, crescent-shaped plain bordering the head of Lake Michigan. At the north end of this crescent is Winnetka, on the lake shore, about 8 miles north of Chicago. From here the plain broadens southward, attaining a width of 12 to 15 miles in a southwesterly direction from the city, whence it again narrows as it passes

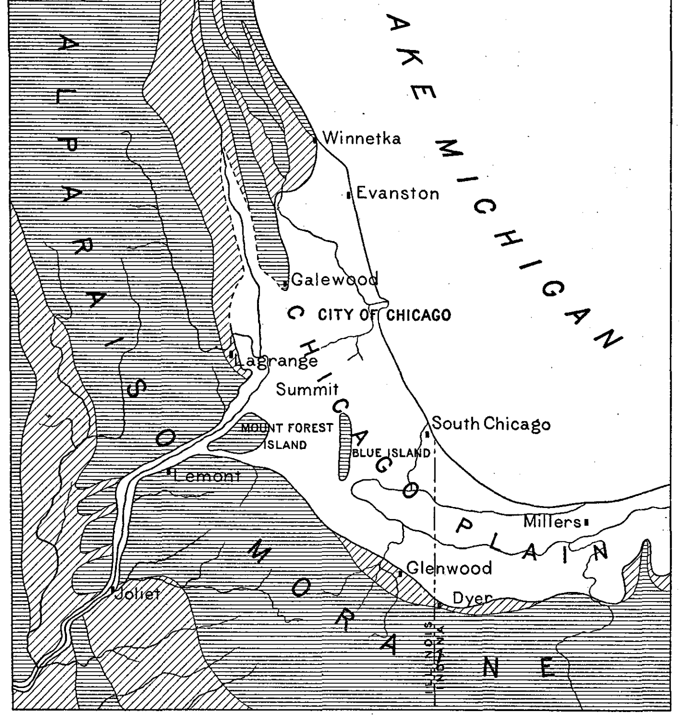

FIG 1.—The Chicago Plain and adjacent territory.

The dense ruling represents the areas of morainal drift topography; the lighter ruling represents the drift-plain areas which were not covered by Lake Chicago; the unshaded area represents the Chicago Plain, which was covered by Lake Chicago during its greatest extension.

eastward about the head of the lake (fig. 1). From the shore of Lake Michigan, the surface of which is about 581 feet above mean tide level, this plain rises gradually to a nearly uniform height at its inner margin, about 640 feet above tide, or about 60 feet above Lake Michigan.

Ridge inclosing the plain—Valparaiso moraine.

West and south of this plain bordering Lake Michigan is an elevated belt of more or less strongly undulating topography. In some parts there is an immediate rise from the plain to a moderately rolling surface, while in western Cook County and eastern Dupage County the surface passes almost imperceptibly from flat to gently undulating. In either case the surface rises until a maximum altitude of about 200 feet above Lake Michigan is reached, whence it declines to the west and southwest. More extended observation shows that this ridge-like belt comes from the north and swings about the head of the lake basin. It is in reality a glacial moraine (fig. 1) and has been called the Valparaiso moraine, from the town of Valparaiso, Ind., which is situated upon it. Where crossed by the Wabash Railroad between Palos and New Lenox, situated respectively on its inner and outer margins, it has a width of 15 miles.

Gaps in morainal ridge—Desplaines Valley and the "Sag."

Cut directly through this low, broad ridge in a southwesterly direction from Summit to Lemont is the valley now traversed by the Desplaines River, the Illinois-Michigan Canal, and the Sanitary and Ship Canal of Chicago. About 2 miles below Lemont this valley bends southward and reaches the outer margin of the moraine near Joliet. The valley has abrupt slopes, varies in width from one-half mile to $1\frac{1}{4}$ miles, and is 30 to 150 feet deep. The floor of the valley is nearly flat from side to side. At its lakeward end the bottom is continuous with the Chicago Plain and is less than 15 feet above the level of Lake Michigan. From Summit to Lemont the fall is so slight as to be spoken of as "the 12-mile level."

Tributary to this valley at Sag Bridge station, about $3\frac{1}{2}$ miles above Lemont, is a second valley of like dimensions, known as the "Sag." This runs nearly due west from the village of Worth, on the Wabash Railroad, to Sag Bridge station on the Chicago and Alton Railway. It is traversed by a small marshy creek, known as the Calumet Feeder. These converging valleys cut off a triangular undulating tract having a length east and west of 6 miles and a width north and south at its lakeward end of 4 miles. This tract is known as Mount Forest.

The floor of the Sag, as well as that of Desplaines Valley, is continuous with the Chicago Plain. The two valleys thus give ample outlet from the plain southwestward across the morainal belt and thence by way of Illinois River to the Mississippi and the Gulf of Mexico, with a rise of less than 15 feet above the present level of Lake Michigan.

Blue Island and other elevations in the plain.

The most prominent topographic feature of the plain is Blue Island Ridge, 7 miles west of the lake at South Chicago. This ridge extends due north and south, having a length of 6 miles, a width of about 1 mile, and an elevation of 25 to 50 feet above the surrounding flat.

Just west of South Chicago, between Blue Island Ridge and the lake, is an elevation of rock known as Stony Island. Its longer axis has an east-west direction. The length of the "island" is $1\frac{1}{2}$ miles, its width one-half a mile, and its height about 20 feet above the surrounding marshy area.

The north side of Chicago, between North Branch of the Chicago River and Lake Michigan, is also occupied by two broad elevations rising 30 to 40 feet above the lake.

Old beach ridges.

Traversing this plain and converging toward the southwestern outlets there is a series of low ridges of sand and gravel so related to the lake, to the outlets, and to one another as to be very significant of the history of the district. These are the shore lines of an ancient lake, the predecessor of Lake Michigan.

Divide between Lake Michigan and Mississippi waters.

Drainage.—The drainage of the district belongs to two great systems, the St. Lawrence system on the east and the Mississippi system on the west. Hence the area is traversed by the continental divide. So insignificant is this watershed near Summit, near Chicago Ridge, and east of Palos that at these places it can scarcely be seen at what point the waters separate. They are continuous, and at a given point sometimes flow eastward to the lake and sometimes westward to Desplaines River. The completion of the Chicago drainage canal has really obliterated the divide at Summit, as a part of the waters of the lake itself now flow through this artificial channel to the Mississippi. This is an artificial reestablishment of what was once a natural discharge of the lake waters through the Chicago outlet to the Mississippi system, and is fully discussed under the heading "Lake Chicago."

The natural drainage of the plain in and about the city of Chicago is very poor, owing to the flatness of the surface and the consequent low gradient of the streams. This has made the sewage problem one of the most difficult with which the city has had to deal. Considerable areas within the city limits would be utterly uninhabitable but for artificial drainage systems.

Chicago River and harbor.

That part of Cook County east of Desplaines River and north of Stony Island has, as its only natural drainage lines, the sluggish North and South branches of Chicago River. North Branch has its origin about 4 miles west of Highland Park, Ill., and flows 27 miles in a southeasterly direction. South Branch has its origin northeast of Summit, not far from Desplaines River, and flows northeastward through the city to unite with North Branch within a mile of the lake. The confluence of the two forms Chicago River, which flows eastward into the lake through the heart of the city. This is a statement of the natural drainage by this stream. These natural conditions have, however, been greatly modified by the opening of the Sanitary and Ship Canal, which took place in January, 1900. This canal, while planned with a view to furnishing a deep waterway from Lake Michigan to Illinois River, was constructed primarily as a drainage canal to improve the sanitary conditions of the city. By a reversal of the flow in South Branch and the main trunk of Chicago River the whole stream and a large amount of water drawn directly from Lake Michigan become tributary to the Illinois and Mississippi river systems. By repeated dredgings Chicago River and its branches have been enlarged to form a river harbor for the immense shipping of the most important port of the upper Great Lakes. South Branch has been made navigable for lake boats a distance of 6 miles through the city, and North Branch for a less distance. North Branch has for some time been flushed by water drawn from the lake through the Fullerton avenue conduit. The Illinois and Michigan Canal has furnished a navigable channel from South Branch of Chicago River through Desplaines Valley to Illinois River. Through the aid of the pumping works at Bridgeport this canal has been made to take part in the drainage of the area by carrying the water to the southwest.

Calumet River and its tributaries.

The drainage of the southern part of the Chicago Plain, together with the lakeward slopes of the bordering moraine belt, is accomplished by Calumet River and its tributaries. This stream follows a very anomalous course (fig. 14). It has an interesting history, which is discussed under the heading "Recent changes." It rises in the western part of Laporte County, Ind., and flows in a westerly direction, nearly parallel with the lake shore, a distance of 45 miles, to the village of Blue Island. Here it turns abruptly and takes an easterly direction nearly parallel to its previous course and but 2 to 3 miles distant. It finally reaches the lake after doubling upon itself nearly 22 miles. To distinguish the two parallel portions crossing Lake County, Ind., the southern portion has received the name Little Calumet, and the northern the name Grand Calumet.

One peculiarity of Calumet River is its apparent possession of two outlets. The Indiana debouchure, just mentioned, is the original one; the other is at South Chicago. A channel from that point passes between Calumet Lake and Wolf Lake and connects with the river proper near Hegewisch. This channel, which is said to be artificial, as well as the main stream between the confluence and Hammond, Ind., has been dredged within recent years, and small steamers now ply daily between Chicago and Hammond. The Indiana debouchure is very largely closed by shore drift, wind-blown sand, and aquatic vegetation, so that there is but little current in Grand Calumet River. The opening of the channel to South Chicago has drawn the flow largely in that direction, and the Grand Calumet may be said to be reversed. During the spring and fall flood seasons the stream fills its low banks and overflows considerable areas, so that early geographers were wont to say: "The country around the extreme south bay of Lake Michigan has the appearance of the sea marshes of Louisiana."

Tributary to Calumet River at a point about $2\frac{1}{2}$ miles northeast of Thornton is Thorn Creek, which, with its tributaries, Butterfield Creek and Deer Creek, drains the lakeward side of the moraine in this vicinity. This is an active line of drainage with a considerable gradient and has cut a sharp channel 20 to 25 feet in depth. Near Glenwood and at Thornton the erosion has reached the limestone below the bowlder clay.

Desplaines River.

Desplaines River has its origin in the southern part of Racine County, Wis.; thence it flows about 65 miles, in a course slightly east of south, to Summit, Ill. About one-half mile north of Summit it turns abruptly southwest and enters the valley which cuts through the morainal belt. Mr. Leverett, in his paper on "The Water Resources of Illinois,"[1] speaks concerning this stream as follows:

> The Desplaines has been found to have at Riverside an extreme flood stage of about 10,000 cubic feet per second, with an occasional higher volume, as in April, 1881, when it reached 13,500 cubic feet. It has been estimated by Professor Cooley that on an average of once in five or six years during the past fifty years the flood has exceeded 10,000 cubic feet, while the ordinary yearly flood, as shown by the marks on the dam at Lyons, just below Riverside, is 6000 to 7000 cubic feet per second. In these extreme floods nearly half the water has been wont to discharge into Lake Michigan, and in ordinary floods a small discharge has usually occurred.
>
> As a consequence the flood stages of the Desplaines are higher above Riverside than those of the lower course of the stream. . . . . .
>
> The drainage area above Riverside is scarcely 1000 square miles. This gives, at the maximum extreme flood of April, 1881, a flow of fully 13.5 feet per second per square mile of area. The low-water volume is exceedingly small. Professor Cooley reports that at Riverside, in 1887, it reached a minimum of 4.27 feet per second and for five months did not exceed $16\frac{2}{3}$ cubic feet per second. He estimates that for nearly every year the extreme low water at Riverside and Joliet reaches above 5 cubic feet per second.

The fall in the flood plain of the Desplaines is 90 feet in 60 miles, or at the rate of $1\frac{1}{2}$ feet per mile above the Lyons dam. At Riverside a rock barrier is crossed with a descent of about 14 feet in 3 miles. Here the stream makes a sharp turn, doubling back upon itself to the northeast three-fourths of a mile and again turning southeast and south. From Summit to Lemont there is practically no grade. The floor of the valley from Summit to Sag Bridge station is of bowlder clay, and from Sag Bridge station to Lemont is of limestone, bare, or but thinly covered. In this nearly level floor the stream has cut a very shallow bed. At present the river, in a large part of its course from Summit to Lemont, occupies an artificial channel, having been shifted toward the north side of the valley to make room for the new drainage canal.

The principal tributary of Desplaines River in this region is Salt Creek. This flows in a direction slightly east of south, in a depression in the morainal belt. Its course is apparently consequent upon the topography as far as Fullersburg. From this point, while the depression continues southward as the valley of Flag Creek, Salt Creek has abandoned what appears to be its natural course and turns eastward, passing out upon the plain and uniting with the Desplaines at the sharp bend at Lyons. The rate of fall in Salt Creek is 3 feet per mile for 18 miles above the Fullersburg dam. From this point to Lyons, a distance of 8 miles by the course of the stream, the fall is 41.3 feet.

The drainage through the Sag is usually very slight, there being but little difference in level

[1] The water resources of Illinois, by Frank Leverett: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1895, p. 741.

between Sag Bridge station and Blue Island. The western part drains through the canal feeder to the Illinois and Michigan Canal at Sag Bridge station and the eastern part drains by Stony Creek to Calumet River at Blue Island. The valley bottom is marshy and covered by an extensive peat deposit.

The outer slope of the morainic belt south of the Desplaines Valley is drained westward and southwestward by numerous creeks, of which the largest is Hickory Creek in Will County. This unites with Desplaines River about 1 mile south of Joliet. Most of these streams drain marshes in the morainic belt.

Lakes and marshes.

Between South Chicago and Hammond, Ind., is a group of shallow, marshy lakes or ponds. These are Calumet Lake, Wolf Lake, and George Lake. The largest, Calumet Lake, covers about 3 square miles. Hyde Lake has been entirely drained. Considerable marsh areas surround these lakes. Extensive marshes also occur east of Auburn Park, north of Stony Island, south of Maynard, Ind., and all through the lake border region of Lake and Porter counties, Ind. Large parts of these marshes have been artificially drained.

GEOLOGY.

SEDIMENTARY ROCKS.

General relations.—The geologic history of this part of Illinois is here sketched only in the barest outline.

Information from deep wells.

The rock forming the substructure of this region may be seen in numerous quarries about the city, and is reached by all borings which pass through the drift. The formation exposed at the quarries and first reached in borings is the Niagara limestone. Where these borings have penetrated to depths of several hundred feet, not only one but several great rock formations are found, limestones, sandstones, and shale overlying one another in alternating series. These are the deposits of early geologic ages. The thickness, character, and general stratigraphic relations of the great sedimentary rock formations underlying this area, as determined by borings for artesian wells, are shown in figs. 2 and 3.

All the deepest wells in this region terminate in the midst of a great sandstone formation, the

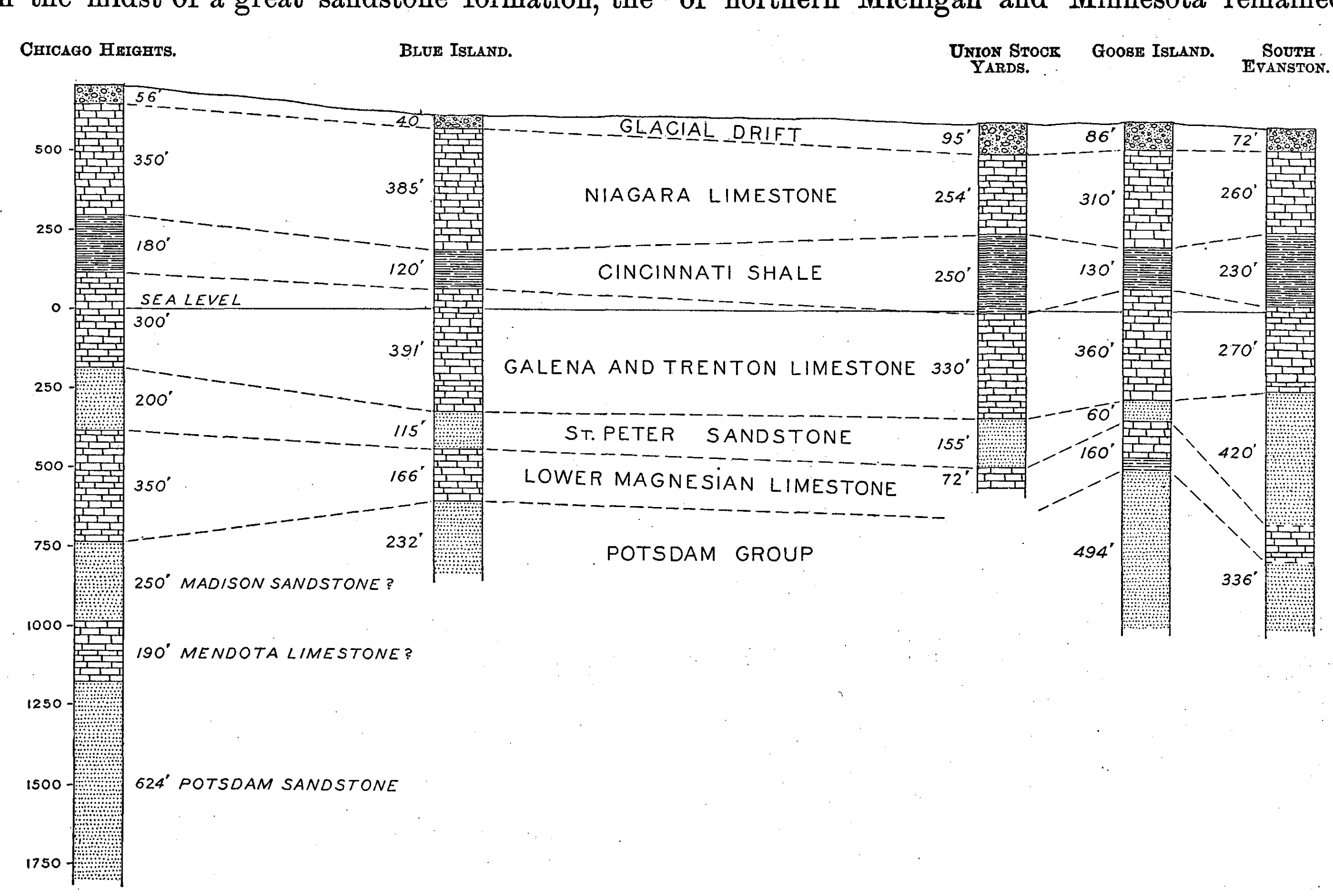

FIG. 2.—Sections of deep well borings at Chicago Heights,[1] Blue Island,[2] Union Stock Yards,[3] Goose Island, Chicago,[4] and South Evanston,[5] showing the underlying formations and their general attitude.

[1] Private well south of the village. Record furnished by Gray Bros., well drillers, Chicago.
[2] Smelter well. Record at the office of the smelter.
[3] Geology of Illinois, Vol. III, p. 244.
[4] Ames and Frost's well in the Twentieth ward of Chicago. Record furnished by F. M. Gray, well driller, Milwaukee, Wis.
[5] Dr. Oliver Marcy, as quoted by Frank Leverett in Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, p. 800.

Potsdam sandstone. This is the lowest known rock formation in the State, and is shown at the bottom of the section. Some of the wells penetrate this sandstone several hundred feet, but none pass through it. In parts of Wisconsin it has a thickness of 1000 feet.

What underlies this sandstone here is not known. When these formations are traced northward into central Wisconsin it is seen that they gradually rise, and, one after another in the order of their succession downward, thin out and disappear as the next formation below rises to the general rock surface, until at length even this lower sandstone reaches the surface, spreads over a great area, thins out, and disappears. From beneath this sandstone there appear crystalline rocks of yet remoter age. It is believed that these latter rocks everywhere underlie the formations found by the well borings beneath the Chicago area, and that their erosion originally furnished the material from which the overlying sedimentary formations were made.

Cambrian Period.

Potsdam group.—This lower group of sediments, the Potsdam sandstone, which is very widely distributed in the United States, is of later

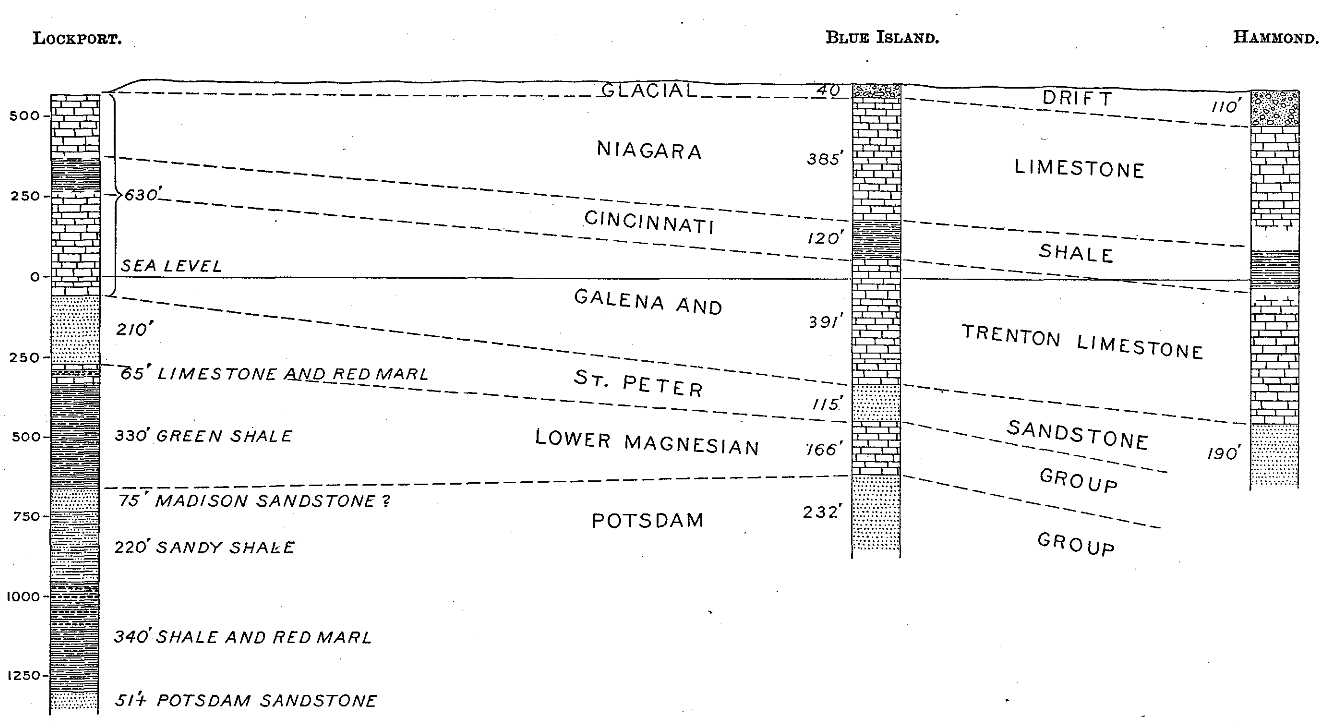

FIG. 3.—Section of deep well borings at Lockport, Blue Island,[1] and Hammond,[2] showing the underlying formations and their general attitude.

[1] Smelter well. Record at the office of the smelter.
[2] Record by W. F. Bridge, as quoted by Frank Leverett in Seventeenth Ann. Rept. U. S. Geol. Survey, Part II, p. 800.

Beach and shore sands of late Cambrian time.

Cambrian age. Since this is the earliest of the Paleozoic formations in the northern interior, it is evident that a large part of the continent was land area and was exposed to denudation while the earlier Cambrian formations were being deposited in the eastern and western seas.

With the opening of later Cambrian time, however, the ocean advanced upon the land from the south, until of all the northern interior of the United States, only the northern half of the area of Wisconsin and parts of northern Michigan and Minnesota remained above water. In this ocean was a characteristic fauna, and in the shallow waters along the advancing shore line the Potsdam sandstone was deposited, much as great beds of sand are now being deposited along sea shores. That the deposit was made in the ocean and not in an inland lake is shown by the fossil marine fauna, found where the rock outcrops.

Whatever may have been the character of this Wisconsin land and its altitude relative to the advancing Cambrian sea, it is evident the relation was such that the erosion of its surface and the deposition about its shores gave rise to a very extensive sand bed of considerable thickness. There appears to have been more or less variation in these conditions, so that in some places beds of limestone and beds of shale occur in the upper part of the formation. The well at Chicago Heights shows 190 feet of limestone and shale in the uppermost part of the Potsdam formation, and above this 250 feet more of sandstone, making 1064 feet of rock to be referred to this group. This bed of limestone and shale indicates an interval of deeper waters, free from beach sands. The limestone probably is to be correlated with a similarly located but thinner bed in Wisconsin, known as the Mendota limestone, while the upper 250 feet of sandstone may be correlated with the Madison sandstone of Wisconsin.

The well at Lockport, on Desplaines River, 8 miles below Lemont, shows the following section, probably referable to the Potsdam group:

Well section of Potsdam rocks at Lockport.

	Feet.
Sandstone (Madison sandstone ?)	75
Sandy shale (Mendota limestone ?)	220
Shale (Mendota limestone ?)	35
Shale and red marl (Mendota limestone ?)	75
Shale (Mendota limestone ?)	230
Sandstone	51
Total	686

At the Joliet Steel Mills, 4 miles farther south, the section of the Potsdam group is as follows:

Well section of Potsdam rocks at the Joliet Steel Mills.

	Feet.
Sharp sandstone (Madison sandstone ?)	175
Blue shale (Mendota limestone ?)	50
Shaly limestone (Mendota limestone ?)	125
Shale (Mendota limestone ?)	230
Total	580

These sections show deposition in water somewhat deeper than that which covered the region lying farther east, for instead of so much shore sand, finer silts were deposited.

Silurian Period.

Calcareous deposits of early Silurian time.

Lower Magnesian group.—Overlying the beds of the Potsdam group is a magnesian limestone formation 160 to 450 feet thick. This formation thickens toward the south and southwest, being 350 feet thick at the Chicago Heights well and 450 feet thick at Joliet. The deposition of silts continued in the Lockport region, so that the well shows the following section:

Well section of Silurian rocks at Lockport.

	Feet.
Limestone	12
Red marl	33
Sandy limestone	20
Green shale	330
Total	395

As a general rule, however, clearer waters prevailed and a new and different fauna was developed. While it is probable that the Lower Magnesian limestone was derived from the calcareous residue of this marine life, well-preserved fossils are very rare in it.

The dolomitic character of the limestone is held by some to have been due to contemporaneous deposits from the magnesian salts of the sea water, and by others to have been due to subsequent alterations.

Sands succeeding the early Silurian dolomite.

St. Peter group.—A return to conditions favorable to the deposition of sands and to changes in the fauna of this region marked the formation of the St. Peter sandstone, which overlies the Lower Magnesian group.

This is a very porous, white sandstone, varying considerably in thickness. It ranges from 60 feet thick where it is reached in wells at Goose Island in North Branch of Chicago River, about $2\frac{1}{2}$ miles northwest of the Chicago Harbor inlet, to 200 feet at Chicago Heights and 450 feet at South Evanston.

Magnesian limestone of mid-Silurian time.

Trenton group.—Limestones of the Trenton group were deposited in this region during the period which next followed. In the clear waters of this Trenton sea lived a prolific and varied fauna, as we may judge from the fossil remains at places where the rock is now exposed at the surface. This fauna consisted of corals, crinoids, mollusks, crustaceans, and other invertebrates. The limestones are mostly magnesian. Wells in the vicinity of Chicago show strata 270 to 390 feet thick, referable to this group. The upper part of the formation, known as the Galena limestone, is the lead-bearing formation of northwestern Illinois. The lower part is known as the Trenton limestone.

Mud rocks or shales succeeding the Trenton limestone.

Cincinnati or Hudson group.—Overlying the Trenton limestones is a formation composed of thin-bedded shales or mud stones. These are, for the most part, composed of the fine, muddy sediments carried into the sea by the drainage of the land. It is possible that these fine sediments so polluted the water as to have a marked effect upon the living organisms therein. At any rate, there was a marked change in the fauna; new species came in, and such as could not adapt themselves to the new conditions were extinguished or forced to emigrate.

Under the Chicago area this shale formation is shown by wells to vary in thickness from 105 to 250 feet. It was found to have a thickness of 250 feet at the first Union Stock Yards well. A 20-foot bed of limestone occurring in the formation at this place shows an interval of clearer water.

At the close of the Hudson epoch two great islands developed in the interior continental sea in the region of Indiana, Ohio, Kentucky, and Tennessee, which very materially affected the rock-making conditions. No marked disturbances of the strata are found in the vicinity of Chicago, but the sea was withdrawn for a considerable period, as is shown by the fact that formations which were elsewhere deposited between the Cincinnati group and the next overlying formation are not present in the Chicago area, and by the fact that the fossils of the succeeding formation show that an interval occurred in which the marine fauna was almost entirely changed. When the sea again submerged the area a fauna composed almost entirely of new species made this their habitat.

Niagara group.—Upon the Hudson shale lies a great limestone formation, the Niagara limestone, which immediately underlies the drift throughout this region (figs. 2 and 3). This formation here varies in thickness from 254 to 409 feet, and it is probable that even this is not its original thickness, since there was a great opportunity for erosion before it was covered by the protecting mantle of drift.

During the deposition of this limestone clear-water conditions prevailed over wide areas and a new and wonderful fauna developed.[1] Just where this new fauna came from is not known, but a careful study of the distribution of the rock of this age and of the forms of life represented has led to the suggestion that the interior sea extended far northward and connected with Europe across the polar regions, and along the shores of this sea the species may have come to the region of northeastern Illinois.[2]

[1] For description and illustrations of the varied and beautiful forms of marine life abounding in the seas of the Niagara period in this region, reference should be made to the publications listed at the end of this paper.
[2] The Silurian fauna interpreted on the epicontinental basis, by Stuart Weller: Jour. Geol., Vol. VI, 1898, pp. 692–703.

Since the Niagara limestone immediately underlies the drift throughout the Chicago district, there is abundant opportunity for its examination and study at the numerous quarries and outcrops.

Exposures of Niagara limestone in and about Chicago.

As shown by the sections (figs. 2 and 3), the thickness of the Niagara limestone varies considerably within this area. The character of the rock at the various outcrops and quarries is indicated in the following description:

About a mile northwest of Humboldt Park, corner of North Central Park avenue and Humboldt avenue, the Niagara limestone rises in a gentle knoll which has a relief of 4 or 5 feet. The rock is here thinly covered by clay and is exposed only in spots, so the dip could not be read.

Two blocks west of Humboldt Park, at the intersection of Homan and Frederick avenues, is a small lenticular elevation of rock, lying in a northeast-southwest direction, having a relief of 4 or 5 feet. It is but slightly exposed, because of the clay covering, and no reading of the dip could be taken.

At the intersection of Chicago and Western avenues, about three-fourths of a mile southeast of Humboldt Park, is a low elevation of rock, partially exposed above its thin covering of clay and having a relief of 5 to 7 feet above the flat to the east. Near Grand and Campbell avenues are two quarries having depths of 80 to 90 feet. The rock as here exposed is a massive gray dolomite, much fractured, so that the product of the quarries is crushed stone for paving and rubble for foundations and lime, no dimension stone being available.

The presence of petroleum, apparently saturating the rock in places, led, in 1864, to an attempt to procure a flow of oil. A well was sunk at the corner of Chicago and Western avenues. While a small amount of petroleum was found the well failed to disclose the presence of oil in sufficient quantities to be of any value, and the attempt was abandoned. The character and succession of the beds penetrated were faithfully recorded,[1] and are here given:

Well drilled for oil at Chicago and Western avenues.

Well section at corner of Chicago and Western avenues (1864).

	Depth in feet.
Gray limestone	0
Buff limestone, Athens or Joliet marble	30
Gray limestone	115
Marble	121
Gray limestone	182
Marble	194
Gray limestone	230
Marble	260
Dark-gray stone	290
Light-gray stone	320
Dark stone—very hard	362
Gray limestone and flint	390
Stone and shale	395

The term "marble," as used here, evidently means even-grained, close-textured limestone.

About a mile east of Douglas Park, at the intersection of Nineteenth and Lincoln streets, is the quarry of the Chicago Union Limeworks Company. The section here shows 10 to 15 feet of bowlder clay over the limestone. The quarry is about 175 feet in depth. Mr. T. W. Phinney, president of the company, states that the limestone here is a dolomite with about 54 per cent carbonate of lime and 44 per cent carbonate of magnesia, affording very strong lime. The strata are 1 to 6 feet in thickness, with thin seams of clay one-fourth of an inch or less in thickness. The beds are nearly horizontal, and so much fractured that no dimension stone is quarried. At a depth of 200 feet the character of the rock changes, showing about 10 per cent of silica, with so much less of the carbonate of lime and magnesia. The rock here does not show the presence of petroleum. In the first and second blocks east of the quarry are outcrops indicating a thin covering of the rock in this vicinity, and about one-half mile south, near the corner of Robey and Twenty-third streets, the rock for several blocks is exposed or but thinly covered.

Quarries near Douglas Park, at Bridgeport, and at Hawthorne.

In the part of the city known as Bridgeport, about 1¼ miles farther southeast, at Twenty-seventh and Halsted streets, south of South Branch of Chicago River, is the quarry of the Stearns Lime and Stone Company. The rock is massive concretionary limestone showing little appearance of stratification. It varies in character from a loosely compacted clayey rock to a solid bluish-gray limestone. The locality is especially rich in organic remains and has yielded many fine fossils.

At Hawthorne, on the Chicago, Burlington and Quincy Railway, west of Chicago, is the quarry of Dolese & Shepard. The excavation here is 60 to 70 feet deep and shows definitely bedded, gray limestone, massive below, weathering yellow. The strata dip strongly in the direction S. 46° E., the angle of dip varying from 10° to 40°. The beds are much fractured and hence furnish only crushed stone, lime, and cement. The rock is highly fossiliferous, especially in the upper layers, where it is composed largely of fragments of fossil organisms.

On the lake shore at Windsor Park, at the foot of Cheltenham place, is an outcrop of the Niagara which is well saturated with petroleum. It is but thinly covered for several blocks back from the shore, so that excavations made for sewers are partially in rock. Two small outcrops occur on Railroad avenue, between Seventy-fourth and Seventy-fifth streets, in Windsor Park, and a third about six blocks west, between Seventy-fifth and Seventy-sixth streets. These outcrops are not shown on the map.

Farther south, at Ninety-second street and Stony Island avenue, a mile north of Lake Calumet, is one of the most interesting exposures within the area, a rock elevation locally known as Stony Island. This exposure is a somewhat elliptical ridge, 1½ miles long and one-half mile wide, with the long axis in an east-west direction. It has a relief of 20 to 25 feet above the surrounding marshy plain. The limestone is exposed almost continuously about the margin of this ridge, though the main part is covered by a thin coating of bowlder clay and gravel. On the northwest side of the elevation, at Ninety-second street and Stony Island avenue, is an old quarry which gives an excellent 15-foot section (fig. 15). The rock, which is a gray, fossiliferous, magnesian limestone, or dolomite, weathering buff, dips in the direction N. 61° W. at an angle of 42°. Across the ridge to the southeast, at a distance of about three-eighths of a mile, is a second quarry, showing a like section, with the beds dipping S. 44° E. at an angle of 33°. At the east end, just north of Ninety-third street, there is a dip of 30° in the direction N. 74° E. On the northeast slope, at Essex street, north of Ninety-second street, the dip is toward the northeast. On the north side of the ridge, about midway of its length, just north of Ninety-second street, on Cloud street, there is a dip of 42° in the direction N. 36° W., and two blocks farther west, near Rupp and Ninety-second streets, the dip is 40° in the direction N. 26° W. At the west end the rock passes rapidly below the till, as a well just west of Stony Island avenue, between Ninety-second and Ninety-third streets, shows 33 feet of till overlying the limestone. This shows a decline of 48 feet toward the west in the distance of about one block. The rock is thus seen to have quaquaversal dips, and the elevation is the result of a local bowing or folding. It is inferred that the strata were once continuous over the fold, but the dome has been truncated by erosion and the edges of the bed have been beveled, smoothed, and striated by glaciation. The especially fine evidence of glaciation is discussed under the heading "Epoch of glacial occupation." It is possible that this "island" is an uneroded remnant of a much larger uplift, since the elevation there is narrow and the dip of the strata is abrupt. If such is the case, the erosion has been very uniform on all sides, so that the remnant coincides with the axis of the fold. It may be, however, that the high dips are not entirely due to flexure or uplift. In the vicinity of Milwaukee, Wis., certain mounds of limestone in the Niagara formation show high quaquaversal dips which are evidently the slopes of original deposition about ancient coral reefs. While there is no evidence here of an ancient reef formation, it is quite possible that the present dips are but the accentuation of the dips assumed in the original deposition on a sea floor. Gentle undulations of the strata are noted at many of the other exposures, and some considerable dips occur, though none so high as at this locality. If there were at this place an original bowing of the strata, a disturbance which resulted in the more gentle flexures might produce the high dips seen without forming any such extensive rock fold as might otherwise be inferred. The date of this disturbance is uncertain.

Niagara limestone at Stony Island.

[1] History of the Chicago Artesian Well, by George A. Shufeldt, Jr., Chicago, 1865. Issued by the Religio-Philosophical Publishing Association, of Chicago, 1897.

Chicago.

Over the truncated rock strata is a thin mantle of bowlder clay with abundant crystalline bowlders. There are also well-defined ridges of sand and gravel lying along the summit of the rock dome. The limestone in the exposures is very largely saturated with a black asphalt or bitumen, which occurs in pores and in cavities a few inches in diameter. This gives to the rock a peculiar and very agreeable mottled appearance, especially where the asphalt has been melted by the sun's rays after the rock has been laid in a wall and has oozed out in blotches upon the surface. The bitumen is probably the product of the distillation of organic matter, and may be the equivalent of the petroleum noted at other exposures.

About a mile southwest of the village of Blue Island the limestone has been quarried. Over a considerable area southwest of this it is but thinly covered. The beds are nearly horizontal, having a dip of 2° to 4° SE., and form no elevation above the plain. The rock at the surface is a thin-bedded shaly limestone showing obscure glacial markings. The quarries being filled with water at the time of examination, the lower beds could not be seen. Dr. Bannister[1] says that a bed of bluish impure limestone was formerly worked here as hydraulic rock.

Quarry near Blue Island.

The Niagara again appears about a mile to the southwest, on the place of Mr. Henry Schwartz, where it has been stripped of 3 to 6 feet of bowlder clay.

At Thornton, on the Chicago and Western Indiana Railroad, there is a low elevation of limestone covering an area of 1½ to 2 square miles. The village is on the southeastern part of the elevation. The rock has a relief of 10 to 18 feet above the plain to the north, and is but thinly covered by drift. About one-half mile north of the village, on the road to Blue Island, the rock is exposed with a dip of 20° NE In the southwestern part of the village is the quarry of the Brownwell Improvement Company. The strata have here a dip of 12° SE., and the upturned edges have been smoothed and striated by glacial action. The quarry shows at present a 95-foot section. The beds increase in thickness downward from about 4 inches to 4 feet and are much fractured, so that no dimension stone is obtained. Near the surface the rock is buff and somewhat shaly, passing downward into a dense, blue-gray, siliceous limestone. Mr. Brownwell states that the rock contains about 36 per cent of silica. Chert concretions several inches in diameter are found. As at Stony Island, the rock contains much bitumen or asphalt in pores and small cavities, and it is also highly fossiliferous. In the bed of Thorn Creek, just south of the village bridge, the rock has a dip of about 24° NNE. About 100 yards to the south the dip is in the opposite direction, toward the southwest, at a like angle, indicating a gentle local anticline. At this place the glacial striations are well shown.

Exposures and quarries near Thornton.

One mile south of Thornton, near the road to Glenwood, the rock is again exposed in the bed of Thorn Creek.

About 2½ miles south of Glenwood the Niagara is seen at Miller's limekiln and also in a road cut on the hill slope. The rock is an impure buff fossiliferous limestone, containing bitumen.

Near Glenwood.

West of the city, the northernmost exposure is seen a mile west of Elmhurst, on the Chicago and Northwestern Railway. The rock is here well bedded (see Illustration sheet 1, fig. 16) and shows abundant traces of organisms. The strata form a gentle anticline, with northeast-southwest strike, and the surface shows glaciation. Some dimension stone is quarried.

Outcrop in the vicinity of Elmhurst.

About 3 miles southeast of Elmhurst, near the Illinois Central Railroad, at the quarry of Kogle & Smith, is an outcrop of a grayish limestone, weathering to a dark-buff or brown color. The upper portion is somewhat decomposed and crumbling. Crushed stone and some building stone are obtained. The rock surface shows abundant glacial striations. As the rock is also seen in the railroad cut one-quarter of a mile southwest from the quarry, it probably forms the body of the small elevation at this place.

About 3½ miles south of Elmhurst, horizontal thin-bedded limestone is seen in the western bank of Salt Creek. The upper 2 or 3 feet are porous and yellow, passing below into an even-textured, light-gray limestone containing nodules of chert. The beds are fossiliferous.

About a mile northwest of Lagrange, on the banks of Salt Creek, is a small quarry in light-gray fossiliferous limestone. The rock is overlain by a few feet of fine stratified gravels and bowlder clay.

Near Lagrange.

At Lyons is an elevation of rock which seems to be the cause of the abrupt recurving of Desplaines River at this point. Directly south of the sharp bend of the river is the quarry of Mr. Fred Schultz. The light-gray limestone is here nearly horizontally bedded and considerably fractured. Some bitumen occurs. On the north side of the quarry there are gentle anticlinal dips. The rock is overlain by a few feet of bowlder clay, with pockets of sand and gravel. The newly stripped surface shows glaciation.

Limestone exposed in Desplaines Valley.

[1] Geology of Cook County, by H. M. Bannister: Geol. Surv. Illinois, Vol. III, 1868, p. 244.

About three-fourths of a mile northeast of this quarry, near the west end of the Ogden avenue bridge over Desplaines River, is a quarry showing gray limestone strata dipping N. 32° to 39° W. at angles varying from 6° to 20°. About one-fourth of a mile north of the Santa Fe Railway bridge, at times of extreme low water glaciated rock surfaces are exposed in the bed of Desplaines River. The area about which the river here makes a detour is an elevation of rock, covered by 1 to 8 feet of bowlder clay.

At McCook station, on the Santa Fe Railway, on the north bank of the Desplaines, the rock is again exposed in horizontal beds in the quarries of the Chicago Crushed Stone Company. The present section is about 35 feet in thickness. The rock is a coarse dolomite. Surfaces stripped of the 3 to 4 feet of stony clay show glaciation. Several excavations nearer the station show the same rock but thinly covered. One shows a slight dip of 5° in the direction S. 31° E.

One-half mile west of McCook station the rock is seen to be near the surface, exposed in the gullies. The rock surface evidently rises somewhat under the slopes forming the sides of the valley, as it is seen in a gully on the northeast slope just northwest of the road crossing of the Chicago Terminal Transfer Railroad. It here shows a dip of 12° in the direction N. 34° E.

Continuing southwest along the bottom of the valley about a mile, one finds two excavations showing yellowish-gray, well-bedded fossiliferous limestone, considerably weathered on the surface. Near these and about three-fourths of a mile north of the village of Gary on the Santa Fe Railway, is a quarry of the Brownwell Improvement Company. The quarry is about 45 feet deep, showing 2 or 3 feet of thin, broken, nearly horizontal strata at the surface, passing down into regular, little-broken courses from 4 inches to 2 feet in thickness. The rock is dense, even grained, and rather hard to dress. Mr. Brownwell states that its composition is 85 to 90 per cent carbonate of lime, with the balance magnesia, silica, and alumina. It is chiefly converted into crushed stone for paving.

About 3 miles west of Gary are two quarries near Flag Creek, in a local uplift of rock, showing dips of 9° to 20° in directions varying from N. 62° E. to N. 57° W. The strata are here very much broken.

The limestone is slightly exposed beside the road about 1¼ miles northwest from Sag Bridge station, on the Chicago and Alton Railway. Southwestward along the valley, from the Willow Springs bridge to Lemont, though no surface exposures are seen until near Sag Bridge station, the excavation for the drainage canal has cut into the limestone under the bowlder clay to depths varying from 1 to 25 feet, and, for the last 1½ miles above the Lemont bridge the excavation is almost entirely in the rock, which here rises to form the valley floor. This shows the undulatory character of the rock surface under the covering of bowlder clay which forms the nearly flat bottom of the valley.

In the mouth of the Sag, for 1½ miles eastward, the limestone is exposed or but thinly covered by a deposit of peat and clay. Here are the quarries of the Phœnix Stone Company. The present section is about 25 feet thick and shows a compact, even-textured, light-drab to white limestone, well bedded in nearly horizontal strata, which increase in thickness downward from a few inches to several feet. The beds are undisturbed and little fractured, so that the product ranges from crushed stone and rubble to fine cut and sawed dimension stone. The rock surface, where stripped, is much waterworn, showing little grooves 3 to 6 inches deep along the fracture lines, crossing at various angles. With these are little potholes, from a few inches to a foot or so in diameter, ground out by pebbles whirled in water eddies. At the village of Sag Bridge, on the south side of the valley, the limestone outcrops in the road about 30 feet above the bottom of the valley. One mile east the quarry of the Calumet Stone Company gives a section, and northeast of here, on the north side of the valley, a small quarry furnishes a dense, fine-grained, light-gray to white limestone.

At Lemont the limestone is extensively exposed, the bare or very thinly covered rock here forming the floor of the valley and being exposed in the bluffs on either side, especially on the north side, at the height of 50 to 60 feet above the bottom of the valley. The upper beds are cherty, thin bedded, shelving, and much weathered. At intervals along the line of the Chicago and Alton Railway, for about 2 miles northeast of Lemont, are the quarries of the Illinois Stone Company and the Western Stone Company. These show 25-foot or 30-foot sections. The thin-bedded cherty layers, such as appear in the bluffs, are seen in the upper parts of these sections and pass downward into nearly horizontal, little-fractured beds, 3 feet or more in thickness. Below the thin, cherty, buff-colored layers the rock is a compact, even-textured, light-drab to nearly white limestone, known by the name "Athens marble." This is extensively used in Chicago and elsewhere as building material, giving fine cut and sawed dimension stone.

The surface of the rock underlying the valley bottom, where exposed in the excavations for the Sanitary and Ship Canal, has given much evidence of strong river erosion. Large cavities, 5 to 10 feet wide and of a corresponding depth, have been cut through by the canal section. These have been taken to be potholes, ground out by stones in the eddying currents. Dr. Bannister[1] reports it as stated that the potholes in the surface layers at the Athens (Lemont) quarries, when of sufficient depth to penetrate one layer and enter another, are occasionally found to be dislocated; that is, one layer has slipped upon the other, so that the upper and lower portions of the pothole are, in some cases, entirely separated from each other. The phenomenon was not observed by Dr. Bannister, but seemed to be well attested. As he stated, this would seem to indicate a horizontal disturbance of limited amount at a comparatively recent period. Mr. Frank Leverett[2] pictures and notes heavy surface grooves in the rock exposed in the excavation for the diversion channel of Desplaines River at Lemont, near the Santa Fe Railway bridge. Mr. Ossian Guthrie reported them to have a bearing of about S. 60° W. These have been regarded by some as glacial groovings, but Mr. Leverett thinks they are probably the product of river erosion.

Details of rock surface in Desplaines Valley.

[1] Geol. of Cook County: Geol. Surv. Illinois, Vol. III, p. 252.

[2] The Pleistocene features and deposits of the Chicago area, by Frank Leverett: Chicago Acad. Sci., Bull. II, Geol. and Nat. Hist. Survey, 1897, p. 53, fig. 7. Also, The Illinois glacial lobe, by Frank Leverett: Mon. U. S. Geol. Survey, Vol. XXXVIII, 1899, p. 417.

About 5 miles east of Orland is an exposure in the banks and bed of a small stream. The rock here is a regularly bedded, nearly horizontal, light-gray limestone, very fossiliferous.

Exposures south of Desplaines Valley.

In the southwestern part of the area, at New Lenox and for about a mile west, Hickory Creek exposes the rock in its bed. It is also seen about 2 miles east of New Lenox, near the Rock Island Railway bridge over Hickory Creek.

The exact stratigraphic relations of the beds seen in these various outcrops can not be determined. The character of the rock varies considerably within the area. In places many fossils have been collected, while in others the beds are almost entirely barren.

Besides the land exposures of the underlying rock, there are numerous rock shoals off the shore of Lake Michigan, on the city front, as shown by the United States coast charts of the Survey of the Northern and Northwestern Lakes. These are the Oakland shoal, about three-eighths of a mile offshore at Fortieth street, with 11 or 12 feet of water; the Morgan shoal, about one-half mile offshore at Forty-eighth street, with 6 to 9 feet of water; the Hyde Park inner and outer shoals, respectively 1 and 2 miles offshore east of Morgan shoal, with 15 or 16 feet of water; the South Park shoal, about 2 miles off the north end of Jackson Park, with about 11 feet of water; the Clarke Point shoal, about five-eighths of a mile offshore at Seventy-ninth street, with 8 or 9 feet of water; and the Cheltenham shoal, about three-eighths of a mile off Cheltenham Beach at Eighty-second street, with about 9 feet of water.

Rock shoals in the lake.

Devonian Period.

Evidence of Devonian sediments.—Until recently it has been thought that the Niagara limestone was the last of the indurated rock formations of which any trace remained in this vicinity. Such, however, is not the case.

In northwestern Indiana deposits of lower Helderberg and Corniferous age and later Devonian shales are known to occur beneath the heavy mantle of drift, and in Milwaukee and Ozaukee counties, Wis., deposits referred to the Onondaga and Hamilton epochs are well developed. It is also probable that the basin of Lake Michigan is very largely excavated in deposits of Devonian age. So it is not at all surprising that Devonian deposits should have extended over the region about Chicago.

At the quarry near the Chicago and Northwestern Railway, 1 mile west of Elmhurst, in eastern Dupage County, evidence has been found showing unmistakably that the Niagara limestone was once overlain by beds of later age. Of a rock specimen purporting to come from this quarry, one-half was Niagara dolomite and the other half was a black shaly rock containing abundant fragments of small fish teeth. A careful examination of the stripped rock surface at the quarry failed to show any black shale, nor was any noted in the overlying drift. Further examination, however, revealed the origin of the specimen. The following description of the deposit is taken, with slight modifications, from Stuart Weller:[1]

Fossils in the quarry near Elmhurst.

At this locality the limestone is much fractured by two sets of gentle folds, and joint cracks are well developed. Some of these cracks are several inches in width, and they are in general filled with black or blue clay. At one point in the east quarry face, about 18 feet below the glaciated surface of the rock, one of these joints is somewhat enlarged to form a narrow, triangular opening about 6 inches in width at the base and about 16 inches in height. This opening, instead of being filled with clay, as are all the other large joints in the quarry, is filled with a breccia composed of angular fragments of the adjacent limestone embedded in a dark-brown, arenaceous matrix. This matrix is abundantly fossiliferous, containing an immense numbers of fish teeth and a smaller number of *Lingula* shells and other brachiopods which indicate its Devonian age.

The situation of this most peculiar occurrence of Devonian fossils, deeply buried in the Niagara limestone, is shown in fig. 16, Illustration sheet 1. The triangular opening filled with Devonian material is just to the left of the hammer and about 18 feet below the upper surface of the rock.

The species of fossils recognized are as follows: Fish teeth: *Ptyctodus calceolus* N. and W., *Diplodus priscus* Eastman n. sp, *Diplodus striatus* Eastman, n. sp. Brachiopods: *Lingula ligea* H. ?, *Orbiculoidea newberryi* H. ?, *Ambocoelia umbonata* Con.

The most abundant species is *Ptyctodus calceolus*, whose tritors are present literally by the hundreds. This species is characteristic of the middle and upper Devonian faunas of the interior

[1] A peculiar Devonian deposit in northeastern Illinois, by Stuart Weller: Jour. Geol., Vol. VII, 1899, p. 483 et seq.

of North America. The remaining fish teeth are two new species of *Diplodus*, which have been described by Dr. C. R. Eastman.[1]

Correlation, and geographic conditions during Devonian time.

The result of the study of the fossils is stated by Mr. Weller thus: "The presence of *Ptyctodus* is certainly indicative of the Devonian age of the fauna, but *Diplodus* has previously been recognized in Carboniferous strata, and the presence of two species of this genus with the Waverly species of *Orbiculoidea* would seem to indicate a very late Devonian age."

The presence of the remains of this fauna of late Devonian age, deeply buried in the Niagara limestone, is very interesting and most significant. The absence of any species of earlier Devonian age would seem to indicate that during the earlier part of this age the strata were so far elevated as to become land. This land is thought to have been 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. Doubtless the shore line was not very far east of the Chicago district, since part of eastern Wisconsin and part of northwestern Indiana were submerged. During this elevation slight flexing of the rock strata produced the joint cracks in the Niagara limestone, and these were doubtless somewhat enlarged by solution by percolating waters. Doubtless, also, more or less of the upper part of the Niagara formation was cut away by erosion during the interval of exposure.

Near the close of the Devonian age the land was submerged beneath the sea waters and the cracks in the sea floor were filled by sand and fine silts, in which were small shells and fish teeth. Coatings of the same material on the sides of cracks leading to the surface of the Niagara limestone show clearly that this was the mode of deposition of the material found.

Besides this filling of the cracks in the sea bottom, doubtless beds of some thickness covered much of the surface of the Niagara limestone in this area. Were these beds, however, so friable as this remnant found at Elmhurst, they would have been readily removed by erosion during their exposure on the emergence of the area which followed.

Heretofore, so far as known, the marine life of this region was confined to invertebrate animals. In some other places fossil remains seem to show that vertebrates appeared at an earlier time, but not until the Devonian submergence do these forms appear to have reached the northern interior sea. The evidence of so great an advance in the life forms thus gives to these Elmhurst deposits an especial interest. Since the Devonian sea reached northern Indiana, Michigan, and eastern Wisconsin somewhat earlier than the time of its encroachment on the Chicago area, it is probable that vertebrate life was already flourishing in its waters when the submergence of the Chicago area took place.

POST-DEVONIAN HISTORY.

Pre-Pleistocene Erosion.

The region long a land area.

So far as known, the close of Devonian time was marked by the final withdrawal of the sea from the Chicago area. Certain evidence developed has suggested a possible resubmergence in marine waters at a much later date. This evidence is noted on page 10 of this folio. No indurated rock formations later than the Niagara limestone and the slight remnant of Devonian rock are known within the district. Upon these formations lies the heavy mantle of unconsolidated material referred to as drift (figs. 2 and 3). This drift not only overlies the rock formations here represented, but, extending out over the greater part of Illinois, and in fact over a large part of northern United States and Canada, it overlies rock formations of all ages, even the most recent; whence it is evident that the drift is the latest of all the great geologic formations of North America. It was deposited in the Pleistocene, the era immediately preceding our own.

A large part of the rock formations of the continent was formed subsequently to the Devonian period, so it is evident that the interval between the deposition of the rock exposed in this district and of the immediately overlying drift was of enormous duration. During the whole of this interval, so far as known, the northern part of Illinois stood above the level of the sea. It is true there may have been, and indeed probably were, many changes in the conditions, due to variations in the elevation of the land and to other causes. There may have been intervals during which the sea waters again encroached upon this land, but no evidence other than that noted on page 10 of this folio has been found. The work of geologic agents did not, however, cease in this region during this great interval. Up to this time the area of northeastern Illinois had been receiving contributions principally from the Wisconsin land to the north; during this interval the rock beds of this area were subjected to erosion and the material thus obtained was carried off southward by the streams, to help in the formation of other rock beds in the sea. So great was this interval of rock disintegration and erosion that the Devonian beds and whatever subsequent rock formations may have been present in this area were entirely removed. More or less of the Niagara limestone was also cut away at this time.

As the rock disintegrated into soils vegetation developed and faunas of the air and land appeared, yet no traces of these faunas and floras here remain. The only evidence here is of destruction; one must go elsewhere to find the results of constructive work of post-Devonian and pre-Pleistocene time. With the deposition of the drift the process of rock destruction in this area practically ceased.

Pleistocene Period.

GENERAL DESCRIPTION.

Characteristic exposures of drift.

The drift.—Drift is the mantle of detrital material deposited directly or indirectly through the agency of extensive glaciers. Good exposures of the drift may be seen along the lake bluffs from Evanston northward, along the line of the drainage canal from Bridgeport southwestward to Lemont, and at the clay pits of the various brickyards of Chicago and vicinity. Some of the pits most readily accessible from Chicago are the following: near North Branch of Chicago River west of Lincoln Park; in the vicinity of South Robey and Forty-third streets; west of the Union Stock Yards; and at Purington station, on the Chicago, Rock Island and Pacific Railway. Apart from these exposures, temporary exposures are frequently seen at various points in the city where excavations are being made for the foundations of buildings, water pipes, etc. In the country districts exposures are frequent along the road cuts and streams.

Unstratified drift or till.

An examination of the drift at these exposures shows that while stratified deposits of sands, gravels, and clays are of frequent occurrence, the drift as a whole is unassorted. It consists generally of a matrix of bluish clay in which is embedded rock material of all shapes, sizes, and lithologic characters (fig. 17). The clay is highly calcareous and is evidently largely the result of abrasion of beds of limestone and calcareous shale.

The stony material embedded in this clay matrix ranges in size from fine gravel to bowlders several tons in weight. For the most part these pieces of rock are less than 1 foot in diameter, but frequently bowlders 2 to 3 feet in diameter occur, and rarely blocks 5 to 10 feet in diameter are seen. These bowlders are of such size that they could not be transported by water currents of ordinary strength unless they were frozen in floating blocks of ice.

The arrangement of the drift is most heterogeneous, fine and coarse, clay and stones being intimately mixed. This is in striking contrast with the assorted and stratified beds of water-deposited material. Yet, from the frequent occurrence of stratified beds at some points, it is evident that considerable water must have aided in the deposition.

The shape of the pebbles and bowlders of the unstratified drift is not that of stream or shore pebbles. Instead of smoothly rounded forms, the pebbles and bowlders of the drift are partly angular and partly somewhat rounded, but largely subangular, with numerous flat faces, or facets. The facets usually show polishing, parallel grooving, and scratching, as though smoothed and striated while being held firmly in one position and moved over a hard surface (fig. 18).

Rock surface beneath the drift.

When the surface of the rock underlying the drift is examined and compared with that under other coverings, significant phenomena are also noted. In a region where the soil is residuary—i. e., derived directly from the disintegration of the rock—there is a gradation downward from the loose soil to partially disintegrated rock, and this shows less and less decomposition until finally rock of the original hardness is reached below the zone of weathering. Most rock is more or less variable in composition and texture, and consequently some parts yield more readily to the agents of disintegration than others, and differential weathering results, in which the more resistant parts remain, while the less resistant disintegrate into soils. Hence a weathered rock surface is uneven, discolored, and pitted with irregular cavities. It is often difficult to say where the soil ends and the rock begins (fig. 4).

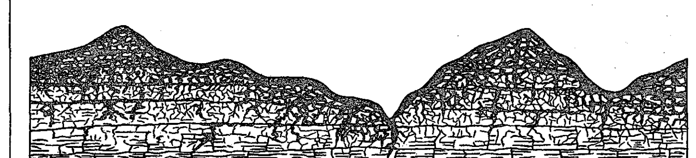

FIG. 4.—Diagram showing the relation of residual soil to the underlying rock from which it is derived.

This, however, is not the character of the rock surface where exposed by the removal of drift. Here the line between the drift above and the rock beneath is sharp (fig. 5). Unless the upper

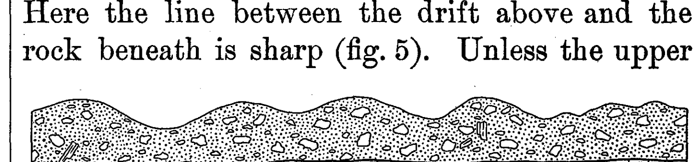

FIG. 5.—Diagram showing the relation of drift to the rock on which it lies.

rock beds be thin and shelving it is usual to find a smoothed and polished surface marked with parallel grooves and scratches, similar to those upon the pebbles and bowlders of the drift. If the rock surface has not been long exposed the striations are usually sharp and distinct. Sometimes they are continuous for several yards. Usually they are shorter. They are sometimes almost perfectly straight, sometimes curved, broken, or jagged. They are usually nearly parallel at any given place, or they cross at low angles.

It is also found that where there are slight inequalities of the surface, as protruding knobs or jutting ledges, one side—in this district the east and northeast—is smoothed, polished, and scratched, while the opposite side is rougher and more or less unmodified. With small, sharp depressions the east and northeast sides are rough, while the west and southwest sides have been smoothed. These different phenomena are well exhibited by the rock surface at Stony Island.

These various phenomena give indisputable evidence that these features are not the results of weathering or of water erosion, but that over the rock surface has moved some great mass with abrasive material at its bottom, smoothing, polishing, and scratching as it went; that this body was more or less plastic in its nature, so that it conformed in a measure to the inequalities of its rock bed, and that the movement was in the direction of the striations and against the abraded sides of surface inequalities. The fine and coarse material of the drift overlying the rock would furnish the abrasive material, the polishing powder, and the graving tools to a moving mass of the right kind.

The drift a glacial deposit.

These various phenomena of the drift and the underlying rock surface give unmistakable evidence of the agency which produced them. The drift is identical in kind with the deposits now being made by glaciers in various parts of the world (see fig. 19 and compare fig. 17), and the characteristics of the surface of the rock beneath the drift are identical with those of the surface of the rock over which glacier ice is known to have recently passed (fig. 20). Hence it is evident that the drift is in reality a glacial deposit.

Foreign material in the drift.

While the clay matrix of the drift is highly calcareous, showing that it was derived very largely from limestones such as immediately underlie it in this area, examination with a microscope shows a considerable percentage of grains of a great variety of minerals such as would result from the abrasion of crystalline rocks. Also, if the coarser material the pebbles and bowlders of the drift, be examined, it is found that about 90 per cent corresponds in character to the underlying rock strata, while the remaining 10 per cent consists of sandstones and crystalline rocks of many kinds wholly foreign to Illinois.

In some parts of the district surface bowlders are more or less numerous. Of these bowlders more than 95 per cent are derived from crystalline rocks foreign to this region.

The glacier no local phenomenon.

The direction of movement of glaciers is shown by scratches or striations on the rocks, called striæ. It is evident from the glacial striæ about Chicago and at other localities that the glacier came from the north, moved up the basin of Lake Michigan, and spread out over the surrounding areas. Retracing the course of this movement, it is found that not within 300 miles are formations known to occur from which the foreign rock constituents of the drift could have been derived. The sandstones and crystalline rocks occur about the eastern part of Lake Superior, northern Lake Huron, and northward. It is thus apparent that the glacier depositing the drift of Cook, Dupage, and Will counties was no local phenomenon. As has already been indicated, the drift not only covers most of the State of Illinois, but also extends over a large part of northern United States and Canada, everywhere showing phenomena similar to those of this vicinity.

Such data, studied over a wide range of territory and under greatly varying conditions, show that there came about climatic changes the like of which had never before occurred in this latitude in all the earth's history. This great change was the development of arctic conditions over all the northern part of North America and southward into the United States to the latitude of southern Illinois, i. e., below 38° north latitude. In consequence of these arctic conditions, a vast continental ice sheet, comparable to that of Greenland, but many times larger, came into existence in the northern part of the continent over the area now covered by the drift (fig. 6). It was to

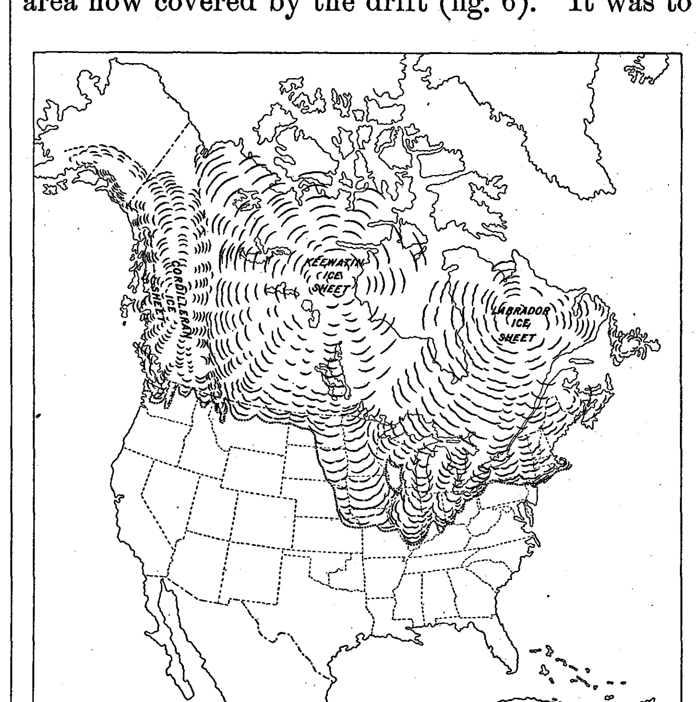

FIG. 6.—Map of area covered by the North American ice sheet of the Glacial epoch at its maximum extension, showing the approximate southern limit of glaciation, the three main centers of ice accumulation, and the driftless area within the border of the glaciated region.

this great continental ice sheet that the Michigan glacier, which deposited the drift in this region, belonged.

Possible cause of climatic change.

The ice sheet.—The cause of this development of arctic conditions in low latitudes has been variously attributed to changes in the elevation of the glaciated territory, to changes in the earth's orbit, to changes in the constitution of the atmosphere, and to a combination of causes. It is sufficient here to note that the cause is not known. Whatever the

[1] Description of new species of *Diplodus* teeth from the Devonian of northeastern Illinois, by C. R. Eastman: Jour. Geol., Vol. VII, 1899, pp. 489-493.

cause, the fact that a great ice sheet, about 4,000,000 square miles in area, came into existence in the northern part of the continent is no longer open to question. The proof is found in the character of the drift, in its relations, and in the peculiar and distinctive features of the rock surface beneath.

It may be well to recall the conditions under which glaciers and ice sheets develop. With an annual temperature such that the summer heat does not fully melt the winter snows, a certain portion of the snow remains over to the following winter. If these conditions prevail for several seasons the quantity of snow remaining gradually increases. If the continuance be long enough the snow field may reach great thickness and extend over vast areas. With this increase in the depth of the snow the lower parts become gradually compacted by the weight of the overlying mass, by downward percolation and refreezing of water from the snows melted at the surface, and by internal changes. Thus the lower part of the mass becomes ice while the top is yet loose snow. If the accumulation of snow continues for many decades or many centuries the ice may become hundreds or even thousands of feet thick.

Development of the ice sheet.

While ice thus formed is generally regarded as a brittle solid, yet, as is well known, it behaves much like a plastic substance, and under favorable conditions will creep or flow over a land surface. It is not intended to assert that ice really flows; the mechanics of the motion are not yet demonstrated. However, when accumulated in such mass as a great snow field would furnish, it spreads in all directions from the highest part much as though it were a very stiff liquid, and for convenience the ice may be said to flow. Motion thus brought about is glacier motion, and ice thus moving is glacier ice. Thus the glacier of a high mountain valley moves down the slope; and thus the ice of a great continental ice sheet moves outward from its highest part, its center of accumulation, and may spread over vast areas of the surrounding territory.

Movement of the ice.

Greenland affords an example of the conditions which prevailed over the northern part of North America during the Pleistocene period. A large part of the half million square miles which Greenland is estimated to contain is covered by a vast sheet of snow and ice, hundreds and perhaps thousands of feet in thickness. In this field of snow and ice there is continuous though very slow movement. The ice creeps out in all directions from the interior until it reaches the sea, where great masses become detached and float away as icebergs, or until it reaches territory where the climate is such as to waste the ice by melting and evaporation as rapidly as it advances.

The great North American ice sheets of the drift epoch appear to have had more than one center of growth. One main center lay east of Hudson Bay, and another west of it (fig. 6). There were perhaps other minor centers; but ultimately the snow fields, extending themselves from their various centers, united, and the resulting ice sheet is commonly spoken of as a unit. Other smaller ice caps occcurred in the west and northwest, but it is with the ice of the main sheet we have here to do. From these centers the ice spread southward over the area now covered by the drift.

Centers of glaciation.

Glacial and interglacial stages.—So long as the rate of accumulation exceeded the rate of waste by melting and evaporation at the edge of the ice sheet, the glacier continued to advance; but when a region was reached where the rate of waste equaled the rate of advance, the margin halted. Where the waste exceeded the advance, the margin retreated. Periodically there seem to have been great oscillations; these were so notable in their extent and in their effects as to be designated stages of the Pleistocene period. During the glacial stages the conditions of glaciation so prevailed that the ice advanced far southward, driving the plants and animals before it, destroying and burying in drift those which could not move, and introduced a fauna and flora of the higher latitudes.

Conditions and effects of advance and retreat of the ice.

During the interglacial stages a reversal of conditions took place. The climate became so much milder that the ice was melted back far northward, a new soil was developed, and plants and animals returned to their former habitats. A return of the arctic conditions caused a readvance of the ice and the deposit of a new sheet of drift, burying the soil and the organic remains.

A careful study of these buried soils and organic remains has led many students of glacial phenomena in America to a belief that the Pleistocene period comprised a series of these glacial and interglacial stages.

Chamberlin[1] and Leverett have given the following provisional outline of the succession of drift sheets of North America formed by the several advances of the great ice sheets, with the intervening soil horizons which mark the stages of recession or deglaciation. The names have been taken from the regions of maximum extension of the ice and from places where the phenomena are best seen. The more extensive of these advances reached southern Illinois and northeastern Kansas, to the limit of glaciation indicated in fig. 6, a distance of over 600 miles from the northern boundary of the United States.

It is probable that the ice of several of these advances passed over northeastern Illinois, but so thoroughly are the deposits intermingled in this area that it has not yet been possible to distinguish the work of the several glaciers. In this discussion of the glacial features of the Chicago district the phenomena are treated as the work of glaciation in general or as the work of the last glacier which advanced to the head of the Michigan Basin.

The deposits are given below in the order of their deposition:

Drift sheets and intervening soil horizons of North America.

11. Late Wisconsin drift sheets.
10. Fifth interval of recession, shown by shifting of the ice lobes.
9. Early Wisconsin drift sheets.
8. Peorian soil and weathered zone[2]—Toronto formation (?); fourth interval of recession or deglaciation.
7. Iowan[3] drift sheet and main loess deposit.
6. Sangamon soil and weathered zone;[4] third interval of recession or deglaciation.
5. Illinoian drift sheet.[5]
4. Yarmouth soil and weathered zone[6] and Buchanan gravels; second interval of recession or deglaciation.
3. Kansan drift sheet (of Iowan geologists).[7]
2. Aftonian gravel and soil deposit; first interval of recession or deglaciation.
1. Sub-Aftonian drift sheet (old Kansan of Chamberlin).

PRE-GLACIAL TOPOGRAPHY.

Bed-rock surface.—If the varying thickness of the drift in the region about Chicago, as shown by means of well borings, be considered, it is readily seen that the topography of the area would be quite different if this unconsolidated material were stripped off the rock surface. Instead of the very flat plain on which Chicago now stands there would be an undulating erosion topography. The present rock outcrops, where the drift is thin or absent, would be the tops of hills rising above their surroundings, where the drift is now thick. Some of these undulations have a relief of more than 100 feet. The figures on the Economic Geology sheet indicate the thickness of the drift at various points. If this thickness be deducted from the surface elevation at the place of boring, the elevation of the rock surface is determined. Mr. Samuel J. Artingstall, while city engineer, prepared a map of Chicago giving the elevation of the rock surface at many points as shown by borings. The data for this map were insufficient to determine the full details of the topography of the rock, but they showed clearly the very uneven character of its surface and the consequent varying thickness of the drift.

Hills and valleys beneath the drift.

The lowest level of the rock as shown by this map is near North Branch of Chicago River, about one-half mile north of its junction with South Branch. The rock is here 124 feet below the level of Lake Michigan. Passing out radially from this point, the surface rises with many undulations and numerous exposures. This rise is continued under the moraine surrounding the Chicago Plain. The highest elevation of the rock surface in this area which has come to the writer's notice is in the town of Frankfort, Will County. The rock is here reached at a level 150 to 160 feet above Lake Michigan. A profile of the lake basin from Racine, Wis., to Holland, Mich., shows the bed of the lake to reach sea level; thence southward to the head of the lake the depth decreases more or less regularly. The thickness of the drift over the rock beds beneath the lake is unknown; but, neglecting this, it is evident that there is a rise in the rock surface along the basin from the latitude of Racine to the crest of the moraine in Will County, Ill., of at least 740 feet.

[1] Editorial by T. C. Chamberlin: Jour. Geol., Vol. IV, 1896, pp. 872-876; See also Pleistocene features and deposits of the Chicago area, by Frank Leverett: Bull. Chicago Acad. Sci., II, 1897, pp. 11-12. Also, The Illinois Glacial Lobe, by Frank Leverett: Mon. U. S. Geol. Survey, Vol, XXXVIII, pp. 19-23.

[2] The Peorian soil and weathered zone, by Frank Leverett: Jour. Geol., Vol. VI, 1898, pp. 244-249. The Illinois Glacial Lobe, pp. 185-189.

[3] The classification of American glacial deposits, by T. C. Chamberlin: Jour. Geol., Vol. III, 1895, pp. 270-277. The Illinois Glacial Lobe, pp. 131-184.

[4] The weathered zone (Sangamon) between the Iowan loess and Illinoian till sheet, by Frank Leverett: Jour. Geol., Vol. VI, 1898, pp. 171-181. The Illinois Glacial Lobe, pp. 125-130.

[5] The Illinois Glacial Lobe, pp. 24-104.

[6] The weathered zone (Yarmouth) between the Illinoian and Kansan till sheet, by Frank Leverett: Jour. Geol., Vol. VI., 1898. pp. 238-243. The Illinois Glacial Lobe, pp. 119-124.

[7] The Illinois Glacial Lobe, pp. 105-118.

EPOCH OF GLACIAL OCCUPATION.

Movement of the glacier over the Chicago district.—In the last glacial stage the Michigan glacier advanced southward along the Lake Michigan trough,[1] and in the region of Chicago, spread out at least 20 or 30 miles beyond the present limits of the lake. As shown by the striations upon the rock surface at the various exposures in Cook County and eastern Dupage County, the movement of the ice over the area was in a generally northeast-southwest direction. Here, then, the bottom of the ice must have moved up a slope of considerable height, if the relative elevations of the rock surface just given were then as they are now, and must have traversed an area marked by considerable inequalities of surface; yet the direction of flow does not seem to have been materially affected by any of these conditions. The direction of flow of a liquid substance does not depend immediately on the slope of its bed, but on the slope of its upper surface; so also glacier ice, while not flowing precisely as does a liquid, has a motion which is clearly controlled by gravitation, and the resultant movement is much the same. For the surface of the ice to have had sufficient slope to cause the movement of its bottom up this rock slope beneath the Chicago district and over the highest rock elevations of Dupage and Will counties, the thickness over the lake area must have been great. Over the site of Chicago the ice must have been at least several hundred feet thick. Over the deepest part of the lake basin the ice was probably a few thousand feet thick. What the elevation of the land and the thickness of the ice at the centers of accumulation at the north must have been to have sent off this glacier 800 miles or more southward can be estimated only with a large measure of uncertainty.

General direction of ice movement.

Work done by the glacier.—As already stated, it is probable that the glaciers of several different stages traversed the area of northeastern Illinois, but the work of the earlier ice sheets can not be distinguished, so that this discussion refers chiefly to the work of glaciation in general.

At the opening of the Pleistocene period the upper rock beds had largely disintegrated into soils and were readily broken up by any disturbance. Exposed surfaces were cavernous and irregular, from the weathering out of soft parts, the more resistant parts being left. In the soils doubtless grew a prolific vegetation. The drainage systems were probably well developed and the whole district was cut up into hills and valleys. This unevenness of the rock surface beneath the Chicago Plain has already been noted. Not so many data have been collected in the surrounding morainal tract, but doubtless the rock surface there is much the same.

Condition of the rock surface in preglacial time.

The present rock topography is probably rather more subdued than that which the first ice sheet was forced to override, for the general effect of glaciation was to reduce its minor inequalities. Where there are now gentle undulations of the rock surface there may then have been sharp ravines and hills, and where there are rounded hilltops beneath the drift there may have been more or less craggy bluffs. Where there were soils, disintegrating rock, and cavernous strata there is now a fresh rock surface, hard, smooth, polished, and scratched; and on this rock surface is the thick mantle of drift. This change is the result of the work of glaciers.

[1] At just what period this great lake basin was formed is not known, but the origin is believed to have been prior to the last glacial epoch. A summary of opinions as to the time and mode of origin of the Great Lake basins is given by Alexander Winchell, in Am. Geologist, Vol. XIX, 1897, pp. 336–339.

When the glacier first invaded the region and advanced over the surface which had been cut up by erosion and whose upper rock beds were disintegrating into soils, while its hills and valleys were mantled with vegetation, it found much material ready to be incorporated in its lower part; and hence all along its course the glacier loaded itself with débris of all sorts. Most of this was carried in the lower part of the ice sheet as subglacial drift, but some was carried higher up. Where ledges, hills, or prominences of any kind stood in the path of the glacier, they were surrounded or overridden by the icy flood, and from their slopes and summits débris appears to have been carried away and incorporated in the ice at levels corresponding to those of the places of derivation, thus becoming englacial drift. If the obstructing hill was high enough to extend above the ice sheet, such débris might be dislodged and fall upon the surface of the surrounding ice, when it would be borne away as superglacial drift.

Derivation and transportation of subglacial, englacial, and superglacial drift.

This loading of the glacier and the weight of the ice itself make it a tool of great power. The pressure for a depth of 100 feet of ice is about 40 pounds to the square inch. Thus beneath a glacier hundreds or thousands of feet in thickness the force with which the rock fragments at its base are applied as abrasive material to the surface upon which the ice rests is well-nigh resistless. When the loose material was removed the solid rock was exposed to wear, and the advancing ice ground down its surface and smoothed, polished, scratched, and grooved it with the earthy matter and rock fragments which it slowly but steadily carried forward. At the same time the rock fragments in the ice were themselves ground, striated, and polished (see fig. 18). While held firmly against the rock bed by the moving matrix of ice, one side of a pebble would be ground flat, polished, and striated. On encountering a resisting obstacle the pebble would be turned into a new position, refrozen into the matrix, and a new face developed as before. Where a prominence of rock obstructed the ice movement, it was pressed upon with great force and the continued advance of the rock-shod ice wore away the irregularities of the surface, and, if it did not entirely grind away the prominence, gave to it a smoothed and rounded contour. The sides facing the ice movement—the stoss sides—were most subjected to wear. The lee sides, being more protected, might retain some of their former irregularities. The minor inequalities of the rock surface would be treated in like manner, and, if not entirely obliterated, would give evidence as to the direction of ice movement.

Glacial erosion.

The direction of movement of the glacier is shown by the striations on the rock. The distribution of the striæ exposed in the district and their bearings are shown on the Areal Geology sheets. The following is a list of those which have been observed:

Glacial striæ in Chicago.

The excavation for the Fullerton avenue conduit, in the northern part of Chicago, showed striæ with bearing S. 60° W. The exact location is not noted on the map.

At the quarry near the corner of Chicago and Western avenues, 1 mile southeast of Humboldt Park, a few faint striæ have a bearing S. 72° W.

At Eighteenth and Robey streets, about a mile east of Douglas Park, the arching layers are glaciated, showing striæ whose bearing ranges from S. 52° W. to S. 57° W.

At the Hawthorne quarry, on the Chicago, Burlington and Quincy Railway, there are two sets of rather heavy scorings. The earlier set follows approximately the strike of the dipping layers, bearing S. 60° W. to S. 64° W. The later set crosses the upturned edges of the layers at a slight angle, bearing S. 52° W. to S. 54° W.

At Stony Island, 1 mile north of Lake Calumet, there is probably the best exhibition of glaciation to be seen in the vicinity. At the old quarry at Ninety-second street and Stony Island avenue, on the north side of the elevation, the strata dip toward the northwest at an angle of 42° to 45°. The whole rock surface of the upturned edges of strata has been planed off smooth (fig. 15) and shows, in places, striæ which have a bearing S. 19° W. to S. 28° W. At the quarry on the south side of the ridge, where the strata dip toward the southeast at angles of 32° and 33°, the upturned edges have been truncated, smoothed, and striated. There are here some heavy groovings nearly in the line of strike, with fine striations having directions varying from S. 45° W. to S. 49° W. One of the most notable phenomena here is an escarpment of the dipping layers, rising about 6 feet above the remainder of the quarry. This is not only smoothed and striated upon its surface and nearly vertical front, but also, beneath one of the lower layers, its dipping under surface is smoothly polished for about 18 inches back from the front of the ledge (fig. 21). This indicates well the quasi-plastic nature of the overriding body which did the striating and polishing and at the same time accommodated itself to the inequalities of the surface over which it moved.

Glaciation at Stony Island.

Striæ south and west of Chicago.

At the quarries 1 mile southwest of Blue Island a few faint striæ were observed with the bearing S. 54° W.

At Thornton, on the Chicago and Western Indiana Railroad, the rock in the bed of Thorn Creek, a short distance south of the village bridge, shows a smoothed surface with striæ having bearings S. 23° W. to S. 27° W.

At the quarry 1 mile west of Elmhurst, on the Chicago and Northwestern Railway, the rock surface shows small grooves and fine striæ with direction S. 90° W. At one point the striæ are seen to be deflected 26° from parallel about a small prominence not more than 6 inches in diameter.

Three miles southeast from Elmhurst, near the Illinois Central Railroad, the rock exposure shows distinct groovings and abundant striæ with bearings S. 64° W.

The planed rock surface exposed a few years ago on the site of the Lagrange Waterworks showed scattering striæ bearing S. 58° W.

At Mr. Schultz's quarry, at Lyons, the newly stripped surfaces show striæ ranging in direction from S. 57° W. to S. 94° W.

Striæ in the Desplaines Valley.

In the bed of the Desplaines River, about one-quarter of a mile north of the Santa Fe Railway bridge, is a heavily glaciated surface of several square rods exposed at low water. Small grooves and fine striæ are numerous with the bearings S. 89° W.

At the quarry near McCook station, on the Santa Fe Railway, are seen striæ showing direction S. 41° W.

In the bed of the Sanitary and Ship Canal of Chicago, near Willow Springs, were seen faint striæ bearing S. 23° W. As noted before, Mr. Leverett considers the heavy groovings reported by Mr. Ossian Guthrie as exposed in the excavation of the diversion channel for Desplaines River, with a bearing about S. 60° W., to be the product of river erosion rather than glacial striæ.

Ground moraine.

Deposits made by the ice.—As the advance of the ice continued, more or less of the subglacial drift was constantly lodging and being left behind. So also on the surface and at the margins of the ice sheet, such material as was there embedded in the ice was constantly being released by melting and separation. Some of this englacial and superglacial drift descended directly to the base of the ice about the margins and through crevasses and moulins, and some was only lowered with the melting surface and carried on to be dropped later. So long as the rate of wasting was less than the rate of advance the ice front moved forward, and this freed material was overridden and commingled and spread out beneath the ice as the ground moraine. In the continental ice sheets the advance continued for long periods and the glaciers traversed vast areas, spreading out the drift in the extensive sheets now found.

Terminal moraine.

When the rate of wasting so nearly equaled the rate of advance as to cause the ice front to halt for any considerable time, there was made a greater deposit of drift; because, though the front of the glacier halted, the ice itself continued to advance and bring up drift to be deposited at the melting front. Such deposition also took place beneath the thinned melting edge of the ice sheet. If this halt continued for some time, or if the ice front oscillated back and forth over a narrow area, a more or less ridge-like belt of thickened drift—i. e., a border moraine or terminal moraine—resulted.

When the rate of wasting gained the ascendency over the rate of advance, either from the increase in the wasting or from the decrease in the advance or from both causes, the ice front retreated, and during the retreat all the drift embedded in the ice or lying upon its surface was let down upon the deposits already made. The subglacial material thus left, and such of the englacial and superglacial material as could not afterward be distinguished therefrom, would be considered part of the ground moraine.

Local character of subglacial drift.

Study of existing glaciers, such as those of Greenland, shows that the great bulk of the drift is carried in the lower layers of the ice, presumably that most recently taken up at the very bottom. Since, as it appears, subglacial drift is constantly becoming lodged and being left behind by the advancing ice, it results that a large part of the drift is deposited within comparatively short distances of the place of derivation. A smaller part, especially that which had become embedded in the ice somewhat above the basal layers, may be carried considerable distances before being deposited.

Foreign aspect of englacial drift.

Observers of glacial phenomena report comparatively little evidence of upward or downward shifting of débris in the body of the ice, except such descent of englacial and superglacial drift at the melting ice front and down crevasses and mountains as that to which reference has been made. Thus englacial drift whose derivation is such as has been indicated, and which is lodged well up in the body of the glacier, may be carried hundreds of miles before being deposited by the melting of the inclosing ice. Conversely, it may be postulated with a good degree of probability that most of the drift whose place of derivation is at a considerable distance from the place of its final deposition by the ice must have been carried well up in the ice as englacial drift, otherwise it would not have been carried so far before being deposited.

Since the englacial drift in any given section of the ice sheet is very much less in amount than the basal drift, it results that an examination of almost any section of the drift in this region shows 80 to 90 per cent of its material to be of very local derivation. It may be from the rock formation that immediately underlies the drift at the place of examination, while 10 to 20 per cent may be from formations 50 to 100, or even several hundred miles back along the route the glacier has traversed. From this arrangement of the drift in the ice sheet it also results that, on the final retreat of the ice front from the area, the englacial material, being highest up in the ice, is left upon the surface. The finer material, being small in amount, is not readily distinguished from the subglacial drift, but the bowlders are largely left upon the surface or partially or wholly embedded in the surficial part of the drift. An examination of these surface bowlders in this region rarely shows as many as 5 per cent which might have been derived from the local sedimentary formations, while 95 per cent or more are of crystalline rocks, with an occasional sandstone, whose place of derivation is several hundred miles northward.

The greater part of the deposits in this region made thus directly by the ice has been dropped promiscuously. The melting of the ice and the rainfall upon the surface of the glacier, however, undoubtedly gave rise to considerable water, which flowed on the surface and plunged down crevasses, so far as these were found, and also flowed beneath the glacier and issued from the ice front, so that a certain part of the drift was assorted and stratified.

Valparaiso terminal moraine.

Within the area here described both ground moraine and terminal moraine are represented. The Chicago Plain occupies the low land of the ground moraine. A broad ridge-like belt comes down from the north and swings around the head of Lake Michigan, inclosing the Chicago Plain. This belt marks the end of the glacier during the later part of the Wisconsin stage and has been called the Valparaiso moraine.

Relation of the Valparaiso moraine and the ground moraine.

The principal difference between the Valparaiso terminal moraine and the ground moraine, as left by the glacier, was in the surface elevation and in the thickness of the deposit. While there evidently was some difference in the original topography, there was probably not so great a difference as now. The Chicago Plain covers most of the ground-moraine area, and its flatness, in part at least, is of later development, being due to the action of lacustrine waters. The area north of Lagrange, from a line near Desplaines River westward into Dupage County, is apparently unmodified. Here is seen the passage from the ground moraine into the thickened terminal moraine. The change in topography is very gradual, passing from nearly flat to moderately undulating. From a point near Lagrange to Homewood the present inner margin of the moraine is clearly marked, being coincident with the limits of the Chicago Plain. Southeastward from Homewood a nearly flat till plain intervenes between the limits of the lacustrine plain and the inner margin of the moraine.

While the rock surface is higher under the moraine than under the plain, the elevation of the surface of the ground is not entirely due to the rise in the underlying rock surface. Owing to the abrupt local variations in level, any estimate of the average elevation of the rock surface would have little value; but, from a consideration of one hundred borings distributed over the plain, the average elevation of the rock surface is roughly estimated at 45 to 50 feet below the level of Lake Michigan, while from about one hundred borings west, southwest, and south of the city, in the area of higher rolling topography, the average elevation of the rock under the moraine is estimated at 35 feet above the lake. In the plain these borings show the drift to vary from 0 to 130 feet in thickness, with an estimated average of 60 to 70 feet. In the morainic belt the records obtained show the thickness to vary from 0 to 160 feet, with an estimated average of 100 feet. The latter average, however, is low as compared with estimates made by Mr. Leverett based upon data obtained from a much broader area. Mr. Leverett[1] has estimated that the average thickness of the drift in that part of Illinois covered by deposits of Wisconsin age is 143 to 165 feet. While the belt of higher land about the Chicago Plain is largely due to a rise in the rock surface beneath it, it is also due to greater thickness of the drift (fig. 3).

Lake border morainic system and Blue Island.

North of the Chicago Plain, between Desplaines River and the lake, is a series of three gentle ridges of drift parallel to one another and nearly parallel to the lake shore. Mr. Leverett[2] describes these as a lake-border morainic system. It is probable that they mark slight stages of halt in the recession of the ice front. Only the western of these ridges extends into the area here described. The southern 5 or 6 miles of its length is seen east of Desplaines River in the towns of Norwood Park and Jefferson Park, gradually decreasing in strength and dying out near Mont Clare, on the Chicago, Milwaukee and St. Paul Railway. In this part it has a relief of 20 to 30 feet above the plain to the east. Its surface is very gently undulating.

The middle ridge does not enter the area, but Mr. Leverett is inclined to correlate with it the till ridge known as Blue Island and the bowlder train which is traceable northward from the north end of this latter ridge in a belt about a mile wide. For 4 or 5 miles the bowlders are abundant upon the surface, at first several hundred to a square mile, but farther northward their number becomes so small as hardly to warrant more than a suggestion of such correlation. It is doubtless true, however, that the Blue Island till ridge was originally a broader and less abrupt swell than at present, extending farther north, east, and south. Unless this is to be correlated with the lake-border moraine system, it is probable that this was one of the larger undulations of drift of the ground-moraine area. That the elevation is of drift and is not due to a rock core is shown by well borings. While the ridge has a relief of 25 to 50 feet above the surrounding plain, the well at Morgan Park shows 76 feet of till over the rock. At Mount Greenwood Cemetery, on the west side of the ridge, the rock is reached at a depth of 94 feet, and at the Blue Island waterworks the depth of the rock is 69 feet. On the flat east of the ridge the Blue Island smelter well shows but 40 feet of drift over the limestone.

The easternmost of the three till ridges at the north is intersected by the lake shore at Winnetka, and is not seen farther south. A bowlder train on the lake bottom has been reported by Prof. Lyman Cooley, of the Chicago Drainage Commission, as running southeastward for several miles from the terminus of this east ridge, and Mr. Leverett thinks this may be a residue from a ridge of till which has been cut away by the lake.

Weathered character of the morainal drift.

Structure and composition of the drift.—The general features of the unstratified drift have already been given. There is no essential difference between the drift of the moraine and that of the Chicago Plain except, perhaps, in the amount of leaching and oxidation which has taken place. This is markedly less on the plain. In the morainic tract the surface has been little modified since the withdrawal of the glacier, so that leaching has extended 5 to 10 feet below the surface, while on the plain but a few inches of the upper part of the clay fails to give a response to acid, which shows that it still contains the calcareous matter derived from the grinding up of limestones. On the moraine, oxidation of the iron-bearing elements in the drift has given to the upper 5 to 15 feet a light yellowish or buff tint, while on the plain the yellowish clay rarely extends more than 5 feet below the surface, and not infrequently excavations pass into the blue clay immediately below the surface. This blue clay forms the body of the till. At some places in its lower part it becomes very dense and is excavated with difficulty. As has been indicated, the microscope shows this clay-like matrix to consist in part of true aluminous clay and silt and in part of minute angular fragments of limestone. Besides these clayey and calcareous constituents there are quartz grains, bits of shale, and fragments of minerals of many kinds, such as would be derived from the erosion of crystalline rocks. In the bits of shale and also in its larger masses, especially in those obtained from the excavation of the first lake tunnel of the Chicago waterworks system, were found abundant minute globules believed to be plant spores.[1] These masses of shale have been thought to be identical with the shale of later Devonian age, and, like the black shales of Ohio, they burn with a bright flame, giving out a strong odor of petroleum. A considerable amount of black shale has been noted in the drift about 2 miles south of Mokena in Will County. It is possible that this Devonian material in the drift was derived from local Devonian deposits, such as are represented by those at the Elmhurst quarry. But it seems probable, judging from the amount of erosion of the Niagara limestone, that these Devonian beds had, for the most part, been removed prior to the last advance of the ice. Black shales, however, occur at the top of the Hamilton beds of the Devonian at Milwaukee, Wis., as has been shown by test borings for the intake tunnel beneath the lake at that point, and doubtless elsewhere beneath the lake.

Devonian material in the drift.

Stones and vegetal matter in the drift.

There is generally only a moderate amount of stony material in the drift, but at some places, especially immediately overlying the bed rock, the drift is little more than a mass of subangular fragments of limestone. Such deposits were noted at various points along Desplaines Valley through the moraine. At a few places bits of timber and small logs have been found in the drift. These have, in some cases, been found beneath 100 feet of bowlder clay. They are remnants of pre-Glacial or of inter-Glacial vegetation which was overridden by the advancing glacier and buried in the drift.

Deposits from waters flowing from the ice.

Stratified drift.—The stratified sands and gravels so extensively present on the Chicago Plain are not here referred to. These are of lacustrine origin and were deposited at a later time under conditions which are discussed under the heading "Beaches of Lake Chicago." More or less local deposits of stratified material are of frequent occurrence in the drift, showing the work of waters from the melting ice. These deposits are usually of sand and gravel, stratified and cross bedded in a beautiful manner. Deposits of sand and gravel immediately over the rock surface beneath the bowlder clay are also frequently found. Almost every well sunk penetrates one or more such deposits, and in the country districts the water supply is largely drawn from these reservoirs in the denser clay. In the Lake View water tunnel, just east of Graceland Cemetery, about 100 yards from shore, a large sand pocket was penetrated, having a length of 100 feet and a height of 20 feet. Much of the difficulty in projecting the various tunnels of the Chicago Water system on land and beneath the lake has been due to encountering pockets of sand, gravel, and quicksand.

In the excavation of the drainage canal from Bridgeport to Lockport, a distance of 30 miles, much stratified drift was exposed. Some of this may have been deposited later, by the lake waters discharging through the valley outlet, but much of it was undoubtedly deposited by glacial waters. From Bridgeport to Summit there is little besides till. Below Summit stratified deposits are frequent. Between Summit and the Chicago Terminal Transfer Railroad bridge were exposed fine sections of interlaminated sand, gravel, and clay, overlain by unstratified till. The delicately laminated beds were doubtless formed in ponded waters near the ice front, while at other points the strong cross bedding of coarse gravels indicates periods of vigorous flow, perhaps in

[1] The Illinois Glacial Lobe, p. 546.

[2] The Pleistocene Features and Deposits of the Chicago Area, p. 42. The Illinois Glacial Lobe, pp. 380-412.

[1] Microscopic organisms in the bowlder clay of Chicago and vicinity, by H. A. Johnson and B. Thomas: Bull. Chicago Acad. Sci., Vol. I, No. IV, 1884.

times of greater melting. The overlying unstratified till may indicate a slight advance of the ice overriding the stratified beds. Considerable deposits of assorted gravels are also seen at various points in the sides of the valley. Perhaps the best exposure is on the north side of the valley a mile north of Willow Springs. Here are several large gravel pits. Well borings seem to indicate that the narrow hill east of Flag Creek in this vicinity is composed almost entirely of gravels below 12 to 15 feet of till. One-quarter of a mile southwest of Worth, on the Wabash Railroad, are extensive gravel deposits at the pit of Henke & Reed.

Outwash gravels.

While the ice sheet was forming the Valparaiso moraine there were streams of water issuing from its front and escaping to Illinois River Valley by the lower Desplaines, Dupage, and Kankakee valleys. These streams became overburdened with material derived from the ice, and, in consequence, built up their beds and valley bottoms to a marked degree and spread out the detritus in extensive terraces. These deposits are principally of coarse gravels. Near Romeo, 3 miles southwest of Lemont, according to Mr. Leverett,[1] the gravel filling in Desplaines Valley reaches 620 feet above tide. This appears to be the head of this gravel, though by reason of erosion the precise location of the head is somewhat uncertain. The small eastern tributaries of Desplaines River, Long Run, Spring Creek, and Hickory Creek, in the towns of Homer and New Lenox, Will County, were lines of escape for the glacial waters over the front slope of the moraine. This discharge gave rise to the gravel deposits in these valleys, and these gravels are continuous with the more extensive deposits to the west, along Desplaines Valley.

A slight outwash from the inner crest of the moraine also spread a thin stratum of gravel over much of the flat south and southeast of Tinley Park.

Brown hardpan beneath the blue.

Earlier till.—As has been stated, it is generally impossible in this district to distinguish between the deposits of the last Michigan glacier and those formed by earlier advances of the ice. Undoubtedly the greater part of the exposed drift is the work of the last glacier. At various places, however, beneath the plain and the moraine a very dense, partially indurated till has been found. This is popularly known as hardpan, and is thought to be remnants of a drift sheet of earlier age. In discussing the wells throughout the Valparaiso morainal belt in Illinois, Mr. Leverett states that if a well is carried to a depth much beyond 150 feet it usually passes out of the blue till into a hard brown till, unless rock is reached. He thinks that this hard till belongs to one of the earlier invasions of the ice. This hardpan was also encountered in the bottom of the excavation for the drainage canal a mile or so east of Summit. Here it was very hard and partially cemented. Its hardness, compared with that of the overlying till, was so marked that the contractors who were engaged to excavate this part of the channel were obliged to abandon the steam shovel which had been used in the soft till and resort to blasting.

The shafts and borings for the various radiating land and lake tunnels of the Chicago city water system show the presence of this layer of brown hardpan overlying the rock surface, with a thickness varying from 10 to 40 feet.

In the clay pit of the Purington, Kimball Brick Company at Purington station, on the Chicago, Rock Island and Pacific Railway, 5 to 7 feet of hardpan was penetrated below 33 feet of blue till. It has here a sort of chocolate color, is stratified, and is very easily fusible.

Buried soils.

At some points buried soils have been penetrated by wells, but their occurrence seems to be rare, and little or no data have been obtained relating to them.

EPOCH OF GLACIAL RETREAT.

LAKE CHICAGO.

General relations.—Every ice sheet has a period of advance, followed by a period of decline. During the advance, while there may be variations in the rate of movement, with slight intervals of halt or even of retreat of the ice front, the growth of the ice sheet on the whole exceeds the waste. During the retreat, while there may be like variations in the rate of movement and minor intervals of halt and readvance, as a whole the waste exceeds the growth and the ice front gradually retires from the position of its maximum extension.

Origin and initial stages of Lake Chicago.

While the ice front was being melted back to the Valparaiso moraine, and while it stood in that position, the water which arose from the melting of the ice and from the precipitation upon its surface flowed off southward and westward by various channels and eventually reached the Mississippi. This discharge and the resulting deposits of outwash gravels heading in the outer slope of the Valparaiso moraine have already been noted. When, however, the ice front first withdrew within the crest of the Valparaiso moraine, there were not such direct lines of discharge to draw off the water, so that it collected in hollows in the surface of the moraine and in a string of ponds bordering the ice front and lying well up on the inner slope of the moraine. At first these ponds or lakelets were presumably isolated and discharged over the moraine as they found opportunity. The scattered marsh areas indicated on the maps may mark the location of many of these ponds. As the ice front gradually withdrew, the ponds that were immediately contiguous to the ice edge were extended laterally and became more and more connected with one another. As lower outlets were opened the higher lines of discharge were abandoned. At length all these lakelets became coalescent into one marginal lake lying between the ice front and the inner slope of the moraine, and a line of discharge was opened along the course of the present Desplaines Valley and the Sag—a Y-shaped outlet whose lakeward arms inclosed the triangular morainic tract known as Mount Forest. This may, perhaps, be recognized as the initial stage of Lake Chicago. As the glacier continued to withdraw, the lake extended itself northward until it occupied an extensive basin. It seems probable that the earlier stages of this marginal glacial lake were contemporaneous with the deposition of the mild ridges of the lake-border morainic system, since it is probable that these till ridges mark stages of halt, or of halt and readvance, of the ice front in its retreat from the Valparaiso moraine.

Origin of names Chicago Outlet and Lake Chicago.

The name Chicago Outlet has come into use by geologists and engineers to designate this line of southwestward discharge from the basin of Lake Michigan across the low divide near Chicago and thence by way of Desplaines and Illinois valleys to the Mississippi. Mr. Leverett suggests that it may appropriately embrace both the points of discharge from the lake to the Desplaines, the one entering at Summit and the one at Sag Bridge. For the glacial lake discharging through this outlet Mr. Leverett[1] proposed the name Lake Chicago. Concerning this name he says:

> The introduction of the name "Lake Chicago" for the glacial lake which was held in the southern end of Lake Michigan Basin seems convenient, if not necessary, inasmuch as its area was not coincident with that of Lake Michigan, and its outlet was in the reverse direction. It is also in keeping with the custom of students of glacial lakes who find it advantageous to have a special name for each of the temporary bodies of water in the several basins. The name "Lake Chicago" seems especially pertinent, since the glacial lake extended about as far beyond the present limits of Lake Michigan in the vicinity of Chicago as at any part of its border. It is also a name which readily suggests the position of the lake, and it is in keeping with the name which has come into use for the outlet.

Lacustrine features early recognized.

The recognition of the outlet and of the beach lines with their sand and gravel deposits as evidence of a former extension of Lake Michigan over the plain upon which the city of Chicago is now situated was made at an early date. Perhaps the earliest mention of the fact in scientific publications is that by Dr. Henry M. Bannister in his article on the geology of Cook County in Vol. III of the Geological Survey of Illinois, published in 1868. In the same year a report on the survey of Illinois River by Col. James H. Wilson and William Gooding was published in the report of the United States Army Engineers, which makes reference to the former southwestward discharge of Lake Michigan. Dr. Bannister opens his discussion of the ancient outlet and beaches with the following statement:[1] "It is evident, with very little observation, that at a comparatively recent period a considerable portion of Cook County was under the waters of Lake Michigan, which at that time found an outlet into the Mississippi Valley through the present channel of the Desplaines."

Age of the Chicago Outlet.

The general features of the outlet have already been given. Concerning the age of the valley cut in the rock there is little direct evidence. Near Lemont the valley floor is almost bare rock from side to side, showing no filling by glacial drift. Neither does the floor in this part show glaciation, so far as known, unless the parallel grooves reported by Mr. Guthrie are of glacial origin. It seems probable, however, as indicated, that these go with the potholes in the rock near Lemont as the product of river erosion. The rock is exposed in the bluffs at this place 40 to 60 feet above the valley floor. While this rock cut may not be preglacial, it may have antedated the last glacial epoch. If such was the case the cut must have been filled with drift to a height at least 60 feet above Lake Michigan, since this is the highest level at which the waters appear to have stood for any considerable time. The erosion of the outlet may have begun at a somewhat higher level, while yet the ice front was but little withdrawn from the moraine and while there was yet no extended lake to develop well-marked shore lines. Shore erosion would probably be inconsiderable in a narrow lake in which there was much floating ice. As the ice retired and the incipient Lake Chicago became expanded this outlet was cut down. At a certain stage in this process, represented by the highest beach, the wave action was sufficient to develop a definite beach line before the further lowering of the outlet had drawn the water down to a notably lower level.

Method of lowering outlet.

It has been suggested[2] as not improbable that the halt at the 60-feet level was determined by the stoping process; that is, after the outlet had reached the 60-foot level, it found its channel resting upon rather resistant drift and rock from the head of the outlet nearly across the whole breadth of the obstructing moraine, while on the outside of the moraine there was a sharp descent. As a result there was, for a period, very little cutting at the entrance of the outlet, while there was comparatively swift cutting at the rapids formed on the outer side of the moraine. These rapids gradually cut back by a process somewhat like the miner's stoping,[3] until the rapids had traversed the breadth of the moraine and reached the head of the outlet. Immediately on doing this, the waters would be rapidly drawn off to a level represented by the foot of the stope thus carried from the outer to the inner side of the obstructing moraine. This would account for the fact that there is not a succession of beaches extending from the 60-foot horizon to the lower horizons, as there should be, one would think, if the outlet was gradually lowered the corresponding distance.

Discharge through Chicago Outlet.

At its maximum the discharge of water through this outlet must have been comparable to that now discharged through the Niagara River. Concerning the area for which the Chicago Outlet was a line of discharge, Mr. Leverett says:[4]

> Enough is known to make certain that the general direction of retreat of the ice sheet was northeastward. The southern and western portions of the Great Lake basins were, therefore, the first to become free from ice and to be occupied by glacial lakes. While the ice sheet was covering the present outlets of Lakes Superior and Michigan these lakes had no connection with each other, nor with the lakes to the east and their discharge was southward or southwestward into the Mississippi, from the present heads of these lakes. A small district west of Lake Erie was also occupied by a lake that discharged southwestward to the Wabash. Upon the withdrawal of the ice sheet from the southern peninsula of Michigan and the southern portion of the Lake Huron Basin, the lake at the western end of Lake Erie became expanded and a line of discharge was opened eventually from Saginaw Bay across the southern peninsula of Michigan to the Lake Michigan Basin, and this being lower than the outlet to the Wabash, that outlet was abandoned. The waters of the Lake Huron Basin being held at a somewhat higher level than those of the Lake Michigan Basin the flow of water was from the former to the latter. The glacial lake which discharged across the southern peninsula of Michigan extended over the district between Lake Huron and Lake Erie, as well as the Lake Erie Basin and the low district bordering it on the south and west. It apparently did not extend far into Ontario Basin, as a study of moraines indicates that the ice sheet occupied that basin at the time of this discharge. It thus appears that the Chicago Outlet at one time was the line of discharge for an area much larger then the present Lake Michigan Basin.

Below Lemont the bed of the outlet declines 90 feet in a distance of 25 miles. Of this fall, 76 feet is made in a little less than 10 miles, from Romeo to Juliet pool. The nature of the rock is such that it is not probable a waterfall was established, but the high gradient must have caused very strong rapids.

Deposits in the outlet.

The outlet above Lemont is in general swept free of débris, and the ravines and gullies cut in the sides of the outlet have very slight alluvial deposits at their debouchures. There are, however, considerable surface accumulations of crystalline bowlders at some places. These are seen along the north side of Desplaines River for $1\frac{1}{2}$ to 2 miles above Willow Springs and over a considerable area within a radius of one-half mile to $1\frac{1}{2}$ miles northeast, west, and south of the village of Worth, in the eastern part of the Sag. It has been estimated that there are in places near Worth a thousand bowlders per acre, the ground being so thickly strewn that a person can almost step from one to another over a considerable area. The tendency toward aggregation in the heads of the outlets has suggested the agency of floating ice, which might have clogged the outlets at certain seasons and allowed the dropping of the bowlders in these places.

The 60-foot, or Glenwood stage.

Stages of Lake Chicago.—There were several more or less distinct stages of Lake Chicago. During the first stage which has been recognized, the Glenwood stage, its water seems to have stood about 60 feet above the level of Lake Michigan. This stage lasted for a considerable period, during which the waves and currents worked along the shore lines, developing cliffs and building beaches and spits of sand and gravel. During this time it is probable that the ice front was retreating northward, allowing the extension of the lake in that direction.

Low-water stage.

Following this was a stage during which the waters are thought to have been too low to discharge through the outlet to the southwest, or even to cover the Chicago Plain. On the emergence of this plain, vegetation sprang up and in the marshy spots deposits of peat were formed. The reason for this lowering of the lake level is not known. Probably the ice had retreated so far northward as to open an eastward outlet lower than that by way of Desplaines Valley.

The 40-foot, or Calumet, stage.

Later the water rose, though not so high as before, and nearly covered the plain, burying the peat deposits under accumulations of sand, where they are now found as evidence of the low-water stage. As the water rose, the discharge through the Chicago Outlet was resumed. This rise marks the beginning of the Calumet stage, during which a second line of beaches was developed about 40 feet above Lake Michigan. The cause of this rise in the lake waters is not positively known, but it was probably due to a readvance of the ice so as to block the northeastern outlet, or possibly to a rise in the land lying northeastward, such as to cut off the discharge in that direction.

Possible second low-water stage.

Certain evidence is coming to light which may show that the lake level was lowered a second time, following the Calumet stage, by the reopening of the outlet at the northeast.

The 20-foot, or Toleston, stage.

The third series of beaches, which were formed about 20 feet above the present lake level during the Toleston stage, may thus really mark the extent of a partial resubmergence of the Chicago Plain after a low-water stage rather than simply a stage in the gradual lowering of the lake level by the cutting down of the outlet.

Still later a permanent outlet was opened at the northeast, probably the result of the final

[1] The Illinois Glacial Lobe, p. 376.

[1] The Pleistocene Features and Deposits of the Chicago Area, p. 65.

[1] Geology of Illinois, Vol. III, 1868, pp. 240–242.

[2] Dr. Chamberlin, personal communication.

[3] For a brief statement of the doctrine of stoping, see "Alternative interpretations," by T. C. Chamberlin, in The Glacial Lake Agassiz: Mon. U. S. Geol. Survey, Vol. XXV, 1896, pp. 250–251.

[4] Illinois Glacial Lobe, pp. 427–428.

recession of the ice. This outlet was lower than that near the site of Chicago, and the level of the lake was drawn down sufficiently to cut off the southwestward discharge. When this was done the present conditions were inaugurated and the history of Lake Chicago was at an end.

BEACHES OF LAKE CHICAGO.

The Upper or Glenwood beach.—The different levels at which the water of Lake Chicago stood for any considerable length of time are marked by a series of well-defined shore lines whose ridges of beach sand and gravel were noted as the significant features of the Chicago Plain. The positions of the various shore lines are indicated on the maps. As before stated, the water at first stood for a notable period at a level about 60 feet above that of Lake Michigan, or 640 feet above tide. At this level was formed the first and highest beach. To this beach Mr. Leverett has given the name Glenwood, from the village by that name on the Chicago and Eastern Illinois Railroad, 4 miles south of Calumet River. At Glenwood this beach is especially well developed. The relations of land and water while the beach was forming are shown in fig. 7.

Extension of the Glenwood beach north and east.

The shore line corresponding to the Glenwood beach extended an undetermined distance northward into Wisconsin. It has been identified at this same level in Wisconsin northward to a point 5 miles north of Racine, where it is intersected by the present lake bluff. From this point northward through Milwaukee and Ozaukee counties, a distance of 45 miles, as far as the investigation has been carried, no trace of this shore line has been found. It is thus impossible at the present writing to say just how far northward the ice front had receded while the water stood at this level. In the Illinois portion of Lake Chicago the beach is present except for a few miles between Waukegan and Winnetka, where its absence is due to the encroachment of the waters of the succeeding lake stages upon the land, so that the present lake shore is farther west than was the shore line during the Glenwood stage. In Indiana (fig. 14) the beach is present throughout the entire extent of the border of Lake Chicago in that State, being nowhere less than 2 miles and in places as much as 12 miles back from the shore. In Michigan it is absent for a short distance at the "clay banks" north of New Buffalo, where the present shore stands farther east than the shore of Lake Chicago. It is also absent for the same reason near the line of Berrien and Van Buren counties and north of St. Joseph, and for a few miles north of South Haven. North of Kalamazoo River only a brief reconnaissance has been made, so the full extent of the beaches in Michigan has not been ascertained.[1]

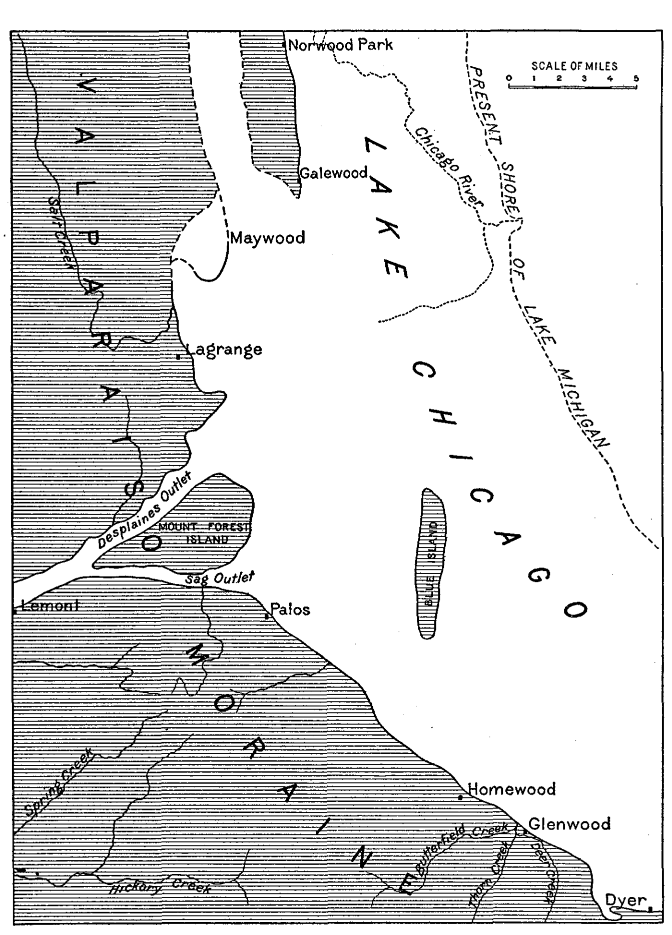

FIG. 7.—Map showing the vicinity of Chicago during the Glenwood stage of Lake Chicago.
Shaded portion represents land area.

[1] The location of this and the succeeding beaches in Illinois, outside the special area under discussion, in Indiana, and in Michigan is a result of Mr. Leverett's investigations. See The Illinois Glacial Lobe, Chapter XI.

Detailed description of Glenwood beach.

From the bluff at Winnetka this Glenwood beach swings southwestward for several miles to Norwood Park on the Wisconsin division of the Chicago, Milwaukee and St. Paul Railroad (see Riverside Areal Geology sheet and fig. 7). Extending northward between Galewood and Maywood there was a shallow bay, 2 or 3 miles in width. It is probable that when the waters stood at their highest level they extended over the plain north and west of Maywood to about the limit indicated on the geologic map and fig. 7, but the only definite indications of a shore line are at a somewhat lower level south of Maywood. It seems probable that this latter line marked the shore when the water level had lowered somewhat and the Oak Park spit began to emerge as a beach. From Maywood the shore line swings southwestward and southward through Lagrange to the line of the present Desplaines Valley near McCook station. Just west of McCook was a prominent point, passing about which the shore line makes for the head of the outlet 3 miles southwest of McCook.[1] The outlet here was about 1 mile in width. The continuance of the point west of McCook in a position so exposed to erosion was probably due to the fact that beneath a thin coating of till are beds of limestone dipping down the slope.

The head of the Sag outlet at the Glenwood stage was about 2 miles northwest of the village of Palos, on the Wabash Railroad, where it had a width of one-half mile. The shore between the two outlets lay along the east slope of the morainic tract known as Mount Forest.

From the Sag the Glenwood shore line passes southeastward along the inner slope of the moraine, which rises in some places gently and in others more abruptly from the plain. Passing about one-half mile north of Homewood, on the Illinois Central Railroad, the shore continued southeastward through Glenwood, on the Chicago and Eastern Illinois Railroad. Just southeast of Glenwood the beach deposits have been almost entirely removed by the erosion of Deer Creek, but one-half mile farther on the beach is again seen flanking the lakeward side of a sharp, narrow ridge of till. Near the State line it turns eastward and runs into Indiana through the village of Dyer (fig. 14).

Cliffs and wave-cut terraces of the Glenwood shore.

The Glenwood shore line has certain features which deserve special mention. Through a large part of the distance between Norwood Park and Dyer this shore line is marked by a wave-cut terrace and low cliff cut in the glacial drift, rather than by a sandy beach.

The method of formation of a cliff and wave-cut terrace is as follows: D A (fig. 8) is a land surface sloping gently to a lake the level of which is D′ A, A being the original position of the shore. As the waves dash against the shore the bank is more or less eroded and the débris is either washed backward by the undertow and spread on

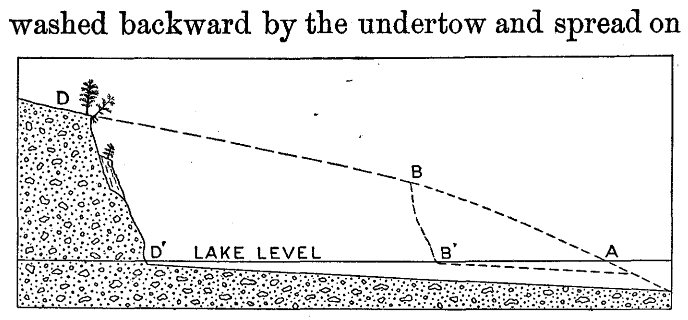

FIG. 8.—Diagram illustrating the formation of a cliff and wave-cut terrace.

the bottom or carried along the shore by the littoral currents, to be deposited wherever motion sufficient for its transportation fails. As the zone of greatest erosion is at the water's edge, extending a little above and a little below the level of quiet water, the shore is gradually cut backward as with a horizontal saw, the material above sliding and falling down when undercut and being worked over and carried away by the waves and currents.

Thus with a land surface rising back from the shore, the shore grows higher and becomes a cliff, while the bottom of the lake near the shore slopes gently up to the water's edge, forming a wave-cut terrace. The horizontality of the landward margin, which also marks its junction with the cliff, is the especial characteristic of a wave-cut terrace. It should be noted, however, that in the case of the ancient terraces from which the lake has withdrawn, their landward margins may be locally rendered uneven by alluvial fans formed at the debouchures of ravines and gullies in the old lake cliff.

[1] The shore lines of the outlet below the villages of Mount Forest and Palos have not been differentiated on the Areal Geology sheet for the various stages of the lake history. The line marking the shore has, for the most part, been placed at the foot of the present side slope of the valley. It is probable that the outlet was widened as well as deepened during the various succeeding stages of the lake history, so that the actual shore lines were destroyed at each succeeding stage.

Desplaines estuary and Oak Park spit.

From Niles southward through Norwood Park to the Chicago, Milwaukee and St. Paul Railway and beyond, the Glenwood shore line lay along the east margin of a moderately high and slightly undulating tract. This tract is the southern part of the western till ridge of those which Mr. Leverett regarded as composing the lake-border morainic system. West of this ridge there was a shallow estuary 2 or 3 miles in width at the time the Glenwood beach was forming. This estuary probably extended some distance northward and brought to the lake the drainage of the inner slope of the Valparaiso moraine. In the western part of this low area Desplaines River has now cut its channel. As there was little or no wave action in this estuary its shore lines, except in the southern part, are not clearly worked. Their position as indicated on the maps has been assumed from the general topographic relations.

From the southern extremity of this peninsula the shore currents, moving southward toward the outlet under the influence of the strong northeast winds, as along the west shore of Lake Michigan to-day, gradually built out the shore drift into a long, narrow spit (see Riverside Areal Geology sheet and fig. 9) diagonally across the debouchure of this estuary. This spit passes through Oak Park, terminating at Forest Home Cemetery, near Desplaines River. The structure of the spit is well shown in the gravel pits of Mr. Haas at Forest Home Cemetery, 1 mile south of Oak Park. The structure is that of a bar overlain by coarser beach deposits. The following section has been noted:

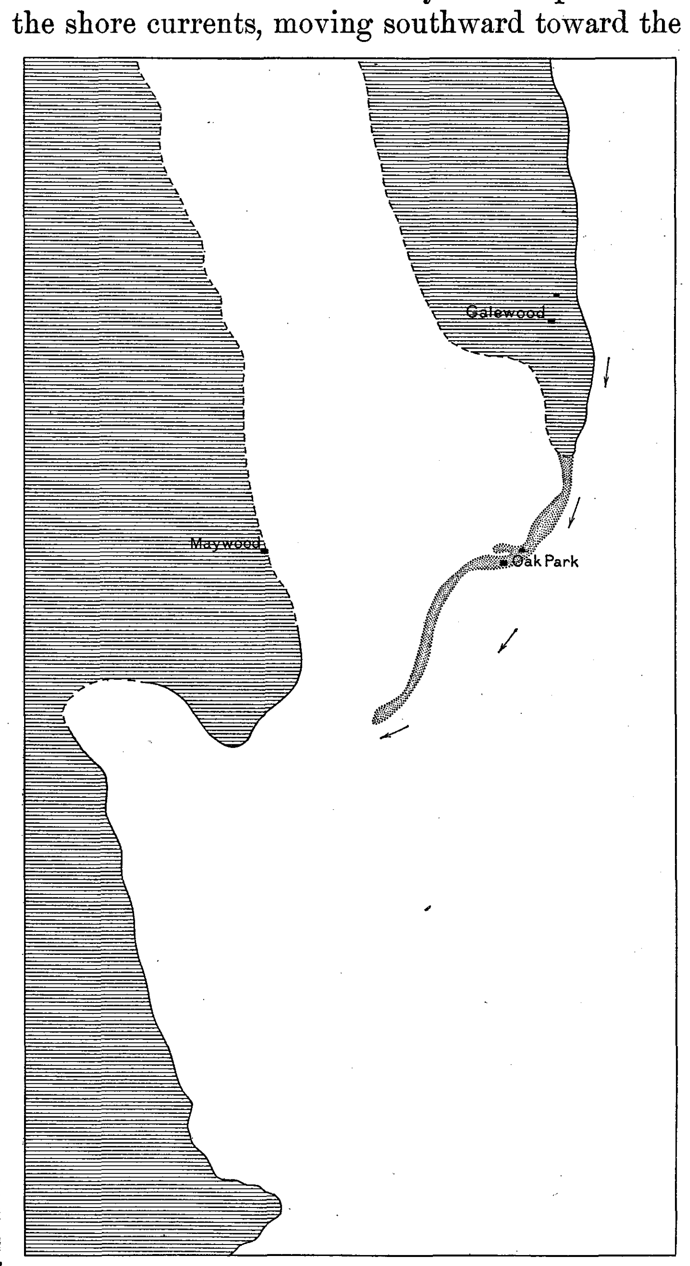

FIG. 9.—Map of the Oak Park spit.
Shaded portion represents land area; dotted portion represents spit formed under water; arrows show direction of shore current.

Section of Oak Park spit at Forest Home Cemetery.

	Inches.
1. Brown-stained gravel, capping summit and slope	18 to 30
2. Fine gravel, fresh or stained but little	24 to 48
3. Sand, very thin at top but thickening toward the side of the bar	0 to 36
4. Fine gravel, increasing like No. 3	0 to 48
5. Fine gravel, nearly 4 feet in thickness, which passes upward from near the east side of the excavation, assuming a nearly horizontal position beneath the crest of the ridge	40 to 48
6. Sand, thickening toward the higher part of the ridge	6 to 36

The method of building the spit is readily explained. Along the east shore of this elevated tract, through a distance of nearly 8 miles northward from its southern extremity, the waves were developing a wave-cut terrace with a cliff 15 to 30 feet in height. The finer material from this erosion was carried back into the deeper water, but the sand and gravel were left near the shore. A current moved along the shore in the direction indicated by the arrows (fig. 9). While flowing on the shallow bottom near the shore the current carried along more or less of this sand and gravel. As it reached the point of land below Galewood the current continued across the estuary in the general direction already assumed, instead of following the reentrant of the shore. As it reached the deeper and more quiet waters its velocity was checked, its carrying power reduced, and the load dropped. More material was constantly brought forward, being carried out each time a little farther over the deposit already made; thus a narrow submerged ridge of sand and gravel was extended out from the headland in the direction of the shore currents.

As a current flows across the mouth of a bay, the sweep of the winds across the open water of the lake is likely to deflect it into the bay and the spit receives a corresponding deflection. If turned in sharply it forms a hook. In the case of the Oak Park spit, the double curve is 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.

If the process of spit building continues until the opposite shore of the bay is reached the bay is completely cut off and the embankment forms a bar. When it is built up to the level of the water of quiet weather the waves of storms may throw up the material still higher and the bar becomes a shore line, with a lagoon shut in behind.

Glenwood spit.

Southeast of Glenwood there was a shallow bay (see Calumet Areal Geology sheet and fig. 10). The shore currents did not follow the shore of the bay, but, as in the case of the estuary near Galewood, they swept onward across the inlet, bearing the shore drift of sand

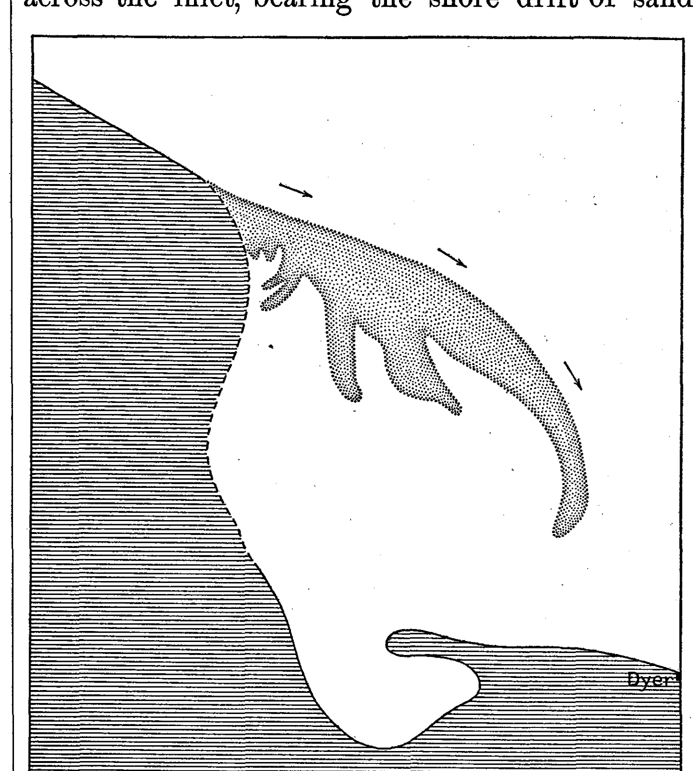

FIG. 10.—Map of the Glenwood spit.
Shaded portion represents land area; dotted portion represents spit formed under water; arrows show direction of shore current.

and gravel with them. As the currents came into deeper water they dropped their burden of detritus and gradually built it out into a great spit, nearly 2¼ miles in length, almost shutting off the bay. The landward deflection of detritus-bearing currents by easterly winds is well illustrated by the curved form of the spit. In quieter weather the current flow, and the consequent spit building, was southeastward in the general direction of the shore line; but during periods of heavy storms from the easterly quarter the currents were deflected into the bay and the spit suffered a corresponding deflection. During storms the distal part of the spit was probably washed away and the material swept back into the bay in the form of a hook, and only with the return of more quiet weather was the extension of the spit in its original direction resumed. The structure of the whole is that of a great curved bar, formed by a series of hooks extended one from the other with the same general front. As this bar increased in height until it stood at or near the water level it became the shore line and was further heightened by accumulations of dune sand. This ridge has now a height of 15 feet above the plain to the north and east.

Dunes of the Glenwood beach.

Beginning 2 miles southeast of the point where the Chicago, Rock Island and Pacific Railway passes from the plain to the moraine, the till slope along the Glenwood shore line is more or less coated with wind-blown sand. About 1 mile east of Homewood this dune sand becomes more prominent, forming a well-defined ridge 10 to 30 feet in height. It is evident, however, that this deposit was formed at a later stage than the beach with which it is associated. It was blown up from a lower beach which is found only a half mile to the north. While this deposit continues eastward in a line of dunes, the beach gravels of the Glenwood stage emerge from beneath the ridge of dune sand and continue southeastward toward Glenwood.

Duration of the Glenwood stage.

It is not known how long the waters stood at this upper level. It was long enough to accomplish considerable erosion of the outlet and of the inner margin of the moraine. Most of the débris seems to have been swept through the outlet instead of being deposited on the lake bottom.

Changes of Glenwood water level.

The level of the lake was probably not constant during the Glenwood stage. The outlet was being cut down and the level of the water in the lake correspondingly lowered. The amount of this lowering must have been nearly 20 feet, inasmuch as the waters of the next stage at which the Chicago Plain was submerged formed their beach at a level about 20 feet lower than that of the Glenwood stage. As the water level became lower the level of wave cutting was correspondingly lowered and more or less erosion resulted at all levels from the highest to the lowest at which the lake waters stood. The effect of this lowering is seen in the wave-cut terraces and cliffs. The landward margins of these terraces as now found, instead of rising to a uniform level 640 feet above tide, are generally somewhat lower. Because of this evident shifting in the lake level it is not possible to determine the exact initial altitude of the lake. The altitude given by the railroad surveys for Maywood, Glenwood, and Dyer is probably approximately the highest lake level. At these points, instead of cut terraces and cliffs, there are simple beach deposits of sand and gravel. The altitude at these places is 636 feet above tide.

In the following table the altitudes of the cut terrace at the base of the cliff shows approximately the lower limit which the lake level reached during the Glenwood stage.

Altitudes of cut terrace along Glenwood shore line.

Station.	Railway.	Elevation above tide.	
		Crest of cliff.	Base of cliff.
Norwood Park.......	C. and N. W.....	640	626
Galewood............	C., M. and St. P.	647	623
Lagrange............	C., B. and Q.....	645	627
Border of moraine....	C., R. I. and P...	658	630

Life during the Glenwood stage.

No satisfactory evidence has been found of life in the waters of Lake Chicago at the Glenwood stage. This is as would be expected in waters largely derived from the melting of the great ice sheet. Shells have been reported from the gravel pit of Mr. Haas at Forest Home Cemetery, 1 mile south of Oak Park, but as there were many Indian graves on the bar which extended down nearly to the level of the base of the pit, it was concluded that the shells might have been introduced in connection with some burial. Mr. Haas also preserved fragments of the tooth of a mammoth found in the gravel pit at the depth of several feet. These fragments are waterworn, and it therefore seems probable that they were introduced during the formation of the bar. So far as known, no other evidences of life have been found in the deposits of this stage of the lake. Supposed *Unio* shells have been reported found in a marsh on the inner side of the beach north of New Buffalo, Mich., but the report has not been verified.

Mount Forest Island.

During the Glenwood stage the Chicago Plain was submerged beneath 10 to 60 feet of water, which discharged westward in a great river filling the outlet from side to side. The lakeward arms of this Y-shaped outlet converted Mount Forest into a triangular island 6 miles long and 4 miles wide. The undulating surface of this island rose 80 to 120 feet above the surrounding waters.

Blue Island.

Other than Mount Forest the only emerging land within the Glenwood shore line in the area here described was Blue Island, the ridge of drift already mentioned. There seems to be no assignable reason why excessive deposition should have occurred at this place. As stated, Mr. Leverett has suggested a correlation of this ridge with the middle ridge of the lake-border morainic system north of the Chicago district. It is probable that, as left by the glacier, this elevation of drift spread out to the east, north, and south with more gentle slopes, such as are now seen on the west, thus forming a broader and less abrupt rise than the present.

At the Glenwood stage of the lake this drift ridge was an island rising 10 to 35 feet above the surrounding waters. The waves beating against this shore on the east and northeast cut away much of the gentle slope and developed a terrace and cliff. The waters from the east and southeast were divided in their flow toward the outlets by this ridge, one part sweeping about the north and the other about the south end. These currents gathered up much of the finer material from the erosion of the cliff and swept it out to the leeward of the island in a pair of spits, one at the north end and one at the south (see Calumet Areal Geology sheet). That at the north is best seen at the Catholic cemetery at Ste. Marie, on the Chicago and Grand Trunk Railway. It may be that the bowlders on the plain at the north end of the Blue Island ridge are the remnants from this erosion, being the coarser material which the waves and currents were unable to carry. The waters flowing about the south end of the island formed the deposit of gravel and sand on which is built the village of Blue Island. These gravels are best seen in the excavation just west of the Chicago, Rock Island and Pacific Railway station, where they are alternately fine and coarse, with cross bedding dipping to the west. Cellar excavations also show the bedding as dipping to the south and west. From this deposit a gentle ridge or spit runs northwestward nearly 2 miles in the lee of the south end of the island.

Morgan Park barrier ridges.

Along the east side of the island, where the waves began to drag upon the gently rising lake bottom and formed a line of breakers, the shore drift was built into an outlying sublittoral ridge or barrier. There were two stages in its development, forming an inner and an outer ridge of sand and gravel. The outer one is that whose margin is followed by Prospect avenue in Morgan Park and Washington Heights. These ridges curve into the shore of the island at the north and south. As the water level lowered they inclosed small lagoons which left a deposit of rich black loam over the surface of the till. The Vincennes avenue ridge, which seems to be correlated with a later lake stage, has corresponding relations, inclosing the ridges just noted and extending $1\frac{1}{2}$ miles farther south before coalescing with the till slope. Its construction may have begun at this stage as the outermost barrier, later, on the lowering of the water level, it became a beach line. The beach gravels along the west side of the island are buried beneath the accumulation of dune sand just noted. The presence of the beach deposit below the dune sand is shown by the wells.

The low stage of Lake Chicago marked by buried peat beds.

After the Glenwood beach was formed a northeastern outlet for the lake seems to have been opened, and the waters receded from the Chicago Plain until they stood near or within the present shore line of Lake Michigan. The opening of the northeastern outlet was probably due to a recession of the ice sheet beyond some valley lower than the Chicago Outlet. As before stated, the evidence of the emergence of the Chicago Plain at this time is found in a bed of peat beneath the deposits of the succeeding lake stage, which is interpreted to mean that the waters were withdrawn from the plain for a time sufficiently long to allow vegetation to grow and its residue to accumulate before the area was resubmerged and the later lacustrine deposits were formed. These later deposits which now overlie the peat bed are the sands and gravels composing the Rose Hill bar. This bar forms the ridge near the south end of which is Rose Hill Cemetery, in the northern part of Chicago. Concerning the structure of this bar Mr. Leverett says:[1]

> An excellent exposure of the structure of the bar noted above is found immediately north of Evanston, where the lake is undermining the bar as well as subjacent deposits. The beach sands and gravels rest upon a bed of peat, which was noted by Dr. Andrews and interpreted by him to be the accumulation of a marsh or partially submerged land surface. The peat not only underlies the bar under discussion, but extends eastward across the interval between it and the Third beach. Its level is no higher than that of the Third beach, being but 12 to 15 feet above the present level of Lake Michigan. The peat is in places several feet thick, but at the point where the bar comes out to the lake shore it has a thickness of only 3 to 6 inches. It contains pieces of mangled wood and has been disturbed by waves. Between the peat and the yellowish-blue till which forms the base of the exposure there is a gravelly sand 6 to 18 inches in thickness, which appears to be a lacustrine deposit. The peat is immediately overlain by about 5 feet of sand, above which there is a bed of coarse gravel. The gravel is thin near the borders of the bar, but has a thickness of 11 to 12 feet beneath the highest part. It is capped by a thin deposit of sand and has layers of sand interstratified with it in its thickest part. The presence of this gravel makes it impossible to suppose that the old land surface has been buried by the drifting of material from the lower beach. There seems no escape from the conclusion that the lake stood at a lower stage than the level of the Second beach before that beach and the bar under discussion were formed.

An excellent section of the beach at the border of the campus of Northwestern University in Evanston was observed in 1864 by Dr. Oliver Marcy. This section is as follows:

Section of beach at Evanston, made in 1864.

	Feet.
1. Surface soil, sandy..............................	$1\frac{1}{2}$
2. Brown sand and fine gravel....................	$2\frac{1}{2}$
3. Coarser gravel, stratified........................	$2\frac{1}{2}$
4. Fine sand..	2
5. Gravel, containing bones of deer.............	$1\frac{1}{3}$
6. Fine sand containing oak logs	$1\frac{1}{2}$
7. Peat or carbonaceous earth, with a marl bed containing molluscan shells in the lower part or interstratified with the peat.............	$1\frac{1}{2}$
8. Gravels	$3\frac{1}{4}$
9. Humus soil, with stumps and logs (Coniferous)	$\frac{1}{2}$
10. Yellow clay, laminated and contorted, containing pockets of gravel.....................	$3\frac{1}{2}$
11. Blue pebbly clay..................................	2
Height of bluff......................	22

This beach was formed at the second succeeding lake stage, the Toleston stage, hence the soil (9) and the peat bed (7) may have been formed during an interval of emergence between the Calumet and Toleston stages. It is possible, however, that they were formed during this interval of emergence between the Glenwood and Calumet stages.

It is stated that peat deposits have been reached in sewer ditches in Hyde Park, west of Grand Boulevard, beneath the deposits of the Toleston stage. It is possible that these also may be referred to this first interval of emergence. Mr. Leverett finds evidence of emergence in the deep channels along the lower courses of the streams tributary to Lake Michigan on the east, and he reports peaty material underlying beach gravels near Michigan City, Ind. Certain evidences in Wisconsin also points to an interval of emergence. Some of this evidence points to more than one interval of emergence, but further study is necessary for a satisfactory interpretation.

Blue Island dunes evidences of prevailing winds.

During this interval of emergence the formation of the deposits of dune sand probably took place along the west side of the Blue Island ridge. The flat west of the ridge had received a considerable deposit of sand during the Glenwood stage of the lake, and when the lake waters subsided this sand was readily blown up by the wind and lodged along the west slope of the ridge. For about 1 mile at the north the accumulation is in individual hillocks or dunes, with the more gentle windward slope to the west. These dunes have reliefs of 15, 20, and 25 feet. The line of the Chicago Terminal Transfer Railroad runs through them, giving some good sections. These sections show fine, clean, buff unstratified sand. Southward the deposit takes the form of a ridge 10 to 30 feet high and 100 yards to one half mile in width, running the full length of the island. Here also the more gentle slope is to the west. This deposit gives evidence of prevailing west and southwest winds, as at present. These dunes are now covered with vegetation and have become fixed, i. e., the sand is no longer shifting.

The Second or Calumet beach.—Following the interval of emergence, the waters of Lake Chicago rose and again flooded the Chicago Plain. This resubmergence may have been due to a return of the glacier to the northern end of the basin, blocking the outlet which had been opened in that direction, or it may have been due to a rise of the land in that direction. The level to which the water rose in this second stage is marked by the Second or Calumet beach, which is found 35 to 40 feet above the present lake level and about 20 feet below the beach of the Glenwood stage. This beach has received its name from Calumet River, with which it is closely associated in Illinois and Indiana. The name was proposed by Mr. Leverett. The lack of evidence that the waters rose higher than this beach level at this time seems to indicate that during the Glenwood stage the outlet had been cut down nearly to this level and had drawn down the lake from its highest stand.

Calumet beach in Wisconsin and Illinois.

Like the older beach, this lower and later beach has its correlative in Wisconsin. A beach has been recognized at a point 30 miles north of Milwaukee at the same level as at Chicago, but from this latitude southward to a point 5 miles north of Racine, a distance of nearly 50 miles, it has been cut away by the encroachment of the lake upon the land in later times. From the Wisconsin line southward to Chicago River the Calumet beach is closely associated with the Glenwood beach wherever the latter remains.

South of North Branch of Chicago River the beach is seen in good development at Jefferson Park (see Riverside Areal Geology sheet and fig. 11). Thence it passes through Cragin and Austin to Riverside. Through this distance of 12 miles there is a continuous, well-developed beach ridge

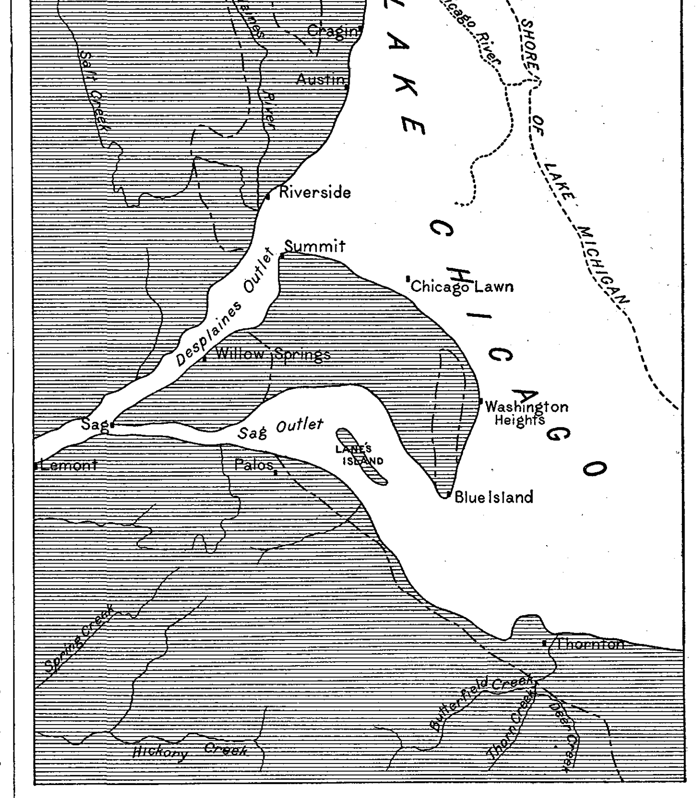

FIG. 11.—Map of vicinity of Chicago during the Calumet stage of Lake Chicago.
Shaded portion represents land area.

of sand and gravel. In the northwestern part of the village of Riverside it has a relief of 10 to 12 feet above the plain to the east, but southwestward through the village this line is only faintly marked. This is largely due to obliteration by the grading of streets and lots.

At this stage of the lake the drainage of the region to the north and west along the line of Desplaines River, and possibly along the line of Salt Creek, entered the lake at the present point of confluence of these streams. It has been suggested that Salt Creek at one time reached Desplaines Valley through Flag Creek Valley, which passes southward from Fullersburg. This may have been the case at this time. It is difficult to determine when the diversion of the stream was accomplished, if such was really the case. Flag Creek Valley may have been a line of marginal

[1] The Pleistocene Deposits and Features of the Chicago Area, p. 73.

glacial drainage at a certain stage in the retreat of the ice front.

From Riverside to the outlet, the head of which at this stage was at Summit, the Calumet shore line is not well defined.

Islands of the Calumet stage.

At the Glenwood stage, Mount Forest Island and Blue Island were separated by an expanse of water. At the Calumet stage the intervening plain emerged and the whole area formed one large island between the heads of the outlet (fig. 11). Sag Bridge station marks the western extremity, Summit the northern, and Blue Island village the southeastern. The flat part of this island may at times have been submerged during this stage, since its elevation is very nearly that of the lake surface at this time.

The east shore of the outlet was not at first coincident with the side of the valley as now seen, but lay upon the flat to the east at distances varying from a few yards to one-half mile from the present cliff. Its position is marked by an interrupted deposit of sand and gravel. The outlet at Summit was about 1 mile in width.

From Summit southeastward the lake shore line swung in a broad curve about the north end of the Blue Island ridge and through Washington Heights. Throughout this distance of $11\frac{1}{2}$ miles the Calumet beach is marked by a continuous well-developed ridge of sand and gravel 5 to 10 feet high and 50 to 100 yards wide. North of Archer avenue, in the village of Summit, there is an excellent 15-foot section showing the structure of the beach. The material ranges in size from coarse sand to pebbles 3 and 4 inches in diameter. It is well assorted and stratified in beds dipping northward at an angle of 10 degrees.

From Washington Heights to the village of Blue Island the outer of the barrier ridges previously mentioned marks the shore line at this stage. This is the ridge now traversed by Vincennes avenue.

The head of the Sag outlet at this stage may be considered as lying between the south end of the Blue Island ridge and the inner margin of the moraine about 3 miles farther south. The waters passing through this outlet were divided by a low body of land known as Lanes Island. This has a width of one-fourth to one-half mile and a length of $3\frac{1}{2}$ miles. Its outline is traced by a low, narrow ridge of beach sand and gravel. This island was submerged during the Glenwood stage, but the lowering of the waters left the crest slightly exposed. Stony Creek now traverses the north channel. The total width of the Sag outlet, including Lanes Island, was nearly 3 miles. West of this island the channels unite and the outlet was contracted to a width of one-half mile. The village of Oak Lawn stands on the north shore of the north channel, and the village of Palos near the south shore of the south channel. The shore lines are for the most part clearly marked.

From the south side of the Sag outlet to the rock elevation at Thornton the Calumet shore line was nearly parallel to that of the preceding stage and about one-half mile within it. Southeastward to the line of the Chicago, Rock Island and Pacific Railway the shore line is rather obscure, but from this railway to Thornton there is a continuous ridge of beach sand and gravel. There is also considerable sand spread over the plain within this beach line. From the Thornton rock elevation, whose north margin formed the shore, this shore line continues eastward into Indiana (fig. 14). East of Thornton the beach gravels are largely covered by dune sand. For some distance the beach gravels are exposed along the south margin of the dune-sand deposit, which gives to the south side rather than the north side the appearance of being the shore.

Of the eastward continuation of this beach Mr. Leverett says:[1]

Calumet beach in Indiana and Michigan.

Upon entering Indiana the beach follows the south border of the Calumet River across Lake County and Porter County to the point where the upper beach * * * passes to the north side of the river. It is closely associated with the upper beach from near the village of Ross, Indiana, eastward. It is also closely associated with it for several miles east from the point where it crosses the Calumet River, but in the vicinity of Furness the two beaches become separated by a nearly level swampy tract about one-half mile in width, and continue distinct to Trail Creek, just east of Michigan City. The Second beach passes through the south part of that city.

Upon passing into Michigan this beach becomes so greatly obscured by the belt of dunes formed along the border of the lake that exposures are found only at a few points. In several places in Berrien and Van Buren counties it was recognized and found to have an altitude 35 or 40 feet above Lake Michigan.

[1] The Illinois Glacial Lobe, p. 443.

Northward from Van Buren County, Mich., no detailed location and examination of the beach has been made.

Spits of the Calumet stage.

During the Calumet stage a slight spit was formed near Cragin (see Riverside and Chicago Areal Geology sheets). This shut in a small lagoon, and its east front eventually became the shore line.

At Washington Heights a spit extended southeastward in continuation of the shore line from Summit. The trend and structure of the spit shows that the effective shore work was done by waves and currents under the influence of the strong northeast winds, rather than by the currents flowing toward the outlets.

The well-developed bar between Washington Heights and Riverdale gives this line much the appearance of having been the shore line, and indeed it may have been such during the latter part of the Calumet stage, with the head of the Sag outlet between Riverdale and Thornton. A careful consideration of the relations, however, seems to indicate that at least during the earlier part of the Calumet stage the shore line lay along the Vincennes avenue ridge between Washington Heights and the village of Blue Island.

Dunes of the Calumet stage.

As indicated, the beach gravels of the Glenwood stage east of Homewood are buried beneath a deposit of dune sand. This was evidently blown up from the lower beach during and after the Calumet stage. The deposit consists of ridges and hillocks of fine, clean sand 20 to 30 feet in height. These dunes are now well covered with vegetation, so that the sand is no longer shifting.

The extensive deposit of dune sand east of Thornton is largely in parallel ridges, the formation of which probably began during the Calumet stage. These ridges are also very largely covered with vegetation.

Rose Hill bar.

From a point on the Calumet beach north of Chicago there extended into the Chicago embayment at this stage a conspicuous bar (fig. 11). Its northern end is found at the present lake shore between Wilmette and Evanston. Its connection with the Calumet shore line was destroyed by the encroachment of the waters of Lake Michigan upon the land. From this point it runs southward through the western part of Evanston, and on it, near its southern extremity, is Rose Hill Cemetery. At the south end this bar has a relief of 15 to 20 feet and a breadth of three-fourths of a mile. Beneath this bar, as already noted, were found the peat deposits which give evidence of an interval of emergence between the Glenwood and Calumet lake stages.

Shells on the Calumet beach.

In respect to the remains of life, this beach is similar to the upper beach; no evidence of a definite character has been secured. The occurrence of shells in the Calumet beach deposits at Summit and near New Buffalo, Mich., has been reported, but no definite information has been obtained concerning them. The only shells found upon this beach by the writer were on the farm of Mr. J. H. Welch, about $1\frac{1}{2}$ miles southwest of Chicago Lawn, in a field about 80 rods northwest of the point where the beach ridge is cut by the Belt Railway. Numerous molluscan shells and one specimen of coral were found, having been plowed up from the top of the beach ridge, but the presence of the coral and the fact that the shells were, without exception, of marine species render it improbable that they were remains from the life of Lake Chicago.

The species as identified by Mr. Frank C. Baker, of the Chicago Academy of Sciences, are as follows:

Pelecypods: *Ostrea virginica* Gmelin, ranging at present from Prince Edward Island to the West Indies. These specimens are very largely perforated by boring sponges. *Arca transversa* Say, ranging from Cape Cod to Key West. *Venus cancellata* Linn., ranging from Cape Hatteras to Trinidad. *Venus mercenaria* (?) Linn. *Pecten* (sp. ?), possibly *Chlamys irradians* Linn., a fragment. *Gnathodon cuneatus* Gray, Gulf of Mexico.

Gasteropods: *Fulgur perversus* Linne, ranging from Cape Hatteras to Cuba. *Cerithium* (sp. ?), apical whorls only found. *Cerithiopsis* (sp. ?), apical whorls only found.

Corals: *Oculina robusta* Pourtales, West Indies.

However, the facts that from time to time suggestions of the former occurrence of marine waters in the vicinity of Chicago have been made,[1] and that a certain line of evidence bearing on the question of a post-Glacial submergence of the continental interior seems to be developing,[2] may warrant the citing of the conditions of occurrence of these specimens with a view to possible future value as evidence, when correlated with other data, and to bringing forth confirmatory or adverse evidence bearing on the question.

The specimens found were largely in the shape of smoothly waterworn fragments, more or less thoroughly perforated by boring sponges. Many of the fragments yet retained their natural tints and luster. The specimens evidently had not been brought into the fragmental condition by the plow and harrow, as the fragments were well smoothed and the recent fractures easily recognizable. Mr. Welch stated that he, himself, cleared the ridge of its native trees and underbrush, broke the sod, and has lived there for nearly thirty years, that he never used any fertilizer containing shells, that he has plowed up the shells, and from time to time picked up the more perfect specimens as curiosities. He stated that the only evidence of Indian residence he has ever found on the place was a single arrow head. The trading of the Indians with the south and east is well known, yet the greater part of the specimens found seem too fragmental and imperfect to have served as Indian ornaments. Also, very delicate, tiny shells were found in the sand, filling the coils of one of the larger gasteropods. The southern range of all the species found would seem to preclude their having been brought here by drift from the northeast, or having lived in the arm of the sea that penetrated the St. Lawrence Basin from the northeast, for all the shells found in this basin by Drs. Bell and Ells, or by others, are arctic species.

In the discussion of the low-water stage between the Glenwood and Calumet stages, reference is made to certain phenomena which indicate the possible occurrence of a second low-water stage following the formation of the Calumet beach, during which the northeast outlet was reopened and the discharge through the Chicago Outlet ceased. At the present writing, however, this evidence is not considered conclusive.

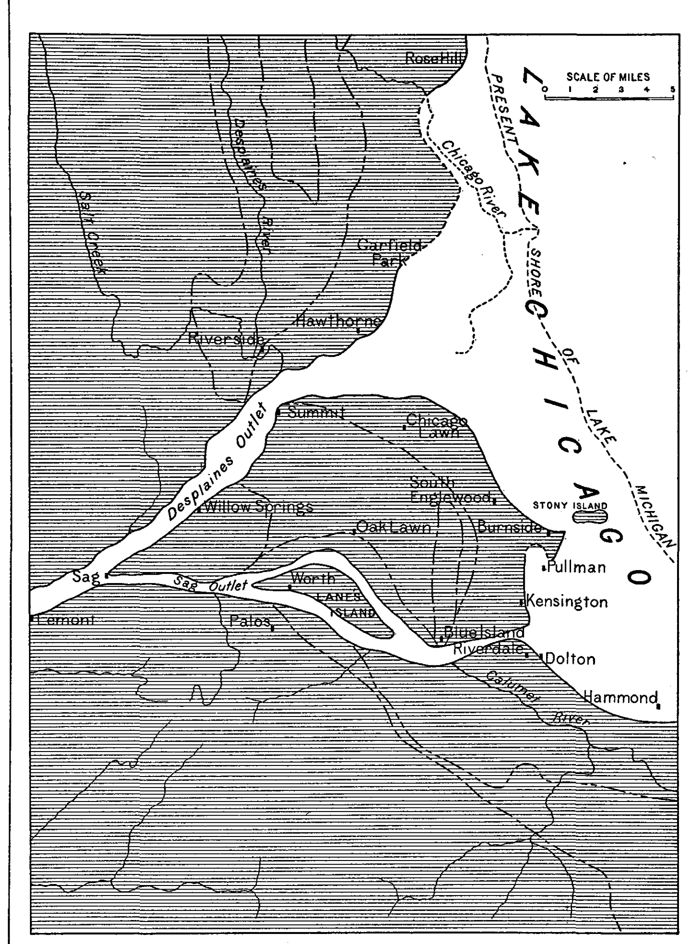

FIG. 12.—Map of vicinity of Chicago during the Toleston stage of Lake Chicago.
Shaded portion represents land area.

The Third or Toleston beach.—If such a low-water stage occurred, it was followed by a partial resubmergence of the Chicago Plain, due to the closing of the outlet to the northeast, and the southwestward discharge through the Chicago Outlet was resumed. This outlet had been so far cut down during the Calumet stage that the third recognizable shore line is found at a level about 20 feet above the present lake.

The beach formed at this stage of the lake has been called the Toleston beach, from the village of Toleston in northwestern Indiana (fig. 14). The relations of land and water at this stage, so far as the vicinity of Chicago is concerned, are shown on the Areal Geology sheet and in fig. 12.

Toleston beach in Wisconsin and Illinois.

Remnants of a terrace at a level corresponding to this shore line have been seen at various points north of Milwaukee, Wis. Between Milwaukee and Kenosha, Wis., it has been almost entirely destroyed by the encroachment of Lake Michigan upon the land. From Kenosha southward to Waukegan, Ill., it is well developed and is followed closely by the line of the Chicago and Northwestern Railway. Thence southward to Evanston the encroachment of the lake has removed all trace of this beach, as of the earlier beaches. At Evanston, on the grounds of Northwestern University, this beach appears at the present shore line and runs southward along the eastern border of the Rose Hill bar. The low area west of Rose Hill was probably flooded for a time at this stage. From Rose Hill to Hawthorne the shore line is poorly marked. Traces of it are seen at Milwaukee avenue and North avenue, at the rock elevation near the intersection of Chicago and Western avenues, and southwestward from the corner of Douglas and Central Park boulevards. From Hawthorne, which marks the north side of the head of the outlet at this stage, to Desplaines River 1 mile north of Summit, the shore is well defined by a sandy beach.

From Summit southwestward toward Willow Springs the shore of the outlet of this stage is marked by the 15 to 20 foot drift bluff now followed by Archer road. From Summit eastward there is a cut terrace and bank; in places it is barely traceable. From one-half mile west of the intersection of Western avenue and Garfield boulevards this shore line is marked by the strong ridge of sand and gravel which passes in a broad curve southeastward through Auburn Park to South Englewood.

In the earlier part of the Toleston stage the shore line seems to have swung off to the south and southeast near the intersection of South Halsted and Eighty-seventh streets, and passing through Fernwood at Stewart avenue and One hundred and third street, turned southward along the till cliff which passes through Kensington to Calumet River at Riverdale.

The Sag outlet, probably not a very active line of discharge at this stage, seems to have occupied the present course of Calumet River (reversed) between Riverdale and Blue Island. The head of the outlet was narrow and was soon blocked by a bar formed of shore drift from the erosion of the Kensington cliff. West of Blue Island the channel was divided as before by Lanes Island, now considerably enlarged by the lowering of the surrounding waters.

From Dolton southeastward into Indiana the line of the Toleston beach is marked by an extensive deposit of sand and gravel. The position of the shore line, as indicated on the map, was probably coincident with the earlier-formed and stronger-developed of the complex series of ridges here formed. The beach sands and gravels are now largely covered by dune sand.

North Side—Englewood bar.

From the position of Rose Hill Cemetery, where the Rose Hill bar was deflected to the southwest, the shore currents continued southward, depositing their material in a great bar over most of that part of the city of Chicago which lies between North Branch of Chicago River and Lake Michigan (see Chicago Areal Geology sheet). The elevation which this deposit made is traversed by North Clark street, and about midway of its length is Graceland Cemetery.

As this bar extended southward and increased in height it finally became the shore line, and cut off whatever part of the bay lay to the west. This bar is readily traceable to a point about 1 mile south of Lincoln Park. It is said to have

[1] There are certain plants occurring along the shores of Lake Michigan which have long been regarded as seashore plants, and the occurrence of these, together with the existence of a *Mysis*, a species of marine crustacean in the lake, has been regarded by some as evidence that salt water has at some geologically recent time existed where Lake Michigan now is. (See The flora of Cook County, Illinois, and a part of Lake County, Indiana, by Wm. K. Higley and Charles S. Raddin: Bull. Chicago Acad. Sci., Vol. II, No. 1, 1891, p. 15.)

These plants are *Triglochin maritima* (arrow grass), *Salsola kali* (Russian thistle), *Cakile americana* (sea rocket), *Prunus maritima* (beach plum), *Lathyrus maritimus* (beach pea), and *Euphorbia polygonifolia* (seaside spurge).

This list of plants is kindly furnished by Dr. H. C. Cowles, of the University of Chicago. It should be stated, however, that Dr. Cowles gives little consideration to them as evidence of former marine conditions here, rather considering it as begging the question to regard plants with such a wide range along the interior lake shores as strictly seashore plants.

[2] Dr. R. W. Ells, of the Geological Survey of Canada, has recently brought forward evidence to show that the ocean extended westward throughout the upper Ottawa Basin in post-Glacial time, leaving marine deposits which are now 1000 feet above the sea level. Dr. Bell also records the presence of marine deposits north of Lake Superior, along Kenogami River, at an elevation of 450 feet above sea level. It is not unreasonable that a subsidence of the area about Chicago should have occured as a part of the more general subsidence of which these marine deposits to the north and northeast seem to be evidence. (Sands and clays of the Ottawa Basin, by Dr. R. W. Ells: Bull. Geol. Soc. Am., Vol. IX, 1898 pp. 211-222.)

been nearly or quite continuous through the city, but now as the result of city improvements, it is scarcely recognizable for a distance of 4 miles southward. From Groveland Park, at Cottage Grove avenue and Thirty-fourth street, it extends southwestward a distance of 7 miles, through the northwestern part of Washington Park, Englewood, and Auburn Park to South Englewood, where it unites with the Toleston shore line above described. The structure of this bar southwest from Groveland Park is that of a series of overlapping hooks, with their distal extremities turned into the bay at the west, extended southwestward one from another with the same general front, in the manner already described. A deposit of sand about 1 mile in width is spread over the bowlder clay west of this bar.

The advance of this bar constricted the channel of free flow toward the outlet; at the same time the lowering of the lake level diminished the outflow in that direction, so that the current was unable to keep a clear channel and the bar was finally completed across the bay to the farther shore at South Englewood. This is the most notable instance, within the area studied, of the cutting off of embayments in the simplification of shore lines. The southern part of the area west of this bar eventually drained out to the east through the depression now occupied by the Auburn Park lagoon, and the establishment of Chicago River probably drained the remainder.

It was probably while this bar was being built and the outflow to the west diminished that the present outlet of the lake to the northeast was being established. As the flow to the north increased, that by way of the Chicago Outlet diminished.

Stony Island during the Toleston stage.

At the Toleston stage of the lake Stony Island had begun to emerge as a reef or an island, and its position (fig. 12) gave it a controlling influence on the currents. Under its protection the currents that were shifted southward by the extension of the bar just described began to work upon the gentle till slope, and a terrace and sandy beach were developed from South Englewood through Burnside to the lee of Stony Island. These southeasterly currents were here met by westward currents south of Stony Island, and the drift was turned abruptly southwestward toward the site of Pullman. With the lowering of the lake level this new line became the shore and the original line through Fernwood was abandoned. The relations of the line through Fernwood to that through Burnside are somewhat obscure.

The large island formed at the Calumet stage by the emergence of the area between Blue Island and Mount Forest Island was still larger during the Toleston stage. This was the necessary result of the lowering of the lake level.

Evidences of life during the Toleston stage.

In striking contrast to the Glenwood and Calumet beaches the Toleston beach contains abundant traces of life closely related to the life of Lake Michigan, if not identical with it. As one of the best exposures of the structure of the Toleston beach, Mr. Leverett[1] has given, with the section observed in 1864 by Dr. Oliver Marcy at the border of the campus of Northwestern University at Evanston, the following section, observed by himself in 1887 after the lake had encroached 75 to 100 feet upon the land.

Section of beach at Evanston in 1887.

1. Yellowish-red, iron-stained sand......	3 to 5 ft.
2. Band of bog iron ore, granular.......	4 to 6 in.
3. Gravel with beds of sand included (the stratification is very irregular in thickness, and assorting very imperfect)............................	5 to 7 ft.
4. Coarse sand, not calcareous..........	6 to 12 in.
5. Calcareous loam......................	3 in.
6. Yellow clay, very calcareous, with leaves embedded...................	3 in.
7. Carbonaceous band, not calcareous...	2 in.
8. Yellow calcareous clay, similar to No. 6..............................	4 to 6 in.
9. Brown sand, with twigs and peaty material...........................	8 to 10 in.
10. Water-bearing sand and talus-covered slope..............................	8 ft.
Height of bluff.........	20 to 22 ft.

In explanation of these sections Mr. Leverett says:

The calcareous clays Nos. 6 and 8 of the last section and Nos. 6 and 7 of Dr. Marcy's section contain numerous gastero pod shells. Dr. Marcy has collected a large number of shells from this horizon, among which there are *Unios*, apparently of several species, but not specifically identified. Mr. C. T. Simpson has identified nine different genera of mollusks, all of existing species, found in No. 7 of Dr. Marcy's section. *Planorbis* and *Lymnæa* are very abundant. Prof. D. P. Penhallow has identified two wood specimens, one a new species of *Picea* (*Picea evanstoni*), the other a new oak (*Quercus marcyana*).

Molluscan shells have been found at many other places on this beach. The occurrence of the bones of a mastodon at the south side of Wicker Park near Milwaukee avenue, about $1\frac{1}{4}$ miles east of Humboldt Park, has been reported.[1] These bones, consisting of part of a jaw, teeth, and parts of a few other bones, now in the collection of the Chicago Academy of Science, are said to have been found beneath 13 feet of silt. Whether these specimens are to be correlated with the beach deposits at this place can not be definitely determined, though they were said to occur on the soil corresponding to No. 6 of Dr. Marcy's section given above, overlying the peat horizon.

POST-GLACIAL EPOCH.

Transition from Lake Chicago to Lake Michigan.

Recent changes.—With the diversion of the waters of the lake from the Chicago Outlet to the northeastern one, the history of Lake Chicago may be considered as passing into the history of Lake Michigan, so that the series of beaches and bars lying between the Toleston shore line of Lake Chicago and the present shore of Lake Michigan mark the closing stages of the history of Lake Chicago and the earliest stages of Lake Michigan. During this stage so much of the Chicago Plain as was still submerged was being built up by deposits of sand and gravel brought to the head of the lake by the southward drift of the littoral currents. In the northern part of the city, as far south as Lincoln Park, there is a close-set series of sand and gravel ridges 10 to 15 feet high, between the Toleston beach and present shore of the lake. These ridges are often capped with a little dune sand. Southward from Thirty-fifth street the deposits of this stage cover a considerable area. Northeast and east of Washington Park there is a series of from ten to twelve low ridges. These were built as subaqueous ridges by drift from the north. They have a generally parallel direction, sometimes branch, and vary in length from 1 to 6 miles, running out into the sandy plain. Their southern ends are usually turned slightly to the west, as in hook formations. The longest and most prominent of these ridges is that passing through the campus of the University of Chicago, where its structure was well seen before being destroyed by grading. It continues southward through the western part of Oakwood Cemetery, terminating a mile north of Burnside.

Extension of the Chicago Plain by shore drift.

The formation of the basin now occupied by Lake Calumet is probably due in part to the influence of Stony Island, which deflected the currents about its eastern end, whence they continued southward, depositing sand and gravel along their course and leaving the area of the shallow lake unfilled. Like ridges inclosed Hyde Lake, Wolf Lake, and Lake George, as well as the adjacent marshy areas.

Between these lakes and the Toleston beach to the south is a remarkable series of parellel ridges, so closely set that they can not all be separately represented on the map. Including those indicated on the Areal Geology sheet as belonging to the Toleston stage, there are, from Calumet River at Hammond north to the south end of Lake George, ninety of these ridges, ranging from 3 to 10 feet in height. They are separated, in many cases, by narrow marshy belts. The ridges running southward between these lakes break up into several narrow ridges, and curve to the east, to form a part of the whole series. These ridges are composed of sand with little gravel, and taken together have the form of a great depositional terrace. This extensive filling, together with a slight lowering of the water level, brought the lake shore to its present position. The drift of the sand to the head of the lake and its accumulation there is still in progress.

Rate of shore erosion.

From Evanston northward the waters of the lake are encroaching upon the land by eroding the bluff and extending the submerged terrace. Locally and very recently this advance of the waters upon the land has been retarded, and in many places stopped, by the building and maintenance of piers and breakwaters. The rate at which the land is being encroached upon by wave action is of considerable importance to persons who own property along the lake shore. In 1870, in his study of the lake beaches, Dr. Edmund Andrews estimated, from a series of observations compiled from various sources, that the average rate of erosion of the lake shore between Milwaukee and Evanston was 6.24 feet a year. This estimate seems, however, to have been too high. In 1874

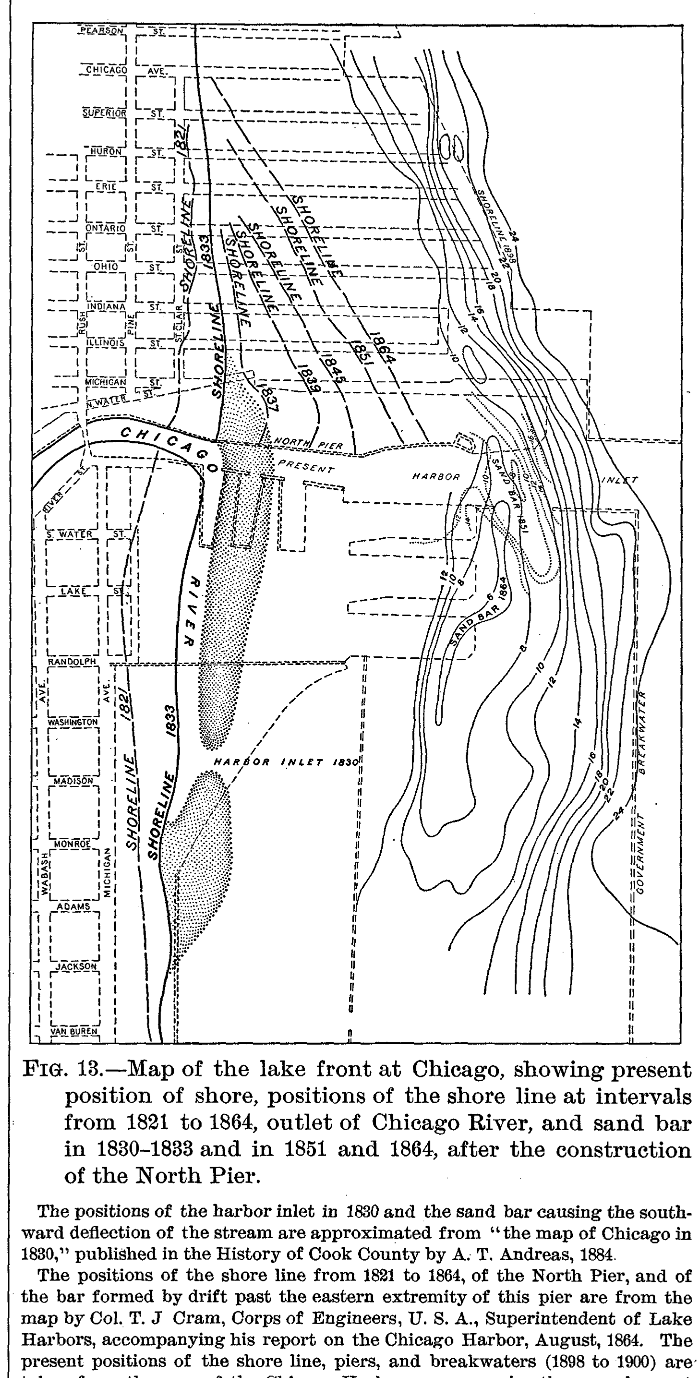

FIG. 13.—Map of the lake front at Chicago, showing present position of shore, positions of the shore line at intervals from 1821 to 1864, outlet of Chicago River, and sand bar in 1830–1833 and in 1851 and 1864, after the construction of the North Pier.

The positions of the harbor inlet in 1830 and the sand bar causing the southward deflection of the stream are approximated from "the map of Chicago in 1830," published in the History of Cook County by A. T. Andreas, 1884.

The positions of the shore line from 1821 to 1864, of the North Pier, and of the bar formed by drift past the eastern extremity of this pier are from the map by Col. T. J Cram, Corps of Engineers, U. S. A., Superintendent of Lake Harbors, accompanying his report on the Chicago Harbor, August, 1864. The present positions of the shore line, piers, and breakwaters (1898 to 1900) are taken from the map of the Chicago Harbor accompanying the annual report of Maj. W. L. Marshall, Corps of Engineers, U. S. A., for the fiscal year ending June, 30, 1898.

Mr. S. G. Smith of Racine, Wis., made careful measurements, for the Wisconsin Geological Survey,[1] to determine the amount and rate of erosion between the Government surveys of 1836 and his own of 1874. He made measurements along all the section lines cutting the lake shore in Racine County, and found that there had occurred in this time a total loss of 126.72 feet, or an average of 3.33 feet per annum. In Milwaukee County, between 1835 and 1874 there was a mean annual loss by erosion of 2.77 feet. It has been estimated by old settlers that from Waukegan to Evanston, during the thirty years from 1860 to 1890 a strip of land about 150 feet in width was undermined and carried into the lake. This amounts to 500 acres, representing at its present valuation nearly one million dollars' worth of property.

The method of erosion along such a lake bluff, shown in the sketch (fig. 8), is also shown in fig. 22. This view was taken in June, 1899, just south of Racine, Wis., at one of the points of most rapid erosion at the present time.

Littoral transportation and deposition.

The material eroded by the waves in cutting back these bluffs has been shifted southward. The fact of this southward transportation in the southern half of the lake may be seen from the accumulation of sand on the north side of every pier extending into the lake and in the spits wrapping about the ends of these piers below the water surface. As at earlier stages of the lake, so now, bars are constantly forming across the debouchures of the streams and must be repeatedly removed by dredging to keep the harbors open.

Chicago River bar.

Before improvements had begun in 1833 on the present Chicago harbor, there was a bar across the outlet of Chicago River which shifted the debouchure southward nearly one-half mile from its present position to a point opposite the foot of Madison street (fig. 13). The present harbor inlet was formed by cutting through this bar and by constructing piers at either side of the cut. The north pier has been extended from time to time as the sand accumulated on the north side. Successive positions of the shore line north of the pier are shown in fig. 13. This figure shows the bar formed by the sand drifted about the end of the pier in 1851, when the shore line had filled out nearly to the end of the pier. It also shows the dimensions to which this bar had grown in 1864, as determined by Col. T. J. Cram, U. S. Engineers, in his survey of that year.

History of Calumet River.

The course of Calumet River has been yet more curiously affected by the deposition of shore drift. At the Toleston stage of the lake, Calumet River discharged its waters into the Sag outlet opposite Blue Island (fig. 12) after having flowed 28 miles nearly parallel to the lake and scarcely 2 miles distant therefrom. When the lake level lowered and the westward discharge through the Sag outlet ceased, the waters of the Calumet occupied the channel between Blue Island and Riverdale and reached the lake at the latter place (fig. 14). As the lake waters continued to subside the stream lengthened; but, instead of flowing northeastward directly to the lake, the continued shifting of the outflow by the shore drift from the north carried the debouchure eastward to the most southerly point in the shore of Lake Michigan, its present position north of Millers station, Indiana (fig. 14), nearly 14 miles from the position of direct discharge by the shortest course. This debouchure is now practically closed by shore drift, wind-blown sand, and aquatic vegetation. A new channel has been opened by dredging from Hegewisch to South Chicago (see Calumet Topographic sheet), and that part of the stream southeast of Hegewisch has been reversed. It is

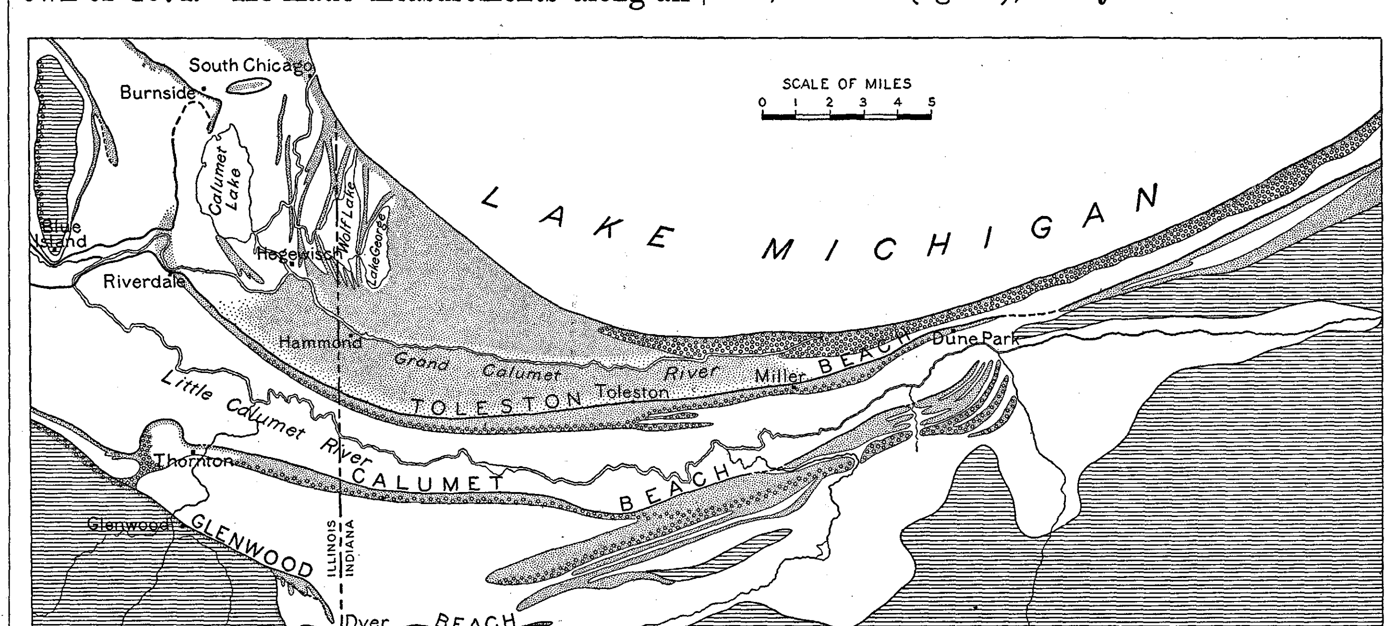

FIG. 14.—Map of the Calumet River and its surroundings.

Shows how the course of the stream was determined by the Toleston beach and by the later shore deposits; shaded area represents the morainal area not covered by Lake Chicago; dotted area represents the beach deposits; the small circles indicate dunes.

The portion of this map east of the Illinois-Indiana State line is from the Twenty-second Annual Report of the Department of Geology and Natural Resources of Indiana, 1897, Indianapolis, 1898.

[1] The Pleistocene Features and Deposits of the Chicago Area, p. 76.
The Illinois Glacial Lobe, pp. 450–451.

[1] Higley and Raddin, Bull. Chicago Acad. Sci., Vol. II, No. 1, 1891, p. 15.

[1] Geol. Wisconsin, Vol. II, 1877, pp. 231–232.

said that this channel at Hegewisch was originally opened by the Indians about ninety years ago; that they pushed their canoes in a line through the marshes until a channel was worn through which the water flowed freely.

Since the process of shore erosion, southward drift, and accumulation has evidently been going on ever since the final withdrawal of the glacial ice front from this region, it is evident that one would have a measure of post-Glacial time if the rate of shore erosion, the rate of littoral transportation southward, and the amount of filling already accomplished were known.

Estimate of post-Glacial time.

Some years ago Dr. Edmund Andrews undertook an investigation of this matter and published his results.[1] The paper is now out of print, but the computations have been partially reproduced and supplemented by Mr. Leverett in his bulletin on the Pleistocene Features and Deposits of the Chicago Area, and in his monograph on The Illinois Glacial Lobe (pp. 456–459). While there are many unknown and undeterminable factors in such a problem, the results were, as Dr. Andrews remarked, useful in showing that it is impossible to allow, even on the most liberal estimates, any such duration of post-Glacial time as 100,000 years, which, at that time, had often been claimed.

The formation of sand dunes by the blowing up of fine sand from the beach into ridges and hills has been noted as occurring in the various stages of Lake Chicago, but the most striking results have been accomplished since the lake shore reached approximately its present position. Small dunes illustrating the essential principles of dune formation may be seen at Windsor Park, near the foot of Seventy-ninth street in Chicago, and at various points on the South Chicago beach (fig. 23). At Dune Park and Millers, Ind., dunes are to be seen in all stages of development, from little drifts of sand in the lee of stumps or shrubs to great hills of shifting sand from 100 to 200 feet in height. An examination of these shows their mode of formation. As a brisk wind which is carrying sand passes an obstructing object, such as a tree, a shrub, or a tuft of grass, its current is interrupted and in the quieter area immediately in the lee of the obstruction some of the sand is dropped. A little pile of sand accumulating in such a position is the beginning of a dune (fig. 23). The growth of the sand pile increases the obstruction at that point, and against it and in its lee more sand accumulates. Thus the dune, under favorable conditions, may attain considerable dimensions (fig. 25). A number at Millers rise 150 feet above the lake. Mount Tom, in Porter County, Ind., is 190 feet in height, and between Michigan City, Ind, and St. Joseph, Mich., are dunes rising 200, 300, and 390 feet above the lake.

Mode of formation of dunes.

But destruction goes hand in hand with construction. The wind takes up sand not only from the beach but from the surface of the dune. It is blown from the windward slope up over the crest, only to be dropped on the lee slope. So the dune may be shifted inch by inch from windward to leeward. This movement constitutes the migration of dunes. In places dunes have moved inland considerable distances, burying vegetation (fig. 24) and devastating fields. Some of the dunes are now far from shore, but it is not always possible to say in what measure their position is due to their migration inland and in what measure to the recession of the shore from them as the result of shore filling. Dunes are likely to be migratory until vegetation gets a foothold upon them. When the surface is thus mantled the sand ceases to be blown and the dune ceases its travels; it becomes fixed. Thus the dunes along the west side of the Blue Island ridge and between Hammond and Thornton are fixed, being covered and held by vegetation, while a large part of the dunes about Millers and Dune Park are still shifting.

After a dune has become clothed with vegetation, sand may accumulate upon it, being lodged in the shrubs and trees. If the sand accumulates more rapidly than the trees grow upward they will be buried. This has happened at various places about the head of the lake. In its migration a dune may encroach upon a forest (fig. 24) and bury the trees. So long as the upper branches of the tree are uncovered by the sand the growth may be vigorous, but, once buried, the tree is usually killed. Since the highest part of the wandering dune is close to its advancing front, if the migration continues the buried forest will gradually become uncovered as the dune passes beyond. The exposing of the dead trunks to the carving and battering of the sand blast gives rise to some of the most desolate scenes of the dune area (figs. 26 and 27). Such uncovered forests are seen at various points near Millers and Dune Park, Ind.[1]

Stream erosion has not accomplished much on the Chicago Plain since the withdrawal of the lake waters from it. The stream courses are little more than trenches cut in the flat, the banks rising but 10 to 20 feet above the water in dry seasons.

Stream erosion.

Young valleys are being developed in the higher till areas. These are seen in the lake bluff north of Evanston, in the slopes of the Blue Island ridge and Mount Forest, in the sides of Desplaines Valley through the moraine, and in the inner and outer slopes of the moraine. One valley debouching into the Sag a mile west of Palos shows 60 feet of erosion 1 mile back from the Sag. This is near the maximum for the district under discussion.

The trifling amount of erosion which the plain has suffered as seen along Chicago, Desplaines, and Calumet rivers is largely due to the extreme youth of the region. This youth is also shown by the lakes and the extensive marsh areas. While it is true that much of the plain is too low for effective erosion, yet even here the streams have not developed the meandering courses of more mature drainage systems.

The only sensible change which has occurred in the drift since its deposition, so far as can be noted, is the leaching of the upper 1 or 2 feet and the oxidation of the upper 10 to 15 feet, changing the original blue-gray color to light buff. Vegetation has also contributed a light layer of humus. In the marsh areas thick deposits of peat are sometimes found overlying the drift. As a general thing the stony material of the drift is fresh and unaltered; but in some places, especially in the sand and gravel deposits, the ferruginous minerals of the more basic crystalline rocks have become so oxidized that, on exposure, the stones crumble to pieces.

Weathering of drift and formation of soil.

ECONOMIC GEOLOGY.

Limestone.—The supply of limestone within the area, so exposed or so thinly covered as to be easily reached, seems to be quite adequate to the demand; at least, not all the exposures are utilized for the production of the commodity. The exposures are so distributed as to be convenient to Chicago and its nearest suburbs, but the country districts lying in the morainal track are not so well supplied. The distribution of these exposures is indicated on the Economic Geology sheets. The exposures now being worked and those which have been worked are indicated by the quarry symbol.

Building stone.—The strata considered by Dr. Bannister as the lower division of the Niagara group afford one of the best building stones in the State. These are exposed on the floor of Desplaines Valley northeast of Lemont. The location, being formerly known as Athens, gave the name "Athens marble" to the rock, by which name it is known wherever used. The same beds are seen in the western end of the Sag, at its junction with Desplaines Valley. The rock at the Western Stone Co.'s quarries, Lemont, is a fine-grained, even-textured limestone, of an agreeable light-drab color when first taken from the quarry. On exposure to the air the color changes to a buff or yellow. The rock rubs well, though not capable of receiving a very fine polish. It is regularly bedded, the layers ranging from 6 inches to nearly 3 feet in thickness, thus affording fine cut and sawed dimension stone and flagging.

Quarries in Desplaines Valley.

The quarries of the Illinois Stone Company in the same vicinity show the same even-bedded limestone and produce dimension and rubble stone and flagging.

At Sag Bridge the quarries of the Phœnix Stone Company produce a fine grade of even-grained, solid limestone. The courses increase in thickness downward, becoming nearly 8 feet thick at the bottom, with little or no fracturing. The product is fine cut and sawed dimension stone, rubble, and five grades of crushed stone for macadam.

The quarry of the Calumet Stone Company $1\frac{1}{2}$ miles east of Sag Bridge shows stone of excellent quality. Also a small quarry on the north side of the Sag has turned out a small amount of a dense, fine-grained rock of very good quality.

These are the principal localities yielding good dimension stone, as here the strata have suffered little or no disturbance and hence show little fracturing. The facilities for transportation by railroad and by canal are excellent.

The quarry 1 mile west of Elmhurst, on the Chicago and Northwestern Railway, puts out building stone, including some dimension stone.

Rubble, macadam, and lime.—As most of the quarries furnish crushed stone for macadam and rubble for foundations, and some furnish lime, they will be noted in order, beginning with those in Chicago. The rock at all the quarries is well adapted for macadam, as it is a hard, gray dolomite, in places very siliceous, and the fractured condition of the strata makes it comparatively easy to remove. At the intersection of Chicago and Western avenues, about three-fourths of a mile southeast of Humboldt Park, the quarries of the Artesian Stone and Lime Works Company produce crushed stone for macadam and lime.

Quarries in Chicago.

The quarries of the Chicago Union Lime Works Company at the intersection of Nineteenth and Lincoln streets, about a mile east of Douglas Park, have been excavated to a depth of 175 feet. The limestone is a dolomite containing about 54 per cent carbonate of lime and 44 per cent carbonate of magnesium.

The quarries of the Stearns Lime and Stone Company at Bridgeport, near Twenty-seventh and Halsted streets, produce lime and crushed stone for macadam.

The quarries of Dolese and Shepard, at Hawthorne, on the Chicago, Burlington and Quincy Railway, produce building and dimension stone, crushed stone for macadam and concrete, and limestone for flux.

At Thornton, on the Chicago and Western Indiana Railroad, the quarries of the Brownell Improvement Company produce crushed stone for macadam containing about 36 per cent of silica, giving it a very durable quality. Their quarries at Gary, Ill., on Desplaines River, produce a dense, even-grained limestone in little-fractured strata. Some foundation stone is gotten out, but the rock is rather hard to dress. The product is largely crushed stone for paving.

Quarries south of Chicago.

At the outcrop 1 mile southwest of Blue Island considerable rock has been removed for foundation stone. It is stated that a bed of bluish, impure limestone has been worked here for hydraulic cement. Mr. J. V. Q. Blaney[1] reports the following analysis of this limestone:

Analysis of limestone 1 mile southeast of Blue Island.

Clay and insoluble matter	43.56
Carbonate of lime	31.60
Carbonate of magnesium	22.24
Peroxide of iron	1.20
Soluble silica	.16
Alkalies, loss, etc	1.30
Total	100.06

At his place about 2 miles southwest of Blue Island, Mr. Henry Schwartz has quarried a limited amount of good foundation stone. There is abundant rock here, easily accessible.

The quarry 1 mile west of Elmhurst, on the Chicago and Northwestern Railway, produces crushed stone.

Quarries west of Chicago.

The quarry of Kogle & Smith, about 3 miles southeast of Elmhurst, yields crushed stone. Some building stone is also taken out.

At the outcrop 1 mile northwest of Lagrange, on the bank of Salt Creek, a quarry has been opened which is turning out crushed stone for macadam.

Mr. Fred Schultz puts out crushed stone and lime from his quarry at Lyons.

At McCook, on the Santa Fe Railway near the canals, are the quarries of the Chicago Crushed Stone Company. Rubble for foundations is also produced.

Not all of the rock exposures have been utilized for economic purposes. The following may be noted as affording productive sites should the demand require: One mile northwest of Humboldt Park; corner of North Central Park avenue and Humboldt avenue; two blocks west of Humboldt Park; in the vicinity of Robey and Twenty-third streets; on the lake shore in Windsor Park at the foot of Cheltenham place; on either side of Railroad avenue between Ninety-fourth and Ninety-fifth streets and six blocks west between Ninety-fifth and Ninety-sixth streets.

Exposures not utilized.

At "Stony Island" two quarries have produced considerable rock, but are now unused. There is abundant rock thinly covered north and west of Thornton. Two miles south of Glenwood and three-fourths of a mile east of the Chicago and Western Indiana Railroad the rock is rather thinly covered in the hill slope. Three and one-half miles south of Elmhurst rock can be obtained in the west bank of Salt Creek. Abundant rock is thinly covered south and east of Lyons; also down Desplaines Valley from McCook, along the north side of the river. At Sag Bridge and at Lemont abundant rock is easily quarried. The southwestern part of the area is most poorly supplied, though the proximity of Joliet may counterbalance this deficiency. Only two exposures were noted in this part of the area, one 5 miles east of Orland along the banks of a small creek, the other along the bed of Hickory Creek near New Lenox.

Where the bituminous limestone has been used for building purposes the staining gives a peculiarly venerable appearance to the structure. There is, however, the disadvantage that the melting and running out of the bitumen may give a disagreeable streaking to the walls.

The abundant drift bowlders of limestone, sandstone, igneous, and metamorphic rocks, have furnished material for many picturesque and beautiful buildings within the district, and could supply a further demand. These are also of value in the construction of piers and breakwaters. Their distribution is shown on the Economic Geology sheets.

Drift bowlders as building material.

Sand and gravel.—The wide distribution of sand and gravel over the Chicago Plain has afforded abundant material for building sand, roofing and road gravels, and for filling. The distribution of these deposits is shown on the Economic Geology sheets. The extensive deposits of dune sand along the present lake shore, along the west side of the Blue Island ridge, southwest and south of Hammond, Ind., and east of Thornton, furnish abundant fine, clean sand. The deposits of glacial gravel furnish the coarser gravels with some sand and fine gravel. Several large pits have been opened about a mile north of Willow Springs, in the north slope of Desplaines Valley. The deposits here are assorted into several grades of gravel for building, paving, and ballast purposes. The output at these pits is 20 to 25 carloads per day. Numerous pits have been opened at various points along Desplaines Valley, showing material grading from sand and gravel to very stony till composed almost extirely of well-worn limestone pebbles and bowlders. In places this limestone is partially cemented into a conglomerate, so as to come out in large masses. One-half mile southwest of Worth, Messrs. Henke & Read have opened a large gravel pit. The gravels here are assorted into grades of two sizes. Ten to twelve thousand cubic yards have been taken out per annum. At Blue Island, just north of the Chicago, Rock Island and Pacific Railway station, there is an extensive deposit of the coarser beach gravel. The entire south end of the ridge seems to be composed of these gravels.

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[1] The North American lakes considered as chronometers of post-Glacial time, by Edmund Andrews, M. D.: Trans. Chicago Acad. Sci., Vol. II, 1870, pp. 1–23.

[1] For an excellent discussion of the vegetation of the dunes see The ecological relations of the vegetation of the sand dunes of Lake Michigan, by Henry Chandler Cowles: Botanical Gazette, Vol. XXVII, Chicago, 1899.

[1] Geol. Survey Illinois, Vol. III, p. 574.

Molding sand.—About $1\frac{1}{2}$ miles north of Lagrange is a pit from which molding and plastering sand has been taken. The molding sand is a dark-brown, partially compacted, coarse, clayey mass, without effervescence. The deposit is probably local and limited.

In a small ravine cut in the south side of the Sag outlet about $2\frac{1}{2}$ miles northwest of Palos is a very interesting deposit. The hill slope, which is composed of bowlder clay, is covered with a fine, light sand showing delicate cross bedding, as if from wind action. Over this on the slope lies a very fine-grained, highly calcareous, buff clay, which resembles closely the deposit which is found spread very extensively over the glacial drift in parts of Illinois, Iowa, and Wisconsin, and which is known as loess. This buff clay is also evidently a wind-blown deposit. The ravine has cut directly through the deposit and exposed on either side a clean section 25 to 30 feet in height. It is not known how far along the valley slope this deposit extends, but it appears to be considerable in amount. It would seem well adapted to the purpose of molding sand. This is the only deposit of the kind known within the area

Brick clay.—There seem to be little or no lacustrine clays within the area, notwithstanding the evidence that the Chicago Plain was for a long period submerged beneath the lake waters. This is one of the remarkable features of the area. All the finer lacustrine sediments seem to have been swept into the outlet, and it is only in deposits in the drift that such stratified silts have been found. They have been exposed in the canal section at Summit. The bowlder clay is thus the only clay available for the manufacture of brick, which is here a very extensive industry. Mr. D. V. Purington, of the Purington–Kimball Brick Company, writing of the company's pits at Purington station, on the Chicago, Rock Island and Pacific Railway, $1\frac{1}{2}$ miles north of Blue Island, which clays may be regarded as having the average composition of the Chicago clays, says:[1]

> The first 33 feet is a coarse-grained clay with a small percentage of limestone [in pieces ranging] from the size of a marble to that of a man's head. All through our clay pits we find deposits of a sort of clayey mud, which, when dry, can be easily pulverized to dust as fine as flour. This is a curious substance and when burned by itself makes a kind of bristol or bath brick, but when thoroughly mixed with the clay, using 75 per cent of clay and 25 per cent of the sand, it improves the quality of the brick.

He estimates the stony material as one-half of 1 per cent of the upper 33 feet. Below this was found a layer of which almost 60 per cent was limestone pebbles varying in size from that of a sparrows egg to that of a goose egg. Below this layer of stones are 5 to 7 feet of hardpan. Of the latter he says:

> This is a sort of chocolate color, is stratified, and very easily fusible. A small quantity of it in a kiln of brick would melt and become a solid mass, but it can be ground up and burned carefully and makes a fairly good brick. If all the limestone found in our clay were used, the brick would be absolutely worthless on account of the lime; but we are able to take out so many of the stones that we reduce the quantity sufficiently to make a fairly serviceable building brick. All our brick should be thoroughly wet down before using. No pottery, tile, fire, or finer-grained clays are ever found in or around Chicago.

There are about sixty brickyards within the area, with a capacity far exceeding the demand for several years past.

The Gottschalk tile factory at Homewood has manufactured common drain tile from the bowlder clays.

Peat and muck.—The rather extensive marshy areas whose distribution is indicated on the maps have considerable deposits of black peaty loam and muck. At some places, as in Desplaines Valley near Willow Springs and in the Sag, beds of peat have been exposed. These deposits afford good lawn and field dressing.

Soils.—The soils of the area are, in general, very productive. Over most of the moraine belt a loamy deposit several inches thick has developed and the leached upper part of the drift is easily tilled. The peaty loam in the low areas, and especially that spread over a large part of the Chicago Plain, gives a very fertile soil. This has made possible very extensive and profitable farm gardening in close proximity to the city market.

Bitumens.—The occurrence of a bituminous asphalt in the limestone at several of the exposures has already been noted. It is nowhere found in sufficient quantity to be of commercial value. This is also true of the petroleum which saturates the limestone in some places. It is stated that, in boring the first artesian well at Chicago and Western avenues, oil was struck. The supply, however, was soon exhausted and was never of commercial importance.

[1] Personal communication.

Chicago.

Minerals.—No metals or ores of any importance are found within the area. The only minerals found are crystals and incrustations of iron pyrites in cavities in the limestone, some of which are beautifully iridescent, and small crystals of quartz and calcite.

Rainfall.[1]—Illinois is one of the most favored of the west-central States in the matter of rainfall. A deficiency of rainfall has never been so serious as to cause a complete failure of any crop over a great part of the State, such as the less humid States of the West and Northwest have experienced. Its greatest danger lies in a deficiency between June and September, there being many years when the corn and other crops which ripen in autumn are shortened by drought at that season. Often heavy rains and low temperature from April to June keep the ground cold and damp; then a reversal of conditions suddenly occurs and the ground becomes baked by the hot, dry atmosphere and blazing sun.

The average rainfall for Illinois is distributed as follows: spring, 10.2 inches; summer, 11.2 inches; autumn, 9 inches; winter, 7.7 inches; giving an annual precipitation of 38.1 inches. The range in the rainfall at Chicago for the years 1867 to 1895, inclusive, was 23.4 inches, the lowest annual rainfall being 22.4 inches in 1867 and the highest 45.8 inches in 1883. In general in Illinois an annual precipitation of less than 25 inches results unfavorably to crops, but this depends very largely upon its seasonal distribution. Often a year with 30 inches or more of rainfall at a given station has a more prolonged and serious drought in the growing season than one with but 24 inches. The distribution by percentage from November, 1870, to December, 1891, at Chicago, was as follows: January, 6.2; February, 6.5; March, 7; April, 8.8; May, 10.2; June, 10.2; July, 10.4; August, 10; September, 7.9; October, 9; November, 7.6; December, 6.2.

The run-off from this area has been treated in connection with the description of the drainage.

Water power.—Desplaines River at Lyons and Salt Creek at Fullersburg have been utilized for water power, and Calumet River at Blue Island was formerly dammed to flush the Stony Creek canal feeder.

Surface waters.—The streams in the rural districts are of great value in the watering of stock, but, excepting the waters of Lake Michigan, no use is made of the surface waters for drinking and culinary purposes. The city of Chicago draws its water supply entirely from Lake Michigan, by means of several tunnels projected through the clays at the bottom of the lake, to distances of 2 to 4 miles from the shore. The positions of the waterworks cribs are shown on the topographic sheets. The water is somewhat hard by reason of the presence of lime in solution.

Drift and shallow rock wells.—In the rural districts shallow wells in the glacial drift form the main source of water supply. These range in depth from 5 to 150 feet. The varying character of the drift, with its frequent pockets of sand and gravel, makes it a source generally adequate to the demand of the farms, but in very dry seasons this supply is seriously affected. The water from these wells is often strongly charged with iron, sulphur, and various other salts contained in the drift. Where the wells are of such depth as to penetrate the underlying rock, a good supply of water for ordinary use is procured.

Deep rock wells.—Most of the villages outside of the city of Chicago, and many manufacturing and other plants within the city, draw their water supply from the deeper-lying rock formations. Most of these rock formations outcrop over wide areas to the north and west in Illinois and Wisconsin, and thus have extensive collecting surfaces from which the waters are transmitted southward and eastward, through the declining porous rock strata, until they pass beneath the area here described. The altitude of these collecting areas is such that before the draft on these formations became so great, owing to the increasing number of deep wells, strong surface flows were obtained. The first artesian well in this area was sunk in 1864[1] at the corner of Chicago and Western avenues. At a depth of 711 feet a strong flow of water was struck, which rose to a height of 80 feet above the surface, or 111 feet above Lake Michigan. A second well, only a few feet distant, sunk the following year, obtained a flow at a depth of 694 feet. Mr. W. T. B. Read, who drilled the wells, reports that the head has decreased to such an amount that the water now stands 15 or 20 feet below the surface, or nearly 100 feet below its original head. Since that time many deeper wells have been sunk within the area and some strong flows are reported, but the number of deep wells in the city is now so large, and the drain upon the rock strata so excessive, that the head is kept below the normal and an overflow is rarely obtained.

Artesian water head.

[1] The data relating to the water resources have been largely taken from Mr. Leverett's paper on The water resources of Illinois, in the Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. II, to which reference should be made for a fuller discussion of the subject. See also The Illinois Glacial Lobe, Chapters XII, XIII, XIV.

Nearly all the main geological formations underlying this area, except the Hudson River shales, have been drawn upon by deep wells for this water supply. In general the most productive is the Potsdam sandstone. This is a very thick formation and is usually sufficiently porous to readily transmit water. It has been estimated that, in its most porous parts in Wisconsin, it has the capacity to absorb water to an extent of 20 to 40 per cent of its volume. Such porosity, however, is not general, though a large part of the deposit probably has a capacity equal to several per cent of its volume. Among the wells within this area drawing water from the Potsdam formation are the following:

Wells in Potsdam sandstone.

Wells deriving water from the Potsdam sandstone.

Location.	Altitude of curb, in feet above tide.	Depth, in feet.	Head, in feet above tide.
Ames & Frost, Chicago	595+	2,700	......
Lehman well, Chicago	595	2,604	......
Consumers' Ice Company, Chicago	595	2,200	595
Oak Park waterworks	630	2,200	610
Riverside waterworks	617	2,200	597
Harvey waterworks	603	2,200	......

The water from this depth is, however, inclined to be highly charged with mineral salts. That from the wells of the Consumers' Ice Company is so strongly impregnated as to be disagreeable to the taste and unfit for use in boilers. That from the Lehman well is also brackish. The water from the Harvey waterworks well was so saline as to be unfit for use, and the well was plugged up at a depth of 1300 feet, thus shutting out the flow from the Potsdam formation.

The next formation in order of importance as a water-bearing stratum, and the leading formation in the order of development, is the St. Peter sandstone. This is also a very porous rock. It is well adapted to transmitting water, but is rather thin, its thickness being but 150 to 200 feet in this area. This formation supplies many wells, among them the following:

Wells in St. Peter sandstone.

Wells deriving water from the St. Peter sandstone.

Location.	Altitude of curb, in feet above tide.	Depth, in feet.	Head, in feet above tide.
Lincoln Park	595±	1,200	......
Humboldt Park	600	1,195	......
Garfield Park	602±	1,229	......
Douglas Park	598±	1,155	......
Stock Yards well No. 1	590	1,200	590
Auditorium Hotel	590±	1,250	......
Morgan Park waterworks	640	1,046	595
Harvey waterworks	603	1,300	593
Hinsdale waterworks	691	864	......
Lemont waterworks (?)	596	1,366	656

[1] History of the Chicago Artesian Well, by George A. Shufeldt, Jr., Chicago, 1865. Issued by the Religio-Philosophical Publishing Association of Chicago, 1897.

The following analyses of the waters of the wells in the West Chicago parks were made for the West Chicago park commissioners by Dr. J. E. Siebel with a view to ascertaining their medicinal properties.

Analyses of medicinal well waters.

Contents of one wine gallon of the water of the artesian well in Garfield Park.

	Grains.
Chloride of magnesium	8.352
Chloride of sodium	87.491
Bromide of magnesium	0.301
Sulphate of lime	21.114
Carbonate of lime	14.802
Carbonate of iron	0.712
Sulphate of soda	13.645
Silicate of soda	0.508
Alumina	traces
Organic substances and sulphuretted hydrogen	none
Total	146.925

Free carbonic acid, 13.44 cubic inches.
Temperature at the well, 71.4° Fahrenheit.

Speaking of this water, Dr. Siebel says:

> This water not only contains the largest amount of solid substances of any of the mineral waters in this neighborhood, but it also contains them so arranged and in such quantities that it can not fail to prove of great benefit in a variety of cases. While its principal character is that of a saline water, it still contains a sufficient amount of iron to allow of its being classified as a chalybeate water.

Contents of one wine gallon of the water of the well in Douglas Park.

	Grains.
Chloride of magnesium	8.236
Chloride of sodium	2.320
Sulphate of soda	28.321
Sulphate of lime	6.422
Carbonate of lime	11.149
Carbonate of iron	0 103
Silicate of soda	0.731
Alumina	traces
Sulphuretted hydrogen	faint tr.
Organic substances	none
Total	57.282

Free carbonic acid, 10.22 cubic inches.
Temperature at the well, 57.1° Fahrenheit.

Contents of one wine gallon of the water of the well at Humboldt Park.

	Grains.
Chloride of magnesium	7.702
Sulphate of soda	23.211
Sulphate of magnesia	4.132
Sulphate of lime	10.229
Carbonate of lime	12.131
Carbonate of iron	0.065
Silicate of soda	0.763
Alumina	traces
Sulphuretted hydrogen	faint tr.
Organic substances	none
Total	58.233

Free carbonic acid, 11.13 cubic inches.
Temperature at the well, 63.5° Fahrenheit.

The upper part of the Trenton limestone, known as the Galena limestone, is an important water-bearing horizon. In its lower portion the Galena limestone becomes a porous, somewhat granular formation, and often has a considerable capacity for transmitting water. The Chicago Artesian wells, at Chicago and Western avenues, draw water from this formation.

Wells in Trenton, Galena, and Lower Magnesian limestones.

Following these, in the order of their importance, is the complex series of limestones and sandstones grouped under the name of the Lower Magnesian limestone. The Oak Park well No. 1 probably draws water from this formation at a depth of 1568 feet. The altitude of the curb is 630 feet above tide, and the head is 610 feet above tide. Mr. Leverett gives the following analysis of water from this well:

Analysis of water from Oak Park well, No. 1.

[G. M. Davidson, analyst.]

	Grains.
Calcium carbonate	8.16
Calcium sulphate	trace
Ferrous carbonate and bicarbonate	trace
Magnesium carbonate	2.33
Silica	.40
Sodium bicarbonate	8.70
Sodium chloride and potassium	30.54
Sodium sulphate and potassium sulphate	6.79
Total grains per U. S. gallon	56.9

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