Photograph by Chicago Aeria ,Survey Company

"Eastward lies the lake, as great a contrast with the city as night with day."

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GEOLOGY OF THE CHICAGO REGION

PART I—GENERAL

BY

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PREFATORY NOTE

Part I of this bulletin is intended for the use of schools and the layman. Part II will be more technical in nature and will include the details needed by geologists, engineers, and others interested in the scientific and economic aspects of the geology and mineral resources of the Chicago region.

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GEOLOGY OF THE CHICAGO REGION

PART I—GENERAL

J Harlen Bretz

PHYSICAL SETTING OF GREATER CHICAGO

Shot upward by express elevator, we step out on the observation platform of the Tribune Tower. A clear sky and a wind off the lake gives maximum visibility. Half of our expansive horizon is the primitive lake, half is dominated by the works of man. North, west, and south, an irregular checkerboard of buildings and streets reaches out farther than we can see. The kings of the checkerboard, closely crowded in the Loop district and along the river, make a city in themselves, an Arabian Nights city unlike anything in the Universe a hundred years ago. The monotony of the lower buildings is like an unmown lawn of brown and gray, spread out around the clustered structures of the Loop (fig. 1). The haze which limits the view westward is man-made also, the dust and smoke of this great site of human activity. Were we blind and on this tower, we could hardly mistake our location. The world had no sounds like these a hundred years ago and our eyrie had only the sounds of wind and waves.

Nor are man's constructions all above the ground within our horizon. The feet of this steel-boned structure are planted on bedrock, a fifth as far below street level as its capstone is above. Its fellows stand likewise, their great weight carried on concrete legs to bedrock. Basements, sub-basements, tunnels, innumerable conduits, all are vital parts of the great city. Even if the entire structural aggregate above ground were swept away, the underground structures remaining would record its former greatness.

Eastward lies the lake, as great a contrast with the city as night with day. A smudge or so on the horizon, moving boats inside the curved dome that brings sky and water together, the intake cribs a few miles out—aside from these, this half of our horizon is as primeval as the day white men first entered the region. Man has done his bit to the lake, of course, but it is trifling. The shores have been changed a little and a subsidiary outlet has been made, in part by reversing the sluggish river. The lake remains, however, the one unalterable primitive feature of Chicagoland.

In but one long lifetime, the second greatest metropolis of the western hemisphere has grown up in the immense central lowland of the continent. Some of the physical reasons for its location and growth are well known. It could not have developed away from the lake; it needed the advantage of head-of-lake navigation and a harbor; it had to have a productive hinterland; it required a suitable topography for its spread and favorable conditions for the growth of a great railroad center. Some factors were important in determining location and early growth; others became more significant as the growth progressed. All of them, in their turn, are only results of earlier causes.

The unmatched history of Chicago's metropolitan development is therefore a consequence of earlier history, even prehuman history. We wish to look into that pre-history. We shall read the story of the Great Lakes, of the prairie soil and subsoil, of the hills and plains of the region, of the bedrock which crops out here and there or is revealed in quarries, reached by caissons, and penetrated by wells. To do this, we must interpret a record unlike any written language. There is only one authentic source—the geological features of Chicagoland. These we must observe, map and interpret as the results of former conditions and changes. The geology of this region is not a distinct separate unit in itself; it is

Photograph by Chicago Aerial Survey Company

FIG. 1.—"Like an unmown lawn of brown and gray spread out around the clustered structures of the Loop."

FIG. 2.—North America as it would appear if depressed 600 feet. The lightly shaded areas would then be shallow sea. (Reprinted by permission from "Historical Geology," by Schuchert and Dunbar, published by John Wiley and Sons, Inc.)

intimately a part of the geology of the Great Lakes country and of the upper Mississippi Valley country.

Chicagoland is near the geographical center of North America, in the midst of a great plain that stretches from the Arctic Ocean to the Gulf of Mexico. Highlands border the plain on the east (Appalachian Mountains and plateaus) and on the west (Rocky Mountains). A large embayment of Arctic water (Hudson Bay) reaches southward on the plain, shallowly submerging an area nearly ten times as large as the state of Illinois. Were Hudson Bay added to the north side of the Gulf of Mexico, it would reach northward from New Orleans to Chicago, which would be only 600 feet above it, the great Loop towers rising as high again. Or in other words, if the great central plain of the United States sank 600 feet (or if sea-level rose that amount), another shallow Hudson Bay would be formed on it (fig. 2). Average oceanic depth is between 12,000 and 13,000 feet, about 2½ miles. Hudson Bay's greatest depth is 600 feet and its average is 420 feet, one-thirtieth of the average ocean depth. The new Hudson Bay we imagined would be very similar. The ordinary map tells us nothing of a very significant thing—the depth of the water.

This picture of great thin sheets of marine water (epicontinental seas) spreading far into the interior of a continent is drawn for a purpose. Relatively slight changes of level in land or sea are competent to make great changes in the areas of both. Knowing in a general way that the earth has passed through many vicissitudes, we may ask here if this vast low interior, of which Chicagoland is a part, ever has experienced such a widespread flooding by the sea. The answer, given in advance of the evidence, is affirmative. It is not enough to say that Chicago might have been a seaport, had it been built some millions of years ago—it would have been a submarine city. The waves of shallow seas rolled completely across the region and the top of a modern skyscraper, had one stood here at that time, would not have reached the water surface. "There where the long street roars hath been the stillness of the central sea."

The record of those epicontinental seas is in the bedrock. The whole interior of the country carries this record—layers piled on layers of sediments now consolidated to thicknesses of thousands of feet. In our region, these old stratified sea deposits are almost entirely concealed beneath surface materials, and our information about them comes from deep well borings. A maximum of 2500 feet has been penetrated in the deepest boring in the region. At many places in Illinois and neighboring states, these stratified rocks crop out. At Starved Rock Park and Deer Park near LaSalle, Illinois, at White Pine State Park and along Rock River near Oregon, Illinois, at Turkey Run State Park near Marshall, Indiana, along the upper Wabash Valley in Indiana, in the Dells of Wisconsin River, and all along the upper Mississippi Valley, there are good showings of these old deposits. Most of the mineral industries within 200 miles of Chicago are based on them, with mines and quarries exhibiting the stratified character of these former sands, muds, lime, and peat, now changed to sandstone, shale, limestone, and coal.

Thus the broad plain country in which Chicagoland lies is a great interior basin, now undergoing erosion but having been for ages beneath shallow seas, some of which reached completely across the continent.

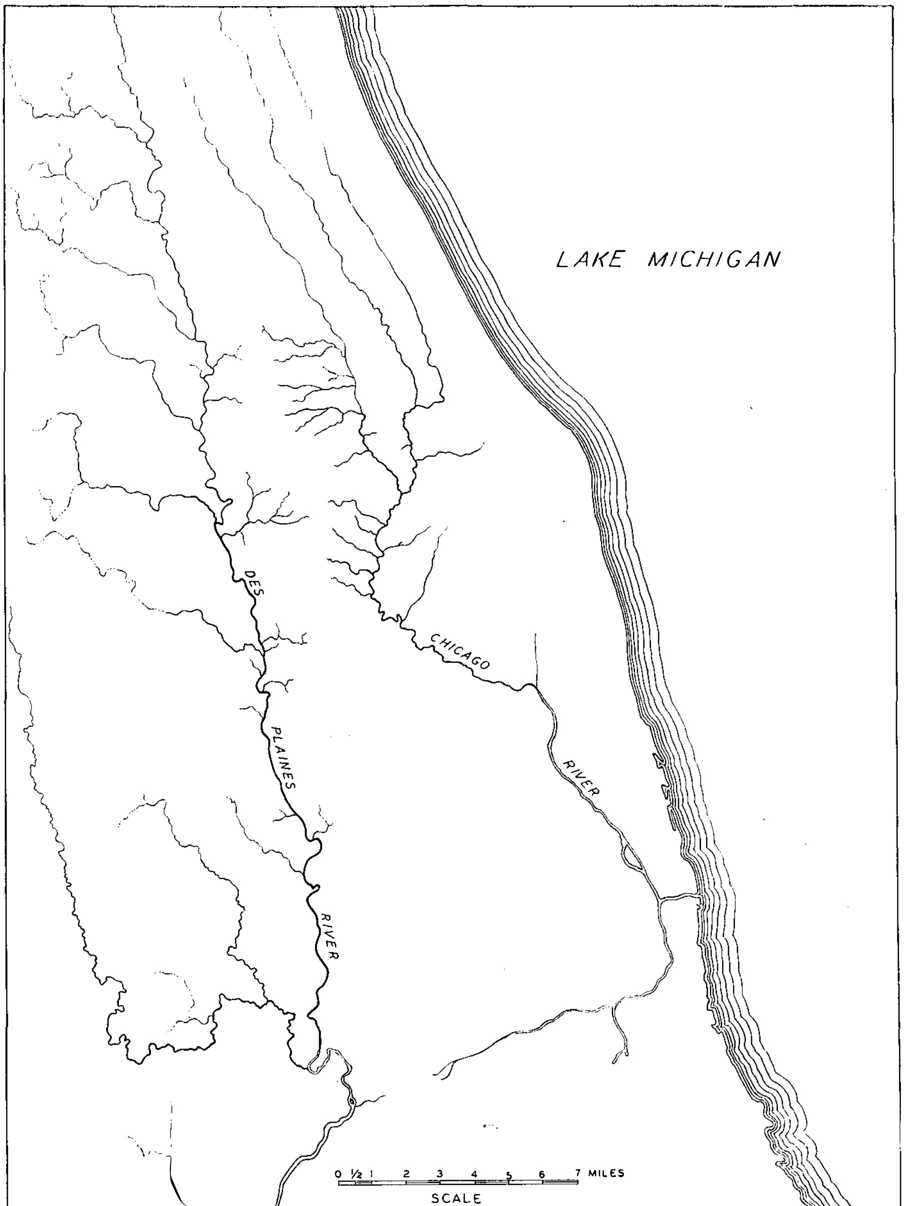


FIG. 3.—Chicago region drainage lines. Note the parallelism of many streams to the lake and the large areas that are undrained. Compare with Figure 4.

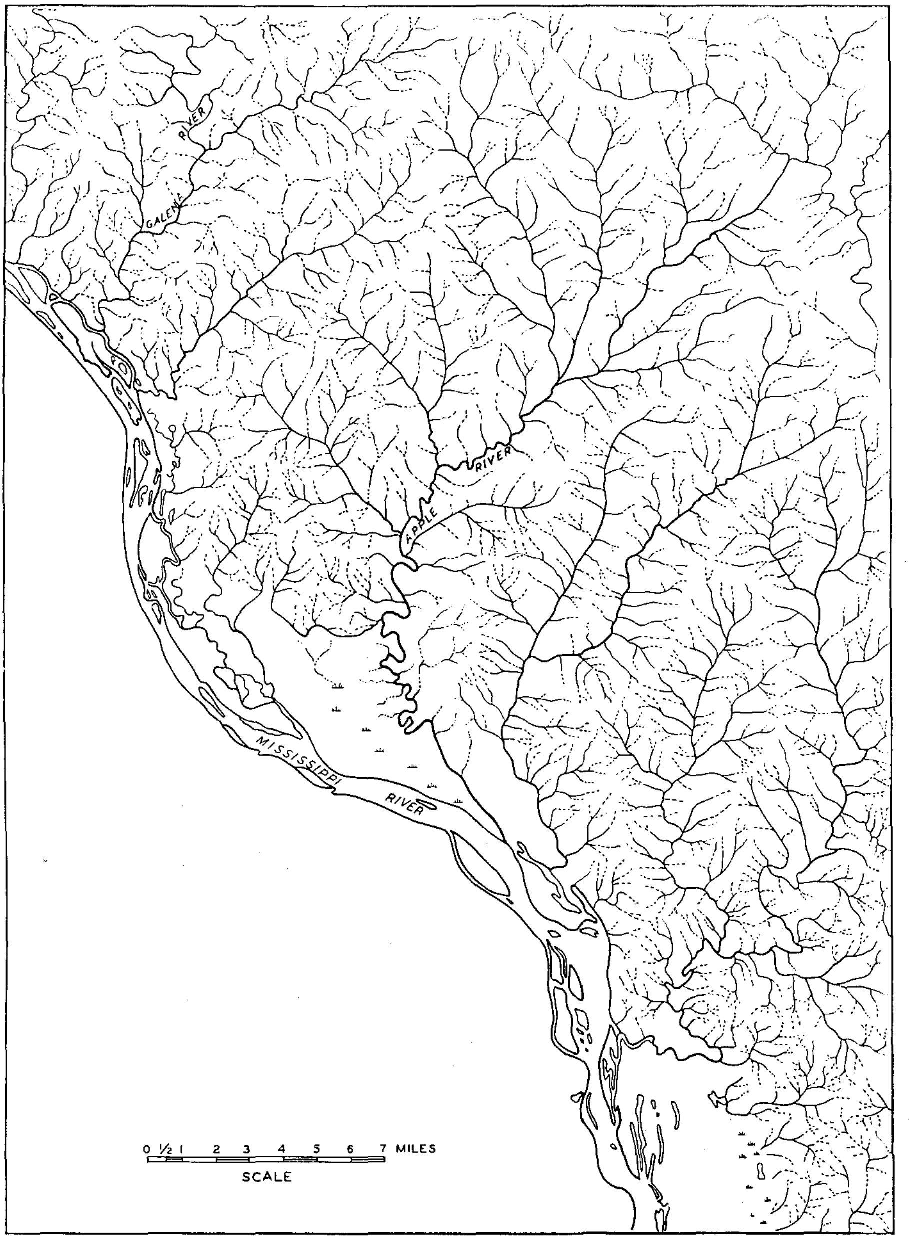


FIG. 4.—Normal drainage pattern in Jo Daviess County, northwestern Illinois. The streams are uniformly distributed, the smaller streams converge toward larger streams, and there are neither lakes nor large undrained areas.

Coal, though a stratified deposit, is not of marine origin, and we alter our picture a bit when considering it. Vast lowland swamps, lying close to sea-level, are visualized. Limestone beds between the coal seams record encroachment of marine waters which destroyed the swamps repeatedly and were as often withdrawn and replaced by swamps again during this time.

Today we are a thousand miles from the nearest sea and 600 to 800 feet above sea-level. No notable deposition of any kind is occurring in the vast plain, and no marine deposition at all. Instead, the former deposits are being destroyed, and the debris is being carried away by streams to make new stratified deposits, either in Lake Michigan or in the Gulf of Mexico. The surface of the plain is being etched out in tree-like patterns of main river valleys and their branching tributaries. It is this etching of valleys by stream work that has exposed the bedrock, the old marine deposits, in the state parks and river valleys just listed. As valleys are deepened by the eroding streams, the hills between them become relatively higher, more tributary valleys develop, and the land surface becomes rougher. In the Chicago region this work has only begun and there is much more for the streams to do than they have yet accomplished. The whole sequence of erosional changes is very, very slow. One's lifetime is far too short a measure. The lifetime of a nation is too short. The history of the human race on this planet is short, compared with these changes. Through the whole story of geological change outlined, time beyond our experience, almost beyond our comprehension, is an essential factor.

The Chicago region is not richly endowed with streamways. Many square miles have no drainage courses at all. But stream water which does flow off the Chicago area goes in two nearly opposite directions to two great drainage systems of the continent. We are in a headwaters region where every stream can be traced to a source in or very near the metropolitan area. All streams entering the lake belong to the St. Lawrence River system. Their waters reach the Atlantic Ocean north of the United States. Streams flowing to the Mississippi River, like the DesPlaines, the DuPage and, a little farther away, the Fox and the Kankakee rivers, drain to the gulf of Mexico south of the United States. The divide between these two systems is a major water-parting, though it is inconspicuous and hardly seems to deserve the name of continental divide. It lies subparallel to the shore of the lake, not more than five miles distant in the latitude of Fort Sheridan and Lake Forest but at a distance increasing to 20 miles south of Hammond, Indiana.

Before man began to tamper with nature's drainage ways here, almost all the St. Lawrence drainage, from Lake Forest to Hammond, was brought together into two streams before entering the lake—Chicago River with four named headwater portions, and Calumet River with half a dozen named headwaters. These streams are curiously parallel to the lake shore (fig. 3). In the southern part of the area, several streams flow directly toward the lake but are intercepted by Calumet River, and their waters are carried parallel to the shore for many miles before entering the lake. Of the streams flowing to the Mississippi and the Gulf, the upper part of the DesPlaines possesses the same parallelism with the shore line, although when it turns it flows away from the lake instead of toward it. Salt Creek is similarly parallel. Some streams flowing toward the lake are intercepted by the DesPlaines, and their waters are carried off to the Mississippi. This parallel drainage pattern, as shown in figure 3, is quite unlike the pattern created by normal valley development (fig. 4). The larger streams of our region almost all found pre-existing lowlands in which to flow between pre-existing higher tracts. Though streams have done some work here and are still working, they have modified but little an inherited topography that was not of stream origin. The parallelism of valleys and divides with the lake shore, abnormal for a stream pattern, is perfectly natural when the mode of origin of these features is explained. The broad low inter-stream ridges were built up to stand higher than their surroundings, some by glacial ice and others by lake waves and shore currents. These agents habitually contruct ridges of their deposits and almost invariably leave other tokens of their presence. A wealth of evidence in support of this interpretation of Chicagoland's parallel streams and divides is submitted in later chapters.

SURVEYS OF THE REGION

The sparse aboriginal population, found here by the early explorers, held the region chiefly for hunting. Metes and bounds of land were of little significance to them. In the wake of the explorers finally came men who stayed, who built habitations, cultivated the soil, dug ditches, and built roads, harbors, canals, and railroads. Land measurement and accurate boundary locations became a prime requisite. Squatter's methods of demarking land units were inadequate and the Federal Government's rectangular grid pattern of townships and sections was laid out, a little more than a hundred years ago.

The public domain of the young nation was surveyed in various large parcels as demands arose at different times. Settlement of Illinois progressed northward from the Ohio and Wabash waterways. The first Federal land survey in the state was made long before the Blackhawk War had extinguished Indian claims west of the Illinois River. That area between the Illinois and Mississippi rivers was surveyed later and from a different base line and meridian.

The Third Principal Meridian of the Federal land survey lies in the center of Illinois, running the entire length of the state. Rockford, Bloomington, Centralia, and Cairo are almost on the line. The base line selected was a parallel of latitude lying a little south of Centralia and East St. Louis. The rectangular pattern of townships, each with 36 square miles, was numbered from the intersection of these lines. Thus in the Chicago region, which is north and east of this intersection, the townships are numbered from T. 35 N. (35th tier, east-west row of townships north of the base line) to T. 44 N., and from R. 11 E. (11th range, north-south row of townships east of the principal meridian) to R. 14 E. (fig. 5). That part of Indiana on the maps of this report has different range numbers since it was surveyed from the Second Principal Meridian, located in that state. Errors in the two surveys show in the failure of the two tiers of townships to coincide along the state line.

There are two surveyed lines in the Chicago region, however, that are older than any township and section lines. One extends from the lake shore near the Evanston-Chicago boundary southwestward across

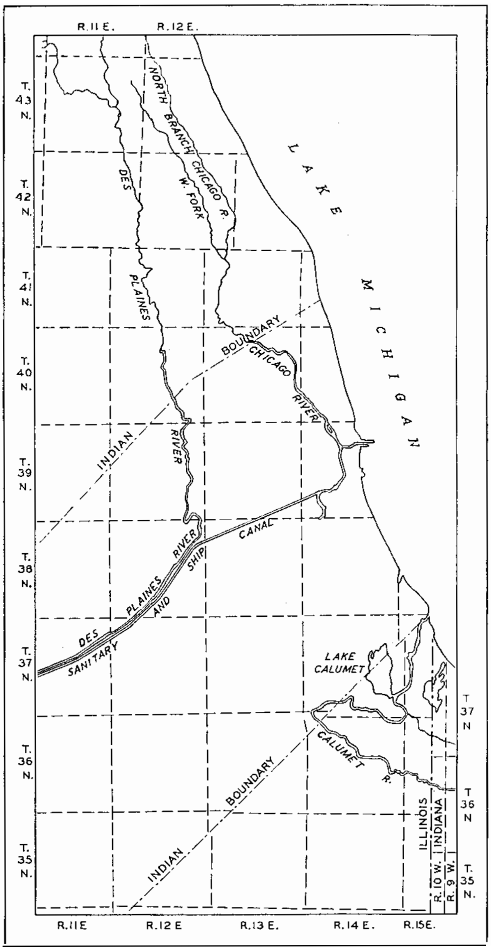


FIG. 5.—Township grid system of the Chicago area covered by this report.

and beyond the region. Rogers Avenue marks the east end of this line. The other line is nearly parallel with and twenty miles south of the first. It begins near the mouth of Calumet River and is marked by offsets in many roads crossing it. Both lines bear the name "Old Indian Boundary." They mark a strip of territory ceded in 1816 by the Sacs and Foxes when Fort Dearborn was re-established, four years after the historic massacre. This gave the United States possession of a strip of land extending as far west as Ottawa and including most of the present site of Chicago. It was intended for protection of the Chicago portage and the canal route already proposed to connect the St. Lawrence and Mississippi navigable waters. The township and section survey was made later and when this ceded tract was subdivided the section lines failed to meet on the two sides of the southern boundary. The consequent road offsets probably will always record that old survey line.

The next Federal survey of the Chicago area, begun in 1889 and completed a few years later, was made by the United States Geological Survey. In addition to the conventional data of land-lines, drainage, and culture, the maps showed the topography of the region by means of contours. Accurate triangulation and leveling, carried across from the Atlantic seaboard, gave the necessary control. Following the procedure of the United States Geological Survey, the boundaries used were longitude and latitude lines, none of them coinciding with state, county, township, or section lines. Six quadrangles were mapped, each 15 minutes of latitude in length and 15 minutes of longitude wide. The region covered by the maps extended from Lake Forest on the north to Chicago Heights on the south, a distance of 53 miles, and from a meridian 1½ miles east of the Illinois-Indiana line to the longitude of Lemont, about 26 miles to the west. The maps were printed on a scale of an inch to the mile and the contours on five of them were drawn at vertical intervals of 10 feet. The remaining map, which included the flattest and most densely built up region, had 5-foot contour intervals. In 1898 the U. S. Geological Survey completed the geological mapping of the four southern quadrangles, publishing it as the Chicago Folio.[1] Geology was shown by overprinting patterns and colors on the contour maps.

For nearly forty years this folio was the chief source book of geological information regarding the region. During this time, Chicago grew from one and a half million to three and a half million, and its suburban towns kept pace. The era of hard roads came, and more grading was done throughout the region than ever before. Swamps and lakes were drained, ditches and canals were dug, and the lake shore was altered. The cultural changes were so great that the old maps, long out of print, would have been useless if reprinted. The need for new maps which would show more accurately

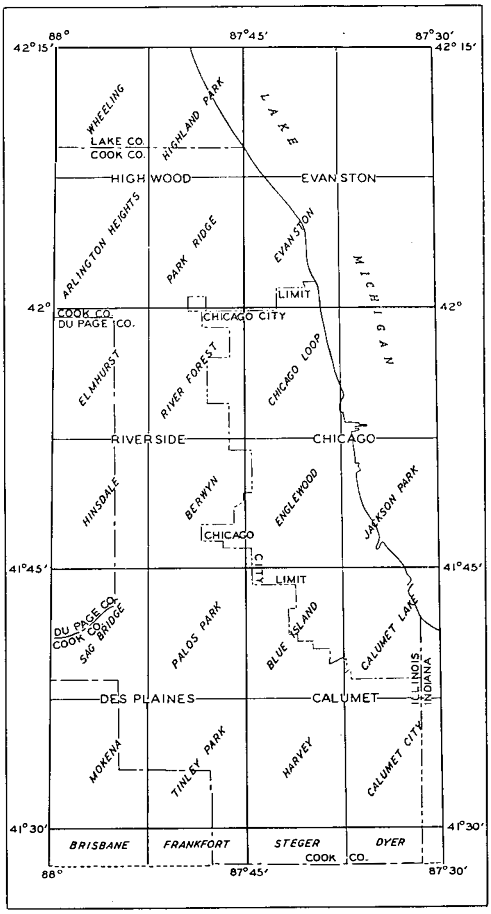


FIG. 6.—Index map to topographic maps of Chicago and vicinity.

the drainage, topography, and geology was a crying one.

The new survey was begun in 1925, the United States Geological Survey and the Illinois State Geological Survey cooperating. A 5-foot contour interval was adopted, and the larger scale of one inch to 2,000 feet. Map sheets of the same size therefore covered considerably smaller areas. Each of the six original quadrangles was subdivided into four but because the lake occupies large areas of two of the original maps, the total number of new quadrangles is twenty instead of twenty-four (fig. 6). The northern portions of four other quadrangles, lying immediately south of the group above described, were also surveyed in order that all of that part of Cook County should be included. Approximately 1,100 square miles of territory is included in these new maps.

[1]Alden, W. C., U. S. Geol. Survey Geol. Atlas, Chicago folio (No. 81), 1902.

Some data were supplied by the Chicago Department of Public Works and Sewer Department, by the Cook County Highway Department and Map Department, by the Sanitary District, and by the Chief Engineers of each railroad in the region. The Army Air Corps made vertical airplane photographs of the entire area. This new mapping was completed in 1927 and publication of maps followed as soon as possible, providing the metropolitan district with as fine a group of topographic maps as has ever been made.[2]

The Illinois State Geological Survey undertook in 1930 to re-map the geology of fifteen of the new quadrangles and to make the first geological maps of five new quadrangles to the north and the portions of four to the south. This consumed three consecutive summers of field work. The results are presented briefly in this volume. The work was placed in the charge of the present author who was ably assisted by George H. Otto and Edward H. Stevens.

[2]An interesting account of this survey is found in the Journal of the Western Society of Engineers, Vol. 33, No. 1, pp. 1–32, 1928.

TODAY'S GEOLOGICAL CHANGES IN THE CHICAGO REGION

No one has ever found an authentic inscription on a rock ledge recording its origin in such and such a year B. C. Nature's structures carry no cornerstone dates. Yet geologists constantly ask us to think in terms of a hundred thousand, five hundred thousand, a million years. These figures must be understood to be approximations, indicating only the order of magnitude of time in earth history, and not precisely measured intervals. But the geology of a region is no more a thing of the past than are its human activities. For both, there is a recorded past and a living present, and for both these are intimately related.

Weathering

Drive out of the city along some new highway. Somewhere in any few miles the highway grade has been cut into the brow of a hill. The cut need be only 4 or 5 feet deep to show what we are looking for, a color contrast between the upper and lower parts of the cut bank (fig. 7). The surface material is generally dark brownish to black. This is the true soil, the cultivated horizon, the sustainer of most food plants. Below the few inches of soil is a yellowish to rusty reddish zone 2 or 3 feet thick, conforming like the dark soil to the undulations of the surface. Below this, probably extending to the bottom of the cut, the material is lighter brown to brownish-gray in color with some irregular gray seams. If the cut is 10 feet or more in depth, the lowest part exposed is generally gray or bluish gray, especially when wet. The bluish-gray color of the basal part is the original color. The rusty colors of the upper part of the section are, precisely as the adjective implies, the product of actual *rusting* in the material. Incompletely oxidized compounds containing iron have yielded to the attack of water and air, most of the change occuring nearest the surface where exposure is greatest. The black top soil contains added carbon from plant debris.

Another important change in the upper few feet of the cut, unrevealed by color differences, is readily shown by a simple chemical test. A few drops of dilute hydrochloric acid poured on the lower part of the slope produces a vigorous foaming or effervescence. Calcium carbonate, the chief constituent of limestone, is breaking down and yielding carbon dioxide gas to make the foam. But in the upper two feet or so of the cut, where the rusty colors are strongest, there will be no response to the acid because calcium carbonate is lacking here. Closer inspection of a clean new cut may show irregular gray seams in the upper part of the light brownish zone just below the darkest part of the rusty zone. Foaming under acid on these seams will be more than vigorous, it will be violent.

Calcium carbonate is slowly soluble in rain-water and water that percolated down through decaying organic matter in the top soil. For centuries this slow process has been removing the "lime" and carrying it downward. At the zone of the gray seams the process has been reversed in part and

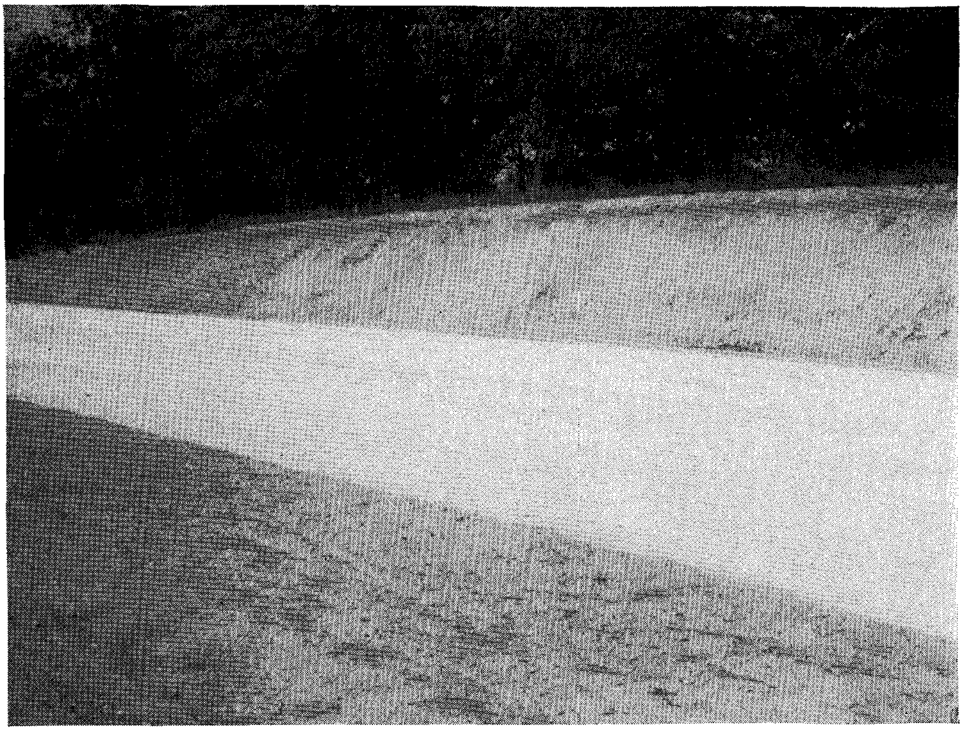


FIG. 7.—Road cut along Southwest Highway at Worth showing soil profile typical of the Chicago region. The uppermost zone of a few inches is ash-colored (forest soil) and has lost its lime and most of its iron. The underlying dark zone is reddish colored owing to a concentration of iron oxide. Below the rusty iron oxide zone is gray unweathered glacial till in about the same condition as at the time of its deposition.

some of the mineral has been redeposited. The rest of it has gone on with the downward percolating water and has been entirely removed by the escaping water.

Leaching and oxidation are the two most conspicuous changes wrought by water and air in rock near the surface. (The unindurated material in the highway cut *is* rock, even though it is unconsolidated.)

If there are boulders or cobbles in the upper part of the cut, they may show a crumbling exterior, a tendency to fracture more readily in the outer part, perhaps a fracturing and crumbling of their entire mass. Often this fragmentation is due to water entering into chemical combination with the rock material. This third process, or hydration, increases the volume of the rock minerals and the resulting expansion produces stresses that may finally cause disruption. Once cracks exist in the boulder, water may freeze in them or plant-roots grow in them, both aiding fragmentation.

Thus all surficial rock material is suffering destructive alteration by several chemical and mechanical means. The sum of all these changes is called weathering and the product is an oxidized, leached, hydrated, and finely comminuted material, commonly termed residual soil.

The making of a residual soil mantle from unweathered rock is much more complex than outlined above, too complex to consider in detail here. It is a series of chemical and physical changes, some occurring simultaneously, others in a definite sequence, some conditioned by the character of the original material, others by the character of the climate. The soil has a beginning, it grows through an infancy and a youth to a maturity as the thickening soil mantle becomes a protection against the attack of weathering. All changes begin at the surface and gradually extend downward. Oxidation proceeds more rapidly than leaching. Thus the zone of brownish rusty earth in our road cut is thicker than the zone which gives no response to acid. Chemical decomposition of silicate minerals is slower than either oxidation or leaching. In Chicagoland it has hardly begun, and we have therefore a young soil profile. In other parts of Illinois, weathering has been longer at work and there both the oxidized and leached zones are thicker, and the slowest change of all—complete chemical decomposition into a colloidal clay—shows in the upper part of the sections.[1] Three waves of alteration, which have progressed downward at three different rates, are therefore spaced out in the mature soil profile. Our region's youthful soil profile shows clearly only the two more rapid ones.

The Chicago region possesses no true residual soil as yet; what we have examined is only an initial stage in its development. Time, an essential item, has been too brief since the weathering started. In other words, the material exposed in the cut has lain out-of-doors only a relatively short while, as geological changes go.

Most land is covered with residual soil from the weathering of consolidated rocks, or bedrock. In our region, as over much of the northern United States, the weathering processes are attacking an unconsolidated deposit which overlies and protects the bedrock, which contains debris from the bedrock, yet which is essentially fresh rock material and is therefore not a product of weathering. Because of the slight amount of weathering already accomplished, the deposition of the unconsolidated material must have been geologically recent.

No directions for finding the highway cut were given except that one drive out of the city. The city lies on a plain along the lake but does not completely cover it. If one drives southward, he will find the plain extending as far as Dyer, Chicago Heights, Homewood, Oak Forest, and Palos Park. If he goes westward, he will find the plain as far as Justice Park, LaGrange, and Hillside, the towns of Hinsdale and Elmhurst being on the higher rolling country beyond its limits. Northwestward, the plain has a very irregular boundary but northward it is recognizable along the lake as far as Winnetka. One must drive into the belt of rolling higher country beyond the limits of the plain to find the highway cuts, almost any one of which, if ungrassed, will show the material described. This hill land is essentially *built up* of the unconsolidated material deposited on and almost completely burying the bedrock. There is a large proportion of unweathered local bedrock debris in it but there is also much material from beneath the lake and some which has come even from Canadian territory. The deeply scratched pebbles, cobbles, and boulders in it indicate a method of transportation unfamiliar to most of us. Almost complete absence of stratification tells of a method of deposition quite different from that which made the well-stratified bedrock beneath.

Anticipating a more ample discussion, let us now accept this thick unweathered blanket of rock debris above the limestone foundation as a glacial deposit, the ice-sheet which left it having spread southward into this region from Canada. Climatic conditions then differed sufficiently from those of the present to allow such an episode. The deposit is henceforth to be called glacial drift. The ice-sheet ground most of the drift so fine that it may be termed *rock flour*. Larger fragments which escaped complete reduction carry marks of the abrasion they suffered. Coarse and fine, all mixed together, were left on the final melting of the ice, mechanically changed but chemically like the parent rock. Thus the glacial drift is fresh, and thus the slight amount of weathering on its surface is evidence that it was deposited in geologically recent times.

Work of Running Water

In the few millenia since the glacial drift was piled on top of the bedrock, rain has fallen on its somewhat hummocky surface, has accumulated in closed hollows to make lakes and swamps, or has flowed off free-draining slopes to become concentrated as streams. Rain also has soaked into the drift and kept it saturated to within a few tens of feet of the top. Winds have whipped across the surface. In the northern part of the area, where the hill lands of glacial drift extend eastward to the lake, waves and shore currents have operated on it. All these agencies have modified the original deposit, in ways which, conspicuous or not, are significant.

[1]Leighton, M. M. and MacClintock, Paul, Weathered zones of the drift sheets of Illinois: Jour. Geol., vol. 38, pp. 28–53, 1930.

Most rock is consolidated and running water alone is relatively ineffective in wearing it away, but a stream of water rolling fragments of rock along with it or carrying sand or silt in suspension, is an effective agent of mechanical wear and so will deepen and widen its channel, even in rock. Rainwash crossing soil-covered surfaces on its way to a stream brings the debris for tools. In so doing, it removes that much of the soil. When brought to a stream by rainwash, the soil detritus is carried away as on a belt conveyor. Continued weathering replenishes the lost soil, and continued rainwash in turn removes the replacement. On steep slopes the bedrock may retain no soil cover at all, but generally in natural situations weathering can maintain a soil blanket of debris despite constant surface removal.

The surficial zone of disintegration is ever migrating downward as material is taken away and thus the hills between the streams are lowered.

Man, however, upsets this balance of nature. His food comes largely from the soil, most of it by the sweat of the plowman's brow. Agriculture absolutely demands interference with nature's balanced soil-making and soil-destroying forces and rarely is that interference other than inimical. Man is the greatest destroyer of the soil mantle. He may return, in fertilizers, the plant food that he removed by cropping, but he cannot return the soil itself after his careless cultivation has allowed, even invited, its removal by rainwash and gullying. He cannot return soil blown away by the wind after he has destroyed the protective prairie sod of sub-humid regions. Only by an intelligent recognition of the usually inconspicuous damage that his cultivation has done year after year, and a thorough understanding of how he has done the damage, will he be able to conserve this most vital resource, the arable soil.[2]

Most consolidated rock goes through the weathering mill before it is ready for transportation, but in our region preparation by weathering is unnecessary before erosion, because the drift has never become consolidated and the impact and friction of running water alone will erode it. Its chief protection from the attack of run-off is its relatively gentle slopes and its cover of vegetation. The effect of rainwash and rivulet erosion on steep unvegetated slopes is strikingly shown on the spoil heaps piled up alongside the Sanitary Canal where it was excavated in glacial drift. This erosion has occurred in less than 40 years (fig. 8). Other badly eroded areas are those laid bare by excavation for fill material for the new highways.

FIG. 8.—Typical "badland" erosion developed on spoil heaps of glacial till along the Chicago drainage canal south of Cicero (Berwyn quadrangle).

Prairie sod or forest growth originally covered the entire region and gave a large measure of protection from the attack of running water. But in some tracts the steepness of the original slopes more than offsets this factor and many ravine valleys have been eroded. Especially marked are the ravines tributary to Lake Michigan north of Winnetka (Highland Park quadrangle) and those tributary to Sag Valley and DesPlaines Valley west of the longitude of Willow Springs (Sag Bridge and Palos Park quadrangles). In both areas, the run-off waters have relatively high gradients, descending a hundred feet or so in a mile or less, so that the velocity of flow has more than compensated for small volume. Stream erosion is better illustrated in these small valleys than along the rivers of the region.

PALOS PARK RAVINES

The ravines in Palos Park (fig. 9) are easily accessible and show valley-making in rapid progress. The ski slide there is on the brink of the original steep slope, about a hundred feet above the Sag Channel flat. Ungullied at first, this slope has now

[2]Bennett, H. H., The problem of soil erosion: Assoc. Am. Geographers Annals, vol. 21, pp. 147–170, 1931. Soil erosion and its prevention in "Our Natural Resources and their Conservation", Chap. 4, Wiley and Sons, 1936.

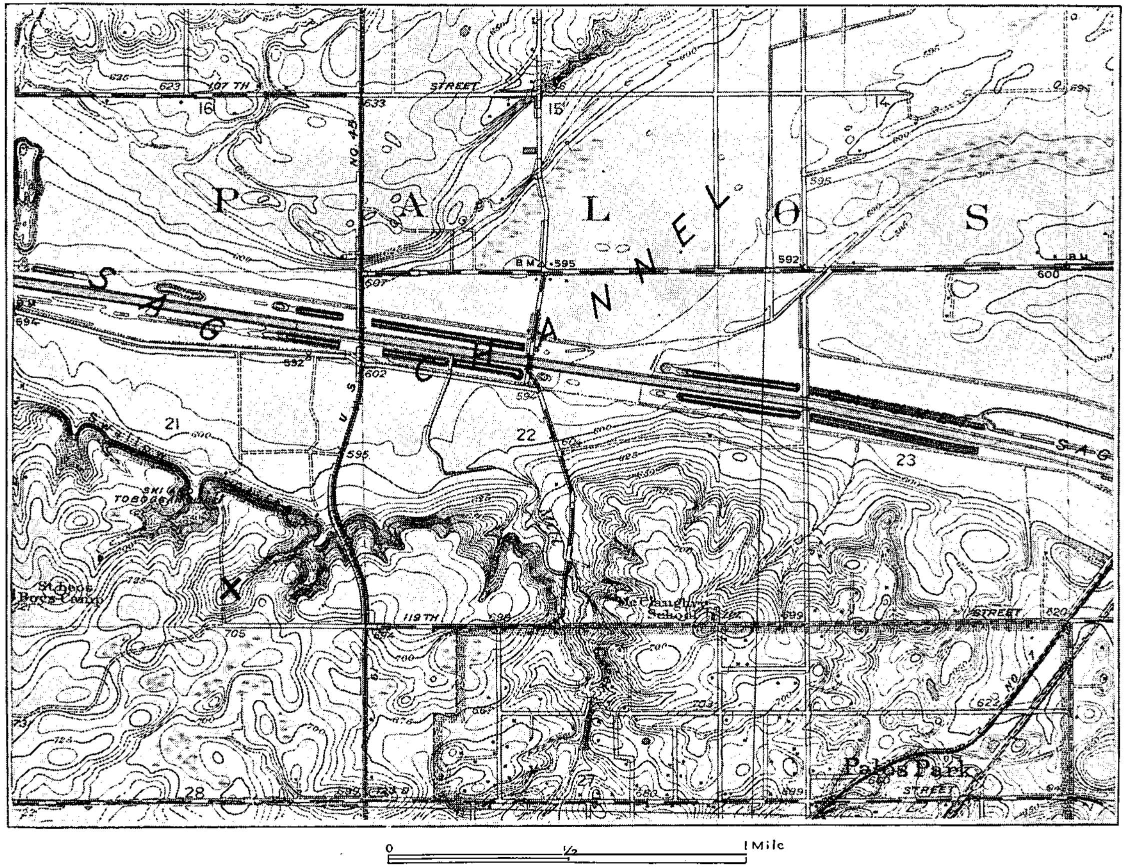


FIG. 9.—Map of ravines in the Palos Park region. The tract marked with X was formerly a lakelet or swamp which has been drained by overflow and by headward erosion of the ravine to the northeast. Note swampy tracts yet to be drained by headward lengthening of ravines. (Part of Palos Park topographic map.)

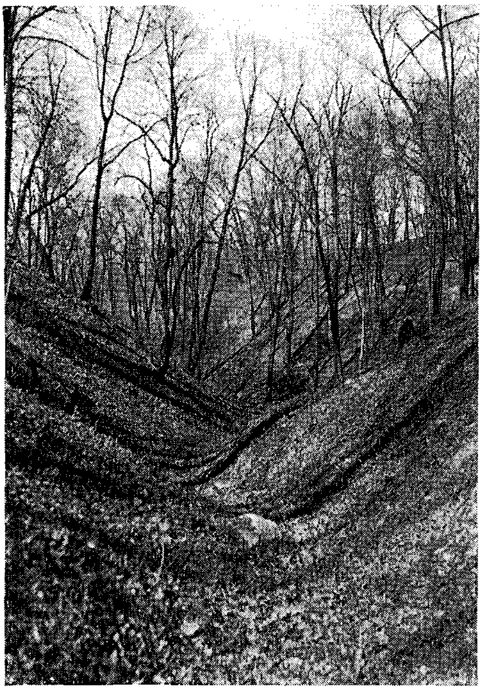


FIG. 10.—Ravine developed by stream erosion in Palos Park.

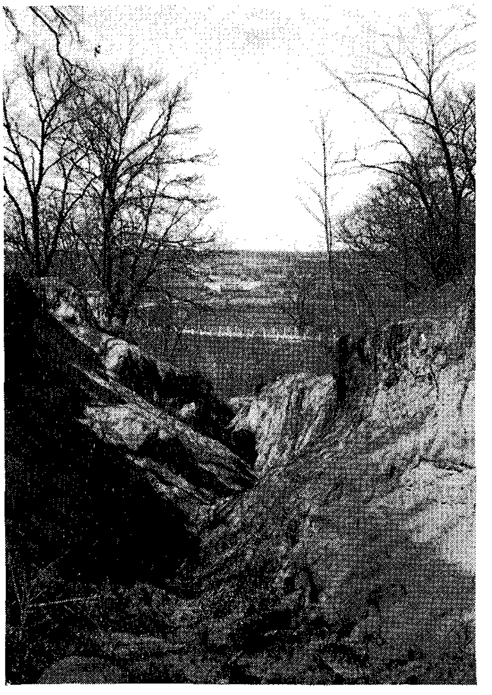


FIG. 11.—A ravine 20 feet deep that within a year developed in an abandoned roadway. (Palos Park Forest Preserve, near Swallow Cliffs, Palos Park quadrangle.)

been gashed with numerous short ravines which carry water only after thaws or heavy rains (fig. 10). How much forest and grass retard this work was strikingly shown here a few years ago. Gullying began in a farm road down the slope of the first ravine east of the ski slide. The roadway was abandoned but nothing was done to protect the slope and Nature was unable to spread her defensive cover in time. Erosion twenty feet deep occurred within a year where the road had been (fig. 11). The Forest Preserve administration, taking over the property at this time, dumped brush and boulders in the young ravine and also attempted to prevent run-off from the upper slope from entering it, but the scar will remain for many years to come.

Deepening and widening of these ravines is evidenced after every heavy rain. Another change, less conspicuous but fully as significant, is their lengthening. The precipitation that falls on a considerable upland tract south of the Palos Park ravines drains into them, either as direct run-off or as slowly percolating groundwater. As yet, this upland bears almost no marks of erosion by running water. The surface is undulatory, as is that of almost all glacially deposited material, and numerous closed basins contain swamps, lakelets, or standing water after rains (fig. 12). Most of these basins do not overflow, but lose their water by evaporation and by percolation into the drift. An overflowing basin discharges the concentrated run-off from its entire drainage area across the lowest place in its rim. Ravine lengthening, accomplished by water entering the head of the ravine from the unscarred upland, follows back toward the greater supply. Thus ravines tend to head toward basins which overflow. In this way the western arm of the ravine east of the ski slide has lengthened headward until it has cut through the low rim of an upland basin and drained it (fig. 13). A flat of mucky soil records the former bottom of a swamp or lake.

MAPLE LAKE

Another instance of basin drainage by headward lengthening of ravines is on Mount Forest Island, the upland area lying between the Sag and DesPlaines valleys

FIG. 12.—Mays Lake, one of the small lakes that occupy depressions on the uneven surface of the glacial drift (Hinsdale quadrangle).

FIG. 13.—The basin of a former lake (foreground) which was drained by the normal development of a ravine. The effect is that of a basin, the rim of which has been notched (background). McCarthy Road, near Bell Road crossing (Sag Bridge quadrangle).

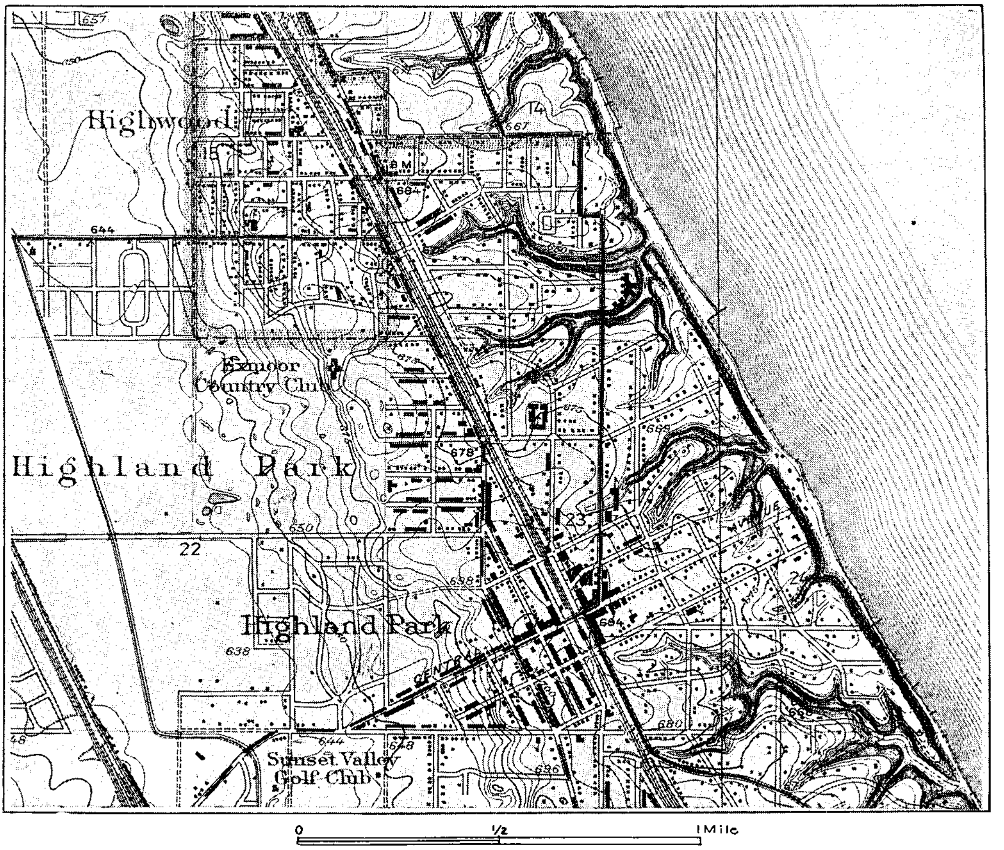


FIG. 14.—Map of ravines in the North Shore District showing their position on the northeast side of the Highland Park moraine that runs through Highwood and Highland Park. (Part of Highland Park topographic map.)

(Sag Bridge and Palos Park quadrangles). The drainage occurred at the corner of 95th Street and Wolf Road. Two ravines once notched the lower rim of the basin. The Forest Preserve administration has blocked them by concrete dams, restoring the basin which now, filled with water, constitutes Tuma or Maple Lake, a popular bathing place in the Preserve. (Compare fig. 13.)

NORTH SHORE RAVINES

The most and longest ravines in the Chicago area are in the "North Shore" district which extends from Winnetka northward along the lake. Sheridan Road crosses about twenty of them south of Lake Forest. The

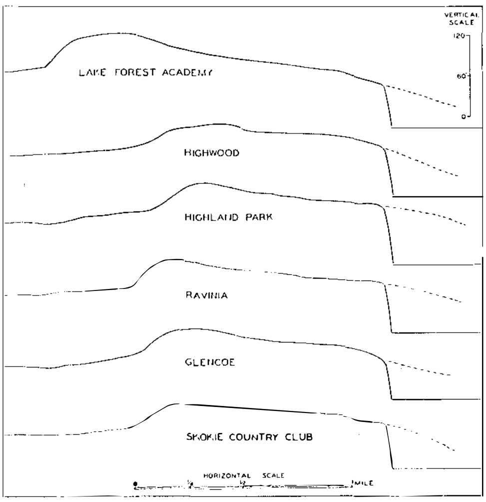


FIG. 15.—Profiles across the Highland Park moraine from Skokie Valley on the west to Lake Michigan on the east at localities indicated. The dashed lines extending beyond the lake bluff indicate the approximate original eastward slope.

district, however, is so largely built up, fenced, and posted against trespass that one can see but little topography. The topographic map (Highland Park quadrangle) shows that all of these ravines lie on the east slope (fig. 14) of a long ridge of the constructional topography (glacial drift deposit) that is parallel to the lake shore. The Chicago and North Western Railroad and the North Shore Electric Railroad follow the divide summit. Although the west side, descending to the Skokie Valley, had steeper original slopes (fig. 15), it has no ravines. This ravine system of the North Shore district is a consequence of the lake bluff which was cut by the waves of Lake Michigan after the ridge of drift (the Highland Park moraine) was built. Here are the steepest slopes of the Chicago area, therefore the steepest gradients for run-off, and hence the greatest changes by stream erosion.

Some of the North Shore ravines show an interesting tributary system with the tree-like or dendritic pattern already referred to. As they lengthen and increase in number, the eastern slope of the drift ridge will become more dissected in future centuries and the remnants of the original slopes will be reduced. A struggle for existence is going on here among the ravines, the competition being for water supply. Ravine nature is somewhat like human nature—the more it gets, the more it reaches out for, with scant respect for consequent loss to others. Thus many short ravines entering the lake never can extend back to the divide—the spreading branches of the longer, more successful ravines have already captured the run-off from the uplands which formerly went to the losers.

FIG. 16.—A small canyon eroded in thin-bedded limestone. The canyon is crossed by 111th Street half a mile east of Sag Bridge (Sag Bridge quadrangle).

A ROCK-WALLED VALLEY

Very few streams in the Chicago region have encountered bedrock in deepening their valleys, and only one has eroded into it deeply enough to have limestone walls. It is an unnamed tributary on the south side of Sag Channel, crossed by 111th Street about half a mile east of Sag Bridge (fig. 16). The stream is hardly two miles long and only the last 1,100 feet of its valley length is cut in rock. Though only 15 feet deep, it is a canyon in form, its walls vertical and its width no greater than its depth. The stream entering Sag Channel discovered a ledge of rock, shallowly buried beneath the drift, over which it descended steeply to the main valley bottom. The high gradient thus provided has been responsible for the development of the little canyon. The limestone is thin-bedded and breaks into pieces small enough to be carried away by the stream when it is in flood. Deepening therefore has been more rapid than it would have been if thick-bedded limestone had been encountered.

Other larger streams of the region flow over bedrock in places but none has eroded into it to a comparable extent. Desplaines River east of Lyons (Berwyn quadrangle) has low ledges of limestone on either side but they are not steep walled. The river either has eroded 5 to 8 feet in rock here or has reexcavated a channel-like low place in the surface of the limestone beneath the drift. Sawmill Creek (Sag Bridge quadrangle) flows on limestone for nearly 1,300 feet in its lower course and in one place has cut 5 feet deep into it.

PLUM CREEK AND HART DITCH

The most remarkable instance of rapid stream erosion in the area is Hart Ditch, the lower course of Plum Creek (Calumet City quadrangle). When this part of Indiana was first settled, and indeed within the memory of living man, the fertile plain north of Dyer, Indiana, was a swamp throughout the year, a duck-hunter's paradise in season. Plum Creek entered this swamp from the south, about three-fourths of a mile north of Dyer. Discharge from the swamp was westward through North Creek, thence northward through Thorn Creek to Calumet River. By stream course it was thirteen and a half miles from the swamp to the river, and the fall in that distance was a little more than 30 feet (fig. 17). About 1850, Mr. Aaron Hart,

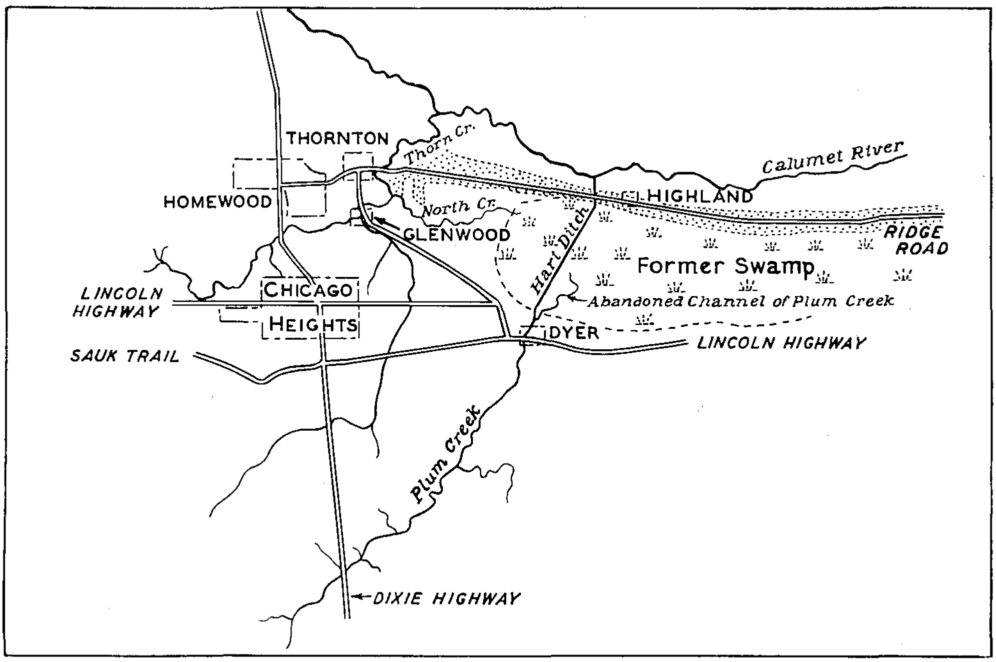


FIG. 17.—Sketch map showing Plum Creek drainage changes.

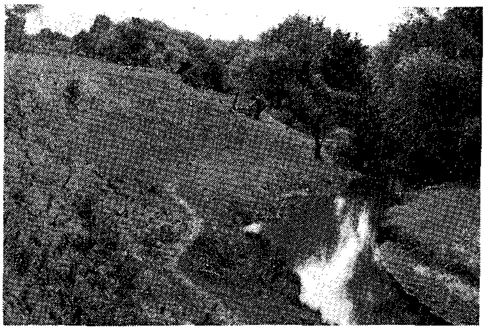


FIG. 18.—Hart Ditch, the new lower course of Plum Creek. This valley has been eroded in about 80 years. Compare with figure 19.

FIG. 19.—Original lower portion of Plum Creek's valley, abandoned when intercepted by Hart Ditch. The man is standing in the bottom of the old stream-bed.

owner of the swamp, dug a ditch north from it through a sand ridge (on which stands the town of Highland, Indiana) to Calumet River, shortening the discharge route to about a mile and a half and providing a fall of nearly 30 feet in that distance. The swamp water, formerly with a discharge gradient of less than 2½ feet to the mile, thus obtained a gradient of nearly 20 feet to the mile. Nature's principles worked with Mr. Hart. The new high-gradient ditch route was rapidly deepened by erosion and the head of the ditch, now become a ravine head, was extended southward into the swamp. Guided by shallow ditching, it lengthened completely across the swamp until it reached the place where Plum Creek entered and thereupon became the uninterrupted course of the creek (fig. 18). The new gradient had been decreased by half through this lengthening across the flat swamp but still was adequate to cause rapid deepening; a deepening which has now extended up Plum Creek south of Dyer for several miles. The ditch, reported to have been but a plow furrow originally (except through the sand ridge), is today a ravine 15 to 20 feet deep and 4½ miles long. Unlike any other ravine of the region, there is no slope to the surface across which it flows. The gradient responsible for its growth all lay north of the sand ridge, between that ridge and the river, and artificial piercing of this divide was essential to its development. If man had not altered the drainage, the head of North Creek, the outlet of the swamp, presumably would have been extended eastward as centuries passed and the standing water would have disappeared in time. But no deep trench like Hart Ditch ever could have been eroded. There would have been a shallow valley, three or four feet deep, like the abandoned course of Plum Creek in the southeastern corner of the Calumet City quadrangle (fig. 19).

PIRACY OF SAWMILL CREEK

This shifting of stream courses to cross a former water-parting, thus obtaining a higher gradient and a shorter course, may occur without man's intervention. An instance of the kind is afforded by Sawmill Creek (Sag Bridge quadrangle), a tributary from the north entering DesPlaines River nearly two miles southwest of Byrneville (fig. 20). The stream is unnamed on the government map but by some is called Warden's Creek. It has eroded a beautiful little valley about 50 feet in maximum depth along the last half mile of its course before entering the broad river valley. The creek valley has a bottom width of a few hundred feet, produced by lateral shifting of the stream and consequent undercutting of its valley walls. It is more advanced in development than are the ravines already discussed. Figure 20 shows another flat-floored valley, semi-circular in ground plan, immediately to the west, entering the DesPlaines Valley 2,000 feet farther west and heading (here is the significant item) in the west wall of Sawmill Creek valley but about 30 feet above that stream. Except for a tributary which enters and uses the west part of this semi-circular valley, it is dry. Yet on the dry floor are two small crescentic swamps such as are formed when streams abandon meander loops (fig. 21). And beneath the alluvial soil of its floor is a deposit of coarse cobbly gravel, 6 feet

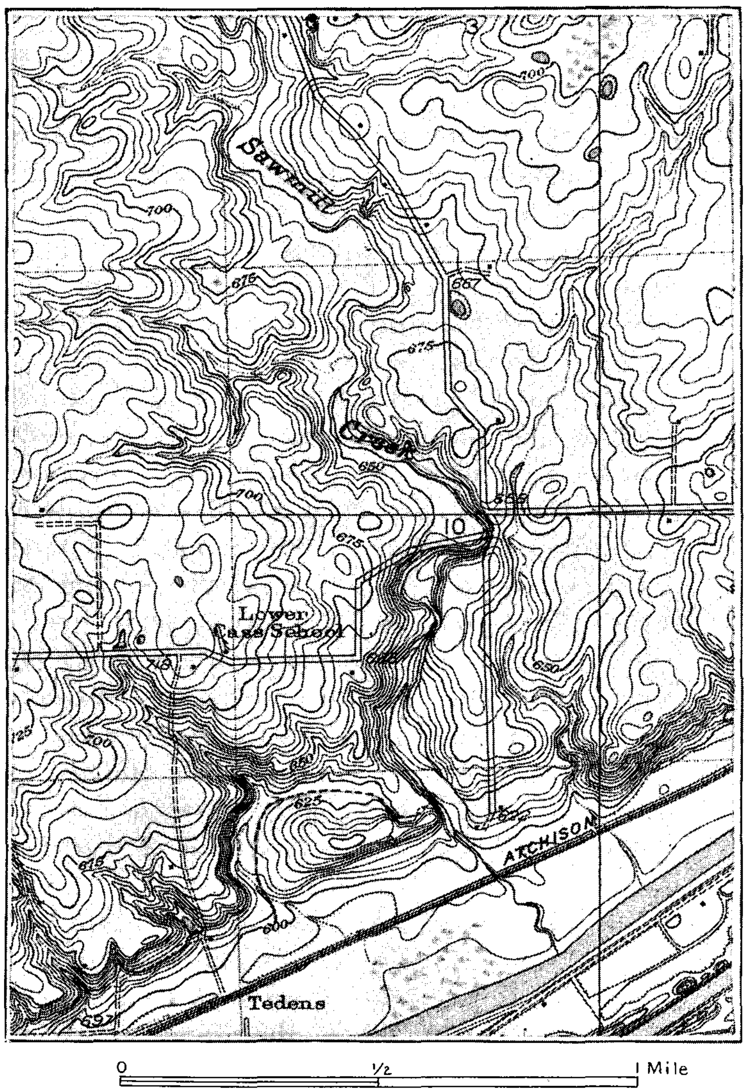


FIG. 20.—Map of Sawmill Creek. The dashed line shows the course formerly followed by Sawmill Creek before "stream piracy" gave it a shorter steeper course. Another case of stream piracy may occur in the center of sec. 10 between Sawmill Creek and the creek to the east. (Part of Sag Bridge topographic map.)

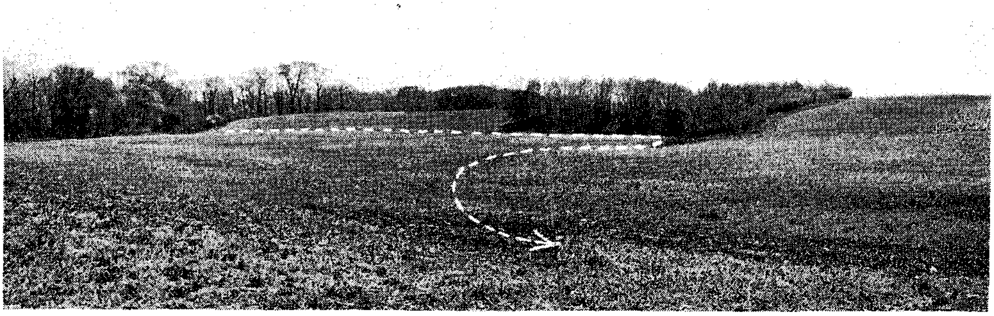


FIG. 21.—Looking southeast across the abandoned portion of Sawmill Creek valley. The present valley of the creek is marked by the woods to the left (east) and is thirty feet lower. The former meandering course of the creek is shown by the dashed line.

in maximum thickness, identical in texture with the gravel that Sawmill Creek is now carrying.[3] Limestone cobbles in it have been softened on the exterior from weathering since they were deposited.

Let us start with the justifiable assumption that Sawmill Creek has made its own valley. If we could put back into it the last 30 feet of debris removed in the deepening and then could add 10 feet more at the place where it now enters the DesPlaines Valley, the stream would have to flow around through the semi-circular abandoned valley, and would enter the DesPlaines 2,000 feet farther downstream. The creek would make a sharp turn in entering the abandoned valley. Swinging to the outside of this sharp turn, it would erode laterally into the 10-foot earthen dam that we built in imagination and, before long, would by this process cut it entirely away. A shorter and considerably steeper route would then be available and the semi-circular lower half mile of its course would be abandoned. This is precisely what is thought to have happened at an early stage in the creek's history, 30 feet of down-cutting having occurred since the diversion. If a short ravine descending the DesPlaines Valley wall where Sawmill Creek now enters had existed before the shift, its headward erosion would have facilitated the lowering of the old water-parting here and the change would justify the term "stream piracy." Domestic stream piracy would be an even more definitive term, since both pirate and pirated streams belong to the same system.

[3]This gravel is not to be confused with cobbles and boulders which have been picked up in the field in the abandoned valley and dumped over the edge into Sawmill Creek valley.

Sawmill Creek has not yet completed the deepening of the new route. A very heavy rain in June of 1929 produced a flood in the creek that swept cobbles and pebbles into large bars and up above the ordinary channel margins in striking fashion. In one place the flood eroded a basin in the channel to a depth of 6 feet and piled up boulders and cobbles on its down-stream margin to a height of 4 feet. Flood time is work time for streams.

Figure 20 also shows a case of piracy, imminent but not yet accomplished, close to the middle of section 10. The reader may here test his understanding of a contour map and of the mechanics of piracy. The problem is to determine whether Sawmill Creek or the creek immediately to the east will lose by the piracy.

EROSION WITHOUT VALLEYS

One learns shortly to recognize the pattern of contour lines that represents a stream-dissected topography. The North Shore district (fig. 14) is our best Chicagoland example. The topographic maps of the Chicago area, however, consistently show very little such topography in the area as a whole. Slopes exist almost everywhere outside the lake border plain, but they belong to the original sag-and-swell topography of the glacial deposits. These slopes have been somewhat eroded by rainwash, but the run-off has not been concentrated and therefore has not produced gullies and ravines. The evidence for their erosion is best seen, not on the slopes, but in the basins enclosed by the higher tracts. Many of these are mapped as "basin fill," for they contain varying depths of silt and clay material, in many cases with traces of decayed vegetable matter. Some of them have been filled until they are no longer closed basins. All this records the inconspicuous work of rainwash, while in more favorably situated places the concentration of run-off has produced gullies, ravines, and valleys. Rainwash is simply the muddy water that runs down slopes, without gullying those slopes, during and immediately after rain storms. Its rills are too minute to threaten seriously a hillside mantled with vegetation. In fields plowed up and down the slope, gullying is very likely to develop from rainwash. Cultivation across the slope (along the contours) tends to destroy incipient gullies and to check the work of the rainwash itself. Probably as much material has been moved downgrade by the inconspicuous rainwash as by the streams since the ice-sheet abandoned the region.

CONSTRUCTIONAL VALLEYS

For the reader who notes the capacious valleys of the upper DesPlaines River, Salt Creek, Skokie Creek, and the forks of the North Branch of Chicago River, it should be repeated that these valleys are constructional, just as are the undrained basins. They have been inherited by their streams and only the valley bottoms have been modified subsequently.

INHERITED VALLEYS

Another group of large valleys of the region also needs explanation. It lies in the southwest quadrangle and includes, from north to south, the valleys of DesPlaines River west of Argo or Justice Park, Sag Channel, Long Run, Fraction Run, Spring Creek, Marley Creek, and Hickory Creek. Although they are stream-eroded valleys, they all antedate the latest glaciation of the region and two of them, DesPlaines and Sag, were also used by great volumes of water discharged from the basin of Lake Michigan before the Strait of Mackinac gave the Great Lakes an outlet to the east. Special attention is given their history in a later section. They all carry good evidence of having been over-ridden by glacial ice but they were not filled with glacial drift and subsequently they have undergone but little modification by their present streams.

DEPOSITION BY RUNNING WATER

It was stated earlier in this chapter that the debris carried away by streams of this region goes either to Lake Michigan or to the Gulf of Mexico. It is now time to qualify this statement. Some detritus is being deposited by streams within the confines of Chicagoland. Deposition by running water occurs whenever the current is sufficiently checked; the larger the load being carried, the less the decrease in velocity needed to cause deposition. Small, high-gradient streams on steep slopes may debouch on more nearly level surfaces at the base and there leave much of the debris removed in cutting the gully above. Such a deposit is commonly fan-shaped or semicircular in outline, sloping downward and outward from its center at the mouth of the gully. Some fans are readily recognized because of the radial slope from apex to margin (the Palos Park ravines have many good examples), others may be so nearly flat that to the eye they are only a part of the general plain. The carefully surveyed contour maps show many of them. Alluvial fan deposits are most common in the Sag Valley and along the landward margin of the lake-border plain.

The largest fan in the region, not now growing, has been built at Dyer, Indiana, where Plum Creek leaves the hilly glacial moraine country and enters the lake-border plain. Though too flat to be recognized as a topographic feature, it is shown by the northward looping of the 620 and 625-foot contours on the Calumet City topographic map and the 625-foot contour on the Dyer map. Borings on the fan also show an alluvial deposit with a maximum thickness of 9 feet above the stratified sand of the plain. Layers of vegetable matter occur in the fan deposit, indicating swampy conditions at times during its aggradation. Plum Creek is a relatively low-gradient stream, and it might well be assumed that 9 feet of aggradation on the plain at its mouth would result in damming which would go on slowly while the fan grew, thereby causing deposition on the valley floor farther upstream. The assumption is borne out by the field evidence. To an average depth of 8 feet, an irregularly interbedded deposit of gravel, sand, silt and peat has accumulated in the lower part of this valley south of Dyer. Shells, deer antlers, and mammoth

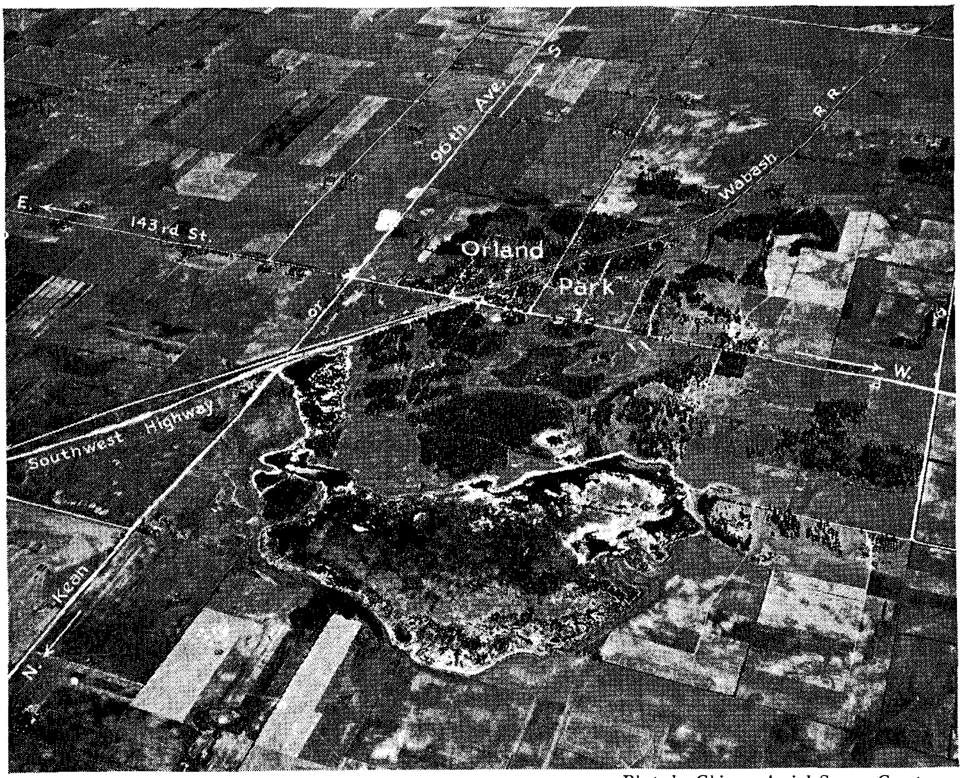


Photo by Chicago Aerial Survey Company

FIG. 22.—McGinnes Slough, near Orland Park (Palos Park quadrangle).

bones and teeth have been found in it, together with numerous fragments of driftwood and even entire tree trunks. Some of the logs can be seen from the Steger Road bridge two miles south of Dyer.

Organic Deposits

We have reviewed the function of vegetation in weathering and erosion. It remains to note that deposits of vegetable debris may accumulate and be partially preserved under favorable conditions. The prime condition is partial protection of the material from decay. This occurs in bogs and swamps where the debris, submerged in water, is protected from the rapid bacterial decomposition that requires free oxygen of the air. Swamp deposits of peat generally occur in undrained hollows of the glacial drift topography.

The largest existing swamp of this sort in Chicagoland is McGinnes Slough (fig. 22) (southwest corner of Palos Park quadrangle), half a square mile in area. It probably was a shallow lake immediately after the retreat of the ice-sheet but subsequently became so filled with peat that no open water remained. The outlet valley has a very low gradient, a complete lack of ravine characteristics, and contains two more swamps, indicating that the former lake has not been drained by headward erosion of young and vigorous streams. The swamp probably could not be drained artificially except by a deep trench more than a mile in length. The Izaak Walton League has proposed a reverse procedure; the building of a dam across the outlet to restore the lake, or rather to raise the water level and make a new lake, higher and more extensive than the original. The marsh is the breeding place of many waterfowl, and bird lovers, taking up arms against the fish lovers, secured an injunction preventing this. The owner of the slough at present floods the eastern part of the marsh by a dam across the lower part of the culvert beneath Kean (96th) Avenue.

Skokie Marsh, west of Winnetka and Glencoe (Park Ridge and Highland Park

FIG. 23.—Muck and peat heaved by a highway fill across a swamp along 104th Avenue (Flavin Road) just south of 95th Street.

quadrangles), lies in an elongated constructional valley between two broad ridges of glacial drift. Though the topographer found a total length of five miles of marsh land, and the botanist knows it to possess a typical hydrophytic flora, the geologist is unable to map all of it as a peat deposit. Skokie Valley is not completely enclosed and the marsh exists simply because the gradient of the valley floor is too gentle for adequate drainage. Borings show that the peat that does exist in the northern part of the marsh is only a foot or so thick, glacial drift or fine sand immediately underlying it.

Marshes in the vicinity of Calumet and Wolf Lakes (Calumet Lake quadrangle) are similarly without peat accumulations adequate to justify mapping them as such. Glacial drift has been found close to the surface in every boring made.

The most extensive peat deposit in the region occurs in the valley of Sag Channel (Palos Park and Sag Bridge quadrangles). It is nine miles long and three-fourths of a mile in greatest width. On the topographic maps the area is shown almost wholly without the symbol for swamp or marsh land. It is a drained swamp lying on the floor of one of the two great abandoned spillways out of the Lake Michigan basin. Artificial drainage was begun about 1870 when the Illinois and Michigan Canal along the DesPlaines Valley proved to have too little water and the Calumet Feeder was dug along the Sag Channel. The swamp was completely drained when the Sanitary District constructed the Calumet-Sag Canal, a much deeper and more capacious waterway. So great was the effect of this canal in lowering the groundwater level that many wells in the vicinity went dry when it was opened. The swamp has entirely disappeared and the peat is so dry that fires occur in it almost every summer. The depth of the peat deposit is variable, depending largely on the surface of the substratum which is chiefly bedrock scoured clean of drift by the discharge from the Lake Michigan basin. Ten feet of peat is known in places.

The contiguous towns of Hinsdale, Clarendon Hills, Westmont, and Downers Grove (Hinsdale quadrangle) are built on an exceptionally irregular surface of the glacial moraine. Undrained depressions containing peat are numerous and the deposit in some is unusually thick, a maximum of 26 feet being known. When sewers were installed in the first three towns, peat-filled basins had to be crossed and the pipes were supported on piles to prevent them from sinking in the peat and were also weighted down to keep them from rising. Even after the sewers had lowered the water level, houses inadvisedly built in some of these basins have settled and cracked.

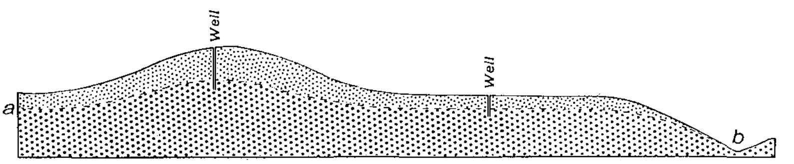


FIG. 24.—Diagram showing the position of the water-table or surface of the groundwater (*a-b*) in a region of undulatory topography and homogeneous materials. The heavily dotted portion is completely saturated.

Some concrete pavements have been laid on earthen fills made in peat-filled swamps of the region. Many such pavements have cracked and sagged badly, some of them being unrepairable and necessitating new paving. Good engineering requires either adequate time between making the fill and pouring the concrete so that complete settling can occur and be rectified by a final grading, or for removal of the weak bog deposit before the highway fill is made. (See fig. 23.)

A striking illustration of the weakness of peat was afforded when the Calumet-Sag Canal was dug. A spoil heap was made on the east side of 104th Avenue (west edge of Palos Park quadrangle.) Its weight squeezed the peat out from beneath and forced it up into large wrinkles encircling the dump. At the time of construction, it looked much as though a huge stone had been dropped into shallow water, remaining partly above the water, the peat wrinkles simulating waves just beginning to spread away on all sides.

The map legend uses the compound term "peat and muck." There is no sharp distinction between the two. Muck contains more earthy material, largely contributed by rainwash from higher slopes, and its vegetal content is more altered by decomposition. Muck is likely to occur in the shallower basins which dry out in the summer and along the margins of peat-filled depressions.

GROUNDWATER AND ITS WORK

Rain which soaks downward into the drift and bedrock is known as groundwater. It produces a permanently saturated condition at sufficient depth in accessible permeable materials. Above that depth the ground is saturated only after long-continued rain. In ordinary weather its pores are partially filled with air. Wells must penetrate through this zone of aeration to a saturated porous bed to provide water throughout the year. In rolling country, hill-top wells are deeper than those in valley bottoms, though the additional depth is not as great as the height of the hills. The water-table (the upper limit of the saturated zone) under a hill may be many feet higher than it is in the adjacent valley. The water-table, therefore, has a relief of its own, corresponding to but less than the relief of the land (fig. 24). During droughts wells in higher land may go dry because, without replenishment, the water-table is lowered and the zone of aeration becomes deeper. Gravity moves the groundwater, just as it does the stream water. This means that groundwater is slowly moving down and out. Ordinarily its circulation is very slow, the water percolating rather than flowing through the minute spaces it finds.

Stream-cut valleys may intersect the water-table, offering escape in seepages and springs, and providing themselves with a water supply during dry weather. Most of the springs in Chicagoland are in stream valleys. Generally their occurrence is in the outcrop of some particularly large-pored deposit, like gravel or sand, which affords free movement of water.

The largest spring in the Chicago region is three miles south of Elmhurst and 3½ miles north of Hinsdale, on Spring Road just west of Salt Creek (Hinsdale quadrangle). It is almost in the center of section 23, T. 39 N., R. 11 E. Its unusual size seems due to subdrainage from an abandoned part of the creek valley west of the present route. The old valley contains basin-fill which is saturated nearly to the surface. Elmhurst secured its municipal water supply from this spring until the population of the town exceeded 5,000. On the Chicago Folio map (1902) it is called Mammoth Springs, but the new map, though showing it, gives it no name.

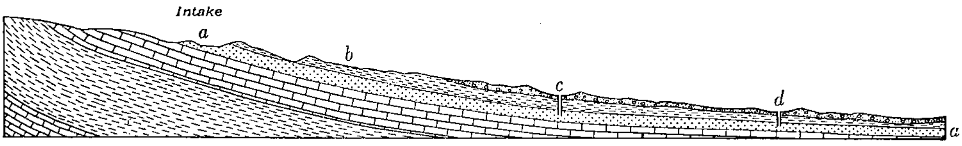


FIG. 25.—Diagram showing conditions necessary for an artesian basin; *a* is a porous layer, *b* is an impervious layer that traps water in *a*, and *c* and *d* are flowing wells.

Perhaps the next largest spring in the region is on the south slope of Mt. Forest Island, 1000 feet southeast of the intersection of 107th Street and Kean Avenue. The specially favoring circumstance here is that the water which falls as rain on the adjacent Mt. Forest upland to the north emerges from the lower slope of a gravel terrace along the north side of Sag Channel. The gravel seems nearly saturated with water, for there are seepages elsewhere along the basal slope and a well at the Greager greenhouse on Kean Avenue obtains an "inexhaustible" supply at a depth of only ten feet.

Wells of the Chicago region are of two classes—those dug in the drift to a depth below the water-table, and those drilled far deeper, penetrating even thousands of feet into the bedrock. Wells of the first class may become contaminated from barnyards, earthen toilets, leaking cesspools, etc., and furthermore they do not commonly yield large quantities of water. For industrial plants and small municipalities, deep wells with large yield of "safe" water may be drilled. An interesting item regarding such wells in Chicagoland is that the water, encountered in porous sandstone far below the limestone of our outcrops and quarries, rises after the water-bearing layers are penetrated and has even flowed from the well mouth. Obviously somewhat different conditions control the movement of this groundwater though it still is true that gravity causes its flow.

The deeper wells of Chicago reach an artesian water supply. The sandstone formations containing the water extend northward and northwestward into Wisconsin, gradually rising in that direction, with therefore a decreasing thickness of impervious stratified rock above until they crop out in south-central Wisconsin. This outcrop area is higher than the land surface in the Chicago region (fig. 25). Wisconsin rain, entering here, moves southeastward down the gently inclined strata at least as far as the Chicago region. It is as though a long water pipe were laid on a gentle incline, the lower end (Chicago area) closed, and water (rainfall) poured into the upper end (south-central Wisconsin) until the pipe is full. A hole drilled into the lower end of the inclined pipe and a small pipe fixed vertically in it represents the artesian well. Water will rise in the small pipe until it is as high as the water in the open end of the main pipe. Should the small vertical pipe be shorter (the land surface lower) than the height to which the water can rise, a flow will result. Should it be longer (the land surface higher) pumping will be necessary.

In Nature, the flow is much restricted by the small openings in the sandstone and by the consequent frictional resistance, and demands on the well may be greater than the subterranean flow can supply. This is particularly true of the artesian wells in the Stockyards district where heavy demands on a number of closely spaced wells have notably lowered the level to which the water originally rose.

The topographic effects of groundwater in the Chicago region are very slight. Limestone is a relatively soluble rock and many regions underlain with it possess caves in the rock and sinkholes in its surface, both the product of long-continued solution by groundwater descending and migrating laterally along vertical cracks (joints). Chicagoland has neither caves nor sinkholes.

In many regions springs have built up deposits of calcium carbonate (calcareous tufa) at their mouths. None of our springs has done this.

Loose material lying on steep slopes, becoming heavy and lubricated with groundwater, may slip down hill in large masses, constituting landslides. Features of this character are not uncommon on our ravine walls, especially where the streams are undercutting, or in deep highway cuts, but

Courtesy of George D. Fuller

FIG. 26.—Wave-cut cliff near Lake Bluff (Highland Park quadrangle).

groundwater in such places is an important conditioning factor, and artificial drainage, executed with a knowledge of geological conditions, often proves corrective.

All spring water and well water of the region is hard, the hardness being due to dissolved mineral matter secured as the water moved slowly through the calcareous glacial drift or the limestone bedrock. Escaping groundwater joins the streams, and thus rock material in solution is removed from the region. The average river load of dissolved material, contributed largely by groundwater, is about one-third as large as the load carried in suspension (clay, silt, and sand). Hard water is objectionable for many industrial uses as well as for domestic purposes. Lake Michigan water is less hard than our groundwater, a fact well known to commuters living in suburban towns whose water supply comes from wells. It is interesting to note in passing that the drainage area of Lake Superior has very little limestone in it and the lake water there is almost as soft as rainwater.

Work of Shore Agencies

North of the city of Chicago, the coast line is cliffed to and beyond the limits of the area but the city waterfront itself has no cliffs. The North Shore cliffs nearly coincide with the extent of the glacial moraine along the shore and the uncliffed coast is wholly in the lake border plain. The north part of the plain, however, in Evanston, Wilmette, Kenilworth, and Winnetka, is higher than elsewhere along the waterfront and is itself cliffed for a few miles.

The origin of the lake cliffs is no puzzle to one who has seen the waves of a "northeaster" attack this shore. It is no mystery to property owners who have seen their land, undercut by the waves, slide piecemeal into the lake from year to year. There is no district of more rapid geological change in the region.

The cliff (or bluff) ranging in height from 15 feet in Evanston to 85 feet in Highland Park, has been retreating before the onslaught of storm waves ever since the lake was formed (fig. 26). The unconsolidated glacial drift yields somewhat as it does to vigorous stream erosion. Boulders and cobbles from the drift, once in the grasp of the waves, are used as tools in the attack. Sliding and slumping of water-soaked material down the cliff faces is a common phenomenon. Once at the bottom, a few storms generally will disperse the material and waves will again steepen the profile for more sliding to occur. The summit area, high above the attacking waves, is wasting away by this attack as surely as though the waves were dashing over it. Greater exposure of the cliff determines greater retreat locally, as also does weaker material in the cliff. Higher lake stages, as in 1929, have caused greater annual recession all along the shore. The level of Lake Michigan varies from time to time, largely because of variations in rainfall and evaporation. In 1927 the elevation of its surface averaged 578.96 feet above sea-level. By April 1929 it had risen to 582.34 feet, more than 40 inches higher. Obviously the waves of 1929 were capable of doing far more damage to the shore than waves of a low lake-level.

The rate of shore recession north of Evanston, as estimated by old residents, has been about 5 feet a year. Measurements made at different times and places give rates varying from 1½ to 16½ feet annually. These were all made before any attempts to check the recession had been undertaken.

For some years after 1845 a small village called St. Johns stood close to the edge of the cliff in the southeastern part of the present Fort Sheridan grounds. It appears to have grown up around a brick plant, for a part of the old pit and the grade of an old railroad spur to it still remain. In 1907 the only surviving traces of the village itself were two orchard trees and the remnants of an old foundation which at that time were on the very edge of the cliff although originally they were in the westernmost part of the village.[4] Today even these traces have vanished, the prey of the attacking waves. The amount of recession thus recorded was estimated in 1907 to have been from 100 to 400 feet. In 1930 Ball[5] reported observations of shoreline recession north of Kenosha which he had made in 1918, 1921, and 1929. He found that between 1918 and 1921, when the lake was

[4]Atwood, W. W., and Goldthwait, J. W., Physical geography of the Evanston-Waukegan region: Illinois Geol. Survey Bull. 7, p. 92, 1908.

[5]Ball, J. R., and Powers, W. E., Shore recession in southeastern Wisconsin: Illinois Acad. Sci. Trans., vol. 22, 1930.

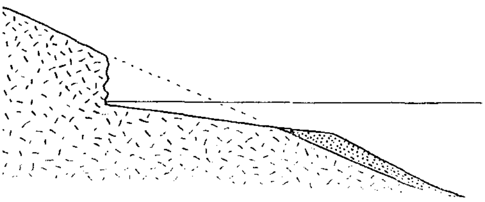


FIG. 27.—Cross-section of a wave-cut cliff and its accompanying cut-and-built terrace. (Illinois Geol. Survey Bull. 7, fig. 20, 1908).

high, the average annual recession at the measured places had been 12.33 feet with a maximum of 15 feet. The lake then dropped steadily until 1927 and, despite another rise before he again measured, the average recession was found to have decreased to less than a foot a year.

At first thought, the simplest and best solution to the problem of checking this encroachment of the lake would be the construction of a sea-wall. On many shores a sea-wall is the only feasible method, though very costly. But the method usually adopted by North Shore property owners has been to build piers or groins extending across the beach and out into the shallow water for 100 to 250 feet or more. The structure does not take the brunt of the attack, it does not stand between the waves and the cliff, and the reason for its effectiveness may not be apparent at first. Other shore processes, thus far undescribed, underlie its success in checking, although not completely stopping, the cliff recession. Let us approach the problem by means of diagrams.

In figure 27 a shelf-like shoal is shown off shore, partly an eroded platform left by cliff retreat but also partly depositional, built from detritus dragged out by the undertow and deposited below the effect of even great storm waves. Not all the debris stops here; the fine rock flour settles on the lake bottom well beyond the terrace. Significant for our problem, however, is the fact that not all the debris from cliff destruction comes out across the wave-cut platform to the depositional terrace. There is another dimension to be considered—along the shore.

The diagram (fig. 27) implies wave attack at right angles to the shore. It is far more probable that the average direction of wave approach is diagonal to the shore (fig. 28). Successive diagonally approaching waves will produce a current along the shore, the effect of which will be felt as far

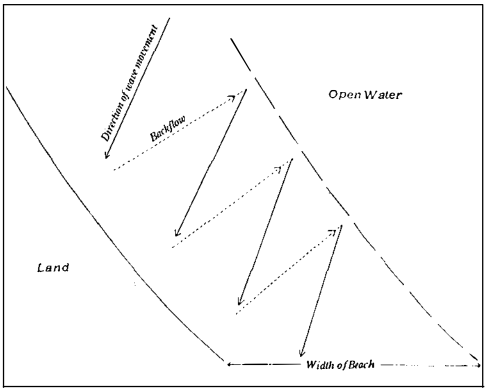


FIG. 28.—Diagram illustrating the course of a particle on a beach when waves impinge diagonally upon the land.

out as the breakers in heavy storms. In waves that reach the beach, the debris tossed back and forth as they break on and recede from the shore will tend to be shifted along the shore a little as each oncoming wave carries it shoreward. The sum of many such zigzag to-and-fro trips means transportation alongshore on the beach itself.

Now examine the Highland Park topographic map, or that portion of it shown in figure 14, and also figure 29, an airplane view of the shoreline, and note the greater width of beach on the north side of each groin. The alongshore current on the Chicago region coast is southward, determined by the dominant northeaster waves. The groins check this drift, retain a portion of the debris, widen the beach zone, and thus provide a buffer more or less adequate to absorb the energy of the wave attack. In this way, the cliff bases are less energetically undercut, vegetation gets a hold, and gullying and slumping are checked.

The ravines of the North Shore have all added their debris to the shore drift. Not one has been able to build a delta in the face of the wave attack. They have also suffered a constant shortening in their lower portions as the cliff has receded. This has maintained in them a steeper gradient than they would otherwise have and is undoubtedly a factor in their marked development.

As the shore drift is southward past this source of supply, one might expect to find somewhere in that direction a region where shore deposition is occurring, or at least was occurring before man took charge of the

Photograph by Chicago Aerial Survey Company

FIG. 29.—Groins and resultant beaches protecting the lake bluff along the North Shore.

shoreline configuration. An enlightening fact relates to the mouth of Chicago River before harbor improvements were begun in 1833. The river, two blocks east of Michigan Avenue, turned a right angle to the south and flowed behind a sand barrier as far as Madison Street, half a mile, before entering the open lake (fig. 30). This sand barrier was a continuation of the sandy beach at Evanston and clearly was a product of the alongshore current. After the present river mouth was dredged and protected by piers, sand accumulated on the north side of the north pier until by 1864 the shoreline had been extended, without further aid of man, half way out from Michigan Avenue to the foot of the present Municipal Pier. This beach accumulation was a triangular area, identical in character with those against the north sides of groins in the North Shore area.

Still more striking was the course of Calumet River before man began his extensive alterations (fig. 31). The complete history goes back to the later high-level glacial lake stages and involves the development of the old beach ridges about Wolf Lake and Lake George, Indiana. Stated briefly here (the section on unconsolidated material contains a more ample account), the mouth of Calumet River was originally near Riverdale. Had there been no alongshore movement of sand while the lake was being lowered to its present stand, the river mouth would have been approximately at the intersection of the lake shore and the eastern edge of the Calmuet Lake quadrangle. But this southeastward drift of sand and the building of beach ridges successively farther out as the accumulation grew, shifted the river mouth southeastward until, by the time the first maps were made, it was entering the lake east of Millers, 14 miles over in Indiana. This was in the area of active dune development and about 1870 the river was seriously embarrassed by dune growth at its mouth. Dredging from Hegewisch to South Chicago, along a canoe waterway used by the Indians, has given us the present lower course and mouth of Calumet River, 20 miles west of the abandoned mouth at Millers.

The entire waterfront from about 53rd Street south to the Indiana dunes was being built out by accretion of shore drift prior to the growth of the city and its need for "made land" additions. The two piers in Jackson Park, protecting lagoon mouths, show today a constant accretion of sand on their north sides.

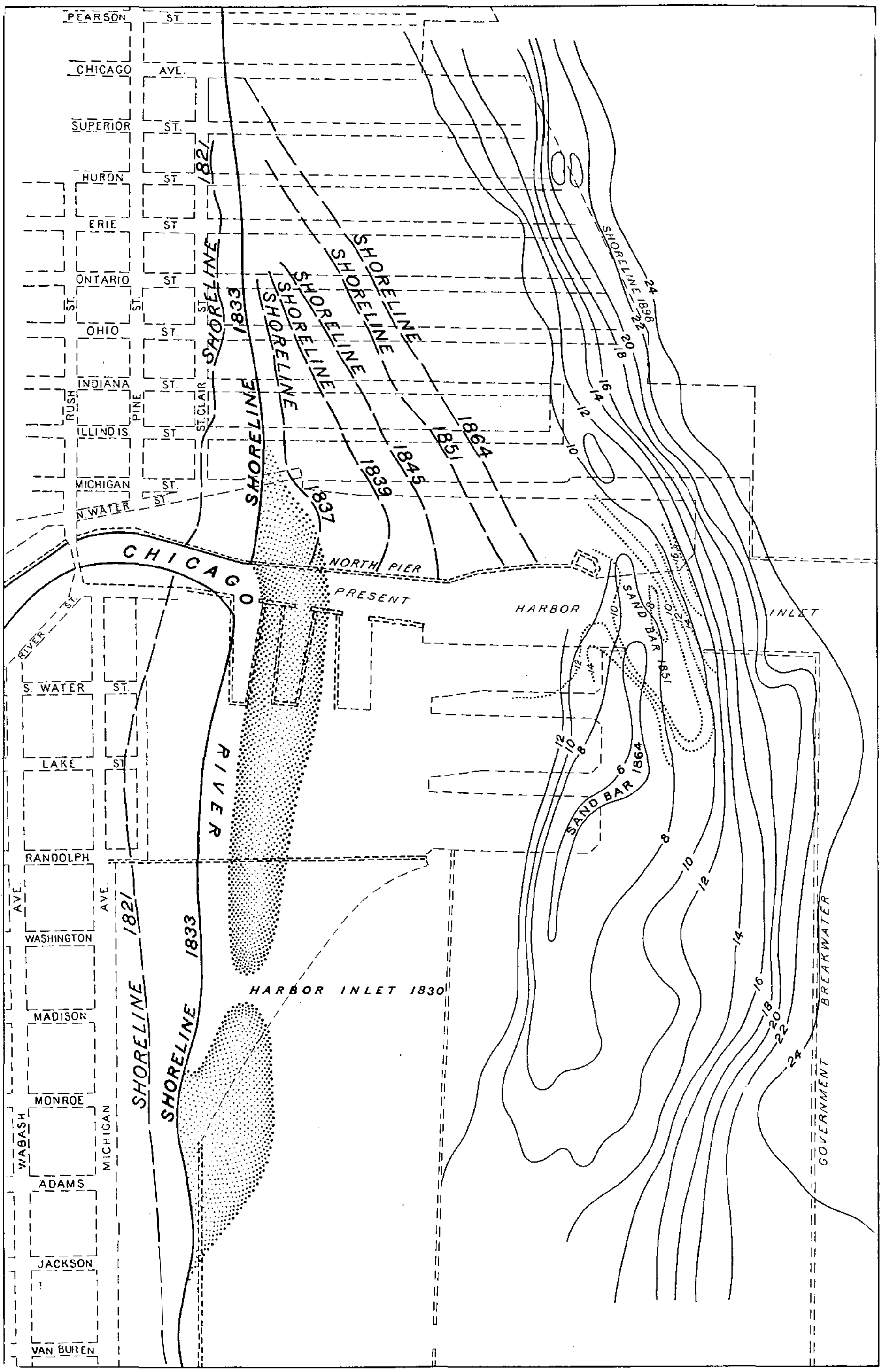


FIG. 30.—Shoreline changes at the mouth of Chicago River. (U. S. Geol. Survey, Geologic Atlas of the United States, Chicago Folio [No. 81], Fig. 13, p. 11, 1902.)

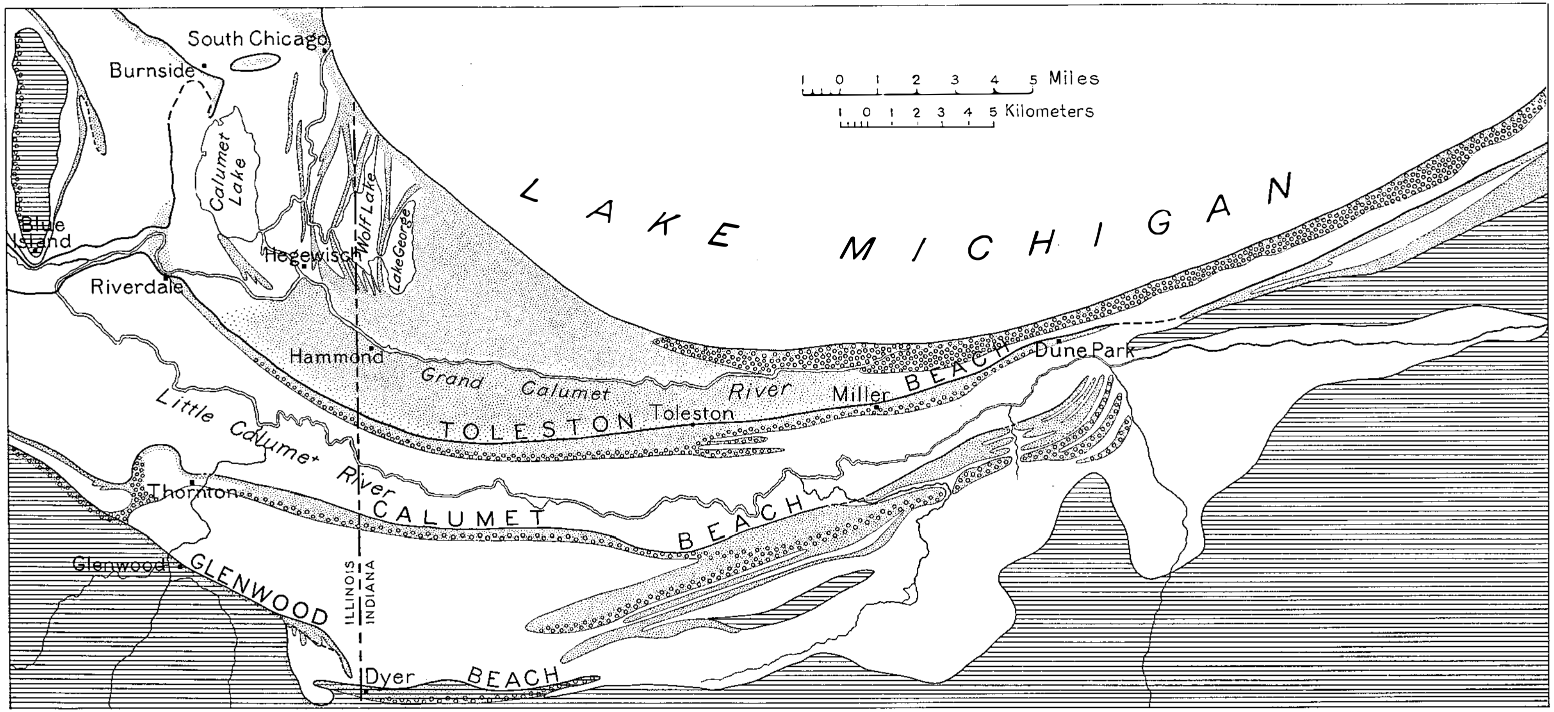


Fig. 31.—Map of Calumet River and its surroundings. (U. S. Geol. Survey Geologic Atlas of the United States, Chicago Folio [No. 81], fig. 14, p. 11, 1902.)

Wind Work

Every Chicagoan with a love for out-of-doors knows the Indiana dunes and recognizes these huge sand hills as accumulations of beach sand blown inland by on-shore winds. Much of the Michigan shore of the lake also has dunes, formed in the same way. But there are almost no dunes on the west shore of Lake Michigan, although sandy beaches, low shoreland, and on-shore winds exist here also and about as many miles of wind per year come off the water as off the land.

It is a weather proverb that east winds bring rain. Meteorologists find the reason in the cyclonic and anticyclonic circulations, so largely responsible for our variable weather. Chicago's on-shore winds are easterly winds which are usually accompanied by rain so that the beach sand is damp, in which condition it will not drift. Northerly winds and most westerly winds are fair weather winds. Beach sands then dry out and in Indiana and Michigan are blown inland to form the magnificent display of dunes extending eastward from Gary completely along the Indiana shore and far north of the Michigan line. The virtual absence of dunes along the Chicago shore therefore seems largely attributable to unfavorable weather conditions when wind directions are right.

However, two dune areas large enough to map occur along the Chicago portion of the lake shore. One is at the lakeward end of 79th Street and extends with an interruption north to 71st Street (Jackson Park quadrangle). The dune features are hardly recognizable today because of building, grading, and park development. The other area is at the east end of Touhy Avenue (7200 north, Evanston quadrangle) where two blocks of park land on the lake shore remain with original topography and vegetation (fig. 32). The sand is heaped into several parallel ridges 10 to 15 feet high, the ridges being successively younger nearer the lake.

FIG. 32.—Low dune ridges in Touhy Park (Evanston quadrangle).

The accounts of the Fort Dearborn massacre tell of Indian ambush behind low dunes along the lake shore a mile or less south of the present Loop, but these dunes have long since disappeared.

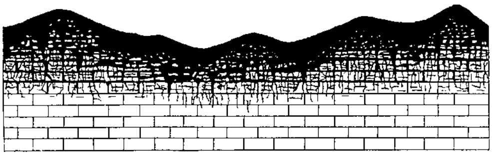
The Chicago region has much more dune sand, piled up in considerably larger masses, than in those areas just described. They are not, however, along the present lake shore but lie some distance inland and their formation dates back to the higher lake levels when discharge was across the present regional divide to the Mississippi. They are described in the historical section.

Summary

Geological changes now in progress in the Chicago region were inaugurated with the final retreat of the ice-sheet and the emergence of the plain by lowering of the lake level. These changes are largely destructional. By chemical and mechanical means present-day agents are removing surficial material and, where concentrated in their action, the land slopes are becoming steeper and the land forms more varied and scenically interesting. These new land forms are being etched or carved from materials deposited during an earlier regime under conditions very different from those of the present. Locally the relief is being decreased by redeposition of material which has failed to travel on beyond the region.

UNCONSOLIDATED MATERIALS AND THEIR TOPOGRAPHY

A superficial mantle of unconsolidated material, spread over hilltop and valley bottom, across upland and lowland, is the rule throughout the earth. It is like a blanket thrown over the topography. Its removal would make little difference with the major relief features except that they then would consist wholly of bare consolidated rock. This cover, known as the mantle rock, is generally the product of weathering, and as it thickens, it serves to protect the deeper rock from weathering (fig. 33).



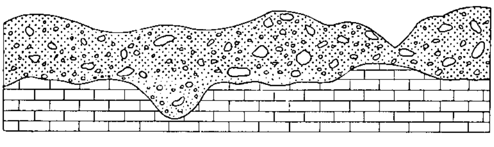


FIG. 33.—Diagrams showing relation of mantle rock and bedrock.

Above—mantle rock is residual soil derived by weathering of the bedrock.

Below—mantle rock is glacial drift deposited on the bedrock.

GLACIAL ORIGIN OF THE MATERIALS

In the northern states, however, the blanket of unconsolidated material is itself unweathered and generally is much thicker than a mantle produced by weathering. Were it removed, the bedrock topography would seldom correspond to the hills and valleys of the mantle itself. This is particularly true in Chicagoland. There are two different topographies here, one of the buried bedrock and one of the superficial material. The metaphor of "blanket" applies here better than in regions where weathering has made the cover, for here a clean-cut separation exists, a sharp contact that is essentially absent under a weather-made blanket (figs. 33 and 34).

Once the cover of mantle rock is removed, as it has been over local areas, another contrast becomes apparent. Much of the bedrock surface shows marks of tremendous abrasion—planed-off surfaces that are grooved, scratched (striated), perhaps polished, the grooves and scratches parallel with each other and in the Chicago area directed very nearly northeast-southwest. Fragments of the local bedrock, themselves bearing similar marks (fig. 35), constitute a large proportion of the mantle rock and indicate that the unconsolidated debris was obtained by the same agent which planed and scratched the bedrock surface. The overlying material seems, therefore, to be the actual abrasive, left in place when the work was completed. The abrading agent has disappeared and its nature must be learned from the clues it left behind. The problem is a kind of detective story, lacking only the elements of "guilt" or "innocence" and of human interest in motives.

The striae in the underlying bedrock indicate that the agent moved either from the northeast or from the southwest. Fragments of rock foreign to the region, but traceable

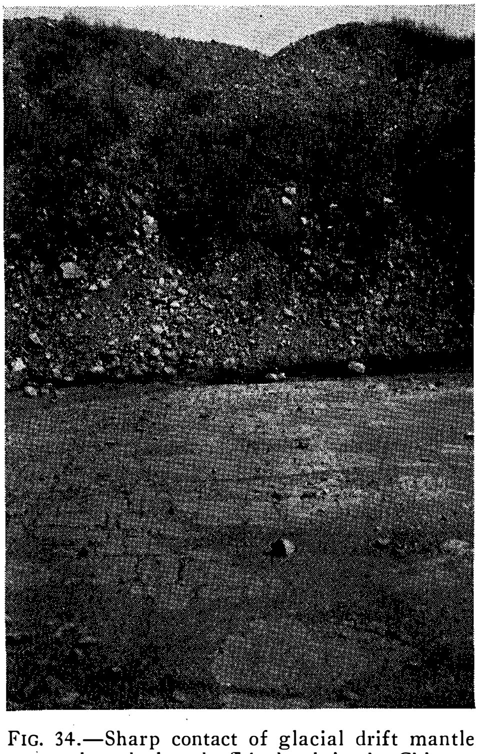


FIG. 34.—Sharp contact of glacial drift mantle rock and planed-off bedrock in the Chicago region.

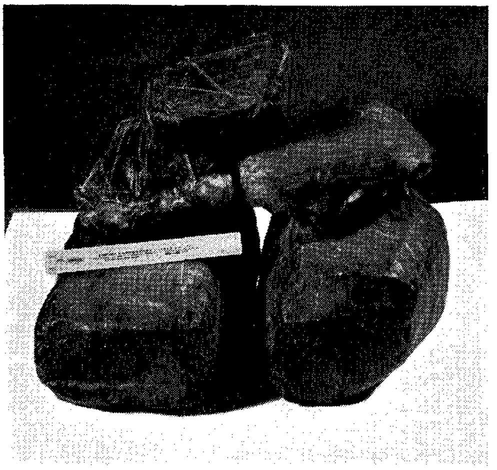


FIG. 35.—Striated boulders from the Chicago glacial drift.

to outcrops about Lake Superior and farther northeast, eliminate the possibility of derivation from the opposite direction. The unweathered nature of the deposit suggests that the work was done either too rapidly for weathering to occur or else under a cover which prevented atmospheric attack. The irregular surface of the deposit, particularly its enclosed basins, proves it to be a "dump" deposit, not sorted and aggraded bit by bit as are stream and shore deposits. The complete lack of assortment, boulders and clay occurring together, is further evidence for this conclusion. The thickness of the debris (a maximum of 216 feet being known in a well on Ridge Road in the Highmoor district of Highland Park) argues for ability of the causal agent to move enormous weight. One square mile of the material, 10 feet thick, weighs more than 20 million tons, yet it assuredly has been moved *en masse* in much greater thicknesses than this. The uninterrupted spread of debris shows that the agent covered the entire region. The broad north-south ridges of the material indicate successive marginal accumulations. Their parallelism with the edge of the lake basin suggests that this basin determined the outline of the agent responsible. The existence of an upgrade out of the basin, in the direction of movement, proves that this agent was able to move up regional slopes. The agent was so thick or deep that the relief of the underlying bedrock surface was of trifling consequence. Yet if gravity were the moving force, that agent must have had a general downhill movement. The only "downhill" possible was its own surface. Great thickness or depth is again implied.

The items above listed rule out every agent now operating in the region. The features are so peculiar that early attempts to explain the origin of "drift" called for purely fanciful catastrophes. One, for example, postulated a tremendous earthquake beneath the Arctic Ocean, producing an inconceivably enormous wave which swept southward across half the continent. Icebergs carried in this debacle, dragging bottom, made the records of great abrasion. As late as 1873, a report of the Illinois Geological Survey[1] indicates the origin of the "drift" to be unsolved and perhaps an unsolvable problem.

Arctic and alpine explorations since have made us familiar with thick masses of land ice, or glaciers, slowly moving under gravitative pull. They originate where snowfall is in excess of melting and evaporation, so that each year sees an additional thickness of snow. Compaction under its own weight and from partial melting and refreezing during the accumulation changes this snow into ice, and when thick enough, movement of the mass begins. Some western mountains in the United States possess glaciers today although they are simply ice streams in the valleys. The continent of Antarctica, however, carries an almost complete cover of ice and snow, estimated at about four million square miles in area. Greenland has the largest single expanse of ice and snow in the northern hemisphere, covering more than half a million square miles. On both these large land areas, the ice moves radially outward from central higher tracts. The Greenland ice is especially instructive because it moves in terms of its own surface slope. The land is known to be actually lower under the central part of the ice than along the margin. The maximum known thickness of the Greenland ice 250 miles in from the edge is 8800 feet (about 1 3/5 miles). The surface of the ice, on the other hand, rises inland to an altitude of nearly 10,000 feet above sea-level in this distance.

If we did not actually know that such enormous accumulations of ice-from-snow do

[1]Shaw, James, The geology of Winnebago Co., in "Geological Survey of Illinois," by A. H. Worthen, and others, vol. V, 1873.

exist, or did not know that the existing ones spread slowly outward because of their own weight, we might still be saying as James Shaw said in 1873, "we shall never perhaps positively know" how the drift in the northern states was formed. But now we know that it was formed by an ice-sheet or glacier of enormous thickness and weight, covering very large regions, moving slowly but resistlessly across the ups and downs of a buried land surface, and carrying a great load of detritus which it used as tools to abrade the rock mechanically. We know that the position of the terminus of valley glaciers and ice-sheets on land is caused by a balance between rates of advance and rate of melting, that at such places the vanishing ice drops its load along its margin, and that in a few decades or centuries, great ridges or moraines accumulate whose topography, composition, and relationship to the underlying planed-off rock closely resembles those of the Chicagoland drift deposits. The back slopes of the marginal moraines descend to surfaces with less relief but with unsorted glacial drift beneath them and with undrained hollows on them. They are almost as definitely ice-made as the marginal ridges themselves. This lower and more softly moulded drift topography is called "ground-moraine," being largely deposited while the ice edge was retreating from the marginal deposit. All but one of the six marginal moraine ridges of Chicagoland have an area of ground-moraine behind them (on the lakeward side). Such lower surfaces of ground-moraine are especially subject to modification by water from the melting ice.

Geologists no longer differ on the problem —most of the unconsolidated deposits of the northern states are now accepted as glacial in origin. Running water from the melting ice made some modifications in the surface deposits at the time, as also did ponded water in front of the ice. These are but details, however, of the general process. Study of the glacial drift and glacial striae in the northern United States and Canada has shown that the ancient ice-sheet had two principal centers of growth, one east and one west of Hudson Bay, and that ice radiated from these centers (fig. 36) much as it does from the Greenland and Antarctic ice-sheet of today. In its southward spread into the Great Lakes region, marked longitudinal depressions (like that which is now

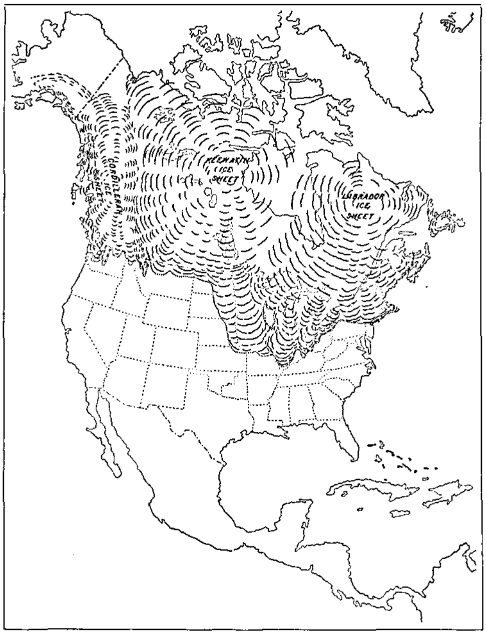


FIG. 36.—Sketch map showing the North American area covered by ice at the time of maximum glaciation.

the basin of Lake Michigan) considerably influenced the shape of the margin and the direction of flow. In Michigan, Indiana, Illinois, and Wisconsin (fig. 37) the moraines near the lake form roughly concentric loops about the southern end of the basin and this pattern records a pronounced lobation of this part of the ice margin. The outermost of the concentric moraines is the oldest. The inner ones are successively younger. The areas of ground-moraines between the moraines record stages of fairly rapid retreat of the lobate glacial margin (melting more rapid than feeding forward of the ice). Amelioration of the climate, by which the ice was being cleared from the region, obviously had pauses in its progress.

VALPARAISO MORAINE

The largest and highest of these concentric moraines in Chicagoland can be traced southeastward from our area (Pl. I) into Indiana, thence eastward and northeastward into Michigan, nowhere being more than 20 miles from the lake. It is known as the Valparaiso moraine because of its marked expression in the region of that Indiana city. The outer border of this moraine is a few miles to the west and south

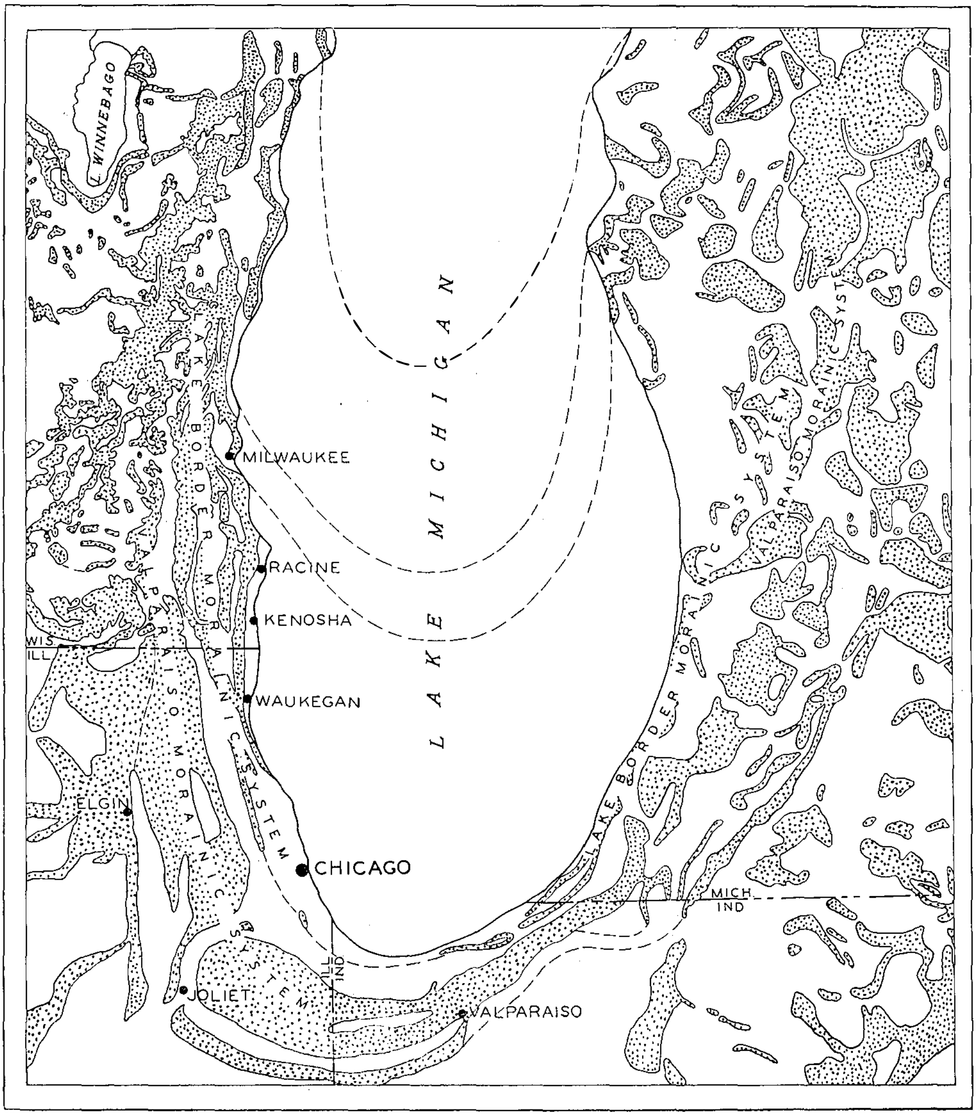


Fig. 37.—Lobate distribution of glacial moraines around the southern part of Lake Michigan. (After Leverett, Alden, and Weidman, U. S. Geol. Survey Prof. Paper 106, Pl. XXIII, 1918.)

of the Chicago area (fig. 37). The inner border is indefinite, the upland descending eastward with very gradual diminution of relief into the ground-moraine plain.

The Valparaiso moraine is not a simple broad ridge but a complex arrangement of hills and depressions, the sum total of which constitutes several parallel broad ridges and elongated hills, basins, and valleys. Its character is perhaps best shown by the series of profiles across the Valparaiso and Tinley moraines (figs. 38, 39).

The width of the Valparaiso moraine is generally 10 to 12 miles. Its highest point within the twenty quadrangles of the Chicago area is near the head of Fraction Run between Lemont and New Lenox (in the western part of the Mokena quadrangle), and is 800 feet above sea-level, 219 feet above Lake Michigan, and 100 to 125 feet above the plain at the base of the moraine. Farther northwest toward Barrington, it is more than 900 feet above sea-level.

The moraine in our area lies almost wholly within the Mississippi River drain-

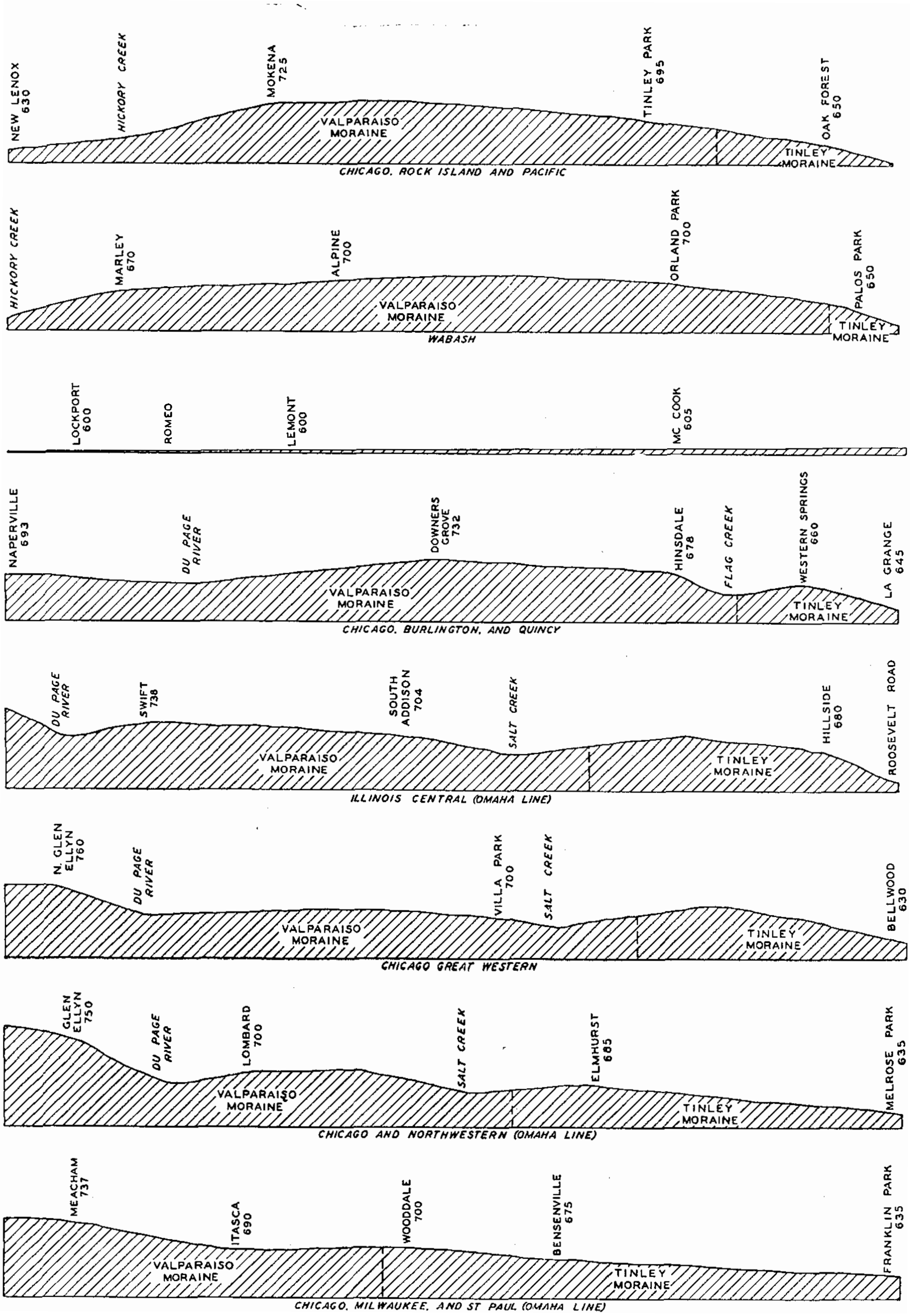


FIG. 38.—Cross-section railroad profiles across the Valparaiso and Tinley moraines. The third profile is that of both the Atchison, Topeka, and Santa Fe and the Alton railroads.

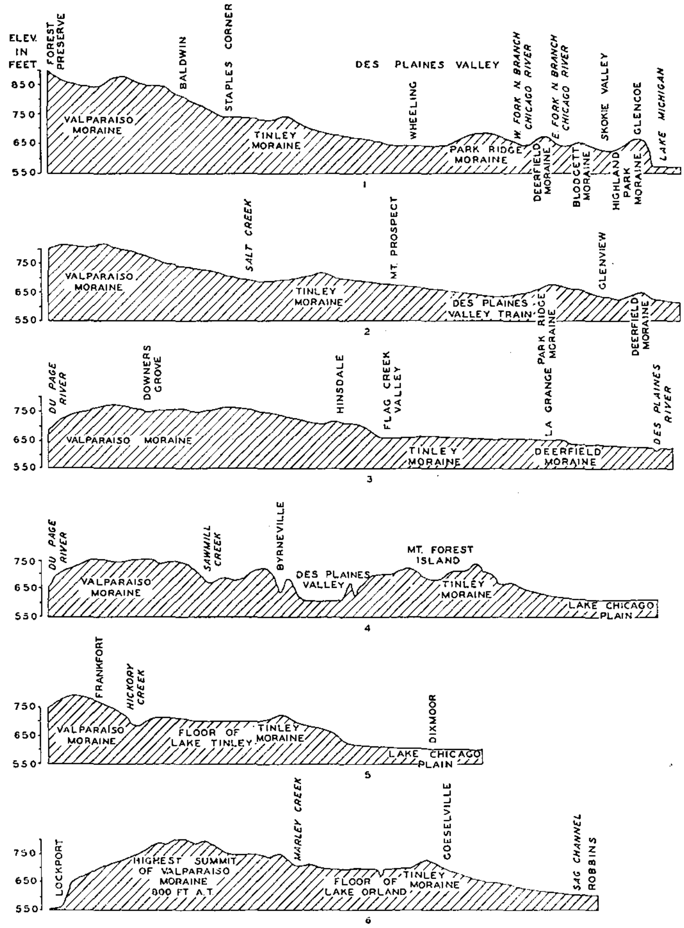


FIG. 39.—Cross-section profiles along highways across the Valparaiso and other moraines.

1. East-west profile along Dundee Road.
2. East-west profile along Central Road.
3. East-west profile along Ogden Avenue.
4. East-west profile along 95th Street.
5. Northeast-southwest profile along southern Old Indian Boundary.
6. Approximately east-west profile across the country traversed by 151st and 159th streets.

age system, only a few square miles of its southern part draining to Lake Michigan. DesPlaines River as far downstream as Riverside and Lyons, flows east of both the Valparaiso and Tinley moraines and parallel with them. Salt Creek, except for the last few miles, flows between the Valparaiso and Tinley moraines. Sag Channel and DesPlaines Valley west of Argo are cut entirely across the two moraines, and for much of the way, each has been eroded down to bedrock. Mt. Forest Island, a part of the moraines, has thus become completely isolated from the rest of them.

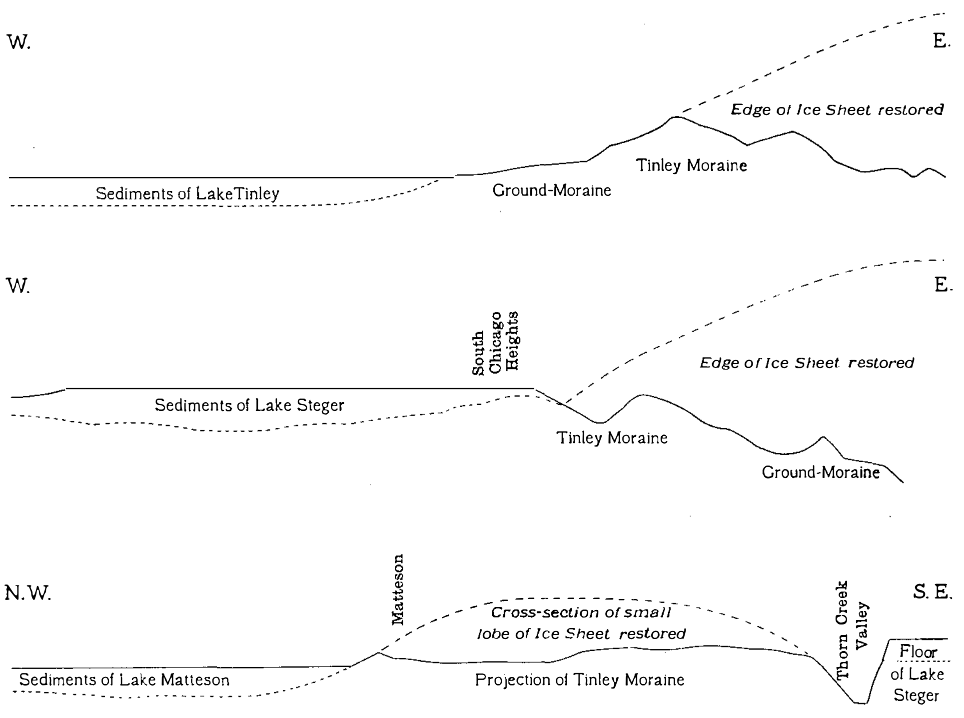


FIG. 40.—Profiles across Tinley moraine and some of its associated lake beds. *Upper*—Along 183rd Street, Tinley Park and Harvey quadrangles. *Middle*—Along Sauk Trail and Old Lincoln Highway, Steger and Dyer quadrangles. *Lower*—From Lake Matteson to Lake Steger.

Lakes Between the Valparaiso and Tinley Moraines

In the south part of the region, particularly in the Tinley Park quadrangle, the Valparaiso ground-moraine includes extensive flat or very gently undulatory areas underlain by stratified pebbleless clay and silt. Four such separate areas are mapped (Pl. I) in the Palos Park, Tinley Park, Harvey, Steger, and Dyer quadrangles, comprising a belt of lowland between the Valparaiso and Tinley moraines and elongated with their trend. The margins of the flats as drawn are very irregular and cannot be identified by topographic features. The areas of ground-moraine which separate and interrupt the stratified clay flats are themselves almost as featureless, but they differ in being composed of unstratified glacial material (till), in having a few boulders scattered about on the surface, and in possessing shallow undrained depressions.

This belt of flat lowland was once a string of shallow lakes. Each of the four separate lakes had its own outlet to the west and each has been filled up to the level of that outlet with clay and silt. None of the outlet routes had sufficient gradient to suffer trenching, and none of the four lakes disappeared by being drained out westward. Each of the four shallow basins now has free drainage to the east through youthful valleys that are trenching through the Tinley moraine.

These lakes, named Orland, Tinley, Matteson, and Steger, first appeared when the ice was building the Tinley moraine. Its irregular crest is generally lower than these flats. Four low places in it have been occupied by postglacial streams and eroded considerably lower. But even if there were no stream-cut valleys across the Tinley moraine ridge, no lakes could exist there today. It follows, therefore, that these four lakes existed when, and only when, the ice front rested on the Tinley moraine and made an effective dam. In figure 40 only the middle profile is so located that a lower surface of the moraine to the east is shown.

There is further evidence that these lakes disappeared when the Lake Michigan lobe of the ice-sheet withdrew from the Tinley moraine. No cut or boring in the stratified deposits has shown a trace of organic material, although such traces are common in all postglacial lake sediments. In a few places along the contact of lake flat and Tinley moraine, glacial till actually overlies the lake clay. It appears from this that a slight readvance of the ice front occurred after the lake history began.

Streams from melting glacial ice are about the muddiest streams on earth. Certainly the ice which deposited the clayey drift of Chicagoland must have yielded very dirty water. This seems to have been the source of the sand, silt, and clay which filled up these shallow basins of the Valparaiso ground-moraine south of Sag Channel. The lakes probably were huge mud puddles, unattractive to anyone but a geologist.

Tinley Moraine

The Tinley moraine, mapped by a separate pattern, is distinct from the Valparaiso morainic system because it was built after the ice had retreated an unknown distance and then readvanced, encroaching upon the Valparaiso moraine. Its position back from the main part of the Valparaiso moraine in the southern quadrangles not only allowed room for but created Orland, Tinley, Matteson, and Steger lakes on an area that would be otherwise all Valparaiso ground-moraine. Farther north (Hinsdale and Elmhurst quadrangles) the sag between the two moraines is narrow and looks, with Salt Creek flowing along it, somewhat like a stream valley. The intermorainic sag here had free drainage southward and no lakes are known to have existed.

The southeastern portion of the Tinley moraine is least well differentiated. It fails to continue south of Flossmoor and Olympia Fields (Harvey quadrangle) as a ridge or belt of hill-land. Lakes Matteson and Steger were separated by some barrier other than the land surface between them as it is too low to serve the purpose. A protuberance of the Tinley ice-front seems to be the only explanation, and the Tinley moraine is therefore drawn to include the region of Richton Park. (Pl. I. See also the third cross section in fig. 40.) In South Chicago Heights and Steger (Dyer quadrangle) the Tinley moraine is again a definite upland separating Lake Steger flat on the west from Deer Creek Valley on the east. Farther east in the Dyer quadrangle, however, the mapping of the moraine is more conjectural than in any other place in the region.

Glacial Stream Deposits

The ice-sheet that once covered the Chicago area disappeared largely by melting as the climate became warmer. Melted ice must be disposed of either as water-vapor or as running water, and such running water can escape only by flowing away from the wasting ice-sheet across the debris-covered country the ice has already abandoned. If the sheet of debris (ground-moraine and marginal moraine) is not thick enough to obliterate the pre-existing topography, the escaping meltwater will very likely follow the larger preglacial valleys. This is what happened on parts of the Valparaiso moraine in our area. The evidence for it, however, is not of the character that one would at first expect.

Streams born of glaciers are commonly overladen. They deposit their excess load, consisting of the coarser debris, in their channels. With channel capacity thus decreased, they overflow to less aggraded places in the valley bottom, in turn abandoning them as the deposition continues. Thus a uniform sheet of gravel and sand is spread from side to side, making a relatively flat-surfaced fill (valley-train) perhaps many feet thick and extending down valley many miles beyond the ice. After the glacial episode is closed the streams of normal run-off take possession of the valley and, far less embarrassed by load, may trench into the glacial river deposit, perhaps eroding away a good share of it and leaving only terraces or benches of gravel along the valley sides to record the originally continuous fill. These are common relationships of glacial streams to preglacial valleys and of postglacial streams to the glacial stream deposits.

Kame Terraces

Now many westward-draining valleys of the Valparaiso moraine do contain deposits of stream gravel, too extensive and too high up on the slopes to have been deposited by present streams. But this gravel is not in terraces. It occurs in mounded and ridged forms, heaped up 10 to 40 feet high, the hillocks and hills enclosing originally undrained depressions, the accumulations patchy instead of continuous, and essentially

FIG. 41.—Kame-terrace knolls in the valley of Long Run (Sag Bridge quadrangle).

FIG. 42.—Tiedtville esker (Sag Bridge quadrangle).

piled up on the glacial till of the valley slope. Glacial stream gravel (outwash) it surely is, but with equal certainty it never was a part of a uniform valley-train fill.

To explain these irregular piles of glacial stream gravel on the slopes of pre-Valparaiso valleys, we invoke the presence of ice in the valleys at the time of their deposition. The front of the retreating ice-sheet was not uniform—the ice melted more rapidly on the exposed hilltops, it lingered long in the protected valleys. Thus water escaping westward found either elongated projections of the ice-sheet or, more probably, abandoned ice masses in these valleys, stagnant and separated from the main mass. Over, around, and among these wasting remnants, the glacial water flowed. Greater melting along contact with valley slopes located channels prevailingly along the valley margins. Deposits from these excessively loaded streams occurred in favorable places between the ice masses and the land. By the time the ice blocks had melted out, the glacial streams had ceased to flow and the gravelly debris was left as low hills and ridges where the hollows had been. Such deposits are called kame terraces (fig. 41). The places that were occupied by the ice blocks are now depressions.[2].

The maps show kame terraces (symbol for kames and eskers) in Hickory Creek valley (Tinley Park quadrangle), Hickory, Marley, and Spring valleys (Mokena quadrangle), and Long Run and DesPlaines River valleys (Sag Bridge quadrangle). In all except the DesPlaines valley striking constrictions of the alluvial flats are produced by some of these deposits. As the present streams have only begun to remove these obstructions, they clearly did not make the valleys. The obstructions, of glacial age, prove the valleys to be older than the moraine building. These conclusions are supported by the occurrence of other constrictions, due to moraine hills instead of kame terraces, and by incongruous widenings, some of them swamp-filled completely across the valley.

ESKERS

Glacial stream deposits along the northwest wall of DesPlaines valley and southwest of Willow Springs have several significant features. Most of them are ridges either elongated parallel with the valley wall or gradually descending that wall toward the southwest (downstream). They are not composed wholly of gravel; the up-valley, higher ends of the ridges commonly consist of clayey till which grades into stratified gravel toward the lower or southwestern ends. The largest of these ridges is half a mile long. It lies 1½ miles southwest of Willow Springs and half a mile north of Tiedtville (Sag Bridge quadrangle). A part of its crest is shown in figure 42. Its highest point, near the north end, is nearly 75 feet above the floor of DesPlaines Valley, its south end is only 10 to 15 feet above. The high part apparently is all till and except for having steep slopes and a marked ridge form, it seems to be simply a part of the general moraine topography.

All of these ridges are apparently the product of combined glacial ice and glacial water. They may owe their form to the existence of major cracks or fissures (crevasses) determined by the pre-existing steep

[2]Another explanation for these gravelly knolls is that the preglacial valleys were subglacial drainage lines along which glacial waters concentrated, due to subglacial slope and crevassing, and that there was rapid melting of the ice.

valley-slope here beneath the thin edge of the waning ice-sheet. Glacial debris collecting in these cracks was partially sorted over by water which utilized the crevasses as channels. The ridges appear to have been successively formed, the youngest being farthest northeast.

Ridges of morainic gravel also occur on the Valparaiso moraine where no buried topography appears to have determined their location. One such ridge is a quarter of a mile from Mammoth Springs (Hinsdale quadrangle), or about 1½ miles south of Villa Park business district. Another is at Halfday, on Milwaukee Avenue (Wheeling quadrangle), and a third is on the south side of Sag Channel, about two miles east of Sag Bridge (Sag Bridge quadrangle). All have gravel pits in them, the material showing that glacial stream water was a factor in their origin. Yet all have till also, the first having in one place 4 feet of unwashed till on top of the gravel. Ice certainly was present when they were deposited. Only ice in motion or overlying ice which had been in motion, would put till on top of the gravel. The last ridge is elongated almost at right angles to the valley wall instead of being nearly parallel like those north of DesPlaines valley and its southwest end is 65 feet higher than the valleyward end. It is composed of gravel at the lower end, though most of it consists either of till or of gravel with a deep cover of till.

These sharply ridged forms, containing considerable glacial stream gravel, seem to belong to a class of deposits called *eskers*. Typical eskers are composed largely or wholly of gravel. They are generally considered to be the product of streams flowing at or close to the bottom of the ice-sheet, in tunnels that started in crevasses which became enlarged by melting as the somewhat warmer water flowed through them.

KAMES

Still another type of morainic gravel deposit is to be considered before the subject is closed. Two good examples lie 4½ miles west of Wheeling (Wheeling quadrangle) and half a mile north of Dundee Road. Each is a hill of gravel standing from 25 to 40 feet above the surrounding undulatory moraine surface. Two pits opened in the northern hill expose gravel containing much clay and fine sand, showing that the sorting action of glacial water greatly reduced the percentage of clay in the normal till, thereby concentrating the coarser debris, but not washing it clean. Another example of this type of glacial stream deposit is half a mile south of Joliet Road (State Highway No. 66) in the northwest quarter of Sag Bridge quadrangle, two miles north of DesPlaines River. Topographically it is not to be distinguished from the rest of the moraine by steeper slopes or greater height, but two pits show that the hill is composed of gravel, nearly or quite to the surface. In one place, 5 feet or so of till overlies the gravel.

Hills like these, not notably elongated into ridges yet surely recording the work of meltwater escaping from the ice, are thought to have been built up where streams emerged from the fissured and irregular edge of the retreating ice-sheet. The essential conditions for their origin are discharge of the stream into a marked re-entrant of the ice edge (probably an enlarged crevasse) and a notable decrease in gradient at the point of escape. The hills are called *kames* and are more closely related to alluvial fans than to any other normal stream deposit.

Where streams of meltwater plunge from the glacier's surface into crevasses before reaching the margin, great well-like tubes become melted out by the falling water. In the bottoms of these, water-washed material may accumulate to considerable depth. After the ice has vanished, such fillings will be left as sharply conical hills of sand and gravel, called *moulin kames*.

PROBLEM OF THE PRE-VALPARAISO VALLEYS

An interesting question concerns the stream-made valleys that are definitely older than the kame terraces and esker ridges on their slopes. In what material were these partially obscured pre-Valparaiso valleys eroded? One thinks immediately of the underlying limestone but finds on examination that bedrock is only rarely exposed in the stream floors and is seldom found in upland wells, even those as deep as adjacent valleys. The bedrock has no relief features corresponding to these pre-Valparaiso valleys and their divides. One finds, however, in highway cuts and stream-eroded bluffs, that the clayey Valparaiso till (the direct deposit of the ice) is surprisingly thin, on hilltops and on valley slopes alike. The till is essentially only a veneer, in many places not more than 10 feet thick, and under it is a distinctly different kind of glacial drift. It is in the underlying drift that the pre-Valparaiso valleys have been eroded.

The best exposures of this lower drift are in the abandoned quarries a mile or so west of Lemont, just outside the Chicago area[3] but there are numerous good ones along and near Sag Channel and along DesPlaines Valley west of Argo (Sag Bridge and Palos Park quadrangles).

This older drift beneath the Valparaiso till is strikingly free from clay, its finest material being a silt or very fine sand. Its oxidized parts are distinctly lighter in hue and yellowish rather than brownish. It has a large percentage of stratified material in it, so much that one hesitates to call it a till. Yet typically unstratified till with an abundance of ice-marked pebbles is intimately associated in many exposures with the water-handled, stratified material. The till itself is far more stony than the overlying Valparaiso till, although almost entirely lacking in the pebbles of shale (consolidated mudstone) that are abundant in the Valparaiso till. From the excellent exposures near Lemont, this glacial and aqueo-glacial deposit is named the Lemont drift. It is a record of a pre-Valparaiso glaciation. Following this was an interval of stream erosion before the Valparaiso glaciation occurred. The Valparaiso ice over-rode the Lemont drift much as though it had been bedrock, and the height of the Valparaiso moraine (at least in the Sag Bridge quadrangle) is mainly an expression of the thickness of the Lemont and not the Valparaiso till.

MAPPING OF CONTACTS

Perhaps the reader, while scanning the maps referred to in this report, has wondered at the apparent precision with which the boundaries between different formations and deposits have been drawn. The author has similarly wondered how he dared show some of these contacts by lines. On the map they look as definite as fence lines. Many of them are just that definite in nature but many others are simply gradations. Particularly is the latter true of the contact between marginal moraine and ground-moraine. For example, the Tinley moraine boundaries are indefinite contacts even though lines have been used. The endeavor has been to include the higher and more steeply sloped morainic topography in the marginal moraine. In places this makes the outline very irregular. Elsewhere, there is complete gradation, with no change in slope from the highest part of the marginal moraine to the lowest part of the ground-moraine, and here the location is simply a matter of opinion. For the gradations of nature, we choose to use lines which show our ideas of genesis and relationship. A geological map cannot have the precision of a photograph. The reader who checks over any part of these maps in the field must permit the geologist one of the privileges of an artist. The map is a picture in which interpretations as well as objects are shown.

SALT CREEK AND FLAG CREEK VALLEYS

One peculiar drainage feature of the Valparaiso and Tinley moraines in our area is the course of Salt Creek. It has already been described as following an intermorainic sag, not a stream-eroded valley. This it does from its head near the northwest corner of our area, southward across the Elmhurst quadrangle to the middle of the Hinsdale quadrangle. About a mile north of the business district of Hinsdale, the creek turns abruptly eastward, leaves the sag, crosses the Tinley moraine, and joins DesPlaines River some miles farther east near Riverside and Lyons (fig. 43). But the morainic sag, largely occupied by Flag Creek, continues southward for six miles to join the DesPlaines valley north of Mt. Forest Island. If Salt Creek had followed this sag direct to DesPlaines River, its route would have been 13 miles shorter. In this detour to the east and back again as a part of the DesPlaines, its waters flow three times as far as appears to have been necessary. If the sag were followed all the way, the creek would have a fall of nearly seven feet per mile from the moraine transection to the river. The gradient of its waters now between these two points is actually about two feet per mile.

Did Salt Creek ever use the shorter route, the Flag Creek part of the morainic sag, and has there been a shift to a longer and less steep gradient? Piracy certainly has not occurred here, for that procedure always

[3]The exposures may be located by reference to the old quarry dumps on the south side of DesPlaines Valley, eastern part of Joliet quadrangle, shown in red on Plate I, Bulletin 51 of the Illinois State Geological Survey, "Geology and Mineral Resources of the Joliet Quadrangle," by D. J. Fisher.

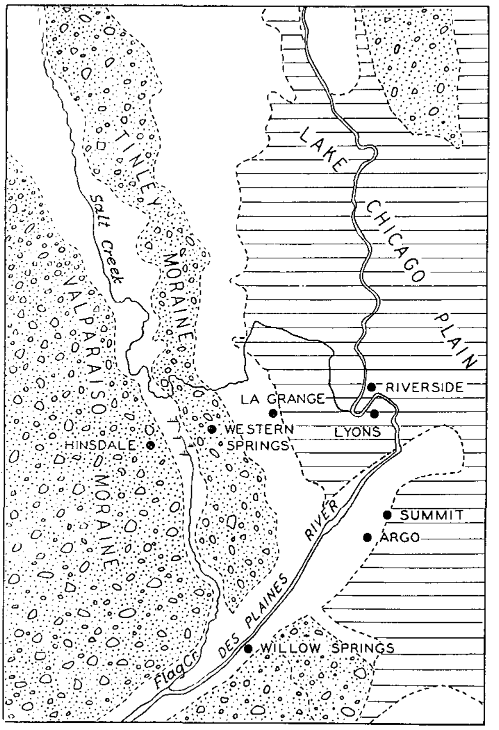


FIG. 43.—Sketch map showing the relationship of Salt Creek, Flag Creek, and Des Plaines River.

gives steeper grades and generally makes shorter courses.

The moraine is extraordinarily low at Salt Creek crossing. A dam here, as high as the valley is deep, would not divert the creek along the shorter Flag Creek route without the aid of a ditch at least five feet deep and a mile long. The floor of the Flag Creek sag is actually higher here than the summit of the moraine. Furthermore, the topography in the sag is itself morainic, the material in the low knolls is glacial till and in the depressions among the knolls it is clay and muck resting on glacial till. There is no abandoned channel across the tract to record its use by the creek. It seems obvious that Salt Creek never has used the shorter route which appears, on first inspection, to be so invitingly open.

Defeated in this attempt to find the plausible looking valley a postglacial streamway, one may recall the four lakes of the moraine sag farther south. The ice-sheet served, in part, for the retention of their waters. At the same time, the ice-front rested on the Tinley moraine north of Mt. Forest Island as well as south of it. A water way across the moraine north of Western Springs was not then possible. And glacial water there was, for the ice certainly did not all disappear by evaporation. One may ask therefore if a glacial river ever occupied the full length of the sag north of the DesPlaines River. The sag contains no kame terraces like those in the valleys of the Mokena and Sag Bridge quadrangles. Is there a valley-train, an aggraded "flood plain", of a glacial Salt Creek?

There are three stretches along this valley where record of a valley-train may be sought. One part is the upper Salt Creek valley portion where postglacial erosion might be expected to have removed part of it; the second is the streamless tract between Salt and Flag creeks where it should be present essentially as deposited; and the third is Flag Creek valley where postglacial deposition might have buried it under peat, muck, clay, and silt.

Dozens of borings along the Salt Creek portion have shown only glacial drift outside the present floodplain. Within the limits of this narrow, crooked meander belt, the upper three to six feet of material consists of alluvial clay, sand, and fine gravel, with many fragments of woody material—clearly a postglacial deposit. Below this in some places is a poorly sorted fine gravel that may be considered either as an earlier deposit of Salt Creek or as glacial river gravel. It certainly does not record a large stream. The Salt Creek portion has no mappable valley-train.

On the sag floor between Salt Creek and the marsh at the head of Flag Creek, no gravel has been found. The floor is gently rolling, the underlying material is till alone or is till beneath basin deposit. There is no valley-train here.

The head of the Flag Creek valley was trenched for three miles at the time of this study, the trench being made for the sewer system of Hinsdale, Clarendon Hills, and Westmont. The excellent exposures showed two to five feet of alluvium and swamp material resting in some places on till and in other places on gravel, sand, and silt. Bedrock crops out in the valley bottom half a mile south of the disposal plant. It was also encountered at several places during the excavation of the trench and presumably is not far below the limit of the trench elsewhere. The stream material in the floor of

Flag Creek valley is doubtless relatively thin everywhere. It also is relatively fine material and so does not record a vigorous current. Yet it can not be a deposit of the present creek because the marsh at the head of the valley is underlain by the same sort of material. The sand, silt, and fine gravel on the bottom of this valley hardly seems to deserve the name of valley-train, although it must have been deposited by a glacial river. Its record is somewhat comparable with that of the outlets of the four lakes of Tinley age south of the Sag Channel. Thus one concludes that melting at the Tinley morainal stage was not very rapid and that the discharge here made only an insignificant glacial river.

Region East of the Tinley Moraine

The Valparaiso and Tinley moraines extend completely across the southern end of the Chicago area and completely along the western side. No other topographic element of the region possesses such areal extent. Between the Tinley moraine and Lake Michigan are several prominent features of varied character.

The most marked and most extensive land form east of the Tinley moraine is the Chicago plain. Neglecting smaller areas which are only interruptions in it, the plain reaches from the Tinley ground-moraine to the lake shore everywhere except in the north where a series of four marginal moraines with intervening sags takes its place. They are, of course, younger than the Tinley moraine, as is the plain itself. Interrupting the plain, really protruding through it, are some elevations of glacial drift and of bedrock. Also interrupting it but really superposed on it are numerous low ridges of sand and gravel. These sand and gravel ridges are subparallel with the lake shore, as are most linear features of the Chicago region, but they also converge roughly funnel-like westward toward the two valleys bounding Mt. Forest Island and crossing Tinley and Valparaiso moraines. Just as the varied features of the Valparaiso and Tinley moraines are closely related in origin and easy to understand when one has the key, so there exists in all this complex east of the Tinley moraine a simple genetic relationship. Let us consider first the northern part.

LAKE BORDER MORAINIC SYSTEM

There are four broad, low moraines in the northeastern part of the Chicago area, all composed of clayey till identical in appearance with the Valparaiso and Tinley tills, all roughly parallel with the lake shore on the east and with the Tinley moraine on the west, all descending to lower elevations southward, and all projecting into the lake plain where they end. The separating sags are all occupied by southward-flowing streams and are really reciprocal projections of the plain dovetailing with the tips of the moraines.

These four broad low marginal moraines constitute the Lake Border morainic system (pl. I). The system is recognized (though not with the same number of members) along both the east and west sides of Lake Michigan, just as is the older Valparaiso moraine. The southward termination of these ridges in Chicagoland and their essential absence around the south end of the lake is a curious thing. The ice edge certainly lay across the moraineless area when the existing members of the system were built. Either no moraines were ever made or they have since been obliterated—the problem will be discussed again when the plain itself has been considered.

Drainage control by the Lake Border ridges is very marked. DesPlaines River enters the Chicago area from the north in the lowland between the Tinley moraine and the outermost member of the Lake Border system, the Park Ridge moraine. It continues southward along the lowest part of the Tinley ground-moraine to River Grove and Franklin Park, a distance of 22 miles, where, the Park Ridge moraine ending, the stream enters the Chicago plain. Still flowing southward in a very shallowly entrenched course across the plain it enters the head of the deep valley on the north side of Mt. Forest Island, in which it flows southwestward across the Tinley and Valparaiso moraines and out of the region.

Along the northern margin of the Chicago area, the Park Ridge moraine is fused with the next moraine to the east, the Deerfield, but about two miles south of this margin a slight sag appears and, increasing in depth and width farther south, separates the two moraines. Run-off that gathers in it gives rise to the south-flowing West Fork of North Branch of Chicago River which, at the southern tip of the Deerfield moraine, is joined by East Fork to make North Branch. Four miles south of the tip of the Deerfield moraine North Branch turns southeastward across the Chicago plain and finally enters the lake, or did before the flow of the river was reversed in the heart of the city. East Fork of North Branch, which heads just north of the Chicago area, utilizes the depression between the Deerfield and Blodgett moraines. The Blodgett moraine is the smallest member of the system and terminates at Northfield. East Fork is there joined by Skokie River, which flows southward along the sag between the Blodgett and Highland Park moraines. Both Skokie River and East Fork swing away from the lake before becoming a part of North Branch. This is owing to a large sand and gravel accumulation on the Chicago plain south of the three eastern moraines of the Lake Border system.

All of these stream courses are determined by pre-existing relief features and the only stream-made changes here have been the deepening of the inherited routes. Skokie River's relation to Skokie Marsh shows this strikingly. The stream water, entering the north end of the marsh, simply filtered through about two miles of marsh (before Skokie Park was made) without maintaining a mappable course. The river here has not even deepened its inherited valley.

The lakeward side of the easternmost ridge, the Highland Park moraine, is the wave-cut cliff already described. Before the cliff-making, this eastern slope descended to much lower altitudes than do any of the sags among the ridges, although it probably was not much steeper than those elsewhere on the ridges today.

Ten miles south of the tip of the longest moraine of the group, the Park Ridge moraine, and entirely surrounded by the plain is the elevation known as Blue Island. It is clearly a morainic ridge in origin. Its marked elongation and its orientation suggest that it belongs to the Lake Border system. Perhaps it is a relict fragment of a once continuous ridge from the north, perhaps no continuous ridge was ever built. It is considered as a part of the Park Ridge moraine. It is older than the surrounding plain and possesses some very interesting marginal features intimately associated with the origin of that plain.

DESPLAINES VALLEY-TRAIN

For almost the full length of the Park Ridge moraine, the DesPlaines valley immediately to the west contains a deposit of gravel, sand, and silt. Its width varies from a third of a mile to 1½ miles. Its surface is flat, except for certain low swells of gravel and for the dissection wrought by the river and its tributaries. Its altitude is about 650 feet above sea-level near the northern limits of the area and thence descends uniformly southward for 22 miles to an altitude of about 625 feet. The slope thus is hardly more than a foot to the mile. One might therefore think the valley should be mapped as a long finger of the Chicago plain extending northward between the Valparaiso and Lake Border moraine system. But none of the other "fingers" in the Lake Border system is floored with gravel, nor does gravel occur under the Chicago plain itself. And this gravel deposit extends northward beyond the Chicago area, rising gradually with increasing distance. It is a marked feature just east of Libertyville and is recognizable as far north as Wadsworth, 13 miles north of our area and within five miles of the Wisconsin state line. In this distance its surface rises 20 feet, or about 18 inches to the mile.

Numerous pits show the material to be well stratified and generally well sorted. It is mostly gravel, the size of pebbles definitely increasing northward. Toward the south the deposit is mostly sand and its gravel is composed only of small pebbles. The maximum known thickness is about 15 feet, with the bottom not reached. The till of the adjacent moraine country goes beneath the deposit, indicating that the gravel and sand is younger than the glacial drift.

Every feature of the DesPlaines valley gravel deposit points to one interpretation—it is a river deposit, but made by a far larger stream than the DesPlaines River of today. Only when the continental ice-sheet was building the Lake Border moraine system could the valley have carried so great a river. Meltwater then discharged into the long sag between the Tinley moraine and the Lake Border system, escaping southward through it to the Chicago plain. The deposit is a valley-train, a good example of the type and the only good one in our region. Other valley-trains lie a few miles to the west beyond the larger Valparaiso moraine. The DuPage valley contains one, so does the Fox valley, and even the DesPlaines valley below Joliet, but these valley-trains had all been completed and abandoned before that in the upper DesPlaines valley of our region was made.

Material of the valley-train is increasingly finer toward the south until in the terminal portion it is almost wholly sand. It grades into the Chicago plain in the vicinity of River Grove and Franklin Park. DesPlaines River continues southward across the plain for miles but nowhere is it accompanied by deposits of the glacial stream. The glacial river did not flow farther south than the two towns named. It did not reach quite as far south as the tip of the Park Ridge moraine. Why should the glacial river have ended where the modern stream flows continuously on? It is a simple question and has a simple answer when the plain is understood.

CHICAGO PLAIN

Next to the Valparaiso moraine, the Chicago plain has the largest surface area of any geological feature in the region (pl. I). The plain is the "vast prairie" of many visitors to the growing city 75 years ago. Lack of roads forbade adequate acquaintance with the prairie in which the city was situated and it appeared illimitable, probably because it was viewed only from the little settlement at the river mouth. The width of the plain (east to west) ranges from 5 to 15 miles, its length is only 40 miles. Its crescentic outline, between the Valparaiso moraine and Lake Michigan, has already been noted.

Neglecting interruptions in it, the plain nowhere is more than 60 feet above the lake, and it averages perhaps 25 feet above. In a general way it slopes lakeward from its western highest parts, but large tracts on it were originally marsh land, so poor was Nature's drainage. Another general feature of the plain is an irregularly longitudinal elongation and distribution of most of its interruptions, so that they lie roughly parallel to the lake shore. In this lies the explanation for the curious parallelism of the plain's streams and the lake shore.

Clues enough have already been given the reader as to the geologist's explanation for this plain. Let us check over the evidences and establish the case inductively, considering first the kinds of materials underlying the plain, and second, the topography and composition of the higher tracts which interrupt it.

During the past 20 years there has been in Chicago an almost uninterrupted series of excavations and some knowledge of what lies beneath the surface has been almost unavoidable for the average resident. In some places the surface material is sand, perhaps with gravelly layers; in most places it is a dense stony clay without layers or stratification. Heavy structures built on the plain require piling or special underpinning for their support because of the weakness of the natural foundation.

The stony clay is identical with that in the moraine ridges. It is a glacial deposit but without the accompanying sag and swell topography. The sand and gravel can be traced back to the same transporting agent but they have gone through some later experience, to which they owe their sorted and stratified condition. The plain, therefore, although composed of glacial drift and its derivatives, was fashioned by other agents after the ice retreated. Where unmodified drift underlies the plain, erosion of some sort apparently has occurred, destroying the characteristic relief of a glacial deposit and producing the plain surface. Where the subjacent material is stratified sand, glacial till generally occurs beneath it. Deposition by an agent capable of sorting the drift apparently has happened in such places, burying the drift and making the plain surface by aggradation. In a general way, the higher parts of the plain (not its interruptions) are underlain by unmodified drift and the lower places by modified (sorted and stratified) drift. Though erosion and deposition are essentially opposite changes, we know that the same agent may do both, provided the conditions vary from place to place.

Of the postglacial agents operating in Chicagoland, only one set is at all likely to have made a plain by eroding away higher tracts and depositing on lower ones. That is the group of shore agencies now working along the margin of Lake Michigan. Visualize the lake surface immediately after the ice-sheet withdrew, 60 feet higher than the lake at present. Put the waves and shore currents at work on the margins of that expanded lake. Allow sand and silt to be carried out into the deeper places from the sites of erosion. Then slowly lower this ancient lake surface through centuries of time, sweeping the migrating shoreline completely across the emerging plain. In this way, we believe, the plain has been made from a tract of gently undulatory glacial topography. The lake was dammed between the ice-sheet on the east and the moraine on the west, and it became extended eastward as fast as the ice melted away. There was no interval of exposure of the plain to weathering and stream work.[4] In the existence of a lake over the entire Chicago plain we find the explanation for the termination of the glacial DesPlaines River at River Grove and Franklin Park, for there it entered the lake, or a bay of the lake, whereas the modern river continues across the lake bottom that emerged after the glacial river had ceased flowing. The glacial lake and river were necessarily contemporaneous.

If the Chicago plain is former lake bottom, the margins and any former islands of the lake should possess old shoreline features. Allowing for subsequent modifications, they should resemble the different types of shorelines Lake Michigan now possesses. Plate I shows the generalized characteristics of the plain. Its most striking features are the sand (and gravel) ridges here and there along or very near the higher western margin and much more prominently displayed out on the plain itself. Most of them are narrow and curvilinear. Many have short, barb-like ridges projecting from the moraine side rather than the lake side. They lie *on* the plain, hence are not glacial deposits of any kind. Each ridge has an essentially horizontal base, a fact not shown on the map but very suggestive of their method of origin. Where close together these ridges are usually subparallel with each other or are disposed end to end in a row.

The sand ridges are clearly constructional. They are not the product of any agency now altering the plain, yet they post-date the glaciation. It is logical to see them as a product of the same general conditions under which the plain itself was made. The theory that they are old shorelines should therefore be tested.

[4]This statement takes account of only the latest glaciation, during whose closing stages the plain was formed.

Chicagoland's existing lake shore is marked by cliffs, sand beaches, and rows of dunes. If the sand ridges of the plain are old beach ridges, they should be accompanied by cliffs and dunes. The cliffs should occur in the intervals along lines of interrupted ridges, thus continuing the supposed shoreline across the stretches where wave erosion instead of deposition occurred. These cliffs should face eastward, toward what was the open lake. The dunes, argued from relations to present shores, should lie in belts alongside the ridges or perhaps occur in place of some ridges in any one line.

Cliffs are not depicted on plate I—it shows only deposits. Several dune belts and groups are on the map however, one between Homewood and Thornton, one between Thornton and Lansing, one through the corporate limits of Calumet City, one along the western edge of the "Blue Island" portion of Park Ridge moraine, one in the corporate limits of Wilmette, and a few others. They are not, of course, active today, nor are any of them comparable in size to the Indiana dunes.

The old shorelines are best developed where facing broad areas of the plain—tracts which were swept by waves travelling in from the open lake. They are faintly developed or even lacking in protected and constricted places. They wrap around the elevations in the plain (formerly islands in the lake). All this is as the theory requires. But there is one peculiar feature which the theory, as presented, does not explain. Old shore features—sand ridges, cut banks, dunes—occur not only along the contact of plain and moraine, but they also occur out on the plain, miles from the "shoreline" contact. Indeed, the sand and gravel ridges on the plain are better developed than those along the margin. They are essentially horizontal, as undeformed shore features should be, but they occur at lower altitudes successively eastward across the plain, so that those about Lake Calumet and Wolf Lake are 50 to 55 feet lower than the highest one to the west. This change in elevation is not because the ridges themselves are smaller and lower, for there is no progressive change in ridge height in the series. It is an expression of the gentle eastward slope of the plain itself.

Obviously, the eastern beach ridges were not formed in water 50 feet deep. Judging from present lake shores, the ridge crests were probably built up a little above the average water-level of their time. It follows, therefore, that this descending series of ridges records an intermittent lowering of the lake level, slow enough to allow a succession of later and lower shorelines to form as the lake margin retreated eastward across the sloping bottom.

The patterns of these old shores out on the plain (pl. I) afford several interesting puzzles. Why the festoon outlines near Dyer, Thornton, and Niles Center and between Lake Calumet and Chicago River? Why the almost complete circular outline in and near Thornton? Why the elongated loop in Alsip? Why the short isolated ridges in many places? Why the disposition at right angles of several closely adjacent ridges? The explanation must harmonize with known variations among existing shores, else the theory becomes suspect. Consideration of these and other peculiarities are given in a later chapter.

One more feature of the Chicago plain and we are through for the present. Although the plain in general slopes eastward toward the lake, some of its drainage escapes westward to reach Mississippi River. Within the plain lies a "continental divide," however unlike the summit line of the Rocky Mountains it may be. The two largest stream-formed valleys of the region, those of Sag Channel and DesPlaines River, lead the Mississippi's share of the drainage westward across the Valparaiso moraine, although the moraine crest is elsewhere 50 feet or more above the highest part of the plain. Profiles of all but two of the railroads which cross the moraine (fig. 38) show this strikingly. The railroads climb as much as 100 feet above the plain before leaving the region. But the Alton and the Santa Fe railroads have no climb to make. They follow the DesPlaines valley and their profile is a continuous downgrade out of Chicago. One may recall the Drainage Canal and the reversal of Chicago River in this connection. Both are further evidence that the plain at one place on its western margin is as low as its entire eastern margin.

If the level of Lake Michigan should rise enough to flood back on the old lake plain, it could never reach the high former level unless the DesPlaines valley, west of the plain, were dammed. Obviously then, this valley probably did not exist to its present depth when the ancient lake lapped up against the moraine country. The valley was, without question, the outlet of that lake and undoubtedly was deepened by such use. If the lake had a constant volume of discharge during its existence, it was lowered by the deepening of the outlet channel. Thus the lake margin would be shifted successively eastward, exposing the western higher parts of the submerged area. This explains the occurrence of shorelines out on the plain, successively lower toward the east.

There are two outlet channels leading westward from the old lake, one on each side of Mt. Forest Island. They join after crossing five or six miles of moraine country. Both lengthened eastward as they were deepened and the lake was lowered. The southern outlet, or Sag Channel, tripled in length, becoming at least twice as long on the plain as it was across the moraine before water ceased to use it; the northern one about doubled its length by this eastward extension into the plain.

Since the channel heads do not reach the present shore and are at least 10 feet higher than the lake today, it is obvious that modern Lake Michigan never has discharged through them and that events outside our region caused the final lowering by which the channels went dry. The old lake, with discharge across the moraine to Mississippi River, is known as Lake Chicago.

Conclusion

The character and topography of the unconsolidated materials record unequivocally the presence of glacial ice and glacial water in the Chicago region. The changes wrought by them were far greater than all subsequent changes by agents and processes now at work. The record is far different from that of the bedrock beneath the unconsolidated materials. In presenting and interpreting the evidence, we have inductively deciphered the larger elements of Chicagoland's glacial history. More careful attention to the details of this history follows in the historical section.

BEDROCK OF THE REGION

Introduction

Though bedrock is the most extensive geological feature of the Chicago region and is almost nowhere more than a hundred feet distant from any resident of the metropolitan area, few people in Chicago are conscious of its existence. The same might be said for most citizens of the state of Illinois or indeed those of all the Great Lakes and upper Mississippi Valley states, so nearly complete is the thick mantle of glacial drift. In our region a few streams have uncovered it, a few places along the lake show it, a few hillside ledges occur. Our best sources of information about it are quarries and deep wells. The wells are of value only if careful logs were kept at the time they were drilled. Walls of abandoned quarries remain satisfactory exposures of the bedrock unless the quarry fills with water or is filled with rubbish.[1]

The surface of the underlying bedrock is not horizontal, nor, as we have seen, is the surface of the overlying glacial and lake detritus. Only where the bedrock surface is relatively high and the overlying drift is thin are outcrops and quarries possible.

There are at present fifteen quarry openings in the region well suited to our purpose. All openings, good or poor, and all the natural exposures, are in the same rock, a formation known as the Niagaran dolomite or limestone. The name comes from Niagara Falls, for the rock that holds up the lip of the cataract is the same formation. Only wells penetrate deeply enough to go completely through it and into other kinds of rock beneath.

The well logs (records of thicknesses and kinds of material penetrated) show that for a depth of nearly half a mile the bedrock of the Chicago region is stratified limestone, sandstone, and shale. The Niagaran limestone at the top of the series has a maximum thickness of about 450 feet. With few exceptions each formation underlies the entire area, so that all wells sufficiently deep, no matter where they are located, penetrate nearly the same succession of sedimentary rocks. Altitudes of the contact between any two successive formations, however, are higher in the northwestern part of the region and lower in the southeast. Thus the formations are not exactly horizontal but slope or dip gently down toward the southeast. This is of great significance in the drilling and use of deep wells, as will appear later in this section.

"Bedrock," a term used repeatedly in preceding pages, implies consolidated rock. The glacial drift, the glaciofluvial deposits, the lake sediments—all are rock but are unconsolidated aggregates. The Niagaran limestone is as hard and as strong as concrete. Only by drilling and blasting can it be penetrated. It is not a monolithic mass, however, for there are innumerable horizontal planes along which it may be split, and many vertical partings. The horizontal structure is stratification, a record of the deposition, layer upon layer, of lime mud to make that entire thickness of 450 feet. The consolidation to "bedrock" came later.

Niagaran Formation[2]

There is no greater contrast in Chicago geology than that between the Niagaran limestone[3] and the overlying glacial drift and its derivatives. The limestone appears almost monotonously the same in every exposure. It possesses nearly uniform induration, color, structure, composition. The drift is uniform only in lack of induration; in all other characters there are variations in every township, almost in every square mile.

That the apparent monotony of the Niagaran limestone means uniform conditions throughout the region during its deposition should not be accepted hastily or uncritically. The monotony is only by contrast with the extraordinary diversity of glacial deposits. The Niagaran limestone carries a record of changes during its deposition, a record of diverse conditions at different places at any one time, and a record of various changes to which the rock was subjected

[1]Several deep quarries in the city have already been filled with refuse and doubtless all eventually will be.

[2]The rock strata covered by the name Niagaran constitute actually a series of at least five geological formations, but for simplicity the series is discussed in this report as a single formation.

[3]The term limestone is used in this report in the popular sense, to include the common carbonate rocks. Technically, however, the common carbonate rocks of Illinois are classified as *limestone* and *dolomite*. Limestone consists chiefly of calcium carbonate and dolomite is composed mostly of calcium carbonate and magnesium carbonate. Most of the carbonate formations in the Chicago area fall into the dolomite group.

after its making but before the glacial conditions arrived.

The limestone was originally lime mud. Its thickness shows that the region was under water for a very long time. The mud was continuously added to the floor of the ancient water body. Its composition is more than 90 per cent calcium and magnesium carbonate; it contains comparatively little weathered detritus from older rocks. The debris did not come directly from erosion of adjacent lands as mud does in Lake Michigan today.

A source for this great quantity of carbonate mud is suggested by the shells and skeletal parts of marine animals, now fossilized, embedded in the rock. They are mostly imperfect, broken, worn, disarticulated; obviously they were swept about by waves and currents after the animals died. Locally the limestone is crowded with such fossils. Furthermore, a microscopic study of the rock shows enormous numbers of fossil one-celled animals, too small to be detected by the unaided eye. The lime mud of the Niagaran sea, therefore, is believed to have been largely an organic sediment, the product of a thriving marine fauna whose abstraction of calcium carbonate from the water was greater than the re-solution of that material after the death of the animals. The net result, now that the Niagaran epoch is millions of years past, is the great limestone formation beneath our glacial drift. The Niagaran sea, like the great ice-sheet, was far more extensive than the region we are studying. An explanation for its existence is deferred for a few pages.

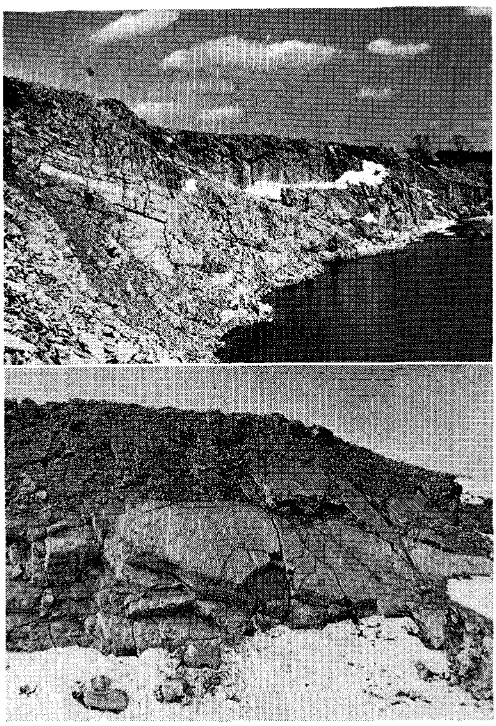


FIG. 44.—Dipping beds of Niagaran limestone in Moulding-Brownell quarry at Thornton
Above—the beds dip toward the right and diagonally away from the observer at an angle of about 30° with the horizontal surface of the pool.
Below—the beds dip directly toward the observer.

Limestone is a common sedimentary rock, widely distributed on all continents. Some limestone is doubtless a chemical precipitate, without the agency of life in its accumulation; some is fresh-water in origin, some may be largely a product of calcareous plant secretions. The Niagaran is undoubtedly marine and its material probably is largely of animal origin. The material was removed from solution in the sea water of the Niagaran embayment by these animals. The sea today is the recipient of soluble substances leached from the land by rain, streams, groundwater—and so it doubtless was during Niagaran time. Thus the limestone does, in spite of our denial, record wastage of the land of its time, although through the medium of solution and later precipitation.

REEFS AND KLINTAR

In many quarry walls, one sees the strata at various inclinations from horizontal (figs. 44, 45), even dipping in opposite directions in the same wall. In the latter case the

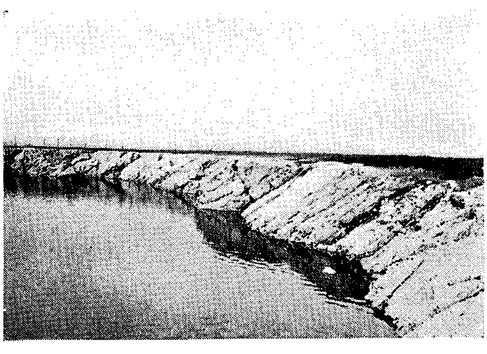


FIG. 45.—Dipping beds of Niagaran limestone in old quarry at Stony Island.

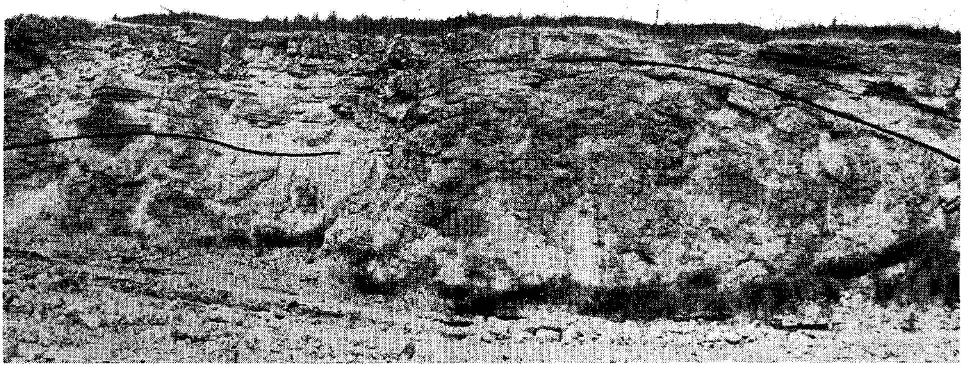


FIG. 46.—Unstratified core of small reef, overlain by dipping stratified rock (Moulding-Brownell quarry at Thornton).

dips are like the slopes of a hill, down away from each other, not like valley slopes which approach each other downgrade. Exceptionally good exposures show these dome or hill dips to be less in the successively higher strata and to grade up into horizontal strata over the dome top. One quarry, now filled with rubbish, showed the bottom of such a dome, beneath which were also essentially horizontal strata. Quarries in the Niagaran formation near Milwaukee, Wisconsin, also show horizontal strata beneath dome structure.

A good observer at a good exposure notes also that the dome has a core of unstratified limestone (fig. 46), that the color of the core differs a little from that of the stratified rock, that the core rock is highly fossiliferous and is full of cavities from which ooze little driblets of asphaltum on hot summer days (fig. 47). Weighing these facts, one concludes that the domes are original aggregates of limey material on the ancient sea floor, formed at places where for some reason the marine population was more dense, or the calcareous detritus was more resistant to being swept about beneath the waves, or both.

A representative collection of fossils from the unstratified core rock, compared with one from flat-lying strata, shows a preponderance of sessile and non-swimming forms —corals occur in profusion, bivalve shells are very abundant, coiled shells are common. In the adjacent flat-lying strata there are far fewer fossils, but the free-travelling forms—floating, swimming, crawling—occur in a considerably higher percentage compared with the fixed and semifixed forms that characterize the dome cores.

The facts, and the reasoning from them, lead us to one conclusion, and only one. The domes are ancient reefs, coral reefs as they are commonly called. While the colonies thrived many kinds of corals grew on the wreckage of their ancestors, and their compound skeletons gave anchorage and shelter to other forms. More food, more oxygen, less danger of burial in mud, greater variety of exposure owing to agitated water created by the reef itself—all these conditions favored a denser and more varied population. When some conditions became

FIG. 47.—Asphaltum oozing from a cavity in core rock.

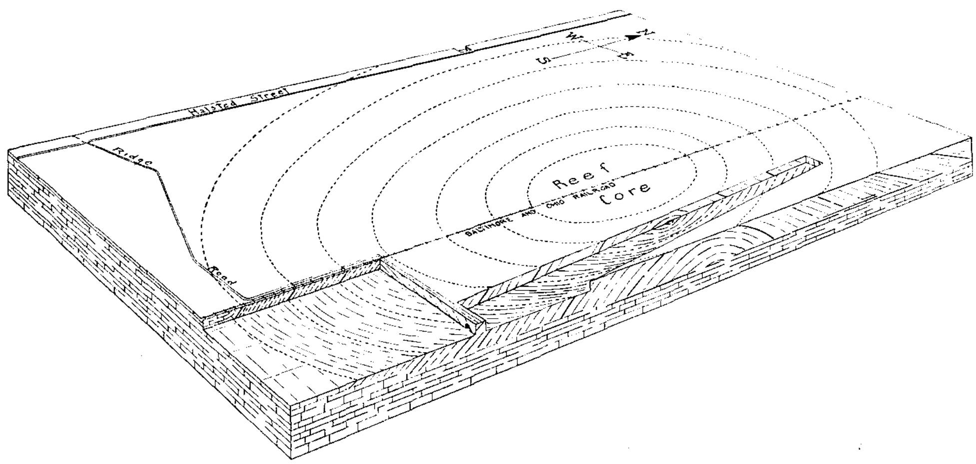


FIG. 48.—Block diagram of the Thornton reef.

altered and consequently upset the nice balance required for the growth of corals (increased muddiness might be adequate), the sessile branching foundational forms died, the forms dependent on them also died or moved away, and the reef ceased growing. Continued deposition of lime mud from storm-stirred waters eventually covered the reef with stratified sediment, thinner on the top and thicker on the flanks, until finally it was completely buried and a smooth bottom was again restored.

Thornton reef.—Probably the largest Niagaran reef in the Chicago region is at Thornton (fig. 48) (Harvey and Calumet quadrangles). It is approximately circular in ground plan and a little more than a mile in diameter. Erosion has stripped off any horizontal strata that may once have overlain it and only a few feet of glacial and lake deposits now cover it. The large quarry of Moulding-Brownell Company has been excavated in the southeast quarter and is being extended northward almost entirely across the reef. The southeastward dip of the bedding can be seen very clearly on both sides of Ridge Road, just west of Thornton village. At the extreme north end of the quarry, too distant to be seen from the road, the beds dip northeastward. The south limit of quarrying is beyond the margin of the reef, in the surrounding horizontal strata. Another quarry, now abandoned, just west of Halsted Street, is in the west edge of the reef. The westward dip of the bedding in its walls may be seen from Halsted Street.

The reef rises 10 to 15 feet above the surrounding lake plain. If the glacial and lake deposits were stripped away, the reef would be considerably more conspicuous topographically because the bedrock surface descends markedly out in all directions beneath the drift. The reef apparently constituted a preglacial hill, being more resistant than was the surrounding rock to the ordinary processes of erosion before the Ice Age. An alternative view is that the reef rock was left in relief by glacial erosion itself. Perhaps its present expression is due to both experiences. We shall have more definite opinions on this after the buried bedrock topography of the entire region has been examined.

Quarrying in the Thornton reef has revealed no definite core nor horizontal strata above or below. If any underlie it, quarrying has not gone deep enough to demonstrate the fact. The exposed reef structure consists only of the beds dipping outwardly at angles close to 30° from the central part of the low rock hill. In the quarry south of Ridge Road, the dip may be seen to decrease southward and pass gradually into the flat strata farther southeast, outside the reef proper. The large Thornton reef therefore fails to show a number of the features listed as characteristic of reefs.

There exists another interpretation of these radially outward-dipping beds, an earlier interpretation which perhaps should be reconsidered. They may be uplifted domes due to movement of the rock since the formation was deposited. Without horizontal strata above or below, and without the peculiar core rock, this hypothesis may look as satisfactory as the one of reef origin. Perhaps there may be both reef domes and uplift domes in the region. Without more facts we might assert or deny with all vehemence and without limit, we might even take a vote on the question, but get no nearer the truth. More facts are necessary.

The southern side of the Moulding-Brownell quarry supplies the facts. Here is that gradation from beds standing 30° from the horizontal to beds that are flat—the margin of the reef, we earlier called it. For the past 25 years this wall has been almost continuously pushed southward as the quarry area has been increased. During this time there has come to light in this wall a series of little domes, from 30 to perhaps 100 feet across, each with a core of dark gray dolomite, full of cavities, usually fossiliferous, unstratified, and containing asphaltum. Many of them have shown horizontally bedded rock above and some have shown it below the core. Most of them have had a minor amount of dipping strata on their flanks. On every count they are true reefs, though only "baby" ones (fig. 46). As the quarrying has been pushed southward, farther from the large structures, the number of exposed baby reefs has decreased. The little reefs are certainly related in some way to the main structure. They seem to be small colonies which grew up like suburban villages about a metropolis. Still, the case is not perfectly clear.

The Thornton tract is diagrammatically shown in figure 48. The only exposed structures, as shown in the diagram, are in the quarry walls. All else is inferential. The east side of the block shows what relations must exist below the quarry floor level if the structure is a reef. Let us ignore this for a moment and consider the surface of the block. If the dome is a product of pushing up of originally horizontal strata, then a great deal of the structure has been destroyed by erosion. The dome has been scalped, even beheaded. To see it as it would have been if formed by doming, we must connect the eroded edges of dipping beds at comparable distances on each side of the center. The dome, thus restored, would have been perhaps 1000 feet higher than it now is. Furthermore, if it was originally an unbroken fold, overlying beds of the dipping strata would have been forced by the folding to slide upward on underlying beds. This becomes clear if we bend a pack of cards or a closed book to the same extent. Such sliding might be expected to leave abrasion marks between beds, scratches or gouges to show the adjustment that occurred under a heavy load during the folding. This is a good test to apply.

Linear marks on the surfaces of these dipping beds do exist and they extend along the dip. But the way they fit into each other clearly shows that each overlying bed moved *down* the dip slope with reference to the underlying bed. So far as this evidence goes, the strata have settled down, they have not been crowded up. This could occur if the dip is original, namely if the dome is a reef; it surely is not a record of folding and uplift.

Yet even if figure 48 represents the cross-section of a part of a reef, the upper surface of the block is erosional. It was erosional at the time the reef was growing. Detritus won by the waves from the core was carried by the undertow radially outward to deeper water. Here it was dropped and slid down the slope to make the inclined beds. Detritus to make the outer beds travelled across the edges of beds already deposited.

From the various dips in the quarry, as shown in the block (fig. 48), one would infer that the reef core must lie north and west of the quarried areas. Its nearly flat surface has been glacially eroded and bears striae that are oriented nearly northeast-southwest. It had already suffered attack by weather and water before the ice-sheet invaded from the north. To what extent the original structure has been reduced by these erosional experiences cannot be determined. The pristine dome surface may have been many feet higher; it may even have been buried beneath later horizontal beds like some of the baby reefs.

A strong suggestion that the dome is a "coral" reef and was considerably higher at the time of its maximum growth is found in the west wall of the south quarry, a little south of the right angle in Ridge Road. Here are numerous masses of thin-bedded limestone with the stratification dipping variously, neither in the same direction nor

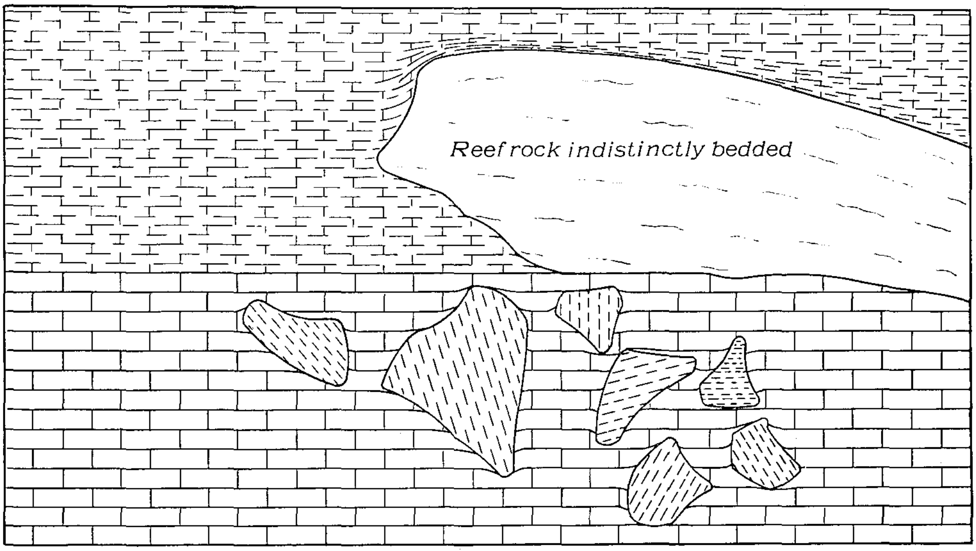


FIG. 49.—Sketch showing dislodged fragments of reef-rock embedded in thick-bedded horizontal layers of limestone, over which a "baby" reef was subsequently built while thin-bedded limestone was accumulating.

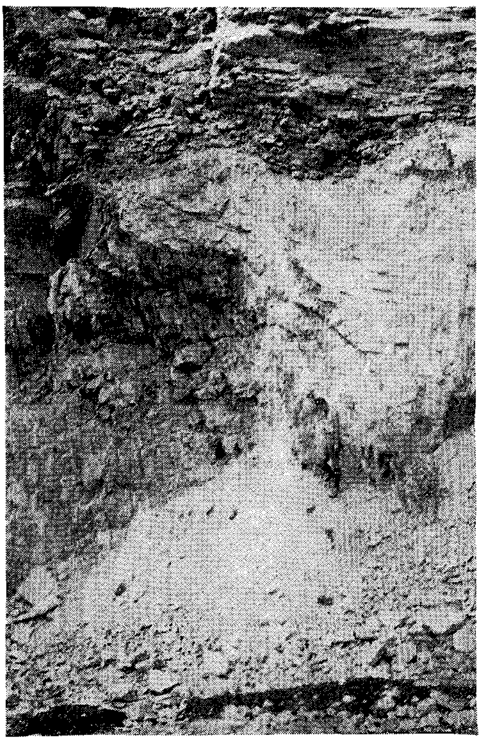


FIG. 50.—Displaced fragment of reef-rock standing nearly vertical and overlain by nearly horizontal beds in place (Moulding-Brownell quarry at Thornton). The man and dog stand at the base of the strata deposited in inclined position on the surface of the reef fragment.

at the same degree in any two masses. In several, the dip is actually northward, against the direction in which the strata in the adjacent dome dip. Inclinations as steep as 75° to 80° exist, more than twice as steep as any beds in the dome. These masses are very irregular in outline, range up to 100 feet in maximum exposed length, and are embedded in indistinctly stratified limestone whose layers are thick and are nearly horizontal. Figure 49 shows the relationships in one section and shows also a "baby" reef that grew later on top of the assemblage of variously oriented masses. Figure 50 shows horizontal beds overlying the nearly vertical beds of one of these masses.

These masses are dislodged reef fragments. Their strata could never have been deposited in their present positions. They are believed to have been broken from the main reef while it was growing and to have fallen, rolled, or slid down its submarine slope to their final resting place, where they became buried in the off-reef horizontal strata. If this is correct, the reef must have been considerably higher than at present. It is impossible to explain them by the hypothesis that the dome is the result of bending of originally horizontal beds.

Stony Island.—Another tract of relatively high bedrock, thinly covered or cropping out on the surface, is the elevation known

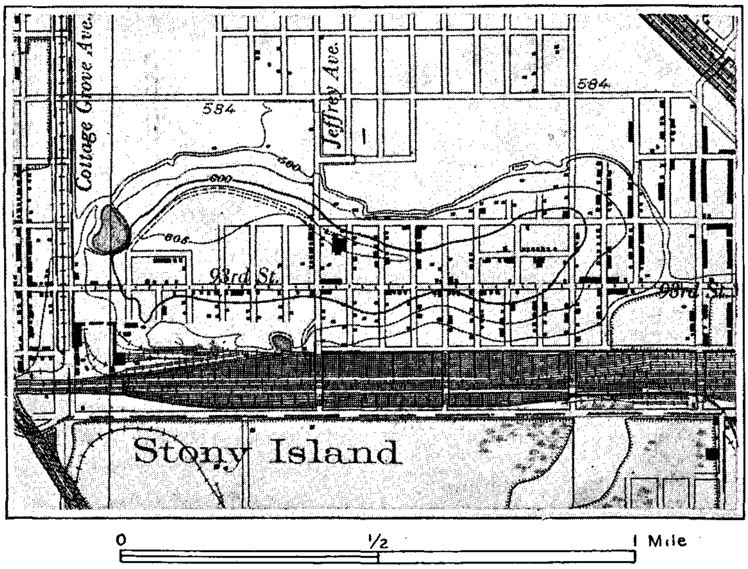


FIG. 51.—Map of Stony Island (part of Calumet Lake topographic map).

as Stony Island (Calumet Lake quadrangle). Ninety-third Street, between Stony Island Avenue and Kingston Avenue, traverses its length, about 1¼ miles. Its width (north-south dimension) is hardly more than a quarter of a mile (fig. 51). It rises 10 to 20 feet above the surrounding lake plain and, like the Thornton tract, the rock surface lies many feet below that plain, so that if the glacial and lake deposits were removed the "islands" would be even more conspicuous. As at Thornton also, the stratification is not horizontal but dips radially outward in conformity with the topographic slopes.

Two abandoned quarries afford the best exposures. The larger one, on the west flank of the "island", shows the dipping beds very well, descending at an angle of 25° to 30° toward the surrounding plain (fig. 45). A smaller quarry on the south side of the "island" shows dips correspondingly southward. No core is now exposed but a core is known to exist. Trenches for sewers and watermains, blasted out along several streets on the summit of the "island" about 1920, encountered typical core-rock, unstratified, very fossiliferous as compared with the stratified rock in the two quarries, and possessing numerous small cavities, some of which contained asphaltum.

Movement of strata has occurred on the flanks of the "island" and has produced on bedding planes parallel linear markings which somewhat resemble glacial striae in appearance, though of course not in location. From these markings it is clear that in all cases the overlying beds have moved down the slope. They testify that the dome has settled and flattened a little. They are not a record of uplift.

Like the Thornton tract in another respect, the Stony Island reef has been scalped and lowered by glacial erosion, with striae well shown along the south and east sides of the larger quarry. Glacial erosion seems to have lowered the elevation. What made it a topographic eminence originally?

Very questionable indeed would be the idea that the Stony Island and Thornton elevations are simply surviving elevations on the Niagaran sea floor. In fact there is evdience that in the Chicago region there was marine deposition after the Niagaran epoch closed, followed by long continued erosion which removed the overlying deposits before the glacial epoch. It is significant that nearly all of the more marked rock elevations of the region, whether exposed or known from borings and soundings, are reef structures. The reef rock was apparently more resistant to the preglacial attack of weathering and running water, and thus was left in relief. The same conclusion has been reached in studies of very similar reefs in the Niagaran limestone along the upper Wabash Valley of northern Indiana, where the rock hills have reef structures and the reefs constitute the hills.[4] Similar hills in Sweden have long been known as *klintar*. A single hill with reef structure is a *klint*. Adoption of the Swedish terminology is advocated by the Indiana geologists and their suggestion is followed in this report.

Chicago Heights.—A rock hill partially buried by glacial drift so that only its northern and eastern slopes crop out occurs in East Chicago Heights near the intersection of Cottage Grove Avenue and Lincoln Highway about four miles south and one mile east of the Thornton klint (Calumet City quadrangle). It rises rather steeply from the highest level of the lake plain on the north and has a relief of 25 to 30 feet. In an old quarry along Cottage Grove Avenue there are northward-dipping reef beds. No core is exposed.

McCook.—In the southwest part of the Berwyn quadrangle, about half way between LaGrange and Argo, there is another rock hill, so low and so nearly buried in drift that nothing in the topography betrays its presence. A small drainage way down its northern slope has been eroded to bedrock, and a large quarry belonging to the Consumers Company has been excavated partly in the klint and partly in lower flat-lying limestone south of the reef. The inclined reef bedding is very well shown in the north and west walls of the quarry. Judging from the direction of dips (southward in the west wall and eastward in the north wall), the unexposed core should lie north of the adjacent Joliet highway and a little west of the Consumer's quarry.

Another large quarry, that of Dolese and Shepard, lies just to the southwest of the Consumer's quarry. It is 3,000 feet long, 2,000 feet wide, and 70 feet in maximum depth, larger than the Consumer's quarry and nearly as large as the Moulding-Brownell quarry at Thornton. Throughout its entire area, except at the extreme northeast end, the limestone is horizontal and thick bedded. Only close to the Consumers quarry is there any reef structure, the beds here dipping southward. The McCook reef structure is probably about three-quarters of a mile in diameter.

[4]Cumings, E. R. and Shrock, R. R., Geology of the Silurian rocks of northern Indiana: Indiana Dept. of Conservation, Division of Geology, Pub. 75, 1928.

Lake Shore Klintar.—There is imperfect evidence along the shore of Lake Michigan of two more rock hills, each determined by an ancient reef. Both occur south of the loop district. The northern one is entirely out in the lake and below lake level, the southern one lifts reefy ledges a few feet above the lake surface on the shoreline and includes some poor outcrops a few blocks inland.

The northern and submerged feature may be termed the Hyde Park klint. It reaches from Pershing Road (3900 block) south to Jackson Park (5900 block), a distance of 2½ miles, and is marked by seven named shoals.[5] Of these the outermost is more than two miles from the shore, in line with 49th Street projected eastward. Rock bottom can be seen on three of the shoals and more than 40 exploratory borings made from scows have found rock in this area 30 feet or less below lake level.

Fewer borings have been made on the land bordering this tract of shoal water but enough exist to prove that the bedrock surface descends westward from these shoals with unusual steepness approximately along the made-land waterfront. Where the present surface of the lake plain descends eastward, the older surface of the limestone descends landward, in exactly the opposite direction.

On three of the shoals, rock ledges may be seen through the water. On Morgan shoal the rock is smoothed by glacial erosion and shows reef bedding which dips lakeward on the outer part and landward on the inner slope. The shoal appears to be a reef in structure. Each named shoal is probably a reef and the unusually large tract of relatively high bedrock is probably a composite of several reefs, seven of which may now be identified on the lake bottom. If there is a dominant central reef, it must lie somewhat deeper and on it as a foundation the smaller reefs have grown later. Burial of earlier reefs by growth of later ones is well shown in two places in the McCook quarry walls, the later reefs developing without reference to the tops of older, lower ones. It is also shown in other Chicago quarries and therefore seems a per-

[5]See "Chicago Lake Front No. 2" map of the United States War Department's "Survey of the Northern and Northwestern Lakes." Oakland shoal is off 39th Street; Morgan, Clemson, and the Outer and Inner Hyde Park shoals are off 47th Street; Madison Park shoal is off 52nd Street; and South Park shoal is off 54th Street.

missible idea to use. The Hyde Park klint, by this view, is compound.

The other lake shore klint, which may be termed the South Shore klint, occupies a considerable area lying mostly south of the South Shore Country Club. It is exposed along the shore approximately from 70th Street to 79th Street, a distance of about 1½ miles, and extends out into the lake at least as far as Clark Point shoal, a bedrock outcrop beneath the lake about 3,000 feet offshore. Its greatest dimension, along a nearly north-south line, is about 2½ miles. Its southern end is not far from the smaller but topographically conspicuous Stony Island klint. Like the Hyde Park klint, the South Shore klint's surface slopes westward, but gently. The highest place on the klint is in the vicinity of 82nd Street and Exchange Avenue.

Some structure is shown in the outcrops in Rocky Ledge Park, which extends north about 1,500 feet along the shore from 79th Street. These ledges are low and at high lake stages most of them may be entirely submerged. They carry traces of glacial smoothing and grooving (fig. 52) but striae, if ever present, have all been worn away. Stratification is poorly shown in general but where recognizable it dips in various directions and degrees. Although not recording a single symmetrical reef, such variations really are the best evidence of reef origin. The alternative hypothesis of warping and bending of once horizontal strata cannot be used. Folds in the rock caused by deformation must have systematic relations among themselves. Downfolding cannot exist beneath or above upfoldings except in minute crumplings. By the concept of irregular reef growth, these variants are possible.

Neither of these lake shore features is truly a klint today, for neither constitutes a hill. But they were hills before the glacial and lake deposits were laid down over them. Their existence explains the shoals and the Rocky Ledge Park outcrops, both known to residents of this section of Chicago. Some of the shoals are obvious even to one never out in a small boat; they are marked by breakers during onshore storms and by piling up of floe ice on them in winter.

Minor Reef Exposures.—Portions of other reef structures have been exposed in the following places, some of which have

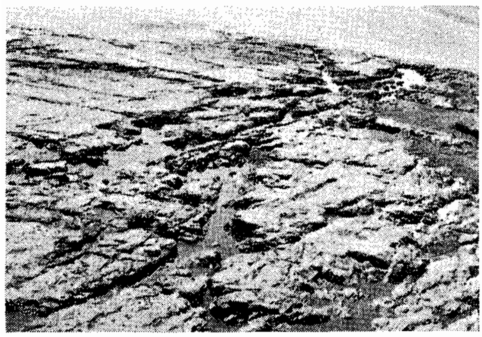


Fig. 52.—A glacially smoothed and grooved surface of Niagaran limestone in Rocky Ledge Park showing reticulated pattern due to jointing and stratification. The beds dip lakeward, the truncated edges of the strata trending from lower left to upper right. The course of the joints is from upper left to lower right. (Jackson Park quadrangle.)

later been covered through conversion of a quarry into a dump.

(1) Sag Bridge quadrangle, central part, along Archer Avenue grade on the south slope of Sag Channel valley.

(2) Hinsdale quadrangle, southeastern part, along Flag Creek south of the Joliet Road. Almost the entire periphery of a reef is shown in shallow quarries and outcrops.

(3) Elmhurst quadrangle, southwestern part, western limits of Elmhurst, quarry of Elmhurst-Chicago Stone Company.

(4) Berwyn quadrangle, western part, along 47th Street. Three closely grouped quarries along the Indiana Harbor Belt Railway south of Brookfield show some reef structure.

(5) Berwyn quadrangle, west-central part, along banks of DesPlaines River, at mouth of Salt Creek, and south of the bridge at about 43rd Street, east of Lyons.

(6) Englewood quadrangle, western part, north of Stickney village, just west of Chicago City limits. The former Hawthorne quarry, now filled with rubbish, exposed the only large reef in the Chicago area known to have horizontal beds beneath the inclined beds.

(7) Englewood quadrangle, northeastern part, quarry of Stearns Lime and Stone Company on 27th Street, two blocks west of Halsted Street. Reef structure is best shown in the upper part of the east wall. The quarry is more than 200 feet deep, most of it in horizontal strata.

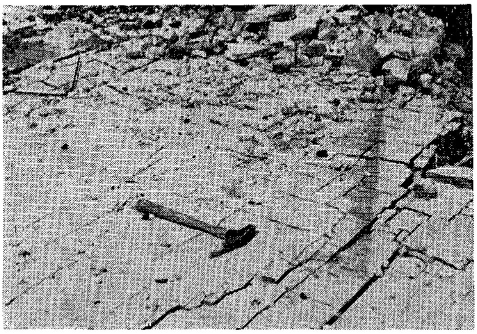


FIG. 53.—Traces of two systems of joints on bedding plane forming the floor of Consumer's quarry at Hillside. The joints are unusually close. (Hinsdale quadrangle.)

(8) Englewood quadrangle, north-central part, quarry of Chicago Union Lime Works Company at Damen and 18th Street. This was the deepest quarry ever excavated in the region, 380 feet below the level of the surrounding plain, 360 feet below the lake surface, and nearly two-thirds of the way to sea-level, almost to the bottom of the Niagaran formation. Reef structure showed in the upper beds of the east wall, but because this quarry was taken over as a city dump, these exposures are obliterated.

JOINTS

Most consolidated rock in place, whatever its character or origin, is penetrated by deep closed cracks called joints. They generally form sets of nearly vertical planes parallel with each other. Two sets of parallel joints, approximately at right angles with each other, are common (fig. 53). Joint traces appear on flat outcrops or quarry floors but joint faces, expressing their extent in depth, appear best on cliffs and quarry walls (fig. 54). Weathering attacks rock more vigorously along these cracks or joints, cliffed outcrops break down rather readily along them, and they facilitate quarrying operations. Vertical joints, in combination with horizontal bedding-planes, may produce rude rectangular blocks in the quarrying operations both of Nature and of man, the size of the blocks depending on the spacing of the joints and of the bedding-planes.

Joints are due to different causes in different cases, but all are subsequent to the making of the rock and are therefore younger than any stratification. The Niagaran limestone possesses two joint systems, recognizable in almost every good outcrop or large quarry (figs. 52, 53, and 54). The reefs of the region possess the poorest jointing; thick-bedded horizontal strata show it best. The two systems are oriented consistently throughout the region. One set runs northeast-southwest, the other northwest-southeast. The two systems extend beyond the limits of the Chicago region and show in outcrops and quarries in the Niagaran dolomite at Joliet, at Kankakee, at Milwaukee, and even farther afield. In attempting to understand the origin of these joints, this widespread consistency of orientation is an important item.

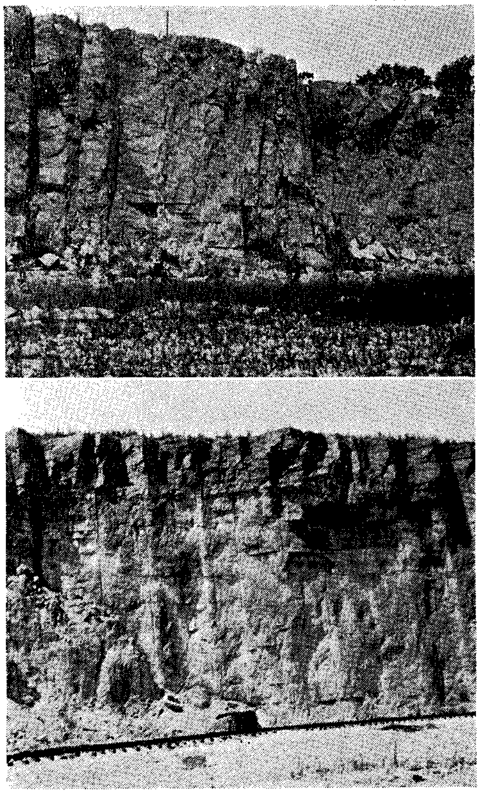


FIG. 54.—Vertical joints in the Niagaran limestone.

Above—Quarry of Elmhurst Chicago Stone Company, Elmhurst.

Below—Quarry of Consumer's Company, Hillside.

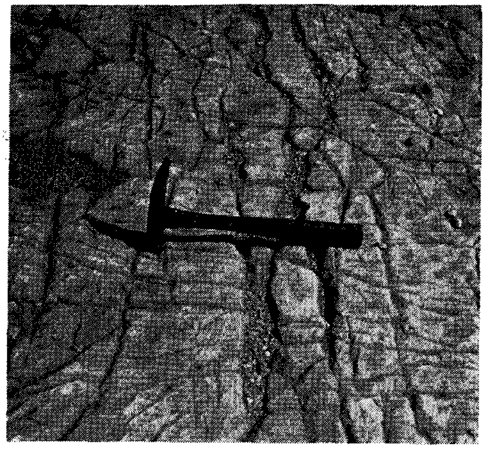


FIG. 55.—Solution of limestone is concentrated along joints and consequently develops an intricate system of small channels on flat exposed surfaces. Dolese and Shepard quarry (Berwyn quadrangle).

Photograph by E. H. Stevens

FIG. 56.—Irregularly weathered surface developed by solution along a fissure wall. One side of the fissure has been quarried away. Note etching of more soluble layers and rounding of edges of less soluble ones. The beds are a part of the Thornton reef structure.

FISSURES AND FISSURE FILLINGS

Joint cracks may have become fissures through tensional adjustments in the limestone. Indeed, the original joints may be only tensional cracks formed after consolidation of the lime mud, if drying out or crystallization caused later shrinkage in volume. Warping stresses (for the formation certainly has suffered some earth movements) may make joints and conceivably may open some to become fissures. Joints afford main routes for groundwater circulation, and some fissure walls show undeniable solution work (figs. 55 and 56). The opening of such may be due wholly to this process.

If joints become open cracks, they constitute fissures, into which loose material from above may fall. The debris may remain unconsolidated, or it may become indurated and thus the "wound" may become "healed". But a scar will remain, recognizable on quarry walls. The Niagaran limestone of our region has some open fissures and many fissure fillings, most of the latter still unconsolidated, known to the quarrymen as "clay seams."

Most of the limestone fissures are filled with clay (fig. 57). One might lose interest at once on hearing this for "clay" does not sound very intriguing. Some one, however, moved as the scientific investigator always must be, dug out some of this clay and looked at it critically. "How did it get here? Where did it come from?" he queried. There was no book, no report, no person to answer his question. No one knew. No one had ever really raised the question before. He found the answer in the clay itself, the only place where it could be found. The clay contained jet-black shiny teeth, the teeth of sharks (figs. 58). There were not only cutting teeth of the type associated with sharks, but "pavement" teeth also, crushers or grinders with which their possessors cracked the shells and carapaces of their prey. No fish teeth are known in the Niagaran limestone itself, their occurrence being limited to the clay fissure fillings.

From studies in other regions where younger sedimentary rocks occur, these shark teeth are known to be Devonian or Mississippian in age, some few millions of years younger than the Silurian system to which the Niagaran limestone belongs. A great gap in time occurred between the making of the Niagaran limestone and of the fissure clay. The fissuring appears to have occurred in this interim. If weathering and groundwater action opened the fissures along joint cracks, as one theory holds, then we have here a record of emergence of the region after the limestone was deposited, the sea being drained off and the

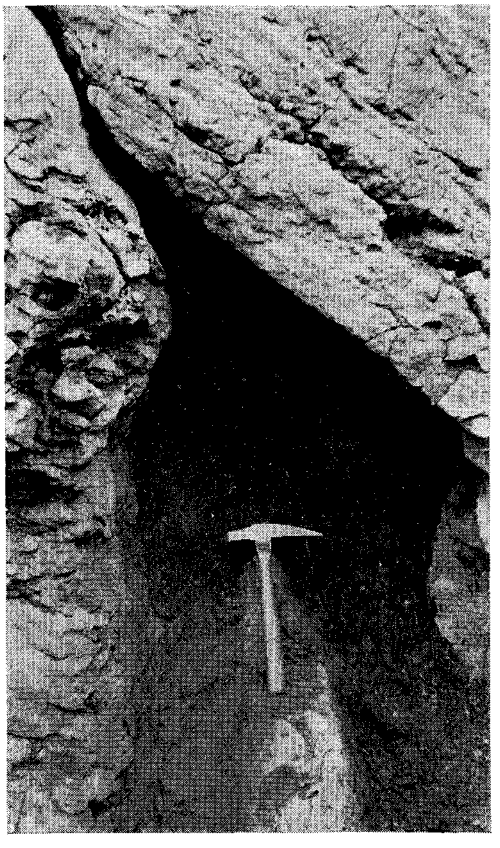


FIG. 57.—An irregular fissure filled with brown shale in which shark teeth are fairly common (Moulding-Brownell quarry at Thornton).

FIG. 58.—Shark teeth (black) and limestone fragments (light colored) in clay filling from a fissure in the Niagaran limestone in quarry at Elmhurst. Teeth are about half natural size.

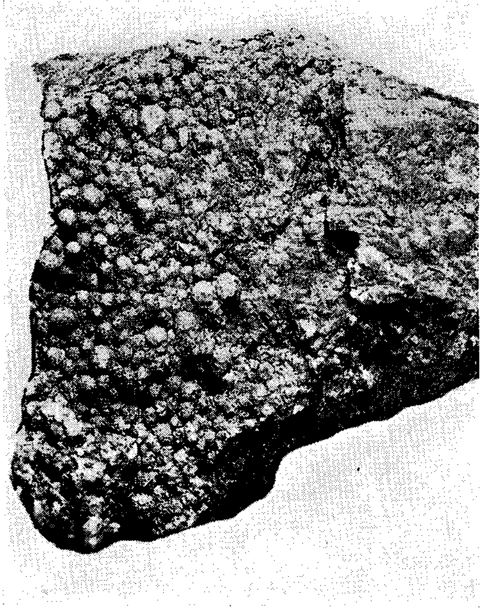


FIG. 59.—A fragment of pisolitic (pea-like) limestone from fissure filling (north quarry, Moulding-Brownell Company, Thornton).

Niagaran limestone undergoing its first encounter with the processes of degradation. The fissures that formed during this time were standing open to receive the first sediments of the returning sea. Sharks that inhabited that sea left a record of their presence.

Probably the Niagaran formation was entirely covered with thick marine deposits before this episode closed. The fissure fillings, then, are only the roots of vanished formations that once overlay the region and were removed when still later erosion scoured the surface down to the more resistant limestone.

Most of the "seams" are of gray or greenish-gray clay, and all search for fossils in this material thus far has proved fruitless. It is only in black or dark clay that the sharks' teeth are found. Still other fissures contain limestone which has healed the cracks much as a filling of cement mud might joint the walls together again. Limestone fillings are difficult to detect because the material is so similar to the surrounding rock. Once found, however, they present interesting problems. In some the filling is vertically banded as though deposited in layers on the fissure walls. In others the limestone filling is composed of pellets, the size of peas, all cemented together (fig. 59).

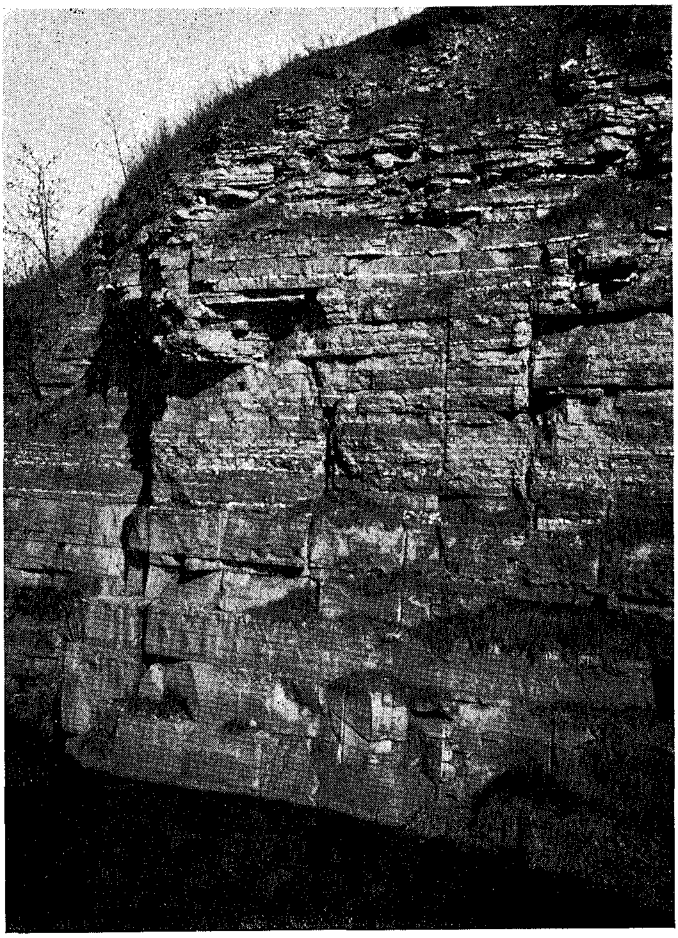


FIG. 60.—Layers of white chert in the Niagaran limestone exposed in a quarry near Lemont (Sag Bridge quadrangle). (Illinois Geol. Survey Educational Series No. 3, fig. 32.)

Broken pellets show by concentric bands how they grew from tiny beginnings. These features seem to record deposition from solution rather than from suspension. They are something like veins in the rock. Where clay seams are associated with the limestone fillings the clay is definitely younger, occupying only the central part of the fill.

Other fissure fillings consist of fragments of the wall rock which fell into the crack as it was opened. Their interstices may or may not be packed with clay. Still other fissures contain brightly colored tough sandy clay, brown, bluish, greenish, yellowish, and reddish, full of black silicified fossils, the original calcium carbonate replaced by quartz. These fossils are mostly new to science, their age unknown except that they more nearly resemble those of the Niagaran limestone than of any other known formation.

The subject of fissuring and fissure filling in the Niagaran limestone has not yet been fully studied. From what is now known, fissuring appears to have occurred at different times and under different conditions. Perhaps different causes for fissures of different ages will eventually be recognized.

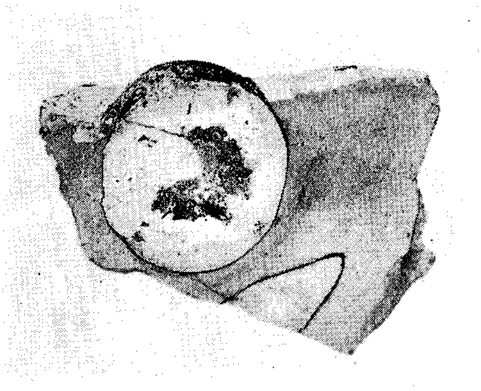


FIG. 61.—Cross-section of spheroidal chert nodule in a limestone fragment. Most of the nodule is hard and white but the dark central portion is porous and friable.

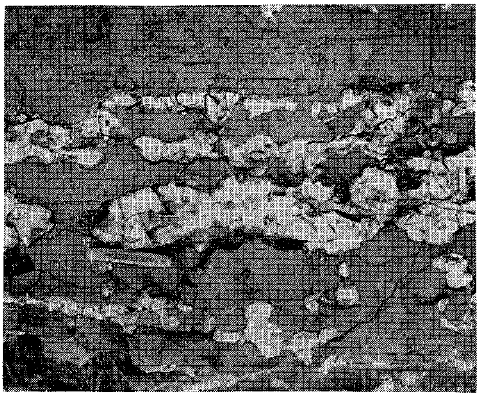


FIG. 62.—Irregular chert nodules in the Niagaran limestone.

CHERT

One may see in some exposures of the Niagaran limestone what looks like rows of pebbles in the rock, distributed parallel with the bedding-planes (fig. 60). They are rarely if ever on the actual parting itself but occur in the midst of a stratum. Though they are composed of hydrated silica and quartz and thus are unlike the limestone in composition, they are not "pebbles." They are nodules of chert, a form of quartz or silica which "grew" by chemical aggregation on the sea floor while the limy sediments were being deposited or which grew in the rock at some later date. The problem of their origin leads us into two fields about which we know very little: (1) the conditions at the bottom of wide, shallow, lime-depositing seas, and (2) alterations in lime mud occuring during its change to firm dense limestone. Neither field can be actually entered and studied at first hand. We as yet understand but little better what goes on in these situations than we would understand political conditions in a strange country by glimpses from an aeroplane of processions and pyrotechnics below us.

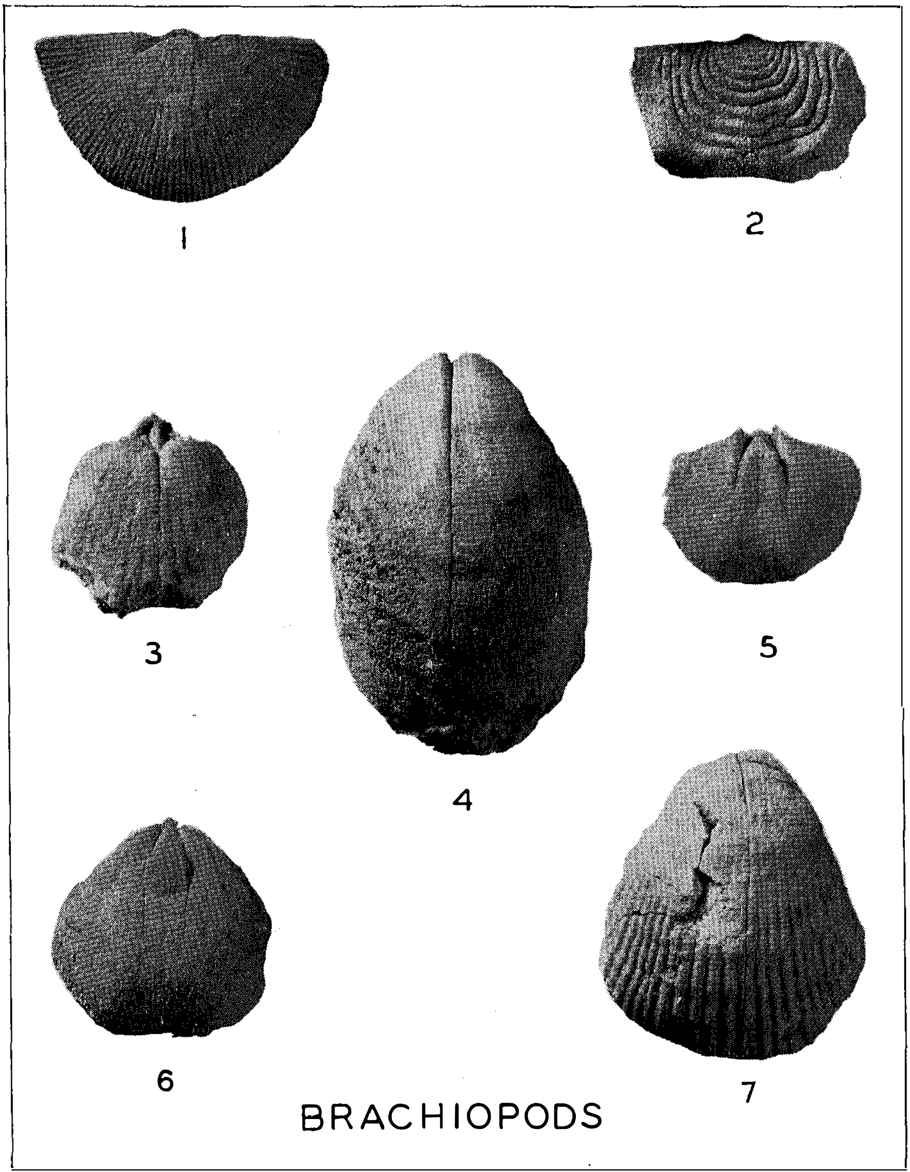
The chert nodules of the Niagaran limestone have exceedingly variable shapes. Most of them are elongated parallel to the stratification. Some are simple egg-shapes (fig. 61). Some are branched in all directions and where closely crowded, the "tentacles" of adjacent nodules are tangled with each other or actually join. Such branched shapes (fig. 62) are obviously impossible in pebbles.

Many of the nodules contain silicified fossils, originally made of calcium carbonate. Some large coral fossils contain nodules which faithfully reproduce those parts of the coral in chert, the rest being lime carbonate. Thin limestone layers penetrating chert nodules or thin chert seams penetrating limestone suggest strongly that the chert is of secondary origin, its growth necessitating concomitant removal of calcium carbonate to make room for the silica. Only groundwater could do this, but apparently it could not occur under present conditions. Perhaps at depths of hundreds of feet this might happen, and if so the chert nodules suggest the former presence of a thick cover of sedimentary rocks younger than the Niagaran limestone but since eroded away.

The texture of the chert nodules also varies widely. Some are dense and flinty, others are porous and somewhat chalky in appearance. The porous ones tend to blacken on exposure, the dense ones remain pure white or light gray. Some have dense cores and porous exteriors, in others the reverse is true. Causes for these variations are as yet unknown. There is still much to be learned about the Niagaran chert nodules and their origin.

BULLETIN 65 · PART I

PLATE II



EXPLANATION OF PLATE II

FIG. 1.—Schuchertella subplana
FIG. 2.—Leptaena rhomboidalis
FIG. 3.—Uncinulus stricklandi
FIG. 4.—Pentamerus oblongus
FIG. 5.—Spirifer radiatus
FIG. 6.—Meristina maria
FIG. 7.—Conchidium laqueatum

FOSSILS

There is perhaps nothing in the Niagaran limestone more interesting to the average observer than its fossils. They are unequally distributed so that large exposures may yield no recognizable forms whereas other layers may be crowded with them. The reef structures in particular afford good fossil hunting. The collector must not expect to find the petrified shells themselves however. What he collects will almost invariably be casts of the interiors of the shells and hard coverings or moulds of the exteriors, made in the lime mud in which the organisms became buried. The actual hard parts have been removed by groundwater during the formation's long subsequent experiences. Interesting "squeezes" may be made from the moulds by forcing soft wax into them. This, on removal, is a replica of the animal's exterior.

There are seven large groups of animals well represented by various species in the Niagaran fauna. One unfamiliar with marine animals must learn a few new names and forms, but paleontology is a science in itself and no adequate presentation of its elements can be attempted here.

Plates II-VII are photographs of specimens of Niagaran fossils from the Chicago region and illustrate some of the more common representatives of all the seven groups. Plate II shows brachiopod shells. The brachiopods are bivalve-shelled forms, somewhat resembling clams in general appearance. The two valves of the clam shell, however, are mirror images of each other whereas the two brachiopod valves are invariably unlike each other. There are living brachiopods in the sea today, although they are not to be found in collections made along the beach. They were far more abundant in earlier periods of the earth's history such as the Silurian, when the Niagaran limestone was deposited. Almost all bivalve fossils found in this limestone are brachiopods.

Plate III shows gastropod and pelecypod (clam) shells. Gastropods are snails and about as common today as during Niagaran time. Most of them are closely coiled shells, with the coil more or less extended into a spire. Each shell constituted a continuous chamber in which the animal lived.

Plate IV shows members of the cephalopod group. Most cephalopods today, quite unlike their Silurian relatives, are soft-bodied and without an external shell. The squid and octopus are examples. Cephalopods of Silurian time lived in shells which are always recognizable, whatever their shape or size, by the presence of numerous partitions across the shell length dividing the structure into separate compartments. As the animal grew, it built successive floors behind it and thus successively abandoned its old living quarters for new and larger ones. Abandoned chambers, sealed off by the partitions, were gas-filled, buoying up the shell so that the animal was free-swimming. One surviving shelled cephalopod with this habit is known—the pearly or chambered Nautilus of the Indian Ocean. Modern cephalopods are tentacled and predaceous. Early forms doubtless were also, though the fossil remains, not recording the soft parts, cannot be expected to prove this. Early cephalopod shells were straight. Later came the habit of coiling as snails have always done, but mostly in a plane, whereas most snails are coiled in a spire. The initial stages of coiling are shown in some of the Niagaran forms.

Plate V shows specimens of trilobites. Trilobites are very interesting fossils. The group has been extinct for many geological periods, probably for two hundred million years, but some of their relatives are living today. These are the aquatic crustaceans like the crab, the crayfish, the lobster, and the shrimp. They are not, however, direct descendants of the trilobites.

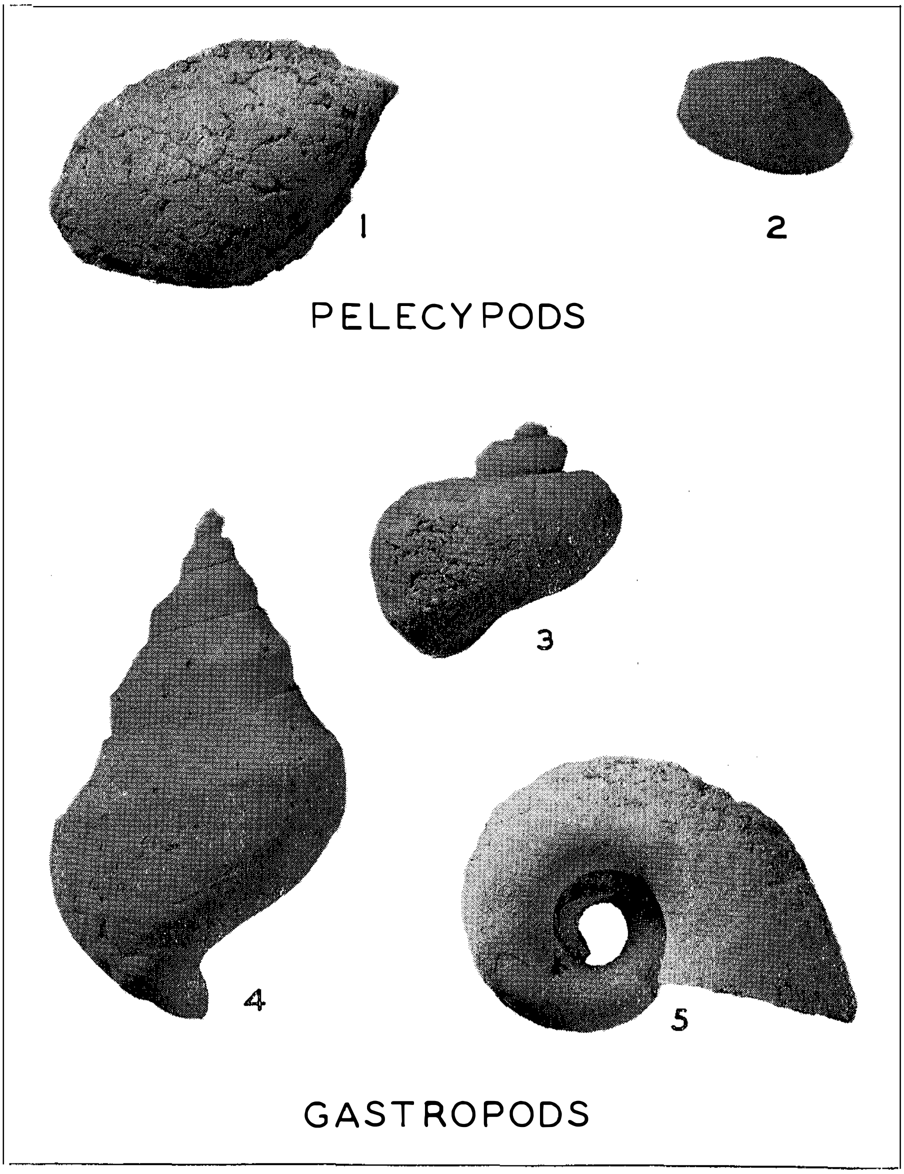
Crustaceans have a jointed or articulated shell or exo-skeleton, like a suit of armor, which allows a much more complex and detailed body structure than does a shell, even a hinged two-piece shell. Complete trilobite fossils show a head, a series of body segments, and a tail. Decomposition and shifting about by the currents often separated these articulated portions before burial so that lone heads or tails are more common than complete forms. An individual trilobite may have left several fossils. This follows from their habit, possessed also by modern crustaceans, of moulting or shedding the entire armour as the animal increased in size. Discarded exo-skeletons made as good fossils as did the suit in which the creature died. Some of the fossil trilobites of the Niagaran formation are found rolled up.

Corals (pl. VI) include both single and compound forms, the compound ones resembling in a general way modern reef-building forms that live in tropical and subtropical seas. Simple or single corals are commonly called cup corals or horn corals from their shapes. Two common compound corals of the Niagaran fauna are the honeycomb and chain corals, each named from fancied resemblances in their cross-sections.

Cystoids are related to the crinoids (fig. 63 and pl. VII). They both belong to a larger group whose best known modern representatives are starfish and sea-urchins. Cystoids are extinct, crinoids still survive although they are not shore forms and therefore do not appear in collections made during a stroll along the sea beach. All members of this larger group have calcareous exo-skeletons or body walls made up of plates which fit together in various mosaic patterns. Commonly a fivefold symmetry is observable in members of the larger group. It is shown in the arrangement of plates and pores on the sea-urchin calyx and in the five arms of the starfish. Crinoids show this, cystoids do not. Living crinoids have been called sea-lilies or stone-lilies, because of their limited resemblance in form and in position when alive. But the crinoid is an animal and the calyx is like a lily only in shape, the crinoid stem is merely a support for the calyx and crinoid "roots" are simply holdfasts for the stem. Fragments of jointed crinoid stems, known as "Indian beads," are fairly common fossils. The calyx is less frequently found.

Bryozoa (pl. VI) still exist although only as encrusting forms, none as upright structures standing by themselves. Bryozoa have the compound or colonial habit exclusively and their Silurian fossils somewhat resemble those of compound corals. The individual bryozoan lived in a tiny compartment, with one window, in the composite structure. Other groups such as foraminifera, sponges, and pelecypods, are more rarely or less conspicuously present.

Most of the Niagaran fossils have living relatives in modern oceans. Few have living fresh-water relatives and only gastropods have living land-dwelling relatives. In this we find further support for the idea of marine origin of the Niagaran limestone.



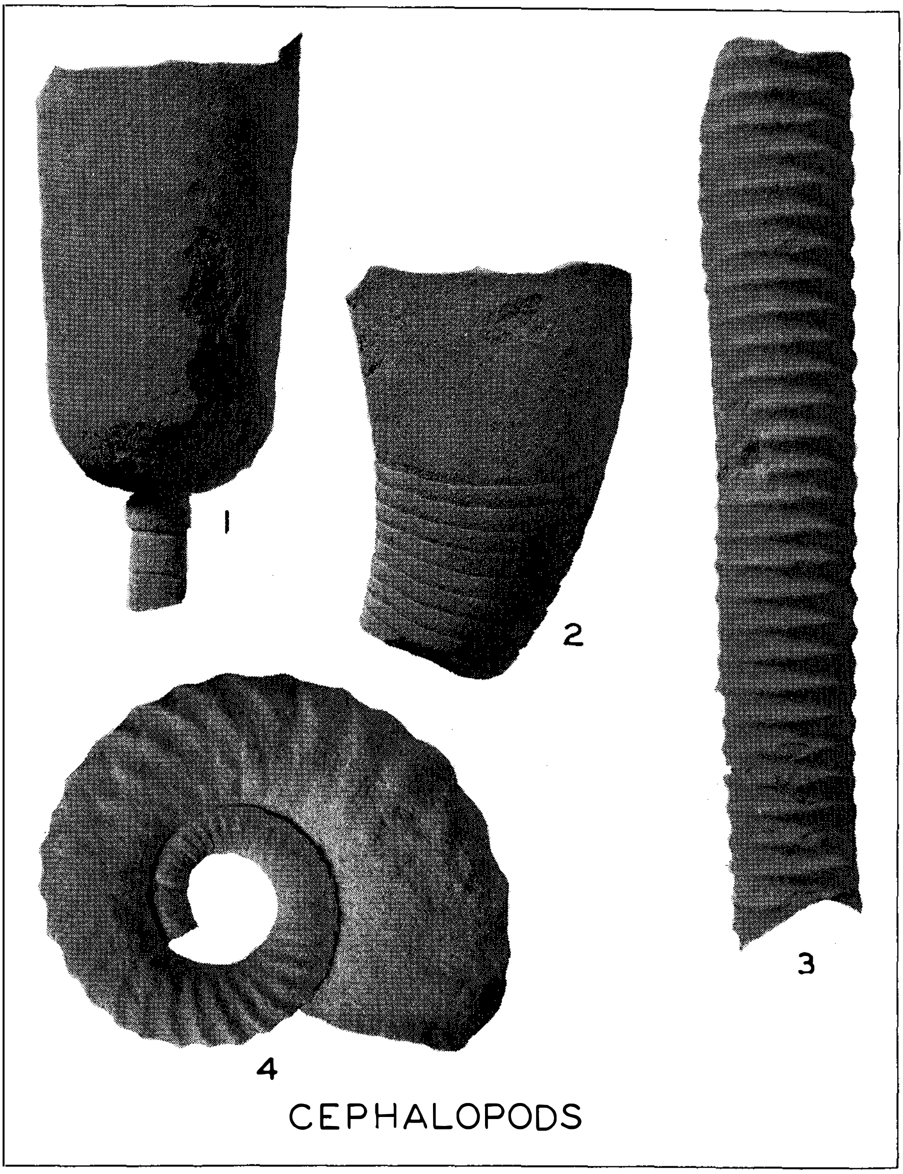
EXPLANATION OF PLATE III

PELECYPODS

FIG. 1.—Mytilarca denticostia
FIG. 2.—Matheria recta

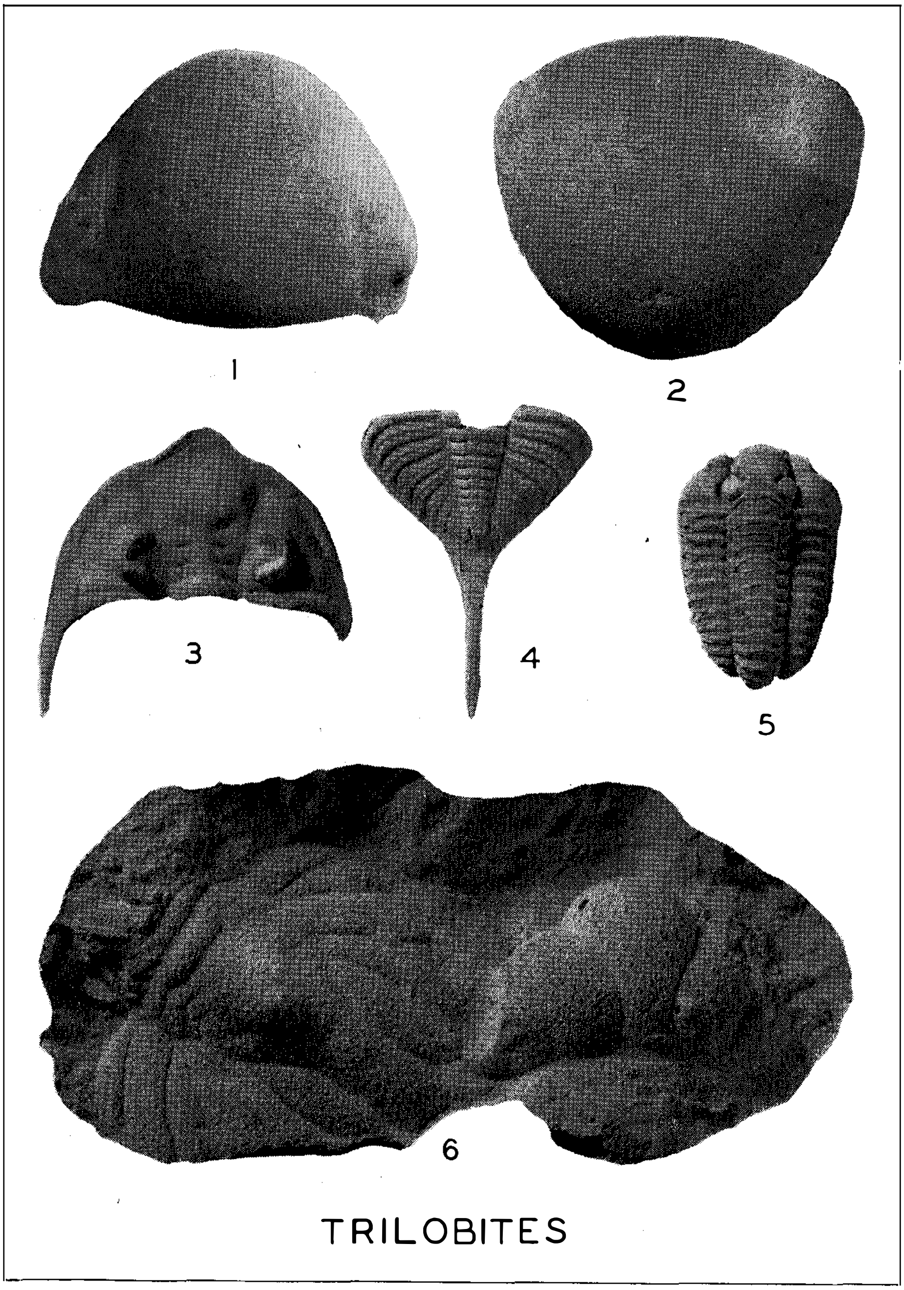
GASTROPODS

FIG. 3.—Phanerotrema occidens
FIG. 4.—Lophospira rotunda
FIG. 5.—Tremanotus alpheus



EXPLANATION OF PLATE IV

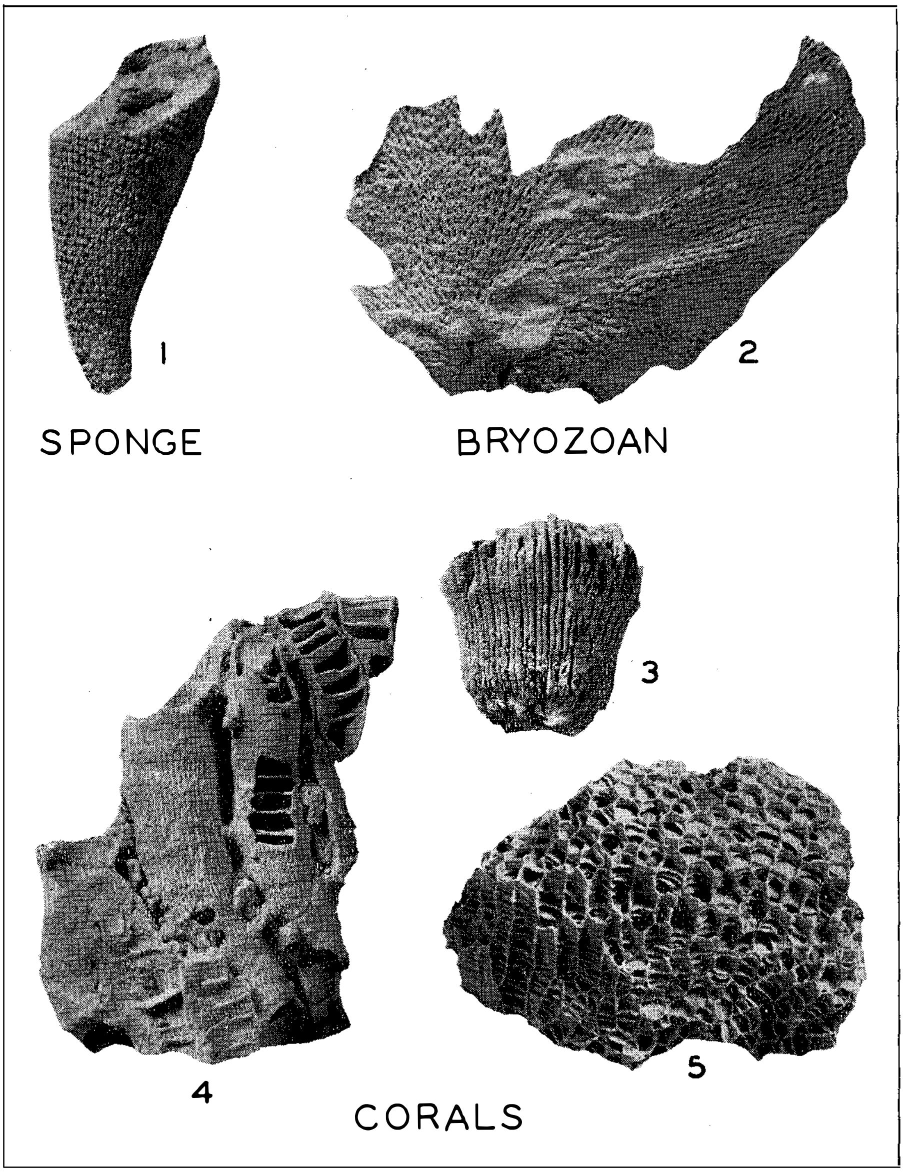
FIG. 1.—Kionoceras cancellatum
FIG. 2.—Cyrtoryzoceras fosteri
FIG. 3.—Dawsonoceras bridgeportensis
FIG. 4.—Discoceras marshi



EXPLANATION OF PLATE V

FIGS. 1, 2.—Bumastus insignis
FIGS. 3, 4. —Dalmanella platycordata
FIG. 5.—Calymene celebra
FIG. 6.—Arctinurus chicagoensis

BULLETIN 65 · PART I PLATE VI



EXPLANATION OF PLATE VI

SPONGE

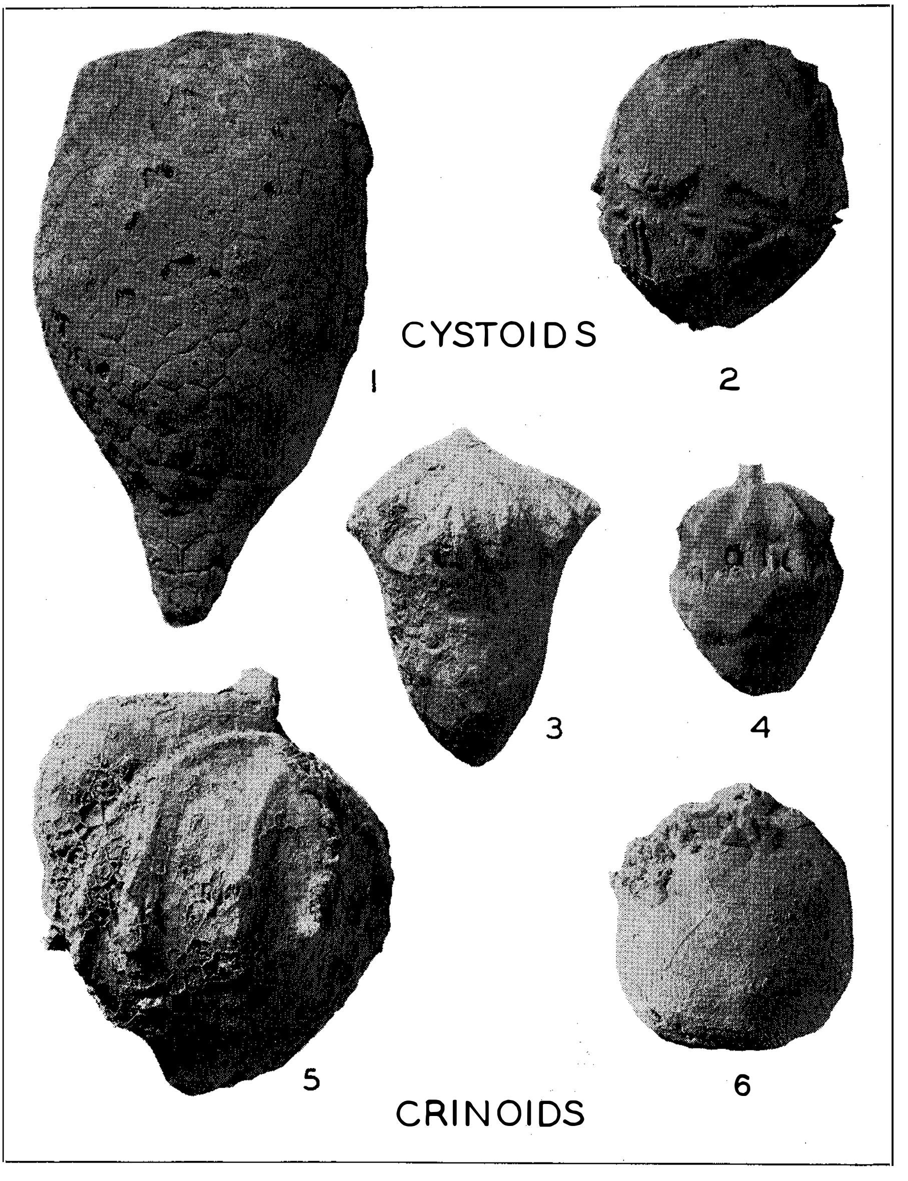
FIG. 1.—Calathium sp.

BRYOZOAN

FIG. 2.—Fenestella sp.

CORALS

FIG. 3.—Lindstromia sp.
FIG. 4.—Pycnostylus sp.
FIG. 5.—Favosites niagarensis



EXPLANATION OF PLATE VII

CYSTOIDS

FIG. 1.—Holocystites sp.
FIG. 2.—Caryocrinites sp.

CRINOIDS

FIG. 3.—Periechocrinus infelix
FIG. 4.—Eucalyptocrinus crassus
FIG. 5.—Syphonocrinus nobilis
FIG. 6.—Crotalocrinus cora

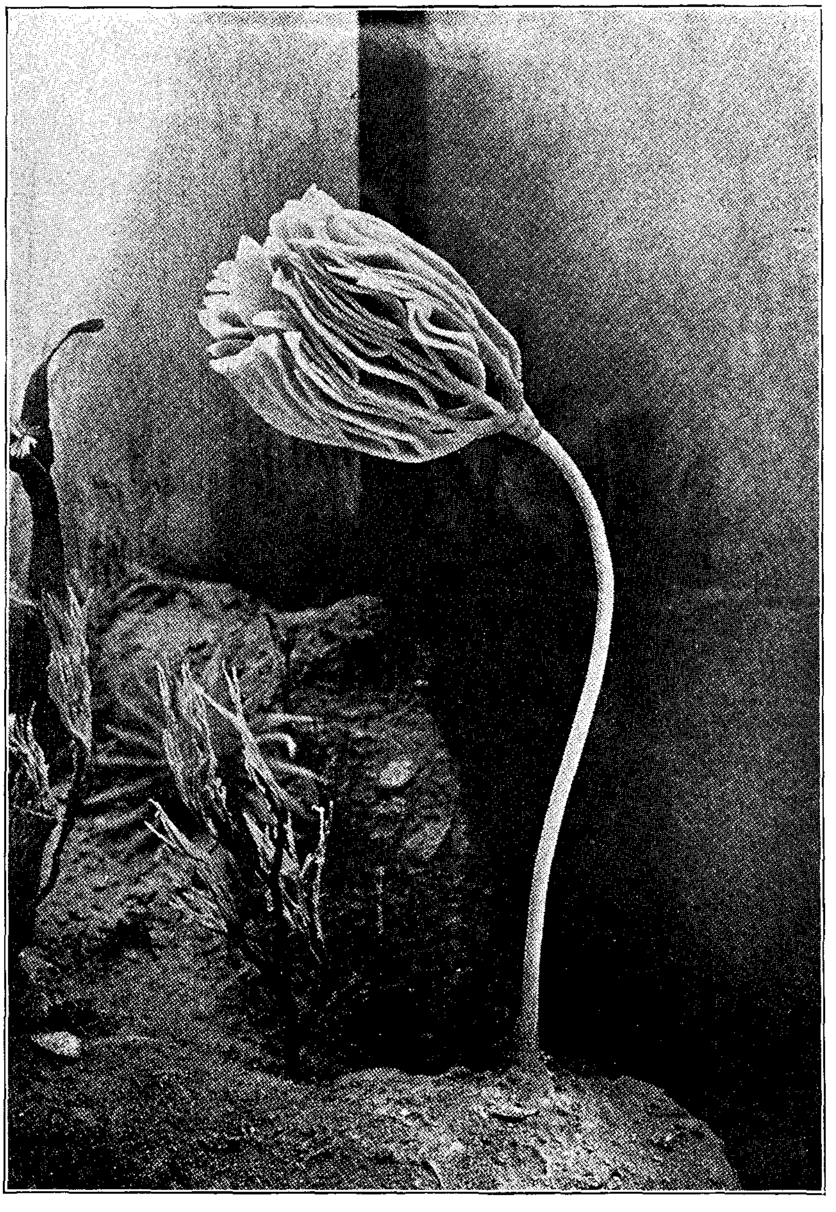


FIG. 63.—Restoration of a fossil crinoid, commonly called sea-lily. (Illinois Geol. Survey Bull. 51, fig. 12, 1925.)

MINERALS

A number of minerals may be found in the Niagaran formation. The principal ones are calcite, dolomite, quartz, pyrite, and sphalerite. The Niagaran formation is very largely composed of calcium-magnesium carbonate but it is only microscopically crystalline. It therefore yields but few specimens of either calcite ($CaCO_3$) or dolomite ($CaMg(Co_3)_2$) for the mineral collector. Of the two, calcite may be expected. It is a transparent or translucent crystal, only slightly harder than the finger nail, and possesses marked cleavage in three directions, so that broken pieces of calcite are usually rhombohedrons, their angles being about 75° and 105°. Calcite crystals are likely to occur in cavities in the limestone, deposited there by groundwater. Dolomite is similar to calcite but is commonly pinkish or brownish in color and has the unusual feature of curved crystal faces. Its hardness is about that of calcite.

Quartz (SiO_2, silica) occurs as crystalline growths in cavities. The crystals are small and crowded but some of them show the typical six-sided prism capped by a six-sided pyramid. It is generally colorless and transparent or translucent and is a groundwater deposit. It is readily distinguished from calcite by its superior hardness, as a knife blade will not scratch it, and it shatters or breaks irregularly. Chert or flint (hydrous silica), a cryptocrystalline variety of quartz, occurs as the nodules described.

Pyrite (FeS_2, iron sulfide, "fool's gold") is not uncommon, occurring in thin seams or as separate crystals on the walls of cracks. It has a bright brassy or golden color when fresh, a metallic lustre, and crystallizes in cubes or modifications of cubes. Pyrite is readily attacked by the air and oxidizes to form rusty stains in the rock. Incipient oxidation produces beautiful peacock colors on the surface of the crystal.

Sphalerite is rare. It is a sulphide of zinc (ZnS) of the color and lustre of rosin. It is not likely to show crystal form. It has a tendency to break along cleavage planes at angles of 60° and 120°.

Other minerals are known in the Niagaran limestone but are very rare. Some are brought to light only by dissolving a limestone sample with acid and studying the insoluble residue under a compound microscope.

General Distribution and Structure of the Formation

There is, or once was, a complete continuity of the Niagaran formation from Chicago to Niagara Falls; both places were under the same shallow sea at the time this lime mud was laid down. So with every other place where the Niagaran limestone is identified. A geological formation is a body of rock made at a particular time, it is the record of its time, a page of the book of earth history in which the events of that time are inscribed. The extent of the formation expresses the extent of the Niagaran sea.

At Chicago, deep wells penetrate four different limestones. At Milwaukee several limestones are similarly known to underlie the city completely, and the uppermost one is also the Niagaran. At Grand Rapids and Muskegon, wells penetrate different limestones also but the Niagaran is there identified far down in the series instead of at the top. So at Detroit and at Cleveland. How does the geologist identify any one limestone, or other sedimentary formation?

The most important evidence for identification is the fossil content. You may collect the same species from the uppermost formation in the river gorge below Niagara Falls that you find in the Chicago quarries. Your friends at Milwaukee or in the upper Wabash Valley of Indiana will find the same species in their local limestone. The collector working the Mississippi River bluffs between Clinton and Davenport will find a formation yielding the same suite of fossils. But he is more fortunately situated because he will find other formations cropping out in the bluffs below and above the Niagaran and yielding different species of fossils, each formation having its own suite. He must conclude that each formation is identifiable by its fossil fauna.

Each formation possesses essentially the same fossils in all its exposures. Significant differences exist between the fossil assemblages in different formations. The order of age is indicated by the order of superposition, the lowest being the oldest, the highest the youngest. In these three conclusions lie the principles of identification and correlation. But "significant differences" does not mean "complete dissimilarity" in fossil fauna.

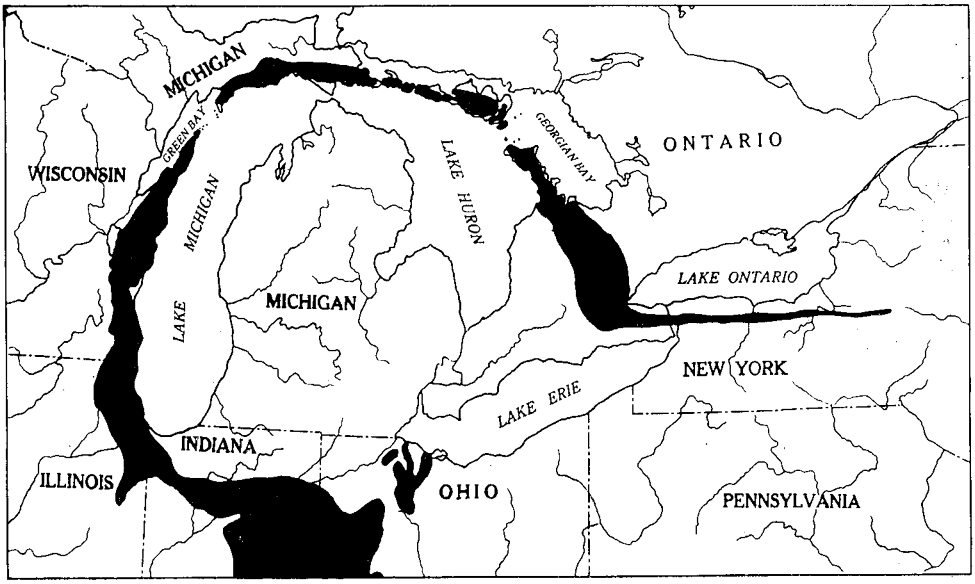


FIG. 64.—Outcrop belt of the Niagaran formation in the Great Lakes region.

Now the Mississippi Valley student, knowing the order of superposition and the character of the fauna of each formation in his section, moves to Chicago or Milwaukee or Detroit where only the uppermost of the bedrock series of each place is exposed. He collects fossils from it and thus identifies it as the formation which yields the same fossils in the Mississippi River bluffs. Using Niagara as a type locality we thus identify the outcropping bedrock at Chicago as the Niagaran limestone.

The Niagaran formation of the Great Lakes region is exposed in enough places to allow the mapping of its outcrop areas. Figure 64 is such a map, drawn as though there were no glacial drift. The outcrop belt swings northward along the west side of Lake Michigan from Chicago, then east through the eastern end of Michigan's upper peninsula and a row of islands in northern Lake Huron, then south across the peninsula that pinches Georgian Bay off the main area of Lake Huron, and across Ontario to cross back turning eastward into the United States between lakes Erie and Ontario where Niagara River takes its spectacular tumble. Thence the outcrop belt continues eastward into New York State.

The rocks immediately below the drift on the outside of this great curved course are older, on the inside they are younger. Since younger rocks in a section must overlie older, it follows that if they were all perfectly flat-lying, the Michigan peninsula inside the curve would be higher than surrounding land. It would stand above its surroundings as high as the younger rocks are thick, which in central Michigan is about 4500 feet. But central Michigan is not higher than Ontario or Wisconsin or Illinois. There is only one other explanation —the Niagaran and overlying formations are depressed so that they dip radially inward toward the center of the rude circle of the Niagaran outcrop. This conclusion is supported by well logs, the Niagaran occurring deeper and deeper toward the center (fig. 65). Lower Michigan is a basin structure. The Niagaran formation in the Great Lakes region is shaped like a saucer and the saucer is full of younger rocks, each unit of them being a smaller saucer and all nested perfectly together. In the same manner, the older formations that crop out or underlie the glacial drift outside the Niagaran belt extend beneath the Niagaran formation in the Lower Michigan basin. As the basin was depressed, the formations in its elevated rim were weathered and eroded away so that except for the youngest and smallest saucer in the stack only their rims may show at the surface or occur immediately beneath the glacial drift. As the formations immediately overlying and underlying the Niagaran limestone are less

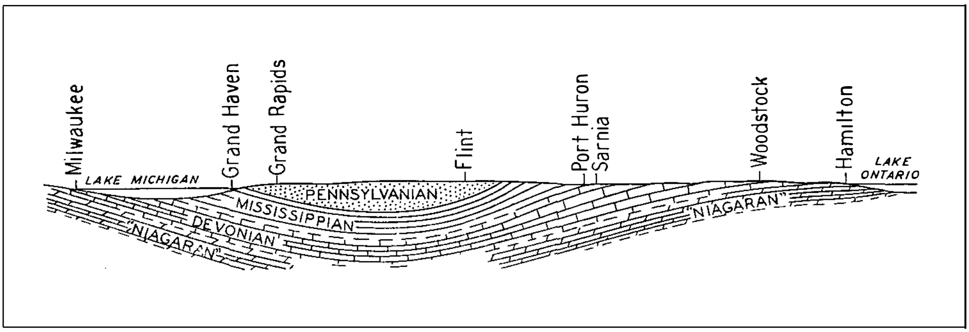


FIG. 65.—Geological cross-section of lower Michigan and southern Ontario. Vertical scale is exaggerated.

resistant to erosion, they were worn down more and along their outcrop belts are the depressions occupied by Green Bay and Georgian Bay (on older rocks) and by lakes Michigan and Huron (on younger rocks), whereas the more resistant Niagaran limestone, holding up better than the weaker rocks adjacent, constitutes the peninsulas and islands, and borders the outer coasts of the two lakes.

If the outcrop belt of the gigantic Niagaran saucer is itself an eroded edge, it can not be the original shore line of the Niagaran sea. The limestone must have been more extensive to the west of the Chicago region, to the north towards Canada, and to the east of Lake Huron. In the southeastern part of the Chicago region, where the Niagaran limestone emerges from beneath younger rocks, it is almost 500 feet thick. It thins gradually westward across the outcrop belt until at the western edge, near Joliet, it disappears and its place beneath the drift is taken by the next older formation. This thinning is wholly a matter of erosion and so is its absence farther west in Illinois. It once was present—it has been entirely removed. The Niagaran limestone along Mississippi River, 200 miles farther west, is an isolated portion of this ancient sea-bottom lime mud deposit. The Niagaran marine faunas are alike in both places and must have migrated freely across the gap. There must have been a continuous sea from eastern Iowa to western New York, even though there is not today a continuous Niagaran formation between these points. Downwarping of the Michigan basin (the basin of saucers, not the lake basin) protected the Niagaran in that region from erosion, while upwarping in Illinois exposed the Niagaran there to inevitable destruction (fig. 65). It was gone long before the ice-sheet arrived to cover the area with its drift.

Using this method of reconstructing the Niagaran sea, outcrops of the same formation near Lake Winnipeg and about James Bay and Hudson Bay in Canada, on the archipelago north of the continent, and even in northern Greenland, less than 9° from the Pole, are tied together to show the extent of this great continental marine flooding. Other regions, known in the same way to have been submerged, make the amazing total of 40 per cent of present North America then under shallow sea water (fig. 66).

Collections of marine animals today from the coast of Florida, of Maryland, of New England, of Labrador, and of Greenland show very great differences, for which the decreasing temperature toward the north pole is most largely responsible. One of the most surprising things about the Niagaran formation is that its fossil fauna in the Chicago region is essentially duplicated in northern Greenland. Its reefs are known from northern Indiana to Hudson Bay. There could not then have existed a temperature range in latitude such as we have today. Mild and equable temperatures seem to have prevailed—subtropical as we now rank them. The Silurian earth did not have climatic zones.

WELL LOGS AND THEIR INTERPRETATIONS

The deepest well in the Chicago region is located at South Chicago Heights (Steger quadrangle). It was drilled in 1893 as an oil and gas test well and is reported to have penetrated to a depth of 2756 feet, more than half a mile.[6] Other reports place the depth of the well as 2500 or 2700 feet.[7] Later the well was purchased by the village

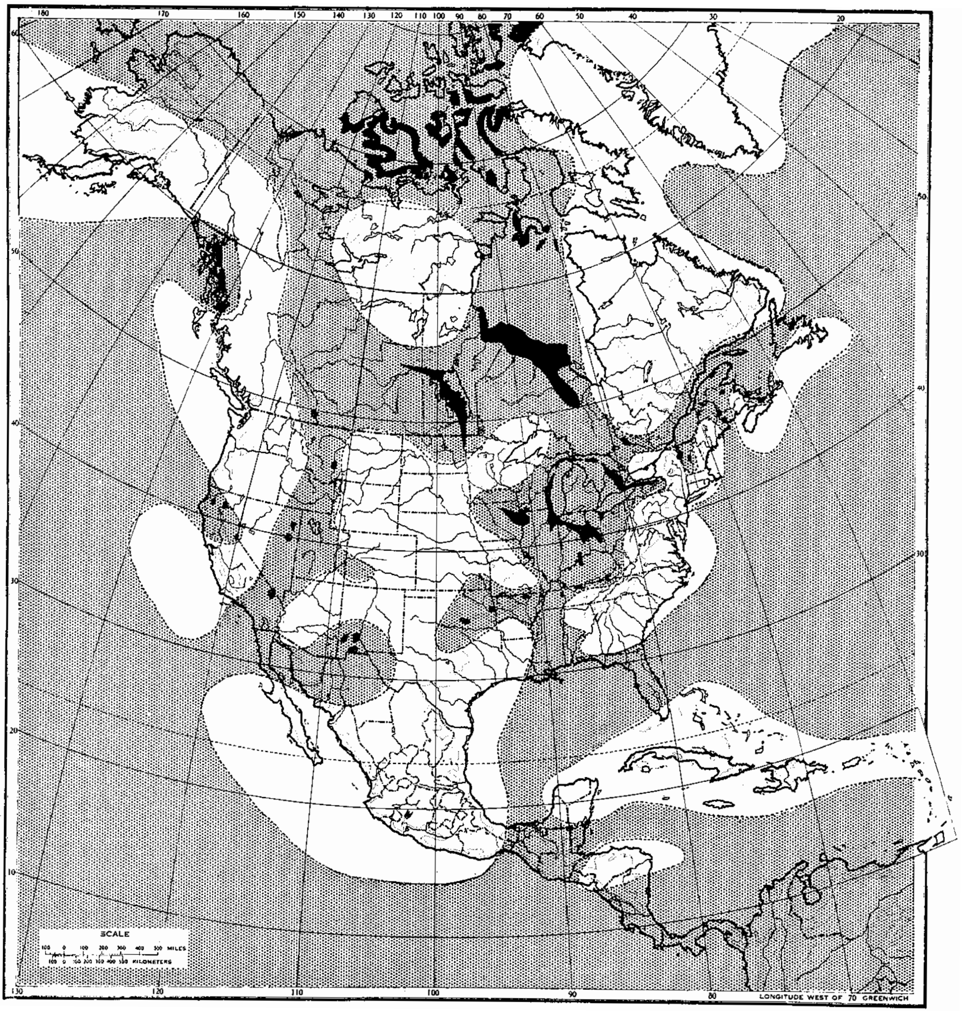


FIG. 66.—The Niagaran interior sea of North America, shown stippled; white areas were land.

and used as the source of its municipal water supply. The water apparently comes from formations in the upper part of the well.

The altitude of the surface of the ground is 712 feet above sea-level and the bottom of the well is therefore a little more than 2,000 feet below sea-level. The drift is 56 feet thick[8] at the well site and penetration into bedrock is thus 2,700 feet. The Niagaran limestone was 350 feet thick below the glacial drift. Below it, the well entered shale, passing into more limestone 180 feet deeper. The second limestone proved to be 300 feet thick, sandstone being encountered beneath it. At this depth the well was already 174 feet below sea-level. This sandstone was 200 feet thick and below it the drill entered still another limestone formation, 350 feet thick. Another sandstone 250 feet thick was found beneath this third limestone, with a fourth limestone 190 feet thick below it. Under the fourth limestone there was a third sandstone into which the drilling was carried 880 feet without passing through it.

[6]Habermeyer, G. C., Public ground water supplies in Illinois: Illinois State Water Survey Bull. 21, p. 607, 1925.

[7]Alden, W. C., U. S. Geol. Survey Geol. Atlas, Chicago folio (no. 81), p. 2, fig. 2, 1902.

Anderson, Carl B., The artesian waters of northeastern Illinois: Illinois Geol. Survey Bull. 34, pp. 107–108, 292, 1919.

[8]The thicknesses of the formations as given here are derived from Alden's record in the Chicago folio, cited above. They are not exactly accordant with the thicknesses revealed by more recently drilled wells in the vicinity.

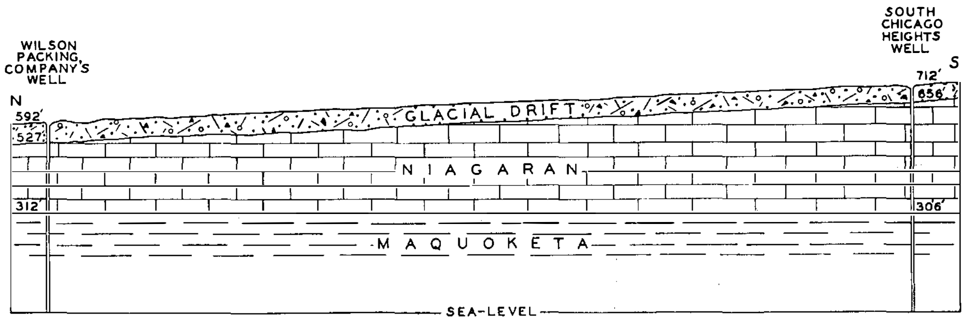


FIG. 67.—Relations of Niagaran formation in two wells in the Chicago area.

A well at 42nd Street and Ashland Avenue, drilled for the Wilson Packing Company, is typical of many in Chicago itself. The log is more detailed than that at South Chicago Heights, recording two limestones and two sandstones in place of the third limestone formation. The complete log, with formational names, is given below.

It may be noted that the Niagaran limestone is only 215 feet thick, 135 less than at South Chicago Heights. The top of the well is about 120 feet lower than that of the South Chicago Heights well and the drift 9 feet thicker, hence the upper surface of the Niagaran formation is 129 feet lower, which is almost the same as the difference in thickness. These differences are the result of preglacial erosion which beveled the upper part of the formation. The bottom of the formation is only 6 feet higher at the Wilson Packing Company well, so the formation is essentially horizontal throughout the 22 miles that separates the wells (fig. 67).

There are numerous wells of somewhat comparable depths scattered throughout the region, serving municipalities, industrial plants, and railroad yards. All find the same sequence and comparable thicknesses of rocks (formations) as far as they go. Virtually all have been continued to the Galesville sandstone; none penetrates through it.

The identification of the various formations below the Niagaran limestone could not be made if we were limited to the well data alone. But the first formation beneath the Niagaran crops out immediately to the west of the Niagaran belt, the second appears in order next west of that, and so on (figs. 68, 69). Due to erosion on the gentle upwarp west of the Michigan basin, all these buried formations appear in sequence, showing here and there through the glacial drift. From studies in the outcrop areas they have been named and classified as indicated in the log of the Wilson Packing Company well and (fig. 69).

Two systems older than the Silurian are thus represented, the Ordovician system being essentially complete. The six lowest sandstones are upper Cambrian, the Niag-

LOG OF WILSON PACKING COMPANY WELL, 42ND STREET AND ASHLAND AVENUE, CHICAGO, ILLINOIS

SYSTEM	FORMATION	CHARACTER	Thickness *Feet*	Depth *Feet*
Pleistocene	Glacial	Drift	65	65
Silurian	Niagaran	Limestone	215	280
Ordovician	Maquoketa	Shale	245	525
	Galena Platteville	Limestone	345	870
	St. Peter	Sandstone	130	1000
	Oneota	Limestone	70	1070
Cambrian	Jordan	Sandstone	50	1120
	Trempealeau	Limestone	150	1270
	Franconia	Limy sandstone	130	1400
	Galesville	Sandstone	180	1580
	Eau Claire	Shale, limestone, and sandstone	120	1700

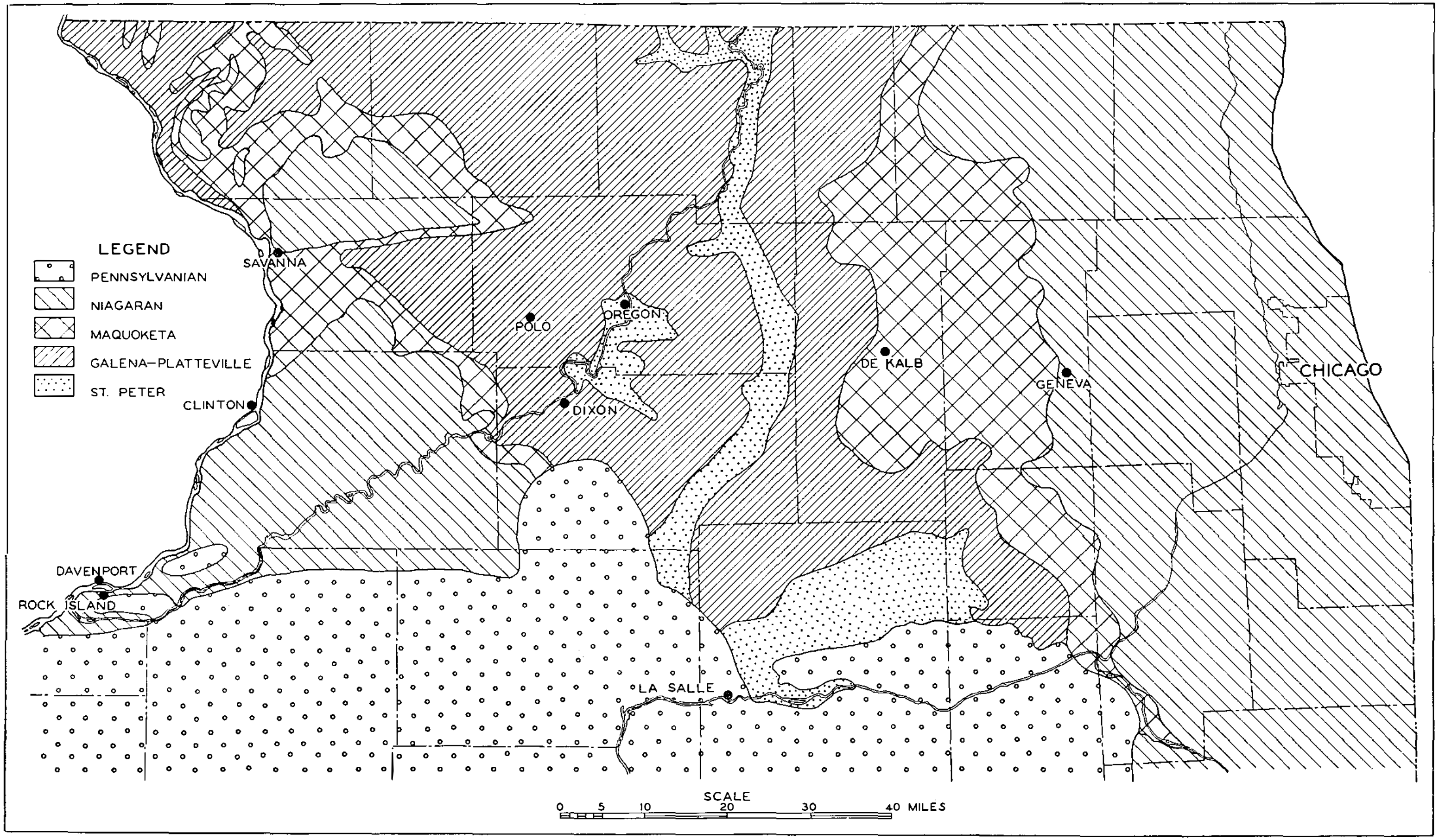


FIG. 68.—Map of northern Illinois showing the general distribution of the various rock formations under the glacial drift. Limited outcrops of Devonian formations in the vicinity of Rock Island are included with the Niagaran, and outcrops of formations older than St. Peter sandstone are included with that formation in the vicinities of La Salle, Dixon, and Oregon.

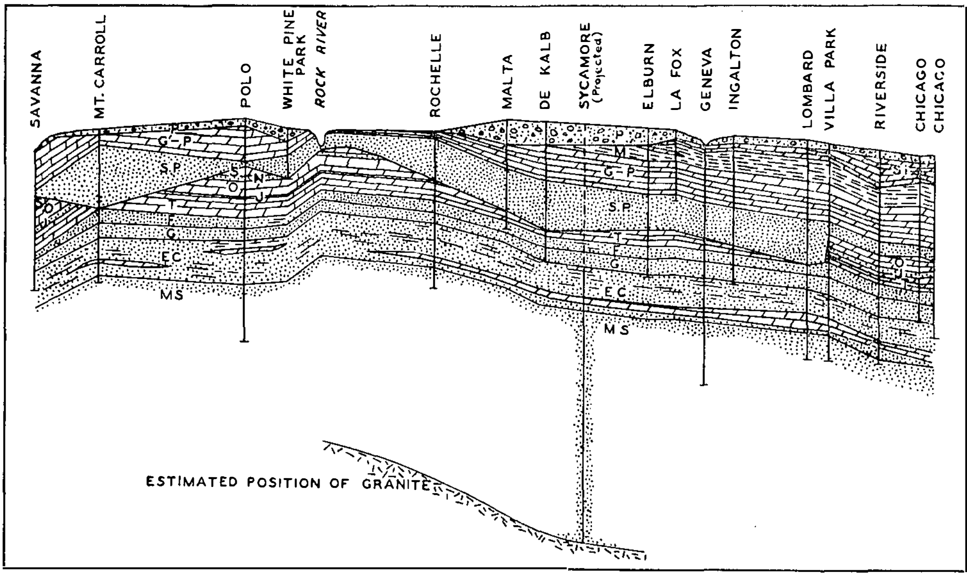


FIG. 69.—Geological cross-section of northern Illinois

P—Pleistocene	SP—St. Peter	J—Jordan	G—Galesville
Si—Silurian	S—Shakopee	T—Trempealeau	EC—Eau Claire
M—Maquoketa	N—New Richmond	F—Franconia	MS—Mt. Simon
G-P—Galena-Platteville	O—Oneota		

aran limestone is middle Silurian. All the formations listed, except the St. Peter sandstone, are known from their fossils to be marine. The St. Peter usually is nonfossiliferous and is composed of remarkably clean quartz sand. Its grains are very well rounded and locally there is considerable cross-bedding in the formation. These facts have led some geologists to infer that the St. Peter formation may be a great wind-blown sand deposit, made perhaps along the low sandy shores of the Ordovician interior sea, and later submerged by a spreading of the sea so that marine deposits covered it, but most geologists now believe that most if not all of it was actually deposited in the sea although it may have been wind-worked before its final deposition.[9] The Platteville and Galena formations are much alike and to the average well-driller pass for one formation. Their outcrops, however, yield sufficiently different fossil faunas to show that they deserve separate formational names.

The Galesville sandstone is so deeply buried that it has no outcrops in the state. At the date of writing, only three wells in Illinois have ever been drilled through the Cambrian. They enter granite, a wholly different rock whose origin was quite unlike that of the marine sedimentaries or of the glacial drift.

If we travel northward or northwestward across Wisconsin, we cross the outcropping edges of all the sub-Niagaran formations and find outcrops of granite and other pre-Cambrian rocks less than half way up the length of the state. In the northern half of Wisconsin, there is only pre-Cambrian rock beneath the glacial drift over many counties. The marine sediments of southern Wisconsin and the Chicago region, if ever covering these northern counties, have been wholly removed by erosion. Yet this is higher country in general than Illinois.

In going "uphill" into Wisconsin, we cross the edges of formations which are hundreds of feet beneath us at Chicago (fig. 70). This can be only if the formations rise in that direction and rise more than does the land surface. They are but gently inclined, it is true, and the dip (amounting to only a few feet to the mile) cannot be detected in an outcrop. It is an exceedingly important factor, however, in the water supply from bedrock wells at Chicago.

[9]Lamar, J. E., Geology and economic resources of the St. Peter sandstone of Illinois: Illinois Geol. Survey Bull. 53, p. 26, 1928.
Dake, C. L., The problem of the St. Peter sandstone: Univ. of Missouri School of Mines and Metallurgy Bull., technical series, vol. 6, No. 1, p. 224, August, 1921.

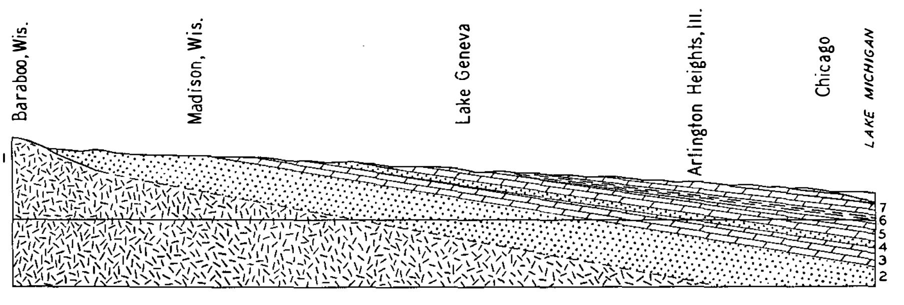


FIG. 70.—Geological cross-section of southeastern Wisconsin and northeastern Illinois.

ARTESIAN WELLS

In 1864, a well drilled at the corner of Chicago and Western Avenues encountered water at a depth of 711 feet, water which rose to the surface and flowed from the mouth of the well. It is reported to have risen 80 feet above the ground but probably this was when confined in a pipe, not as a fountain jet. Within a few decades Chicago had many flowing wells, supplying many thousands of gallons of water a day. Today it has none, and never again under present conditions will water flow from its wells.

Water in a pipe will rise no higher than the surface of its reservoir. Lake Michigan therefore, which lies below the mouths of the wells in Chicago, has no relation to their flow. The reservoir must be sought in country higher than Chicagoland. That country lies to the northwest, in central and south-central Wisconsin. The reservoir, however, does not consist of a lake or lakes on the surface—the reservoir is underground. It does not consist of a cave or of caves with subterranean lakes. It is the sum total of many millions of tiny interstices among the millions of sand grains in the two sandstones which crop out in this higher land (fig. 71) and descend southeastward beneath impervious limestone and shale formations to altitudes below sea-level at Chicago. Rainfall in Wisconsin enters the sandstones and moves slowly down-dip, to supply Chicago's deep wells. It is Chicago's relatively low altitude as compared to Wisconsin which made possible the flow from these wells 40 to 70 years ago. It was Chicago's enormous demands on these two reservoirs, exceeding the normal rate of flow through them, which caused the wells to cease flowing. It is Chicago's present and probable future use of the wells now being pumped, which banishes any hope that they will ever flow again.

Artesian water, like many other natural resources, is not inexhaustible. Earlier wells obtained their flow from the St. Peter sandstone. When this ceased to supply the demand, which it did in the 1880's, the old wells were deepened and new ones were drilled past the St. Peter to the Galesville sandstone about 400 feet below. Although the Galesville is a thicker sandstone and has a larger outcrop area in Wisconsin, it also gradually failed to supply the increasing number of flowing wells. Pumps have been installed and this has further lowered the "head" until today in the Stockyards district, where the heaviest draft is made on the subterranean supply, the lift is more than 250 feet, a lift which Nature provided gratis a few decades ago.

Serious conditions in the artesian basin of northeastern Illinois are limited to the districts where there are numerous wells and heavy demands. Some suburban towns and railroad yards right at the city limits still had, as late as 1919, an artesian lift from the Galesville sandstone to within 10 or 20 feet of the surface.

Although the water from Chicago's deep wells is supplied by Wisconsin rainfall, the long slow journey underground (its estimated rate of flow is half a mile a year) gives ample opportunity for the water to acquire soluble substances from the rock it so minutely seeps through. By the time it

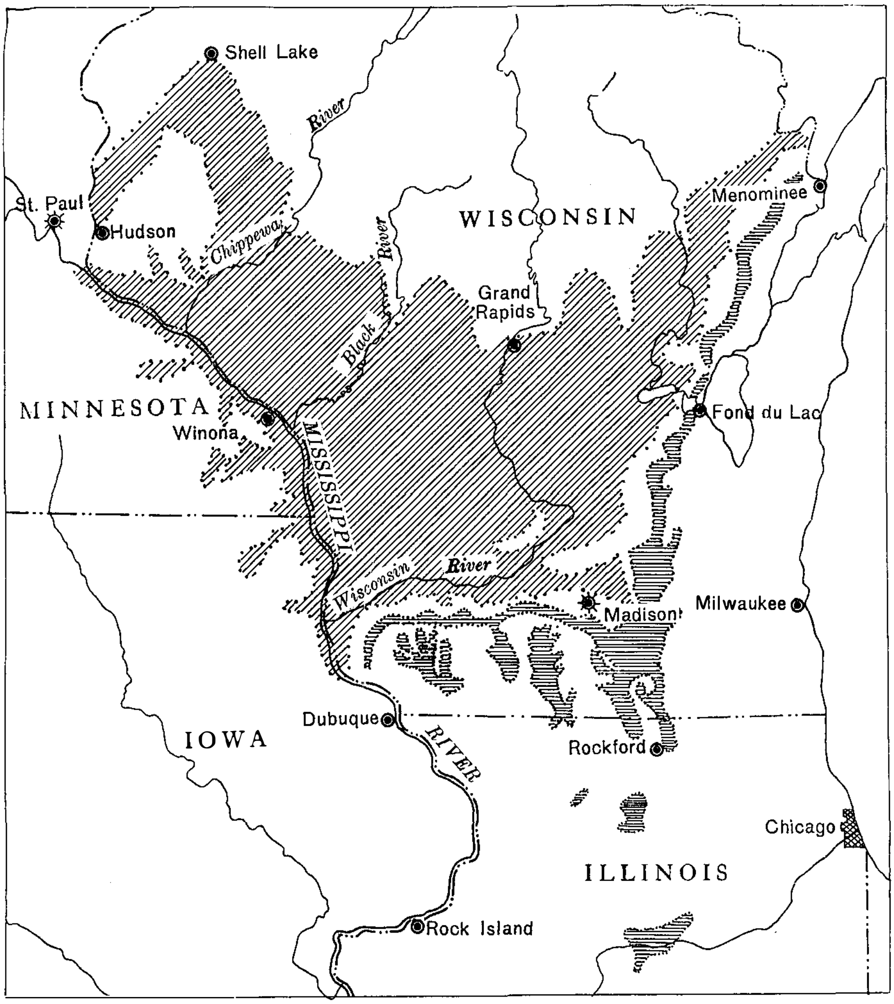


FIG. 71.—Map showing outcrop of Cambrian (diagonal lines) and St. Peter (horizontal lines) formations in Wisconsin and Illinois. (Illinois State Geol. Survey Bull. 43, fig. 76, 1923.)

reaches Chicago it is so "hard" that it must be treated for some uses. Different horizons in the Cambrian sandstones yield differently mineralized water, the least desirable being deepest, so drillers are careful to stop their wells as soon as the supply is adequate.

However, the Chicago area is still an artesian basin, for water still rises in the different wells varying distances above the tapped water-bearing horizon. Any well in which the water rises when the impervious overlying rock is penetrated is an artesian well. If the pressure is such that it rises to the surface and there escapes, it is a flowing well, the most desirable kind of artesian well.

TOPOGRAPHY OF THE BEDROCK SURFACE

The Lake Michigan basin, as a closed basin, is a product of glaciation. It was occupied by a great lobe of ice during the last glacial episode, ice erosion having scoured out the bottom, and deposits by the ice having mounded up the margins during this and earlier episodes. But the basin was a lowland before glaciation occurred. There is plenty of evidence that streams had already excavated a large portion of its present depth and width. Part of this evidence is found in the buried topography of the Niagaran limestone beneath Chicagoland.

Referring again to the cross-sections (fig. 65) one notes that the lake lies on the eroded edges of the soft Devonian shales, and that harder rocks bound it on the east and on the west. The soft shales, being most easily eroded, determined the location of the largest preglacial valley. The harder rocks constituted uplands and possessed only small tributary valleys leading down toward the main valley, the precursor of the lake basin.

Laborious search for all existing data on depths to bedrock in the Chicago region has yielded literally thousands of records of wells, tunnels, trenches, caissons, test-borings, etc. These, carefully located on the maps and adjusted to altitudes above sea-level, will make possible the construction of a contour map of the buried surface.

There are two different elements in the topography of the bedrock surface. One is the klint type of elevation (p. 66), a mound or hill standing alone, its relief due to superior resistance of its rock. The other is a linear trench or trough prevailingly oriented nearly at right angles to the present lake shore and increasing in depth toward the lake. The positive form, the klint, has been explained but the share that the two unlike erosional attacks, preglacial and glacial, played in producing it, has not been settled. The explanation of the second, the negative or valley form, should have a bearing on the problem of the first.

These troughs in bedrock are true valleys, without doubt. They lead toward the lake basin. For their erosion, an agent is required whose attack is concentrated along a linear course. This clearly points to running water—streams tributary to the larger valley in softer rock which now holds the lake. If these valleys were by any chance gigantic grooves cut by glacial ice, they should be oriented parallel with the striae and smaller grooves which the ice produced. If they were weathered out of belts of weaker rocks, they should parallel the edges of the formations, and correspond roughly to the lake basin. Neither of these two conditions is true. It seems safe to conclude that in them Chicagoland has a record of minor preglacial streams descending the dip slope of the outcrop belt of Niagaran.

Since softer rock underlies, as well as overlies, the Niagaran, the outcrop belt of the Niagaran should have been a preglacial divide and the western portion should have similar buried minor stream valleys draining westward down the far slope of the divide and belonging to another system. The outcrop belt of the Niagaran formation in Chicago's latitude is nearly twice the width of our mapped region, so that we can hope for but little evidence from our bedrock map. Geological studies of the Herscher, Wilmington, Joliet, Wheaton, Barrington, and Elgin quadrangles supply the information.

There are such buried valleys in the bedrock and they deepen, widen, and converge westward as the theory requires. They were apparently tributaries to the preglacial Mississippi system just as those of our own region were tributaries to the preglacial St. Lawrence. The preglacial regional divide stood almost where the present Mississippi-St. Lawrence divide now stands. The Valparaiso moraine here was built on the old Niagaran upland, and postglacial streams obey its control as preglacial streams were controlled by the limestone belt.

On this identification of the troughs or trenches in the buried Niagaran as stream valleys depend several other conclusions. One is that the lake basin is not wholly a product of glacial erosion, with minor upbuilding of the rim by moraine construction. Even though no one has yet located the continuation of the major preglacial valley toward the St. Lawrence (the strait of Mackinac is too shallow and too narrow), we must accept the conclusion. Similarly, the location of the preglacial regional divide is based on the concept of stream origin of the buried valleys. The inadequacy of glacial erosion to bevel off all the older rock-carved topography is likewise concluded from them. Thus the klintar must be a product largely of preglacial erosion.

In spite of the coincidence of the preglacial and postglacial divide, the older stream pattern of the Chicago region differs markedly from that of today. The former streams flowed almost directly eastward and down the slope beneath the present lake. Some of today's streams wander for miles parallel to the lake, trying to find escape from the obstructing moraines and beach ridges. Lakes and marshes exist along their courses. They have not yet wrested control of their routes from the still-living mastery of the vanished ice-sheet. They are young in their own cycle of erosion. The earlier streams had established direct routes to the major valley, they had developed with that valley, they were much older in terms of the growth of a simple drainage pattern.

GEOLOGICAL HISTORY OF CHICAGOLAND

Adventure by land and sea, in the tropics and in the Arctic—these have all come to Chicagoland while that region has stayed at home. "In the beginning . . . ." but we cannot use that phrase for earth history does not carry back to a beginning. "The earliest record . . ." this is correct . . . the earliest record of our region is at the bottom of the deepest well. That record is the Mt. Simon sandstone. A shallow sea was here, land to the north was discharging muddy rivers into it, waves and tides were sweeping its floor, sandy waste from the northern land was being carried far and wide over the great midcontinental marine embayment. The time was Cambrian, the first geological period to leave us an adequate record of life.

Beneath the Mt. Simon sandstone in Wisconsin lie granite and gneiss and schist and quartzite—rocks dating much farther back and telling stranger stories than anything in our own geological archives. Without doubt, such rocks are here also; we simply have not yet gone deep enough to find them.

Above the Mt. Simon sandstone lie layer upon layer of sedimentary rock, each with an interesting contribution to the geological history of the region. Geologists have found that rock formations may be logically grouped into major and minor divisions which record equivalent divisions of time in geologic history. To each of the divisions has been applied a distinctive name, significant either of the type of life existing at the time or of the localities in which the rocks are well developed or were first studied. The world-wide geological timetable, almost universally accepted, is as follows, the youngest being at the top:

Cenozoic era Pleistocene period	The glacial record, and geological processes now at work
Pliocene period Miocene period Oligocene period Eocene period Mesozoic era Cretaceous period Jurassic period Triassic period Paleozoic era Permian period	No rock making in the Chicago region
Pennsylvanian period	Rock making perhaps, but if so the deposits have all been eroded away
Mississippian period Devonian period Silurian period Ordovician period Cambrian period	The Chicagoland bedrock records made
Proterozoic era Keweenawan period Huronian period Archeozoic era Laurentian period Kewatin period	All rocks beneath the Cambrian in the Great Lakes region date from these eras. The accessible geological record at Chicago begins with the Cambrian.

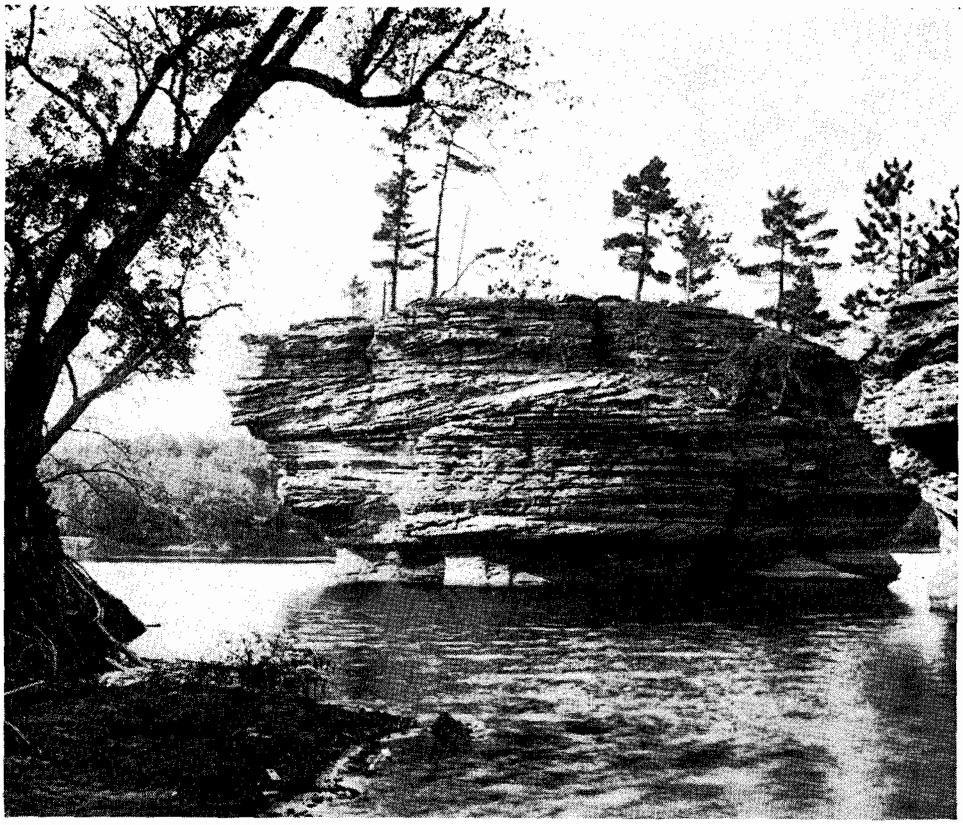


FIG. 72.—Cross-bedding in Cambrian sandstone, Dells of Wisconsin River.

CAMBRIAN PERIOD

The Cambrian strata beneath Chicagoland are late Cambrian in age. Earlier sediments of the period are known in the Appalachian Mountains, about the Adirondack Mountains, in New England, and in Quebec. Our region during the early Cambrian was probably a land of granite and gneiss. Slow, inexorable spreading of that shallow Cambrian sea in the east finally reached us, we went under and became buried in sand brought from surviving portions of the continent.

The Mt. Simon sandstone is thick—several times as thick as any other formation in our wells. The sea, however, never was as deep as the thickness might suggest. Most exposures of the formation show current-bedding, splendidly displayed in sandstone cliffs of the Wisconsin Dells (fig. 72). Currents in the sea are superficial affairs. At considerable depth the sea is still. The late Cambrian marine embayment of the continental interior apparently was filled about as rapidly as its waters rose, so that its bottom most of the time was swept by the currents.

But the rising sea-level meant a shifting of the Cambrian coastline farther and farther away from Chicagoland. Limey sand and limestone appeared in Franconia and Trempealeau times, and again in the Jordan. In the Franconia and Trempealeau formations are good fossil records of the late Cambrian marine life.

ORDOVICIAN PERIOD

Because of increasing distance to the retreating shore, the supply of sand eventually entirely ceased coming into Wisconsin and Illinois. Lime mud was deposited on the Jordan sand; the Oneota formation was begun. Approximately coincident with this, the sea in the eastern part of the continent was largely withdrawn, mountains were raised in New England by earth movements there, and the Cambrian period came to an

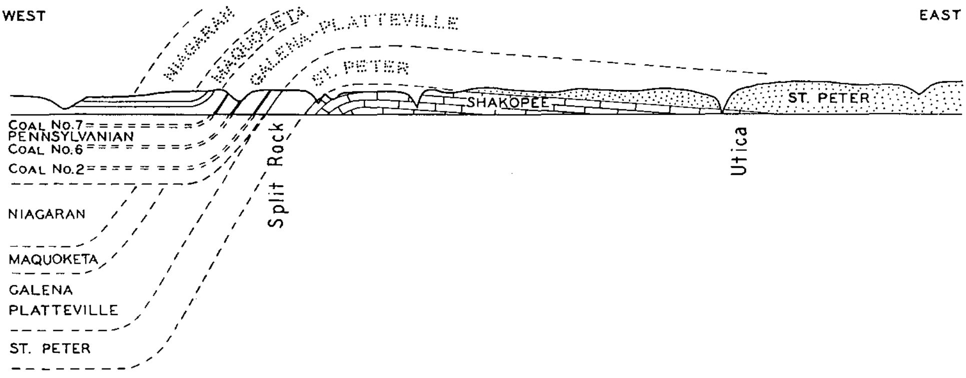


FIG. 73.—Diagrammatic cross-section of the LaSalle anticline along the north bluff of Illinois River.

Definitely known positions of formations are drawn with full lines, inferred positions of formations below the present surface are shown by dashed lines, and their former positions across the eroded portion of the anticline are shown by dashed lines and dotted names.

The Pennsylvanian (coal-bearing) rocks on the west were deposited horizontally across the anticline after an early erosion period, were themselves deformed by a second arching of the anticline, and were in turn eroded off the crest.

end. The second period of the Paleozoic era began, the Ordovician.

During the Ordovician period seven different major formations were deposited in the interior sea: the Oneota limestone, the New Richmond sandstone, the Shakopee limestone, the St. Peter sandstone, the Platteville and Galena limestones, and the Maquoketa (or Richmond) shale. Geographical changes in land and sea are surely on record in these changes from lime mud to sand and back to lime mud twice over, and then finally to a land-derived mud, the Maquoketa shale. Perhaps climatic changes are also involved. It is difficult to make a precise analysis of the causes—changes in depth of water, in distance from the land, in direction to the land, in character of the land, in climate—all of these may have played a part.

At least once during the Ordovician period the sea was entirely withdrawn from the upper Mississippi Valley and Great Lakes states. It happened between Shakopee and St. Peter times. The record is found in wells in northern Illinois but is better shown in the Wisconsin outcrop areas. It consists of an irregular thickness or even complete absence of the Shakopee and older formations as far down as the Franconia (fig. 69). This irregularity is the expression of an eroded land surface identical in origin with that of the bedrock surface buried beneath the glacial drift. From 200 to as much as 500 feet of these formations was removed in the Chicago region. Supporting this view is the occurrence of Shakopee and Oneota chert nodules *as pebbles* in the base of the St. Peter sandstone. Weathering of these limestones during the interval of exposure had left the insoluble nodules while removing the lime of the formations. The nodules were rehandled and incorporated in the first of the St. Peter sand to be laid down. In our region part of the Oneota still remained.

The St. Peter sandstone lies on the old land surface exposed when the sea withdrew after Shakopee times. The sand to make the St. Peter formation must have come from distant lands of granite and of Cambrian formations, as it could not have been derived by weathering of the local Oneota and Shakopee limestones. Probably northern rivers, lengthening as the sea withdrew, carried this sand southward to low coastal lands where it accumulated as deltas and broad sandy beach flats. Here the waves and wind reworked it to that remarkable purity and evenness of grain which characterizes the St. Peter sandstone. With the return of the sea, this coastal belt of deposition shifted northward over the eroded land surface, and the former sand belt was inundated and buried beneath the Platteville limestone.

Another notable feature of Ordovician history lies in the great extent of limestone of Galena and equivalent age. It was de-

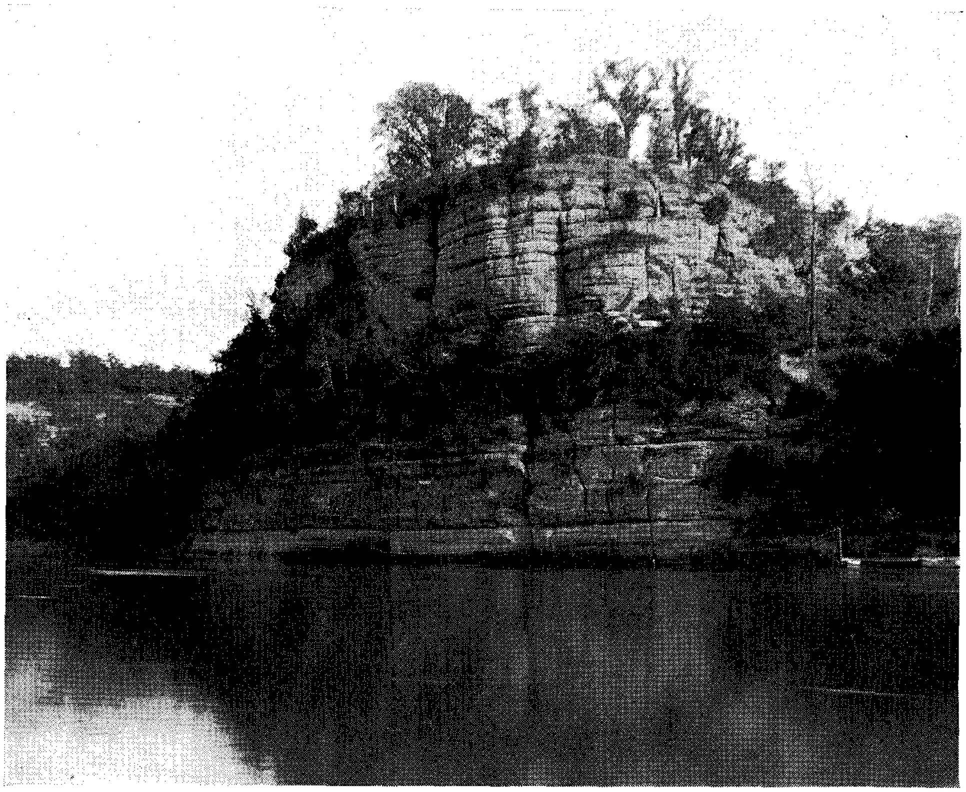


FIG. 74.—Starved rock, composed of St. Peter sandstone.

posited over a greater area in North America than any other marine formation of all time, originally covering 60 per cent of the present continent. It therefore records the most widespread known flooding of the continent by the sea, the nearest approach to victory of those forces which destroy the lands and extend the kingdom of the sea. Yet this mid-Ordovician sea was shallow—it is not to be compared with the true oceans.

Good exposures of the Ordovician formations are found in the gently upwarped portion of northern Illinois. One particularly sharp upfold, the LaSalle anticline (fig. 73), brought up the Ordovician formations as high as younger rocks on either side, and subsequent erosion has exposed them, especially where Illinois and Rock rivers cross the anticline near LaSalle and Dixon respectively. Starved Rock and its associated canyons (figs. 74, 75) are carved from the St. Peter sandstone, and the glass-making industry at Ottawa obtains its sand from the same formation. The Shakopee formation forms cliffs along Illinois River between Utica and Split Rock. Nearby, Deer Park Canyon and Vermilion River valley show Platteville limestone overlying St. Peter sandstone.

Shrinkage of the great marine sea of Middle Ordovician time was accompanied by other changes. The interior sea became muddy with the wash from the adjacent, newly emerged lands. The resulting sediment constitutes the Maquoketa shale, most of it composed of clayey detritus but calcareous where the sea was clearer and organisms could give character to the deposit. The Maquoketa shale, named from outcrops in Iowa, is more limited in extent than any other formation of the Ordovician system. The sea was withdrawing and the close of the period is marked by the largest area of land in North America since the early part of the Cambrian period, millions of years before. In southern New England, in New York, and in Pennsylvania, strong lateral compression at this time folded up a mountain range parallel with the Atlantic coast.

FIG. 75.—Amphitheater in the St. Peter sandstone at the head of the gorge in French Canyon, Starved Rock State Park.

Silurian Period

The continental interior was land for a long time after the withdrawal of the Ordovician seas. But our area remained low, so low that streams were unable to erode it effectively. The sea began its next slow advance from the east, as it did earlier, spreading westward from the region of the present Appalachian Mountains but not reaching the Chicago region until about middle Silurian time. This spread culminated in the Niagaran submergence, the extent of which has already been outlined. The Niagaran sea was generally clear during its whole history as shown by the prevalence of limestone with coral reefs. The land about it and draining to it must have been low and featureless and, for most of the epoch, far away. Shallowness of the sea is indicated by the reefs and by the character of fossils elsewhere in the rock. Probably the region subsided about as rapidly as the lime mud accumulated. The lowest Niagaran strata are 450 feet below the top of the formation, yet they indicate water no deeper than that recorded by the uppermost strata. Without subsidence during the period they must have been deposited in water 450 feet deeper. This subsidence was a part of the continental movement which allowed the sea so wide a Silurian domain.

New York, Michigan, and other eastern states have younger Silurian strata above the Niagaran. Our region does not. Instead, we have only the "roots" of Devonian or Mississippian deposits inserted in Niagaran fissures. Chicagoland emerged from the sea again before the Silurian period closed, having been submerged only during middle Silurian time. In later Silurian time, the interior sea still covered large parts of the East, its coast lying at least as far west as Detroit. This sea, in its own later history, was separated from the rest of the great marine inundation and became a landlocked waterbody. An arid climate then prevailed and under it the landlocked waterbody became a great salt lake or lagoon. The salt deposits of New York and Michigan are products of this episode.

A time of exposure for our region had begun. The Silurian period closed with great mountain making in both eastern and western hemispheres about the Arctic and North Atlantic oceans. The Niagaran strata in north Greenland were folded, uplifted, and subjected to erosion.

The Devonian period opened with seas creeping in from the Arctic Ocean, the Atlantic Ocean, and the Gulf of Mexico. The mingled waters closely approached Chicagoland by the middle of the period and very likely covered it for a time, because the known Devonian strata beneath Lake Michigan and in the lower Michigan structural basin are thick and come actually to the west edge of the lake, they crop out in a limited area along the lake shore near Milwaukee, and they are known in Indiana wells just east of our region. For the shark teeth in the clay in the fissures, whose age is probably Mississippian, we must predicate withdrawal of the sea at the end of the Devonian, erosion during this new emergence, and then during at least part of the Mississippian period a return of the sea in which the sharks swam above the drowned land surface.

Post-Silurian Pre-Pleistocene Interval

Now follows the longest break in our geologic record. There are no deposits between the Niagaran limestone and the glacial drift. Most of the earth's history is written in the sedimentary rocks. Where pages of the history of any one locality are missing it is usually impossible to tell whether they were never written or were once written and then torn out.

The precise succession of events in the Chicago region during this long interval, which covered several geologic periods, is unknown due to lack of good evidence, pro or con. For most of the interval our region was low-lying land. If any sediments were deposited, and there are good reasons for believing that there were at least some Devonian, Mississippian, and Pennsylvanian sediments, subsequent erosion has removed them.

The great coal swamps of early Pennsylvanian time grew over the continental interior, were inundated by salt water, were re-established when slight uplift drained off the sea, were repeatedly re-inundated and re-established, making the great Pennsylvanian system of alternating fresh-water sand and coal deposits and marine shales and limestones in the great Interior and in the Appalachian regions. But we must go 50 miles or more to the southwest of Chicagoland to find this record. The story is not found in the pages of our local history.

Though the seas came far up the Mississippi Valley from the Gulf several times during the Mississippian and Pennsylvanian periods, they never more than briefly lapped over Chicagoland.

Local deformations of the sedimentary rocks occurred in several places in Illinois at different times during the latter part of the Paleozoic era, the movements making both upfolds and downfolds in strata originally horizontal. The most marked fold in the state, the LaSalle anticline, seems to date from late Mississippian time, though it suffered further movement after Pennsylvanian sediments had been laid down on the already folded and eroded beds. The Appalachian mountains were born of tremendous compression and uplift at the close of the Pennsylvanian period and perhaps the gentle upwarping of northern Illinois and the downwarping of the Michigan basin date from this time. Mountain-making occurred in other continents. Great withdrawal of the shallow seas over much of the world, great climatic stress (aridity and glaciation), great changes in plants and animals came with or in immediate consequence of this mountain-making revolution. With these events, the Paleozoic era closed and a new era opened. The Mesozoic era began.

During the Mesozoic era startling forms of grotesque reptiles moved across the landscape; their lowly contemporaries, the early mammals, appeared briefly now and then; seed-bearing land plants developed, interior seas came and went in the present Rocky Mountain region; and finally, to climax the Mesozoic era, the Rocky Mountains and other mountain ranges from Alaska to Cape Horn were upheaved.

None of these events find record in our region. Nor do we learn anything of the great volcanic activity of the next era, the Cenozoic, nor of additional mountain-making, nor of the wonderful rise and spread of the mammals over the world, supplanting the reptilian dynasties which went out with the birth of the Rocky Mountains. All these events occurred during the great gap in our record—the hiatus between the Niagaran limestone and the glacial drift.

Pleistocene Period

In late Cenozoic time, only yesterday as we have already phrased it, the North American ice-sheets formed in the latitude of Hudson Bay. For their growth we must conceive of far-reaching climatic changes, of lowered effectiveness of oceanic warming and atmospheric blanketing, perhaps of decreased solar efficiency. The ice-sheets spread slowly but as inexorably as did the sea in earlier times. They flowed together to make one great sheet (fig. 36) which finally reached our territory, overwhelming a land of streams and fertile valleys and wooded hills. Ahead of it, century by century, the intensifying Arctic climate cleared the region of its inhabitants. Musk-oxen, reindeer, hairy mammoths, arctic foxes, hares, and lemmings migrated southward across Illinois; the broad-leaved trees perished and were supplanted by northern conifers, aspens, and birches. These in turn were destroyed as the ice entered into its climacteric stage. All but the southern tip of Illinois became buried under glacial ice; Chicagoland became part of another Antarctica or Greenland.

In the ice and beneath it, dragged by the enormous power of the thick spreading glacier, was borne the debris from Canada, northern Michigan, and Wisconsin. The preglacial soils were wiped off, the preglacial valleys were buried in the debris, except where oriented in the direction of ice movement. The hard Niagaran limestone was scoured and grooved by detritus in the basal ice; in fact the limestone itself yielded much debris to travel far down the state and to be left as burial clods over the Pennsylvanian coal beds.

The glacial epoch was long and it was varied. Three times the ice-sheet was melted back, each time only to gather strength and advance again from Canadian territory. The fourth defeat of the Arctic invader brought the geological present. The events of the enemy's last rout are learned from the battlefield. Moraines are entrenched positions where for long the conflict became a stalemate. The glaciofluvial deposits are the stains of the glacier's prodigious bleeding. Weapons abandoned in its retreat lie everywhere—the battered striated weapons that scarred the country rock. The reinforcements poured into the Illinois sector

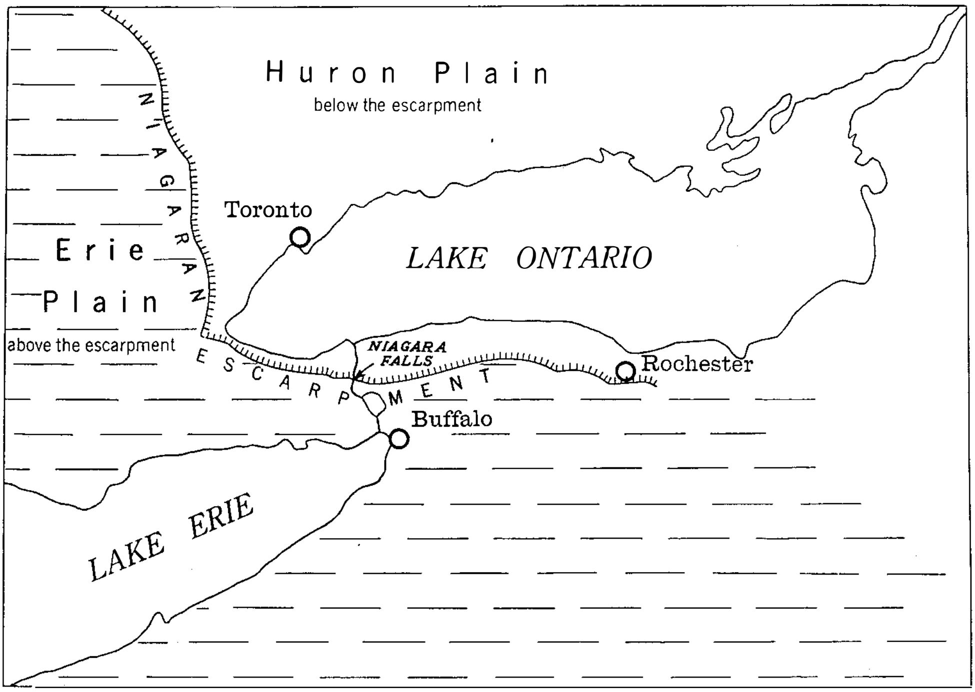


FIG. 76.—The Niagaran escarpment between Lakes Erie and Ontario.

along the valley now containing Lake Michigan still held the front after most of Wisconsin, Illinois, and lower Michigan had been surrendered. The great pool of Lake Chicago was formed as this valley became impossible to hold. It lengthened northward, it received discharge from a similar great pool in the Erie basin, and then from another in the Huron basin. All this water went to the Gulf of Mexico. Finally, the ice retreated so far that a lower outlet was opened to the east, the Great Lakes discharged to the Atlantic Ocean, Niagara Falls was born, and shortly the Sag and DesPlaines outlets to the Gulf of Mexico went dry.

NIAGARA FALLS AS A GEOLOGICAL CLOCK

When Niagara Falls began, a geological clock started running. It has run continuously ever since and its present reading tells how many years ago it started. The clock consists of the falls and gorge of Niagara.

Preglacial erosion in western New York had etched out the softer rocks, leaving a north-facing cliff of Niagaran limestone (fig. 76) 200 feet high. Capacious stream valleys drained from the upland south of the cliff to the lowland on the north. The ice-sheet failed to obliterate the cliff, but it filled the valleys completely with detritus. When the retreating ice finally abandoned the district, the glacial Great Lakes to the west poured their discharge across it, but the escaping waters found no valley to follow. Flowing across the open country, they came to the edge of the cliff at Queenston and plunged directly into Lake Iroquois, the expanded glacial Lake Ontario. From Lake Iroquois they flowed through Mohawk River to Hudson River.

Beneath the Niagaran limestone in the cliff is the softer Clinton formation. This, more rapidly eroded away by the cataract, left the edge of the limestone unsupported. It broke off from time to time and the waterfall thus became recessed or notched back in the cliff (fig. 77). Recession, continued ever since, has lengthened the notch into a gorge seven miles long—a gorge which still is lengthening as the cataract recedes. The present average rate of retreat of the falls is about four and a half feet a year. The gorge is about 36,000 feet long. If the clock has run at the present rate since it was started, the falls have existed 8,000 years.

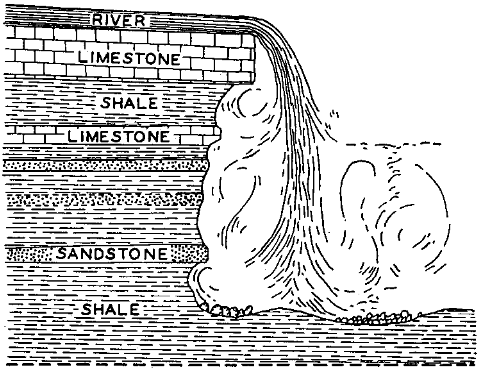


FIG. 77.—Diagram illustrating the conditions at Niagara Falls (After Gilbert).

But the story of the glacial Great Lakes has been more complicated than this brief sketch indicates. When the falls were born, the edge of the continental ice-sheet was still in sight. But its continued northward retreat in Ontario eventually uncovered a still lower outlet for the Superior, Michigan, and Huron basins, an outlet from Georgian Bay through Trent River valley directly to the Ontario basin. Niagara thus lost all but the discharge from Lake Erie. The clock then ran much more slowly—at what rate can only be estimated.

In the meantime a curious thing was happening. The weight of the great ice-sheet appears actually to have depressed this part of the continent. After the melting back was well under way, the region of the Great Lakes and north of them began to rise, very slowly and very slightly but in increasing amount with increasing distance northward, enough to tilt the abandoned shorelines of the earlier glacial lakes. North of Sheboygan, Wisconsin, and of Saginaw and Port Huron, Michigan, they became progressively higher northward. The oldest and highest ones were tilted most, the latest and lowest ones least. The movement thus was in progress as the lake stages came and went.

This movement raised the Trent River country, across which the eastward discharge was occurring. It thereby raised the level in the upper three lakes, which had been lowering during the earlier lake stages. The time came when the lowest notch in the surrounding rim was reached by their rising waters and a spill over into a new outlet occurred. This was at the southern end of the Huron basin and for a time the three-fold lake (Michigan-Huron-Superior) had two outlets, the new one through St. Clair and Detroit rivers to Lake Erie and to Niagara Falls. Continued rising finally brought the floor of the northeastern outlet above the surface of the new St. Clair outlet, Niagara River again secured the whole discharge, and the geological clock resumed its former rate.

We have passed hastily through this complicated lake history, noting briefly only the leading items which bear on Niagara Falls. The original rate of cataract recession was approximately re-established. How long a time is recorded in the making of the gorge? Like most clocks, our geological clock was an imperfect timekeeper. This became obvious when the outlets across Ontario were discovered. Various geologists well acquainted with the glacial Great Lakes history have made estimates of the time this stage endured. They find the stage recorded in the gorge itself, as a notable narrowing of the part made by Erie discharge alone. Their figures have been recast as new details have come to light. Most of the significant evidence seems now to have been collected and present estimates probably will not be greatly changed in the future. We say now that Niagara Falls has existed between 25,000 and 30,000 years.[1] Chicago outlet has been abandoned for almost that length of time, and Lake Chicago's lowest stage dates almost that far back.

This is not a measure of the time since the last ice-sheet stood at its maximum. The ice reached 600 miles south of Niagara, down into southern Ohio, at that maximum. The entire history of the last glacier in Illinois was written before Niagara Falls were born. Perhaps 15,000 years were consumed in the slow wastage which finally bared the region of Niagara Falls, so that the total time from the last glacial maximum to the present may well have been 50,000 years.

[1]Kindle, E. M. and Taylor, F. B., U. S. Geol. Survey Geol. Atlas Niagara Folio (no. 190), 1913.

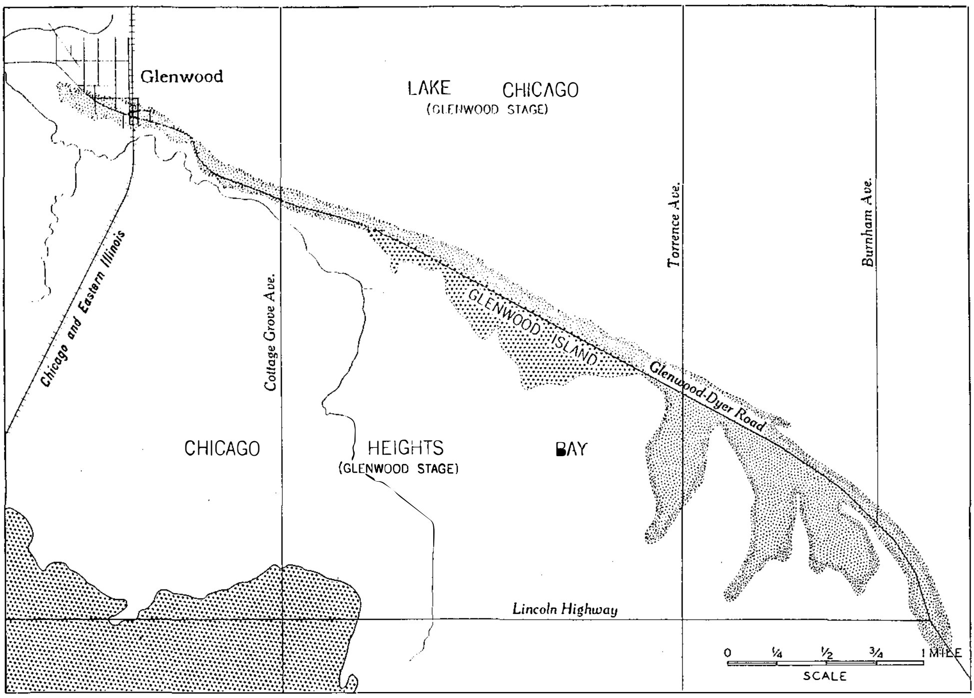


FIG. 78.—Sketch map of Glenwood Island and associated features of the Glenwood stage of Lake Chicago.

HISTORY OF LAKE CHICAGO

In any account of the history of Chicagoland, the history of Lake Chicago, the glacial ancestor of Lake Michigan, should receive more attention than almost any other event, for the records lie under our feet wherever we may be on the Chicago plain.

There were three marked lake stages, about 20, 35, and 55 feet above the present lake level. The Sag and DesPlaines channels (the Chicago Outlet) served as outlets for all of them. Their sequence is generally accepted as in the order of altitude, the highest being oldest, the lowest youngest. The lake surface is generally thought of as having been lowered rather rapidly from one stage to the next. The cause of the lowering is commonly considered to have been down-cutting of the outlet channel, although geologists are not all agreed on it.

Glenwood stage.—The highest and earliest shoreline of the extinct glacial lake is called the Glenwood shore, the highest lake-level was the Glenwood stage. Only the Glenwood shore has moraine topography on one side and lake bottom on the other. The lower shores were made on what had been lake bottom during earlier stages, and thus they are not markers for the contact of glacial and lacustrine topography.

In some places the Glenwood waves broke against fairly abrupt moraine slopes. There they eroded sea-cliffs, just as Lake Michigan waves are doing today in the North Shore district. In other places the ground-moraine was so low and featureless that no cliffs could be formed. But where sufficiently exposed to large waves from the open lake (in open water waves grow larger, the farther they travel), sweeping of the shallow bottom brought sand and gravel shoreward, to be deposited as beach ridges along the lake margin or perhaps across the mouths of exceptionally shallow lagoons or small bays. Where littoral currents existed, sand and gravel were swept along the shore and built into spits at places where the current crossed the mouths of re-entrants in the original shoreline. A shoreline with a littoral current is a transportation line, at the collecting end of which is usually a cliff. A spit, receiving the wastage from the cliff, is the delivery end of the line.

Let us make a rapid traverse of the Glenwood shore to see where some of these features occur. The shoreline is named from the village of Glenwood, 1½ miles south of Thornton (Calumet City quadrangle), through which it runs. East of Glenwood, along the Glenwood-Dyer road, a small "island" of ground-moraine is shown (fig. 78 and pl. I). The north side of the island is steep and straight, a Glenwood sea-cliff, its base 630 feet above sea-level. The broad lake-plain stretches off to the north, higher and gently rolling country lies to the south. At the inception of the Glenwood stage, no cliff existed and the "island" extended somewhat farther north. On the north side waves from the open lake attacked the island while in the shallows between the island and the mainland no effective waves were possible. Some of the detritus removed by cliff-making may underlie the flat to the north, but much of it travelled along the shore, both southeastward toward Dyer and northwestward toward Glenwood. It came to rest where the storm waves broke in the shallowing water. A fine spit grew out toward Dyer, four successive "fingers" of it curving back into what we may call Chicago Heights Bay. The northwest spit was built under somewhat different conditions and failed to curve back toward the south or to develop fingers. As it grew across its part of the bay, it encountered competition in the form of another spit growing southeast from Homewood, the debris for which was coming from a Glenwood cliff north of that village. Apparently the Homewood and Glenwood spits never joined to close this opening into Chicago Heights Bay. Thorn Creek's use of the unclosed space seems to indicate a passage there for the earliest drainage after the Glenwood stage closed.

The 635-foot contour is approximately the initial shoreline of the Glenwood stage. Here the cliff and sand ridges associated with the Glenwood islands stand as the final product of this stage. Note the striking simplifications accomplished (fig. 78). Had this stage endured long enough, all the shallow waters south of the island and its depending sand ridges would have been filled in, a further simplification of the kind inevitable on initial shores of this type. The Glenwood stage offered much greater opportunity for such changes than did either of the later stages. Its waters lapped back on the irregular ground-moraine; the later levels made contact only with the smooth bottom-plain of higher lake levels.

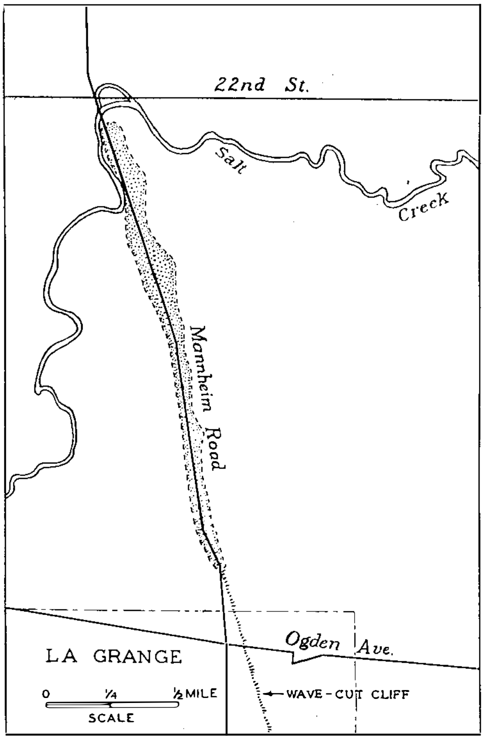


FIG. 79.—Sketch map of La Grange spit, Glenwood stage of Lake Chicago.

The Thornton klint was an offshore shoal during the Glenwood stage, and before the stage closed, a shallowly submerged bar had grown back of it, connecting the shoal with the Homewood spit. Its altitude is 630 feet. Indeed, much of the Glenwood shore deposits are below 635 feet, the specified height of the lake-level. The tips of the spit fingers are 625 to 630 feet where they terminated in the deeper water of the bay. Even the base of the cliffs may be a little lower than the actual water surface if no beach was formed in front of them. All told, these shoreline changes from Dyer to Homewood exemplify early maturity of the shore cycle. The initial irregularities had been largely removed by reduction of headlands and closing off of bays, a new coast line far simpler had been outlined, only the filling in of the shallow bays remained to be done. No changes on such a scale mark the later shores of the glacial lake, chiefly because they never were initially so irregular.

Triangular Mt. Forest Island had the Glenwood lake on the east and outlet rivers

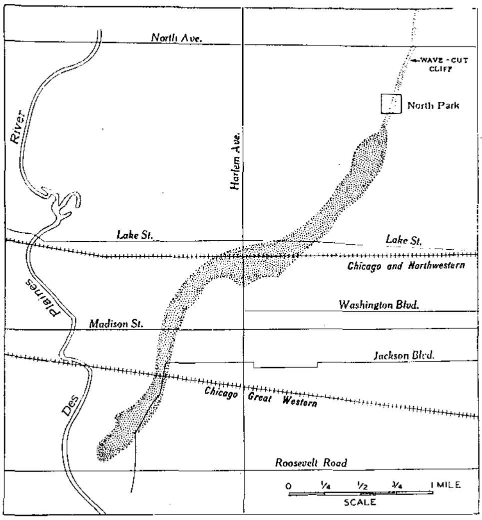


FIG. 80.—Sketch map of Oak Park spit, Glenwood stage of Lake Chicago.

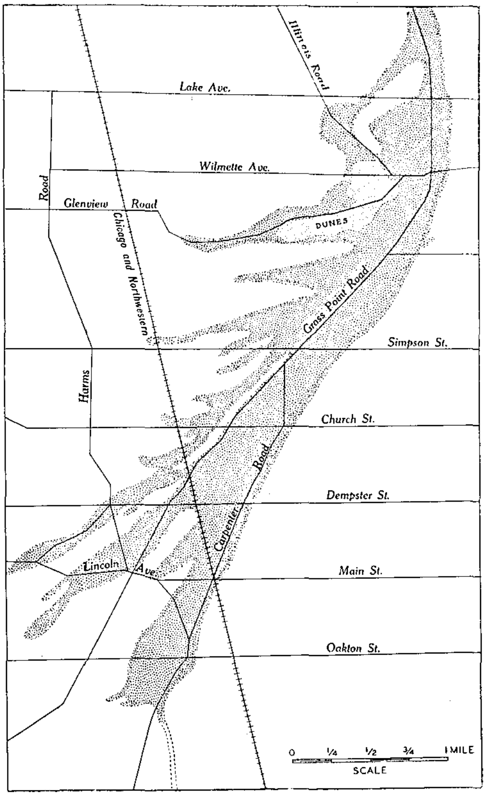


FIG. 81.—Sketch map of Wilmette spit, Glenwood stage of Lake Chicago.

on the northwest and on the south sides, the two rivers uniting six miles from the lake at the west end of the island. Wave work is recorded of course only at the east end and largely in cliffs. Most of the resulting debris carried along this shore was swept off down the outlet channels.

North of the DesPlaines outlet, the Glenwood shore is a cut bank as far north as LaGrange Park. Here an embayment in the ground-moraine, now used by Salt Creek, furnished opportunity for the growth of a spit. Current-swept sand and fine gravel from the cliff farther south travelled nearly a mile out across the mouth of the small bay. The spit today determines a marked angle in the course of Salt Creek. Mannheim (or LaGrange) Road traverses most of the length of the spit (fig. 79).

North of Salt Creek embayment are the long narrow bays interfingering with the Lake Border moraines. Only faint traces of the Glenwood shore occur in them. The westernmost bay was largely filled by the terminal portion of the DesPlaines valley-train during the Glenwood stage. It also became partially closed off from the open lake by the Oak Park spit which grew southwestward from the tip of the Park Ridge moraine. That spit reaches almost from Division Street to Roosevelt Road, measuring nearly three miles along its rather sinuous length. It lies within the city limits of Oak Park and Forest Park, taking its name from the former (fig. 80). A low but definite cliff is recognizable north of the spit for several miles along the east side of the Park Ridge moraine. The erosion of this cliff supplied much of the debris of which the Oak Park spit is made. Riis Park includes a portion of this cliff.

The region between Morton Grove and Winnetka has marked Glenwood features, better developed here than anywhere else in the Chicago region. A sea-cliff 20 to 30 feet high is a very definite feature in Winnetka, extending from the present lakeshore near the city waterworks southward along the east margin of the Highland Park moraine for 1½ miles to Indian Hill Club. Here both the moraine and the sea-cliff end, but a large mounded deposit of sand and gravel, the Wilmette spit, on the lake-plain continues this old shoreline for at least six miles farther to the southwest (fig. 81). The east side of the spit is a simple flowing curve but the west side is remarkably digitate, ridges of sand projecting westward

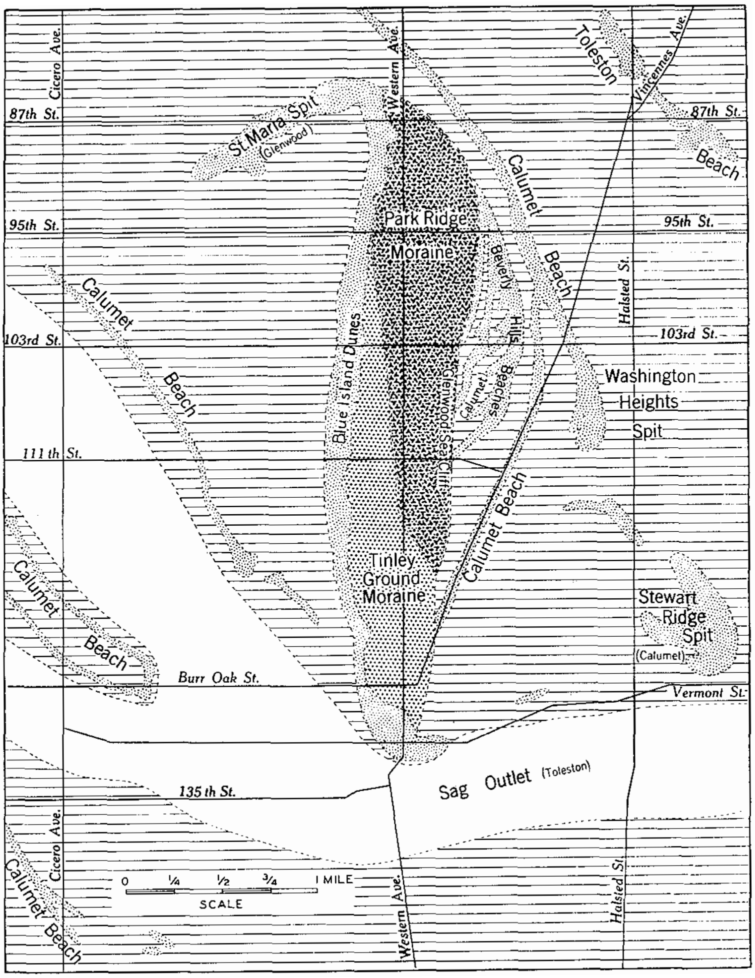


FIG. 82.—Sketch map of Blue Island and associated features, various stages of Lake Chicago.

out on the plain, the intervening linear depressions being reciprocal dove-tailing fingers of the plain.

We need not analyze the situation in detail, it is so similar to others already described. Waves from the open lake during the Glenwood stage undercut the east face of the Highland Park moraine. A southward-flowing littoral current swept the coarser debris along the cliff to the moraine tip. Here it was deposited, shoaling the water and extending the Highland Park peninsula southward. This made more shoreline on which the current could carry debris farther and farther southward as the low growing tip of the peninsula advanced. Storm waves tended to swing the end of the spit back into Skokie Bay, but the addition of debris shoaled the water most at the beginning of the curve and thus repeatedly these growing spit fingers were abandoned and new ones were built farther south. The Glenwood stage came to an end while the southernmost, the Niles Center, finger was growing. There are at least a dozen well marked fingers on the Wilmette spit. Had some of them grown a mile longer, both Skokie Bay and Chicago Bay would have been completely cut off from the main lake.

A tract of dunes three quarters of a mile long occurs on the Wilmette spit, near the junction of Illinois Road, Wilmette Avenue, and Glenview Road. Westmoreland Golf Club is located on their western part. The dune sand has a maximum known

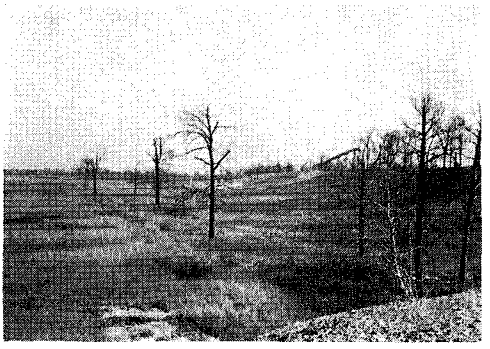


FIG. 83.—Wave-cut cliff of the Glenwood stage of Lake Chicago, near 87th Street and Western Avenue, north end of Blue Island.

FIG. 84.—Dune on the west slope of Blue Island. Built during the Glenwood stage of Lake Chicago, the dune migrated from right (west) to left (east) up on the moraine above the shoreline of the lake.

thickness of 12½ feet and rests on gravel or gravelly sand of the spit. The dunes were formed after that part of the spit had been built.

There are complications of the story as outlined above, for a sand ridge continues farther south than the spit group is mapped. It is about 15 feet lower than the ridge tops of the spit. It runs along the base of the east or lakeward side of the ridge group and is a product of a later and lower lake stage, the Calumet. A map showing the area during Glenwood times should not include it.

In the northern part of Winnetka the Glenwood cliff comes to the present lake margin, and thence northward almost to Waukegan the present cliff summits are higher than the Glenwood level so that no old shorelines exist. These cliffs are receding today. They originally stood farther out in the lake. Each of the three Lake Chicago levels doubtless had cliffs here also. All have been destroyed in the present shore cycle, lake waters encroaching on the land instead of withdrawing from it as elsewhere in Chicagoland.

We have one more district to examine for Glenwood features, the only island of this stage on the Chicago plain (fig. 82). It is a morainic elevation whose margins are decorated with almost every type of shore feature left by old Lake Chicago. It is known as Blue Island. Two high-class Chicago residential districts, Beverly Hills and Morgan Park, are built on its eastern slopes, three golf clubs and three cemeteries mark its western margin. Western Avenue from 85th Street to the Sag Canal traverses its entire length. The northeastern part of Blue Island is a continuation of the Park Ridge moraine, the southwestern part is ground-moraine belonging to the Tinley stage.

The east side of Blue Island (fig. 83) is a splendid wave-cut cliff, 40 feet high in Morgan Park and 35 feet high in the Forest Preserve at the north end. A maze of anastomosing beach ridges, probably spit fingers in large part, lies at the foot of this cliff and from the north end a single sand spit swings westward into the lake-plain for 1½ miles. A gravel spit, small and blunt, swings in the opposite direction at the opposite end, in the east part of the city of Blue Island.

The west side of the island carries next to the largest belt of Chicago dunes in the mapped area. They extend the full length of the island, 5½ miles. Though they are unquestionably a marker for the Glenwood shore here, they lap up on the island above that level, having migrated inland from the water's edge. Some individual dunes are 30 feet high above their base. Many show the gentle windward (western) slope and steeper leeward (eastern) slope so common among the present lake shore dunes (fig. 84).

The cliffed eastern shore and the dune-covered western shore of Blue Island are in strong contrast and record markedly different conditions during Glenwood time. The east side faced the open lake. On the west, it was only five or six miles to the land and waves here could not grow to great size. This seems an adequate reason for cliffing only on the east. For the dune growth, we need beach sand swept by dry-weather on-shore winds. Dunes attain marked development only on west-facing and north-facing coasts of Lake Michigan today, for reasons already outlined. The west side of Blue Island was a west-facing coast in Glenwood time. Figure 85 shows Lake Chicago in our region during the Glenwood stage.

Calumet stage.—Much more bulky shore deposits mark the Calumet stage of Lake Chicago and much more largely were they derived by on-shore wave-drag over the shallow bottom than is true of Glenwood shores. The drop of 20 feet in the level of Lake Chicago drained all the bays of Glenwood time. Large areas of Glenwood bottom emerged, new land, miles in width in places, separated the new shores from the abandoned ones. Mt. Forest Island and Blue Island became joined by a low flat that stood just above the new lake level. A new island appeared at the head of the Sag Outlet, named from the village of Worth at the intersection of 111th Street, Harlem Avenue, and Southwest Highway. The outlet heads were extended eastward into the plain.

A wide beach was developed where the Illinois-Indiana state-line now crosses the Calumet shore. Some of its sand was drifted into dunes, some of it was carried westward along the shore to make a spit with a terminus near Thornton and with several small fingers curving back into North Creek Bay, nearly shutting it off from the rest of the lake.

The Thornton klint became so nearly emerged at the Calumet stage that waves breaking on its margin built a small beach ridge almost completely around it, making the curious circular pattern shown on Plate I. A group of dunes grew on the beach along the west side of the klint, overlying both Glenwood and Calumet beach deposits.[2]

The Calumet beach east of Blue Island lies close to the group of Glenwood shores. But whereas the Glenwood ridges were built largely of detritus from the local cliff-cutting on Blue Island, the associated Calumet ridge nowhere was supplied by wastage from the island. Its material came from the shallow lake bottom. With essentially no break, this Calumet shore ridge is easily traceable for nearly 15 miles, extending northwestward about 10 miles across the flat lake-plain to terminate at Summit in a spit-like form at the head of the DesPlaines outlet channel of that time and southeastward to Stewart Ridge, just north of Calumet River. Thence it swings around the south end of Blue Island and continues northwestward toward Oak Forest on the south side of the low flat land which then joined Mt. Forest and Blue Islands (fig. 86). Southeastward from Stewart Ridge, through Riverdale and Dolton toward Hammond, there is a sand ridge that appears to be a continuation of the Calumet beach, but it is 20 feet lower and is a product of the third or Toleston stage of Lake Chicago.

Worth Island has a curious hairpin-shaped beach ridge of Calumet age, showing how long and narrow the island was at this first stage of its history and also showing that the outlet river did not head this far east during the Calumet stage.

In Evanston and the north part of Chicago are two very marked beach deposits, the western one of Calumet age. It is a mile wide at Howard Street, the boundary between the two cities. South from Howard Street it extends 3½ miles into Chicago, bluntly terminating near the intersection of Lincoln and Western Avenues. Northward through Evanston, where it is followed by Ridge Boulevard, it narrows to about two blocks in width at the junction of the boulevard and Sheridan Road. Six blocks farther north, it terminates in a low cliff on the lakeshore just south of Wilmette Harbor. This deposit, named the Rose Hill bar, is a spit similar to the Wilmette spit in its growth from North Shore feeding grounds. It differs in being separated from the cliff-line to which it was appended when formed, whereas about two miles of the Wilmette spit's cliff remain.

Another interesting feature is that there are two Calumet shores here. One is the Rose Hill spit, the other is a faint sand ridge along the eastern foot of Wilmette spit. The latter extends southward and southwestward across Chicago, with one interruption, to Cicero, then southwestward through Berwyn and Riverside into Brook-

[2]Excavation by the Illinois Central Railroad has removed most of the Homewood spit and its dunes on both sides of Ridge Road immediately west of Halsted. The surface in places here is now 30 feet lower than when the earlier topographic map of the region was made.

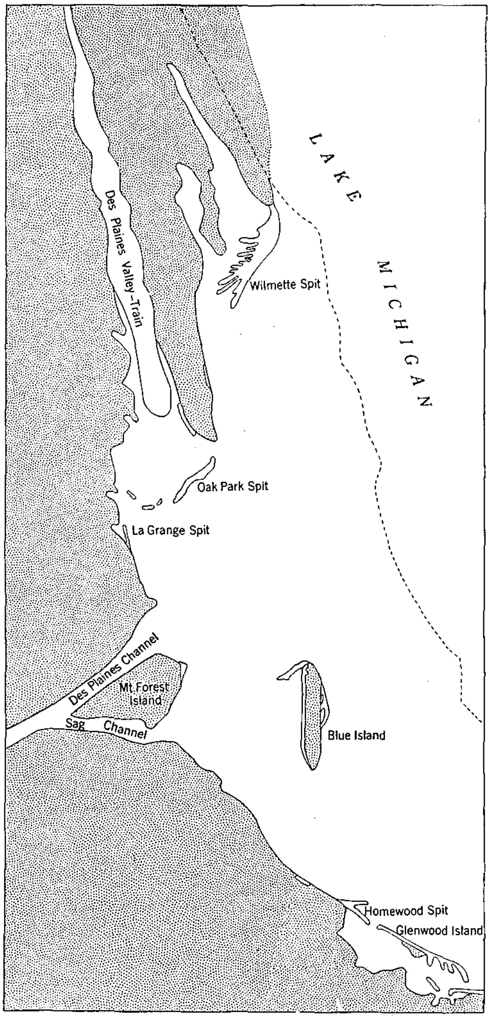


FIG. 85.—Sketch map of the Chicago region during the Glenwood stage of Lake Chicago.

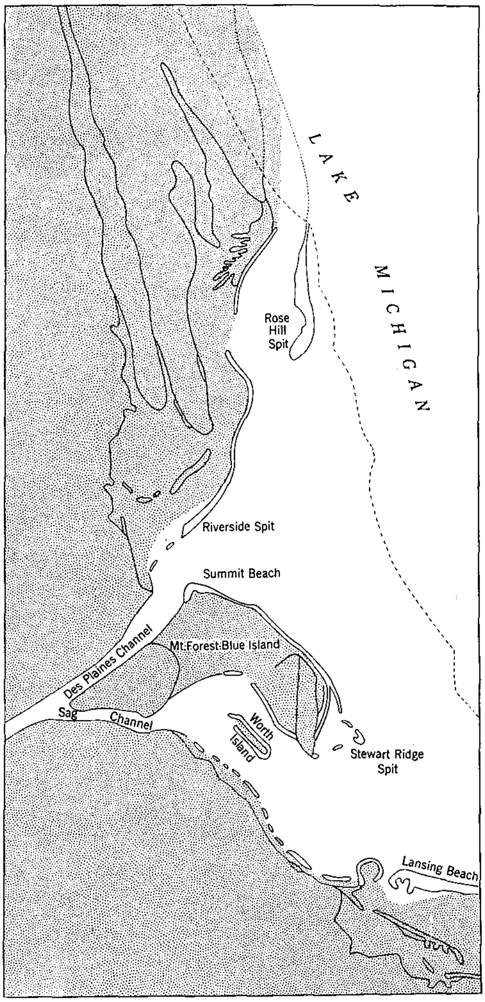


FIG. 86.—Sketch map of Chicago region during the Calumet stage of Lake Chicago.

field, nearly to the north side of the Des-Plaines outlet channel. In Riverside it has some of the characteristics of a spit.

The two shores lie nearly parallel, a featureless plain two to three miles wide separating them. The explanation is simple if the growth of spit shores is understood. The Wilmette spit had grown out into water more than 20 feet deep, so that when the lake lowered to the Calumet level, its waves still reached the eastern margin of the deposit, and there, in early Calumet time, built the beach extending from Wilmette to Brookfield. The Rose Hill spit was begun at the same time, gradually growing southward from some point now out in the lake north of Wilmette, and before the Calumet stage ended the lengthening spit had shut off about 10 miles of the earlier Calumet shore from the open lake, making Wilmette Bay. The bay did not become land, however, until the lake lowered to its third level, the Toleston.

Toleston stage.—Before Gary, Indiana, existed, the village of Toleston stood on a sandy ridge at the intersection of the Michigan Central and Pennsylvania railroads. It disappeared with the growth of the industrial city of Gary. Through the built-up parts of the city the ridge has likewise disappeared, but westward across the prairies it is readily traceable into Illinois as the third shoreline of the glacial lake. The shoreline was named from the village of

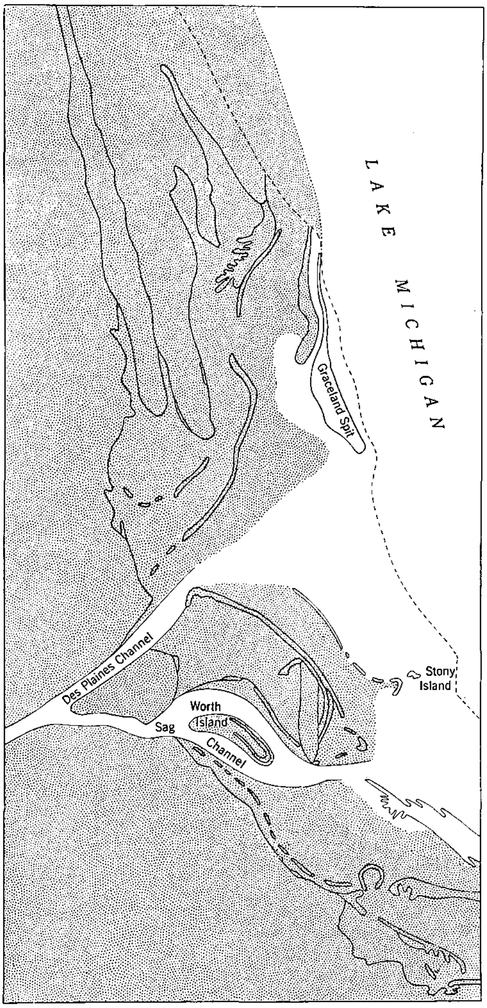


FIG. 87.—Sketch map of the Chicago region during Toleston stage of Lake Chicago.

Toleston before Gary was more than dreamed of. Though the village has vanished, its name will remain on geological maps as that of the third stage of Lake Chicago.

The relatively abrupt drop to the Toleston stage brought the level of Lake Chicago to within about 20 feet of the present lake surface (fig. 87). Again large areas of shallow water became low, flat, poorly drained land. Again the two outlet streams were lengthened eastward, the Sag Channel to Riverdale and the DesPlaines channel to Stickney. Again new shorelines were built, nearer the present lake than any earlier ones. Again spits grew southward from now vanished cliffs on the east side of the Highland Park moraine. Again dunes were piled up where drying winds found newly deposited sand along the shore. Most of the present stream courses of the Chicago plain were established, and before the stage closed an abundant molluscan fauna appeared in the lake, and driftwood was buried in the lake sediments.

In the southeastern part of our region, about Hammond and as far northwest as Dolton and Riverdale, there was very extensive shoreline aggradation during the Toleston stage. A series of parallel ridges constituting one broad sandy area marks the Toleston level here. The largest belt of dunes on any of the old shorelines was developed here. An alongshore current made weak spit "fingers" in South Holland Bay at Dolton. The last "finger" built was not recurved but points directly northwestward, across the head of the Sag outlet, toward the Stewart Ridge spit of Calumet age, and in so doing gives a misleading idea of the further course of the Toleston shoreline.

The Michigan Avenue business district in Roseland and Kensington (100th to 115th Streets) stands on the edge of a terrace. Immediately east of the avenue is a "drop-off" of 10 to 15 feet to the level on which Pullman is built. This low bluff is the continuation of the shoreline in Dolton and Riverdale. It is the only sea-cliff of Toleston age in the Chicago region and hardly deserves the name of cliff. There is no beach at its foot, hence it cannot be located on plate I. North of 95th Street, however, the Toleston shore is again a beach ridge, traceable with some difficulty northwestward to Garfield Boulevard, almost to Kedzie Avenue. The ridge was faint originally and city growth has almost obliterated it.

North of Chicago River the Toleston shore cannot be definitely located over many miles. One reason for its very weak development or total absence lies in the existence of another great bar or spit extending southward, like the Wilmette and Rose Hill spits, from cliffs in the North Shore district. The Graceland spit enclosed a bay too small and too shallow for wave action to make a good beach in the time available.

The Graceland spit extends from the north part of Evanston almost to Chicago Avenue, a total distance of about 12 miles. Its width, measured along such east-west streets as Fullerton, Diversey, Belmont, Irving Park, and Montrose, is about 1½ miles. Its top is flat and only the gravel and sand in excavations and its marginal slopes indicate its existence to one crossing the district. Like the Rose Hill spit, it is named for a large cemetery on it. Neither the Rose Hill nor the Graceland spits have the finger-like ridges so prominently developed on the back side of the Wilmette spit.

As the shoreline receded during the lowering of Lake Chicago, streams from the bordering moraine country lengthened across the emerging plain, but they could rarely flow directly to the lake because the abandoned sand and gravel ridges commonly blocked their way. Thus Skokie River, whose mouth would logically be at Kenilworth or Wilmette, was forced to flow westward around Wilmette spit and to join the North Branch of Chicago River, itself also deflected by Wilmette spit and still further detoured by Rose Hill and Graceland spits for a total of nearly 10 miles south from its own shortest course to the lake. Calumet River, heading about nine miles south of Michigan City, flows westward into the Chicago area almost to Blue Island where it is even farther from the lake than at its head. It rises in Glenwood lake-bottom in Porter County, Indiana. Several streams flowing down the back slope of the Valparaiso moraine join it, their combined waters cross to the north side of the Calumet shore near Wicliff and Ogden Dunes. Getting but little nearer the lake by this maneuver, the stream wanders on westward in search of a break in the Toleston barrier. It finds none and is forced actually three times as far away from the lake as it was at Wicliff. Only the Sag Outlet channel of the Toleston stage, west of Riverdale, provided escape from the labyrinth. Calumet River never entered Lake Chicago. Only after the Toleston stage was closed did it finally join the St. Lawrence drainage, and then only by utilizing, in reverse direction, the break in the Toleston shore afforded by the head of the Sag channel at Riverdale.

That remarkable parallelism of stream ways with the lake shore in the Chicago region involves two different factors. Above the Glenwood level, moraine ridges are the cause. Below that level, shorelines effected the same result. Running water has not yet put its mark of possession on the topography; the constructional forms of the glacial episode still control. Calumet River's endeavor to reach the lake did not end on securing the Sag channel head; more difficulties lay ahead in later stages.

Worth Island in the Toleston stage was a river island, the Sag channel dividing around it. The lake shore was five miles to the east and the bluffs encircling the island below its hairpin-shaped Calumet beach were cut by the river.

A new island appeared in the Toleston lake. The Stony Island klint emerged or so nearly emerged that waves were able to built a beach ridge around it. Both Stony Island and Worth Island are remarkable for the number and size of boulders lying on them, boulders from the glacial drift, "erratics" unlike the underlying bedrock. These islands were shoals in the lake stage just preceding their emergence and so were vigorously swept by waves. The finer material of the glacial drift was removed, at least in the upper part of the deposit, but the boulders were too large for the waves to handle and were left behind. Numerous boulders strewn over the lake-plain at the foot of old sea-cliffs tell much the same tale—removal of the finer constituents of the drift, accumulation of the boulders. Without doubt some boulders were dropped from icebergs floating in the lake but where they are grouped so significantly as above noted, this explanation is not adequate.

Later lake stages.—Seeking to make a complicated story simple, we have omitted or only barely mentioned a number of changes outside the Chicago region. In order to understand what happened after the Toleston stage, some of these must receive a little attention.[3]

The Lake Michigan basin was given its finishing touches during the retreat of the last ice-sheet. When completed, the lowest place in the basin rim was the Strait of Mackinac at the north and the next lowest was the Chicago Outlet at the southwest.

[3]For a complete account of the glacial Great Lakes, from which there since have been but few departures in interpretation, see "The Pleistocene of Indiana and Michigan and the History of the Great Lakes.": U. S. Geol. Survey, Mon. 53, 1915.

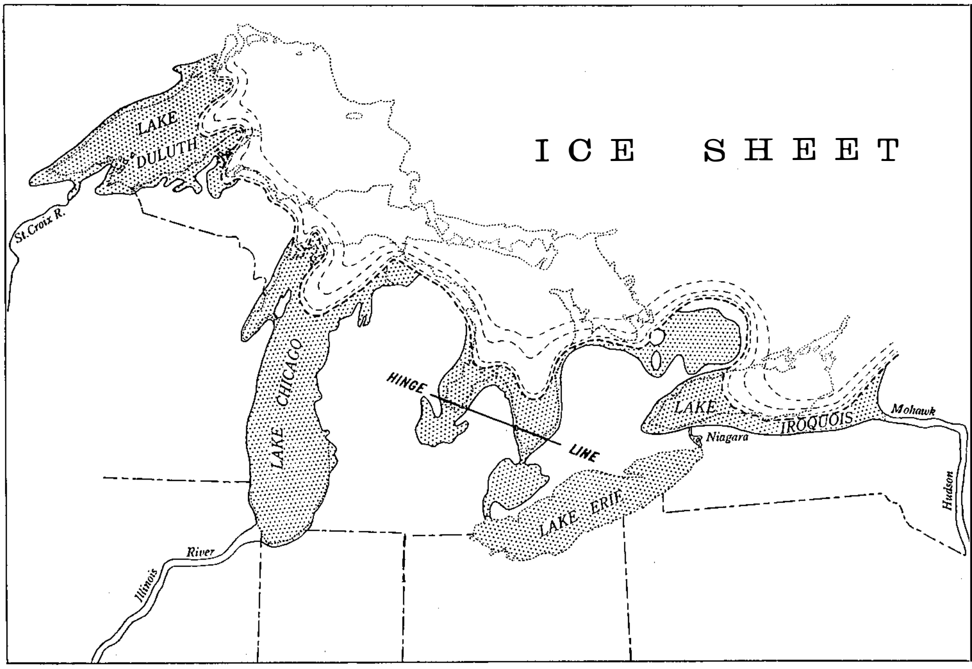


FIG. 88.—The Great Lakes region during the Toleston stage of Lake Chicago and the first stage in the development of the gorge below Niagara Falls. (Partly after Leverett and Taylor, U. S. Geological Survey, Mon. LIII, Pl. XIX.)

The south end of the basin became ice-free long before the north end. This held Lake Chicago, lengthening but lowering during its existence. Had there been no rock floor in the Chicago Outlet channel, or had Lake Chicago endured for a longer time, it is conceivable that Lake Michigan would today have a natural discharge to the Mississippi. But the Strait of Mackinac, and with it an opportunity for continuous eastward flow to the Atlantic, was opened before this happened, and Chicago Outlet ran dry. Niagara Falls had already been born, had had its first great discharge, and had dwindled to a fifth of its early volume because the lower Trent River valley route in Ontario had been uncovered. The Toleston stage was probably contemporaneous with the early stage of Niagara Falls (fig. 88), the immediately post-Toleston events with discharge through the Trent River outlet and with the shrinkage of Niagara.

Shorelines adjusted to the Trent River outlet from Georgian Bay show that one great lake now occupied the three upper lake basins, the Strait of Mackinac between the Michigan and Huron basins and St. Marys River between the Superior and Huron basins being widely submerged. This lake was Lake Algonquin (fig. 89), the largest continuous sheet of glacially ponded water in the Great Lakes region. At Chicago it was very little below the Toleston level and its shorelines cannot be positively separated from the last ones made by Lake Chicago.

During the life of Lake Algonquin, the ice continued to retreat toward the northeast, and the northern region continued to rise. Since the Trent outlet lay north of the so-called "hinge-line" (south of which the shore lines remained horizontal) its uplift produced a rise in Lake Algonquin's surface. This made no change in shorelines adjacent to the outlet, but in the south and southwest the lake surface rose on the land as the northward uptilting progressed. This rise of water south of the hinge-line is what caused the spill-over at Port Huron, returning to Niagara approximately the former large volume of discharge. It seems probable that for a short time the Toleston shores were re-occupied in their entirety and that a part of Lake Algonquin discharged through the Chicago Outlet. If so, it was but a shallow stream and soon

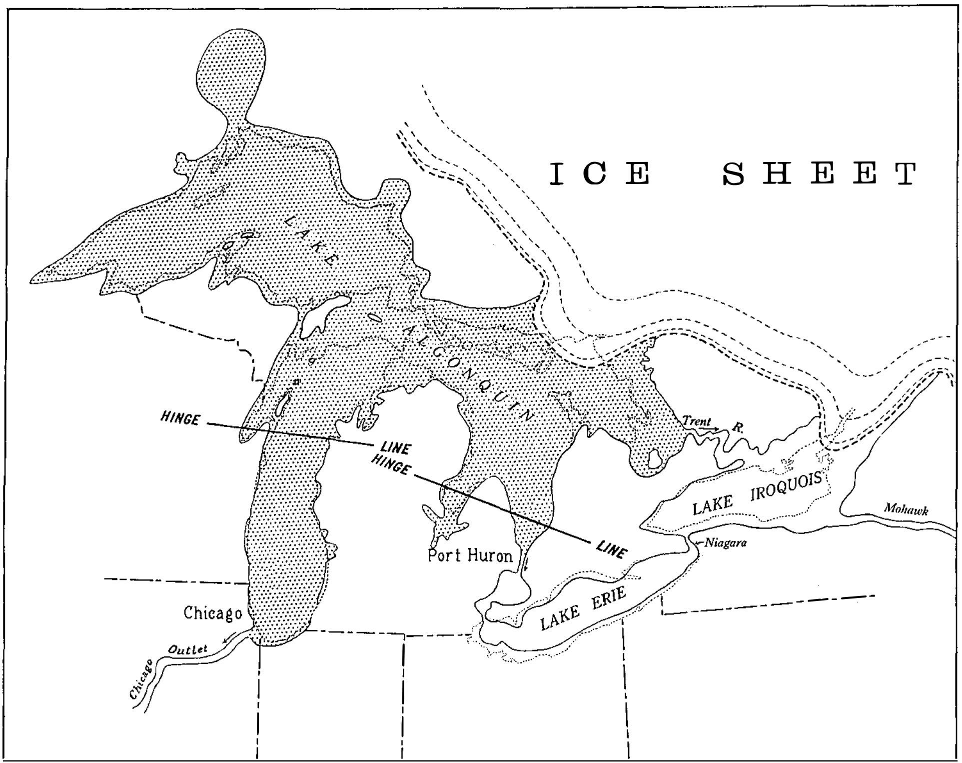


FIG. 89.—Lake Algonquin with three outlets. (After Leverett and Taylor, U. S. Geol. Survey Mon. LIII, Pl. XXI.)

went dry, as the Port Huron outlet channel, which is in glacial drift, was rapidly deepened. Both the Sag and DesPlaines channels already had been scoured to bedrock during the life of Lake Chicago, and this minor discharge did nothing further to them. Lake Algonquin thus may have had three different outlets functioning simultaneously for a time (fig. 89)—the waning Trent River outlet, the rock-floored shallow Chicago Outlet, and the deepening Port Huron drift-floored outlet.

Lake Algonquin was an ice-dammed lake, the continued retreat of the ice gradually exposing most of the basin of Lake Huron and Georgian Bay. The last area abandoned was the northeast part of Georgian Bay and beneath the ice here was, in spite of the preceding northern uplift, still the lowest place in the rim. When this was finally exposed, a new discharge route opened via the Mattawa and Ottawa rivers to the Ontario basin, Port Huron and Chicago outlets went dry, Lake Algonquin's history came to an end, and the first of the postglacial lake stages Nipissing began.

Lake Nipissing, or the Nipissing Great Lakes, had one level throughout the three upper lake basins but the connections had become so narrow and the levels had lowered so much that a map of it (fig. 90) looks very much like a map of the present lakes. The Nipissing level at Chicago was not high enough to send water westward to Mississippi River, and it is represented by a complex group of low sand ridges between the Toleston beach and the present lake shore. They are well shown in undeveloped areas about Gary and Hammond (fig. 91) but have almost entirely disappeared in the built-up portions of Chicago. The geologic maps (Calumet Lake, Jackson Park and Chicago Loop quadrangles) show these beaches as they were surveyed in 1902, the dotted boundaries indicating that they are but ghost outlines. One still recognizable member crosses the northwest corner of Washington Park, swings south-

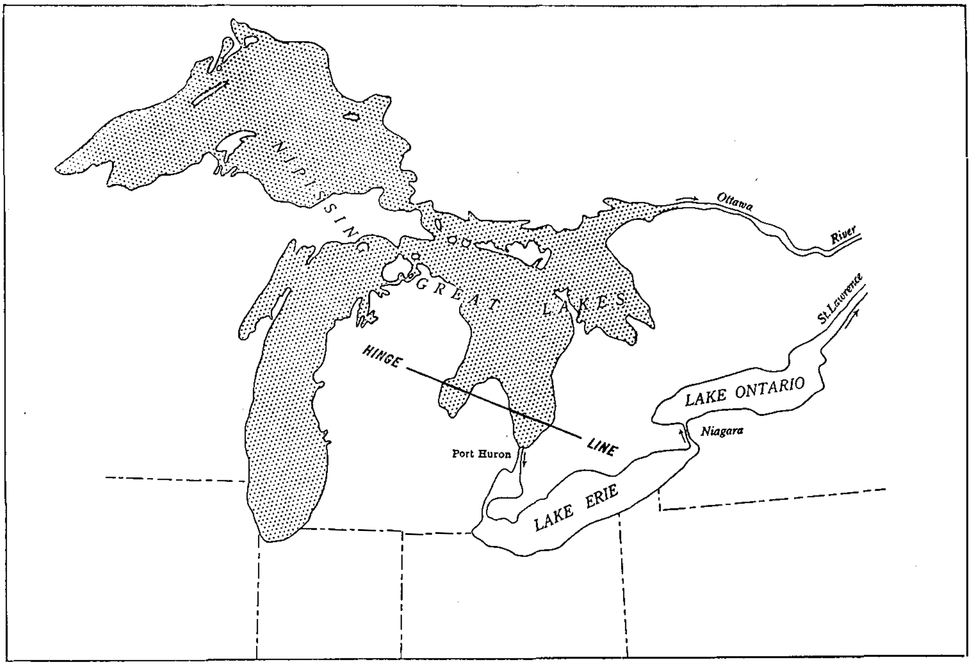


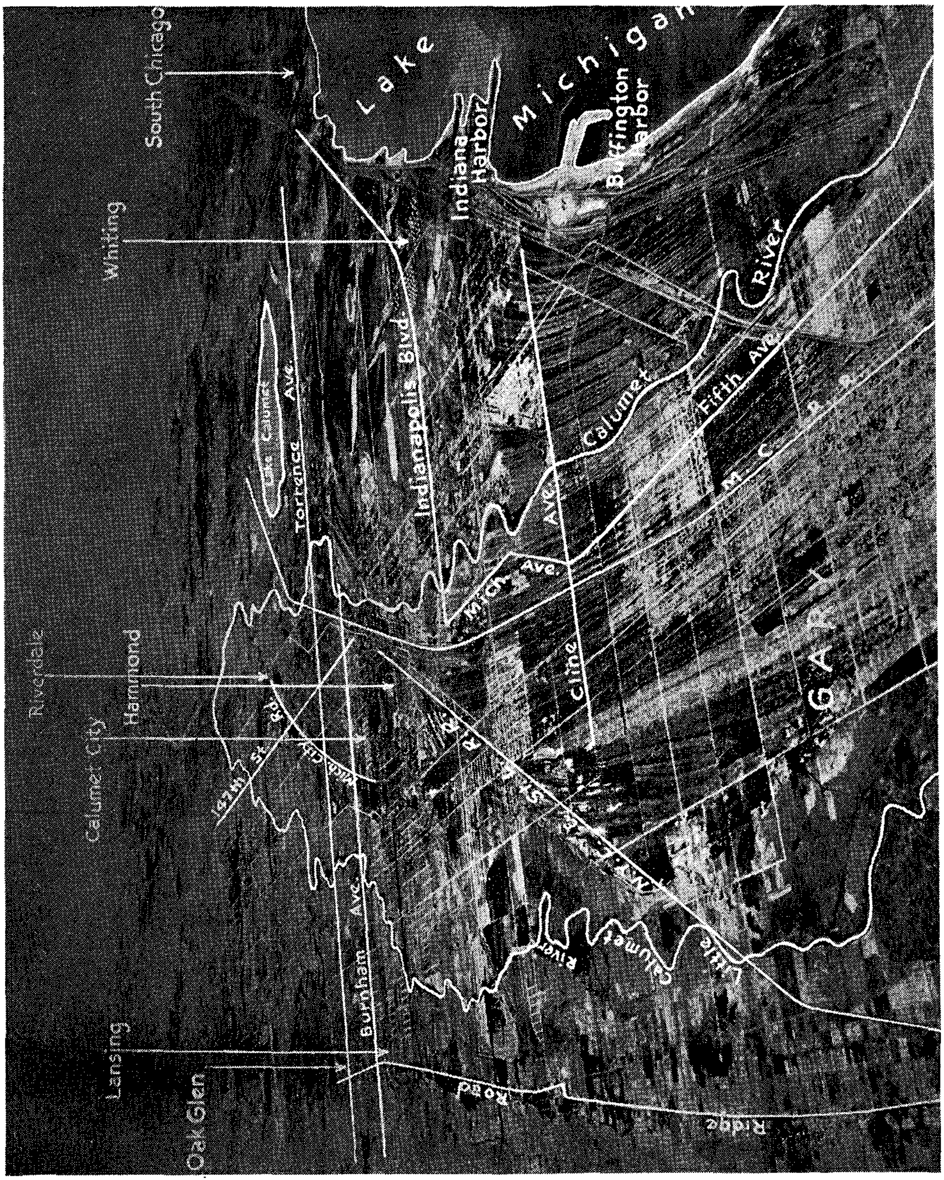
FIG. 90.—Nipissing Great Lakes. (After Leverett and Taylor, U. S. Geological Survey, Mon. LIII, Pl. XXVII.)

ward across to the west side of State Street, and terminates at 87th Street, near the foot of the Toleston beach. It is lower than the Toleston and its orientation departs about 45° from that of the Toleston here. It has, or had, a series of barb-like projections on the landward side, indicating its origin as a spit from the north. Indeed, the whole group of sand ridges in the Englewood and South Shore districts as mapped in the Chicago Folio (1902) is a compound spit. There could hardly have been a discharge down the DesPlaines channel at this time, for an uninterrupted alongshore current from the north for some distance would have been necessary to supply this sand. Furthermore, these shores are too low to have belonged to a stage of the lake that had westward discharge.

Fragments of beach ridges and spit "fingers" in front of the Sag channel farther south and lower than its floor indicated the same thing for this outlet. The plexus of sand ridges here is in part responsible for the enclosure of the basins of Lake Calumet and Wolf Lake, both very shallow pans on the lake-bottom of the Nipissing stage.

The Nipissing beach in Georgian Bay is at least 40 feet below the lowest of the Algonquin beaches, opening of the Mattawa-Ottawa outlet having lowered the water level in the northeastern part of the threefold basin (Superior, Michigan, Huron) that much. But the Nipissing shore in Chicagoland is only 5 to 10 feet below the Toleston-Algonquin shores, although the surfaces of both Lake Algonquin and Lake Nipissing must have been level. The explanation lies again in that northern uprising which, continuing through the Nipissing stage, raised the outlet floor. As the Chicago region underwent no uplift, the water level here was forced to rise to keep pace with the rising outlet. Thus the earliest Nipissing shorelines at Chicago must have been destroyed by the rising waters, and the existing beaches of this stage are late Nipissing. The continued tilting finally repeated at Port Huron outlet what had happened in Algonquin time. A spill-over occurred to Lake St. Clair and thence to Lake Erie; the discharge soon became the main outlet and finally the only outlet, and with this, the Nipissing Great Lakes came to an end and the modern lake-levels and outlines were determined.

Niagara Falls must be mentioned again—its history as thus far outlined is too briefly



Courtesy of the Chicago Daily Illustrated Times

FIG. 91.—Beachlets of post-Toleston lake stages between Hammond and Gary, Indiana. There are 68 separate beach ridges recognizable in the photograph. The Toleston beach, overgrown with dunes, lies between the two Calumet rivers and is the cause of the great detour. Michigan City Road follows the crest of the Toleston beach. Ridge Road is on the Calumet beach.

told for accuracy. The cataract was born full grown when Lake Chicago was still discharging to Mississippi River, melting of the closely adjacent ice front contributing a large volume of water. When the Trent River outlet of Lake Algonquin opened, Niagara River shrank to about a fifth of the maximum volume. The falls again received maximum volume when tilting had lifted the Trent outlet above the low place in the rim at Port Huron. But it lost all this gain and operated a second time on the discharge from Lake Erie alone when the Mattawa-Ottawa outlet of the Nipissing Great Lakes was exposed. Finally it regained the discharge from lakes Superior, Michigan, and Huron when the continuing uplift reestablished the Port Huron outlet and the modern lakes were born. In the gorge below Niagara Falls there are three wide stretches and two narrow portions, to be correlated with these outlet shiftings. There is still more to Niagara's history but it is not intimately bound up with events in Chicagoland and is not reviewed here.

Calumet River, escaping from behind the Toleston beaches near Riverdale, encountered more trouble during the Algonquin and Nipissing stages. The rate of growth of beach ridges and spits from the north was more than the river with its low gradient could cope with. Like Chicago River before dredging and harbor improvements (p. 40), the mouth of the sluggish Calumet was forced southward by the spits constantly growing from the north. The river flowed into Lake Algonquin near Riverdale, but by the end of Nipissing time, its mouth had been shifted south and east at least as far as Gary, and by the time of exploration and early settlement of Chicagoland, its mouth was three quarters of a mile east of Millers, 14 miles east of the Indiana state line. Thus about 20 miles were added to the river's length after it discharged at Riverdale. Had not the shore current interfered, there would have been needed no more than six miles of added length to reach the lake today. By 1870, beach and dune sand had closed the mouth at Millers and the river was again in serious difficulty. Man, for his own purposes, then provided a dredged route to the lake between lakes Wolf and Calumet. Still later, by digging the Calumet-Sag canal, he reversed the flow of that portion of the river between Millers and Blue Island and provided, with the accompanying reversal of Chicago River also, two converging westward artificial outlets for Lake Michigan. But only the glacial river channels, on either side of Mt. Forest Island, have made possible these works of man.

Low-water stages.—Another item of Lake Chicago history should be noted before our account is fairly balanced. It will be stated very briefly. There is evidence that when Lake Chicago fell from the Glenwood level, it went much lower than the Calumet level and that later when it rose to make the Calumet shoreline it re-submerged part of the Glenwood bottom that had been exposed during the low-water stage. There is evidence that similar low-water stages, lower than each succeeding shoreline stage and perhaps lower than the present lake-level, may have occurred between all of the shoreline stages of the glacial lake. The evidence for the low-water stages alternating with the high-level stages consists of swamp deposits under portions of the various beaches and of stream channels completely buried under the sand in the lake-plain. These could have been formed only if the lake water had been withdrawn.

Such low-water stages during Lake Chicago's history could occur only if the margin of the ice-sheet had withdrawn in each case so far north that lower outlets toward the east were afforded. Re-advance of the ice-front made the next high-level stage by closing the eastward discharge routes, but the re-advance also obliterated the evidence for the temporary outlets.

Such oscillatory behavior of the ice-front is known from other evidence as well. The successive moraines of the northern states (32 are known between Ohio River at Cincinnati and the Canadian boundary near Plattsburg, New York) show in many places that they probably were each formed by a re-advance of the ice after a retreat from the preceding moraine several times as great as the distance between the moraines. Even our minor Tinley moraine ridge records a slight re-advance after a retreat, because in one place the drift overlies the eastern part of the laminated clay and silt of Lake Tinley. We must remember, in using this concept, that the terms "retreat" and "re-advance" refer only to the position of the ice-front, and that the ice-mass itself never moved back—it was moving forward even when the ice-front was retreating.

Recent Changes of Level in Lake Michigan

All the Great Lakes are known to undergo seasonal changes in level. Since measurements were inaugurated in 1860, their surfaces have averaged about a foot higher in summer than in winter. In addition to these regular changes of the year, there have also been larger variations of level, enduring for irregular but longer periods. Furthermore, these larger and longer fluctuations are somewhat unlike in the different lakes, Huron and Michigan being considered as a single water body. Lake Michigan (and Lake Huron) was unusually high in the summers of 1917 and 1918, reaching 582 feet above sea-level. Then for nearly a decade its summer high level fell lower and lower, eventually failing by four feet to reach the mark of 1918. The steamer route south from Lake Huron and many harbors in both lakes became dangerously shallow.

In 1900 the Sanitary District of Chicago completed a 28-mile canal extending from Chicago River across the St. Lawrence-Mississippi divide and down glacial Lake Chicago's outlet as far as Lockport where a drop of 34 feet was utilized for power. Upon completion of this canal Chicago River and its south branch were reversed, and for the first time in about 25,000 years water again flowed from the Lake Michigan basin into Mississippi River.

During the 1920's much blame for the low level was placed on the diversion of 10,000 cubic feet per second through the Chicago Drainage Canal. Legal proceedings were instituted against the Sanitary District of Chicago, and eventually a reduction to 4,167 cubic feet per second was ordered by the Federal Court and confirmed by the U. S. Supreme Court in 1930. While the Supreme court was weighing the evidence, during which period 10,000 cubic feet per second were still being taken for the canal, the lake level started rising and in little more than a year, it had nearly touched 582 feet above sea-level again. In 1929, storm waves of the continued high level did damage estimated at many millions on the shores, particularly of Lakes Michigan and Erie. In 1938, just preceding the reduction in volume to 4,167 cubic feet per second, summer high level of Lake Michigan, according to the Sanitary District of Chicago was 579.7 feet.

Precise causes of the longer, irregular variations of lake level are difficult to determine and no predictions of their occurrence or alterations are yet feasible. But the general causes certainly are variations in weather. The lakes extend through 7° of latitude and 16° of longitude, an area large enough to have noteworthy variations in storm tracks across it and variations therefore in rainfall and snowfall and in amount of evaporation from both land and water during fair weather interludes. Combinations of these as yet incompletely measured variables caused the long-term fluctuations in levels of the different Great Lakes. It is to be expected that cycles of decreased run-off and increased evaporation will recur in the future. The three per cent of discharge volume, recently going to Mississippi River through the canal and now returned to Niagara, will make only a few inches difference in the lake level.

Life of the Glacial Lake Stages

If swamp deposits occur immediately beneath the sand and gravel of the glacial lake shores, then plants must have migrated back into the region, from which the ice-sheet had earlier erased them, before the glacial barrier had vanished from the lake basins. In the wave of life returning to the devastated country, animals should have accompanied the plants, or followed very shortly after. Pioneers of the more hardy species would be expected to arrive first, then increasing numbers of them, followed and replaced later by types requiring milder climates until finally the present flora and fauna of northern Illinois became established. Insofar as the sediments and beaches of Lake Chicago contain or cover fossil plants and animals, they afford a consecutive record of the return of living forms up to the time of Lake Algonquin.

There is very little evidence in the Glenwood records that organisms had already reached the region by that time. A water-worn fragment of a mammoth tooth, found many years ago in a gravel pit in the Oak Park spit, seems to tell of these subarctic animals in Chicagoland at that early stage, and therefore of adequate pasturage for the great beasts. But an oyster shell also found in this deposit surely does not record postglacial marine water here any more than do the Floridan and West Indian subtropical mollusc shells and coral once unearthed in the somewhat later Calumet beach. Man has introduced these shells. The water-worn mammoth tooth is far better evidence. The only other record known of Glenwood life is that of ten species of minute molluscan shells found in stratified silts of Skokie Bay.[1] All but one are freshwater shells. The exception is a land snail, probably washed out into the bay from the land. Here, without doubt, is an aquatic fauna of the earliest stage of Lake Chicago, a fauna living in ice cold water even in the summer.

In the deeper parts of Wilmette Bay is a wide-spread silt and peat deposit, from 10 to 18 inches thick and nowhere more than 10 feet above present lake level.[2] It has yielded remains of oak, poplar, spruce, cedar, balsam, tamarack, and sedges and of nearly forty molluscan species characteristic of quiet shallow ponds. This is the best, though not the only, record of life in the region during the Bowmanville low-water stage that preceded the rise to Calumet levels. The flora recorded is north-temperate and boreal. At the Bowmanville low-water stage, Chicagoland was the extreme northern limit of these trees. They had just arrived in the first forest wave repossessing the glaciated region.

Another deposit containing peat, fragments of wood, and numeruos molluscan shells, referred to the same interval of time, is exposed in the low lake-cliffs of today, a little north of Evanston. The peat is several feet thick a few blocks back from the shore and is nowhere more than fifteen feet above Lake Michigan.

There are no authentic records of organisms of Calumet age. The beach sand and gravel has proved to be barren and no one has yet succeeded in dating any fossil-bearing open-water sediments as Calumet. The alluvium of Plum Creek, south of Dyer, has been accumulating ever since that part of the Calumet shore (the Lansing Beach) was built. The shells from its lower part have been identified by F. C. Baker as lake snails. The assemblage is not like what Baker found in definitely dated Toleston sediments and may be Calumet in age. The driftwood, found higher up in the alluvium, has not been identified, but its abundance and the large size of the tree trunks tell of a complete forest cover on the adjacent moraine slopes. A mammoth tooth and numerous fragments of deer antlers complete the picture of an established biota by Calumet time or a little later.

Authorities disagree on the question of a low-water stage between Calumet and Toleston times. A peat deposit has long been known to exist under a ridge that crosses Northwestern University campus in Evanston. It is clearly older than that ridge. By some, the ridge has been called a Calumet offshore bar, others consider it a Toleston beach ridge. If the former, it never was built up to the Calumet level of Lake Chicago. If the latter, its crest grew by storm wave action to stand a few feet higher than the Toleston level. The problem is further complicated by the recent discovery that this ridge contains two peaty horizons, separated by about six feet of sand. The upper one has never been reported by previous workers. Apparently there are two highwater stages of the lake history recorded here, the ridge shape dating from the second. The final interpretation of this Evanston record has yet to be made.

For Toleston and subsequent time, the region contains a wealth of records. Freshwater mussels became as abundant as they are today. In the Toleston bays were deposited layers of shell marl, containing myriads of tiny gastropods. Mammoths, mastodons, and deer lived on the land, driftwood from the forest collected along the shore and in favorable places became buried along with shells of the shore-living forms. A detailed example of the Toleston (or Algonquin) record is worth recording. Excavation in a clay pit in the northern part of Dolton in 1930 exposed 4 to 7 feet of clean sand overlying glacial till, the contact occurring at an altitude of about 590 feet, in the lower edge of what is mapped as the Toleston beach ridge. Here a log of oak, a foot in diameter, lay in contact with the till and the thin layer of clean wave-washed gravel that surfaces the till. The roots were mere stubs, having been worn off as the log rolled in the waves on the glacial lake beach.

[1]Ball, R. R. and Powers, W. E., Evidences of aquatic life from the Glenwood stage of Lake Chicago: Science, N. S., Vol. LXX, pp. 284-285, 1929.

[2]Baker, F. C., pp. 69-73 in Life of the Pleistocene or Glacial Period; Univ. of Ill. Bull., Vol. XVII, 1920.

In a broad shallow cavity beneath the log was a mat of stems, seeds, bits of wood, and a few beetle wing-covers, lying on a bed of tiny pebbles just as they were left by the last waves that forced water through the hollow beneath the log. The wood was soft and weak, and it cracked badly on exposure to the air. But, after drying, it burned. In the wall of this same pit was a buried ravine, about 40 feet wide and 16 feet deep, eroded in the glacial till and filled with beach sand and gravel, a record of postglacial, pre-Toleston stream erosion in a low-water stage of Lake Chicago.

The Coming of Man

Many plant and molluscan species of these glacial lake stages now live wholly north of our region, having followed the cooler climate to which they are best adapted. The mammoth and mastodon have vanished from the earth. Some of the molluscs are extinct. Chiefly because of that northward migration, the myriad forms of our fauna and flora have changed considerably in the past 25,000 years. A member of the fauna, a creature much like ourselves, came in some thousands of years ago. He had not lived here before; indeed, he may not have existed anywhere on the earth before the glacial period. His home continent, it is generally agreed, was Asia. By what route and at what time did Man enter North America, thence to spread to every part of its vast area before Leif Erickson or Christopher Columbus arrived?

Except for one item, this is debatable ground. Man entered the continent, all authorities concede, by way of Bering Strait or the Aleutian Island chain. Some would have him migrate southward along the Pacific coast, others see him go south along the Great Plains east of the Rockies and actually between the waning continental ice-sheets on the east and the glacier-clad Rockies on the west. Some believe that early Man in North America was contemporaneous with the mammoth and the wasting glaciers, others insist that our meager evidence does not justify this early date for Man's arrival. The acceptable solution of the problem of Man's appearance in our continent awaits the careful collection of much more evidence than we now possess.

Conclusion

History records and interprets the events of the past. The significance of history becomes apparent when one recognizes that every "present" contains its own past. Had that past been different, the present would be unlike what it is. The law of cause and effect is implicit in this. Chicagoland did not fall ready-made out of the sky, it did not take origin at the wave of a wand. It is the inescapable consequence, the cumulative consequence, of things that happened thousands, millions, even hundreds of millions of years ago. The geological story is complex and involved. Much yet remains to be deciphered and understood. We have endeavored, in this account, to transcribe the high points alone in what has thus far been decoded and interpreted. To the mind attuned, this endeavor to understand our present from the record of its past is an intellectual adventure of absorbing interest.