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DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

BULLETIN NO. 65, PART II

# GEOLOGY OF THE CHICAGO REGION

## PART II—THE PLEISTOCENE

BY

J HARLEN BRETZ

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS

1955

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June 1, 1954

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# GEOLOGY OF THE CHICAGO REGION

## PART II — THE PLEISTOCENE

BY

J HARLEN BRETZ

### ABSTRACT

The events most concerned in the making of the surficial physical features of the Chicago region came late in its geological history. Glaciation of subcontinental proportions was part of that extraordinary experience of the northern half of North America, and is the theme of this report. Earlier (preglacial) events, recorded in the bedrock beneath the glacial record, are outlined in portions of Part I of this bulletin.

The stages of Pleistocene glaciation in North America were fourfold, and each successive invasion of glacial ice partially or even completely destroyed evidence of earlier ones in many places. The glacial history of the Chicago region as now interpreted includes records of the two later glacial episodes, the Illinoian and the Wisconsin. But the record is incomplete for each glaciation and understandable only by comparison with the glacial history of adjacent regions.

Starting with the description of the features of the area and the processes by which they were formed, the author proceeds to a systematic treatment of the succession of drift sheets, glacial-lake stages, and Recent changes. Radiocarbon dating is also discussed.

Although this bulletin is not a compilation of previous studies, earlier students have laid the foundation and outlined the principles which, tested and approved as research in Pleistocene history of North America has advanced, are the fundamental building stones of today's interpretations. Some rejections and revisions of previous conclusions have been inevitable because of our increasing knowledge under more favorable conditions for checking early ideas and for elaboration of concepts. This bulletin is not a final, complete elucidation of Chicagoland's glacial history. Many problems remain unsolved, much new and significant data will be discovered.

# CHAPTER I — INTRODUCTION

## LOCATION AND EXTENT OF THE CHICAGO REGION

THE CHICAGO REGION, in the northeastern part of Illinois, borders on Lake Michigan and extends from Indiana almost to Wisconsin. There are no generally accepted boundaries; the industrial cities of Hammond and Gary, Ind., and Joliet and Waukegan, Ill., are often included in the Chicago region. For the purposes of this report, the Chicago region, or "Chicagoland," will be considered as that area included in the topographically mapped portions of 24 quadrangles of the United States Geological Survey (fig. 1). Thus defined, the region overlaps about 1.3 miles into Indiana on the southeast and falls about 17 miles short of reaching the Wisconsin line on the north. All of Cook County is included, with small portions of DuPage, Will, and Lake counties, Ill., and of Lake County, Ind. Since all quadrangle boundaries are latitude and longitude lines, following the standard practice of the United States Geological Survey, no political boundaries are used. The total area is 1064 square miles.

Each of the Chicago region quadrangles measures 7½ minutes of arc (1/8 of a degree) on a side. Because the Chicago region is nearly halfway from the equator to the pole, a degree of longitude here has a length only about three-fourths that of a degree of latitude, and therefore the quadrangles are not square. Each measures 8.65 miles north and south and 6.45 to 6.50 miles east and west. Because of northward convergence of the meridians, the northern edge of each of the northernmost quadrangles is about one-twentieth of a mile shorter than the southern edge of the southernmost ones.

This group of contiguous quadrangles constitutes a block ½ degree (four quadrangles) wide and 7/8 degree (seven quadrangles) long. The bounding meridians are 87° 30′ and 88°, the bounding parallels are 41° 22′ 30″ and 42° 15′. This is nearly 26 miles east and west by 55 miles north and south. Two of the 28 quadrangles which fill the block are entirely on Lake Michigan, hence do not appear in this group. Two are so largely lake surface that the fraction of a square mile of land in each is made a part of the adjacent quadrangle to the west. Five of the quadrangles have varying proportions of land and water, and the remaining nineteen are entirely land.

Only the northern fourth of each of the 4 southernmost quadrangles has been mapped topographically and geologically. The overlap on the four southern quadrangles made it possible to include all of Cook County in the mapping.

The topographic and geological maps are available separately from the Illinois Geological Survey. The geological maps, numbered as shown in figure 1, are also available in a set covering the area described in this report. Where reference is made to a geological map, the map number in the set is given, both for convenience in finding the map and to differentiate it from the topographic map, which is not numbered. Although the topographic maps are used as the base for the geologic maps, the overprinting of the geologic pattern partially masks the topographic contours, and references are made to the topographic maps for features best shown on them.

## IMPORTANCE OF THE AREA

The area of Cook County, Ill., is 933 square miles and its population in 1940 was 4,063,342, making an average of 4,355 people to the square mile, which is exceeded by few areas of similar size on the earth. There are few greater concentrations of varied industries than in the Chicago region, and no greater railroad network radiates from any city in the world.

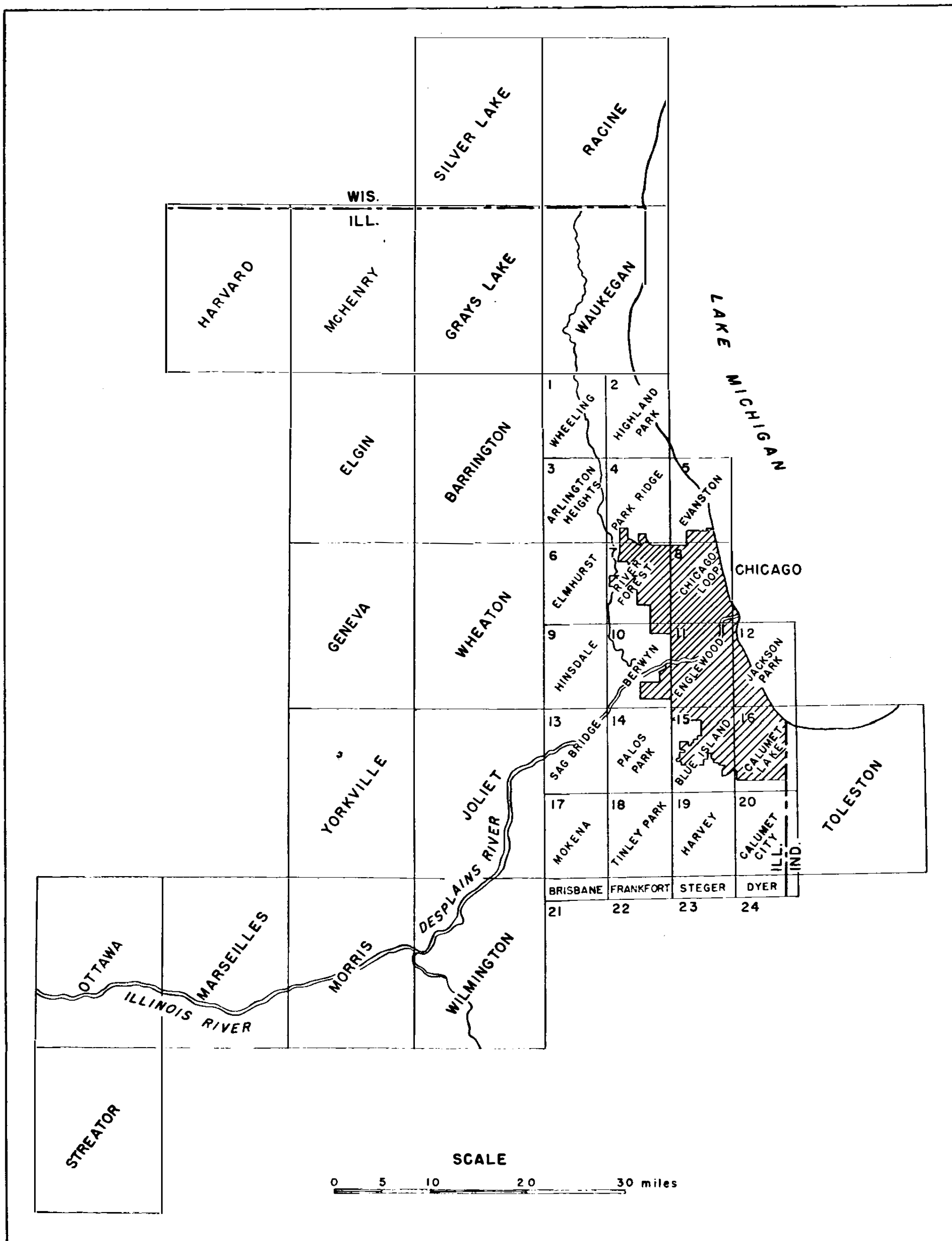



FIG. 1.—Map showing location of all quadrangles referred to in this bulletin and the numbers of the geologic maps in the Chicago region.

For the well-being of this great metropolitan center, modern engineering has provided a safe water supply and an adequate sewerage system, both conditioned by factors which are geological. The engineering problem of adequate foundations for the towering structures which commerce demands involves geological considerations. The common building brick, used in great quantity in the construction of Chicago, is a local product of local earth materials. Concrete, the rival of brick in many ways and its superior in some, contains crushed limestone from Chicago's numerous quarries. Sand, for filling and for building purposes, comes into Chicago from the inexhaustible supplies heaped up in the dunes along the nearby Indiana lake shore. Sand and gravel dredged from the floor of Lake Michigan has many industrial uses.

## PURPOSE OF THE INVESTIGATION

The purpose of the present investigation is to assemble, interpret, and make available basic geological data on the Chicago region. This information is needed (1) for the continued development and efficient use of mineral resources of soil, stone, clay, gravel, sand, and groundwater; (2) for engineering analysis and design of foundations and other engineering works relative to earth materials; (3) for land-use planning; and (4) for perfecting our knowledge of the natural history of the area.

Several universities, colleges, and high schools in the area teach geology, which makes for constant demand for geological descriptions and interpretations of the Chicago region. The interest of many intelligent laymen adds to that demand. The geologically recent glacial history is well recorded and may be fairly readily read from the unconsolidated deposits and their topographic forms, the much older bedrock history from outcrops and quarry walls. Scenic features of the great belt of natural parks, the forest preserves of Cook County, virtually all have geologic elements, the explanation of which is attempted in the following pages.

## HISTORY OF THE INVESTIGATION

The topographic base maps for the Chicago region are the product of a cooperative arrangement between the United States Geological Survey and the Illinois State Geological Survey and bear the names of both organizations. Shortly after the completion and publication of the entire set, the Illinois State Geological Survey commissioned the writer to make a geological survey of the 24 quadrangles, to prepare a geological map of each for overprinting on the topography, drainage, and culture, and to write a geological report on the region which would be suited to the needs of laymen and students.

Field work began in the summer of 1930, the writer being assisted by George H. Otto. During the summer of 1931, Mr. Otto took charge of the collection and interpretation of all subsurface data on unconsolidated deposits and Edward H. Stevens became assistant to the writer. This arrangement was continued during the following summer. Approximately nine months of field work was sufficient to cover the region in the detail planned.

Part I of the report was written largely in 1934. As funds for printing the geological maps were not immediately forthcoming and it was desirable that they accompany the report, publication of Part I was deferred. It was decided to publish the report with a much-reduced (2 miles to the inch), folded geological map inserted in the book and to distribute the full-scale maps later. Accordingly, the report appeared in 1939 as Part I of Bulletin 65 of the Illinois State Geological Survey.

Because man-made changes along the lake shore had been extensive during the two decades after the topographic maps appeared, the shorelines were resurveyed in 1936-37-38, and the topographic maps revised with these data and with corrected and additional highway information. The geological maps were printed during 1942 and 1943 and their distribution announced in 1943.

The present part, Part II, concerns the topography of the region and the geology of the exposed glacial deposits. Other parts, dealing with subsurface glacial deposits, buried bedrock topography, stratigraphy of the exposed bedrock formations, and various mineral resources, are in preparation.

## ACKNOWLEDGMENTS

Field conferences with other workers have been of great value in the development of interpretations which appear in Parts I and II of this bulletin. Sharing in these conferences have been M. M. Leighton, Chief of the Survey, George E. Ekblaw, Head of the Engineering Geology and Topographic Mapping Division, H. B. Willman, Head of the Stratigraphy and Areal Geology Division, Carl A. Bays, Lewis E. Workman, and Leland Horberg, formerly geologists of the Survey, D. J. Fisher, of the Department of Geology, University of Chicago, the late John R. Ball and W. E. Powers, of the Department of Geology, Northwestern University, and I. D. Scott, of the Department of Geology, University of Michigan. The faithful and intelligent assistance of E. H. Stevens and George H. Otto has aided considerably in covering the field geology.

The entire text has been critically read by Dr. Willman, and Chapter IV was read by Dr. Scott and G. M. Stanley, of the Department of Geology, University of Michigan. Their criticisms and suggestions have resulted in some modifications of form and interpretation. The writer assumes responsibility for all statements, however, except where qualified by reference to others.

## PREVIOUS PUBLICATIONS

This investigation is, of course, not the first one devoted to the subject of the geology of the Chicago region. An earlier treatment of the entire field was published in 1902 as the *Chicago folio* (No. 81) of the United States Geological Survey. It was written by William C. Alden, who for many subsequent years was in charge of Pleistocene geology for the United States Geological Survey. Alden was assisted in the field by W. W. Atwood, Eliot Blackwelder, and N. M. Fenneman, who were students at the time and who all subsequently became authorities in North American geology. The topographic maps used as a base in the *Chicago folio* were four 30-minute quadrangles, covering a little less than two-thirds of the area treated in the present report. The horizontal scale of these maps was 1 to 62,500 (approximately one mile to the inch), and three of them had only 10-foot contour intervals. Though actually smaller maps than those used in this study, each one covered four times as large an area, and far less detail could be shown on them. Furthermore, great changes in culture and considerable changes in the lake shore had taken place, and Alden's excellent report no longer sufficed.

In addition to this general treatment on the Chicago area, there are many other published papers on various aspects of the region's geology, some earlier, some later than the folio of 1902. The earliest geological report seems to be H. M. Bannister's "Geology of Cook County," appearing as Chapter XIII in Vol. III of the *Geological Survey of Illinois* in 1868. Containing only 17 pages of text and no maps or illustrations, it reports only a reconnaissance examination of the county. The author was aware, even at this early date, of the glacial, glaciofluvial, and lacustral origin of the unconsolidated materials and the Niagaran (Silurian) age of the underlying limestone bedrock.

The earliest significant paper in the region's geological bibliography is Edmund Andrews' "The North American Lakes Considered as Chronometers of Post-Glacial Time," published as Article I of Volume II of the *Transactions* of the Chicago Academy of Science in 1870. Between this time and the date of Alden's *Chicago folio*, several papers bearing on the region's glacial and postglacial history appeared, the most important ones by G. K. Gilbert, Frank Leverett, J. W. Spencer, R. D. Salisbury and W. C. Alden, and F. B. Taylor. Specific references to these and other studies that bear on Chicagoland's geology are given in the proper places in the text of this report.

# CHAPTER II — TOPOGRAPHY

## INTRODUCTION

Although most of the drainage of the Chicago region now goes to the Mississippi River, the region belongs topographically to the lake section. Much of it bears the impress of a former submergence under the waters of the Lake Michigan basin. Much consists of undulating glacial moraines deposited along the margin of the Lake Michigan lobe of the last ice sheet, which here moved southwestward out of the basin. Elongated parallel to the lake margin, these moraines are traceable in great curved belts southward from Wisconsin into and across the Chicago region, eastward into Indiana, and thence northeastward into Michigan. Most of the slopes of the region descend toward the lake, but most of the detritus of the underlying unconsolidated deposits, glacially excavated from the bed of the lake, has been carried upgrade to its present location.

*Physiographic province.*—The great plain of the North American continent, centrally located, is wholly shut off from the Pacific on the west by mountain ranges and plateaus, and is largely shut off from the Atlantic on the east. But, as an almost uninterrupted lowland, it stretches from the Gulf of Mexico to the Arctic Ocean. Three major physiographic provinces of this plain are recognized[1]: the Gulf Coastal Plain on the south, the low Laurentian Plateau on the north, and between them the Interior Plains, consisting of the Central Lowlands on the east and the Great Plains province on the west. The Chicago region lies in the Eastern Lake section of the Central Lowlands and is crossed by a major drainage divide, the water parting between the Great Lakes—St. Lawrence and the Mississippi River systems. Though it is a major divide (between the North Atlantic and Gulf of Mexico drainage), it is low and almost unrecognizable unless one studies a drainage map. It is so low that man has trenched it with the Chicago Sanitary and Ship Canal, the water supply for Chicago being taken from Lake Michigan and the storm and sewage discharge sent to the Mississippi.

*Relief and altitudes.*—Within the limits of the Chicago region as herein defined, the total relief of the land surface is only 227 feet. The lowest part is the lake shore, the mean level of the lake in 1926 being 578 feet above the sea.[2] The bottom of the DesPlaines Valley on the extreme western margin of the region is almost as low—585 feet above the sea. The highest place is a hilltop a mile and a half south of the village of Frankfort (Frankfort quadrangle) which is ringed by the 805 contour line. There is an 800-foot hilltop six miles north of New Lenox (Mokena quadrangle), and several 790-foot hilltops are shown on the Hinsdale, Mokena, and Frankfort quadrangles. The highest point indicated on any railroad grade in the region is on the Elgin, Joliet, and Eastern line, four miles east of Brisbane (Brisbane quadrangle), at 771 feet. The railroad grade descends westward from this point for 11 miles to Joliet (B.M. 546), three miles west of the western limits of our region.

Nearly half of the 1064 square miles of Chicagoland, as shown in the 24 quadrangles, is a monotonous plain, largely lake-bottom, recording earlier and higher stages of standing water in the Lake Michigan basin. The altitude of this plain above the lake of today is almost nowhere more than 60 feet. This flat terminates to the north, west, and south against higher, rolling morainic country, some of it hilly. The roughest country lies in the vicinity of the Des-

[1] Fenneman, N. M., Physical divisions of the United States, *map in* Physiography of Western United States: New York, McGraw-Hill, 1931.

[2] Though some quarries and clay pits have floors below lake level, they are not natural features of the land surface and, unless constantly pumped, they promptly fill with groundwater.

Plaines and Sag valleys on the Sag Bridge and Palos Park quadrangles, its roughness due largely to dissection of the morainic uplands by many postglacial stream valleys. Steep bluffs up to 100 feet high may be seen in this district, as at the toboggan slide in the Forest Preserve near Palos Park.

The Mokena quadrangle is similarly a district mostly in slopes due to stream dissection, but because the major valley walls were formed before the last glaciation and were mantled with glacial drift, the slopes are smoother and gentler than in the Sag Bridge quadrangle immediately to the north.

A narrow zone of rugged topography on the Highland Park quadrangle closely margins the lake. It is the one place in Chicagoland where morainic country borders Lake Michigan, where no old lake bottom flat intervenes. Because the moraine here is 75 to 100 feet above the lake, dozens of small high-gradient postglacial streams have cut the eastward slope into a maze of ridges and valleys. Wooded, high, and overlooking the adjacent lake, it has become one of the choicest of Chicago's suburban residential districts.

*Topographic maps.*—The 24 maps covering the Chicago region show the relief of the region by brown contour lines. In thus depicting the elevations and the character of slopes, they are topographic maps. They also show water (lakes, swamps, streams, and canals) in blue, and culture (the works of man, such as cities, towns, highways, railroads, and land boundaries) in black.

The horizontal scale selected for the mapping was 1/24,000. One inch on the map thus represents 24,000 inches on the ground it depicts. This comes very close to 2 5/8 inches on the map equalling a mile on the ground. The contour interval

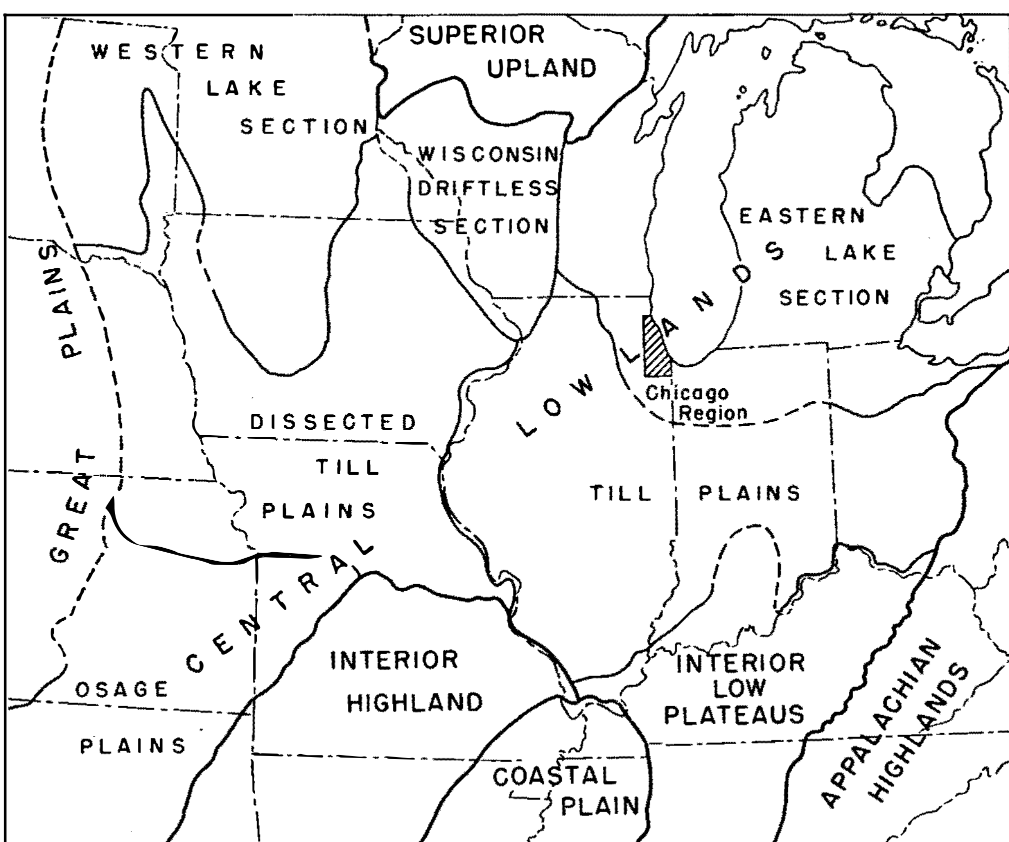



Fig. 2.—Physiographic divisions of the Middle West, showing the location of the Chicago region.

selected was five feet. Since contour lines by definition are level lines, every place through which a given contour passes is at the same altitude. Slopes thus are shown by a series of parallel or subparallel contours, the slope being at right angles to the lines. Altitudes are printed on every fifth line, which is also a thicker line. Where successive contours on the map are shown close together, slopes are steep; where far apart, the land depicted may appear to the eye to be almost level.

Altitudes to the foot are printed at many road intersections and other places on the maps. Those preceded by the letters B.M. indicate the existence there of a permanent bench mark with the precise altitude inscribed on it. The altitude of any place not on a contour line or elevation point can be estimated with an error not greater than five feet. Altitudes are reckoned from mean sea level. The level of Lake Michigan varies, but averages about 580 feet above sea level. By subtracting 580 from the altitude, therefore, one may know how high any point is above the lake.

## GEOLOGIC FACTORS

The Chicago region is the cumulative result of many and varied geologic factors, some of which are operating today and some of which were wholly different from those of the present. The factors now in operation have had control for so short a time relatively that the region's physiognomy is still dominated by the impress of processes long since nonfunctional here. Although not conspicuous in the details of our hills, valleys, basins, and plains, bedrock is nevertheless the foundation beneath all other materials and has yielded much debris for the surface deposits, whose general distribution and altitude also depend on the buried topography of the bedrock. The geological events recorded by the half-mile and more of lithified marine sediment beneath were like nothing occurring in the region today, except in the depths of Lake Michigan. When the bedrock material was being aggregated, shallow seas covered the region and consistently caught and kept the waste contributed from distant lands. The alternations of limestone, sandstone, and shale members in the well logs record changes in local depths of submergence, in distances to bordering land, in steepness or gentleness of slopes on that land, and perhaps also in climate and vegetative cover.

### Topographic Processes

The unconformities which separate some of these ancient marine sedimentary formations, and especially that very marked unconformity between the overlying unconsolidated materials and the subjacent uppermost marine formation, record periods much like the present—of exposure to the atmospheric attack of wind, weathering, rain, running water, groundwater, and in some cases glacial ice. During such times the principal events were destructional. Rock material was broken up and carried away instead of being added, as in the making of the sedimentary formations. These unconformities are old land surfaces now buried beneath later deposits.

#### STREAMS

During the periods of exposure, drainage ways were carved out by the concentration of the run-off from rainfall into streams. Between such stream valleys were residual elevations, perhaps still carrying summit remnants of the original surface. A definite sequence of changes in this attack is known as the cycle of erosion.

*The cycle of erosion.*—In the initial stages of the cycle, the major drainage courses are determined by whatever slopes the newly exposed land may have. These become the major stream valleys as they are deepened by the vigorous flow on youthful, high gradients. Because of the deepening, relief of the region increases toward a maximum. Small tributary streams can never cut deeper than the main stream at point of junction and, when traced upstream, must by reason of their own gradient be progressively higher than the main. Into the tributaries enter still smaller streams, the branching pattern of the whole much like that of a tree. Finally, the ravine and gully twigs of the drainage system, well up on the slopes of the divide, are supplied only by slope runoff not concentrated into streamways. Only this slope wash can reduce the residual hilltops, and this process is very slow indeed compared with the rate of major valley deepening.

The streams, however, by deepening their valleys, reduce their gradients and thereby reduce their erosive ability. Undisturbed at this work, they must finally cease downcutting. Valley-bottom widening will have already begun in these later, slower stages of deepening, and it will eventually become the dominant, and finally the only, method of valley enlargement. By this time, tributaries and subtributaries will have multiplied and lengthened back into the divide areas so that the transportation system for removal of slope-wash debris is functioning at its best. Youth in the erosion cycle is past; the region is now mature, with the maximum number of drainage ways, the maximum amount of slopes, and almost all surfaces the product of erosion by running water. Surviving remnants of the original surface are to be found only on hilltops, if at all. The major streams have now reached base level, the lowest gradients on which the region's runoff will flow and still carry its load of detritus. This base-level condition advances progressively up toward all headwaters as old age approaches. Lowering of upland slopes continues and finally is the only erosional change possible. Relief and steepness of slopes are now decreasing as the hills are lowered. The peneplain stage is being approached—the penultimate product of the attack by running water during a cycle of erosion.

*Topographic age of the Chicago region.*—The topography of the Chicago region is exceedingly youthful. Lake Michigan has proved a local base level for eastward-flowing streams, and under present conditions they can never do much valley-deepening on the plain because of inadequate gradients. Westward-flowing stream water has more than a thousand miles to go before reaching sea level in the Gulf, and, with altitudes here of only 600 to 700 feet above that level, valley-deepening by main streams flowing to the Mississippi is also severely limited. We judge the region to be youthful, therefore, chiefly by the existence of numerous swamps, lakes, and undrained basins, by the lack of marked valley-widening and the lack of well-developed dendritic drainage pattern.

The present cycle of erosion began here with retreat of the last ice sheet from the region. This is not to say that Chicagoland's topography is compounded wholly of late glacial and genetically associated forms, plus what changes stream erosion has been able to superimpose on them. Some valleys, in the Mokena and Sag Bridge quadrangles in particular, predate that last glaciation yet are eroded in glacial drift. They were made after an earlier glaciation and were still usable for drainage after the last of the ice sheets overrode this region. They are records of an earlier cycle of erosion that assuredly progressed further than the present one. And there are a few bedrock projections through the glacial deposits which were hilltops of a preglacial topography. The visualization of that marked unconformity, that preglacial land surface of the bedrock, must depend very largely, however, on well-log data. When other regions of northern Illinois and southern Wisconsin are considered, it appears possible that the late youth or early maturity of this preglacial bedrock topography is itself the second cycle recorded by the bedrock surface. There appears to have been an earlier cycle that progressed essentially to peneplanation, and the peneplain seems then to have been rejuvenated by uplift of what is now the upper Mississippi drainage area, and perhaps the present Great Lakes area as well. An amplified statement of the evidence for this concept appears in Chapter IV.

## GLACIERS

The glaciation of the northern half of North America occurred during the latest or Pleistocene epoch. Four times the ice sheets formed in the higher latitudes of the continent and spread southward to invade the northern part of the United States. Four times climatic amelioration brought about their destruction. Later invasions did not coincide in outline with preceding ones.

Where later ice sheets fell short of the limits reached by earlier ones, the older glacial drift deposits lie unburied. Where one drift sheet was overridden in a subsequent ice invasion, it may survive beneath the younger deposit. In the Chicago region, erosion of older drift by the later ice was more common, and earlier glacial deposits survive beneath the latest drift only locally. Generally exposures and excavations show the latest deposits to rest on bedrock.

### LAKES

Besides the overlap of Lake Michigan, which is one of the great lakes of the earth and more than 20 times as large as the Chicago region itself, there are seven named lakes within the region. The largest of these, Calumet Lake, is a shallow pan originally about 3 1/3 square miles in area, but it is constantly being reduced by marginal filling. Calumet Lake quadrangle, taking its name from this centrally placed lake, also contains Wolf Lake and Lake George. Wolf Lake is partly in Illinois and partly in Indiana; Lake George is wholly in Indiana. Wolf Lake covers about 1 1/2 square miles; Lake George today is only about a tenth of a square mile in area. Comparison of the Calumet Lake sheet of 1938 with the Calumet sheet, whose latest survey date is 1899, shows several changes in outline of these water bodies and particularly a great shrinkage of Lake George during the 40-year interval. Most, if not all, of these changes are from marginal filling, channel dredging, and drainage alterations as industry has developed here. Calumet and George are shown today to have the same surface level as Lake Michigan. Wolf Lake's surface in 1927 was 2 feet higher than Michigan's mean level.

The three lakes are merely shrunken remnants of that larger expansion of Lake Michigan during the final glacial retreat from the Great Lakes region. Because that vanished lake had a higher surface and discharged to the Mississippi, it has received the name of Lake Chicago. It, of course, was the cause of the levelness of the Chicagoland plain, to some extent by filling but to a much greater extent through bottom erosion by large waves entering from deep, open water into the shallower tract and there dragging bottom. Calumet, Wolf, and George have been shut off from present Lake Michigan by the growth of beach ridges during the latest stages of the glacial lake's history. Details on this subject will be found in later chapters.

During retreat of the ice front across the western morainic upland, before Lake Chicago's history had begun, one stage was marked by ponding of meltwater between the ice front on the east and abandoned morainic ridges and hills on the west. A row of four lakes existed at this time, their rather flat bottoms now shared by the Palos Park, Tinley Park, Harvey, Steger, and Dyer quadrangles. Three were somewhat smaller than the present Calumet Lake; one had about twice the area of Calumet Lake. All were very shallow and probably were completely obliterated by deposition of sediment before the ice front withdrew farther east. The ice front constituted part of the retaining wall on the east, as it did on the east and north for Lake Chicago a little later. There are no shoreline records of these lakes; a laminated clay overlying glacial drift constitutes the best evidence for their former existence.

The 24 topographic maps show dozens of ponds and small lakes whose basins are wholly artificial. Most of them are on the lake plain. Some are park lagoons, and many are abandoned pits and quarries that were excavated below the water table. None in this category is to be considered evidence that the region is topographically young.

### WAVES AND SHORE CURRENTS

During the existence of Lake Chicago, three definite levels occurred, each maintained long enough for waves and shore currents to cut cliffs and, to an even greater extent, to build bars, beaches, and spits. These old shorelines record lake levels approximately 20, 40, and 60 feet above Lake Michigan today. An interesting history is recorded in them, which is more fully treated in a later chapter. The wave and current work during these three stages was much like that going on along Lake Michi-

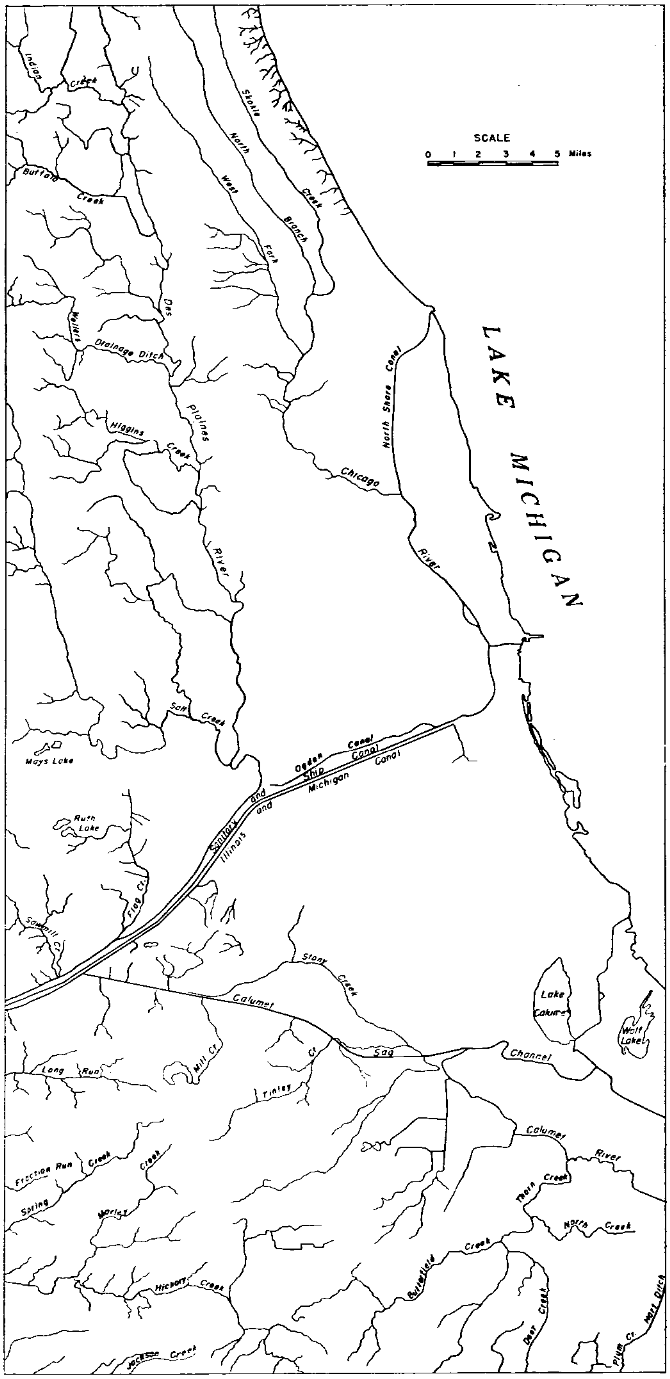



FIG. 3.—Drainage map of the Chicago region, including lakes, canals, and the larger ditches and temporary streams.

gan today: shore erosion in places decreased the land area, while deposition along the shore in other places added to it. As noted above, there was bottom erosion also.

### WINDS

Wave work is the consequence of wind acting through an intermediary agent, but wind also makes topographic changes directly. This is best shown in ancient dunes which closely parallel old shores where sand blown back from those shores lodged and accumulated. To a very limited extent, winds have done the same thing along present shores, but man has largely obliterated them in adapting the coastal stretch to his own purposes. East of Gary, Ind., however, dune growth along the present shore has produced many square miles of wild and attractive country. Indiana has a state park of about three square miles in these dunes, fifteen miles from Gary. Many other tracts in this dune belt are summer home incorporations, resorts, and picnic places well known to Chicagoans.

## DRAINAGE

A drainage map of Chicagoland, showing every temporary streamway however slightly incised, nevertheless has large blank areas. Much of the moraine country still has its constructional slopes and no integrated drainage ways. Most of the old lake bottom is untouched by running water simply because water does not run on its flat surface. To get adequate gradient for storm and sanitary sewers, the Sanitary District of Chicago has had to provide 14 pumping stations, where the total discharge of trunk sewers is lifted an average of 15.3 feet,[3] and started again at the higher level on a gravity flow toward the drainage canals. Many hundreds of undrained tracts in the uplands are still occupied by swamps and some by lakes. Larger swamps covered tracts of low, flat plain when the city was young, disappearing as man has ditched, sewered, and filled for the needs of a metropolis.

[3]The smallest lift is 5.3 feet, the largest is 36 feet.

### RIVERS

Before the natural drainage was interfered with, there were three rivers in the region. The Chicago and Calumet rivers flowed sluggishly in shallow channels across the eastern flat to Lake Michigan. It would be a misnomer to call these channels valleys. The DesPlaines River, with a better gradient, flowed southward from the northern morainic tract onto the same flat but then turned westward to enter a deep valley and cross a high part of the western morainic country. Joining the Kankakee River west of Joliet, the two formed the Illinois River, one of the Mississippi's large affluents. The divide between the Chicago and DesPlaines rivers was only a few miles wide and so low that a continuous swampy tract connected the two streams. During the epoch of exploration, Marquette, Tonti, Joliet, LaSalle, and others were able in wet seasons to travel by canoe, without portaging, between the Great Lakes and the Mississippi River by way of this swamp.

The three rivers still exist but their routings have been greatly modified. Three drainage canals have been cut across the divide. The earliest one, the Illinois and Michigan Canal, has long been abandoned. The largest one, the Chicago Sanitary and Ship Canal, takes the discharge of the Chicago River westward along the site of the swamp above noted and pours it, with considerable added water from Lake Michigan, into the DesPlaines River at Lockport. A smaller one, the Calumet Sag Channel, takes the Calumet discharge in a similar fashion from the St. Lawrence drainage across another place on the low divide and adds it to the main canal at Sag Bridge village. Thus the natural drainage has all been shifted to the Mississippi. The former mouths of Chicago and Calumet rivers now are outlets from Lake Michigan, and a third has been constructed in Wilmette to supply the North Shore Channel, a canal feeder to add volume to the North Branch of the Chicago River. Besides these additions to the region's normal runoff, almost all the water consumed by the five and a half million people in metropolitan Chicago is pumped from the lake into the water mains and eventually finds its way westward along the drainage canals. To make room for the main canal, several miles of the DesPlaines course were shifted bodily to more favorable lateral positions. These new routes are marked "Diversion Channel" on the Sag Bridge, Palos Park, and Berwyn sheets.

### CHICAGO RIVER

The Chicago River consists chiefly of two branches, the North Branch and the South Branch, and the trunk stream below their junction is only a mile long to its mouth on the shore of Lake Michigan. The North Branch has two tributaries, the West Fork and Skokie River. All flow southward for miles subparallel to the lake shore, finding their way along sags that separate various moraines and old beach accumulations which are themselves elongated subparallel to the shore. In other words, the valleys occupied by these streams are largely inherited from earlier conditions and are not the erosional consequences of these streams. More than half the total length of the North Branch streams is on the lake plain where the gradient is about two feet to the mile. In the moraine country to the north, gradients are about half again as great.

The South Branch of the Chicago River originally headed in the swampy divide and flowed northeastward. This stream has been dredged and its flow reversed, so that Lake Michigan water now discharges southwestward along the trunk to the junction of the two branches and thence along the South Branch into the Chicago Sanitary and Ship Canal, eventually entering the DesPlaines River at Lockport. Thus North Branch water now flows "up" the South Branch to reach the Mississippi drainage system.

### CALUMET RIVER

There are two Calumet rivers also, the Little and the Grand Calumet. They bring Indiana runoff westward into Illinois and join about a mile south of Calumet Lake on the quadrangle of the same name. The trunk stream continues northward 7 1/2 miles to Lake Michigan at South Chicago. Like the North Branch streams, and for the same reason, the two Calumets are subparallel to the lake shore. The Little Calumet, southern and longer of the two, originally flowed westward almost to Blue Island, there turned right, and flowed back essentially in the direction from which it had come. Before 1870, it flowed all the way back into Indiana, entering the lake near Miller, east of Gary. There was then no trunk channel northward to South Chicago, no differentiation into two streams. Instead, what is styled the Grand Calumet was only the lower portion of the Little Calumet, its water flowing eastward, backtracking nearly 25 miles from Blue Island to reach the lake. So sluggish was this stream that beach and dune deposits actually were blocking its entrance into the lake in 1870. Earlier maps show an open mouth at Miller. Nearly coincident with this blocking was the opening of an artificial channel from the lake shore at South Chicago to Calumet Lake. This channel became the trunk of the two Calumets, with the flow of Grand Calumet reversed. Obviously, such reversals as this and as that of the South Branch of the Chicago River are possible only in very low-gradient streams.

The Calumet Sag Channel was opened in 1922. It taps the Little Calumet in the abrupt bend at Blue Island, leads all Calumet water westward, and thus reverses the flow between Blue Island and South Chicago. The Mississippi–St. Lawrence divide in the latitude of Blue Island was shifted about 50 miles farther east by this change, as far as LaPorte County, Ind.

Another diversion of Calumet River has been made a little west of the Indiana Dunes State Park. Burns Ditch, across the barrier of dunes, carries all Calumet discharge from the east directly to the lake and reverses the river for a few miles west of the head of the ditch. The river has been "beheaded" by this canal. It is an artificial stream piracy.

Below Lockport, where the combined discharge of the Calumet Sag and the Sanitary and Ship canals enters the DesPlaines River, it has been augmented by the total discharge of the Chicago system and all of the Calumet system west of Burns Ditch, plus the discharge from Lake Michigan through the three artificial outlets, as well as the pumpage from all crib intakes into the Chicago city water mains. The total westward discharge allowed since 1938 by the War Department, from Lake Michigan and its former tributaries, the Chicago and Calumet rivers, is 1500 cubic feet per second.

#### DESPLAINES RIVER

Heading 40 miles north of the Illinois–Wisconsin state line, the DesPlaines River flows southward subparallel to the lake shore as far as Lyons, on the Berwyn quadrangle. There it turns southwestward and so continues across the Sag Bridge quadrangle to leave the Chicago region at Lemont. Near Lockport, 9 1/2 miles from Lemont, it receives the discharge of the Sanitary and Ship Canal, which here falls about 39 feet through penstocks. This is the only hydroelectric plant utilizing Chicagoland drainage. About 17 1/2 miles farther downstream is the junction of the DesPlaines and Kankakee rivers, their confluence forming Illinois River, the longest and largest stream in the state.

### Minor Streams

A few perennial streams drain from the uplands of the Chicago region into the DesPlaines and Calumet rivers. Thorn Creek enters south of Calumet City from the south side of the Little Calumet. Thorn Creek has three named tributaries, Deer Creek and Butterfield Creek, which join it at Glenwood, and North Creek, which enters it half a mile south of Thornton. Tinley Creek enters the Calumet Sag Channel near Alsip, and Mill Creek joins it near Palos Park. On the west side of the DesPlaines River, Indian Creek enters at Half Day, Buffalo Creek at Wheeling, Higgins Creek and Willow Creek near Orchard Place, Salt Creek at Riverside, Flag Creek at Tiedtville, and Sawmill Creek between Lemont and Sag Bridge. Four other named streams, all in the southwestern part of the region, flow into the DesPlaines from the Chicago region, but they enter it west of Chicagoland; all drain from the east side of the river. They are Long Run, Fraction Run, Spring Creek, and Hickory Creek with its tributary Marley Creek. Farthest to the southwest is the head of Jackson Branch, the only stream of the region to enter the Kankakee River.

Unnamed streams are more numerous but are largely temporary, their water courses indicated on the maps by interrupted blue lines. Some are vigorously eroding streams, though most of them have had too small a volume and too low an original gradient to cause much stream erosion. On the Highland Park sheet 18 small streams are indicated as mouthing along the lake shore,[4] and many of them have several tributaries. Only one is more than a mile long. All head on the eastern part of the crest of the Highland Park moraine at altitudes of 650 to 685 feet. Gradients of 100 feet to the mile are common. This is an enormous figure when compared with the gradient of Skokie River—3 feet per mile—immediately west of and paralleling the moraine ridge. With such favorable gradients, these small-volume, temporary, wet-weather streams have been able to cut steep-sided ravines 50 to 60 feet deep. The low gradient of the Skokie was an inherited slope, and the stream, despite its perennial character, has been unable to erode more than a channel for itself.

Another region of youthful, vigorously expressed ravines is found on the Sag Bridge and Palos Park quadrangles, where high gradients were provided by the steep bluffs of DesPlaines and Sag valleys that were cut across the western morainic upland. These river bluffs are 75 to 100 feet high, comparable to the coastal bluffs above described. Ravine development, however, is considerably less than on the Highland Park quadrangle. There are two reasons for this. At the North Shore ravines, waves and shore currents have constantly carried away the detritus brought down by the streams; hence gradients at the mouths have never been decreased by stream deposition. In contrast, neither Sag Valley nor DesPlaines Valley has been used, during

[4] By using contour groups that show ravine forms instead of the interrupted blue lines, 29 can be counted.

ravine growth, by main streams adequate to remove such detritus. Consequently, every ravine is likely to show an alluvial fan deposit on the flat floor of the larger valley, the effect of which has been to check the deepening, if not actually to cause some filling in the lowermost portion of the ravine.

The second reason is that in the North Shore district, waves have been driving the cliff back by undercutting while the ravines have been growing. This has shortened ravines at their lower ends and consequently has actually steepened the original gradients on which they started to grow.

## Submerged Portion of the Chicago Plain

The Chicago plain is clearly emerged lake bottom and records a former submergence of about 60 feet maximum. If this plain was fashioned largely by subaqueous processes in the geologically recent past, one may inquire if a similar plain now underlies the marginal portion of Lake Michigan. The question is answered affirmatively by an inspection of the numerous soundings on the two 1926 Chicago Lake Front charts of the United States Lake Survey. Con-

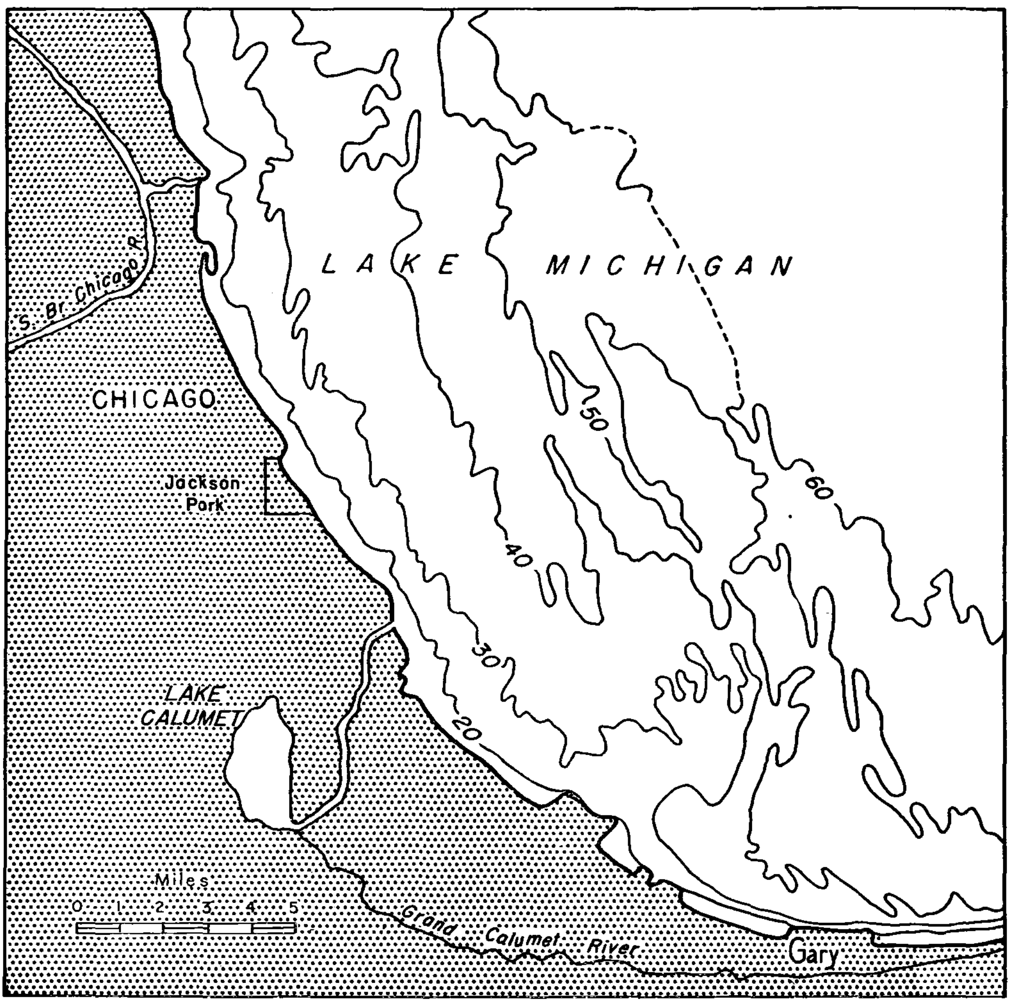



FIG. 4.—Contour map of a portion of the lake bottom in the Chicago region. After Hough. Depth of water in feet.

tours drawn by Hough[5] for these soundings show a slope as gentle as that now exposed which continues out under the lake for about 10 miles to a depth of 60 feet. Beyond the limits of Hough's map, the Lake Survey's Coast Chart 75, 1939, shows that the bottom slopes gently out into the lake for another 10 miles, its gradient being scarcely half again as great as on Hough's map or on the landward plain. Therefore, the Chicago plain may be visualized as continuing under Lake Michigan for 20 miles offshore at much the same slope as its land portion. The procedures by which this partly emerged, partly submerged plain has been formed will be discussed later in this report.

### Lake Levels

The earlier stages of standing water in the Lake Michigan basin, during some of which almost the whole of the Chicago plain was submerged, will be dealt with more fully later. Since there is no lowering in water surface through Mackinac Strait, the present Lake Michigan stage is determined by the level of the outlet of Lake Huron. Were the St. Clair River outlet to become deepened, the lake surface would lower; were it to be dammed, the surface would rise.

Yet with no change in location, altitude, or capacity of this outlet, the level of Lake Michigan varies. The United States Geological Survey's first topographic survey of Chicago, dated in the 1890's, bears the figure 581 printed on the lake surface. The second survey, whose maps are used for this report, carries the statement, "Mean elevation of lake surface in 1926 578 feet above sea level." In January 1926, the lake surface actually stood as low as 577.35, the lowest since observations began in 1835. In 1838 it had stood at 584.69, the highest on record in a century of observation. The total measured range of lake level thus is 7.34 feet. Based on these dates and figures alone, there seems to have been a startling decline in volume of the lake. The problem is not that simple, however.

[5]Hough, J. L., The bottom deposits of southern Lake Michigan: Jour. Sedimentary Petrology, vol. 5, no. 2, pp. 57-80, 1935.

Measurements during the past century show that there is an annual fluctuation of about 1 foot in lake level, the high coming in late summer, the low in midwinter. Seasonal variations in snowfall, snow melting, rainfall, and evaporation are held accountable for this one-foot annual range.

A larger cycle of about 11 years, with a larger range in levels, is recognized[6] and has been correlated with the sunspot cycle of that duration.[7] Sunspot minima and maxima are already known to affect terrestrial weather, producing corresponding extremes in rainfall and evaporation. When the algebraic sum of the annual cycle is plus, the annual mean lake level is rising; when it is minus, the mean level is lowering. The range in level throughout the 11-year cycle is not a constant value. Reading from highest summer to lowest winter level in each cycle, the range has varied from 2 3/4 to nearly 5 feet. The most marked change on record came immediately after the making of the topographic maps used in this report. By 1929, the level of Michigan (and Huron) had risen almost 5 feet from the all-time low of 577.35 in 1926.

The solar cycles themselves are variable, and there may be larger rhythms in their succession than we have yet detected which may become apparent in the next few centuries. They have been occurring in the postglacial, prehistoric past.

Stability of lake levels within the limits of the annual range is highly desirable. The high water of 1929 lifted storm waves and floating ice high against harbor and shore structures and against vulnerable seacliffs, which caused damage amounting to millions of dollars. Wood[8] argued convincingly that forecasting the larger fluctuations is within the ability of modern science, and

[6]Musham, H. A., Rhythmic fluctuations of the levels of the Great Lakes: Western Soc. Eng. Jour., vol. 48, pp. 185-196, 1943. Musham reported that an intermediate low level has occurred 7-8 years after a maximum high and has been succeeded by an intermediate high within about 3 years. The minimum low has occurred 11-12 years after the maximum high. Then between the minimum low and the next maximum high, there has been another intermediate high, 15 years after the beginning of the cycle, and another intermediate low, 18-19 years after the beginning of the cycle. This compound rhythm is found in the accurate records since 1855. It has been repeated three times between 1855 and 1930.

[7]Wood, Sidney M., The cycles of the Great Lakes: Bull. Assoc. State Eng. Socs., Oct. 1936.

[8]Ibid.

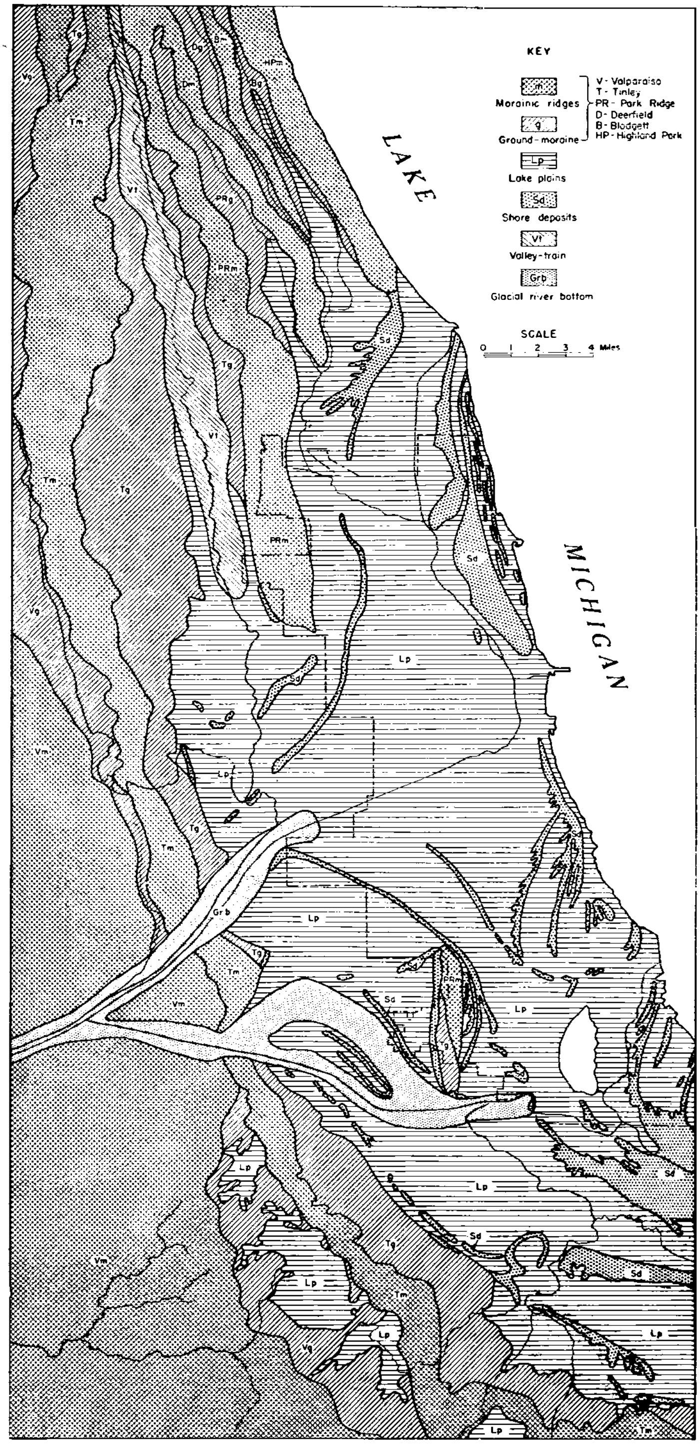



FIG. 5.—Distribution of topographic features of the Chicago region.

that controlling works at the outlet, guided by the forecasts, can give that stability.

## TOPOGRAPHIC FEATURES

The major topographic features of the Chicago region can be grouped under four categories: (1) the morainic uplands to the north, west, and south, (2) the lake plain partially enclosed by these uplands, (3) the shore features of Lake Chicago and its successor, Lake Michigan, and (4) the stream-occupied valleys, some inherited from the glacial topography, some eroded by streams working largely in glacial drift, though locally in bedrock.

### Uplands

*Moraine ridges.*—Generally the ridges are not readily recognized in views across the region. Rarely do the moraines have definite linear crests or marked lateral slopes. Instead, each is more like an elongated series of partially coalesced and overlapping hills. The elongation becomes clear on a map, where many miles of country can be seen at once. The elongated moraines might be thought of as belts of upland rather than ridges. The abundance of undrained depressions on them testify to the immaturity of their drainage.

There are six separate mappable units in this category, all traceable across the region's boundaries into adjacent country. Orientation of these linear moraine tracts is dominantly northwest by north, southeast by south. In the southern quadrangles, the orientation is northwest-southeast and well into the southeastern corner of the region; the one moraine present trends approximately east-west. These orientations are definite records of the shape of the glacial front and are successively younger from west to east. Two of them were built before the recorded beginning of Lake Chicago, and four are contemporaneous with the early history of that glacial lake.

Separating these marginal moraines are similarly elongated lower tracts of ground-moraine, across which the ice front retreated more rapidly than it did across the moraine ridges, hence deposited less drift. One glacier-born river utilized such a ground-moraine belt. Postglacial drainage has followed some of them, giving rise to the various tributaries of the North Branch of Chicago River, to the DesPlaines River upstream from Lyons, to Salt Creek, and to Flag Creek.

*Valparaiso morainic system.*—The Valparaiso moraine is the widest of the six, and therefore the least ridgelike. Its full width does not come within the region; its frontal edge lies on the Joliet and Wheaton quadrangles to the west. Its irregular inner margin is traceable from an intersection of the region's western boundary 2 or 3 miles west of Elmhurst southeast by south to an intersection of the southern boundary 2 or 3 miles south of Matteson. The Valparaiso moraine constitutes most of the western uplands and contains the highest parts of the entire region. There is more relief and more rough country in this moraine than in any of the others, though the relief and roughness are not wholly due to the moraine itself. The moraine's relief, caused by unequal deposition of the Valparaiso glacial drift, rarely exceeds 50 feet. An older topography buried beneath the Valparaiso drift sheet, and reflected in its surface irregularities, has locally twice as great relief.

Three named lakes, two named sloughs, and a large number of unnamed marshes and swamps lie in the abundant undrained depressions that so commonly typify morainic topography. Some of the deeper depressions appear to be parts of pre-moraine stream valleys that became blocked but not obliterated by the Valparaiso drift deposits. Two stream-made valleys cross the moraine —that of the DesPlaines River and of Hickory Creek. Both are parts of the pre-moraine buried relief, resuming their original function after the Valparaiso ice disappeared.

The suburban towns of Lombard, Hinsdale, Clarendon Hills, Westmont, Downers Grove, and Orland Park are wholly within the moraine boundaries. Villa Park is partly on the marginal moraine and partly on ground moraine immediately to the east. Salt Creek as far downstream as Western

Springs and Flag Creek for its entire length are on the Valparaiso ground moraine.

*Tinley moraine.*—East of the Valparaiso moraine is the Tinley moraine, with the greatest length in the region of any of the six moraines. It extends from the northern boundary, a mile east of Mundelein, southeast by south to Chicago Heights, where its course becomes nearly east-west as it is crossed by the southern boundary. Its total length on the nine quadrangles in the region is 60 miles. The Tinley moraine is much narrower than the Valparaiso, its greatest width in the region being 5 miles, its average width about 2 miles. In the vicinity of Tinley Park, it has an unusually marked western front that rises 25 feet above the flat left by one of the four glacial lakes already noted. It has its greatest relief, about 60 feet, in the Mount Forest Island region (Palos Park quadrangle). This may be a composite of the Tinley's own relief superimposed on an older relief beneath, as is the case with the Valparaiso moraine.

Undrained depressions, many containing swamps and lakelets, are well distributed but most numerous on the Palos Park and Tinley Park quadrangles where the moraine is roughest. The moraine is transected by two major valleys, the westward-draining DesPlaines and Sag valleys. It is also crossed, in the opposite direction, by eight creeks along its 60-mile length. The two major valleys are older than the moraine; the creek valleys are all younger. North of the latitude of LaGrange, Salt Creek closely margins the western or frontal edge of the Tinley moraine, and the DesPlaines River parallels it on the east. Both stream courses, along ground-moraine sags, are consequent on the constructional topography left by the retreating ice sheet.

On the Palos Park quadrangle, the Tinley marginal moraine overlaps the back slope of the Valparaiso, there being no Valparaiso ground moraine of gentler slopes and lower relief between. The Valparaiso ground moraine is widest on the Tinley Park quadrangle, next to the south, attaining here a width of 5 miles in the region of the largest of the four extinct glacial lakes.

The suburban towns of Arlington Heights, Elmhurst, Western Springs, Palos Park, and Matteson are built on the Tinley moraine. The western part of LaGrange and the southern part of Chicago Heights also stand on the Tinley. Half Day, DesPlaines, Bensenville, Hillside, most of LaGrange, Oak Forest, Homewood, Flossmoor, and most of Chicago Heights are on lower ground moraine belonging to the Tinley stage.

*Lake Border moraines.*—East of the DesPlaines Valley in the northern half of the region, four moraines project southward from the northern boundary. Known collectively as the Lake Border morainic system, they constitute the northern morainic upland. All of them die out on reaching the lake plain, the westernmost and longest reaching scarcely 25 miles into the region. This dying away is only an interruption, for the system is found again in Indiana and is traceable thence northeastward and northward into Michigan, thus describing a great curve closely conforming to the margin of the lake.

In order from west to east, these moraines are the Park Ridge, the Deerfield, the Blodgett, and the Highland Park.[9] On the Waukegan quadrangle, immediately north of the Chicago region, the sags separating them are less prominent, and recognition of all four units is difficult.

The total width of the system is about 6 miles, the three ground-moraine sags making up nearly half of that width. The morainic character of the system is very mildly expressed, and the contacts of ground moraine east of a marginal morainic ridge are difficult to determine. The steeper frontal slopes of the broad, low moraines, however, are readily recognizable on the topographic maps from the habitual closer grouping of contours.

In the south where the floors of the ground-moraine sags become lower, they were occupied by long narrow bays of Lake Chicago's highest stage, and today they all carry southward the consequent drainage of the North Branch of the Chicago River.

The easternmost, or Highland Park, moraine was built higher than any of the

[9]Names first published in Bull. 65, Part I, pp. 55-56, 1939.

other three. Its frontal slope rises from 25 to 40 feet in the steepest constructional slopes to be found among these Lake Border moraines. Its summit in several places stands 50 to 60 feet above the Skokie Valley to the west and more than 100 feet above Lake Michigan to the east.

Previously noted is the continuous sea-cliff facing the lake from Kenilworth northward to and beyond the boundary of the region. Except for the southernmost 2 miles, this cliff everywhere is cut in the eastern slope of the Highland Park moraine. Retreat of the cliff has been in progress ever since the early stages of Lake Chicago. The back slope of the Highland Park moraine thus differs markedly from that of any other moraine of the region.

Numerous suburban towns of the North Shore residential district have grown up on these moraines, and some of them have spread their corporate limits down onto ground moraine or lake bottom. Four towns provide names for the four ridges. Norwood Park and Elmwood Park stand largely on the Park Ridge moraine; Northbrook on the Deerfield; and Winnetka, Hubbard Woods, Glencoe, Highland Park, Ravinia, Highwood, Fort Sheridan, and Lake Forest on the Highland Park moraine. The Blodgett moraine, smallest of the four, carries overlapping portions of Lake Forest and Highland Park in addition to the town for which it was named.

### The Lake Plain

Nearly half of the land area of the region is the plain which Lake Chicago left when its level was lowered to that of Lake Michigan. It is rudely crescent shaped, with convexity toward the west. Northward it is terminated by the Lake Border moraines; eastward, it continues into Indiana between the Tinley moraine and Lake Michigan, the Lake Border moraines being absent here. The southward projections of these moraines into the plain suggest long narrow peninsulas, as indeed they once were. Elsewhere, the outline of the plain is simple. The convex western margin is highest, its concave eastern edge is lowest and descends beneath Lake Michigan. Across the crescent is a low place reaching from Lake Michigan to the western moraine uplands. In this was the swampy divide between the Chicago River and the DesPlaines River.

Many square miles of this plain appear perfectly level to the eye. Such irregularities as exist are islands of the glacial lake, or shore features of the three successive stages, or postglacial stream valleys and channels. One other feature of the plains, easily overlooked in the field or on the topographic map, is a series of faintly shown steps descending from the convex to the concave side. The "risers" in these steps are low wave-cut cliffs, some of which are masked by beach sand and gravel ridges. The risers then are shorelines of the stages of the glacial lake. Of two "treads" separated by a riser, the lower one was eroded under water by the drag of the waves which, on reaching the shoreline, cut the riser. More will be said on this subject later.

The largest of the islands of Lake Chicago now standing out in the plain is Blue Island, on the quadrangle of that name. It is elongated north-south, is 5 1/2 miles long, and a little more than 1 mile wide. It is essentially a portion of the Park Ridge moraine, isolated on the plain about 13 miles south of the southern tip of this moraine. It rose as much as 30 feet above the highest level of the lake. Its eastern side is a sea cliff, easily recognized in the residential sections of Beverly Hills and Morgan Park. Its western side is a row of sand dunes, marked now by several cemeteries and country clubs. The business and residential portions of the city of Blue Island stand on the southern tip of this "island."

### Shore Features of Lake Chicago

Accompanying maps (figs. 5, 52, 53, 54, and 57) show many elongated beach ridges subparallel with the outer and inner margins of the crescentic plain. Classified by their altitudes, there are three groups of them, the two uppermost belonging to the Lake Chicago stages (the Glenwood, highest and oldest, and the Calumet, intermediate) and the lowest including Toleston (lowest) with beach deposits made by the later Lake Algonquin and Nipissing Great

Lakes stages, which rose to the Toleston level. The vertical interval between any adjacent two of these is approximately 20 feet; the horizontal spacing is highly variable. Throughout the Chicago region and as far north as Milwaukee, these old shorelines are as horizontal as when they were first built. There has been no warping of this part of the Great Lakes country in all postglacial time.

Though some of these tracts of beach sand and gravel are more than a mile wide, linear elongation along the old shore is still evident. The term *beach* is here used to include all deposits along the shore in wave- and current-agitated water. Specifically these linear deposits are made up of beach ridges built on the land at the water's edge, bars built somewhat offshore at the line of breakers, and spits built out at low angles from the land where the shoreline receded somewhat in a bay. The more conspicuous and easily identifiable spits occur: (1) near or in part of Wilmette (Park Ridge and Evanston quadrangles), (2) in Evanston and the northern part of Chicago (Evanston and Chicago Loop quadrangles), (3) in Oak Park and River Forest (River Forest and Berwyn quadrangles), (4) north of LaGrange Park (Hinsdale and Berwyn quadrangles), (5) in Berwyn and Riverside (Berwyn quadrangle), (6) north of Evergreen Park (Blue Island quadrangle), and (7) between Thornton and Lansing and east of East Chicago Heights (Calumet City quadrangle). Only where dunes have grown up on the beach deposits do they possess any marked relief. In built-up portions of Chicago, many of the more weakly expressed features have almost disappeared.

The noteworthy dune tracts contemporaneous with the Lake Chicago beaches are: (1) on the Wilmette spit (Evanston quadrangle), (2) on the west shore of Blue Island (Blue Island quadrangle), (3) between Homewood and Thornton (Harvey quadrangle), (4) between Dolton and Hammond (Calumet City quadrangle), and (5) east of Dyer (Dyer quadrangle). The highest dunes are on the west side of Blue Island, near the north end of that belt, where their summits stand 30 feet above the adjacent lake plain.

Another subcategory of the Lake Chicago shore features is the group of cut shorelines, the ancient sea cliffs where waves and currents eroded instead of depositing. They alternate with depositional shores along each of the three shorelines and range in height from those that are just recognizable to 20 or 30 feet. The most marked of these cutbank shores are: (1) in Winnetka (Evanston quadrangle), (2) in Riis Park and the Galewood district (River Forest quadrangle), (3) in Beverly Hills and Morgan Park (Blue Island quadrangle), (4) in Kensington and Roseland (Calumet Lake quadrangle), (5) between Homewood and Hazelcrest (Harvey quadrangle), and (6) between North Creek and Deer Creek, southeast of Glenwood (Calumet City quadrangle). Where feebly developed and constituting only what are here termed "risers" in the plain, they can be identified within the city in many places only by the occurrence of a grade, perhaps half a block long, interrupting the long level stretches characteristic of Chicago streets.

## Valleys

As already outlined, the region possesses two types of free-draining valleys. One type was made during the moraine-building and the beach-building, the streams in possession today having done little to modify their inherited courses. The other type of valley is the product of stream erosion, the courses reflecting earlier slopes that determined the routes they follow now.

### CONSTRUCTIONAL VALLEYS

Valleys of this type are most numerous, and most easily recognized as such, in the northern half of the region. The larger ones drain to the south and belong to the Chicago River and DesPlaines River systems.

*Salt Creek Valley.*—Flowing on Valparaiso ground moraine and closely hugging the front of the Tinley moraine, Salt Creek flows southward for 16 miles (20 miles if measured on the meanders of the channel), on the Arlington Heights, Elmhurst, and Hinsdale quadrangles, to the northern boundary of the town of Hinsdale. Here it turns eastward for 2 miles to cross the Tinley moraine and enter the lake plain, northward for 1 1/2 miles to go around the northern tip of the LaGrange spit, and southeastward to join the DesPlaines. The Hinsdale and Sag Bridge topographic maps show that where the creek turns east, it leaves the morainic sag, and that farther south Flag Creek occupies this same sag. A cursory inspection suggests that Salt Creek once did not cross the Tinley moraine but continued all the way southward along what is now Flag Creek Valley. Field data, however, prove that the marshy floor at the head of Flag Creek separating Hinsdale and Western Springs has never been used by Salt Creek and is a fair sample of what all these constructional valleys would be like if no streams had ever utilized them.

In the north-central part of the Hinsdale quadrangle is an "island" tract of somewhat more than a square mile, separated from surrounding Valparaiso morainic surfaces by Salt Creek Valley on the north and east and by a marshy valley without through drainage on the northwest and south. It is almost as low as Salt Creek Valley, with which it connects at each end of its irregularly semicircular course. An attractive explanation for it is that an early Salt Creek flowed through it when the present course was blocked by the ice front retreating down the back slope of the Valparaiso moraine. But there are morainic spurs projecting into the marshy flat in a fashion that stream erosion never could produce or tolerate. This marshy valley never was eroded by Salt Creek drainage, either during glacial retreat or subsequently, and must be interpreted either as a morainic sag or as the trace of a pre-Valparaiso valley not entirely obliterated by the moraine deposits.

Salt Creek, above its crossing of the Tinley moraine, has a gradient of only 2 1/2 feet to the mile and is the most markedly meandering stream of the region, though the outline of its valley floor shows little effective widening by meander undercutting of the sides.

*Flag Creek Valley.*—This creek (Hinsdale quadrangle) heads in an elongated tract of "basin fill," a former closed depression now obliterated by deposits of surface wash and organic material. The fill, 1 1/2 miles long, occupies the broadest place in the valley, six times as wide as at the crossing of Joliet and Wolf roads 1 3/4 miles farther south. This downstream narrowing also has the highest (50 to 60 feet) and steepest bluffs of any place along Flag Creek, facts consonant only with the interpretation above offered.

On entering the Sag Bridge quadrangle, the valley ends, but the stream continues past Tiedtville along the west side of the DesPlaines transmorainic valley. From the basin at the head, the creek descends 55 feet to the DesPlaines, a gradient of 8 feet to the mile. Had Salt Creek ever used Flag Creek Valley, it would assuredly have eroded sufficiently on this gradient to trench across the site of the basin fill.

*DesPlaines Valley north of Lyons.*—The DesPlaines River heads almost on the Racine–Kenosha county line in Wisconsin, 40 miles north of the northern boundary of the Chicago region. In this region it crosses the Wheeling, Arlington Heights, Park Ridge, River Forest, Berwyn, Palos Park, and Sag Bridge quadrangles. Except for one place on the Silver Lake quadrangle, Wis., its entire course south to Lyons is determined by ground-moraine sags. For most of its length, it flows on Tinley ground moraine and fairly close to the front of the Park Ridge moraine. Its gradient upstream from bedrock outcrops in its channel at Lyons is 1 1/3 feet per mile.

The valley floor from River Grove northward almost to the Wisconsin line, if not farther, possesses a fill of gravel and sand overlying the ground moraine and containing the present river channel. This is a valley train, deposited by a river of meltwater fed from the waning ice front during the earliest of the Lake Border stages. The glacial DesPlaines was far larger than the stream of today, for the valley fill is a stream-bed deposit 1 1/2 miles wide for long stretches. Gravel bars standing 5 to 10 feet above the surface of this valley bottom fill are part of the glacial-stream deposit and indicate that in the heavy melting of summertime, this channel was full for the entire width and as deep as the bars are high. The maximum known depth of the fill is 15 feet, with the bottom not reached. The gradient of the plane surface of the fill is from 1 1/2 to 2 feet per mile. Into it, the postglacial river has eroded an inner valley, rarely more than 10 feet deep or more than a quarter of a mile wide.

The southern portion of the valley train terminates where the glacial river entered Lake Chicago. The present river continues beyond this for 8 miles across emerged lake-bottom beyond River Grove as far as Lyons.

Much of the riparian land along the Des-Plaines in Cook County above Lyons has been acquired by the Forest Preserve, and several dams have been built to retain sufficient water during low summer stages for recreational purposes.

At Lyons the DesPlaines has encountered two high places in the buried bedrock but has not eroded more than 5 feet into the limestone. A dam at Riverside makes it impossible now to figure the original gradient of the stream surface at this place. Below the dam, the stream descends 10 feet in 1 1/2 miles to the next bedrock portion of the channel. This is the steepest gradient in any portion of any major stream of the region.

*Valley of West Fork North Branch, Chicago River.*—The ground-moraine sag between the Park Ridge and Deerfield moraines (Wheeling, Highland Park, and Park Ridge quadrangles), determines the course of this stream, and in its southern portion it determines also one of the long, narrow bays of Lake Chicago. The West Fork therefore flows southward on ground moraine for 8 miles to Northbrook and on lake bottom for the next 6 miles to its junction with the North Branch at the southern tip of the Deerfield moraine. For its size it has a relatively low gradient, 4 feet per mile. Considerable stretches have been ditched to improve the drainage of the valley bottom. Only in the last 3 miles has the West Fork done anything to make a stream valley in the bottom of the morainic sag. At the junction with the North Fork, this minor valley is 10 feet deep.

*Valley of North Branch, Chicago River.*—North of Northfield (Wheeling and Highland Park quadrangles), this valley is confined between the Deerfield and Blodgett moraines, most of its length having a ground-moraine floor. The Blodgett moraine ends in the northern part of the Northfield corporate limits, projecting southward here as a small peninsula into the fingered northern margin of the lake plain. The valley from there to its junction with the South Branch, in the heart of Chicago, is entirely stream-made. The course bends back from the lake a little to go past the Wilmette spit and then turns east toward the lake, only to be forced to go 7 miles farther south to get around the two spits in Evanston and in the northern part of Chicago. Erosion by this stream in the lake plain is most marked in the northeastern part of the River Forest quadrangle where the Calumet or intermediate shoreline is crossed and the stream descends across a "riser" between two "treads" of the plain. Although the valley is only 15 to 20 feet deep here, meandering has made a floodplain. Some of the crenulate outlines of the floodplain are being enlarged today by meander undercutting of the bluffs; others obviously are abandoned meander scars. Across the lake plain, the river flows on a gradient of about 2 feet per mile. On the ground-moraine sag farther north, its gradient is about 3 feet to the mile.

*Valley of Skokie River.*—The sag between the Blodgett and Highland Park moraines (Highland Park quadrangle) was the lowest of this series of intermorainic valleys. It therefore contained the longest bay of Lake Chicago, and its present-day stream traverses only 4 miles of ground moraine within the region before reaching and flowing on lake bottom. On the ground-moraine floor, Skokie River has a gradient of 4 1/2 feet per mile, but on the bottom of the bay its gradient is scarcely more than 2 feet per mile. Much of the stream course in Lake County has been ditched, and in Cook County the Highland Park and Park Ridge sheets show a marsh 3 miles long into which the stream enters at the north end and from which it drains at the south end. Since the map was made, the marsh has been extensively altered by construction of lagoons and artificial hills to make a recreational area. Its existence when the geological map was made is convincing evidence of the stream's inability to trench into the lake plain.

The Lake Border moraines are so narrow and have so low a relief that no named tributaries to the streams discussed above have developed. Only the DesPlaines River possesses such tributaries, and they all drain from the Valparaiso and Tinley slopes. Excepting Salt Creek, all the named streams of this group (flowing in constructional valleys) have been ditched or possess swamps (or both) in parts of their courses. One such stream, entering the DesPlaines at the town of DesPlaines, is called Weller's Drainage Ditch on the Arlington Heights sheet. It flows southeastward down the back slope of the Tinley moraine and across Tinley ground moraine with a gradient of 10 feet per mile and was clearly a natural drainage line before ditching. Had it possessed adequate volume with this gradient, stream erosion would have made a definite valley.

*Calumet River Valley.*—Considered as a river valley, the original course of the Calumet River (Calumet City, Blue Island, and Calumet Lake quadrangles) is strikingly aberrant in its 180-degree turn near Blue Island from west to east, and its nearly 25-mile backtrack to the lake. It is only 2 1/4 miles southeast from this original mouth to the west-flowing portion in the southeastern part of Gary. The stream flows 50 additional miles to go around the belt of old dunes which constitute the 2 1/4 mile-wide barrier. The "valley" of the river for most of its length is nothing more than a linear belt of old lake bottom between rows of abandoned beach and dune ridges. The river has made nothing more than a channel for itself and has largely failed to drain the swampy lowland along much of its course. Lack of topographic maps covering the Indiana territory traversed by the river prohibits a statement of its gradient.

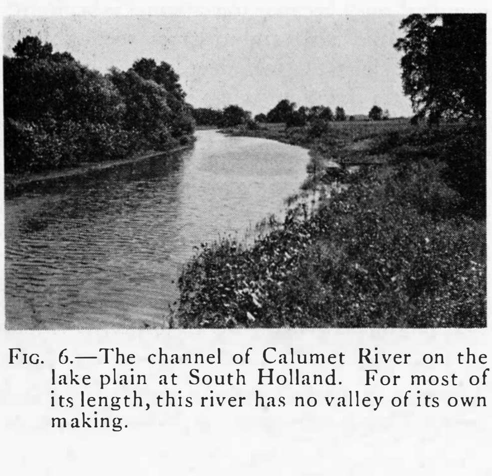


Fig. 6.—The channel of Calumet River on the lake plain at South Holland. For most of its length, this river has no valley of its own making.

### EROSIONAL VALLEYS

*DesPlaines Valley south and west of Lyons.*—At Lyons the DesPlaines River enters one of the two outlet channels of Lake Chicago and flows southwestward out of the region. Except for the first 3 miles of the course, the valley averages 75 feet in depth and is the transmorainic portion of the DesPlaines River. The rather complicated history of this valley, discussed more fully in a later chapter, began with trenching across a preglacial divide before the building of the Valparaiso and Tinley moraines—therefore during a somewhat earlier glaciation. Modified by Valparaiso and Tinley deposits, it nevertheless again became a river course, this time the outlet of Lake Chicago. A little later it carried discharge from glacially ponded water in the Superior, Huron, and Erie basins, as well as the Michigan basin. During the past century, man has considerably altered the valley floor by digging two canals, the Illinois and Michigan Canal of 1848 and the Sanitary and Ship Canal of 1900, and by diverting portions of the postglacial DesPlaines channel to make room for the later canal. Some suggestions of old channel routes are recorded in political boundaries shown on the Sag Bridge sheet. Irregularities in the line between DuPage and Cook counties and in that between Lyons and Palos townships of Cook County obviously were determined by the DesPlaines channel of the time. Some parts of these irregular boundaries now are considerably off the river course.

The gradient of the DesPlaines transmorainic valley, reflected in the gradient of the Sanitary and Ship Canal, is extraordinarily low. The canal water flows on a bottom slope of one in 40,000, or only 1 foot in almost 7 1/2 miles. Torrential rains over Chicago sometimes pour storm-sewer water into the South Branch much more rapidly than the current can carry it away down the canal. The river several times has reversed its flow under these conditions and polluted the lake with sewage. To help prevent such danger to the city's health, floodgates at Lockport (9 miles downstream from Lemont) are opened at such times and the canal surface lowered as much as 11 feet. This provides a surface gradient in the canal water greater than the bottom gradient. The flow can thus be increased fourfold, and the city's storm water is drained more promptly into the canal and away from the lake. Not even this was sufficient to the purpose, however, so the Sanitary District constructed locks at the mouth of the Chicago River which, when closed, allow no water to pass between river and lake.

One of the most extensive "made-land" tracts of the Chicago region extends along the Sanitary and Ship canal from the city's western boundary to Lemont. The long, narrow made-land units on the maps are spoil heaps from canal excavation. From Willow Springs to the western edge of the region, the Sanitary and Ship Canal has a bedrock floor throughout. In some places it has been cut for its full depth into rock—hence these long, narrow hills of limestone boulders along the DesPlaines transmorainic valley floor, utterly unlike river-made valley topography. Near Lemont, bedrock crops out extensively on the valley floor, and large quarrying operations there have added other made-land hills of waste rock.

The lower slopes of the valley walls at Lemont are of bedrock, rising to a maximum of 40 feet above the floor. This part of the valley is trenched in the summit of a preglacial divide.

Considerable coarse river gravel occurs in bars and rude terraces along the transmorainic stretch of the DesPlaines, and the bedrock surface in places is strikingly grooved and pitted with river-made potholes. Both these features are records of the large glacial river which drained portions of the glacial Great Lakes during part of their history. Other stream-washed gravel occurs in ridges and mounds on the northern valley wall. It was deposited during retreat of the Valparaiso ice and is, therefore, a little older than the glacial river gravel on the valley floor, though it is definitely younger than the valley.

*Sag Valley.*—One of the most prominent topographic features of the Chicago region is the large Y-shaped valley which crosses the western morainic uplands (Sag Bridge and Palos Park quadrangles). Viewed on the map (fig. 5), the Y lies on its side, the stem to the west, the tips of the two arms connecting with the lake plain on the east. The stem and northern arm constitute the DesPlaines transmorainic valley. The southern arm is Sag Valley, and that part of the upland between the converging arms is called Mount Forest Island.

The Sag Valley arm of the Y, although streamless, is very similar in proportions and in altitude of floor to the arm occupied by the DesPlaines River. As befits a trunk-valley below the junction of two confluents, the stem of the Y, west of Sag Bridge village, is a somewhat wider valley. The gradient of the Sag is too low to be read from successive contour crossings on the valley-floor. The Sanitary District's Calumet Sag Channel has a bottom gradient of 1 foot in 7 miles. The canal drains on this low gradient only because the channel is straight, smooth, and uniform in cross section; the water in it is 20 feet deep. Thus there is very little friction with walls or bottom and little internal friction from turbulence. Natural streams rarely develop so uniform a channel or so low a gradient. The Mississippi's lowest gradient is twice that of this drainage canal.

Sag Valley is clearly an abandoned stream-eroded feature and its magnitude bespeaks a large stream. To say that it is one of two converging outlet valleys for Lake Chicago is to tell only a part of its history. The lower part of its walls expose older drift in many places, locally as much as 50 feet thick beneath the Valparaiso drift. Yet the Tinley moraine descends almost to the bottom of Sag Valley and makes definite projections into it from each side. A ridge of gravel, deposited by meltwater in close association with the Valparaiso ice-front, extends down the southern wall to an altitude only 20 feet above the marsh on the bottom. Sag Valley, therefore, is pre-Valparaiso in origin, as is the DesPlaines Valley below Lyons and the valleys of Long Run, Spring Creek, Marley Creek, and Hickory Creek.

The Sag is a through valley, scarcely 5 miles long and more than half a mile wide at the bottom. It has no headwater, upland tributary system as do the creeks of this same subcategory. Sag Valley records a pre-Valparaiso, large-volume discharge from the Lake Michigan basin to the Mississippi.

There is more bedrock showing in the floor of the Sag arm than in that of the DesPlaines arm. Near Sag Bridge village the bedrock is exposed in several abandoned quarries and two active ones, and on the southern wall of the valley, bedrock crops out as much as 50 feet above the marshy floor. Into the bedrock of the southern wall, an unnamed tributary stream has cut a little canyon about 15 feet deep and 1100 feet long, the only completely rock-walled valley in Chicagoland. The Calumet Sag Channel has a rock bottom for the full length of the Sag Valley, in some places cut to a depth of 20 feet.

*Sawmill Creek Valley.*—This valley (Sag Bridge and Hinsdale quadrangles) drains into the deep DesPlaines transmorainic course entirely from Valparaiso moraine surfaces and is largely a product of stream erosion. From undrained swamps at its head, Sawmill Creek descends 135 feet to the DesPlaines valley floor 4 miles distant. Thirty-five feet of the descent is close to the bluffs of the large valley, where the gradient is about 60 feet to the mile. Above the 635-foot contour crossing, the gradient is less than half as steep. Figure 7 shows this graphically and contains information necessary to explain this unusual break in gradient. Briefly stated, the lower part of Sawmill Creek has undergone a domestic piracy by which its original course has been shortened half a mile. The abandoned part of the valley lies immediately west of the present mouth. By such shortening, the gradient at the new mouth was abruptly increased to something like that shown by the row of double dots in figure 7—almost as steep as the slope of the DesPlaines

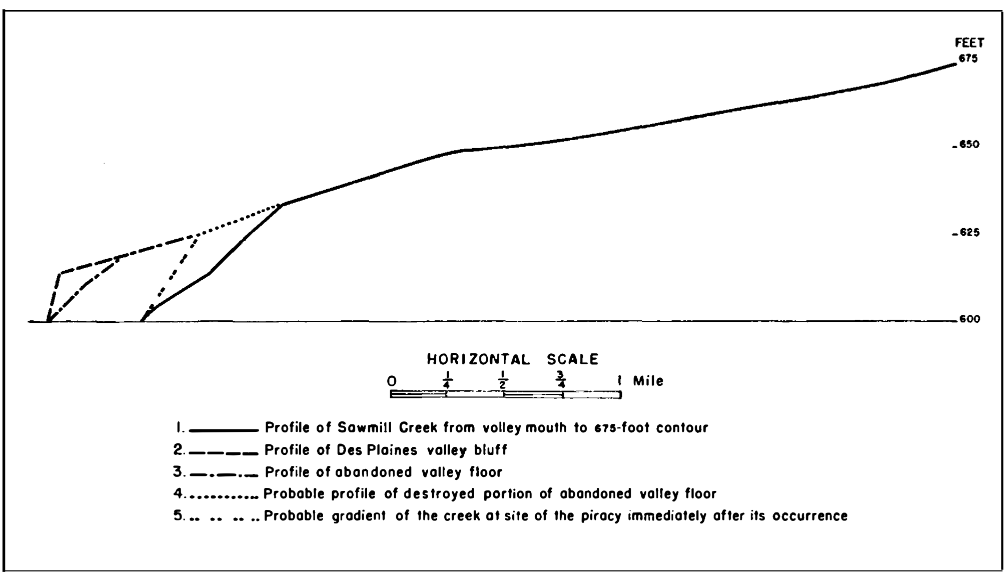



Fig. 7.—Profiles of Sawmill Creek.

bluff (the steeper part of the dashed line) over which the stream initially discharged. Upstream migration of the head of the steepened grade has carried the break in profile about twice as far back from the mouth as it was originally. The gentler gradient, which continues to the head of the creek, appears to have been determined by the moraine slopes. On this gradient, less than 12 feet to the mile, the creek has deepened its valley only a little but has widened the valley floor several times as much as in the steeper downstream portion.

The vigorous downcutting at the site of the piracy has exposed bedrock for 1200 feet along the stream channel. Most of the outcrop is simply channel floor, but in one place the creek has cut 5 feet into the thin-bedded limestone.

*Valleys on the frontal slope of the Valparaiso moraine.*—South of the DesPlaines transmorainic course, two valleys drain westward out of the region and are limited to the frontal slope of the wide Valparaiso moraine belt. From north to south, they are occupied by Long Run (Sag Bridge quadrangle) and Spring Creek (Mokena quadrangle). Both valleys in places are more than 75 feet deep. The streams in both have a relatively low gradient, 8 feet per mile for Long Run and 9 for Spring Creek. Both valleys have marked widenings and narrowings of the bottom flat, with marshy places and ditched watercourses in some of the widenings. The character of the narrowings, however, is the clue to the history of these valleys.

At each narrow place knolls and low hills of morainic aspect stand on the valley bottom and lower slopes. Most of the hills are deposits directly from glacial ice; some are composed of water-washed gravel deposited in depressions partly enclosed by glacial ice. Some of the wide places are marshy because the streams have not yet cut adequate drainage courses through morainic knolls immediately downstream.

The conclusion is unavoidable that the two valleys antedate their partial blockades, that they therefore are older than the Valparaiso glaciation. This conclusion is amply supported by the thinness of the Valparaiso drift on the adjoining uplands. Most of the bulk of this part of the Valparaiso moraine is made up of an older and conspicuously different drift, in which the valleys were originally eroded. Since the valleys were modified by the Valparaiso ice, their streams have done little to make them adequate drainage routes again.

The valley of Fraction Run between Long Run and Spring Creek (shown by contours but not named on the northwest part of the Mokena quadrangle map) may belong to the same subcategory. It seems equally probable that Sawmill Creek Valley (Sag Bridge quadrangle), upstream from the deeply cut ravine portion, dates back to the same episode of pre-Valparaiso stream erosion. It is certain that Hickory and Marley creek valleys, now to be described, have had the same history.

*Valleys of Hickory and Marley creeks.*—Both streams, joining a mile northeast of New Lenox (Mokena quadrangle), take some drainage from the back slope of the Valparaiso moraine and from the Valparaiso ground moraine farther east. Reaching the DesPlaines River at Joliet, they thus cross the full width of that moraine belt.

The gradient of Hickory Creek across the Mokena, Tinley Park, and Frankfort quadrangles is 7 feet per mile, that of Marley Creek above the junction 6 feet per mile. Both valleys exhibit the same kind of narrowings and widenings that are found in Long Run and Spring Creek valleys, much the same marshiness of wide places, and the same kind of obstructing morainic piles. Hickory Creek has the largest tracts of gravelly knolls of this genesis in the Chicago region. Though there are no known exposures of the underlying older drift, the gravel piles deposited on the valley bottoms by meltwater escaping from the Valparaiso ice are sufficient evidence that Hickory and Marley creek valleys are older than the building of the Valparaiso moraine.

*Valley of Mill Creek.*—One of the large swamps of the region, McGinnis Slough near Orland Park (Palos Park quadrangle), discharges northward by way of four other swamps to Mill Creek across the corporate limits of Palos Park. For 2 1/2 miles of

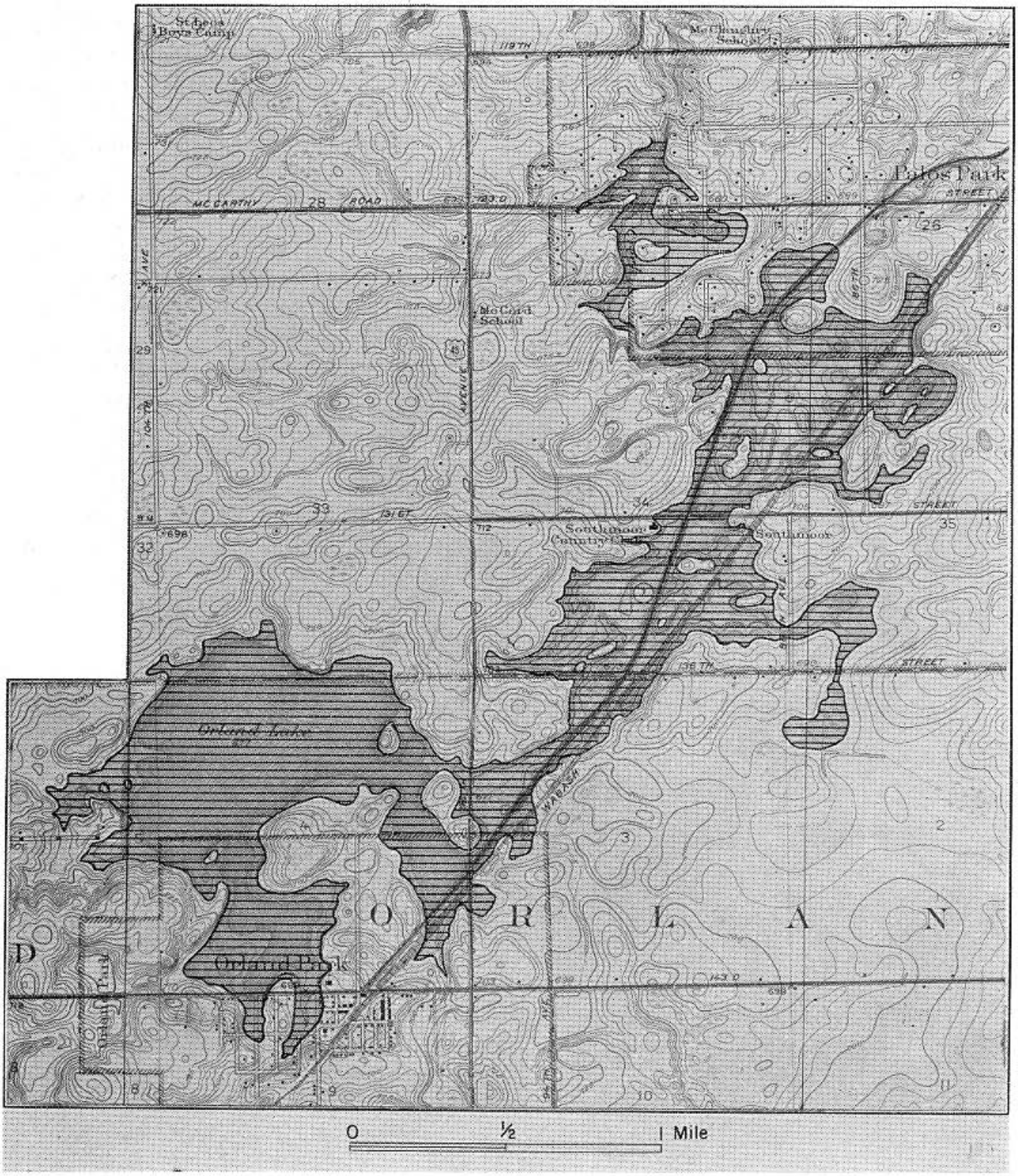



FIG. 8.—Vanished postglacial lakes near Orland Park and Palos Park (Palos Park and Sag Bridge quadrangles).

this string of swamps, the descent is only 15 feet, a gradient of 6 feet per mile. There has been no stream erosion along this stretch, the valley being only a line of connected morainic depressions. But from the southwest corner of the Palos Park incorporation, the stream descends 55 feet in 2 miles to its debouchure in the head of Sag Valley. The gradient here is 27 feet to the mile along an attractive wooded valley whose bluffs near the mouth reach a maximum of 50 feet above the valley bottom.

The Palos Park quadrangle map shows two narrow, deeply cut places in this two-mile stretch, separated by more than half a mile of broad valley floor centrally located in section 27. The northern narrows is 25 feet deep; the southern one has a 40-foot

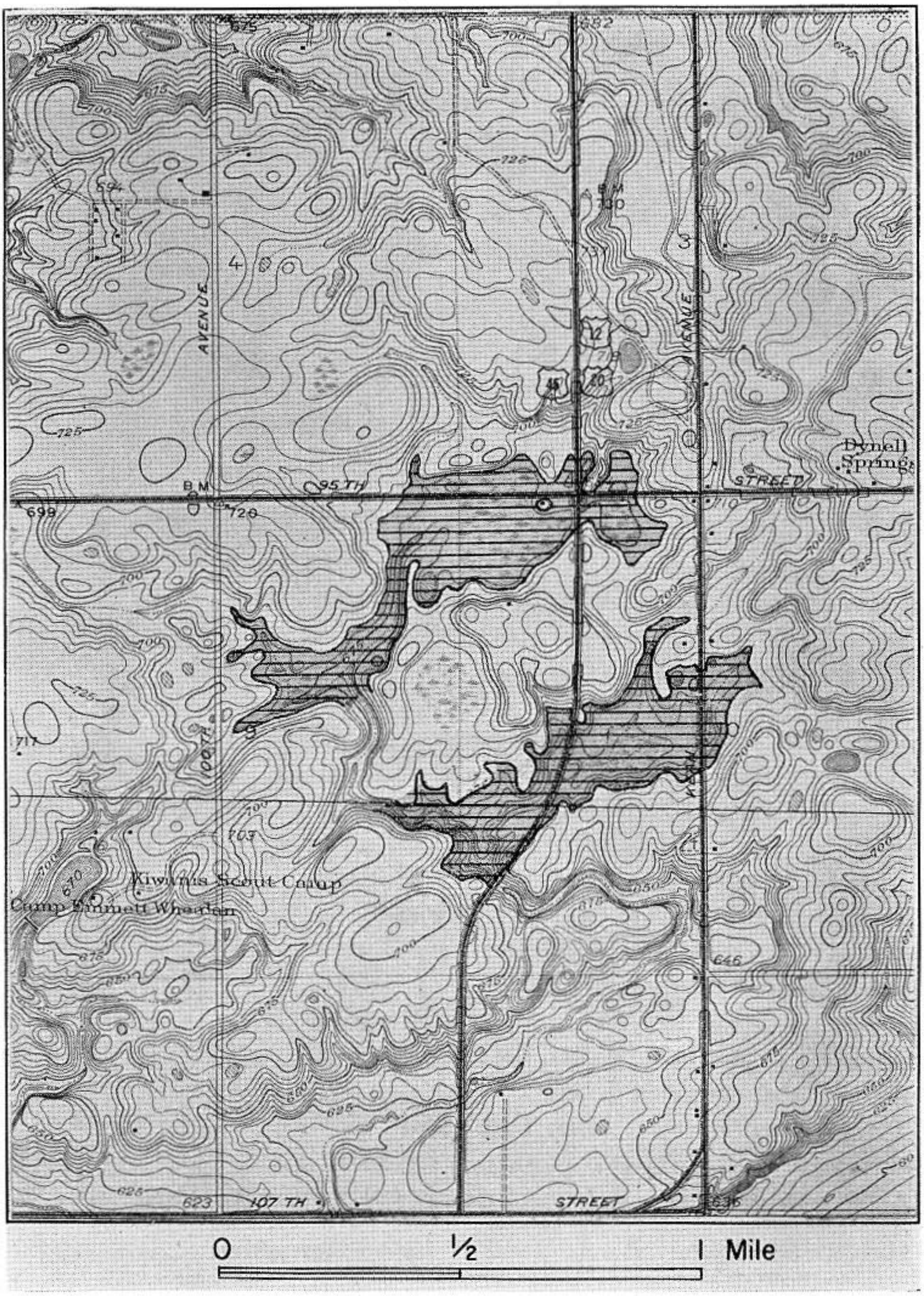



Fig. 9.—Vanished postglacial lakes of Mt. Forest Island (Palos Park quadrangle).

bluff along its southwestern side. Though there is much morainic relief in the topography of the Palos Park district, these narrow valley portions are unquestionably of postglacial stream origin. Before they were cut, the lowland tracts now draining northward through them must have been lakes. Inspection of the topographic map shows that the lake occupying the broad valley floor between the two narrow places must have had a surface altitude of 660 feet above sea level. Its maximum depth to the top of the fill was probably about 10 feet. A much larger lake existed south of the southern narrows. It was 3 1/2 miles long, backing up into the lower western part of the village of Orland Park. Its surface altitude was 685 feet, its maximum depth to the top of the fill about 20 feet, and its area about 1 1/2 square miles. McGinnis Slough and the string of four marshes are surviving remnants in still undrained portions of its bottom. The lake's outline was very irregular (fig. 8), and it contained 15 islands.

Had the steep-sided, deep Sag Valley not been nearby, Mill Creek would never have had the gradient necessary to cut these two narrow places in the morainic dams, and standing water, either lake or swamp or both, would fill these lowlands today.

It may be noted here that Mount Forest Island, across Sag Valley from the Orland and Palos districts and similar in topography, has been the site of three such postglacial lakes drained by the high-gradient streams descending to the adjacent deep Sag and DesPlaines valleys. The outlines of two of them are restored in figure 9 by the method used for the lakes just described—tracing the highest contour of the former basin that would become closed on itself if a dam were built in the narrow postglacial valley. For the third lake, the Forest Preserve has actually built such a dam, made such an undrained depression, and thus restored the lake. This is Tuma (or Maple) Lake on the Sag Bridge quadrangle.

*Valleys draining glacial lake flats west of the Tinley moraine.*—When glacial water covered the four lake flats in this district, the drainage was westward, away from the Tinley ice front, the dam which prevented the water from escaping eastward. The moraine, when abandoned by the ice, had not been built high enough at all places to maintain the westward drainage. Four eastward-flowing creeks took origin across the moraine; Tinley Creek (Tinley Park and Palos Park quadrangles), draining the Lake Orland flat; an unnamed creek flowing through Oak Forest (Tinley Park and Harvey quadrangles), draining part of the Lake Tinley flat; Butterfield Creek (Tinley Park and Harvey quadrangles), draining the Lake Matteson flat; and Thorn Creek (Steger quadrangle), draining the Lake Steger flat. Drainage from three-fourths of the Lake Tinley flat still goes westward to Hickory Creek.

All four of these post-Tinley creeks are on low sags across the moraine. All originally drained from approximately 700 feet above sea level down to the highest shore of Lake Chicago, 640 feet above the sea. Since distances traversed ranged from 2.1 to 5 miles, original gradients ranged from 12 to 28 feet per mile. There is a definite relation between these gradients and the amount of dissection by each stream in its headwaters. But another variable, volume, is involved, and comparisons cannot be made too closely. Hickory Creek, still obtaining the lion's share of runoff from the Lake Tinley flat, has been unable to erode a valley here because of the low gradient of the stream. Most drainage of the flat today is by ditching.

*Valley of Thorn Creek.*—Thorn Creek heads in Valparaiso moraine country south of the region, skirts the western margin of

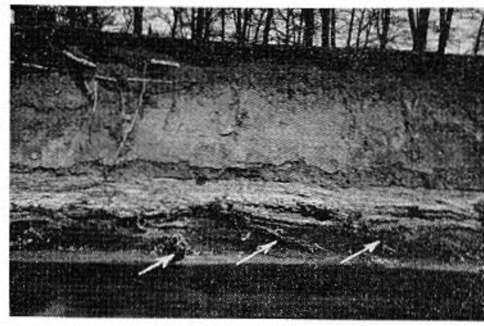
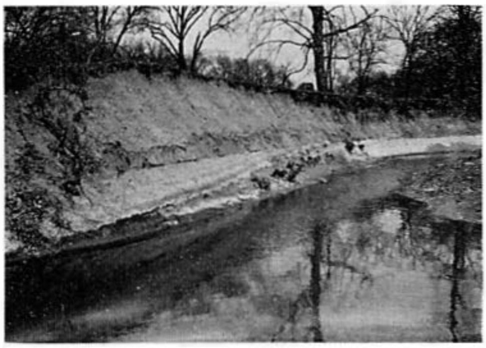


FIG. 10.—Driftwood in lower part of alluvial fill in Plum Creek Valley.



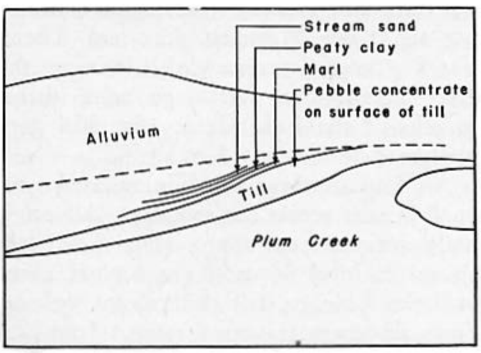



FIG 11A.—Marl, peaty clay, and sand beneath alluvium in Plum Creek Valley. 11B.—Diagram showing positions of materials in photograph.

glacial Lake Steger (Steger quadrangle), crosses the Tinley moraine in a low place in Chicago Heights, and enters Little Calumet River after traversing about 6 miles of the Lake Chicago plain (Harvey and Calumet City quadrangles). It meanders considerably on the plain, its channel length in this 6 miles being a little more than 10 miles. Its gradient for this stretch is nearly 5 1/2 feet per mile. In its upper course across morainic country, its gradient is 13 feet per mile. Expectable, therefore, are contrasts in valley depths in the two portions. In the moraine, some of the valley bluffs are 35 and 40 feet high; on the lake plain the average is 15 feet.

East of Thornton, the creek descends across a riser between two treads of the plain and has cut a valley 25 feet deep. But before the stream reaches the Little Calumet, two miles farther by the valley course, it is on lake bottm so low that no valley has been eroded. Therefore, Thorn Creek Valley ends downstream short of the mouth of the stream itself.

Between Thornton and Glenwood the valley on the plain is very constricted in several places, owing largely to half a dozen outcrops of bedrock in the valley floor.

*Valley of Plum Creek.*—Only 2 miles of this valley (south of Dyer) is topographically mapped on the Dyer quadrangle; most of it, like that of Thorn Creek, lies south of the area mapped. Its interesting history is set forth in Part I and will be only briefly outlined here.

Plum Creek enters the Lake Chicago plain at Dyer, which is built partly on the Glenwood beach ridge. The strongly developed Calumet beach, 15 feet high and half a mile wide, is 4 1/2 miles farther north. The creek was able to erode a valley in the moraine south of Dyer, but its water collected between the two beach ridges to make an extensive swamp, and drainage from the swamp had to follow a circuitous route by way of North Creek to go around the Calumet beach at Thornton to reach the Little Calumet. Lack of adequate gradient on the lake bottom made it impossible for North Creek to deepen enough to drain the swamp. Plum Creek, on approaching and entering the swamp, deposited silt and sand in a low alluvial fan. This decreased the gradient upstream, in the moraine portion, and caused considerable alluviation on that valley floor.

Then, about 1850, a drainage ditch was dug across the Calumet beach ridge, much

FIG. 12.—Fragments of deer antlers and a well-worn mammoth tooth from deposits in Plum Creek Valley.

of it east of the eastern boundary of the Chicago region. Hart Ditch shortened the route between the swamp and the Little Calumet River from 13 1/2 miles to about 1 1/2 miles and increased the gradient of swamp discharge, including Plum Creek water, from 2 1/2 feet to the mile to nearly 20. In consequence, the swamp has completely disappeared, a valley 15 to 20 feet deep has been eroded by Plum Creek water along the original shallow ditch, and entrenchment of the alluvial fan at Dyer and of the valley-bottom fill south of that town has occurred in less than a hundred years. Mammoth teeth, deer antlers, clam and snail shells, peat, marl, and driftwood logs have all come to light in the valley fill because of this entrenchment.

# CHAPTER III—GLACIAL GEOLOGY

## INTRODUCTION

European and American geologists a century ago were puzzled by the cover of unconsolidated materials above the bedrock which clearly was not derived from it by the ordinary process of weathering. Below a zone of surficial alteration by air and water, the material was largely undecomposed rock debris, and it generally rested on a clean-cut surface of unaltered bedrock. In many places abrasional markings occurred on the rock surface. The material was commonly a heterogeneous mixture of various-sized fragments, from clay to boulders, and many of the fragments were derived from many kinds of bedrock foreign to the region. The early geologists called it *drift* or *diluvium*, for it surely had been moved into the region it covered and, in moving, had abraded the underlying bedrock. It had been moved along the direction of the grooves and scratches, either from northerly or southerly regions. Many fragments were identical with rocks in bedrock-outcrop areas to the north. Therefore the drift was explained as the product of some cataclysmic action in northern Europe and North America which swept debris southward halfway across each continent. There was, they thought, no process in operation today akin to that action.

About this time, Louis Agassiz, a young Swiss naturalist, became interested in the mountain glaciers of the Alps and the changes they were producing. Shortly he conceived the idea that the glaciers he was studying were but shrunken remnants of far larger ones which had covered all the Swiss lowland, had eroded bedrock, and had left their characteristic grooves and scratches beneath a heterogeneous mixture of debris identical with that which existing glaciers deposit. Later he found the same kind of record in Scandinavia and the British Isles and, coming to North America, found it all over those parts of Canada and the northern United States which he visited. His first announcement—that the drift or diluvium was the product of glacial action—is dated 1840; his assertion of the geologically recent existence of enormous continental ice sheets appeared in 1848. It took 20 years of critical observation by a large number of investigators, however, to displace the older concepts and bring about a general acceptance among geologists of his interpretation.

One glaciation was all that Agassiz asked for and all that many geologists would accept for the next 20 years. Several workers, however, insisted that peat beds in the body of the drift, and old soils on drift but beneath a cover of fresh drift, proved that there had been at least two such glaciations. By 1898, it was clear to most that there had been four stages of continental glaciation in North America, separated by stages of deglaciation comparable to the present postglacial stage.

## Drift

The drift has been differentiated into that deposited directly as the ice melted and that modified by the associated meltwater into a variety of glaciofluvial (glacial river) and glaciolacustrine (glacial lake) deposits.

Fig. 13.—Planed and striated bedrock surface. Quarry of Elmhurst-Chicago Stone Co., Elmhurst. Scale is shown by the black spot, which is ¾ inch in diameter.

### TILL

Till is ice-laid material, a heterogeneous mixture of fragments of all sizes, with only rarely any suggestion of stratification. The marginal moraine ridges and the ground-moraine sheets are till deposits, differentiated on the basis of topography, and they record times when the ice front was either maintaining the same position (because the rates of advance and of melting were in balance), or was retreating (because the rate of melting exceeded the rate of advance). Till is also called *boulder clay*, especially in the earlier literature.

The till of the Valparaiso and later moraines has a very high clay content and a paucity of pebbles, cobbles, and boulders, whereas the older till, cropping out along the Sag and the transmorainic DesPlaines valleys, is silty rather than clayey and has an abundance of coarse material. The older till also has an exceptional amount of stratified material, and in limited outcrops it may look more like a water-laid deposit than a glacial deposit. In both types of till, many pebbles and larger fragments show glacial scratches (striae) and planed and beveled surfaces from grinding against each other or against the underlying bedrock, which also may show abrasion marks.

### GLACIOFLUVIAL DEPOSITS

Glacial ice melted not only at the frontal margin but over a wide surface zone back of that margin. Where crevasses existed, meltwater penetrated down into the body of the marginal zone of ice, perhaps to the bottom. Eventually it escaped, from superglacial, englacial, and subglacial courses, at the glacier front, constituting extraglacial streams or, if no free drainage was possible, lakes.

Supplied with debris from the melting ice, the streams became overloaded in many places and deposited part of their load. Such deposits are stratified, the layers distinguished generally by differences in size of constituent particles. Such layering records variation in velocity of the depositing stream, which is commonly the result of fluctuating volume, and meltwater streams are as variable in volume as any streams on earth. Fine material is likely to remain in suspension, despite slackening in velocity, and to be carried on down the valley. If it is ever deposited by the stream, it will be left where slackening current could bring no coarse material and could not transport all the fine. The extreme is, of course, entrance of the stream water into a glacial lake where, with no current at all, the very finest clay and rock flour will settle out.

*Eskers.*—Ridged accumulations of glaciofluvial sand and gravel—eskers—are fairly common in morainic country. They generally are oriented approximately at right angles to the course of the moraines and must have had retaining ice walls when deposited. They seem to indicate deposition in fissures or crevasses close to the ice front. An esker is not necessarily of contemporaneous deposition throughout its length; it is more probable that a superglacial stream, or streams, debouching into a fissured reentrant of the ice front, added constantly to the proximal end of the ridge as the ice front retreated. However, eskers are often interpreted as subglacial stream deposits that record a continuous tunnel at the bottom of the ice.

Fairly common in eskers is inclined stratification, due in part to original deposition (cross-bedding or foreset bedding), and in part to slumping when the ice wall melted away. There may be masses of till in or on top of the esker, resulting from ice thrust during or at the close of esker growth. Ice thrust may also crumple strata already deposited.

Eskers or eskerlike deposits are not common anywhere in the Chicago region. One is at Half Day on the Wheeling quadrangle (map 1), two lie centrally in the northwest quarter of the Hinsdale quadrangle (map 9), there are two on the Sag Bridge quadrangle (map 13), one a mile north of Tiedtville, and one near Visitation Boys Camp.

*Kames.*—If the gradient of a meltwater stream debouching at the edge of the ice is notably reduced as it passes from the ice slope to the slope of the moraine, stratified washed coarse material may pile up on or against the lower ice slopes, located most probably in fissured re-entrants of the glacial front. A superglacial stream falling into a crevasse near the front may find itself unable to continue to carry the coarser material of its load, and the pile of debris will then be built beneath the edge of the ice; melting will constantly enlarge the cavity to accommodate the increasing bulk of the deposit. After retreat of the ice, the piles are left as hills, called *kames*. Genetically, they are closely related to eskers.

Kames in the Chicago region, like eskers, are limited almost wholly to the Valparaiso moraine. There are two kames on the Wheeling quadrangle (map 1), 3 miles west of the town of Wheeling, and about a dozen in the northern half of the Sag Bridge quadrangle (map 13).

*Kame terraces.*—If, as the ice front retreats, a pre-existing valley leading away from the glacier is exposed, ice may remain longer within the protection of its slopes than on the uplands on either side. Stagnant ice masses may thus be left behind in the valley bottom and will interfere with escaping extraglacial meltwater. The stream is likely to find the lowest places along one or both sides of the lingering ice tongue and leave its deposits on the lower slopes but not in the deepest, middle part of the valley. These deposits are called *kame terraces*. They may be somewhat knolly but rarely are as knolly as kames. Hickory Creek Valley has a good showing of kame terraces on the Mokena and Tinley Park quadrangles (maps 17, 18), and the valleys of Marley Creek and Long Run possess a few.

*Valley train.*—When no lingering ice masses obstruct a pre-existing valley which is a route for escaping meltwater, sand and gravel from the overloaded stream are likely to be deposited as a valley-bottom flat. Across the flat the stream makes a series of channels, which shift location as they become aggraded and thus give origin to a fill known as a *valley train*. Such a deposit is very similar to what heavily laden streams in nonglacial regions produce. Valley trains, however, head in moraines, and their detritus is readily identifiable as drift released by melting of the glacial ice. The Chicago region has one good example of a valley-train—in the DesPlaines River Valley on the Wheeling, Arlington Heights, Park Ridge, and River Forest quadrangles (maps 1, 3, 4, 7).

### GLACIOLACUSTRINE DEPOSITS

*Deltas.*—When standing water is ponded along the ice front, meltwater streams on entering abruptly lose all velocity and consequently build deposits at the debouchures and contribute fine material to be distributed widely in the feebler lake circulation. Characteristic of a sand or gravel delta is foreset bedding; the strata dip into the lake at the angle of rest (between 12° and 20°) and terminate at the top in a uniform horizontal plane determined by the lake surface.

The Chicago region has no good showing of sand or gravel deltas. What seems to be a fragment of one occurs near Worth (Palos Park quadrangle—map 14), where it is a part of the older, buried drift sheet.

*Offshore deposits.*—The very fine mud and clay that takes days to settle out of suspension gets wide distribution in a lake and may make a fairly uniform deposit over the whole bottom. This depends, however, on depth and amount of wave agitation. Lakes Orland, Tinley, Matteson, and Steger accumulated thick deposits of finely laminated clay during their brief lives; indeed, they became completely filled with such material. But in general the big storm waves of Lake Chicago dragged bottom on the Chicago plain and eroded instead of depositing. Only in the protected bays did sediment accumulate under water on the Chicago plain. The best showing of this has been in excavation for the North Shore Channel, in a bay back of the large spits in Evanston and the northern part of Chicago.

*Beach deposits.*—More extensive, and topographically much more conspicuous than any other deposits left by glacial Lake Chicago, are the long ribbons of shore accumulations that stretch for miles across the lake plain. To some extent, the bulkiness of each of the three beach accumulations is a measure of the duration of the stage, though other factors were also involved. In total mileage, most of the deposits are simple beach ridges on the different shores, their sand and gravel tossed back to the storm-wave limit. In volume of deposit, the large spits at Wilmette, Evanston (Rose Hill), northern Chicago (Graceland), Dolton-Hammond, and Thornton-Dyer exceed perhaps all the beach ridges together. In depth of deposit, they are excelled by shores on which the wave-making winds also piled up dunes (Wilmette, Blue Island, and Dolton-Hammond). In area of unit deposits, the Evanston (Rose Hill) and northern Chicago (Graceland) spits are the largest, covering a total of about 4 and 6 1/4 square miles, respectively. All these deposits are composed of the pebble and sand fractions of the eroded glacial till. In the shallow water offshore or at the foot of sea cliffs, the boulders were left where they were, the sand and gravel were dragged shoreward or along the shore, and the clay and mud fractions were carried off in the undertow, to be deposited eventually out in the basin of the lake.

### Eolian Deposits

Distinction is almost universally made between two types of eolian deposits—loess and dunes, composed of dust and sand, respectively. The region possesses no loess, although farther downstate many deposits are recognized as made by the winds of the glacial and interglacial stages. There are limited examples of dunes on each of the Lake Chicago beaches and on the present shore. The dunes of the glacial lake shores have already been listed. A tract between 71st and 79th streets and a small park at the east end of Touhy Avenue, just south of the Chicago-Evanston boundary, encompasses almost the only dunes of the present lake within the region. They are small and readily obliterated when they are built over. Accounts indicate that there were similar small dunes south of old Fort Dearborn at the time of the historic massacre of 1812.

### Source of Drift Materials

Larger fragments in the drift, whose lithology and structure are apparent, are readily traced to their general source area. Dominant among these fragments are dolomite and limestone, most of which is dolomite identical with some phase of the immediately underlying bedrock, the Niagaran group of formations of Silurian age. Fossils in the fragments make the identification positive. Less common are limestone fragments traceable to Ordovician formations that crop out farther north along the route of the advancing ice—the elongated trough of Lake Michigan. Still less common, but conspicuous because of strongly contrasted lithology and structure, are fragments of granite, gneiss, schist, slate, quartzite, etc., whose source areas are unquestionably in the great Laurentian province of Canada, northeast of the Chicago region.

The drifts of north-central Indiana, north-central Illinois, and southeastern Wisconsin differ in the types of igneous and metamorphic rocks which they contain. This is because the ice which overrode these areas travelled different, though subparallel, routes and thus encountered different bedrock.

The Valparaiso and later tills contain a vast quantity of finely ground shale derived from the bed of Lake Michigan by glacial erosion. Pebbles of the weak shale which have survived the grinding clearly are from the Devonian shale formations now largely submerged. So are the very abundant, almost microscopic, fossilized spores of the genus *Sporangites*, a Devonian type. Much less sandstone was traversed by the ice-sheet than shale or limestone, hence the relatively small quantity of sand in the till.

### Thickness of the Drift

The maximum known thickness of the glacially deposited debris of the Chicago region is 216 feet, in a well on Ridge Road in the Highmoor district of Highland Park. The district, on the Blodgett moraine, has only a moderate altitude, and the thickness is caused by an unusually low place in the underlying bedrock surface. If this surface were a horizontal plane, the uplands would have the thickest drift, the low lake plain and the deep Sag and transmorainic DesPlaines valleys the thinnest. We find, however, a marked relief in that buried surface and little correspondence between it and the relief of the drift itself. The average thickness of the drift is therefore difficult to estimate. Well data show that it averages 60 to 70 feet under the lake plain, 100 feet under the western morainic upland, and 140 feet under the northern morainic area.

### Differentiation of Drift Sheets

Newberry and Orton, about 1873, argued independently that a "forest bed" (a peat bed with abundant wood) in a body of till recorded a time of deglaciation and reforestation interrupting the glacial domination of a region. T. C. Chamberlin in 1882 argued that differences in amount of erosion on horizontally adjacent drift sheets indicated differences in age—the more eroded, the older. Salisbury in 1893 proposed that, in a vertical succession, a buried weathered surface or a buried stream-eroded surface indicated that the subjacent till had been long exposed before the superjacent one was deposited. These criteria, with others, have established the Pleistocene succession as we now know it.

But Chicagoland is well back from the limits reached by the ice sheets which have overrun it. So located, it is not to be expected that excavations here will discover a full Pleistocene stratigraphy, for later invasions either destroyed the deposits left by earlier ones or eroded their upper portions.

Another criterion can be used in some situations. If the ice of two successive invasions came from somewhat different directions, thus passing over different kinds of bedrock, the two drifts will possess certain lithologic differences. This criterion appears to find application in the drift deposits of the Chicago region.

Otto's utilization (p. 83) of difference in water content of till sheets, essentially based on the principle that buried till becomes densified because of a later overriding, is a related criterion for differentiation of drift sheets of successive ages. It is applicable only in situations where the till never subsequently became desiccated.

Till sheets in vertical sequence in a region may be distinguished from each other by differences in color, hardness, nature of the fine matrix, and kinds of included pebbles. But the composition of till must vary with the kinds of bedrock contributing to it and with the amount of water action at the time of deposition. Hence no one till possesses constancy of all characters, if indeed of any one of them, throughout its extent. The problem of identifying a till which cannot be traced continuously is not simple.

The pioneer study of this problem in the Chicago region[1] was made during the progress of this survey, although it was independently executed. It was in part an attempt to learn if a till sheet possessed any constancy in textural composition, or any consistent variations in the composition, along the length of a moraine. A considerably larger area was chosen, of which the Chicago region was but a part. Valparaiso till was selected because the moraine topographically is identifiable continuously for many miles through Illinois, Indiana, and Michigan.

Krumbein's study demonstrated that throughout "a length of forty miles . . . samples taken at intervals of 1 or 2 miles showed only slight changes in composition from one sample to the next. The study indicated that intervals of 10 miles would not be too great if a considerable length of moraine was involved."

Another phase of this study dealt with identification of bedrock fragments in the till. It was found that along the Valparaiso moraine from Elgin, Ill., to Benton Harbor, Mich., dolomite and limestone fragments constitute about 80 percent of all pebbles for the first 30 miles, that the percentage drops to about 10 in the next 13 miles, and remains there for nearly 100 miles, to Benton Harbor. Conversely, shale and siltstone pebbles average about 10 percent for the first 30 miles, then rise in percentage as the dolomite and limestone pebbles decrease, and for the last 100 miles remain close to 75 percent of the total. This, Krumbein thinks, is due to the difference

[1]Krumbein, W. C., Textural and lithological variations in glacial till: Jour. Geol., vol. 41, pp. 382-408. 1933. This paper was a Ph.D. thesis in the Department of Geology, University of Chicago.

TABLE 1.—CLASSIFICATION OF THE PLEISTOCENE EPOCH

| *Rock term: Series*<br>*Time term: Epoch* | *Group*<br>*Subepoch* | *Stage*<br>*Age* | *Substage*<br>*Subage* | *Stages in*<br>*Europe* |
|---|---|---|---|---|
| Pleistocene | Eldoran | Recent | | |
| | | Wisconsin (glacial) | Mankato<br>Cary<br>Tazewell<br>Iowan<br>Farmdale | Wurm |
| | Centralian | Sangamon (interglacial) | | Riss-Wurm |
| | | Illinoian (glacial) | | Riss |
| | Ottumwan | Yarmouth (interglacial) | | Mindel-Riss |
| | | Kansan (glacial) | | Mindel |
| | Grandian | Aftonian (interglacial) | | Gunz-Mindel |
| | | Nebraskan (glacial) | | Gunz |

in bedrock: Niagaran dolomite underlies the till high in dolomite and limestone pebbles, and Devonian shale and siltstone underlies that portion rich in pebbles of shale and siltstone. The change in pebble dominance, however, occurs 40 miles west of the bedrock change, probably because the ice moved diagonally across the contact farther north, under Lake Michigan. Krumbein warns his readers not to expect too close a correspondence, too uniform a percentage, in any pebble waste from underlying rock, because portions of older drift sheets covering the rock locally may produce variations in percentages.

The conclusion of Krumbein's study is that "a given ice sheet tends to produce till having a fairly well-defined frequency distribution" of the various grade-sizes of particles. Sedimentological studies may profitably be made on the region's buried tills. The silty and stony till beneath the Valparaiso drift should be studied in this manner, and for the investigator attracted by the problem, there is on page 68 a list of all localities where, though not shown on the maps, it is known or suspected to exist. It may well be that a gradation can be shown between this older till of the region and some morainal till farther west.

The method should be applied to the deeper tills encountered in the clay pits of the region, in the caissons of the Loop district, and in other excavations. They are in some places apparently alike though separated by sediments, and may prove to be the same deposit with intra-till stratified members. In other places, they are distinctly unlike.

## CLASSIFICATION

Following the most recent revision of the Pleistocene[2] series and its nomenclature, we now have the classification presented in table 1. It is most applicable in the northern part of the United States east of the Rocky Mountains.

The interglacial intervals following each of the first three glaciations were long, and the exposed part of each drift sheet was greatly weathered and eroded before it was covered by the next younger drift.

[2]First used by Lyell, C., Charlesworth's Mag. Nat. Hist., vol. 3, p. 323, footnote, 1839.

In contrast is the relatively brief postglacial interval of today and the relatively shallow depth of weathering of the latest drift sheet. A cyclic succession of glacial and nonglacial climates gives rise to the concept of four subepochs, each one including a complete oscillation of the climatic pendulum. The record is clear enough, but the causes for the climatic rhythms are as yet little understood.

Each of the Wisconsin[3] substages[4] has subdivisions determined by a series of marginal moraines built during pauses in the general retreat. The ice front often retreated extensively before readvancing and depositing successive moraines (fig. 14).

The great lobe of the Wisconsin continental ice sheet which spread southward out of the Lake Michigan basin deposited in Illinois the moraine system illustrated in figure 15. The Tazewell[5] substage includes all the moraines from the oldest and outermost (Shelbyville[6]) to the Marseilles.[7] The oldest of the Cary[8] substage moraines is the Minooka,[9] the youngest is the Lake Border system. Ice did not reach this region during Mankato[10] time. The change in outline of the Lake Michigan lobe between Marseilles and Minooka time suggests an unusually marked retreat. On readvancing at the beginning of Cary time, the Minooka moraine was deposited on top of the Marseilles near Elgin, where the two are elongated almost at right angles to each other.

## Stratigraphy

Beneath the glacial drift lies Niagaran dolomite of Silurian (mid-Paleozoic) age. The break between the two involves a vast stretch of geological time. The only record for the region is that of erosion, and the

[3]Named for the state of Wisconsin where drift of this age is widely distributed. Chamberlin, T. C., *in* Geikie, James, The Great Ice Age, 3rd ed., pp. 754-774, 1894; The classification of American glacial deposits: Jour. Geol., vol. 3, pp. 270-277, 1895.

[4]These Wisconsin substage names were first published in: Leighton, M. M., The naming of the subdivisions of the Wisconsin glacial age: Science, vol. 77, no. 1989, p. 168, Feb. 10, 1933.

[5]Named for Tazewell County, Ill., in which the moraines of this substage are well developed. It was formerly designated as "Early Wisconsin." Leighton, M. M., op. cit.

[6]Named for the town of Shelbyville, Ill., which is located at the extreme southwest part of the moraine. Leverett, Frank, The Illinois glacial lobe: U.S. Geol. Survey Mon. 38, p. 125, 1899.

[7]Named for the town of Marseilles, Ill., which is situated at the place where the Illinois River cuts the moraine. Leverett, Frank, op. cit., p. 307.

[8]Named for the village of Cary, Ill., which is located on a prominent part of the Valparaiso morainic system. The substage was formerly called "Middle Wisconsin." Leighton, M. M., op. cit.

[9]Named for the village of Minooka, Ill., which is situated on its crest. Leverett, Frank, op. cit., p. 319.

[10]Named for Mankato, Minn. The substage was formerly called "Late Wisconsin." Leighton, M. M., op. cit.

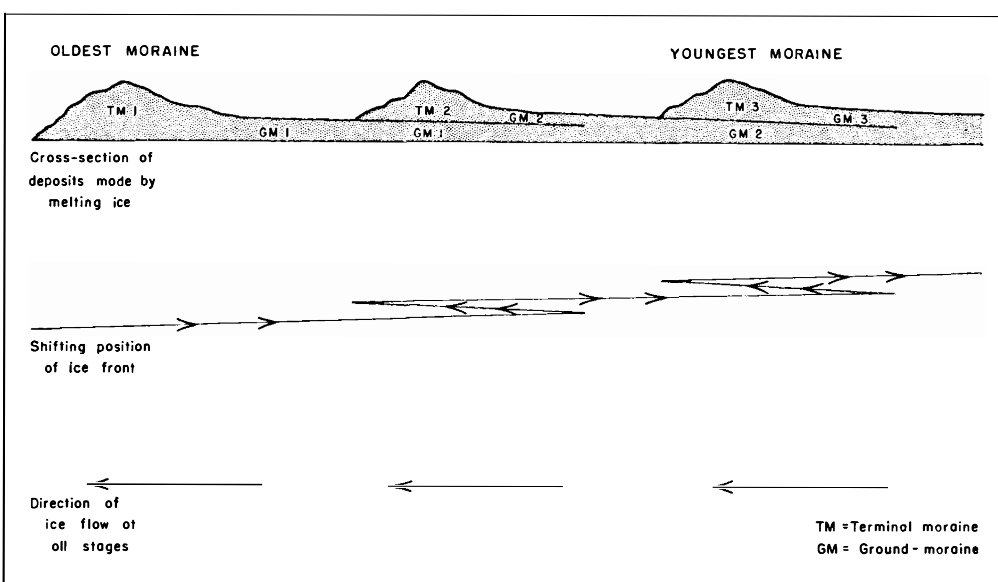



FIG. 14.—Development of successive moraines by minor readvances in general retreat of an ice sheet.

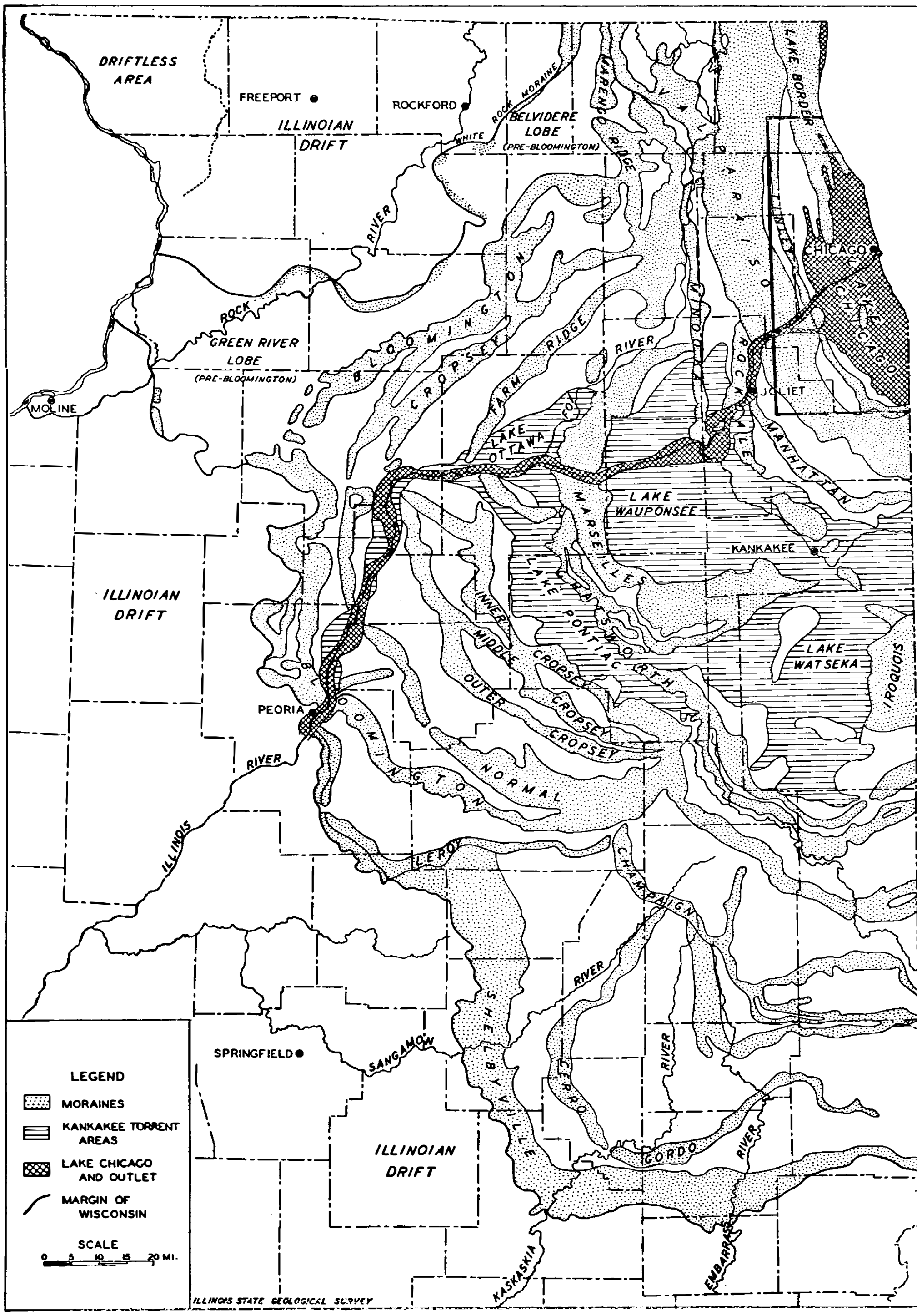



FIG. 15.—Moraines and associated features in northeastern Illinois. Compiled by George E. Ekblaw from data furnished by the Survey, January 1, 1942.

| SERIES | STAGE | SUB-STAGE | UNIT | SECTION | MAXIMUM THICKNESS | MATERIAL | ORIGIN |
|---|---|---|---|---|---|---|---|
| PLEISTOCENE | RECENT | | | | 12 | Silt, clay, sand, gravel, peat | Stream, lake, wind organisms |
| | WISCONSIN | MAN-KATO | ALGONQUIN | | 6 | Sand, gravel | Beach deposit |
| | | | LAKE CHICAGO | | 30 | Sand, gravel | Beach ridges and dunes |
| | | | | | 13 | Clay, silt, sand, marl, peat | Offshore lake deposits |
| | | CARY | HIGHLAND PARK | | 70 | Till, gravel, sand, silt | Ice deposits, frontal outwash |
| | | | BLODGETT | | 20 | Till | Ice deposits |
| | | | DEERFIELD | | 23 | Till | Ice deposits |
| | | | PARK RIDGE | | 27 | Till, sand, gravel | Ice deposits, valley-train |
| | | | TINLEY | | 45 | Till, sand, gravel, clay | Ice deposits, frontal outwash, lake deposits |
| | | | VALPARAISO | | 60 | Till, sand, gravel | Ice deposits, kames, eskers, kame terraces |
| | | TAZE-WELL | BLOOMINGTON | | ? | Till, clay | Ice and lake deposits included in younger till |
| | ILLINOIAN? | ? | LEMONT | | 60 | Till, silt, sand, gravel | Ice deposits, outwash, lake deposits, delta |
| | | | | | 85 | Till, clay, sand, gravel | Ice deposits, outwash |

FIG. 16.—Generalized columnar section of the Pleistocene deposits of the Chicago region.

contact is a great unconformity. Post-Silurian Paleozoic deposits were laid down here but they were completely stripped off later, and only fissure fillings in the Niagaran dolomite record their former presence.

The Pleistocene sequence of the region (fig. 16) is nowhere all present in one section. If it were, that section would be located under the youngest moraine of the region (Highland Park), whose till covers only 12 to 13 square miles in the northeastern corner. Otto (unpublished manuscript, Illinois Geological Survey) has shown that at least three older tills occur here, but they are nowhere exposed. Our section must be made by a horizontal traverse of the region from northeast to west-central, based on the knowledge that each stratigraphic unit overlaps westward on an older one (fig. 17). Constructed in this way, the section is just a list of the moraines, youngest (Highland Park) at the top and oldest

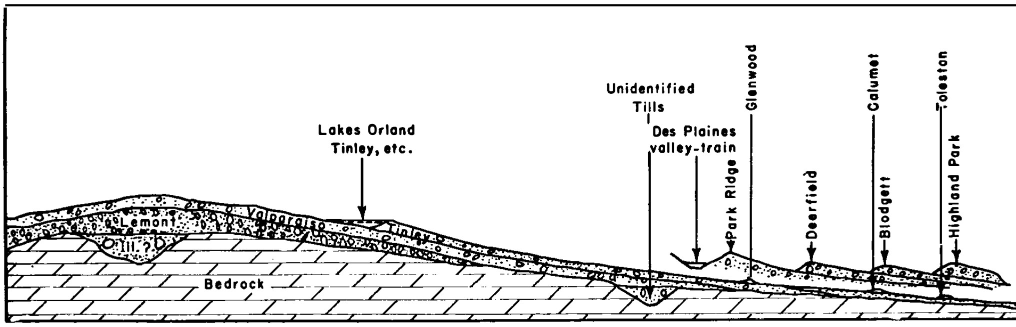



FIG. 17.—Diagrammatic cross section of the Pleistocene deposits of the Chicago region.

(Valparaiso) at the bottom. Repeatedly referred to, however, is a once completely buried drift in the western part of the region, without surface expression in the form of marginal moraine and ground moraine. It is the Lemont drift, which is not to be thought of as now underlying all the others. It may never have been a complete cover, and if it was it may have been largely eroded away during later glacial invasions.

Nor should the Valparaiso till sheet be thought of as having continuous contact with bedrock where not underlain by Lemont drift. Subway sections, deep caisson records, and the sections of the Sanitary and Ship Canal encounter some dense, hard tills whose correlation is uncertain. The upper till of the lake plain may be Tinley or one of the Lake Border sheets, depending on location. Valparaiso till should be beneath them. These densified tills may be Valparaiso or Lemont, or perhaps some other till not yet identified in the region.

## BEDROCK TOPOGRAPHY

Silurian dolomite, nearly 500 feet in maximum thickness, underlies all the Chicago region except a small area near DesPlaines. It has a gentle eastward dip that carries it under the Lake Michigan basin and beneath the Devonian shales that underlie the lake. The north-south strike prevails northward along the entire east side of Wisconsin, and the dolomite becomes much more prominent topographically in Door and Garden Island peninsulas, which separate Green Bay from Lake Michigan. In general, the surface of the bedrock slopes with the bedding, descending gradually toward the east. The western edge of the Silurian formations therefore is the highest part and constitutes the divide between Lake Michigan and Mississippi drainage approximately as far north as Lake Winnebago. In the Chicago region, it coincides with the preglacial and early Pleistocene bedrock divide under the western morainic uplands.

Hundreds of wells recording depth to bedrock have made possible the contouring of its surface. The contour maps (to be published later) show that the bedrock surface is diversified by a number of stream valleys with their tributaries and separating divides and that the direction of valley-bottom slopes is generally a function of the eastward bedrock slope (fig. 18). They show that the Lake Michigan basin must have been a free-draining valley at the time the valleys were formed, and that they are the eastward headwater drainage of the St. Lawrence-Mississippi divide of that time. The master stream to which they flowed was a contemporary of the Mahomet (Teays) River,[11] which received the drainage westward from the same divide through Kempton and Newark valleys (fig. 19). The degree of dissection of the bedrock surface indicates a mature stage in the erosion cycle.

Although we do not know if Nebraskan ice ever invaded the region, it probably advanced far enough from the Labradorean center to interfere with free drainage from what is now the Lake Michigan basin. It seems likely, therefore, that these bedrock tributary valleys are largely of preglacial origin.

[11]Horberg, Leland, Bedrock topography of Illinois: Illinois Geol. Survey Bull. 73, 1950.

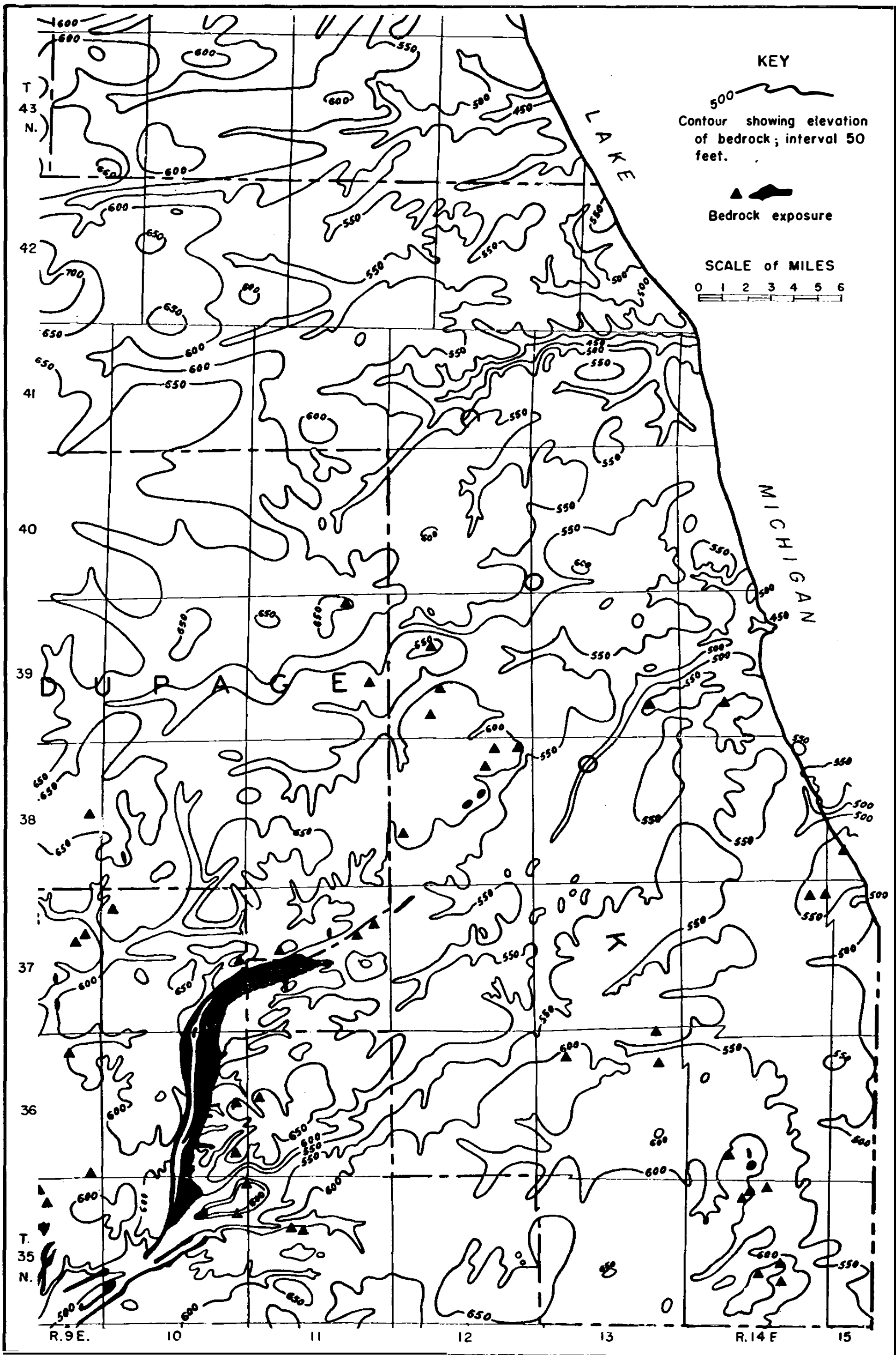



FIG. 18.—Generalized map of bedrock valley system in the Chicago region. *After* Leland Horberg, Bedrock topography in Illinois: Illinois Geol. Survey Bull. 73, pl. 1, 1950.

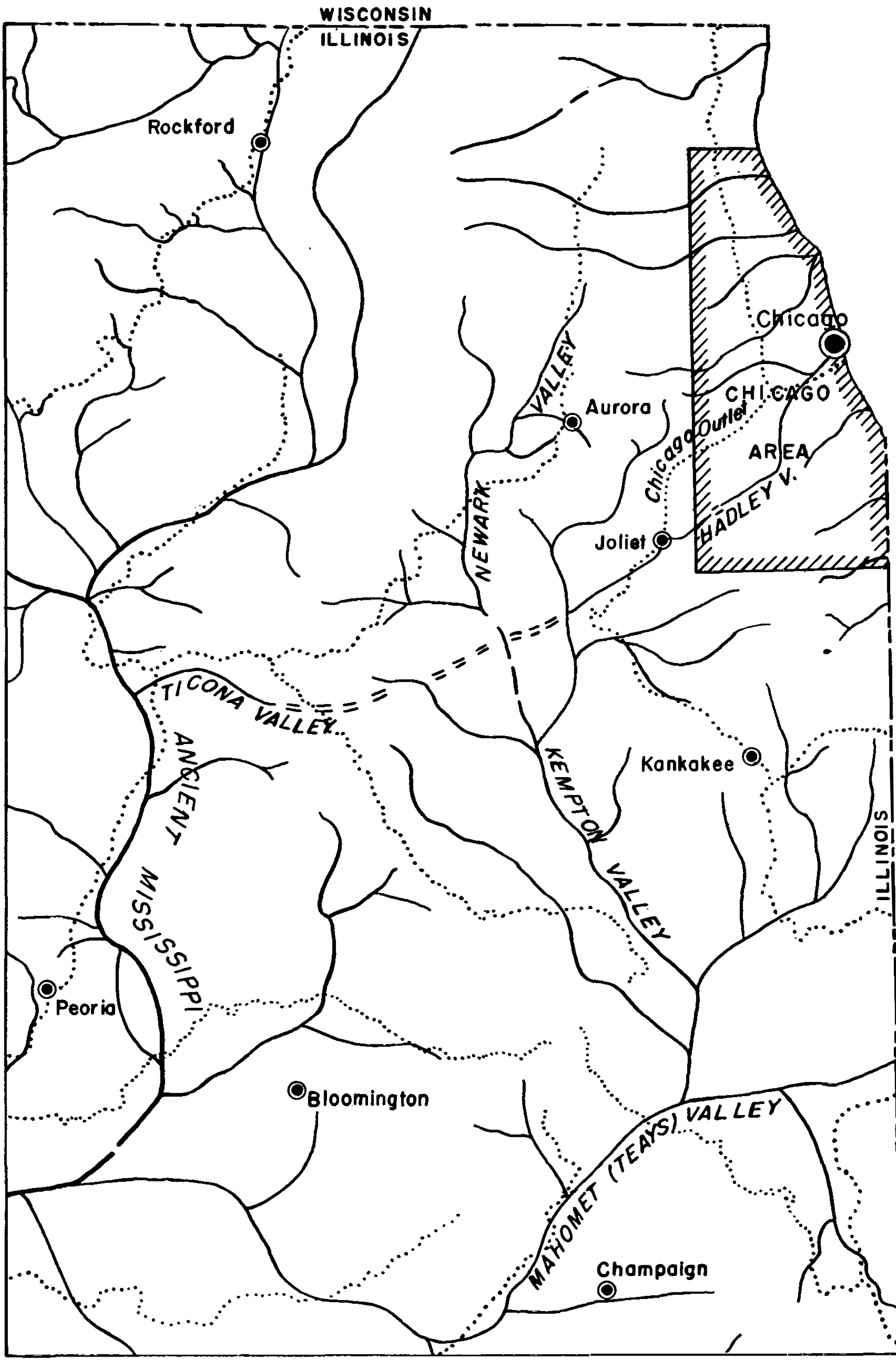



Fig. 19.—Preglacial drainage. *After* Leland Horberg, Bedrock topography in Illinois: Illinois Geol. Survey Bull. 73, pl. 2, 1950.

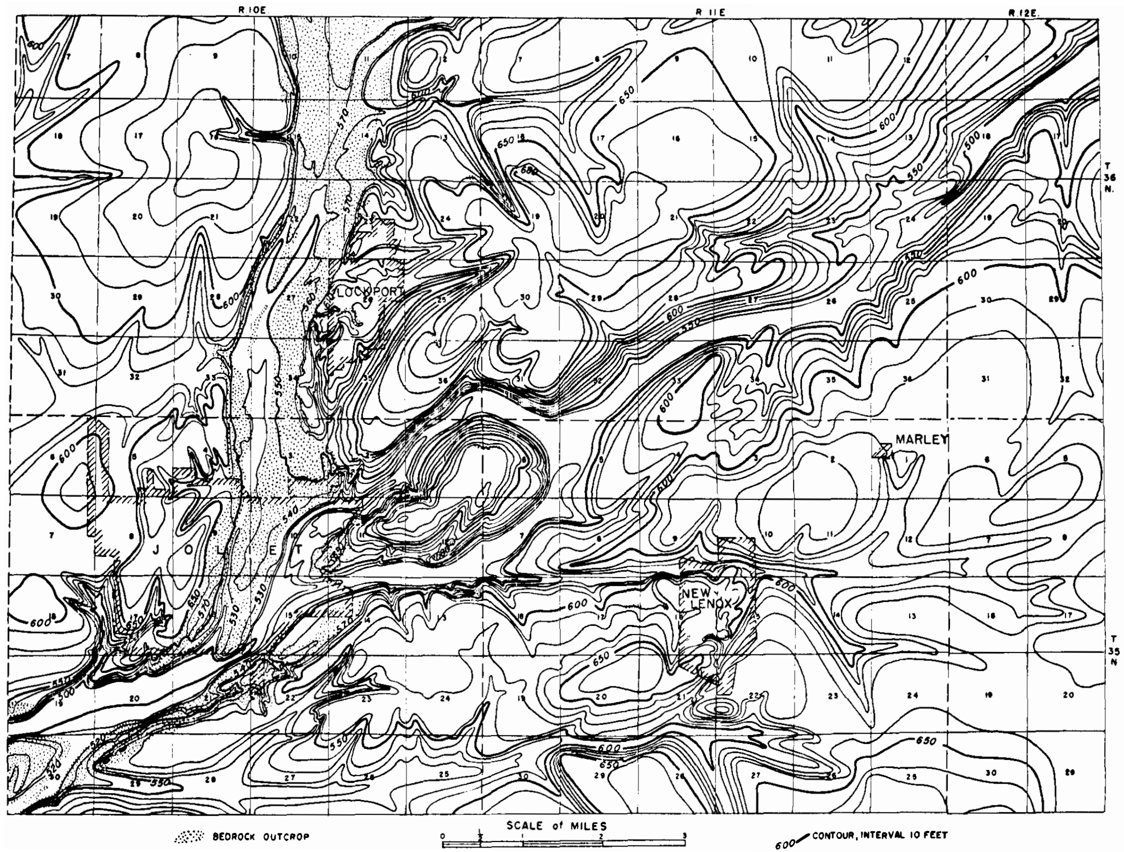



FIG. 20.—Contour map showing bedrock surface in vicinity of Joliet. *After* Leland Horberg and K. O. Emery, Buried bedrock valleys east of Joliet and their relation to water supply: Illinois Geol. Survey Circ. 95, pl. 1, 1943.

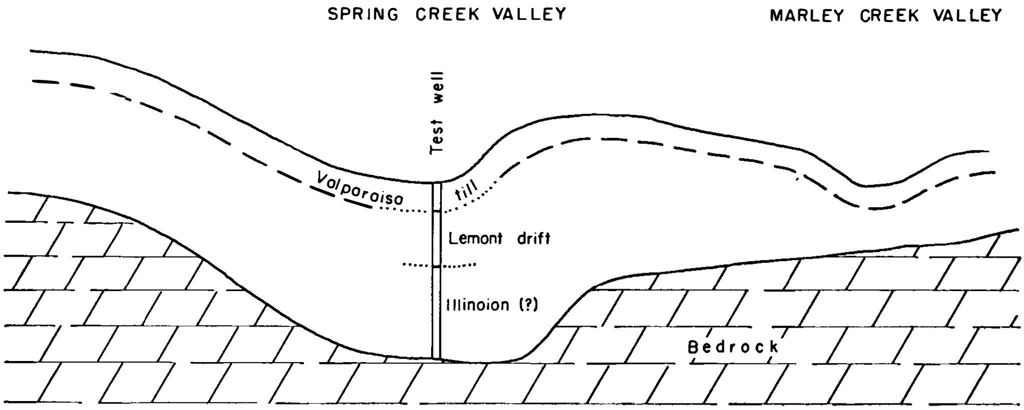



FIG. 21.—Cross section of buried Hadley Valley and its overlying drift.

The maps give no hint that subsequent glacial overriding did more to these valleys than fill them with drift. Divide tops which here and there form rock outcrops in the Chicago region, or are very shallowly covered with drift, undoubtedly suffered some erosion; an especially high percentage of dolomite boulders in the drift to their lee establishes the fact. Yet glacial erosion largely failed to modify this buried stream-carved topography. Certainly the surviving relief and its character indicate that Martin's estimate[12] of 100 to 200 feet of glacial erosion on the Niagaran of Wisconsin is far too great for northeastern Illinois.

A remarkable trench, called Hadley Valley (figs. 19, 20), across the bedrock divide between the St. Lawrence and Mississippi drainages is clearly younger than the other bedrock valleys.[13] It was discovered by the use of earth-resistivity methods, and its existence is substantiated by numerous well logs. Instrumental data show that thick unconsolidated deposits buried beneath the Valparaiso till along the valley of Spring Creek (Mokena quadrangle) continue eastward across the present divide to the headwaters of Mill Creek drainage near Orland Park. Hadley bedrock valley here underlies these deposits, its floor about 540 feet above mean sea level, its depth from 75 to 100 feet, and its course followed by the pre-Valparaiso Spring Creek Valley. The line of deep, poorly drained depressions in the northeastern part of Mokena quadrangle, ditched to drain to Spring Creek, also lies along the buried valley's course. The present divide, almost on the east edge of the Mokena quadrangle, determined by drift in and above the old valley course, is between 710 and 715 feet above sea level, and bedrock at this place is at 500 feet. As the bedrock summits on either side of the buried valley average 630 to 640 feet, the bottom of the present valley in drift actually lies higher in general than the top of the valley in bedrock (fig. 21).

Seven miles northwest of Hadley Valley, the DesPlaines Valley, cut into bedrock, is a functioning drainage way across the buried divide. The surprising thing about the DesPlaines Valley is that its floor has an altitude of 585 feet, 45 feet higher than that of Hadley bedrock valley. Two parallel valleys across a bedrock divide only 7 miles apart seems an extraordinary consequence of glacial derangement of drainage. That the surviving and functioning one is the shallower makes it at once evident that the two cannot be contemporaneous in origin. The earlier one must be the Hadley trench, and the later DesPlaines Valley could have developed only if the earlier valley became buried by drift which accumulated there until its surface was higher than at the site of Lemont.

Both these transections must have been

[12]Martin, Lawrence, The physical geography of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 36, 2nd ed., p. 251. 1932.

[13]Horberg, Leland, and Emery, K. O., Buried bedrock valleys east of Joliet and their relation to water supply: Illinois Geol. Survey Circ. 95, 1943. Horberg, Bull. 73, p. 44.

initiated by glacial damming of the Lake Michigan basin and discharge of ponded water westward to the Mississippi. The Hadley buried valley has been eroded 75 to 100 feet deep in rock, the DesPlaines trench has been cut about 40 feet into the limestone. Both figures suggest a longer occupancy by discharging lake waters than seems provided by the duration of a glacial dam.

Hadley Valley may have been made by discharge from Nebraskan and Kansan "Lake Chicagos" across the divide. The DesPlaines transection may have been made by a late Illinoian "Lake Chicago" discharge which may have continued as an ice-free "Lake Michigan" discharge during the following interglacial interval; there was the post-Lemont discharge of a "Lake Chicago" of that time; there was the ensuing pre-Minooka substage of stream-valley erosion; and there was the discharge of the post-Tinley Lake Chicago. The postglacial DesPlaines has added little if anything to the sum of valley-deepening and need not be considered. Presumably the pre-Minooka occupancy was also a "Lake Chicago" discharge and its duration was probably as long as the other two episodes combined.

Yet the bedrock valley at Lemont falls 45 feet short of the depth reached by the buried Hadley Valley. The highest place on the floor of the buried valley is 40 feet lower than the surface of Lake Michigan, and were it drift-free today, the three great lakes, Michigan, Huron, and Superior, would be draining through it to the Mississippi instead of discharging to the St. Lawrence.

It seems a plausible inference that, in some pre-Lemont Pleistocene epoch or epochs, the outlet of these three lakes was through Hadley Valley and thence, by way of the Mississippi, to the Gulf of Mexico. This concept would allow water enough and time enough for the buried valley's incision of 75 to 100 feet into the late Tertiary and early Pleistocene bedrock divide.

The first waters diverted across the divide through Hadley Valley flowed by way of Kempton and Mahomet (Teays) valleys to join the Ancient Mississippi south of Peoria. After ice covered the region, at least by Kansan time, the drainage from Hadley Valley was westward to Ticona Valley,[14] joining the Ancient Mississippi River southwest of LaSalle (fig. 19).

Inspection of figure 20 will show three unusual features of the buried Hadley Valley: (1) the altitude of its floor descends both to the southwest, which the interpretation requires, and the northeast, which the interpretation will not explain; (2) traced westward, the valley becomes divided into two equally capacious valleys, both of which reach the DesPlaines in the eastern part of Joliet; (3) the bedrock floor of the DesPlaines at Joliet "hangs" above the floor of the buried valley at their junction. These features require special explanation.

For the first, it is suggested that in the preglacial cycle two tributaries headed nearly opposite each other on the buried divide—one flowing to the St. Lawrence, the other to the Mississippi—and that the earliest "Lake Chicago" found here the lowest place across which to spill westward. The large glacial river widened the two opposite-flowing valleys at the time it initiated the steep-walled trench that connects them. Subtributary drainage to the northeast-flowing stream is clearly recorded in the bedrock contour map.

The second feature, the separation of the trench into two valleys, each as wide at the bottom and as steep-sided as the main trench, is abnormal for a stream valley. It seems to demand so great a volume of glacial water as to overrun one of the existing valley-walls. Here the overflow appears to have found a minor tributary valley, down which it spilled to the head of River Ticona. The demand for extra spillway capacity was met by deepening in the overflow route, hence the distributary character of Hadley Valley on the extreme western edge of the Mokena quadrangle.

The third noteworthy feature is the altitude of bedrock in the DesPlaines valley-floor at Joliet where it is joined by Hadley

[14]Willman, H. B., Preglacial River Ticona: Ill. Acad. Sci. Trans., vol. 33, pp. 172-175, 1940; Illinois Geol. Survey Circ. 68, pp. 9-12, 1940.
Horberg, Leland, op. cit., pp. 56-57.

Valley. The buried valley's course is continued as a trench about 25 feet deeper in rock than the floor of the DesPlaines Valley north of the junction. The low rock-floor below the junction belongs to the buried-valley profile; it was cut deeper than the DesPlaines rock floor above that junction. This feature agrees with the age relations already pointed out and, indeed, is required to make the hypothesis consistent.

Spring Creek does not follow either of the two distributary valleys in bedrock for their full length. Instead, it crosses the buried hill between them, uncovering the very top of the hill in the bottom of its channel in sec. 6, T. 35 N., R. 11 E., and sec. 1, T. 35 N., R. 10 E., on the Joliet quadrangle. Similarly, Hickory Creek fails to follow its preglacial valley, cutting into buried rock hills on the south side of the old valley course in four places in the vicinity of New Lenox and in one place on the north side, 1 1/4 miles east of Joliet city limits. Both Spring and Hickory Creek valleys have normal widths at these places, hence are not to be interpreted as simply sags in the surface of the Lemont drift because of underlying bedrock valleys. Their courses were not entirely controlled by such sags; their widths were determined by stream erosion during a post-Lemont, pre-Minooka erosional interval. Marley Creek, with a valley proportionately capacious, has no bedrock valley beneath it. This fact strengthens the conclusion that it was stream erosion which made these pre-Valparaiso valleys of the Mokena quadrangle.

## ILLINOIAN (?) STAGE

### Sub-Lemont Drift in Buried Hadley Valley

Sub-Lemont drift 85 feet thick nearly or completely fills the buried Hadley Valley as revealed in a test well drilled for the Illinois State Geological Survey. It consists of alternating till and washed materials, all characterized by the presence of brown shale occurring as pebbles or as comminuted material in the matrix. There are probably four till members. Some of the till is very hard when dry because of the high percentage of clay. Some of it is very sandy, and its lumps are soft and crumbly. Yet its matrix has so high a percentage of comminuted shale that its color is dark brown instead of gray. One clay member, 11 feet thick, has a few small pebbles scattered through it and some small elliptical cavities which seem to record gas bubbles in the clay when it was being deposited.

There is no evidence of weathering or groundwater staining in the entire section. Because it is buried beneath Lemont drift, it can be no younger than that formation, and it is probably of Illinoian age (p. 63).

### Lemont[15] Drift

The identification of a previously unrecognized sheet of drift in the Chicago region is one of the important additions to our knowledge of the Pleistocene that resulted from this study of the region. The discovery was possible largely because there was an abundance of fresh highway cuts when the study was undertaken. By the time this report is published, these cuts will be so largely covered with grass that most of the exposures will have disappeared. One splendid exposure, however, promises to remain clean for many years and has been chosen as the type exposure. It lies about a mile west of the town of Lemont (Joliet quadrangle), just outside the Chicago region as defined in this report.

[15]Name first published in Bull. 65, Part I, 1939.

FIG. 22.—Lemont till in ravine wall, one mile west of Lemont.

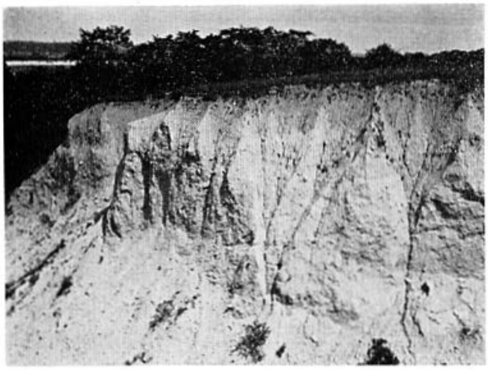


FIG. 23.—Lemont till overlain by Valparaiso till, one mile west of Lemont. The contact is at the top of the vertical faces of the buttresses between gullies.

FIG. 24.—Contact between Valparaiso and Lemont tills, one mile west of Lemont. The older till maintains nearly vertical cliff faces, the gentler slope in the profile is on the clayey Valparaiso till.

#### TYPE LOCALITY

Lemont was formerly the center of an active quarry industry. The Niagaran dolomite here crops out extensively or lies close to the surface of the DesPaines valley floor for several miles. It is unusually well bedded and some strata are fine textured and desirable for flagstone and building stone. Before concrete, hard-burned brick, and terra cotta appeared, it was in great demand in Chicago, Joliet, Aurora, and nearby smaller towns. One quarry or group of quarries, on the south side of the DesPlaines and a mile or so west of Lemont, found desirable stone back in the base of the bluff under a heavy cover of drift. It was worth the additional cost of removing the overburden, and before the industry waned and died, the removal of the glacial deposits produced a cliff about a mile long and as much as 50 or 60 feet high. Though this cliff of unconsolidated material has stood untouched by man for fifty years, it still constitutes an excellent exposure. It is the type exposure for the Lemont drift.

#### THICKNESS

Debris from ravine erosion and slopewash has obliterated the quarries and all but concealed the bedrock at the foot of the cliff. Valparaiso clayey till appears in a few places at the cliff summits. Otherwise, the entire section here exposed consists of various phases of the Lemont drift. Its maximum thickness is about 60 feet.

#### CHARACTER IN THE TYPE LOCALITY

The term *drift*, instead of *till*, is used advisedly. Much of it, though undoubtedly of glacial derivation, is not till, but consists of washed products of till—gravel, sand, and silt—very irregularly associated with each other. The exposures generally show till above the washed sediments, although in some places till is intercalated in the stratified material. The till is strikingly different from Valparaiso till anywhere in Illinois. Valparaiso till is clayey, weathers brownish, has a starchy fracture in the weathered portion, contains very few stones, and has a lime-enriched zone at the proper depth in its soil profile. The till of the Lemont drift is silty, not clayey, is distinctly yellowish rather than brownish in weathered portions, has a laminated structure instead of a starchy fracture, is well-charged with stones, and shows no lime enrichment. There are many shale pebbles in the Valparaiso till but almost none in the Lemont till.

FIG. 25.—Coarse gravel beneath till. Lemont drift one mile west of Lemont.

Till varies with source material and with conditions at time and place of deposition. The above-listed contrasts, therefore, might exist in well-separated areas of the same till sheet. But where they occur in the same section, as they do near Lemont, and the clayey till is sharply separated from the silty till below, they definitely suggest two different till sheets. And when the contrasts are found to be the same in dozens of other exposures in the Mokena (Map 17), Sag Bridge (Map 13), Hinsdale (Map 9), Tinley Park (Map 18), Palos Park (Map 14), Joliet, and Wheaton quadrangles, the case for a pre-Valparaiso drift in the Chicago region becomes much stronger.

In the type locality, the Lemont drift is highly variable both vertically and horizontally, and its glaciofluvial material appears to have been deposited in proximity to ice, the till being laid down by an advance of that ice over the outwash material. Some of the sand and gravel is sufficiently cemented to yield boulder-sized fragments of sandstone and conglomerate when excavated and gullied.

The drift is tan to buff in all but one of the exposures west of Lemont. The exception is a blue unoxidized till mass exposed in the lower slopes of the easternmost ravines in the quarried area west of Lemont. Above it is buff till. A dolomite slab 18 inches in maximum dimension was found standing edgewise at the sharp contact, half in the blue till, half in the overlying buff till. The blue till was wetter at the time of observation, suggesting less-ready escape of seepage from the bluff through it and, therefore, less permeability, although both are clearly parts of the same till mass. The most interesting feature is a bright orange sand immediately beneath the blue till, grading downward into a yellow sand, which in about 2 feet grades into the normal tan or buff sand. The strongly colored sand is incipiently cemented with iron oxide. Locally the sand has been deformed by ice thrust; blue till and yellow-to-orange sand are interfingered. Only groundwater can be the cause of the coloration of the sand.

### OTHER EXPOSURES

A deep ravine in Lemont (Sag Bridge quadrangle—Map 13) separates two residential districts on the bluffs south of the business district. Only the clayey Valparaiso till is exposed in cuts and excavations on the bluff slopes and summits, but in the ravine walls the yellow silty Lemont drift underlies the clayey till, and in one place near the mouth the contact of the two is shown in the ravine floor. Both the stratified silt and the very stony silty till are present. A marked descent of the contact of Valparaiso till and Lemont drift in crossing the valley indicates a pre-Valparaiso depression here, filled during the later advance, and now re-excavated. It is exactly what would exist if ravines had been eroded in the Lemont drift during a pre-Valparaiso interval of deglaciation, and this suggestion is supported by similar evidence from other places.

The south bluff of the DesPlaines Valley for a mile and a half west of Sag Bridge village (Sag Bridge quadrangle—Map 13) is mapped as Lemont drift. It is the most extensive outcrop known, except in the cliffs west of Lemont, but at present it is very poorly exposed. Slight cuts have been made in the five ravines which here trench the bluff, and a good cut was made at the east end of the exposure when Archer Avenue was graded and paved. At a height of 80 or 90 feet above the adjacent valley floor, 4 feet of brownish clayey till is shown overlying 8 feet of yellowish very stony till, with some silt or clay layers in it. The most marked difference between the two tills is in the clay content. The yellow lower till, though damp, will not make a slippery surface between thumb and forefinger, nor will it pinch out into a wafer without crumbling. The upper till will do this readily. Indeed, the upper till's damp starch-like fragments are slightly adhesive even when lightly touched.

Several hundred feet downhill along Archer Avenue, actually 30 feet lower in altitude, 4 feet of clayey Valparaiso till overlies 15 feet of stratified silt. Most of the silt is dark reddish-brown, but the basal few inches is yellow or orange-yellow, and the intervening few inches is bluish. Below the silt is 1 foot of very stony yellowish till resting on Niagaran limestone. The brownish silt effervesced moderately under acid, the blue silt vigorously, and the basal yellow silt faintly. Neither the color differences nor the responses to acid are distributed vertically, as they would be in a soil profile; groundwater changes, rather than weathering down from the surface, must have been responsible. These sections along the Archer Avenue grade, from valley floor to upland, show that the Valparaiso till was deposited as a thin veneer on a preexisting valley slope. The Sag-DesPlaines Valley was here before the Valparaiso glaciation.

Highway cuts along 107th Street west of 109th Avenue exposed Lemont drift at the base of the north bluff of Sag Valley (Sag Bridge quadrangle—Map 13). A ravine eroded in the south slope of Mt. Forest Island, a mile west of Palos Golf Club, also shows Lemont drift and will do so long after the highway cuts are obscured.

The best exposure in the ravine is just below the common junction point of three tributary gullies. Six feet of clayey till, crumbling into hard starchy lumps that resist crushing in the fingers when dry, overlies a reddish-to-yellowish sand, beneath which is 15 feet of a stony till which contains so little clay that it does not smear or stick to the fingers when damp. Its color, however, is bluish gray, not yellowish. The section is in the lower wall of the ravine, hence is much farther below the upland level than the thickness of the Valparaiso till here might suggest. The 107th Street cuts, which are still lower, displayed only Lemont drift in which the predominant constituent was yellow silt. Borings showed that this silt was bluish 5 to 10 feet below the road grade. The yellow color is due to oxidation, just as is the brown color of Valparaiso till.

An old pit along the Santa Fe Railroad, about a mile southwest of Byrneville (Sag Bridge quadrangle—Map 13), in the north slope of the DesPlaines Valley shows the two tills in section. The pit has been unused for twenty-five years, the cut bank has become obscured by slumping, and the sections are so poor that considerable digging with a spade was necessary. There is a body of cemented gravel beneath the lower till, which is no longer exposed, but abandoned masses of it lie on the pit floor.

Swallow Cliffs, along the south side of Sag Valley in the Palos Forest Preserve (Palos Park quadrangle—Map 14), are composed almost wholly of Lemont drift, although Valparaiso till covers the forested upland and comes to the cliff edge in some places. The exposures in general are poor, the best ones occurring in the ravine just west of 96th Avenue. One of these is "Swallow Bank," a small cliff of yellowish silt and very fine sand fenced off to allow bank swallows to nest in it undisturbed. Another is the very active gully, described in Part I of this bulletin (p. 24), which has developed on the site of a former farm-road down the bluff. It shows Valparaiso till above the very fine sand. The 96th Avenue cuts, before they were planted, also showed Valparaiso clayey till above Lemont drift, which here consists of till, gravel, and fine sand. Several other cut banks in ravines of the Palos Forest Preserve show Lemont drift, chiefly the fine buff or yellow sand.

For years, this silt and fine sand has been interpreted as a loess, although apparently there is no published statement to that effect. Its fineness and evenness of grain, its lack of pebbles through considerable

Fig. 26.—Swallow Bank, Palos Park Forest Preserve. An exposure of silt of the Lemont drift. Clayey Valparaiso till overlies this silt farther back up the slope.

thicknesses of the deposit, and its ability to maintain steep faces in cuts, seemed to substantiate the hypothesis. There is a delicate cross-bedding in some exposures of the fine sand, interpreted as eolian in origin. If this is correct, the deposit should be considered as fine dune sand rather than as loess.

Since cross-bedding is also produced by streams and shore currents, it is necessary to examine this structure critically. The cross-bedding is on a minute scale, the lenses or unit groups of inclined laminae being rarely more than an inch thick. The foresets of associated units all dip in the same direction. The assemblage is that of horizontal beds made up of the lenses of dipping laminae. In some places definite layers of clay are present, most of them thin, but some are as much as 2 inches thick. Rarely also pebble layers are found in the sand. Vertical gradation from cross-bedded members to evenly bedded ones is common. No unconformities of the sort that cross-bedded dune sand commonly possesses have been found in the deposit. It seems clear that the surface of the deposit remained flat at all times during its growth. The texture of the material is everywhere much finer than dune sand, so fine that if wind-whipped it would be more likely to rise in the air like dust than to drift close to the ground like dune sand. Yet the cross-bedding shows that it was rolled along. The most satisfactory interpretation of the silt and fine sand in Swallow Cliffs and vicinity is that it was carried by gentle currents of water over a wide flat of aggradation. It is outwash silt associated with the silty till and is a part of the Lemont drift.

Excellent exposures of the Lemont drift were made when the Wabash Railroad relocated its right-of-way through Palos Park. However, before this study was undertaken there was much slumping at the exposures and many details were lost. A vertical section at one place was cleaned of its slump debris and described in a Master's thesis[16] written a few years after the cut was made. Nearly 20 feet of Valparaiso till was found in the top of the section, underlain by a 3-foot "boulder stratum," this in turn resting on 2 feet of washed gravel. Under the gravel was 10 feet of the silt (the so-called loess), and beneath that was a till. The Valparaiso till was brown except for the basal portion, which was an unoxidized blue. The boulder stratum was a heterogeneous unstratified mixture of clay, sand, pebbles, and striated cobbles and boulders. It very probably was till. The matrix had an oxidized brown color and, whatever the origin of the deposit, an explanation for this oxidation beneath unoxidized basal Valparaiso till is needed. The 10 feet of silt is described as "typically buffish-yellow" except in the lowest part, which is bluish.

From memory of the cut when freshly made, only four characteristics of this section can apply in general to the entire cut: (1) the brown clayey Valparaiso till everywhere was the uppermost member, (2) the yellow silt was a large constituent of the material exposed, (3) gravelly members occurred, and (4) in a few places a stony till was associated with the silt and gravel. There was no constant order of succession of the members below the uppermost till. There was great irregularity of thickness of the members except for the uppermost clayey till. There were notable contrasts of color, ranging from unoxidized blue to oxidized yellow-orange. There was considerable deformation of the stratified members of the Lemont drift, caused probably by thrusts from overriding Valparaiso ice. Three features will need more attention when the remaining sections of Lemont drift have been described: (1) the marked oxidation in certain portions beneath unoxidized Valparaiso till, (2) the silty character of the till, and (3) the occurrence of silt as the only well-washed product from the till.

The Southwest Highway, when newly graded, afforded an interesting cut a few hundred feet north of 119th Street in the Palos district. Almost all the material exposed was yellow silt; in a few places, at the base of the cut, the silt was bluish or bluish gray. It was stratified, though rather

[16] Bolyard, G. L., Pleistocene features of the Palos Park region: unpublished Master's thesis, Dept. Geology, Univ. of Chicago, 1923.

indistinctly so, and showed no cross-bedding. The most interesting feature of this section was the great distortion of the silt. In some places the stratification was vertical; almost everywhere it departed from the horizontal. The blue silt appeared only where there had been up-squeezing, and in one place a mass of blue silt with vertical beds was entirely wrapped around by the yellowish and brownish distorted silt. The thrust appears to have come from the northeast; the narrower, sharper folds leaned toward the southwest. Ice thrust seemed the probable cause of the deformation, but there was no till in the section above the silt.

In one place, however, there was a filled channel 10 feet deep in the silt (fig. 27). The channel for the most part contained coarse, poorly sorted gravel but on the east side of the highway it graded into a gravelly clayey till which occupied about a fourth of the cross-sectional area of the channel. The gravel thus appeared to be a subglacial stream deposit and the channel to have been eroded beneath the ice. That this was Valparaiso ice cannot be affirmed from the evidence, though it is known that elsewhere deformation was caused by Valparaiso ice thrust. Lemont ice may have overridden this silt shortly after deposition. The silt is lacustrine but not a deposit of the post-Valparaiso Lake Chicago. The widely distributed exposures of silt of very similar character and definitely pre-Valparaiso age suggest that perhaps there was a "Lake Chicago" of Lemont age. But the silt is closely related to Lemont till and outwash gravel—in some places it underlies the stony, silty yellowish till—indicating that more probably it was deposited in local lakes, lying close to the ice, and here and there obliterated by the advance of Lemont ice.

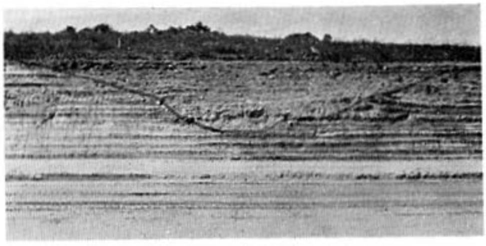


FIG. 27.—Gravel-filled channel in Lemont silt. Southwest Highway, south of Sag Canal.

Lemont drift is well exposed in the southwestern part of the village of Worth, along the Southwest Highway, and in a gravel pit east of the highway and south of 111th Street. The highway cut was studied during its excavation. It revealed irregular bodies of yellow silt, coarse gravel, and yellow laminated silty stony till, some of them originally irregular, but some obviously formed by squeezing and kneading when the thin clayey Valparaiso till was deposited on top. Especially good evidence of kneading is the incorporation of masses of gravel in distorted silt, as is found in the roadside pit at the intersection of 111th Street and Southwest Highway.

The deepest part of the long highway cut showed bluish-gray silt (now covered by the pavement), but elsewhere the silt was light yellow or tan, from oxidation since its deposition. Along with the oxidation one expects leaching, but there is surprisingly little evidence of this, most of the silt being as calcareous at the top as at the bottom.

The gravel pit in Lemont drift lies south of 111th Street and between the Southwest Highway and the Wabash Railroad. Its maximum depth is about 20 feet, the upper 3 or 4 feet consisting of brown clayey Valparaiso till. The section below this grades from all gravel at the east end to all silt about a thousand feet farther west. No Lemont till is exposed. The noteworthy features of the Worth pit section are the gradation westward from gravel through sand to silt and the west-dipping foreset

FIG. 28.—Delta foreset bedding in Lemont drift near Worth.

FIG. 29.—Foreset bedding in Lemont drift near Worth. Two delta lobes are recorded, the one to the left younger and overlapping on the one to the right.

beds of the gravel and sand (figs. 28 and 29). The deposit is part of a delta, probably recording a glacial river that debouched here in a lake. The silt is the offshore lake sediment, laid down beyond the delta edge. The topography is not now that of a delta, for the Valparaiso ice sheet has overridden it, and there may have been other alterations in form after its deposition and before the Valparaiso glaciation. But the foreset beds shown in figure 29 dip toward each other, and also toward the photographer (which does not show in the photograph); these relations can only mean that a delta lobe at the right was later encroached on by one at the left.

Beneath the cover of Valparaiso till the gravels in one place are oxidized for a depth of several inches, and the limestone pebbles are etched and softened, suggesting the remnant of a weathered zone developed after the Lemont glaciation and before the Valparaiso till was deposited. But the same result might be produced by groundwater in the porous gravel while the dense clayey till immediately above remained unaffected.

Recent excavations in this pit, since the field work for this report was completed, have exposed Lemont drift so decomposed that Leland Horberg, who found it, is fairly confident that it is a surface-weathering product. Depth of leaching reaches a maximum of 40 inches, a figure strongly suggesting that the Lemont drift may be Illinoian in age, instead of early Wisconsin. The upper part of this weathered material, although disturbed by the overriding Tinley ice, constituted a maturely developed B zone.

A large but shallow borrow pit, worked when 119th Street was graded and paved, lies a few hundred feet southwest of the intersection of 119th and Harlem Avenue (Palos Park quadrangle—Map 14). A foot or so of clayey till overlies 5 or 6 feet of gravel with depositional dip westward. Beneath the gravel is finely laminated gray silt, nowhere more than 6 or 8 feet from the surface. Except in color, this silt is identical with that of the Lemont drift, and almost nowhere is silt known in association with the Valparaiso till. If it is of Lemont age, its lack of oxidation so near the surface indicates that the yellow color is pre-Valparaiso in age and that in the later overriding the weathered zone was entirely removed. If this interpretation is correct, one might expect to find masses of stained Lemont drift embedded in Valparaiso till.

Three low gravelly knolls on the lake-bottom plain east of Ridgeland Avenue and north of 127th Street are mapped as Lemont drift. All have gravel pits in them. Two of the knolls are composed chiefly of floury, velvety yellow silt, associated with gravel which has west-dipping beds. In one, the washed gravel grades into a very poorly washed phase in which yellow silty material is a prominent constituent. This is taken to be modified Lemont till. Over the till, gravel, and silt is the Valparaiso clayey till, and above that is beach sand of the Calumet stage of Lake Chicago.

Washed gravel is commonly associated with the Lemont till—much more commonly than with the Valparaiso till. It has been noted already in the exposures in the old Santa Fe pit (p. 60). A ledge of cemented gravel crops out in the mouth of the ravine just west of the ski jump in Palos Park Forest Preserve. The large pit at Worth is in similarly associated gravel. From these relations, it is a fair inference that beds of clean gravel which lie beneath Valparaiso till in the general region of the outcrops of Lemont drift belong to the earlier deposit. Two such bodies of gravel are to be noted here as probably of Lemont age, though the exposures do not show the characteristic yellow, silty, stony till or the commonly associated yellow silt.

One of these gravel deposits underlies a terrace on the north side of Sag Valley where it is crossed by Kean Avenue (Palos Park quadrangle—Map 14). A large spring discharges from it, there are many seepages from it, and shallow wells in it yield abundant supplies of water. It is not mapped as Lemont drift because its age has not been definitely established and because the surface is covered by gravel of the Lake Chicago outlet river. Indeed, it may all be related to that river and not Lemont in age.

What may be the same gravel underlies the Tinley moraine just north of the terrace. Wells near the intersection of Kean and 107th Street find it at about 625 feet above sea level, 5 to 10 feet higher than the terrace top. Its thickness is unknown, and its maximum known horizontal extent beneath the till is only half a mile. It may be related to an earlier Valparaiso glacial river along the Sag, before the Tinley readvance occurred and before Lake Chicago began.[17] It may also be outwash deposited during the Tinley readvance and overridden by Tinley ice shortly afterward.

The other gravel deposit suspected of belonging to the Lemont drift is in the north bluff of the DesPlaines transmorainic valley a mile north of Willow Springs (Sag Bridge and Hinsdale quadrangles—Maps 13, 9). This area was extensively excavated years ago, but subsequently the cuts have become greatly obscured. At least 25 feet of dominantly limestone gravel is overlain by 12 to 15 feet of clayey till. The contact is sharp, and the gravel for a few inches below the till is so solidly cemented that it resembles concrete. Here and there cementation sufficient to make boulder-like masses (fig. 30) has occurred deeper in the gravel. There is a slight brownish stain locally in the upper few inches of the gravel; otherwise its only alteration is the partial cementation. Blue

FIG. 30.—Mass of cemented gravel in pit near Willow Springs.

clay 7 or 8 feet thick is reported to underlie the gravel, beneath which is said to be an even cleaner gravel. The gravel is well above the nearby Flag Creek morainic sag, hence must be a pre-Valparaiso deposit.

In a pit south of Fifth Avenue, half a mile farther northeast (Hinsdale quadrangle—Map 9), there is no gravel, but 5 feet of yellow silty stony till underlies a cover of clayey till and is underlain by clean sand, part of it current-bedded, with westward dip. Here apparently are both Valparaiso and Lemont tills, the Lemont again associated with material reworked by glacial water. Indeed, it is the writer's belief that essentially all the well-sorted sand and gravel bodies below Valparaiso till along both Sag and DesPlaines valleys above their junction belong to the Lemont drift.

#### LEMONT DRIFT IN YOUNGER TILLS

The miles of fresh highway cuts available when this study was made afforded a

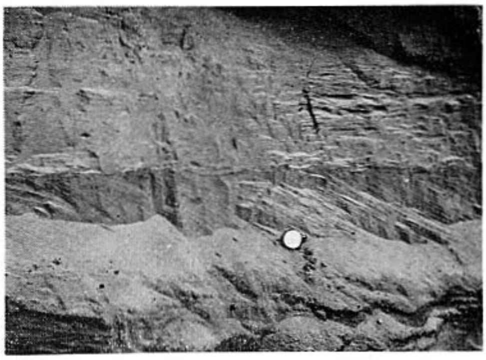


FIG. 31.—Cross-bedded sand in Lemont drift near Willow Springs.

[17]This possible Lemont gravel is not to be confused with the gravel shown on the Palos Park geological map on both sides of 96th Avenue and south of 107th Street, which is definitely outwash deposited when the Tinley moraine was being built.

short-lived opportunity to search for masses of older drift embedded in Valparaiso till. It was suspected that the Lemont drift had undergone much weathering before the Valparaiso glaciation, but none of the sections really proved this; a complete profile of weathering could not be found. Two conflicting interpretations were possible: (1) the Valparaiso ice had removed the upper part of a normal weathered zone, and (2) the Lemont drift had oxidized beneath the Valparaiso till, exceeding the oxidation of the clayey till because of greater porosity. If masses of Lemont drift could be found in the Valparaiso and Tinley tills, sealed by the dense clay from air and water except what the tills contained in their own interstices, and if such masses were definitely leached and oxidized, the concept of pre-Valparaiso weathering would be greatly strengthened.

A cut near the intersection of Harlem Avenue and 135th Street, 2 miles southeast of Palos Station, 3 miles south of Worth (Palos Park quadrangle—Map 14), is typical of many of its kind. It is on the east side of Harlem Avenue, 400 feet north of the intersection; it is illustrated in figure 32. An irregular mass of stratified yellow silt 3 1/2 feet thick and 10 feet long is completely surrounded by clayey Tinley till, the layers of the silt much distorted. Associated with it are half a dozen smaller masses of red-stained silty gravel, their stratification also distorted, and one of them partly in the silt and partly in the clayey till.

Figure 32 shows enough of the weathering profile in the Valparaiso till to make it clear that the masses of red gravel are distinct from the till and are blocks incorporated from an older deposit, already stained at the time they were embedded in the till. The iron-stained horizon of the till itself lies above two of the gravel masses and largely above a third. Three small blocks are in the most heavily stained till but, like all these fragments, are considerably darker than the till. Further evidence here is afforded by two small stringers of unweathered clay penetrating from the surrounding till for 6 and 18 inches respectively into the oxidized silt block. They do not show in the photograph. A similar feature from another cut nearby is illustrated in figure 33.

A highway exposure showing a mass of older and more weathered drift enclosed in

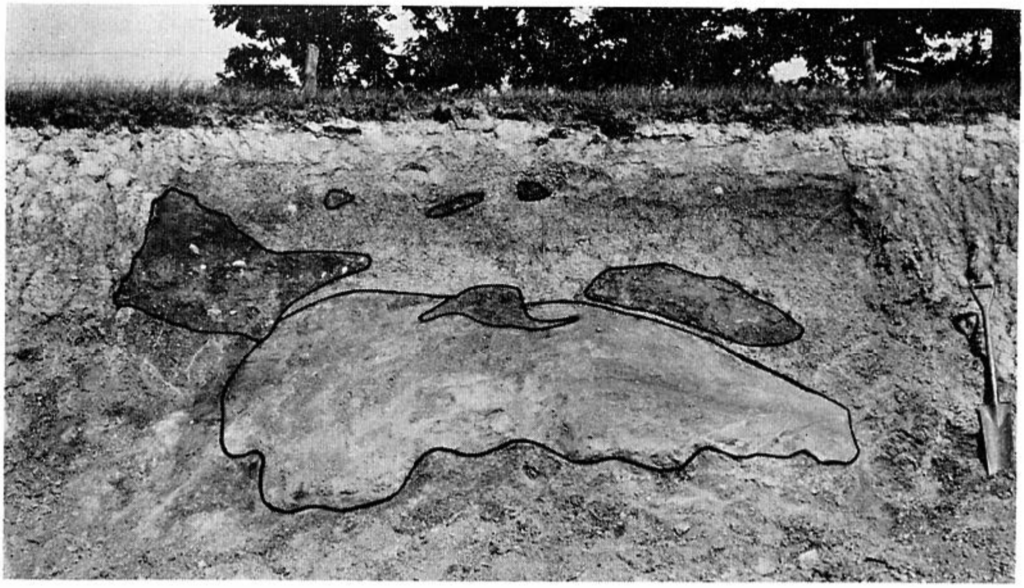


FIG. 32.—Masses of Lemont drift included in Tinley till. The large mass is composed of yellow silt, the smaller and darker masses are of reddish gravel. East side of Harlem Avenue, north of 135th Street (Palos Park quadrangle). Photograph by Paul MacClintock.

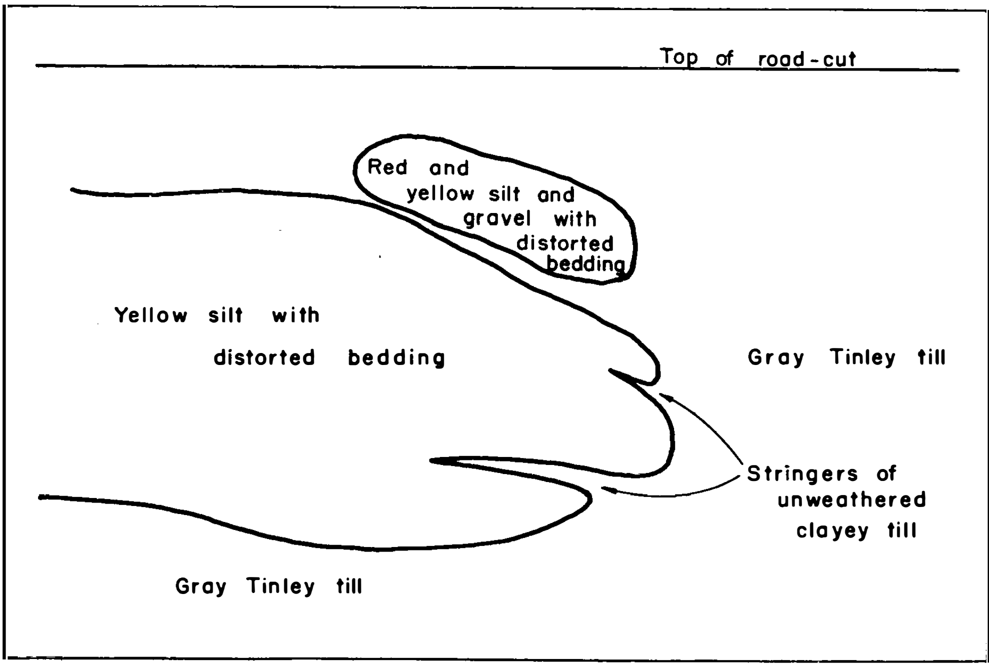



FIG. 33.—Sketch showing masses of Lemont drift included in Tinley till. Corner of Harlem Avenue and 135th Street.

Valparaiso till was found in the cut through the hill on 143rd Street, a mile west of Orland Park and just east of the junction of 108th Avenue (Sag Bridge quadrangle —Map 13). Six feet of typical Valparaiso till, leached to a depth of 4 feet, overlies a foot of dark fine gravel, beneath which is a foot of unleached clayey till, and below that 6 feet of silt and fine sand, brownish to yellowish in places but gray in large part, to the bottom of the cut. The silt and sand is leached for 3 or 4 feet down. Four feet to the side of this vertical sequence, the Valparaiso till extends down to the silt and sand. There is no dark-stained gravel with unleached till above and below. The gravel therefore is a mass of older drift included in the Valparaiso till. A third vertical section, a dozen feet distant, shows the clayey till to extend below the level of the bottom of the first section. Therefore, the silt and fine sand probably is also a fragment of the older drift enclosed in the Valparaiso till. Complete outlines of fragments were impossible to obtain because the cut had already slumped considerably at the time of examination.

Only one other highway section showing older drift incorporated in the Valparaiso till will be described, although there are several others known in the southern part of the region. It was exposed in grading for the 26th Street crossing of Thorn Creek Valley just west of Chicago Heights (Steger quadrangle—Map 23). Tinley till constitutes the material, but when cuts were fresh, several blocks of older drift were recognizable, the largest 6 feet across. Some of these were of sandy yellowish till, distinctly unlike the matrix till; some were of sand and gravel, with distorted bedding. The included fragments effervesced with acid but none as vigorously as the enclosing clayey till. Furthermore, in the largest included mass, which has nearly horizontal bedding, the least effervescence was found in the lower part, the most in the upper. It seems logical to interpret this block as now upside down in its matrix.

### LEMONT DRIFT IN THE BURIED HADLEY VALLEY

A test-well drilled to bedrock in the middle of Spring Creek Valley, above the buried Hadley Valley, showed 27 1/2 feet of clayey Valparaiso till, 51 feet of Lemont drift, and 85 feet of gravel, sand, clay, and till beneath the Lemont materials. Identification of the Lemont drift was based on the silty character of its till and the absence of shale pebbles and of finely ground shale in the matrix. Both the overlying Valparaiso till and the 85 feet of drift beneath the Lemont contained shale, so abundantly in some samples from the lower drift that the material was dark brown and gave a marked brown smudge on white paper. Three till members were found in the Lemont part of the section, separated by two sand and gravel members. The upper member was tan, whereas the remainder of the Lemont drift was gray.

### CORRELATION

Considering the preceding data, it is clear that there is a body of drift beneath the Valparaiso till in the region of the Sag and DesPlaines transmorainic valleys which differs markedly from that till. The evidence strongly suggests that considerable time intervened between the two glacial overridings, though nowhere was a true soil horizon or a true loess found separating the drift sheets.

The position of the Lemont drift in the Pleistocene succession has not yet been positively determined, for no facts now in our possession seem to be conclusive. Several possibilities exist: (1) The Lemont drift may be older than Wisconsin, and the recent discovery of a weathered zone in Lemont drift at Worth (p. 63) supports its identification as Illinoian in age. (2) It may be the ground-moraine correlative of some earlier Wisconsin moraine farther west, although its material is unlike the till in any of them, at least along the line of glacial movement across and beyond the Chicago region. They are all more clayey till moraines, while the Lemont is a more silty till with an abundance of stones at almost every exposure. Further objection to this interpretation is that much of the Lemont drift was deposited by free-flowing extraglacial water, therefore is not a subglacial ground-moraine accumulation. (3) It may be that the Lemont drift was deposited during the pause at the end of a retreat from one of the Wisconsin moraines farther west and before a readvance occurred. Its survival under such conditions would be no more remarkable than its survival from the Valparaiso overriding. (4) It may be that the Lemont ice never advanced beyond the present known limits —that this drift is the record of an early Wisconsin advance which later was exceeded by those which built the moraines farther west.

The notable differences between the Lemont till and the other Wisconsin tills is another problem. Three interpretations are open to us at present: (1) it may be that an excess of escaping water removed clayey constituents and left the till silty and stony; (2) it may be that an earlier "Lake Chicago" left quantities of beach sand and gravel, dune sand, and lacustrine sand, which became incorporated in the till of the advancing Lemont ice and thus gave it the stony and silty character repeatedly noted; or (3) it may be that a somewhat different route was followed by the Lemont ice in reaching the region, and thus debris from different kinds of bedrock gave a different lithological aspect to the deposit.

The first of these tentative explanations seems the least probable for it requires almost complete removal of a dominant constituent of the till while leaving it a till. The second suggestion requires that a clayey till, from being dragged over a few miles of sand-, silt-, and gravel-covered country, became a completely different material. The third interpretation is supported by the fact that the silty Lemont till has very few shale pebbles in it whereas the clayey Valparaiso till has an abundance of them. Spores of *Sporangites huronensis* are in both the clay matrix and the shale pebbles and indicate that the Devonian black shales in the glacially eroded bed of Lake Michigan supplied at least some of the pebbles and clay. If the Lemont ice which traversed this region had come more nearly from the north than northeast, it would not have crossed the shale outcrops. Accessory evidence would be glacial striae on bedrock beneath Lemont till. The only place where these are known is in Sawmill Creek Valley, Sag Bridge quadrangle; but here the striae strike N.55° E., a course which if projected far enough back to the northeast will intersect the black-shale outcrop beneath the lake. The explanation therefore must be emended or discarded. A possible emendation is that the local Lemont ice travelled southward along the western edge of the lake basin and had turned southwestward before it reached the bedrock now exposed in Sawmill Creek bed.

### JOLIET OUTWASH PLAIN AND LEMONT DRIFT

The type exposure of the Lemont drift lies just outside the mapped limits of the Chicago region, a mile or so in the Joliet quadrangle. The Illinois State Geological Survey Bulletin 51 on the Joliet quadrangle[18] describes cemented gravels at this place but makes no mention of a pre-Valparaiso till here. The cemented gravel of the Lemont drift is correlated in Bulletin 51 with other exposures of cemented gravel in the quadrangle and environs. The interpretation is that after the Minooka moraine (8 to 10 miles west of Joliet) was deposited, the ice withdrew to a position east of the present Valparaiso moraine, while an extensive sheet of outwash sand and gravel was deposited in front of it, later to be overridden when the ice advanced at the Valparaiso moraine-building stage. This gravel Fisher called the "Joliet outwash plain."[19] He clearly thought the indurated gravel and sand to be older than Valparaiso.

Although Fisher specifically refrained from correlating all the cemented sand and gravel of the Joliet quadrangle with that near Lemont, it now appears that most of the sub-till gravels he reported may well belong to the Lemont drift. They appear to have been deposited beyond a moraine whose outer margin slightly overlapped the eastern edge of the Joliet quadrangle. Most of these cemented gravels are clearly older than the valleys in whose lower slopes they now outcrop and therefore older than the valley train gravel in the valleys. A suggested correlation of the Joliet outwash plain with the Algonquin gravels along Fox River northwest of the Chicago region is considered under a later heading.

### ADDITIONAL LOCALITIES

Localities where Lemont till is known or believed to be present, but which are not shown on the geological maps, are as follows:

Mokena Quadrangle (Map 17):

Hickory Creek Valley. Tributary flowing from Cleveland School, sec. 20, extreme SE corner of quadrangle. In hill spur projecting from the south, northeast of the schoolhouse. Also in bluff on south side of ravine, almost directly north of the schoolhouse.

Hickory Creek Valley. North side, in SE 1/4 sec. 13.

Intersection of Bell Road and 151st Street, cornering of secs. 11, 12, 13, 14, northern part of quadrangle, 4 1/2 miles north of Marley, in road cut.

Maple Street Road. Near the western edge of the quadrangle in several road cuts.

Sag Bridge Quadrangle (Map 13):

Intersection of Archer and Highway 4A, 1 1/2 miles south of Lemont, on west edge of quadrangle, in road cut.

Sawmill Creek Valley, in west bluff a little upstream from the place of the piracy.

Hinsdale Quadrangle (Map 9):

Flag Creek Valley, west bluff, extreme southeastern part of Hinsdale city limits, in road cut.

Tinley Park Quadrangle (Map 18):

Hickory Creek Valley, along Lincoln Highway south of Gatter School, in road cut.

Frankfort, northern part, 200 feet south of Lincoln Highway, along 96th Avenue, in road cut.

Palos Park Quadrangle (Map 14):

Southwest Highway, 3/8 mile south of Southmoor Country Club, in road cut.

Southwest Highway, 1 mile northeast of Orland Station, in ditch along roadway.

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[18] Fisher, D. J., The geology and mineral resources of the Joliet quadrangle: Illinois Geol. Survey Bull. 51, 1925.

[19] J. W. Goldthwait had earlier called it the "Joliet conglomerate." *See* Physical features of the DesPlaines Valley: Illinois Geol. Survey Bull. 11, p. 42, 1909.

Southwest Highway, about 1/10 mile southeast of Southmoor Country Club, in road cut.

## WISCONSIN STAGE

### TAZEWELL SUBSTAGE

#### BLOOMINGTON[20] (?) DRIFT

Well known to glacialists of the north-central states is the pink-to-red color of much of the Bloomington drift, the hue being deeper when the material is moist. One recognizes it in highway cuts west of Chicago, as soon as one has crossed the younger moraines. It is also found in places beneath the younger drift sheets, the nearest occurrence probably being in the southwest corner of the Joliet quadrangle,[21] where "there is a two-foot section of highly calcareous pink till underlying about 4 feet of laminated lake-clays, which are overlain by till of Minooka age." This till is very sandy, its pink color mottled with yellow, and the yellowish parts are apparently more sandy than the pink. In its sandiness it resembles the pink Bloomington till along the upper Illinois Valley.[22] Bloomington till is also known in the eastern part of the Elgin quadrangle, west of the northern part of the region. There it is beneath the West Chicago moraine, the outermost member of the Valparaiso system.

Fragments of pink-to-red drift, incorporated in the clayey till of the Valparaiso, Tinley, and Lake Border drift sheets, have been found in six quadrangles. In another quadrangle, pink till has been reported in sewer trenches and in a well. In another, a pinkish till is known *in situ* beneath two other tills. Most of the incorporated fragments are small and owe their discovery entirely to a notable contrast in color.

The largest fragments known were observed in a cut along the McHenry road half a mile southeast of Buffalo Grove, Wheeling quadrangle. Five different masses of deep pink till were embedded in yellowish Tinley ground moraine, in the lower part of the oxidized zone and below the leached zone. The largest was 3 feet in maximum diameter. All were irregular in shape and several fingers of yellow till were thrust into the pink or red till.

Excavations for a grade separation of Lake Street and North Avenue, almost on the county line in the northeastern part of Elmhurst, showed several masses of pink till, harder and more pebbly than the enclosing gray Tinley till. The largest mass was close to the bottom of the cut, perhaps 18 feet below the surface. In the dump from this excavation, there were many pieces of pink till.

Two fragments of pink till were cut through in an auger boring in the Tinley ground moraine at the Lake Street subway beneath the Chicago and Northwestern Railroad tracks, less than half a mile southeast of the intersection of Lake Street and North Avenue. They were 7 and 10 feet below the surface, embedded in bluish-gray unweathered till. Neither was more than 4 inches thick. This and the Buffalo Grove occurrence are about 30 and 17 miles, respectively, southeast and east of known Bloomington till in place in the Fox River Valley on the Elgin quadrangle.

Fragments of an unctuous red clay, which might be a derivative of the Bloomington drift, were found in the Bohnsack Brick Company's pit along the Soo Line tracks three blocks south of Irving Park Boulevard in the southeast part of the River Forest quadrangle. They were small (the largest only 2 inches in diameter) and were found within 6 feet of the surface. Similarly, in both the Illinois Brick Company's pits near Bernice, Calumet City quadrangle, small fragments of red clay are embedded in till. Workmen report them as 1 foot in maximum dimensions, generally elongated horizontally, but none that large was seen at the time of examination. They appear to be limited to a lower clay till, 18 feet or more below the surface. A third occurrence of small bits of the red clay in unweathered bluish till is south of Burnside, Calumet Lake quadrangle, directly east of the Illinois Central Railroad shops. A fourth place

[20] Named for Bloomington, Ill., which stands on a prominent portion of the moraine. Leverett, U.S.G.S. Mon. 38, p. 240.

[21] Fisher, Bull. 51, p. 73.

[22] Willman, H. B., and Payne, J. N., Geology and mineral resources of the Marseilles, Ottawa, and Streator quadrangles: Illinois Geol. Survey Bull. 66, p. 158, 1942.

where they have been found is the Illinois Brick Company's pit south of Deerfield and just north of County Line Road, Highland Park quadrangle, in ground moraine of the Lake Border system.

During excavation for the Chicago subway, numerous bits and one large fragment of unctuous red clay were found in the soft gray clayey Lake Border till underlying the downtown district. The large mass had an estimated volume of 2 cubic yards. They were not till and none possessed any laminae such as a lake clay might be expected to have. Many pieces showed outlines of interfingering stringers of red and gray and clearly had undergone kneading and squeezing while being plowed up by the ice and incorporated into the gray till. In some places the red clay fragments were so numerous that they constituted a breccia.

The large mass possessed a unique feature, so far as Chicago geology goes. The red clay enclosed many fragments of dark greenish-gray clay, from a quarter of an inch to an inch in diameter, fully as soft and unctuous as the enclosing red clay and certainly not bits of the surrounding gray clay or fragments of Devonian shale.

The red and pink till fragments may, as suggested, be Bloomington, and the red clay may be a lake sediment derived from Bloomington till before any of the later tills were deposited. This interpretation best fits the meager evidence but is only tentative. It would be strengthened if masses of red clayey till occurred in the Lemont drift, but none has been observed.

Pinkish and reddish areas a few inches to a few feet in diameter, but without definite outlines, in many exposures of unweathered Valparaiso and Lake Border till in the Chicago region suggest that older reddish drift has been mixed enough to obliterate all fragment outlines. The source of this incorporated material must be either beneath the younger tills of the region or somewhere to the northeast beneath Lake Michigan. It seems a fair inference that Bloomington drift may locally exist *in situ* beneath the Chicago region, but so far only one well, at the post-office building in Harvey, Harvey quadrangle, has been reported to penetrate a pink or red drift. Sewer trenches in Homewood and Chicago Heights (Harvey quadrangle), dug a few years before this study was undertaken, entered a pinkish clayey till unlike anything in excavations made after 1930 in these towns. There was an overlying gray or bluish-gray till in both places. Future deep digging in this quadrangle may add to our knowledge.

A peculiar section along the Chicago Drainage Canal, which includes three tills of notably different characters, should be mentioned. The lowest till, definitely in place, is itself slightly pinkish in color (see p. 77).

#### PRE-VALPARAISO TOPOGRAPHY

Previous writers on the geology of the Chicago region have described the upland west and south of the lake plain as a terminal moraine built at the Valparaiso stage of the Wisconsin retreat.[23] Back of it, according to their interpretation, the ponded waters accumulated as the ice sheet withdrew and over it in two places the discharge spilled westward into Mississippi drainage. They thought that both discharge ways were simultaneously deepened 40 feet or more, through the Valparaiso terminal moraine to bedrock. Subsequent drainage of a large part of the lake plain has continued to use both these outlet channels. Similarly, earlier writers considered that the irregularities of the upland belt were due to irregular deposition of the Valparaiso drift, and to subsequent stream erosion.

There are remarks in the early studies on the probability of pre-Valparaiso drift existing in the region. A "brown hardpan" found in wells and caissons, a very dense till exposed in the Drainage Canal a mile east of Summit, and the gravel beneath till a mile north of Willow Springs are the only deposits specifically referred to as perhaps pre-Valparaiso. The Lemont sections are noted in two of the early papers, but no

[23] Leverett, Frank, The Pleistocene features and deposits of the Chicago area: Chicago Acad. Sci., Geol. and Nat. Hist. Survey Bull. 2, 1897; Salisbury, R. D., and Alden, W. C., The geography of Chicago and its environs: Chicago Geog. Soc. Bull. 1, 1899; Alden, W. C., The Chicago folio (no. 81): U.S. Geol. Survey, 1902; Goldthwait, J. W., Physical features of the DesPlaines Valley: Illinois Geol. Survey Bull. 11, 1909.

suggestion is made that they may expose a pre-Valparaiso drift.

The Lemont drift is now known to exist beneath Valparaiso till as far north as Hinsdale and as far south as Hickory Creek Valley. The many occurrences within these limits have led to the conclusion that the Valparaiso till in most of the Chicago region is much less thick than the moraine is high. An average of 10 to 15 feet of Valparaiso clay till has been found above Lemont materials on summits and slopes alike; the Valparaiso till constitutes a veneer-like deposit over a buried upland of Lemont drift with considerable relief.

If this interpretation is correct, the relief and the roughness of the Valparaiso moraine in this region depend in large part on the buried topography of the overridden Lemont drift. If the Lemont topography was itself morainic, its expression through the Valparaiso cover would not differ from what the Valparaiso till alone would be expected to have. If, however, streams had developed capacious valleys and prominent divides during the Lemont-Valparaiso interval, and if the Valparaiso glaciation had failed to obliterate them, they would then be identifiable in existing contours of the Valparaiso moraine.

Unusual smoothness characterizes the Valparaiso moraine in the Chicago region, a fact noted in nearly every publication dealing with it. There are very few kettle holes or deep-set undrained basins. Almost all swampy areas can be drained by ditching across a low marginal tract. Almost all lakes in the moraine topography have become swamps, so shallow were they originally. Though a thick drift deposit might have only shallow undrained morainic depressions, a thin drift could not have deep ones.

There has been very little stream erosion on the surface of the Valparaiso moraine, except for some ravines tributary to the Sag and DesPlaines deep valleys where steep gradients were provided. Many square miles of the Mokena, Sag Bridge, Hinsdale, Palos Park, and Tinley Park quadrangles have essentially no streamways. Yet there are seven capacious valleys descending the western slope of the Valparaiso moraine in the Mokena and Sag Bridge quadrangles.[24] All carry streams, but in every one there is ample evidence that the streams found the valleys waiting for them when the ice withdrew. The floodplains of the streams (alluvium and basin fill) vary extraordinarily in width; they narrow downstream abruptly in places and constrict to as little as a tenth of the average width or even pinch out completely. Outlines of the valley bottoms are extremely irregular, and peat-filled embayments indent the marginal slopes. Wide basin fills and even swamps interrupt the continuity of alluvium. Kame-terrace piles,[25] with original slopes almost unmodified by running water, nearly fill some places in the valley bottoms. "Islands" of till stand in the middle of some valleys, and "peninsulas" of till project far out in them. The floors and sides of some valleys are mappable only as morainic topography, so little have the streams affected them. Yet they have every other characteristic of stream-eroded valleys.

The region of these peculiar stream valleys is also the region of Lemont drift exposures in stream banks, road cuts, and excavations. It is the region of thin Valparaiso till on many slopes and hilltops. It includes the highest uplands in our region and the lowest valley bottoms. Most of the relief is clearly determined by the thickness of the Lemont drift. These relations are true also of the southeast part of the Wheaton quadrangle, west of Downers Grove, where at least two valleys, St. Joseph Creek and Prentiss Creek, belong to the category of the seven already listed. Probably the large linear swamps and basin fills near the head of Long Run and Spring Creek also belong to the same category. Although they do not have stream courses today, they are shaped and oriented like heads of capacious tributaries to these streams and are just barely shut off from them by low Valparaiso morainic hills.

That these valleys and depressions record

[24]Hickory Creek, Marley Creek, Spring Creek, Fraction Run, Long Run, an unnamed valley between Fraction Run and Long Run, and Sawmill Creek.

[25]Goldthwait (Bull. 11) called them remnants of eroded valley trains.

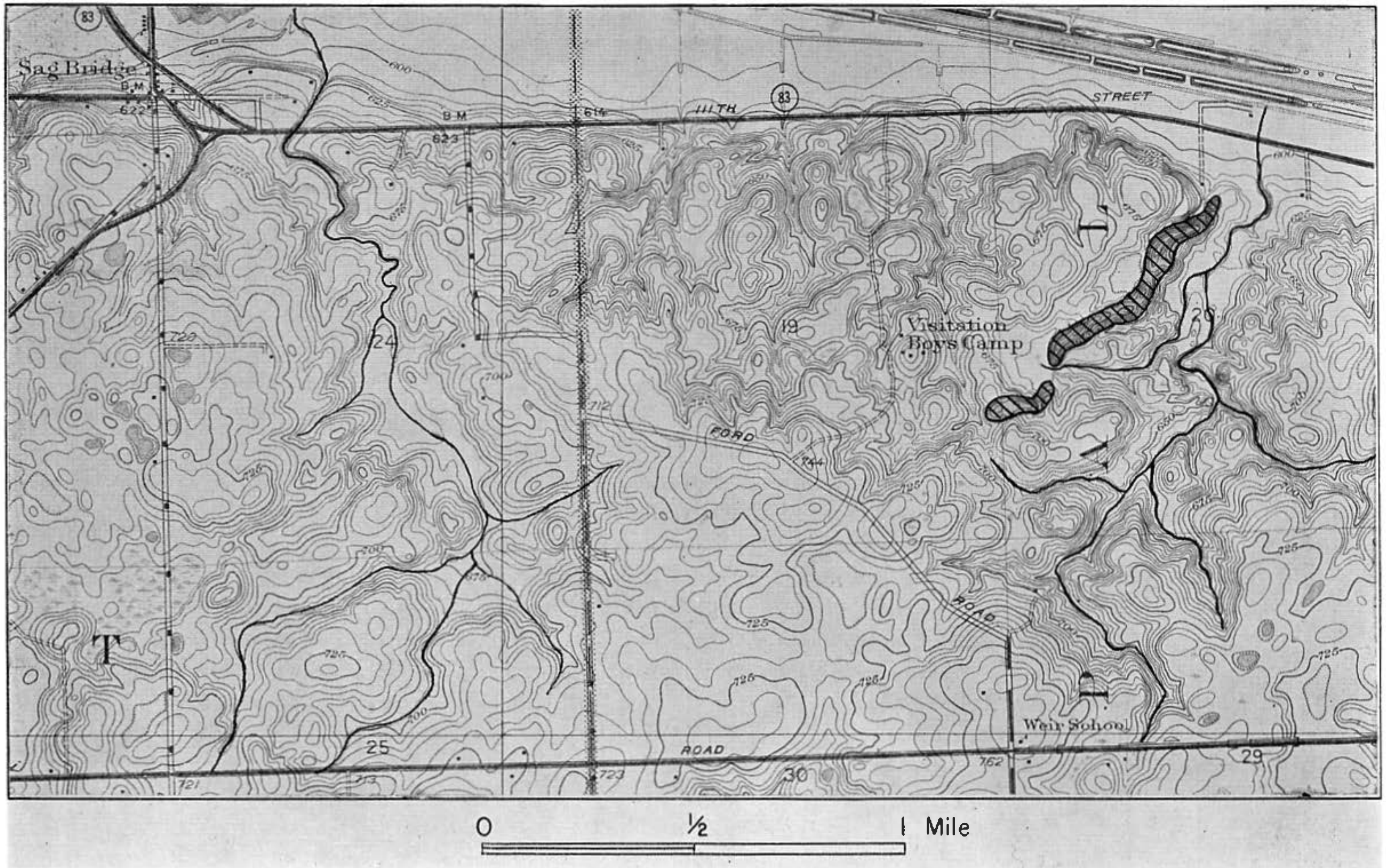


Fig. 34.—Pre-Valparaiso valleys tributary to Sag Valley. Visitation esker shown in pattern. (Sag Bridge quadrangle.)

a drainage system down the west slope of the upland before the Valparaiso glaciation seems by far the most probable explanation. They are recognizable here because they were more deeply eroded than contemporary valleys elsewhere in the region. Deeper erosion and better development were consequent on steeper slopes of the Lemont drift accumulation. The necessary gradients were provided by a higher piling up of the drift and the existence of a nearby DesPlaines trunk valley.

Earlier writers[26] report low rock bluffs and a glaciated bedrock floor in the DesPlaines Valley near Lemont, and comment on the probable existence of a river valley here before the Valparaiso glaciation. No one, however, argued that the pre-Valparaiso valley extended northeastward along its present course to the Chicago plain. That it did so has been concluded from the field studies for this report. Three kinds of evidence are found along both the Sag and DesPlaines valleys east of the rockbound part at Lemont. One consists of modified tributaries to main valleys and surviving bluffs of the main valleys, all overridden by the Valparaiso ice and partially obliterated by its drift. Another is pre-Valparaiso gravel deposits near the two main channelheads, requiring for their origin open valleys in pre-Valparaiso time. The third is the presence of eskerine ridges of Valparaiso age on the main valley slopes.

Two unnamed valleys on the south side of Sag Valley (Sag Bridge quadrangle) may be taken as examples of the first kind of evidence. One discharges to the Sag through a little canyon (Cowles Canyon) in bedrock less than half a mile east of Sag Bridge village; the mouth of the other is a mile west of the Palos toboggan slide. Both are far larger and more capacious than the post-Valparaiso ravines of Swallow Cliffs and both have tributary valleys. Yet in both there are morainic knolls and ridges, undrained depressions, and even lakelets. Running water has done little to this morainic topography. It certainly has not eroded the valleys since the Valparaiso glaciation. They belong in the category of Hickory Creek, Marley Creek, Spring Creek, Fraction Run, and Long Run valleys, differing only in size and orientation. They lead to the deep Sag Valley and could have developed only when such a valley existed. Since they are pre-Valparaiso, the Sag must be pre-Valparaiso.

Another unnamed creek enters the Sag from Mt. Forest Island, crossing 107th Street between 96th and 100th Avenues (Palos Park quadrangle). Its course has several peculiarities. It drains half a dozen swamps in the center of the "island," flows in a fairly narrow valley southeastward as far as Kean Avenue, and there makes a hairpin turn southwestward. It flows for a mile across a tract with mild morainic topography which has a marked bluff about 50 feet high overlooking it on the north but no corresponding bluff on the south. The topographic map clearly shows this bluff to be fairly straight and very definite, yet it is not a bluff of the post-Valparaiso discharge of Lake Chicago. Traced northeastward, it runs into the Tinley moraine ridge just east of Kean Avenue, the trends of bluff and ridge outlining an angle of about 45°. A similarly oriented bluff half a mile southeast, eroded by post-Valparaiso drainage and cutting into the south side of the Tinley moraine, is entirely distinct from the one in question (fig. 35). There seems to be good topographic evidence that the eastern end of a bluff of an older Sag channel here has been overridden and obliterated in the Tinley moraine-building and that a portion of the Tinley moraine-dam across this channel still remains on the north. The post-Tinley Sag channel here appears to be a little farther south than its predecessor, and Swallow Cliffs owe their prominence and their youthful ravines to post-Tinley undercutting in this southward shift.

If the above interpretation is correct, the old bluffs on Mt. Forest Island west of the Tinley moraine should contain Lemont drift. Exposures are poor in the ravine where the creek makes a hairpin turn, but spade and soil auger show that the silty yellowish Lemont till is present, under a cover of clayey Valparaiso till. The Lemont till occurs in the bluff and ravine walls

[26] Leverett, Salisbury, Alden, Goldthwait, and Ekblaw.

up to 680 or 685 feet, 45 to 60 feet above the mildly morainic flat south of them. The Valparaiso ground-moraine deposit did not greatly change the character of the old bluff, though it put its own mark on the flattish summit and base. The thicker Tinley marginal-moraine deposit east of Kean Avenue completely obliterated the bluff in that direction. The hairpin turn of the creek may be compounded of a pre-Valparaiso stream course above the turn and a post-Tinley course below it.

The well-washed gravel deposit at Worth (p. 62), associated with other phases of Lemont drift, and the one a mile north of Willow Springs (p. 64) are beneath Valparaiso till and record glacial rivers escaping westward. Excavations in both deposits have gone below the higher Lake Chicago levels. For westward escape of the vigorous streams, there must have been a pre-Valparaiso "Sag channel" and a pre-Valparaiso "DesPlaines channel" fully as deep as today's channels.

In the Sag Bridge quadrangle several ridges, or elongated mounds, of Valparaiso moraine gravel lie on the northern bluffs of the DesPlaines channel and there is one such deposit on the southern bluff of the Sag channel (see fig. 35). These ridges are definitely eskerlike and kamelike. They owe their form to the fact that they were partially enclosed by glacial ice when the deposits were made. They antedate the discharge of Lake Chicago water across the Valparaiso moraine. Because most of them lie on the bluff slopes and the longer ones reach almost from upland to valley bottom,

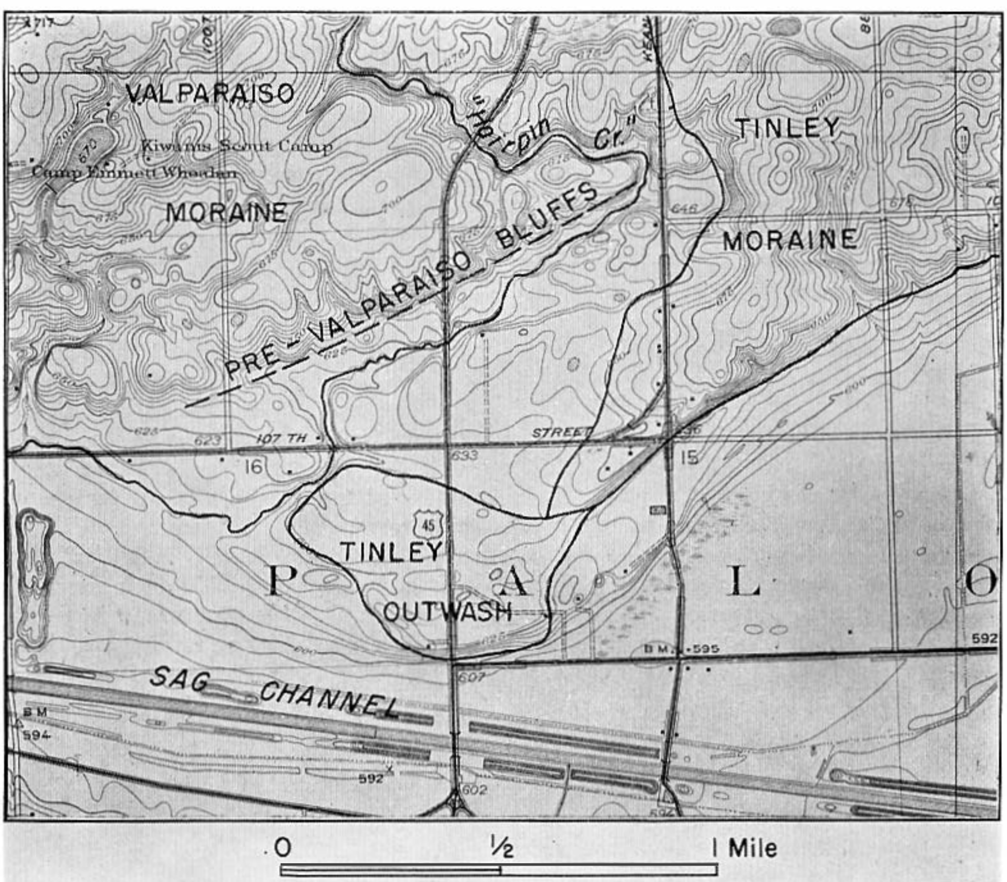


Fig. 35.—Pre-Valparaiso bluffs, Tinley moraine, and "Hairpin" Creek near head of Sag Valley (Palos Park quadrangle).

the Sag and transmorainic DesPlaines valleys must have existed beneath the Valparaiso ice sheet during its retreat. Lake Chicago's outlet waters cleaned out what till and outwash still obstructed the outlet, the Tinley moraine being the major deposit. On the north side of the DesPlaines channel the largest eskerine ridge comes down from 675 to about 610 feet above sea level. This ridge is 1 1/2 miles west of the Tinley moraine; on the east side of the ravine near the center of the N 1/2 of sec. 6, T. 37 N., R. 12 E. (Sag Bridge quadrangle—Map 13). The valley floor here, therefore, was at least 25 feet lower than the highest stage of the lake and only 3 miles distant. From 625 feet to 610, this eskerine ridge has been eroded by the lake's outlet river and is very cobbly and bouldery on the surface. Only the Tinley moraine could have been the Lake Chicago dam in this channel.

Similarly, on the north side of Sag Valley (Palos Park quadrangle), gravel constituting a terrace of Tinley outwash (crossed by 96th Avenue) extends down at least to 615 feet above sea level just west of the Tinley crossing (fig. 35), and, on the south side of the Sag Valley, the eskerine ridge 2 miles west of the Tinley (fig. 34) begins at 615 or 620 feet and ascends to 685 or 690 feet above sea level. Thus the valley slope through that range in altitude was in existence while the Tinley moraine was being built.

North-south profiles along the Valparaiso and Tinley moraines, across the two channels, show that if there were no pre-Valparaiso valleys here, there must have been two most extraordinary transverse morainic sags. To be low enough for Lake Chicago's initial discharge, they would have had to be lower than outcrops of Lemont drift in almost every place it is known along these "channel" walls. That they existed as erosional valleys before the Valparaiso glaciation seems an almost undeniable conclusion. Goldthwait[27] says that "no precise reason can be given for the presence of the two initial sags in the moraine." That problem of his day is believed now to be solved.

Fig. 36.—Section in kame near Byrneville. Foreset beds dip down toward the left (west).

Part 1 of this bulletin contains a brief statement regarding the pre-Valparaiso, post-Lemont stream erosion. Since the publication of Part I in 1939, a study of the Grays Lake quadrangle has appeared which contains significant contributions to the problem.[28] The Grays Lake quadrangle is northwest of the Chicago region, mostly in Lake County, and lies within the Valparaiso moraine belt. The moraine here is resolvable into five subordinate members. It buries older drift, both till and outwash, as it does in much of the Chicago region, and the buried relief, greater than that of the moraine itself, was made in part by stream erosion. Fox River Valley is the major pre-Valparaiso streamway on the Grays Lake and Barrington quadrangles. It transects the Marseilles moraine west of the Valparaiso moraine, hence is adjudged younger. The later Minooka ice front appears to have displaced the earlier Fox River near Elgin for a time, forming a broad lake (Lake Wauconda) whose clays were later overridden by the Valparaiso ice. Fox Valley was therefore in existence before the Minooka advance. The West Chicago moraine, oldest of the Valparaiso ridges, crosses the Fox Valley near Algonquin (Barrington quadrangle), modifying the 100- to 150-foot valley walls at the crossing even more strikingly than the Valparaiso moraine modifies the slopes of Long Run and Spring Creek valleys in the Chicago region.

[27] Goldthwait. Bull. 11, p. 52.
[28] Powers, W. E., and Ekblaw, G. E., Glaciation of the Grays Lake, Illinois, quadrangle: Geol. Soc. Am. Bull., vol. 51, pp. 1329-1336, 1940. Reprinted as Illinois Geol. Survey Circ. 63.

Is it justifiable to correlate the pre-Valparaiso Sag and DesPlaines valleys of the Chicago region with the pre-Minooka Fox Valley? All of them are main stream valleys eroded during pre-Minooka time. If they were eroded during the post-Marseilles interval of deglaciation, the Lemont drift would be post-Marseilles, perhaps recording the pause in Marseilles retreat before the Minooka advance began.

The Fox River Valley on the Barrington quadrangle is eroded in a widespread sheet of pre-Valparaiso gravel recognized in outcrops and wells in the Grays Lake, Barrington, Elgin, and Geneva quadrangles. Since to the west of the Valparaiso moraine this gravel sheet (Algonquin gravel formation[29]) is overlain by the Minooka moraine, it must be older than that glacial advance. The Algonquin gravel appears to have been spread as a great outwash plain in front of the Lake Michigan glacial lobe during a long pause after retreat from a moraine to the west. It has been presumed to be intermediate in age between the Marseilles and Minooka moraine-building advances. No till deposited during this pause is recognized in the Grays Lake or adjacent quadrangles. But if the Lemont gravel, the Joliet "outwash plain" gravel along the DesPlaines, and the Algonquin gravel along the Fox[30] are contemporaneous, then the Lemont till is probably the record of this pause.

By this interpretation, the margin of the Lake Michigan lobe must have withdrawn still farther north and east after deposition of the Lemont drift, freeing the streams of the excess load recorded by the outwash gravels and allowing them to trench into the newly made deposits. This interval of erosion was long enough for main drainage lines, with adequate volume and gradient and with only glacial drift to deal with, to trench such valleys as the Sag, DesPlaines, and Fox. But the Chicago region also has well-developed tributary valleys of the same erosional interval. Because the growth of tributary valleys always lags behind that of the main ones, the post-Marseilles, pre-Minooka interval could not have been brief.

An alternative interpretation considers that all these pre-Valparaiso valleys may be pre-Wisconsin in age, that they may record stream erosion during the long Sangamon interglacial age. The deep weathering profile Horberg found in Lemont drift at Worth seems to demand a much longer interval of exposure than the preceding estimate of the post-Marseilles, pre-Valparaiso period allows. The tributary valleys (Long Run, Fraction Run, Spring Valley, Hickory Creek, etc.), which definitely are pre-Valparaiso in age, also seem to require a longer time for development than allowed by the preceding estimate.

#### TILLS EXPOSED IN THE SANITARY AND SHIP CANAL

Leverett in 1897[31] commented on the exposure of a "very hard, partially cemented till apparently of early glacial age" beneath a soft clayey till in the then newly made sections of the Sanitary and Ship Canal a mile or so east of Summit (Berwyn quadrangle). Alden in 1902[32] added a comment on stratified deposits beneath till in the same sections between Summit and Willow Springs. No other mention of these sections has ever appeared in the literature although they have remained fairly clean and are readily accessible.

In the present investigation, the sections were studied from Kedzie Avenue bridge (Englewood quadrangle) to 96th Avenue bridge (Berwyn quadrangle), a distance of nearly ten miles. The eastern half of this distance has a monotonously similar sequence of 2 or 3 feet of lake clay above till; the middle of the stretch has three distinct tills in vertical sequence without separating sediments; and the western part has till with sediments both below and above.

The eastern half of the section extends

[29]Leighton, M. M., Powers, W. E., and MacClintock, Paul, Geology and mineral resources of the Elgin, Geneva, and Barrington quadrangles: Illinois Geol. Survey, unpublished manuscript. Earlier called *Crystal Lake gravels*, *in* Leighton, M. M., The glacial history of the Elgin region: Trans. Ill. Acad. Sci., vol. 17, pp. 69-70, 1924.

[30]Fisher found no gravel beneath the Minooka moraine in the western part of the Joliet quadrangle, but this is only negative evidence. It may be that ground-moraine in that particular district stood high enough to escape being gravel-covered. Fisher's lowest exposures were along the DuPage Valley, which here may not be cut down to the level of the gravel.

[31]Leverett, Chicago Acad. Sci. Bull. 2, p. 49.

[32]Alden, Chicago folio (No. 81), U.S. Geol. Survey.

from Kedzie Avenue westward to the Santa Fe Railroad bridge, a mile east of Harlem Avenue. Postglacial alluvium covers 2 or 3 feet of Lake Chicago clay which probably was deposited back of the Englewood extension of the Graceland spit during the Toleston or Algonquin stage. Below that is a soft gray till, so clayey that spade cuts in it have a waxy luster. It is so lacking in rock fragments that, although its surface was eroded before the spit had grown very far southward, there is no lag accumulation of pebbles or cobbles between it and the clay above.

West of the north end of the Santa Fe Railroad bridge, the soft clayey till comes to the top of the canal trench and is underlain by a dense hard sandy dark-gray till which continues in the sections southwestward along the canal to 96th Avenue. It is highly charged with small black shale pebbles and is very difficult to spade even when water-soaked. It is the "hardpan" till noted by Leverett. Beneath this, for a few hundred feet along the north bank of the canal, is a reddish till, very sandy and "short," distinctly laminated or foliated, and as pebbly as the dark-gray till above. It cannot be excavated in blocks; it breaks up into thin lamellar pieces. No other till seen under the lake plain is so "short" and so foliated. Fragments of it occur in the dark-gray till above.

The upper soft clayey till is probably Tinley ground moraine, for it lies east of the Tinley moraine and west of a line connecting the Park Ridge moraine with its isolated Blue Island portion. The pebbly sandy dark-gray till beneath might be thought Lemont in age. The nearest exposure of typical Lemont till is in the northwest corner of Justice Park corporate limits, 4 miles to the southwest, in a low erosional remnant in the glacial river channel. At that place, the usual yellowish color is present. If any till at the Santa Fe bridge section is Lemont, the oxidized zone has all been scoured off. But the abundance of shale pebbles is wholly out of harmony with the Lemont elsewhere.

Except for its reddish color, the lowest till might be called Lemont on the basis of characteristics. The middle till would thus become Valparaiso, despite its notable differences from Valparaiso till in general. The reddish color suggests the possibility that this lowest till is Bloomington; because it is near the bottom of the zone of oxidation its color is light. If the reddish color is due to weathering and is not an original color, a period of exposure before the deposition of the dark-gray till is recorded. Thus if we call it Bloomington till, we must conclude that the Wisconsin ice retreated from the Bloomington moraine to the Lake Michigan basin before advancing to build the next later moraine.

Sections between the Santa Fe bridge and the 96th Avenue bridge are noted by Alden. He found sand, gravel, and clay beneath till but made no suggestion that the till itself is pre-Valparaiso or that the stream gravel with "strong cross-bedding" is evidence for the existence of a DesPlaines valley before the Valparaiso moraine was built. The section is curiously irregular in character but seems interpretable in terms of sub-till sediments, a till sheet, and super-till sediments unlike those below the glacial deposit. In places the 15-foot bank is all till, in other places it is all sub-till material, in others it is wholly of the super-till deposits. Generally both the till and one of the sedimentary members are exposed, and in a few sections all three are present.

The till is the dominant deposit. It is a very tough dark-gray stony clay, not too closely resembling the Valparaiso till, not at all like the Lemont till, and not very much like the dark-gray median till at the Santa Fe bridge. It may be basal Valparaiso which has, by thorough incorporation of material from an overridden dark-gray sandy till, become somewhat intermediate in character.

The sub-till sediments are largely slack-water deposits. A uniform dark-gray silt predominates, finely laminated in some places, irregularly bedded in others, locally interbedded with sand and very rarely with gravel. These sediments are commonly distorted and in some places have till fingers thrust into them. In only one place was there any suggestion of varves (indicating seasonal deposition), and in only one place was there a suggestion of carbonaceous coloring. The sediment is doubtless glaciolacustrine and glaciofluvial. The gravel and sand tell of free discharge for stream water, and if ice lay to the east, that discharge was across the now-existing high tract to the west, composed of Lemont and Valparaiso drift. The deposit is in the very bottom of the DesPlaines channel, just east of the Tinley moraine crossing, but no moraine dam existed when the fluvial sediments were laid down. They are either pre-Valparaiso in age or were deposited during the Valparaiso advance.

The super-till sediments are mostly river gravel and postglacial peat. The coarseness of the gravel suggests something more than the postglacial DesPlaines; the Lake Chicago outlet river is indicated. It also eroded the till, for channels filled with cobbly and even bouldery gravel are exposed in the sections.

The inconclusiveness of the study of the Drainage Canal sections indicates that the problem of correlating these buried tills in the Chicago region is still unsolved and that data of a different kind are necessary for solution.

#### GRAVEL EXPOSED IN DOLESE AND SHEPARD QUARRY

A sub-till gravel deposit 20 feet thick, resting on a glacially smoothed pavement, is exposed in a broad sag in the surface of the Niagaran dolomite at the west end of the Dolese and Shepard quarry, directly across the DesPlaines Valley from Summit and Argo, Berwyn quadrangle. The material is morainal gravel, poorly sorted, its dolomite pebbles and cobbles little worn and rather slabby, and its base highly charged with armored till balls as large as 6 inches in diameter. Foreset bedding and imbrication of the slabs record southward flow toward the DesPlaines Valley. The overlying till, also 20 feet thick, constitutes the floor of the Lake Chicago outlet at the Calumet stage and probably is Tinley ground moraine.

Though there is no conspicuous difference between the material of the armored balls and that of the overlying till, the underlying morainal gravel surely is much older, because its fine matrix material is leached of carbonates to a depth of 54 inches. Very probably the upper part of its zone of leaching has been lost in the later glacial overriding. Nothing resembling the B-zone of a soil profile remains. A deep rusty color marks most of the gravel, but irregularity in strength of color and distribution through the stratiform members indicates it to be largely groundwater staining. The lowest few inches of the overlying gray till is also yellowish.

Neither the till above the gravel nor that constituting the till balls in it are silty like the type Lemont drift. Shale pebbles and cobbles are found in both. It seems likely that this gravel may be of Lemont age, or it may be considerably older.

### Cary Substage

#### VALPARAISO DRIFT[33]

*Thickness.*—Where it overlies Lemont drift in the Sag Bridge and Mokena quadrangles, the Valparaiso till has been recognized in dozens of road cuts and many natural sections. In these quadrangles, the Valparaiso till probably has an average thickness on the upland slopes of 10 to 15 feet. Valparaiso outwash deposits in the Chicago region are wholly limited to eskers, kames, and kame terraces of extremely variable thicknesses. The maximum known depth of Valparaiso glaciofluvial material here does not exceed 30 feet.

The tills of all the Wisconsin moraines in, and to the south and southwest of, the Chicago region are generally clayey. Because ground-moraine deposits belonging to any of these clayey moraines to the south and west may underlie the Valparaiso clayey till and, together with Valparaiso till, may also underlie the Tinley till, it is impossible at present to measure the thickness of either Valparaiso or Tinley till. Thickness of the total clayey till above bedrock can

[33]Named by L. C. Wooster for the town of Valparaiso, Ind., which stands on a prominent portion of the moraine. Leverett, U.S.G.S. Mon. 38, p. 339.

be readily obtained from many hundreds of well and boring records. The thickness of the superimposed Lake Border tills has been obtained by using compaction data from test borings for foundations in Chicago, but comparable data are not available for the Valparaiso and Tinley till sheets.

*Till.*—Krumbein's study[34] of variations in the texture and lithology of glacial till included 24 samples taken near the outer margin of the Valparaiso moraine at average intervals of 7 miles throughout 165 miles of the moraine. The line of samples began northeast of Elgin, Ill., swung southeastward toward the Indiana line, then eastward and northeastward around the lake, ending near Benton Harbor, Mich. The Valparaiso drift was found to be a clayey till as far as Valparaiso, Ind., and dominantly a sandy till east of there. The difference in texture is ascribed by Krumbein to differences in the amount of washing the till received from escaping meltwater and to differences in character of the older material (bedrock and pre-Valparaiso sand dunes and drift) which was overridden, eroded, and incorporated in the till. The most important of these causes he thought to be the loading of the Valparaiso ice with "surficial unconsolidated materials in the path of the ice."

Another line of samples, 23 in number, began in the Tinley moraine and extended southward from the Chicago region across the entire assemblage of Wisconsin moraines, a distance of about 125 miles. The spacing in this line was determined by the intervals between the moraines. The relative proportions of clay, silt, and sand and gravel in the samples from thirteen successive moraines showed that dominantly clayey till occurs as far south as the Chatsworth moraine, [35] next older than the Marseilles moraine. Less clayey till was found in the moraines farther downstate. Krumbein suggested that the heavy loading with clay in the northern seven moraines may mean that, between the building of each, the Lake Michigan lobe receded far enough north to allow a lake to form in the southern portion of the basin. Clay deposited in the lake was then incorporated in the till of the next advance.

Krumbein also collected a series of 12 samples, equally spaced through a vertical range of 60 feet, on the slopes of a valley cut across the Bloomington moraine. Though there was no visual evidence of two till sheets here (the Bloomington above an older one), mechanical analyses showed a "break" in composition between samples 1 to 8 and samples 9 to 12. Thus the thickness of the Bloomington till was figured from the top of sample 9 to the top of the moraine. As post-Tinley valleys in the Chicago region are not deep enough to provide data for this method of determining thickness of Valparaiso or Tinley tills, the method can be used only when samples can be secured from properly located bore holes.

*Eskers.*—In the north-central part of the Hinsdale quadrangle (Map 9) are two eskerine-ridged tracts, the better developed standing on the "island" already noted (p. 31), in the SE 1/4 sec. 23, T. 39 N., R. 11 E. The ridge is about 20 feet high and half a mile long. Its sides are steep, and it is margined by a trough on each side, a common esker feature. Two old pits afforded an imperfect exposure of its composition at the time of examination. Cobble and pebble gravel and coarse and fine sand make up the bulk of the sections. One section showed 4 feet of unwashed till at the top, overlying clean fine sand. The other esker-like ridge, along the south line at the NW 1/4 sec. 27, T. 39 N., R. 11 E., has no exposures and is mapped on the basis of its unusually knolly topography and steep sides. Perhaps it could as well be considered to be a row of kames.

The Tiedtville esker, half a mile north of Tiedtville in the northeastern part of the Sag Bridge quadrangle (Map 13), is mapped as a little more than half a mile long. Its highest point is 25 feet above a little lake in the more western of two margining troughs. The surface material is till on most of the ridge, and there are only two exposures of gravel in it, and both are poor. It margins the top of the Des-

[34]Krumbein, Jour. Geol., vol. 41, 1933.

[35]Named for the village of Chatsworth, which is on the moraine. in southeastern Livingston County, Ill. Leverett, U.S.G.S. Mon. 38, p. 259.

Plaines valley wall; toward its distal end, it descends from 650 to 615 feet, its tip thus reaching below the higher levels of the Lake Chicago outlet river. Here it is very cobbly and bouldery below 625 feet, apparently from erosion by the outlet river. Its steep slopes and sharp ridges are quite out of harmony with the till slopes of the Valparaiso moraine. With nearly a dozen kame piles on this same valley wall in the next 3 miles to the southwest, the Tiedtville esker is a part of the evidence for the existence of a pre-Valparaiso DesPlaines valley.

Another, smaller gravel ridge lies about a third of a mile north of the Tiedtville esker along the same nearly north-south line. Traced southward, the little ridge ascends the western slope of Flag Creek Valley for about 30 feet, indicating an older slope here under the Valparaiso ice. An old pit showed cobbly and pebbly gravel in it. Between it and the larger Tiedtville esker to the south, a cut along 83rd Street showed about 8 feet of washed gravel on the line connecting the two ridges. The two may well be interpreted as one interrupted esker.

The Visitation esker, on the southern slope of the Sag Valley, largely in the west half of sec. 20, T. 37 N., R. 12 E. (Sag Bridge quadrangle—Map 13), is three-fourths of a mile long, interrupted in two or three places, narrow and sharply expressed, but not very high. An abandoned pit at the north end showed about 8 feet of silt and coarse sand with scattered pebbles. Reject material on the pit floor, however, contained hundreds of boulders a foot or so in diameter, more than 90 percent of them composed of Silurian dolomite. This is much higher than the percentage of Silurian dolomite boulders among the rejects on the floors of brick-plant pits in the Chicago region, excavated in till. There are no other exposures in the ridge, but there are boulders lying on the surface. Among these, igneous and metamorphic rocks are more numerous than limestone and dolomite. Like the Tiedtville esker, the ridge diagonally traverses a pre-Valparaiso valley slope through a vertical range of 60 feet or so. The bottom of the valley parallel to and immediately east of the esker is diversified with morainic hillocks. If, as is confidently believed, this gravel ridge was deposited by the retreating Valparaiso ice, the high end is the distal end, the reverse of the relations at the Tiedtville esker.

"Till eskers" is a field term used to describe two unusual drift ridges in the Chicago region. One is on the Valparaiso moraine just west of Orland Park, in the NW 1/4 NE 1/4 sec. 8, T. 36 N., R. 12 E., Sag Bridge quadrangle (Map 13), and the other is on the Tinley moraine in Mt. Forest Island, largely in the NW 1/4 sec. 2, T. 37 N., R. 12 E., Palos Park quadrangle (Map 14). In dimension, proportion, and orientation, these ridges are strikingly eskerlike. No excavations existed; auger borings showed only till in the upper four-fifths of the ridge. In one ridge sand and gravel was encountered below the till, but auger penetration into this was impossible, and the amount of washed material could not be ascertained. If they are eskers, they are more than veneered with till—they are buried in it. Yet the form has persisted and it is both incorrectly oriented and much too vigorously expressed to be a normal morainic ridge.

*Kames.*—As with eskers, most of the kames of the region on Valparaiso drift are in close association with pre-Valparaiso valley courses and most of them are partially or completely covered with till. The kames of the DesPlaines transmorainic valley, already noted, all lie on the valley slope, the bases standing above the valley floor and probably above the highest levels of the outlet river. One of the kames, half a mile southeast of the Byrneville school, in the SW 1/4 NE 1/4 sec. 11, T. 37 N., R. 11 E., Sag Bridge quadrangle (Map 13), has been extensively opened for gravel, and its composition and structure are very well shown for a depth of 25 feet. It is poorly sorted material—cobbles, pebbles, and sand mixed together in many places—although in some places there is clean gravel with open interstices. Irregular stratiform till masses are fairly common in the gravel, but none of them are horizontally continuous for more than 20 feet. The till cover in some places is 10 feet thick; in others it is wholly lacking. The dominant structure is inclined bedding, the dip being southwestward along the valley wall rather than southeastward down the slope. Clearly, the DesPlaines Valley, when this kame was built, contained a lingering tongue of the receding Valparaiso ice when the upper valley slopes had already emerged and, with the ice, constituted the two sides of the meltwater course. The tabular till masses indicate minor advances during an oscillatory retreat past this place. The kame gravel was deposited at the very edge of the ice. Noteworthy cementation of the gravel has since occurred in the central and highest part of the deposit.

Most of the DesPlaines Valley kames are elongated subparallel with the valley wall, but they are not aligned sufficiently to allow grouping them as an interrupted esker.

*Kame terraces.*—Only the Valparaiso drift bears any kame-terrace gravels in the Chicago region, and they are found only in valleys of the pre-Valparaiso topography where free westward drainage was possible. Hickory Creek Valley's assemblage of kame terraces is more than 11 miles long, the sum of intervals between deposits being about twice the aggregate length of the gravel mounds themselves. The largest kame-terrace unit, near the junction of Hickory and Marley creeks, in the Mokena quadrangle (Map 17), is 1 3/4 miles long, and its highest part is 25 feet above the stream. All have rolling, even knolly, surfaces, but slopes are gentler and heights less than among the true kames. Almost all are on valley bottoms, some cause notable constrictions in width of valley floor, and very few overlap up on the middle slopes of their containing valleys. Exposures of their structure are rare, for the streams are not actively undercutting them and few excavations have been made in them. They appear largely to lack the cobble-sized fragments of kames and eskers. Some have yielded gravel in commercial quantities, but there have been no active pits in them for years.

*Correlation.*—Direct tracing of the Valparaiso drift between the type locality in northern Indiana and the Chicago region has established a positive correlation. Considered in its vertical range, Valparaiso drift includes all the clayey till underlaid by silty Lemont drift. Elsewhere its base may be uncertain, for reasons already set forth.

In our latitude it is difficult to differentiate the broad Valparaiso morainic belt into ridges of subordinate rank. Studies made by the Illinois State Geological Survey in the McHenry, Grays Lake, Barrington, Elgin, and Harvard quadrangles, north and west of Chicagoland, have shown that the Valparaiso moraine there consists of five successive ridges or elongate groups of morainic hills. From west to east, they are the West Chicago, the Monee, the Fox Lake, the Zurich, and the Palatine moraines.[36]

The best evidence in the region for this succession of Valparaiso units is probably the constricted places already noted along the pre-Valparaiso valleys of Fraction Run, Long Run, Spring Valley, Marley Creek, and Hickory Creek on the Sag Bridge and Mokena quadrangles. M. M. Leighton[37] is inclined to think that another unit, the Clarendon, is identifiable, which is younger than the Palatine but distinctly older than the Tinley moraine.

## TINLEY[38] DRIFT

*Thickness.*—Determination of the thickness of the Tinley drift is impossible from data now at hand. To the eye and hand, the Valparaiso till is indistinguishable from the Tinley, and it certainly underlies much of the Tinley. It is possible that mechanical analysis may someday show differences between the two and that sufficient excavations may be so located as to give an average figure for the thickness of the Tinley drift.

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[36]Powers and Ekblaw, Geol. Soc. Am. Bull., vol. 51, p. 1331, 1940. The name *Monee moraine* is proposed by M. M. Leighton (personal communication, 1953) for the name *Cary moraine* used by Powers and Ekblaw. The name *Cary* is pre-empted by its use as a substage name.

[37]Personal communication.

[38]Name first published in Bull. 65, Part I, p. 50, 1939. Named for the town of Tinley Park, which is just west of the front of the moraine in the Tinley Park quadrangle (Map 18). Earlier called Arlington Heights moraine and Tinley Park moraine. *See* Leighton, M. M., and Ekblaw, G. E., Annotated Guide across Illinois: *in* Guidebook 26, 16th Internat. Geol. Congress, p. 15, 1933.

The approximate thickness of the Tinley drift can be determined from the height of the Tinley moraine ridge. Twelve cross sections, distributed among the seven topographic maps that show the full width of the Tinley moraine, show that high points on the crest average 30 feet above the western toe of the moraine and 45 feet above ground moraine immediately to the east. The Tinley till sheet in these cross sections is at least 30 feet thick.

*Till.*—The clayey till of the Tinley end moraine and ground moraine is uniform in texture, color, degree of compaction, and lack of washing throughout the Chicago region.

*Eskers.*—The only true esker of Tinley age in the region is on the north side of Indian Creek in the village of Half Day, centrally located in the Wheeling quadrangle (Map 1). It is about half a mile long and no more than 20 feet high. The gravel in it is uniformly sorted and contains no large cobbles or boulders. It is to be distinguished from gravel mounds lying on the DesPlaines valley train in the vicinity of Half Day. The esker lies wholly on ground-moraine slopes above and west of the DesPlaines valley floor and was deposited before the retreating Tinley ice had uncovered the valley. Water that deposited the gravel of the esker escaped westward, whereas the low mounds on the valley train were built by south-flowing water after the ice front had receded to the Lake Border moraines.

A "till esker" lies on the back slope of the Tinley moraine on Mt. Forest Island (p. 80).

*Kames.*—On the crest of the Tinley moraine in the southwest part of the Wheeling quadrangle (Map 1) are two kames, one on each side of Nichols Road, in sec. 6, T. 42 N., R. 11 E. The larger one stands 25 to 30 feet above its surroundings, and in it are two gravel pits. The material is poorly washed; clayey gravel predominates although there are many cobbles and some boulders.

*Frontal outwash.*—A prominent gravel terrace about half a mile wide lies on the north side of Sag Valley, Palos Park quadrangle (Map 14), just west of the southern tip of the Tinley moraine on Mt. Forest Island; 96th Avenue crosses it north of 111th Street. Its surface is about 630 feet above sea level, nearly 10 feet lower than the highest shoreline of Lake Chicago, about 2 miles distant. Its steep descent to the Sag valley bottom is an erosional product of the glacial lake's outlet river, but its surface bears no record of having been swept by that stream.

An active gravel pit east of 96th Avenue has provided a series of sections in the terrace. The excavations have revealed that the eastern part of the deposit, at least the upper 15 feet, consists of poorly sorted gravel, some of it very cobbly and bouldery, and abundant till balls, till masses that have not been rolled since deposition, and a partial till cover. Westward-dipping bedding is common, although no true delta foresets have been seen. Deformed bedding, the gravel strata wrapped halfway around a mass of superjacent till 20 feet in diameter, has been exposed. Channel unconformities, with very coarse gravel in the filled channels, are common. There are many shale pebbles in the gravel and in the included and overlying clayey till.

In the western part of the pit, the gravel is cleaner, more uniformly stratified, and boulders, large cobbles, till balls, and till masses are largely lacking. There is no till above the gravel here.

All characteristics and all gradations in character indicate this terrace to be a stream deposit made at and just beyond the edge

Fig. 37.—Till masses in poorly sorted gravel. Frontal outwash of Tinley moraine, Sag Valley.

of the Tinley ice in a wide valley whose floor was no higher than 610 feet and whose drainage escaped westward along Sag Valley. The bluff of the pre-Tinley valley is about half a mile north of 107th Street. The northern extension of the terrace to the foot of the bluff has minor morainic forms on it and a till cover over sand and gravel. This till lies half a mile and more in front of the Tinley moraine and should be Valparaiso ground moraine. If it is so considered, the underlying sand and gravel are not a part of the outwash above described, but more probably belong to the extensive sheet of gravel underlying, and older than, the Tinley moraine to the east (see p. 64), and are considered to be Lemont in age.

*Glaciolacustrine deposits.*—Fronting the Tinley moraine from the latitude of Orland Park to the southern boundary of the Chicago region is a series of lake flats aggraded when the ice front stood on the moraine and blocked eastward drainage. The flats are primarily underlain by laminated clays which cover a total of more than 16 square miles to probably rather slight depths. The maximum thickness exposed in valleys cut in the flats is 12 feet. A fair presumption is that the lamination is varving, but sections have been too poor to establish this.

Only one deltaic tract associated with the lake flats is known. It is about 2 miles west of Flossmoor (largely in sec. 10, T. 35 N., R. 13 E., Harvey quadrangle—Map 19) and is mapped as different from the lake flat because its material is silt and sand rather than clay, and its very gently sloping surface descends from the toe of the moraine to the level of the adjacent flat.

FIG. 38.—Imperfect foreset bedding in Tinley frontal outwash, Sag Valley. Some of the cobbles are composed of till.

*Correlation.*—The Tinley moraine has been traced directly northward into the Waukegan quadrangle where it is overridden by the Park Ridge moraine.[39] Eastward, the Tinley moraine has been identified for about 40 miles beyond the limits of the Chicago region.

### LAKE BORDER[40] DRIFT

The till sheets of the Lake Border system will be discussed in a later publication by Otto, and therefore they will not be described here. To the eye and touch alone, there are no consistent differences among them; they are all clayey tills. And the differences Otto has found are limited largely to a certain constituent seldom thought of as a part of the composition of a till. Mechanical analysis would never detect it; neither would mineralogical nor lithological analysis. It is an impermanent constituent, for it is decreased by repeated overridings of glacial ice and by subsequent exposure to groundwater drainage. It is the original water contained in the till—the connate water that is actually the melted glacial ice of Pleistocene time. Only a clayey till so buried that groundwater circulation has never affected it could retain the connate water and make possible the differentiating criterion Otto has found.

*Valley train.*—Although the four Lake Border moraines in the Chicago region (see p. 28) do not have eskers, kames, and kame terraces, the system possesses the only valley train of the entire region. It occupies the DesPlaines Valley west of the Park Ridge moraine and reaches almost as far south as the tip of that moraine (fig. 5). The material is a well-sorted gravel, coarsest at the north and decreasing until, near its southern end, it is only granule gravel and sand. The river that deposited this valley-train gravel was largely supplied from regions farther north and presumably continued to flow during much of the Lake

[39]Ekblaw, G. E., personal communication.

[40]Name first used by Leverett, Chicago Acad. Sci. Bull. 2, p. 42.

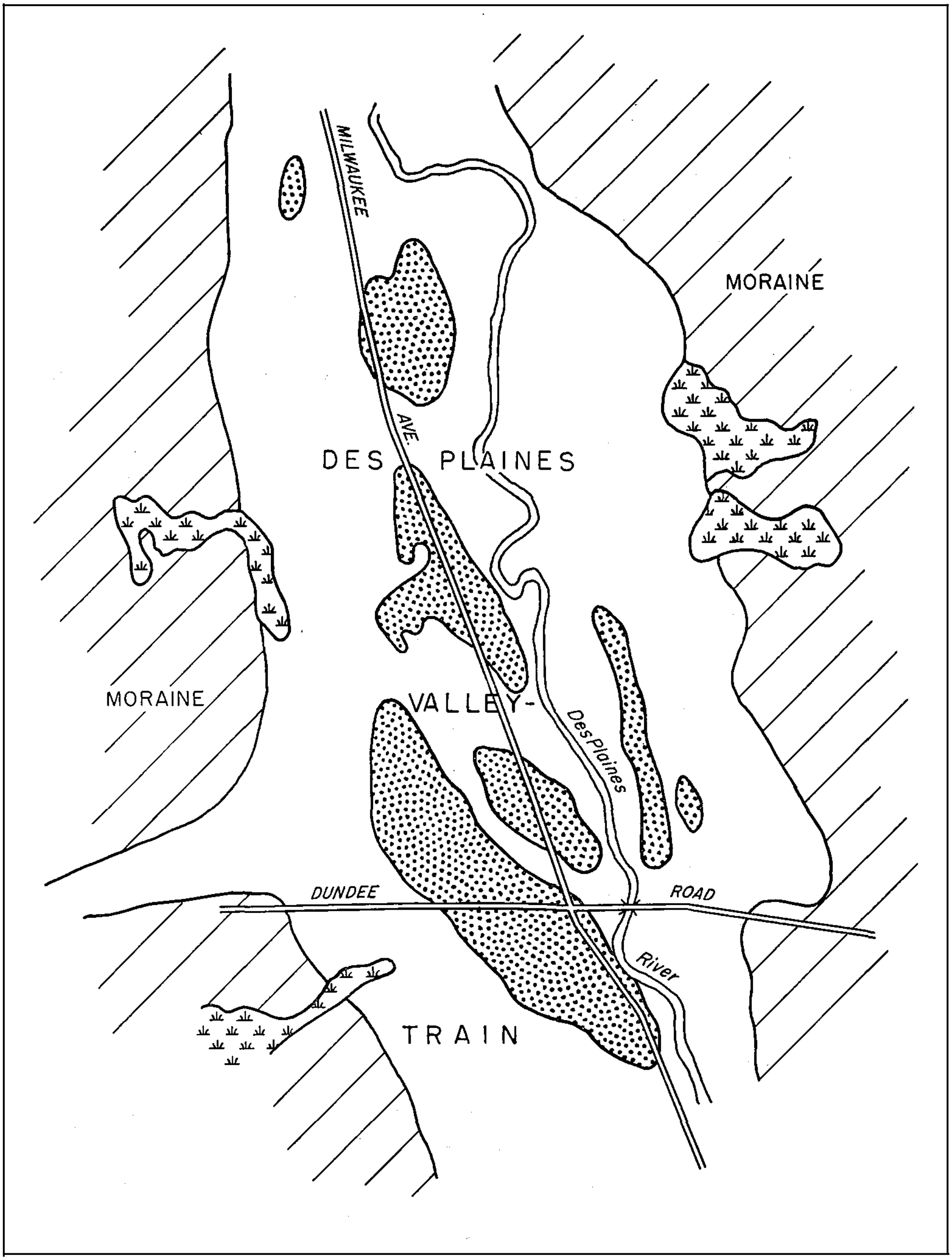



FIG. 39.—Glacial river bars on the DesPlaines valley train near Wheeling.

Border moraine-building stage. Little addition to its volume was made from ice on the Park Ridge moraine in the Chicago region, and none was possible from the three younger moraines farther east.

Traced northward from the Chicago region, the valley train is identifiable as far as Wadsworth. A large pit has been excavated in it at Libertyville. Around Gurnee in particular, there are numerous kames both on the valley slopes and in the valley. They appear to record vigorous drainage off the ice when the Park Ridge moraine was being built. Water that deposited them had no escape other than the DesPlaines valley train. The DesPlaines River north of Gurnee flows along the east side of the Park Ridge moraine and crosses to the west side near that place. In this northern region water probably continued to reach the valley train as the ice front retreated from the Park Ridge moraine past the younger units of the system.

This valley train appears to have escaped the notice of all earlier students of the region. It possesses one unusual feature which deserves further attention. Throughout 15 miles of its length in the Chicago region its plane surface is interrupted by broad, low mounds of gravel, all elongated with the valley length, most of them near the middle of the valley and none in contact with the valley-train margins. Fifteen of them are shown on the Wheeling, Arlington Heights, Park Ridge, and River Forest quadrangles (Maps 1, 3, 4, and 7). Some of these mounds are three times as long as wide, others nearly ten times. None of them rise higher than 15 feet above the surface of the valley train. Generally they are simple in outline and topography, but some are aggregates of coalesced mounds which have lobed outlines and which may be almost as wide as long.

When these mounds were first encountered, it seemed likely that they would prove to be kamelike deposits, subsequently surrounded and partially buried by the valley-train gravel. But kames, built in contact with glacial ice, consistently show evidences of the presence of the ice. The many pits in the mounds show only well-sorted evenly bedded gravel like that in the valley train itself. Nowhere is there disturbed stratification, irregular foreset bedding, cobbly material, poor sorting, or till. Furthermore, there are kames in the DesPlaines Valley for comparison, fairly numerous north of Libertyville, and farther up the valley than the mounds under consideration. They are much steeper and higher, their stratification is much less perfect, and the sorting of their material far less advanced than in the mounds. Till balls and till masses occur in them.

There is no basis for considering the mounds in the Chicago area as kame piles. Nor can the mounds be satisfactorily explained as erosion remnants, for they are not akin to terraces in position or in topography. Long stretches of the valley have no mounds, whereas in one place (at Wheeling) where the valley in all other ways appears identical, about half the width of the valley floor is covered by mounded gravel. There certainly are channels in this Wheeling group, but not the simple kind that a shifting postglacial DesPlaines river would make. Instead, the channels unite and divide, deepen and shoal along their length, and are genetically like the linear closed depressions that exist also among the mound units of a compound group.

The interpretation that has proved most satisfactory is that the mounds are gravel accumulations on the bottom of the glacial river and contemporaneous with the rest of the valley train. This conclusion is not arrived at wholly by elimination of other possibilities. Gravel bars in streams have peculiar structures of their own, one of which, a convexity of the bedding parallel with the bar slopes, is shown in some of the mounds. The detritus that goes into the accretion of a bar is the bottom load, which is rolled along by traction and dropped where the current slackens. Pebbles on the top of a bar and on any growing slope have been rolled up to their resting

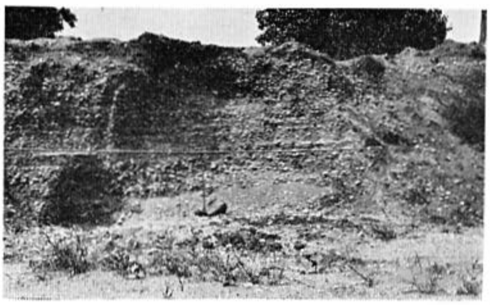


FIG. 40.—Section in glacial river bar, DesPlaines valley train. Corner of Milwaukee Avenue and Deerfield Road (Wheeling quadrangle).

place. This means that stratification in the mounded deposit parallels the growing slopes. Figure 40 shows a section in a bar at the corner of Milwaukee Avenue and Deerfield Road, Wheeling quadrangle (Map 1). The excavation is near the western edge of the bar and the observer is looking north. The slight westward inclination of the bedding is obvious though its parallelism with the surface slope could not be shown in the photograph. The uniformity of bedding and the well-sorted condition of the gravel, shown in the illustration, are characteristic of all the bars.

The most serious objection to the river-bar hypothesis is the absence of other evidence for a torrential stream. There are no boulder-strewn and cobble-covered flats, and no channel walls eroded in the marginal morainic slopes. The gravel in many places fails to reach the adjacent margins, grading into sand and even silt along the valley-train margins. Yet if the mounds are bars, a river at least 15 feet deep flowed southward down this stretch of the DesPlaines Valley, and its current would seem to have been vigorous across the entire cross section of the valley flat. The sand and silt tell, however, of a marked slackening of current along the margins. With the maximum known depth of the valley train 15 feet, the total thickness of the gravel under the higher bars should be at least 30 feet.

The Lake Border morainic system possesses three other outwash deposits, one on the west slope of the Deerfield moraine and crossed bv Willow Road on the Park Ridge quadrangle, and two on the west slope of the Highland Park moraine (Highland Park quadrangle—Map 2)—one in the western part of Highwood and one in Lake Forest. The one on the Deerfield moraine, in the center N 1/2 sec. 23, T. 42 N., R. 12 E. (Park Ridge quadrangle—Map 4), is thought to be a small deltaic deposit of the Glenwood level of Lake Chicago. The two others, in the east part of sec. 32, T. 44 N., R. 12 E., and in the W 1/2 sec. 15, T. 43 N., R. 12 E., are mapped as small outwash plains above the lake plain. In none of them is there much gravel; their material is mostly sand and silt.

*Glaciolacustrine deposits.*—Three of the bays of the Glenwood stage of Lake Chicago received glaciolacustrine deposits from the Lake Border ice. These deposits are mostly silts that cover the ground-moraine floor of the bays and have not been differentiated on the maps. The fourth bay, between the outermost Park Ridge and the Tinley moraine, contains the lower deltaic end of the DesPlaines valley train. No pits in this terminal portion, however, show delta foreset-bedding. The water apparently was too shallow.

*Correlation.*—The Lake Border moraines were first recognized and described by Leverett[41] in 1897. Their type locality, like that of the Tinley moraine, is within the limits of the Chicago region. Leverett recognized only three moraines, which he called Outer or West, Middle, and East ridges. Apparently he grouped the Deerfield and Blodgett together as one moraine. Leverett also thought that Blue Island ridge was an isolated portion of the Middle member, whereas in this report it is considered as a portion of the Park Ridge (Outer) moraine.

#### OFFSHORE DEPOSITS ON THE FLOOR OF LAKE CHICAGO

In the *Chicago folio*, the lake plain was mapped largely as "glacial drift chiefly ground moraine," and nowhere else was ground moraine shown on the four original quadrangles. The present survey reverses this procedure, showing large areas of ground moraine above the lake's highest level and none below. Ground moraine is here defined in terms of its original topography. The lake waters submerged extensive areas of it and so remade the surface that it is mapped as "lake bottom," even where it does not carry a lacustrine sedimentary cover.

The *Chicago folio* also mapped considerable areas of the plain as "sandy soil," which is chiefly lacustrine sand. The sand is rather thin and patchy in distribution, and in many built-up areas its remapping is no longer possible. For these reasons it has been omitted as a depositional unit on

[41]Leverett, Chicago Acad. Sci. Bull. 2.

the new maps. The principal fact of its distribution—prevalence below and paucity above the Toleston shoreline—is shown, however.

The ground-moraine knolls and swells submerged by Lake Chicago were beveled off by wave erosion, and the detritus was transferred elsewhere. The gravel and coarser sand was tractionally carried shoreward to the beaches and spits, while the fine sand, silt, and clay was carried in suspension in the opposite direction, most of it beyond the present shoreline. Lacustrine sand occurs to depths, locally, of 15 feet inside the Toleston shoreline but, except in beach accumulations, nothing approaching such thicknesses of sand are known above this level. The Lake Chicago plain is largely a clean, wave-swept till floor. Calumet Lake, Wolf Lake, and Lake George occupy incompletely erased depressions of the former ground-moraine surface.

These statements are more easily made than proved. The till floor of Lake Chicago seems remarkably smooth for a wave-eroded tract made over from a ground-moraine surface. Even if that ground moraine was itself unusually smooth, there perhaps should be faint linear elevations recording the Lake Border moraine ridges across it. Yet nothing other than Blue Island can be pointed to, and it was never submerged.

*Boulders.*—The numerous clay pits scattered over the Lake Chicago flat contain large numbers of reject boulders encountered in excavating the clayey till for brick-making material. The pits may average 25 feet in depth. It would seem that a like abundance of surface boulders should occur on the lake plain, where a comparable thickness of ridged till was removed by Lake Chicago waves. Boulder belts thus might be expected to mark the course of the Lake Border moraines.

The floor of Lake Chicago does have, or has had, a few boulder-strewn areas. They are shown by Alden on the *Chicago folio* maps. The most remarkable ones are in the outlet-channel heads and are due to scour of the underlying till by stream erosion. The boulders of the lake floor, as mapped by Alden, are not in belts. The *folio* maps do not attempt to indicate abundance of boulders. The present study was undertaken too late for such mapping, for boulders are useful, ornamental, and free-for-the-taking. The writer's observation over the years on the distribution of boulders on the Lake Chicago floor is that they occurred most abundantly at the foot of the Glenwood-stage sea cliffs. Alden thought those in the heads of the outlet channels had been berg-carried or ice-rafted to present positions; the writer believes them to be residual from erosion of till. Leverett, Alden, and the writer agree that those on the lake floor record erosion of till, but Alden thought sea-cliff recession more probable than bottom-dragging by open-water waves. If this idea is correct, and if there were no great variations in the original abundance of boulders in the till, then there has been but little wave erosion in making the till floor which so largely characterizes the lake plain.

Leverett described[42] a boulder belt extending north from the north end of Blue Island to the North Branch of the Chicago River, saying that south of 63rd Street to Blue Island the boulders "remain in about their natural abundance." He thought this boulder belt was a record of a former low till ridge connecting Blue Island and the Middle Ridge moraine. Alden mapped this area in 1896, and his depiction is of five boulder patches with so little elongation of the group that if they are interpreted as remnants of a former till ridge, the connection can as well be made with Leverett's West ridge as with his Middle ridge. Of that portion of Leverett's belt of boulders north of 63rd Street, Alden said, "Their number becomes so small as hardly to warrant more than a suggestion of such correlation."

It is interesting to find that a similar glacial till or boulder-clay floor exists over large areas about lakes Winnipeg, Winnipegosis, and Manitoba, the successors of glacial Lake Agassiz in southern Manitoba. Such surfaces lie below the beaches of the glacial lake, and though they may be rolling or gently sloping they have stony soils

[42]Leverett, U.S.G.S. Mon. 38, p. 383.

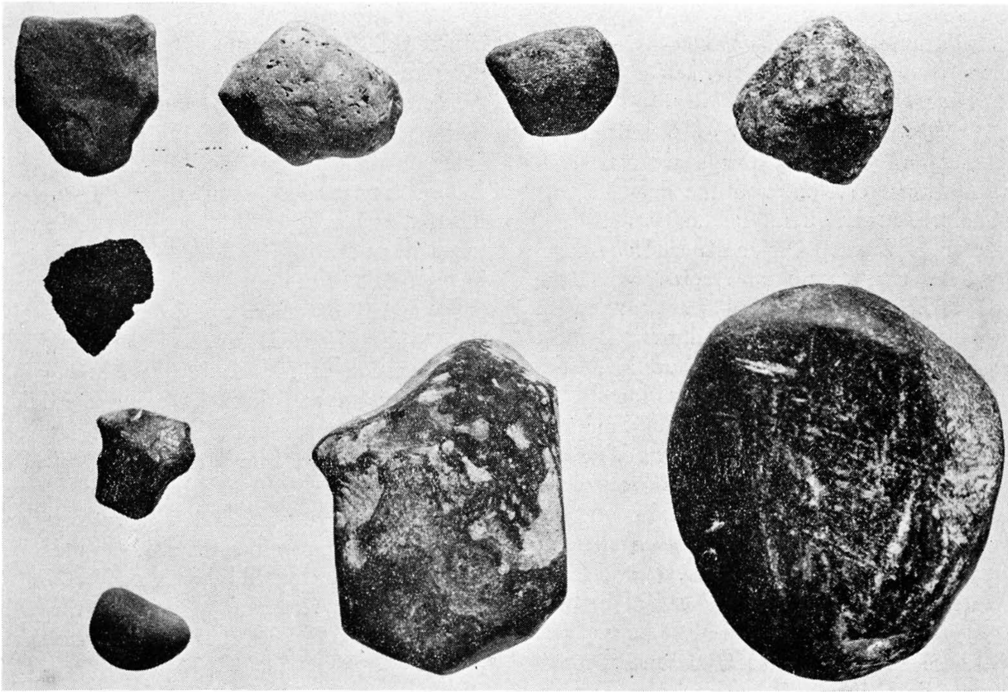


FIG. 41.—Glaciated pebbles dredged from lake bottom near Indiana Harbor buoy. Photograph by J. L. Hough.

because "wave action during the existence of the lake washed away the fine particles and left the stones and boulders on the surface."[43] In contrast are the boulder-clay areas above the level of Lake Agassiz, unmodified by subsequent wave action, where the soils contain few stones or boulders.

It is also interesting that Hough's[44] bottom-sampling of Lake Michigan off the Chicago shoreline revealed extensive areas of gravel or gravel-veneered till, miles out in the lake and at depths as great as 60 feet. Hough interpreted the gravel as "a lag concentrate of the coarser constituents of glacial till, resulting from wave and current action on the bottom under present conditions." The pebbles are subangular and some are striated; hence they are not beach pebbles, either from the present shore or of some earlier and lower shoreline now submerged. Some core samples also were taken by Hough, one of which is illustrated in figure 42. The pebble concentrate is thin, and the core consists mostly of a pebbly sandy clay, undoubtedly glacial till.

Such a thin pebble concentrate does not indicate any considerable removal of the finer constituents, but it does indicate the occurrence today of erosion, instead of deposition, at these depths. A pebbly veneer of this thickness would hardly remain after the lake water had been drained off and weathering and soil-making had gone on for several thousand years. We therefore do not ask, in substantiation of the theory, that the till plain carry a gravel cover. The scattered boulders on the smooth plain are all we may now expect.

Our topic is lacustrine sedimentation in Lake Chicago, and thus far we have been endeavoring to show how little of it there was. In the clay pits, canals, and other excavations examined during this study, there is so little offshore lacustrine sediment above the till that glacial Lake Chicago never could be mapped from its distribution

[43] Johnston, W. A., Surface deposits and ground-water supply of Winnipeg map area, Manitoba: Canada Geol. Survey Mem. 174. 1934.

[44] Hough, Jack L., The bottom deposits of southern Lake Michigan: Jour. Sed. Pet., vol. 5, pp. 57-80, 1935.

FIG. 42.—Core sample from lake bottom near Indiana Harbor buoy, taken about six miles offshore, in 50 feet of water. Photograph by J. L. Hough.

and probably could not even be proved to have existed.

*Hobart sections.*—One of the few areas of lacustrine deposits of Lake Chicago known in the general region is some miles east of the mapped area, in Lake and Porter counties, Ind. The numerous good sections of this clay deposit, made when U.S. Highway No. 6 was graded, have largely disappeared, but the deepest and best section, in the National Fireproofing Company's clay pit at Hobart, about 14 miles east of the state line, probably will remain available for years. Further study of the deposit is needed, for this lake sediment is not a conventional glaciolacustrine deposit.

Thickness of the Hobart clay exceeds 40 feet in the pit. Its surface constitutes a smooth plain, except for some sharply trenched V-shaped valleys cut into it and some beach and dune ridges of Calumet age built on it. So far as is known, it all lies east and northeast of Hobart Island, a low till island of the Glenwood stage in Lake County, Ind.[45] The island surface carried a few boulders, no more than any ground-moraine surface of the region, but none was found on the plain, in contrast with the old lake bottom across the line in Illinois.

The Toleston topographic map shows the plain to lie between 630 and about 645 feet, but the map is an old one, sketchy and undependable for this purpose. No precise altitudes have been obtained in this study, for the tract lies well to the east of the Chicago region.

The pit section is as follows:

| | *Thickness in feet* |
|---|---|
| Stratified yellow clay | 12 |
| Stratified blue clay | 32 |
| Gravel—largest pebbles about walnut size | 1 |
| Stratified clay, sand, and pea-sized pebbles; more sand and gravel than clay | 20 |

A clean section 27 1/2 feet in height was made in the north wall of the pit, extending from the bottom of the oxidized zone to the base of the cut. It showed throughout an alternation of clay layers and sand layers, 127 of each in the section. One might think of them as varves, except that there are other facts which deny that hypothesis or at least demand additional causes for the stratification.

The clay layers are four to ten times as thick as the sand layers and are more dis-

[45]See map *in* Cressey, George, Indiana sand dunes and shorelines of the Lake Michigan basin: Chicago Geog. Soc. Bull. 8, 1928.

crete units. Whereas very thin seams of clay occur in some of the sand layers, no sand seams occur in the clay layers. The thicknesses of the couples are highly variable, ranging from half an inch to 6 inches in immediately adjacent layers.

The alternation of thick clay units with thin sand units clearly records some alternation of conditions of sedimentation, but it does not indicate seasonal varving. A clue may lie in the fact that some of the interleaved very thin clay members of the fine sand units aggregate more than the sand itself. Storms or stormy seasons may be recorded by the sandy material, and longer periods of quiet by the clay. A detailed study of the deposit is necessary before it can be explained satisfactorily.

Another problem afforded by the Hobart pit sections is a 30-inch layer of pebbly clay 15 feet below the surface in the west wall. It looks like an unusually clayey till. There are striated stones in it, and its flat shaley pebbles are oriented at all angles. It contains very thin discontinuous laminae of fine sand, visible only when the material is broken horizontally. It does not occur in the north wall where the 27 1/2 feet of stratified clay and sand was examined, nor was any evidence of an interruption in sedimentation found there.

Because the entire deposit goes beneath the Calumet beach and dunes, it would seem to be a record of the Glenwood stage only. There is a possibility, however, that this particular Calumet beach grew first as an offshore bar which later accumulated a beach on offshore sediments of the same stage and shifted the shore north from the original Calumet land-and-water contact. Cressey seems to believe this though his statement was not explicit. In this case, the upper part of the clay deposit could be Calumet in age.

If the 30-inch layer of pebbly clay is till, there is a possible place for it in the sequence of events known from the moraines beyond the lake plain. The Tinley moraine probably records a minor readvance of the ice front to the position marked by it, which followed a greater recession after the main Valparaiso system was built. Such a recession may well have allowed ponding in front of the ice, earlier than Lake Chicago's beach-recorded history, and in such early ponds, with the edge of the glacier close by, much of the clay and sand might have accumulated. The thin, discontinuous till sheet would, by this hypothesis, record the Tinley readvance, the clay beneath being pre-Tinley but post-Valparaiso. Or a similar sequence, immediately preceding and contemporaneous with the Park Ridge moraine-building, might have left the intercalated till, in which case Glenwood sediments would underlie as well as overlie the supposed till.

*Other Indiana sections.*—Another tract of lacustrine sediments between the Glenwood and Calumet shores is found in Porter County, Ind., exposed along U.S. Highway 6 and the banks of Salt Creek Valley. The McCool landing field is on this deposit. The silt and clay here are at least 25 feet thick, the upper 10 feet oxidized, the lower portion bluish. There is no till and no true varves in the section. At the bottom of the zone of oxidation, there is an abundance of calcareous concretions, thin, very irregularly branched, and lobed in the plane of stratification (fig. 43). Concretions in Pleistocene deposits are exceedingly rare in the Chicago region and, except for these, are small and without noteworthy features. These concretions, however, are characterized by a peculiar ridge along the middle of the arms and branches, always at the bottom of the con-

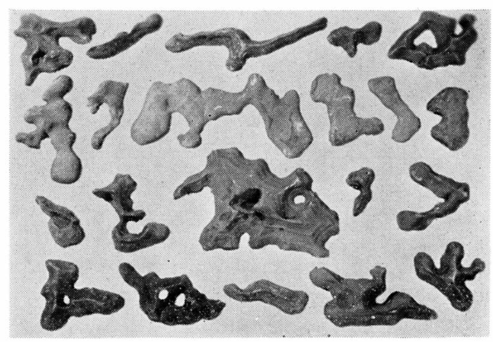


FIG. 43.—Calcareous concretions from lacustrine sediments near McCool, Ind. The longest specimen measures 7¼ inches. Specimens in next to top row show upper side; all others show bottom side.

cretion. In proportions and size, it resembles a ripple-mark ridge, though there surely is no genetic relationship. The restriction of the concretions to one horizon, their surprising abundance at that horizon, and the median ridge on the bottom of each are worthy of further study. In steeply tilted strata, such concretions would afford a clue to upper and lower sides of beds.

A little east of the Salt Creek crossing on U.S. Highway 6 and 13 miles east of of Broadway in south Gary, till appears in the section. Its maximum thickness in the highway cuts is 10 feet. Beneath the till is 6 feet of clean, pebbleless, unstained sand, as light in color as sand on the lake Michigan beaches today. The bottom of the sand was not reached in cutting the highway grade. Its top constitutes a broad mound, buried by the till. Also buried by the till, and lapping up on the eastern slope of the sand mound, are stratified silt and clay with some interbedded very fine sand. Another till member lies beneath the silt and clay and apparently goes beneath the sand mound also.

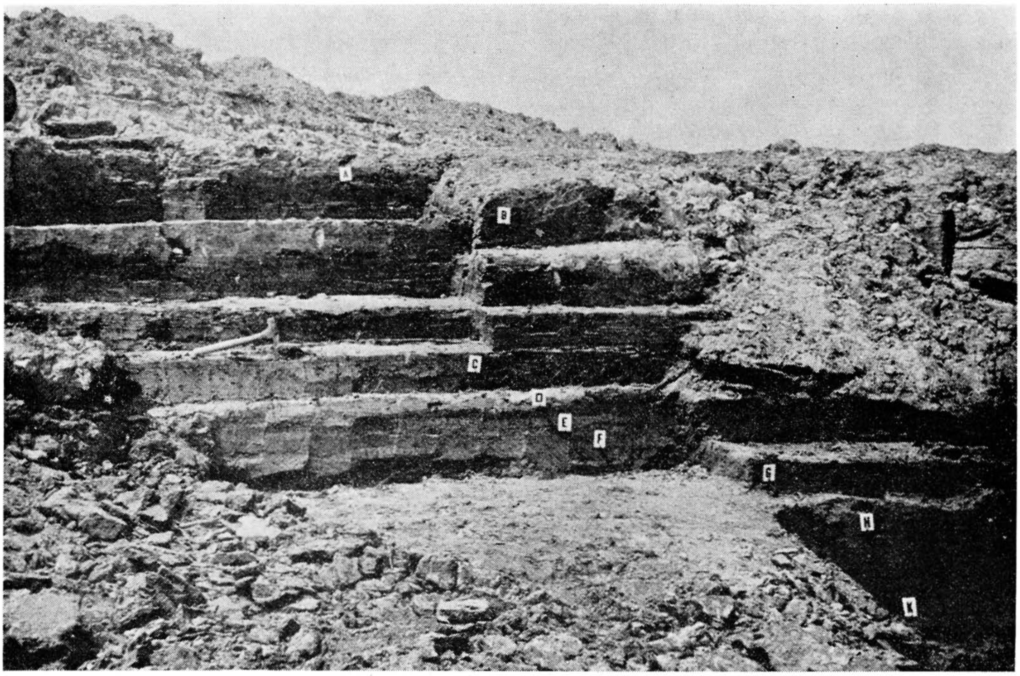



FIG. 44.—Baker's station 33 along North Shore Channel. 500 feet south of Devon Ave. *From* Baker, Frank Collins, The life of the Pleistocene or Glacial period as recorded in the deposits laid down by the great ice sheets: Univ. of Illinois Bull., vol. 17, no. 41, plate XVII, 1920.

| | *Material* | *Thickness in inches* |
|---|---|---|
| | Silt and loam | 20 |
| | Silt | 32 |
| A— | Peat, interstratified with thin beds of sand | 38 |
| B— | Occasional sand pockets, rarely 12 inches thick. Gray sand | |
| C— | Silt. Anodonta (clam) and wood on top of this layer | 6 |
| D— | Gray sand, with wood and Sphaerium (clam) | 4 |
| E— | Silt | 4 |
| F— | Gray sand | 2½ |
| G— | Silt | 2½ |
| H— | Silt and sand | 11 |
| K— | Wood, solid layer | 1 |
| | Sand and gravel | 8 |
| | Wood with spruce cones | 1½ |
| | Sand with shells, wood, and spruce cones | 4 |
| | Sand with some gravel | 4 |
| | Boulder clay | 44+ |
| | Total thickness | 180 inches |

The upper till of this section is interpreted as Tinley or possibly Lake Border in age. The clean sand is a small dune built close to a glacial lake in the southern part of the Michigan basin. The level of this lake rose as the advancing ice front altered discharge routes; the overlapping silt and clay were then deposited; and finally the overriding ice buried everything beneath the upper till. When Lake Chicago came into existence after the recession of the last ice advance, this till floor in Indiana was too shallowly submerged for sediments to lodge on it, and it was wave-swept as was most of the lake bottom now exposed in the Chicago region.

*North Shore Channel sections.*—Excavations for the three canals across the lake plain of the Chicago region afforded unparalleled opportunities for observation of lacustrine sediments, opportunities which promptly ended when the canals were completed and their upper slopes slumped or became covered with vegetation. The geological literature on the Chicago region contains one outstanding study based on such observations. In 1911, F. C. Baker[46] "was fortunate in being able to follow the excavation of [the North Shore Channel] foot by foot and thus to secure fresh exposures." This canal, more than 8 miles long, was dug in the bed of a long bay of the later stages of Lake Chicago, a bay protected behind the great spits in Evanston and North Chicago; it could hardly have been better located for our purpose. Sixty-three sections were measured and described, all cutting through the bay sediments into underlying till. The till surface was highest in the northern part of the cut and was, in general, more undulatory than the wave-cut lake flat. Sediments over the till were 1 foot to 12 2/3 feet thick and were composed of clay, silt, sand, gravel, peat, and marl, the sections varying considerably in kind and amount of the constituents. Fifty-four sections yielded some organic relics, ranging from peat and marl to scattered rootlets, leaves of oak, spruce cones, twigs, sticks, logs, and gastropod and pelecypod shells. Crayfish burrows and a duck humerus were also found.

Baker generalized the succession of deposits in all the sections and, from his summary,[47] we may make a composite column of the stratigraphic units of the North Shore Channel.

7. Sandy silt and peat beds. Average thickness 20 inches. Shallow-water molluscs in lower layers.
6. Silt and peat beds, 15 to 52 inches thick. Oxidized zone and crayfish burrows in upper part.
5. Silt, sand, peat, and marl; 19 to 59 inches thick. Lower layers generally without fossils; upper layers filled with shells and fish remains, representative of shallow-water types. Oxidized zone and crayfish burrows in upper part.
4. "Heavy" bed of shells, mostly *Unios* (clams).
3. Gravel and sand, 2 to 19 inches thick. No record of life except in upper part where *Unios* begin to appear.
2. Silty, carbonaceous, and peaty material; 1 to 40 inches thick. Shells of shallow-water molluscs, spruce cones, oak leaves.
1. Sand or sand with pebbles. From a fraction of an inch to 12 inches thick. No evidences of life.

Baker reviewed all earlier literature bearing on the history of Lake Chicago and attempted to correlate the sedimentary record he found with a more complicated succession of events than has so far been presented in this bulletin. A correlation will be discussed in Chapter IV. It will be sufficient here to say that unit 1 was considered Glenwood in age, unit 3 Calumet, and units 4 and 5 Toleston; unit 2 was interpreted as a record of a low-water stage (Bowmanville) between the Glenwood and Calumet stages; and the oxidized zones of units 5 and 6 were believed to record a complete emergence and weathering of those sedimentary units before the next overlying deposits were laid down.

Evidences of aquatic life in Lake Chicago had been known before Baker's study; Bannister in 1868 mentioned shells, wood fragments, and "vegetable mould" (probably peat) beneath lake sediments on the Chicago plain. But no one ever announced any record of Glenwood life until 1929 when Ball and Powers[48] briefly described the

[46]Baker, F. C., The life of the Pleistocene or glacial period: Univ. Illinois Bull., vol. 17, no. 41, 1920.

[47]Baker, F. C., op. cit., pp. 65-67.

[48]Ball, J. R., and Powers, W. E., Evidence of aquatic life from the Glenwood stage of Lake Chicago: Science, n.s., vol. 70, p. 284, 1929.

discovery of the fauna of minute molluscan shells from lake silts and clays in Skokie Valley above the Calumet level of the glacial lake. Baker identified ten species in the collection. Only a meager biota is to be expected in the cold waters of this early stage of the lake.[49] As the ice retreated northward, more and varied forms entered its waters and lived on its shores, as Baker has shown.

Lake Chicago took origin in Cary time and glacial lake waters continued to overlap some of the Chicago plain until the end of Mankato time. In this region there is no precise marker for the break between the two substages. Field evidence along the Wisconsin lake shore indicates that the Bowmanville low-water stage immediately preceded the readvance of the Lake Michigan lobe at the beginning of Mankato time (see "Causes for the Lake Chicago Stages," p. 109). For convenience in the absence of definite indications of substage position, the Lake Chicago deposits are all considered here under the Cary substage and the outlet-channel bars under the Mankato substage.

## Mankato Substage

### GLACIAL RIVER BARS

*Sag outlet channel.*—During the Calumet stage of Lake Chicago, a low island, Worth Island (Palos Park and Blue Island quadrangles—Maps 14, 15), stood just east of the Tinley moraine crossing, in the middle of a bay leading from the lake to the Sag outlet. A current capable of eroding the bay bottom seems to have flowed westward along both the north and south sides of the island during this stage. When the lake was lowered to the Toleston or Hammond level, the two parts of the bay became definite river channels, the discharge dividing to pass around the island and reuniting before entering the deeper, older part of the Sag outlet. The till became considerably scoured then, definite channel walls were cut, and a boulder-strewn floor was produced.

[49]Subsequent to the field work on which this report is based, excavations in a spit-like extension of the Glenwood beach, a mile west of Dyer, Ind. (Dyer quadrangle), have revealed wave-worn fragments of driftwood in the deposit.

The northern channel around the island also has at least seven mounded aggregates of pebbles and cobbles on the outlet-river bottom, none more than 10 or 12 feet high and all elongated with the channel length. The largest, a mile in length, has three lobes pointing down-channel. It is crossed by Harlem Avenue a mile northwest of Chicago Ridge (Palos Park quadrangle—Map 14). One other is also compound, from partial coalescence of narrow parallel ridges. Old pits show a little of the composition but nothing of structure. These channel-floor bars are composed of coarse material, including even boulders. The definite channel walls and the boulder-strewn floor agree with the coarse detritus in recording a vigorous current here, a current which eroded 10 to 15 feet deep in the till and, removing the finer constituents, left the scattered boulders and the cobble bars. Some of the boulders, of course, may have been contributed by floating ice, although at the Toleston or Hammond stage the ice front was far to the north and bergs probably rarely reached the outlet.

*DesPlaines outlet channel.*—In a similar way, the head of the DesPlaines outlet channel contains bars of coarse gravel for a stretch of 5 miles on both sides of the Tinley moraine transection. The village of Hodgkins (Berwyn quadrangle—Map 10) stands on the easternmost bar, Tiedtville post office (Sag Bridge quadrangle—Map 13) on the westernmost. A trench dug through some of the bars for a 24-inch natural gas pipeline at the time this study was undertaken showed an amazing coarseness of the mounded debris on the old glacial river floor. The material is almost wholly cobbles and boulders, most only slightly worn, some slabby, and 99 percent Niagaran dolomite. In the Hodgkins bar, upstream from the Tinley moraine, the dolomite debris apparently came chiefly from the southern slope of the bedrock hill which outcrops near McCook. The pipeline trench showed also that till immediately underlies the bars and constitutes the channel floor around and among them.

The most interesting of the three large mapped bars of this channel lies at the mouth of Flag Creek Valley, more largely in the valley mouth than in the DesPlaines channel. It covers most of the NW 1/4 sec. 32, T. 38 N., R. 12 E. (Sag Bridge quadrangle—Map 13) but extends into adjacent areas. It is exceptionally prominent topographically, descending 30 feet from its summit to the floor of the channel on the southeast and more than 10 feet to the alluvial flat of the tributary, Flag Creek, to the north. It nearly blocks Flag Creek, which is detoured over to the west side and there confined in a narrow "inner" valley with steep bluffs on both sides, three to ten times as high as any other place along the creek. The summit of the bar is 635 feet above sea level, approximately the altitude of the Glenwood shoreline of Lake Chicago. The southern base is 605 to 610 feet, the floor of the Toleston outlet.

Apparently the whole mass is a bar, or compound group of bars, the surface material cobbly on the channel side and pebbly and sandy on the much gentler northern slope, and apparently it is all of Glenwood age. The steeper southern slope is erosional and dates from the Calumet and Toleston lake stages. The bar was built in the morainic sag between the main Valparaiso moraine and the younger Tinley ridge, not in the channel proper. The low altitude of the base of the deposit (almost equally low on the west side along the creek) means that a free escape for Glenwood water beyond the Tinley moraine existed when the bar was initiated, that the DesPlaines channel was essentially as deep west of the Tinley moraine then as it is now, and therefore that the Tinley moraine alone was the Lake Chicago dam.

The interpretation of the mounded gravel deposit as a river bar considers that the bar owes its location to an embayment along the river channel afforded by the Flag Creek morainic sag. The deposit was a complete barrier to the sag at first, and silts were deposited on its back slope in a small lake. Debris came largely from destruction of the Tinley moraine dam and differs correspondingly from the slabby material of the Hodgkins bar east of the moraine. The bar is a dependency of the moraine, extending out from the river-cut bluff across the embayment like a bay-mouth spit from an adjacent cliffed headland.

It is interesting to compare this bar with the gravel terrace deposit in the Sag Channel, crossed by 96th Avenue, also immediately downstream from the Tinley transection (p. 82). There are no mounded bar forms on the terrace; the material is only poorly washed and there are many till balls, till masses, and soft shale pebbles in it. Although the top of the deposit is 630 feet above sea level, 10 feet below the highest Glenwood level, it is apparently not a river bar. It is a poorly differentiated outwash deposit made when the Tinley moraine was being built. Glenwood waters, pouring over the Tinley moraine after it was abandoned by the ice, eroded away that part of the original terrace where the channel floor now is and left this portion back of the moraine projection just high enough to prevent flooding by the glacial river.

An alternative interpretation for this bar at the mouth of Flag Creek Valley, with less supporting evidence known, is nevertheless worthy of consideration. Future excavations may show that, although the surficial gravel is truly a bar deposit, the body of the deposit contains till balls, poorly sorted gravel, irregular stratification, channel unconformities, ice-push deformations, etc., like the outwash in front of the Tinley moraine in Sag Channel. The Tinley moraine lies immediately to the east. Possibly the Tiedtville bar is also a modified remnant of a Tinley valley train in the DesPlaines transmorainic channel. If the Tinley moraine and outwash constituted the dam for Lake Chicago, as argued in this report, some outwash remnants are to be expected in the DesPlaines channel.

### GLACIAL RIVER BARS NEAR THE CHICAGO REGION

Another tract of glacial river bars, just outside the Chicago region, is on the valley trains of the DuPage River system, on the Wheaton and Joliet quadrangles. When the mounds of the DesPlaines valley train were being studied, this district was examined briefly to test the theory that glacial rivers in the region built bars. The outwash is closely associated with the Valparaiso moraine, part of it in a valley within the moraine, part lying just in front of it.

Mounds of gravel with all the features and relations of those in the DesPlaines valley train are found on the East Branch valley train, from a point about 2 miles north of Lisle downstream to the junction of the two branches and thence over a much wider valley train, or more properly an outwash plain, as far as Plainfield. The mounds are 5 to 15 feet higher than the surrounding gravel flats, elongated with direction of current flow, and none are found along the margins of the gravel fill. As in the DesPlaines Valley, kames are built on the slopes or uplands but none out in the flat. The mounds are not kames.

The area covered by the mounds on the East Branch valley train is much less than that of the channel floor. But farther downstream and out on the broad gravel plain, the channels become less prominent and the bar mounds predominate. From Plainfield southward, the bars are so much broader and more numerous that their tops constitute the plain, the channel-floor plain disappearing in the narrowing and decreasing number of channels. This is in perfect harmony with the concept argued for, because here the river current spread most widely, and its ability to transport was reduced to a minimum. Only certain routes carried currents of sufficient vigor to keep them open.

Four miles north of Plainfield, pits in a bar just east of the DuPage River show gently dipping strata parallel with the original surface slope, the common structure in river bars. River bars are rarely described in the literature on Pleistocene glaciation. There is no reason why this region should be exceptional in possessing them. They probably exist on many valley trains but, being minor topographic features, have been overlooked.

## RECENT STAGE

Since subsidence of lake waters and emergence of the present Chicago plain, various deposits have been made by the agencies of wind, running water, standing water, waves, and organisms. They record a regimen identical with that of the present, and generally such deposits are still accumulating.

### Character

*Floodplains.*—Alluvial deposits of silt, sand, and gravel characterize most floodplain accumulations chiefly in floodtime and, geological maps. Streams add to their floodplain accumulations chiefly in floodtime and, because the locus of currents across the flats may change considerably from flood to flood, the deposits vary from place to place and show marked differences in vertical sequences of materials. No one stratum is likely to be very extensive laterally. Floodplain deposits of low-gradient streams, however, are unlikely to contain coarse material.

Organic material commonly enters into the composition of floodplain deposits, the most striking example in the Chicago region being the buried peat, marl, and driftwood of Plum Creek (see p. 40).

*Alluvial fans.*—When a tributary stream of relatively high gradient enters on the floodplain of a larger stream, the abrupt decrease in velocity commonly causes local deposition in the form of an alluvial fan. If coarse material is thus deposited, the resultant fan has an easily recognizable slope, even though finer materials also enter into its composition. The silt fan at Dyer (see p. 40) has so gentle a slope that the eye fails to detect it, and the material in it is indistinguishable from that in the floodplain of the creek farther upstream.

*Slope-wash deposits.*—Similar in genesis to alluvial fans are the deposits of silt and sand at the foot of steeper slopes by unconcentrated slope wash. They do not constitute topographic forms, but their inconspicuousness is no indication of unimportance. Largely, these slope-wash deposits consist of material from the A-zone of the hillside soil, agriculturally by far the most valuable part of the soil.

*Swamp deposits.*—Enclosed depressions in morainic country, among the abandoned beach ridges and old dunes or in abandoned glacial-river channels, are favored sites for dense growths of hydrophytic vegetation, and the carbonaceous material is largely preserved by the constantly high level of the groundwater. The largest deposit of peat in the region is in the Sag channel, of Toleston age (Sag Bridge and Palos Park quadrangles—Maps 13, 14). It is 9 miles long, three-fourths of a mile in average width, and 10 feet in maximum thickness. The original swamp in which it accumulated was largely drained when the Calumet feeder ditch was dug in 1870. Another large peat deposit is in the morainic sag between Salt Creek and the head of Flag Creek, in the western part of Western Springs (Hinsdale quadrangle—Map 9), and a third is in the semicircular depression partially enclosing the "island" in the north-central part of the Hinsdale quadrangle (p. 31). The latter two deposits contain some surface wash and are mapped as basin-fills. Many other peat deposits are mapped in the Valparaiso and Tinley moraine country. Shell marl below the peat in many deposits records an earlier lake or pond in the depression.

There is no sharp line between peat and muck, although the two, if typically developed, are readily distinguished. The mixture of mineral matter brought from nearby hillsides by slope wash and of accumulated vegetal material in a depression is classified as muck.

*Groundwater deposits.*—Calcareous cementation of some gravel deposits of the region has been produced by groundwater work in Recent time. Perhaps some of the cementation shown by the "Joliet conglomerate" and other Lemont gravels is of intraglacial origin, although degree of cementation is not a criterion of age.

*Wind deposits.*—The two small areas of dune sand along the lake shore (see p. 45) are probably of Recent age. Much larger wind deposits lie a little to the east of the Chicago region, along the Indiana shore of Lake Michigan. None of the Lake Chicago dune sand appears to have been reworked during Recent time.

*Shore deposits.*—A continuous beach-sand accumulation marked the lakeward edge of most of the Chicago plain before the city began to grow. It was the product of wave and shore-current work of postglacial Lake Michigan. Some of its material appears to have travelled southward with the prevailing currents from the sea cliffs north of Winnetka, and some probably was dragged inshore by storm waves. The comparison of the bulk of this Recent beach material with that of the glacial lake shores constituted the theme of the first outstanding geological research in the Chicago region.

### Correlation

The end of the Wisconsin age (glacial) and the beginning of the Recent age (postglacial) is generally accepted as marked by the disappearance of all ice barriers to drainage from the Great Lakes basins. This is only a marker of convenience in classification, for geological processes now in operation began in the Chicago region before that time, and glacial conditions prevailed in northern Ontario for some time afterward. The oldest "postglacial" deposits of the region are on the Valparaiso moraine, where deposition has been continuous in the swampy depressions ever since the ice withdrew and plants first reinvaded the region. The Lake Michigan shore accumulations have the shortest "postglacial" history, save only where strictly local conditions have initiated deposition later. Thus the bogs on Cary drift, which give us a continuous pollen record, the beach sands of the last great storm, and floodplain deposits of the last great flood, perhaps only a year ago, are all classified as Recent.

## GEOLOGIC ASPECTS OF SOILS

Most geologists describe the alteration product of the agencies of weathering as *mantle rock.* It generally grades downward into unaltered subjacent material, maximum change having occurred at the surface. Because time is one factor in its production, mantle rock generally becomes deeper with increasing age. *Soil* is a more common term than mantle rock and, although not strictly synonymous, is used here as meaning the same thing.

Soil covers all the varied surficial deposits of Chicagoland, save where streams are eroding and where man has excavated or filled. As the deposits are not all of the same age, weathering must have begun on the oldest before it could have attacked younger deposits. But soil-making is so slow a process that no detectably greater weathering has occurred on the Valparaiso till than on the Highland Park till or the still more recently exposed till floor of Lake Chicago. There are differences in the soils in the region, to be sure, but they are traceable to other factors, chiefly differences in parent materials. The greater age of the Valparaiso drift could never be established from a comparison of depths of the altered zones on it and on the younger tills. Duration of Valparaiso exposure over and above that of Highland Park is clearly a small fraction of all postglacial time.

*Thickness.*—Soils of the Chicago region are deeper in the more porous sands and gravels than in clayey deposits of the same age. Depths of the soil vary also in the same parent material because of differences in slope of the surface and in depth to groundwater. Varying degrees of slope-wash removal make important differences in thickness of the soil remaining. All the variables render impossible any precise figure of the thickness of soil in Chicagoland. Oxidation of the iron, recognized by yellowish or reddish staining, has occurred to depths of 10 feet in some of the Lake Chicago dunes where favored by high permeability and a low water table. In clayey till, the zone of oxidation may average not more than 2 to 3 feet deep. These figures pertain to situations where neither removal of the topsoil on steep slopes nor additional deposition at the foot of such slopes has occurred.

*Character.*—Chicagoland soils are young compared with most soils of the earth. They are young compared with soils on the drift-sheets of the pre-Wisconsin glaciations. Their shallowness is one expression of their youthfulness; another is the very slight development of zonation.

Soil zones result from three simultaneous processes in soil-making. One is oxidation, another is leaching of calcium carbonate, and the third is development of colloids and their downward migration. These changes go on at different rates, hence their depths of penetration into the subjacent material are different. Oxidation proceeds the most rapidly and the lower limit of iron-staining gives the maximum depth of what we are here calling soil. Leaching of calcium carbonate by downward-percolating water is slower, hence its depth of penetration is less, rarely exceeding 2 feet in the region. Above that depth, there is no effervescence when acid is dropped on the soil, below it effervescence is likely to be brisk. The making of soil colloids has hardly begun, and the drift sheets have nothing to compare with the sticky gumbotil which characterizes the shallower depths of the weathered Nebraskan, Kansan, and Illinoian drifts.

In the soil classification of the University of Illinois Agricultural Experiment Station, stress is laid on the effect native vegetation has had in determining the existing soil types. On this basis, the three large categories of soils in Illinois are prairie, forest, and marsh or swamp. "Forest vegetation produces a thin accumulation of leaf and twig litter on the surface where it is exposed to the air; and being, therefore, subject to rather rapid and complete decay, it supplies little organic matter for the soil. Moreover, the roots of trees are coarse, penetrate deeply, and are relatively few in number. As compared with grass roots, they add little to the organic matter supply when they decay. . . . The grass vegetation of the prairies, on the other hand, produces enormous quantities of fibrous roots which are mostly concentrated in the surface 12 to 18 inches of the soil. Because air does not move freely through the soil, these roots decay slowly, and when decomposed the resulting organic residue tends to be preserved for a long period. Since the incorporation of organic matter in the soil produces a dark color, the grassland soils have brownish-colored surface strata. Marsh or swamp vegetation also produces large quantities of fibrous roots; but the low-lying pond-like nature of a swamp area is conducive to a more or less permanent high water table which prohibits the entrance of oxygen and so practically prevents complete decomposition. Thus immense accumulations of organic matter were preserved in the wet areas of the lowlands and the soils became dark brown to black in color."[50]

*Correlation.*—Essentially all soils of the region have been developed on parent materials of Cary (Wisconsin) age. Organic matter and wind-transported dust have been added in varying quantities during post-glacial time (the Recent age). The lack of a definite age contrast between soils on the oldest and the youngest till surfaces of the region is a consequence to two factors, time and climate. The time interval between the building of the Valparaiso moraine and the disappearance of Lake Chicago appears to have been a relatively small fraction of all post-Valparaiso time. The climate since the ice sheet withdrew from the lake basin has been warmer, and the chemical and biologic activities concerned in soil-making correspondingly greater, than during the Valparaiso-Lake Chicago interval.

[50]Wascher, Herman, Smith, R. S., and Smith, L. H., Boone County soils: Univ. Illinois Agr. Expt. Sta. Soil Rept. 65, p. 10, 1939.

# CHAPTER IV—GLACIAL HISTORY

The glacial and genetically associated stream, lake, and wind deposits of the Chicago region have been described, and their relationships discussed, in the preceding chapters. It remains now to weave these facts and interpretations into a coordinated history of the region during the Pleistocene. Because depositional records of the earlier part of the Pleistocene, known from other regions in the upper Mississippi drainage area, are lacking here, the history will largely be of the latter part of the Pleistocene.

## PRE-PLEISTOCENE EROSION

For more than a geological era before the first ice sheet invaded Chicagoland, the region was a land area. The lithified marine sediments which, as bedrock, underlie the glacial deposits today were weathered and eroded. From features of north-central Illinois, we know that an essentially complete cycle of erosion occurred late in this interval, and that the peneplain thus produced (the Central Illinois peneplain)[1] was then uplifted a few hundred feet and slightly tilted, inaugurating a new cycle of erosion early in the Pleistocene.

How great a thickness of rock material was removed during the preglacial erosional attack is unknown. From fossils found in clay fillings of fissures in the Silurian dolomite in the region, we know that younger Silurian strata,[2] and probably Devonian and Mississippian strata,[3] once overlay the Silurian rocks. In most of Illinois and much of the southern peninsula of Michigan, Pennsylvanian strata are found above the Mississippian, and the northeastern edge of the Illinois Pennsylvanian is only 20 miles distant from the southwest corner of the Chicago region. Probably, therefore, even Pennsylvanian strata existed in the region, and the rock removed to expose the Silurian strata may have been hundreds of feet thick.

The peneplain referred to, the Central Illinois, is the third known to have eroded in Illinois bedrock. The earliest, the Dodgeville,[4] was first recognized in the Driftless area of southwestern Wisconsin. Opinion has varied as to its age, and indeed as to its very existence,[5] but conviction has grown that the uplands of the type area[6] are remnants of a former erosional lowland of Tertiary age, now standing more than 1400 feet above sea level near Sparta and Tomah, Wis., and sloping gently down to about 1000 feet in extreme northwestern Illinois. The second peneplain, the Lancaster, bevels several tilted formations in the LaSalle anticline, but apparently all traces of both earlier ones were destroyed in the Chicago region during the Central Illinois erosion cycle.

The Silurian surface beneath the Lemont and Valparaiso drift a little east of Joliet has a fairly uniform altitude of 630 and 640 feet above sea level. This surface, correlated with the Central Illinois peneplain, bevels the Silurian formations, whose strata have a gentle eastward dip. The surface itself descends westward 30 to 40 feet in the 50 miles to the Ottawa region.

[1]Horberg. Leland, Preglacial erosion surfaces in Illinois: Jour. Geol., vol. 54, pp. 179-192, 1946. Reprinted as Illinois Geol. Survey Rept. Inv. 118.

[2]Carey Croneis, personal communication.

[3]Weller, Stuart, A peculiar Devonian deposit in northeastern Illinois: Jour. Geol., vol. 7, pp. 483-88, 1899.
Eastman, C. R., Description of new species of Diplodus teeth from the Devonian of northeastern Illinois: Jour. Geol., vol. 7, pp. 489-93, 1899.

[4]Trowbridge, A. C., The erosional history of the Driftless area: Univ. Iowa Studies in Nat. Hist., vol. 9, no. 3, 1921.

[5]Martin, Lawrence, Physical geography of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 36, 2nd ed., 1932.

[6]Bretz, J Harlen, Geology and mineral resources of the Kings quadrangle: Illinois Geol. Survey Bull. 43, pp. 273-277, 1923.
Knappen, R. S., Geology and mineral resources of the Dixon quadrangle: Illinois Geol. Survey Bull. 49, pp. 90-92, 1926.
Bevan, Arthur, Geology and mineral resources of the Oregon quadrangle: Illinois Geol. Survey, unpublished manuscript.
Thwaites, F. T., *in* Guidebook Ninth Annual Field Conference, Kansas Geol. Soc., 1935.
Bates, R. E., Geomorphic history of the Kickapoo region, Wisconsin: Geol. Soc. Amer. Bull., vol. 50, pp. 819-850, 1939.
Willman, H. B., and Payne, J. N., Geology and mineral resources of the Marseilles, Ottawa, and Streator quadrangles: Illinois Geol. Survey Bull. 66, pp. 204-205, 1942.
Horberg, Leland, Preglacial erosion surfaces in Illinois: Jour. Geol., vol. 54, pp. 179-192, 1946.
Horberg, Leland, Bedrock topography of Illinois: Illinois Geol. Survey Bull. 73, pp. 87-96, 1950.

## EARLY PLEISTOCENE EROSION

Uplift and slight warping of the Central Illinois peneplain occurred in late Pliocene time, and stream entrenchment consequent on this rejuvenation continued into the early Pleistocene. Westward across the plain a major river, the Mahomet (Teays), flowed from West Virginia, Ohio, and Indiana to the ancestral Mississippi. Its course across Illinois was held during Nebraskan and Aftonian ages, but the Kansan ice sheet, coming from the northeast, obliterated its valley and a new drainage system formed. One trunk stream was the River Ticona, ancestral to the Illinois River of today.[7]

The stream-carved surface of the Niagaran dolomite beneath the drift of Chicagoland (see p. 51) was made during the Mahomet (Teays) cycle by the local headwater drainage of a main river that initiated the Lake Michigan depression. Theoretical reconstruction of this major drainage system east of the divide is much less advanced than is that of the Mahomet (Teays). The main valley undoubtedly occupied part, if not all, of the elongated basin, but glacial erosion in the soft underlying Devonian rocks has so greatly altered it, and glacial deposition in southern Michigan and northern Indiana has so masked the bedrock valleys, that until much more is learned from well-log data, reconstruction will remain uncertain. It is not even known yet whether this pre-Lake Michigan river belonged to the St. Lawrence or the Ohio drainage. A connection between the south end of the Lake Michigan basin and the deeply buried Mahomet (Teays) valley in the general region of Lafayette, Ind., believed to be the trunk valley of what is now the Ohio drainage,[8] may be found when more is known of the drift-covered bedrock topography of extreme northwestern Indiana.

In all likelihood stream occupancy of the Michigan basin ended and lake occupancy began with the coming of the earliest ice sheet.

[7] Horberg, Bull. 73, pp. 56-57, 99.
[8] Fidlar, M. M., The preglacial Teays valley in Indiana: Jour. Geol., vol. 51, pp. 411-418, 1943.

## PLEISTOCENE EPOCH

### Character of the Pleistocene Epoch

The Pleistocene, or "Glacial," epoch is not unique in earth history. There were several much earlier great ice sheets which grew and waned and left their record in striated rock surfaces, till (tillite), and varved lake clays (banded slate). The northern Central Lowlands, however, have no known earlier record of the experience that came to them late in the Cenozoic era, a million years or so ago, and was repeated three times, the fourth glaciation ending only about 10,000 years ago. During these glaciations the northern half of North America must have resembled the interior of Greenland or Antarctica today, a vast monotonous expanse of snow and glacial ice, completely deserted by living forms.

#### CENTERS OF ACCUMULATION

The glaciers invading the Chicago region came from far to the northeast. Ice from a center in the Labrador peninsula (fig. 45) spread out in all directions, particularly to the south, covering the New England states and New York and invading northern New Jersey and Pennsylvania. Most of Ohio was covered by this ice sheet, five-sixths of Indiana, and all but 400 square miles of Illinois.

Another great center of ice accumulation, the Keewatin, existed at the same time west of Hudson Bay, its southward expansion reaching into the United States all along the Canadian border on the Great Plains and spreading down along the Central Lowlands west of the Mississippi nearly half-way across Missouri and into northeastern Kansas. Although the Labradorean and Keewatin ice sheets coalesced, the Chicago region appears never to have received any glacial ice from the Keewatin center.

Direction of movement is read from bedrock striae, from ground plans of moraines, from lithological features of the drift, and from comparisons of preglacial drainage systems with glacial derangements of drainage and with modern drainage patterns. From such data we know of several smaller centers of glacial growth and radiation in


FIG. 45.—Northern part of the Northern Hemisphere showing areas glaciated during Pleistocene time. *After* Encyclopaedia Britannica, vol. 10, p. 375, "Glacial Epoch or Pleistocene Ice Age," 1949.

North America, probably contemporaneously developing and wasting away through the four Pleistocene epochs along with the two great ice sheets.

### THICKNESS AND MOVEMENT OF THE ICE SHEETS

Unlike mountain glaciers, which move downgrade for the same reason that streams flow downhill, the enormous Pleistocene ice sheets moved radially out from thick central dome-like accumulations, largely unaffected by the slopes of the land beneath them. They were more like the icecap of Greenland today, which is 8800 feet thick at the thickest known places; its average may be about 3000 feet. Surface gradients, except near the margin of the icecap, are too low to be detected by the eye alone. Whether the upper ice flows over the lower ice on low gradients or the lower ice is squeezed out laterally by the weight of the upper part is a matter as yet undetermined. The important point here is that the Pleistocene ice sheets of North America were in only a general way responsive to underlying topography, that they overrode most hills and valleys in their way without changes of course, that they eroded deep basins like that of Lake Michigan, and that the bottom ice successfully rode up out of those basins with the debris it had abstracted from them. The thickness of the ice in the Chicago region probably was at least a mile.

If the ice sheets were like Greenland's, the Pleistocene ice moved very slowly, probably only a few feet a day. Since advance of an ice front is the rate of movement of the ice body minus the amount of marginal melting, our estimate of the time required for a glacial invasion from Labrador must again be lengthened.

If the rate of invasion was comparable to that of retreat (in which excess melting over the still-continuing forward flowage determines the rate), we may have something better than estimates. By counting and correlating annual layers of silt and clay (varves) deposited in glacial lakes, the retreat of the Wisconsin ice sheet is estimated to have been at the rate of less than half a mile a year across a stretch of 745 miles and at the rate of about 250 feet a year across another stretch of 185 miles.[9]

### CAUSES OF GLACIATION

No one cause for glaciation ever proposed has satisfied all geologists. Many theories have been urged, the more plausible ones including: (1) higher altitude of the land, (2) decrease in percentage of atmospheric carbon dioxide, (3) shifting of ocean currents and wind belts, (4) climatic consequence of sunspot cycles, (5) precession of the equinoxes, (6) shifting of the earth's axis, (7) variations in solar radiation, and (8) effects of great quantities of volcanic dust in the atmosphere. Opinion today[10] is that favorable and simultaneous combinations of several of these influences on terrestrial climates probably gave the earth its Pleistocene epoch.

[9]Antevs, Ernst, The last glaciation, with special reference to the ice retreat in northeastern North America: Am. Geog. Soc. Res. Ser. 17, 1928.

[10]See pages 105-110 of F. T. Thwaites' *Outline of glacial geology* (1937) for a good summary of various theories.

### LENGTH OF THE PLEISTOCENE EPOCH

Again we must deal with estimates. The glacial lake varves give us definite annual units, but they bridge only fractions of the glacial retreats. Depth to which the oldest exposed drift has been leached is an expression of elapsed time, but it cannot be formulated in precise numbers of centuries or millenia. Development of stream-erosion patterns on drift sheets affords another approach, but it too is incapable of precise evaluation. The retreat of Niagara Falls is widely used to measure a part of late Wisconsin and all of postglacial time, but that is all it can measure. The figure that has been generally accepted during the past few decades is 25,000 years. A notable and sweeping revision of the duration of the Pleistocene and post-Pleistocene time is discussed on page 128.

Because the Mankato drift in Iowa is thought to have been deposited essentially contemporaneously with the opening of the Niagara route, depth of leaching in that young drift is a yardstick for estimating the time required for the deeper leaching on older drifts. Thus one authority arrives at a figure of a million years for the duration of all Pleistocene time.[11] But in the next paragraph he admits that it may have been two million years. Since publication of Part I of this bulletin (1939), the "yardstick" has been shortened by half (see page 128).

### LIFE OF THE PLEISTOCENE EPOCH

As geologists measure earth history, a million years back in the past was only an hour ago. No great extinctions, like that of the Mesozoic dinosaurs, mark the transition from Pleistocene life to that of the present. Some conspicuous species, like the mastodon, mammoth, sabre-toothed tiger, dire wolf, cave bear, giant sloth, and giant beaver, have disappeared from the earth, and the ranges of many surviving species have changed greatly. Mammoth teeth and bones have been found in several places in the Chicago region, buried in late glacial and

[11]Kay, G. F., Classification and duration of the Pleistocene period: Geol. Soc. Am. Bull., vol. 42, pp. 425-466, 1931.

early postglacial swamp deposits. Associated remains are deer antlers and the shells of bivalves and snails, the latter so abundant that they constitute marly layers in the sediments of Lake Chicago.[12] Logs, sticks, twigs, leaves, and pollen grains[13] give a fairly good picture of the late glacial and early postglacial flora. Although no interglacial faunal or floral relics have been identified in the Chicago region, they are known from Aftonian (first interglacial), Yarmouth (second interglacial), and Sangamon (third interglacial) deposits elsewhere in Illinois and in adjacent states. Some northern conifer species show, by growing in these latitudes, the effect of the glacial stage which has just passed or foretell the approach of the ice of the next glaciation. Biota of the middle of the interglacial stages record a climate as mild as that of the present.

Man was a member of the European Pleistocene fauna; his tools and bones have been found in gravels whose stratigraphic position is definitely determinable. For a long time, the search for Pleistocene man in North America was fruitless, but much new evidence on early man in the continent has recently been found. We now know that our species lived in Colorado,[14] Texas,[15] and elsewhere during early postglacial time and perhaps during some of the later Pleistocene epochs.

### Nebraskan Age

If the Nebraskan ice sheet ever invaded the Chicago region or adjacent territory, all evidence of the invasion has been obliterated by erosion or concealed by complete burial. Ice from the Labradorean center apparently thrust farther south in New Jersey at this time than did any later ice, but most of the known Nebraskan drift lies west of the Mississippi River and was deposited by Keewatin ice. The later Kansan ice from the same center appears to have reached as far as the Nebraskan, hence Nebraskan drift is to be seen only where streams have cut through the younger drift cover.

The rough, stream-eroded topography of the Driftless area is believed by Trowbridge[16] to be post-Nebraskan, pre-Kansan in age. But if Nebraskan ice invaded the Lake Michigan area far enough to block the preglacial river that is believed to have initiated the depression (later occupied by the lake), the bedrock valleys beneath Chicagoland are probably pre-Nebraskan.

### Aftonian Age

A deep weathered zone on the surface of the Nebraskan till sheet and beneath the unweathered basal Kansan till overlying it, found widely west of the Mississippi Valley, clearly records a long period of exposure between the two glaciations. The soil profile, where undisturbed by overriding Kansan ice, shows the three zones well developed. The colloidally enriched upper part is a typical gumbotil—a dense clayey material entirely the product of weathering of the till. In addition, peat and silt deposits are found in undrained places on the Nebraskan topography.

### Kansan Age

Any drift of Kansan age in the Chicago region was deposited by Labradorean ice. Kansan drift of Labradorean origin has been identified in the Marseilles-Ottawa-Streator area.[17] There is no conclusive evidence, however, that any of the undated tills of Chicagoland are of this age.

Most of the known Kansan drift in the Upper Mississippi Valley lies largely west of the Mississippi, and was deposited by ice from the Keewatin center. The eastern margin of this ice sheet crowded across the Mississippi into Illinois. Thus Illinois has Kansan drift (buried by younger tills) from both centers.

It is probable that advancing Kansan ice made a "Lake Chicago" in the southern

[12]Baker, F. C., The life of the Pleistocene or Glacial period: Univ. of Illinois Bull., vol. 17, no. 41, 1920.
[13]Voss, John, Comparative study of bogs on Cary and Tazewell drift (abst.): Ill. Acad. Sci. Trans., vol. 29, no. 2, p. 81, 1936.
[14]Bryan, Kirk, and Ray, L. L., Geologic antiquity of Lindenmeier site in Colorado: Smithsonian Misc. Coll., vol. 99, no. 2, 1940.
[15]Sellards, E. H., Artifacts associated with fossil elephant: Geol. Soc. Am. Bull., vol. 49, pp. 999-1010, 1938.
[16]Trowbridge, Univ. Iowa Studies in Nat. Hist., vol. 9, no. 3, 1921.
[17]Willman and Payne, Bull. 66, p. 151.

part of the Lake Michigan basin and that this was repeated during its retreat. Discharge of such a lake across the bedrock divide might, at this time, have initiated the erosion of the Hadley bedrock valley.

### Yarmouth Age

The longest interglacial interval of the Pleistocene followed the Kansan glaciation. Gumbotil on Kansan drift west of the Chicago region has a maximum thickness of 15 feet, an average of 11 feet. Local peat deposits are found above the gumbotil. Yarmouth time encompasses the interval of formation of these deposits and includes considerable erosion of the underlying deeply weathered Kansan till before the Illinoian glaciation. It has been suggested that the long Yarmouth age might well justify a bipartition of the Pleistocene.

The lowest 85 feet of fill in the Hadley buried valley is an undated drift below the typical Lemont drift. If Lemont drift is Illinoian in age, then the subjacent fill is Kansan, and the buried valley must have been completely developed during Aftonian time and ceased functioning as a lake outlet with the Kansan advance. A corollary of this conclusion is that the rock-bottomed DesPlaines Valley at Lemont was initiated during the Kansan retreat.

If, however, Lemont drift is Tazewell (Wisconsin) in age, the lowest drift in the Spring Creek buried valley is probably Illinoian, and the valley presumably functioned as an outlet for a late Kansan "Lake Chicago" and perhaps for a Yarmouth "Lake Michigan," possibly even for a Yarmouth "Michigan-Huron-Superior" lake.

### Illinoian Age

The Labradorean ice made its maximum advance during Illinoian time, nearly reaching the southern end of Illinois and advancing westward a short distance across the Mississippi River into Iowa. Illinoian till lies farther south in Illinois than any other till left by the great ice sheets of North America. In contrast, drift of Illinoian age from the Keewatin center has not yet been identified in Illinois.

Since Illinoian ice must have covered the Chicago region, some of the undated tills may be of that age. The weathered drift at the Dolese and Shepard quarry (p. 78) appears to be at least as old as Illinoian. The Lemont drift may have been deposited by the Illinoian ice sheet but, if so, the deeply weathered zone which developed during the Sangamon interglacial age and which generally separates Illinoian drift from Wisconsin deposits west of the Chicago region was almost entirely eroded by the advancing Wisconsin glacier. Of scores of exposures, only the one recently found at Worth (p. 63) shows part of a weathered zone which may be comparable to the Sangamon profile of weathering.

With each succeeding glaciation, glacial scour doubtless increased the depth of the Lake Michigan basin, and a late Illinoian glacial "Lake Chicago" is therefore even more probable than one during Kansan retreat or Yarmouth time. But if the lowest drift in the buried Hadley Valley is Illinoian, the outlet of any such late Illinoian glacial lake probably was the DesPlaines Valley at Lemont.

### Sangamon Age

Like the Yarmouth age, the Sangamon interglacial age records a long time of weathering, during which 2 to 5 feet of gumbotil was formed and peat and humus were accumulated in low places. None of its history is decipherable from the Chicago region.

The Hadley buried valley may conceivably have operated during Sangamon time if Illinoian drift had so filled the Ticona Valley that the gradients across the divide were low. The sand and fine gravel below the Lemont drift in the test well indicate only gentle currents. It is probably glacial outwash, not the bottom deposit of a Sangamon river. The favored interpretation of the buried valley's history calls for final blocking during the Illinoian retreat.

### Wisconsin Age

On the eastern seaboard, in New England and New Jersey, the Wisconsin ice sheet reached or almost reached the limits attained in earlier glaciations. Also in places in the northwestern states, Wisconsin ice reached and probably exceeded previously attained limits. In the Great Lakes and Upper Mississippi Valley states, this latest glaciation, despite vigorous moraine-building, fell considerably short of the southern extensions attained by Kansan ice west of the Mississippi and of Illinoian ice east of it.

The Wisconsin glaciation in the Mississippi and St. Lawrence drainages involved oscillations of the ice front not recorded during any of the earlier glaciations. There were five definite advances separated by four retreats. The earliest advance was generally overridden by the later advances and is recognized principally by a deposit of loess which shows the presence of valley trains. During the remainder of the Wisconsin age each succeeding advance generally fell short of the limits reached by the immediately earlier one. The retreats were of unknown extent and duration but were much less than those during the interglacial ages. In the region of the Great Lakes, the ice front may have retreated each time to stand within the limits of the Lake Michigan basin.

The five advances are the basis for the subdivisions of Wisconsin time. The source and extent of the ice during the earliest subage, the Farmdale, is not known, but its associated loess is widely recognized in the Mississippi, Missouri, and Ohio valleys. The second, or Iowan, subage is recorded by Keewatin ice mainly in east-central and western Iowa; the third, or Tazewell, by ice mainly from the Labradorean center; the fourth, or Cary, presumably by ice from a secondary center, the Patrician, lying south of Hudson Bay; and the fifth, or Mankato, by ice again from the Keewatin center. As a consequence of these differences in expansion from the different centers of growth, the outlines of the ice front changed so greatly that some later Wisconsin moraines actually overrode earlier ones at considerable angles.

### TAZEWELL SUBAGE

Tazewell drift covers about 20 counties in northeastern Illinois and portions of a dozen more. The moraine pattern on figure 15 is largely a record of the oscillation of the Tazewell ice lobe that deployed out of the Lake Michigan basin from the much larger Labradorean ice sheet of this time. Closer to Lake Michigan, the Tazewell drift was overlapped by Cary ice, which built the Minooka and all later moraines. Although there are no moraines of Tazewell age in the Chicago region, there probably is buried Tazewell drift.

*Bloomington (?) glaciation.*—The oldest drift of Chicagoland to which a tentative Tazewell age can yet be assigned consists of the inclusions of pink and red till and red clay in Valparaiso, Tinley, and Lake Border tills. If these inclusions have been derived from Bloomington drift, as the color suggests, then remnants of that drift should underlie the younger deposits somewhere in the region. If the suggestion is correct, the Lake Michigan lobe, which built the Bloomington moraine in early Tazewell time, must have retreated until its margin was back somewhere in the lake basin. In the northern part of Chicagoland the Bloomington moraine lies only 40 miles west of the lake shore, and its red till is known *in situ* within 30 miles of the lake. Farther south, Bloomington retreat would have to be at least 75 to 80 miles to account for the Burnside, Bernice, Chicago Heights, and Homewood pink-to-red till.

*Lemont glaciation.*—Labradorean ice undoubtedly deposited the Lemont drift in close association with a west-facing ice front. If it is of late Tazewell age, it probably records a pause (or minor readvance) during retreat from the Marseilles, the youngest of the mapped Tazewell moraines, 40 miles from the Lemont drift along the direction of glacial striae. Thickness of the ice-laid drift and abundance of the associated coarse washed drift indicate that it is part of a once strongly marked marginal moraine. Its silty character and almost total lack of shale pebbles argue that the transporting ice did not cross the Devonian shales in the bottom of the Lake Michigan basin but probably traversed the western part of the basin and the extreme eastern part of Wisconsin. If this is a correct view, drift of Lemont age in northern Indiana, if it exists there, will never be identified by extreme siltiness and a lack of shale pebbles.

If, however, pre-Lemont ponding in the Lake Michigan basin had accumulated great quantities of shore sand and gravel and offshore silt, and if their later incorporation in the Lemont drift gave rise to the characteristic sandy and silty texture, then this drift in northern Indiana, if it exists there, will closely resemble in composition the type exposures.

*Post-Lemont, pre-Minooka interval.*—The ice front retreated from the Lemont "moraine" for an unknown distance, probably not entirely from the Lake Michigan basin. Discharge from a post-Lemont "Lake Chicago" used the new west-draining valley across the bedrock divide (the present DesPlaines and Sag transmorainic valleys), locally cutting down into bedrock beneath that drift but failing to attain either the depth in rock or the low altitude above sealevel of the floor of Hadley buried valley.

Total depth of this major valley was of the order of a hundred feet. High gradients were thus afforded for drainage into it from adjacent surfaces. The silty Lemont drift was eroded more rapidly, probably, than a clayey till would have been, yet the tributary-valley development during this time is so extensive that a long interval is required. Much of the oxidation of the Lemont drift occurred at this time, perhaps largely caused by circulating groundwater in the porous drift below the soil zones instead of by downward-moving soil water but nevertheless it required a long interval.

This interval may coincide with the time of the "break" between the Tazewell and Cary subages. The separation was originally established on the basis of notable changes in alignment of the ice front on its return to build the Minooka moraine. The extent of tributary-valley growth during the Lemont, pre-Valparaiso interval argues for a longer exposure than this "break" would provide and suggests that the Lemont drift may be Illinoian in age.

Lake Illinois disappeared before the beginning of Cary time, its valley again becoming a streamway. Much of the Lemont outwash[18] was eroded away during this interval by the re-established Illinois River.

#### CARY SUBAGE

The change in outlines of the Cary moraines is taken to mean that the Patrician center, somewhat farther west than the Labradorean center, dominated in supplying ice for northeastern Illinois and adjacent Wisconsin during this time. All the moraines of the Chicago region are of Cary subage.

*Valparaiso glaciation.*—Three Cary moraines lie west of the Valparaiso moraine—the Minooka, Rockdale, and Manhattan—all composed of clayey till indistinguishable at present from Valparaiso till. Hence all the clayey till, rich in shale pebbles, that overlies the Lemont drift is treated as Valparaiso till.

The Valparaiso ice, probably of Patrician derivation, built a wide moraine belt encircling the southern end of the Lake Michigan basin. Excavation of the basin was now almost complete, and the shape of the ice lobe clearly reflects the basin's control of its spread. A neighboring lobe in Wisconsin, the Green Bay lobe, underwent a greater expansion, causing the Valparaiso moraine near the state line to overlap the north end of the Minooka just as the Minooka had overlapped the north end of the Marseilles moraine. Five minor oscillations of the ice front occurred during Valparaiso time, well recorded farther north[19] but less pronounced in the Chicago region's record.

The Valparaiso moraine stands higher than any other in the Chicago region because it was built on high bedrock and thick Lemont drift. The same relative thinness of Valparaiso drift over buried relief much greater than that of the moraine itself is found north of the region.[20]

The pre-Valparaiso tributary valleys on the Mokena and Sag Bridge quadrangles were little modified by Valparaiso erosion or deposition. The major DesPlaines and

[18]Joliet outwash plain of Bull. 51 (pp. 79-87).
[19]Powers, W. E., and Ekblaw, G. E., Glaciation of the Grays Lake, Illinois, quadrangle: Geol. Soc. Am. Bull., vol. 51, 1940. Reprinted as Illinois Geol. Survey Circ. 63.
[20]Ibid.

Sag valleys emerged from beneath the wasting Valparaiso ice essentially as capacious as today and nearly as capacious as before the Valparaiso overriding. Kames and eskers were built in positions that only the preexisting valleys could have determined. Parts of the bedrock floor still carry the glacial striae[21] left by Minooka, Rockdale, Manhattan, and Valparaiso ice. The striae were protected from the later Lake Chicago discharge by their higher marginal position along the channel or by a cover of till or outwash.

Valparaiso valley trains were built of outwash gravels in the Dupage and DesPlaines valleys beyond the moraine front.[22] They were subsequently eroded greatly, but remnants indicate that the glacial rivers entered standing or slack water near the present junction of the DesPlaines and Kankakee rivers, about 15 miles below Joliet. If the DesPlaines valley train west of the Valparaiso moraine ever was extended back upstream as the ice retreated across the wide moraine belt, it has been entirely removed by the post-Tinley Lake Chicago outlet river.

Much water flowed down Fox River Valley during the Valparaiso glaciation; the valley-train gravels deposited there overlie and are distinct from the older Algonquin gravels of possible Lemont age.

In the Kankakee River Valley, relatively enormous quantities of meltwater were discharged at this time. The meltwater came (1) from the eastern and southern margins of the Lake Michigan lobe, (2) from the entire free margin of the Saginaw lobe in south-central Michigan, and (3) from the western side of the Erie lobe in southern Michigan and northeastern Indiana.[23] The great volume of water made extensive pondings among the Tazewell moraines,[24] one of which (Lake Wauponsee) was the slack water which terminated the Valparaiso DesPlaines valley train.

*Tinley glaciation.*—Neither the time nor the distance of the retreat from the Valparaiso moraine and the readvance to the Tinley moraine position are known. The Tinley moraine was built across the heads of the Sag and DesPlaines transmorainic valleys, and Tinley meltwater found the valleys open westward with floors at the head not higher than 610 feet. A post-Valparaiso, pre-Tinley "Lake Chicago" is argued from this, the discharge being large enough and the interval long enough for eroding the Valparaiso drift to the level of 610 feet. There is no other known evidence for this pre-Tinley lake.

The Tinley is a slender moraine, comparable with the units of the Valparaiso north of the Chicago region. But the Tinley's distance from them and the marked morainic sags between it and the Valparaiso clearly establish it as a separate moraine. Furthermore, the Tinley moraine projects somewhat out into the transmorainic valleys, unlike the Valparaiso moraine. It seems clear that the Tinley moraine was built as a continuous ridge across the head of each valley.

In the Sag Valley, a terrace remnant of outwash gravel in front of the Tinley moraine (see p. 82) indicates that a valley train was built down along the Sag from this crossing. All but this remnant was removed during the post-Tinley lake discharges. It may well be that the two bars in the head of the DesPlaines transmorainic valley, at Tiedtville and in the mouth of Flag Creek Valley (see p. 93), will prove to be largely only eroded remnants of a similar valley train on the north side of Mt. Forest Island. The question will be settled only when adequate excavations are made in the gravel deposits.

*Lake Border glaciation.*—The four Lake Border moraines are probably as closely related as are the five Valparaiso units north of the region, and consistency requires that the term *Lake Border system* be matched by the term *Valparaiso system.* All the oscillatory shiftings of ice front that

[21] Guthrie, Ossian, The Lake Michigan glacier and glacial channels across the Chicago divide: Geol. Soc. Chicago, p. 9, Oct. 30, 1890.
Leverett, Frank, The Illinois glacial lobe: U.S. Geol. Survey Mon. 38, 1899.
Goldthwait, J. W., Physical features of the DesPlaines Valley: Illinois Geol. Survey Bull. 11, 1909.
Fisher, D. J., The geology and mineral resources of the Joliet quadrangle: Illinois Geol. Survey Bull. 51, 1925.

[22] Leverett, U.S.G.S. Mon. 38, pp. 375-378.

[23] Ekblaw, G. E., and Athy, L. F., Glacial Kankakee torrent in northeastern Illinois: Geol. Soc. Amer. Bull., vol. 38, pp. 417-428, 1925.

[24] Willman and Payne, Bull. 66, pp. 167-170 and 222-225.

produced these four moraines were minor. All four of the moraines date from the Glenwood stage of Lake Chicago. Otto's work supports the early suggestion[25] that, south of Winnetka, the Highland Park ice-front did not reach as far west as the present shoreline. The Blodgett and Deerfield moraines were not built in sufficient strength across the floor of Lake Chicago to survive the wave drag of later lake stages and, of the Park Ridge moraine, only Blue Island survives. Standing water up to about 640 feet above sea level lapped against the ice front of these four stages, providing most unfavorable conditions for building ridge accumulations of the highly water-charged clayey till.

During the deposition of at least the earlier of the Lake Border moraines, a glacial river drained southward along morainic sags to enter the Glenwood stage of Lake Chicago at the head of a long bay between the Tinley and Park Ridge moraines. It is recorded by the only well-developed valley train of the region, now traversed by the DesPlaines River as far south as River Grove. By the time the glacial river ceased to flow, the advancing deltaic front of the valley train had almost obliterated the bay. This Lake Border DesPlaines valley train is to be distinguished from the possible Tinley valley train farther downstream in the transmorainic DesPlaines Valley.

*Lake Chicago time.*—Immediately after glacial retreat from the Tinley moraine, ponded water accumulated over the lower ground moraine in front of the ice, confined between morainic highlands on one side and the great ice sheet on the other. Overflow had to go across the morainic dam, and the already-existing Sag and DesPlaines valleys localized the discharge. This condition persisted throughout the remainder of Cary time and all Mankato time. The area of Lake Chicago expanded as the ice receded, and its level lowered as the outlet was deepened, until it finally merged into the much more extensive lakes Algonquin and Nipissing, which flooded the combined basins of Superior, Huron, and Michigan late in this episode of glacial and early postglacial Great Lakes.

The history of Lake Chicago[26] includes the three highest well-recorded water levels, adjusted to successive lowerings of a westward outlet. There are no other known drainage routes for the lake, although it is well established that at least one low-water stage occurred during its history, too low to discharge westward.

The highest recorded stage of Lake Chicago[27] is the Glenwood[28] level, 635 to 640 feet above sea level. During this time the ice front built the Lake Border moraines and meltwater deposited the DesPlaines valley train. How far northeast of the region the ice withdrew can be approximated by tracing the Glenwood shoreline northward into Wisconsin and Michigan. Alden[29] found it as far north as Racine, Wis. Beyond Milwaukee, he thought it had once been developed but had later been overridden by a post-Glenwood readvance of the ice front. Leverett[30] believed that it could be identified in Michigan as far north as Ludington, nearly 150 miles north of the Michigan–Indiana line. There is weak development of the old shoreline in several places because of unfavorable conditions for its formation, and there is discontinuity in other places because of encroachment of the modern shoreline or burial under modern dune-sand accumulations. If these facts are coupled with the fact that, in its northern part, any possible Glenwood shore (in common with all later glacial-lake shorelines) has been warped by crustal movements, the identification this far north becomes uncertain.

[25]Cooley, L. E., *in* Leverett, U.S.G.S. Mon. 38, p. 384.

[26]Named for the city of Chicago. Leverett, Chicago Acad. Sci. Bull. 2, p. 65.

[27]There have been suggestions of pre-Glenwood Lake Chicago stages, but the field evidence supporting them is unconvincing. See Atwood, W. W., and Goldthwait, J. W., Physical geography of the Evanston-Waukegan region: Illinois Geol. Survey Bull. 7, p. 60, 1908; Cressey, G. E., The Indiana sand dunes and shorelines of the Lake Michigan basin: Geog. Soc. Chicago Bull. 8, pp. 54-55, 1928; and Ekblaw, G. E., Some evidences of incipient stages of Lake Chicago: Ill. Acad. Sci. Trans., vol. 23, no. 3, pp. 387-390, 1931.

[28]Named for the village of Glenwood where this shoreline is well developed. Leverett, Chicago Acad. Sci. Bull. 2, p. 66.

[29]Alden, W. C., Quaternary geology of southeastern Wisconsin: U.S. Geol. Survey Prof. Paper 106, p. 328, 1918.

[30]Leverett, Frank, and Taylor, F. B., The Pleistocene of Indiana and Michigan and the history of the Great Lakes: U.S. Geol. Survey Mon. 53, p. 354, 1915.

To these limitations on earlier identifications must be added the fact that an intensive search by the writer and colleagues[31] has completely failed to find any Glenwood shorelines north of Milwaukee, Wis., and Muskegon, Mich.

Since the front of the ice lobe doubtless bulged southward in the middle of Lake Chicago, the areal extent of the Glenwood stage should not be visualized as approximating the southern half of present Lake Michigan. It was doubtless a crescent-shaped lake throughout the entire Glenwood stage. The area of Lake Chicago increased during Calumet[32] and Toleston[33] times, the shorelines of these stages being identified farther north on slopes of moraines which themselves are younger than Glenwood. It may be that ice had entirely abandoned the basin by early Toleston time.

After many thousand years of exposure, the three Lake Chicago shorelines can hardly be expected to yield precise altitudes for the lake stages. Indeed, with Lake Michigan's fluctuations in mind, it may be justly suspected that every Lake Chicago stage had variations in level of a few feet on both sides of its average. The figures generally cited are 635 to 640 feet above sea level for the Glenwood stage, 615 to 620 feet for the Calumet, and 600 feet for the Toleston.

*Causes of the Lake Chicago stages.*—The three definite shorelines left by this glacial lake, about 60, 40, and 20 feet above the level of its lineal descendant, Lake Michigan, appear to record three stillstands in the lowering from 635 or 640 feet above sea level to Michigan's present average level of 579 feet. The level was lowered largely while the retreating glacial front still blocked discharge from the basin to the St. Lawrence and while escaping water crossed the Tinley moraine-and-outwash dam to enter the Mississippi drainage. The successive shorelines, interrupting wide expanses of flat and featureless lake-bottom topography, should find their explanation in the detailed history of erosional destruction of the dam.

Leverett, who named the lake and the three shorelines (Glenwood, Calumet, Toleston), did not write on this problem. Alden, Goldthwait, and Wright[34] have argued that there was an abrupt descent in the outlet river as it crossed the Valparaiso moraine that gave rise to rapids which, by stoping, retreated upstream until the dam was breached. Detailed knowledge of the outlet region acquired subsequent to their writings[35] shows this idea to have been based on inadequate knowledge and incorrect assumptions.

The interpretation here presented differs from those of earlier students (1) in recognizing the Valparaiso moraine in the outlet region as only a veneer over a body of Lemont drift, (2) in identifying the outlet valleys as pre-Valparaiso in age, (3) in making the Tinley the moraine dam (earlier writers did not know of the existence of a Tinley moraine), (4) in using the concept that erosion-resistant boulder pavements checked moraine incision and thus caused stillstands, and (5) in utilizing a greatly increased discharge contributed by glacial lakes in Ontario, southeastern Michigan, and western Ohio to explain the removing of these boulder pavements and re-establishing of the erosional deepening across the Tinley dam.

The pavement of boulders in many modern streams flowing on glacial till represents the coarsest fraction of the till, which the stream has been unable to remove. It is an effective protection against further deepening. The Chicago outlet channels seem to have developed such pavements during discharge through them of Lake Chicago alone, and then to have had the boulders swept away when the erosive and transporting ability increased because of increased discharge from the east. The top of Worth

[31]Bretz, J H., The stages of Lake Chicago: their causes and correlations: Am. Jour. Sci., vol. 249, pp. 401-429, 1951.

[32]Named for the Calumet River, whose course is determined largely by the beach built at this stage. Leverett, Chicago Acad. Sci. Bull. 2, p. 72.

[33]Named for the former village of Toleston, which stood on the beach of this stage, and which is now a part of the city of Gary, Ind. Leverett, Chicago Acad. Sci. Bull. 2, p. 74.

[34]Alden, W. C., The Chicago folio (no. 81): U.S. Geol. Survey, 1902. Goldthwait, Bull. 11.
Wright. G. F., Explanation of the abandoned beaches about the head of Lake Michigan: Geol. Soc. Am. Bull., vol. 29. pp. 235-244. 1918.

[35]Bretz. J H., Geology of the Chicago region: Illinois Geol. Survey Bull. 65, Part I. 1939.
Bretz, Am. Jour. Sci., vol. 249.

FIG. 46.—Boulders from the bed of the glacial river in the DesPlaines transmorainic valley.

FIG. 48.—Another view of boulder pavement near Willow Springs.

(Lanes) Island originally carried a boulder pavement dating back to the highest (Glenwood) stage. Alden says in the *Chicago folio* that there were as many as a thousand boulders to the acre. When the rate of erosion increased, the channel became divided as it was deepened, and the boulder accumulation on Worth Island was spared. Spoil heaps of the Sanitary and Ship Canal contain so many boulders that a boulder pavement beneath postglacial deposits in the DesPlaines transmorainic valley seems indicated. The trench for the natural-gas pipeline north of Willow Springs was dug through a boulder accumulation on the Toleston channel floor, the upper part of which can be seen in the boulder-strewn fields in the vicinity. Stony Creek is a small, low-gradient stream in the Toleston channel north of Worth Island. This stream never could have carried the large number of boulders that litter the channel bottom in places. If, however, another maximum discharge were to be turned into the Stony Creek channel, these boulders would undoubtedly start travelling.

FIG. 47.—Boulder pavement in DesPlaines outlet channel near Willow Springs.

A boulder pavement increases in volume and therefore in effectiveness as a channel is deepened, and it should eventually put an end to deepening. Thus the discharge across the Tinley dam finally ceased eroding because of the growth of channel-bottom armor, and the lake back of the outlet ceased lowering. This determined the Glenwood stage of Lake Chicago, which persisted until a new factor appeared: greatly increased volume of the outlet river.

The interpretation of this study takes account of the succession of pondings in the Saginaw, Huron, and Erie basins, contemporaneous with that in the Lake Michigan basin.[36] Twice during the history of the eastern lakes the discharge flowed westward across southern Michigan by way of Grand River and entered Lake Chicago. Glacial lakes Maumee, Arkona, and Whittlesey contributed the first discharge, glacial Lake Warren the second. During the intervening time the levels of the eastern lakes were lower because retreat of the ice in western New York had afforded a temporary escapeway to the Mohawk and Hudson rivers, lower than the Grand River channel.

Because the ice front which blocked the eastern lakes from draining to the St. Lawrence was larger than that holding Lake Chicago, their levels were higher, and when their discharge was added to Lake Chicago its discharge across the Tinley dam more than doubled. Increased volume alone, without changes in load of debris, channel shape, gradient, and roughness of channel, will produce increased velocity in a stream. Doubling the discharge may cause as much

[36]Leverett and Taylor, op. cit.

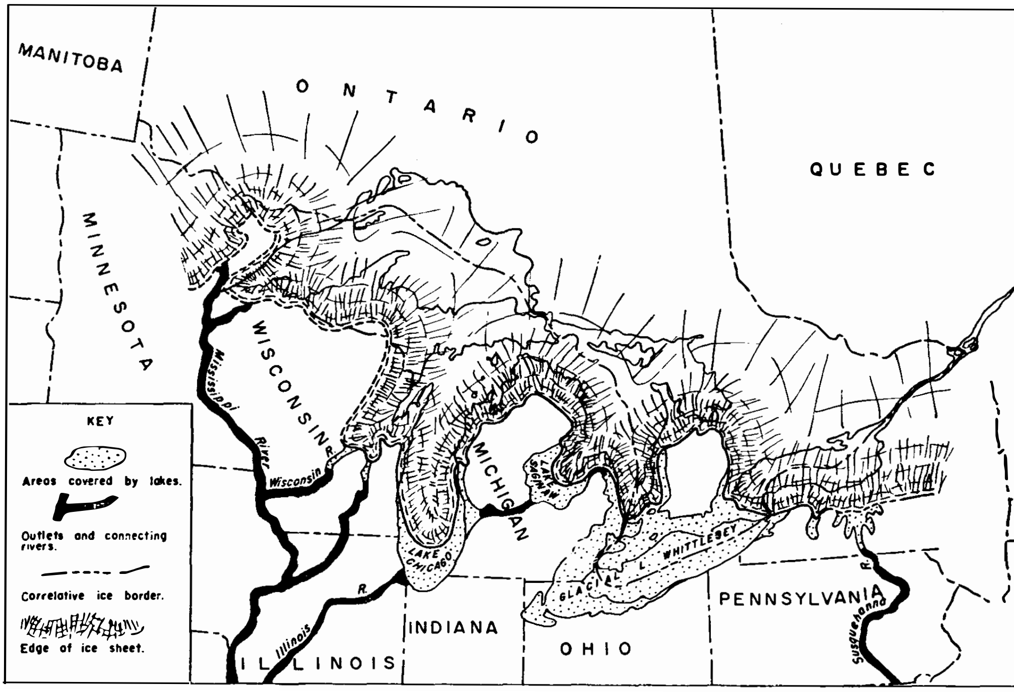



FIG. 49.—Glacial lakes Whittlesey, Saginaw, and Chicago. *After* Leverett, Frank, and Taylor, F. B. The Pleistocene of Indiana and Michigan and the history of the Great Lakes: U.S.G.S. Mon. 53, pl. 16, 1915.

as a 20 percent increase.[37] Because erosive ability of running water varies as the square of the velocity, a small increase in velocity might produce a noteworthy increase in a stream's erosive work. The two episodes of channel deepening which lowered Lake Chicago about 20 feet each time are therefore ascribed to the two times when the eastern lakes were discharging their overflow westward.

Excavation of the North Shore Channel about 1911 (see p. 92) revealed a new chapter in Lake Chicago's history, a chapter dealing with a low-water level intervening between the Glenwood and Calumet high-level stages. The outlet channels went dry at this time because a recessional shifting of the ice border far to the east of the Chicago region exposed a lower discharge-way eastward for all glacial lakes in the Great Lakes basins. Baker named this low-water stage the Bowmanville stage.[38] The present writer has correlated the Bowmanville with a low-water stage recorded in the Two Creeks, Wis., forest bed.[39] The forest grew on till exposed by Cary retreat and became buried later beneath the red Valders (Mankato) till. The low-water period preceding Lake Chicago's Calumet stage is also correlated with the Lake Wayne low stage of the eastern glacial lakes, when their overflow abandoned Grand River and escaped eastward down the Mohawk.[40]

Because there is no Glenwood shore on the Valders till sheet and only a weak Calumet beach on the southern portion of the till sheet, it is believed that this Bowmanville–Two Creeks–Lake Wayne stage coincided with a marked retreat after the Cary moraines had been built and before the readvance which deposited the Valders drift as far south in the Lake Michigan basin as Milwaukee and Muskegon. At this time the Strait of Mackinac probably was the outlet of Lake Chicago to Lake Wayne in the Huron and Erie basins.

[37]Einstein. H. A., personal communication.
[38]Baker, Univ. of Illinois Bull., vol. 17, no. 41, 1920.

[39]Bretz, Am. Jour. Sci., vol. 249.
Wilson, L. R., The Two Creeks forest bed: Wisconsin Acad. Sci. Trans., vol. 27, pp. 31-46, 1932.
Thwaites, Outlines of glacial geology.
[40]Bretz, Am. Jour. Sci., vol. 249.

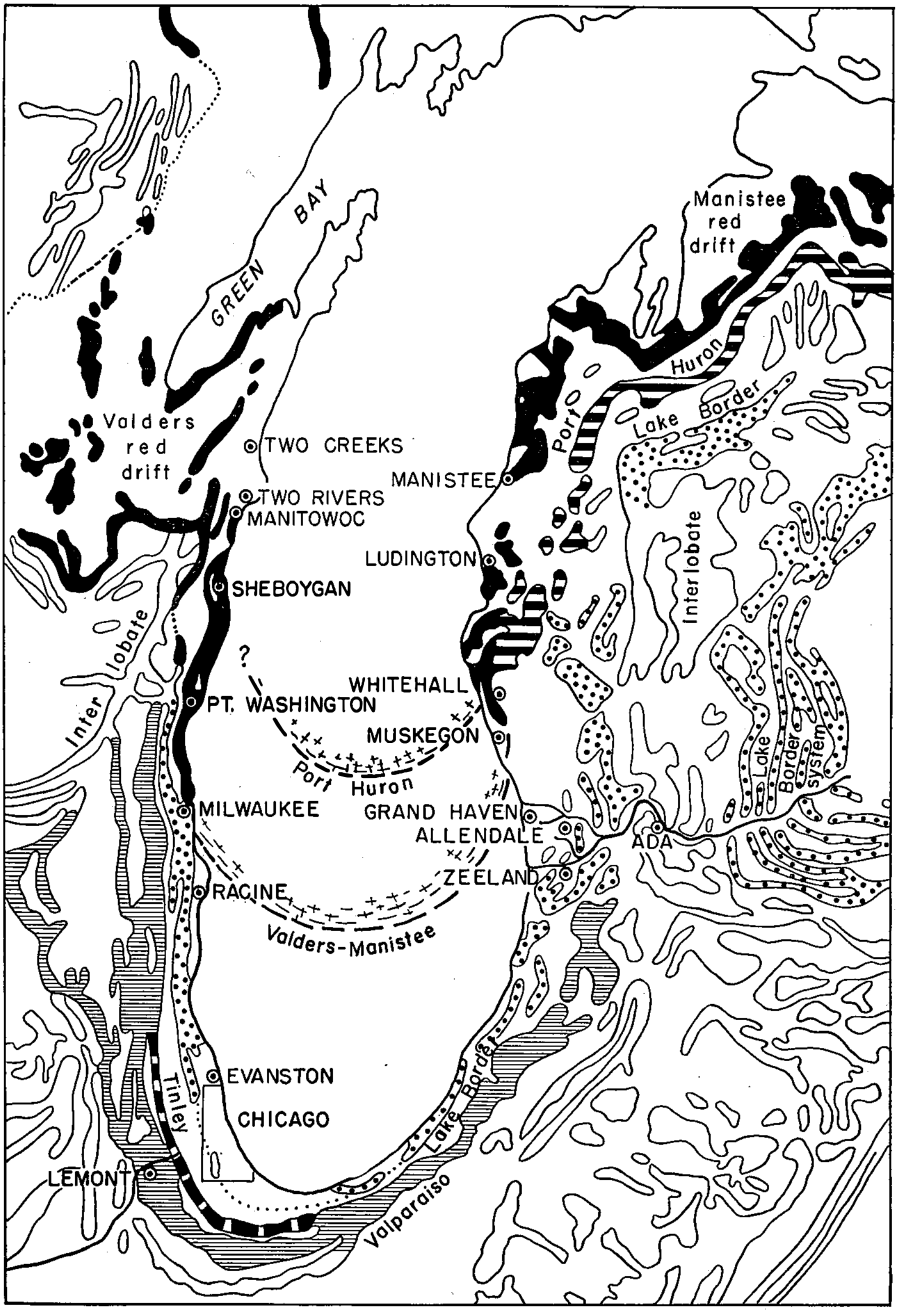



FIG. 50.—Moraine correlation across Lake Michigan. *From* Bretz, J Harlen, The stages of Lake Chicago: their causes and correlations: Am. Jour. Sci., vol. 219, fig. 1, June 1951.

With the Mankato readvance there was considerable realignment of the Lake Michigan ice front and a marked change in the character of the till deposited over the earlier Cary drift. The change in till indicates a notable recession, adequate to use as a Cary-Mankato break. If Glenwood shores had ever been made north of Milwaukee and Muskegon, they became obliterated by this Mankato advance. The weak Calumet beach on the Valders till near Port Washington, Wis., indicates that a lake at the Calumet level existed during at least the early part of Mankato retreat.

The idea that the Bowmanville–Two Creeks–Lake Wayne low-water stage came before Calumet time requires that we visualize the Chicago outlets as already deepened to the Calumet level by the time the eastern outlet initiated the low-water level in the entire group of basins. It is possible that the first-attained Calumet level was not a stillstand of Lake Chicago and that no Calumet shoreline had yet been made when the lake began dropping to the Bowmanville level and the western dischargeways went dry. It is also possible that a boulder armor had already checked the downcutting of the outlets and the lowering of the lake, in which case a Calumet shoreline would have been left.

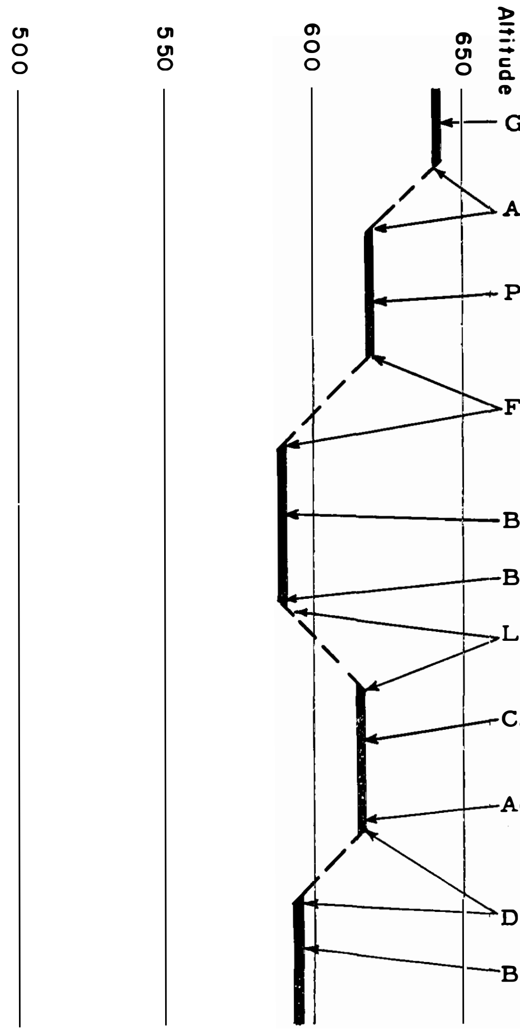
The Mankato advance which buried the Two Creeks forest and closed the eastern spillway returned all eastern lake discharge (Lake Warren) to Grand River and thence to Lake Chicago. The lowered lake began rising, eventually to spill back through the Chicago outlet and again to enter the Mississippi drainage. As it flooded up on the nearly level lake bottom that had become exposed during the low-water stage, waves tossed beach materials before them in an aggregate that constantly increased as it was shifted across the flat.

Thus by the time the flooding basin's water level had reached the level of the abandoned outlet, the beach had been carried up the slope with the rising strandline to the outlet's altitude, here to be added to any beach that might have been left when the water fell to the Bowmanville level. The beach of the second-attained Calumet level does not record a long stillstand because, with discharge shortly augmented from the eastern Lake Warren, larger than any earlier glacial lake, any boulder armor on the channel floor was swept away and erosional deepening was promptly re-established.

Lake Chicago at once began dropping from the second-attained Calumet level toward the Toleston, its lowest level determined by the western outlet. This lowest level with Mississippi connections marks the final attainment of a bedrock bottom in both the Sag and DesPlaines channels. On the resistant floor, even the maximum discharge from Lake Chicago had little effect. Bedrock instead of boulder armor determined the Toleston level.

Another factor that entered into the complex of the glacial Great Lakes history was the differential uplift that occurred during the changing scenes of these lakes. North of the "hinge line," all glacial lake shorelines depart from the horizontal and become higher toward the northeast; the older and higher ones depart most, the younger and lower ones, least. It is possible that the Bowmanville low-water stage (for which we have no shorelines) was terminated and the level of Lake Chicago was raised 30 feet back to the abandoned western outlet by the uplift of the eastern or northeastern region where the Bowmanville outlet must have been. A slow rise in lake level caused in this way would be more likely to drive the beach materials forward, instead of submerging them, than would the more rapid rise caused by an ice advance. Probably, however, the uplift was too slow to have accomplished this before readvance of the lobes produced the same effect on the lake level. Stanley believed that "hinge line" warping did not begin until long after Bowmanville time, a conclusion supported by Hough's later researches (1953).

*The Glenwood stage.*—Several earlier students of the region have stated that the Glenwood shores vary somewhat in altitude and have attributed the variations to minor fluctuations of lake level. The total range seems to have been little more than Lake Michigan has shown during the past




Glenwood stage. Initial spill over Tinley dam at 640 feet. Little erosion in outlet-channels.

Addition of Maumee, Arkona, Whittlesey discharge, deepening outlets and lowering lake to Calumet level, 620 feet. Port Huron moraine.

Pause in deepening of outlets when retreat of Huron and Erie lobes opens eastern outlet, lowers Whittlesey, and deprives Lake Chicago of large influx from the east. First-attained Calumet level.

Further retreat of eastern lobes opens still lower outlet, location unknown. Recorded only by Bowmanville stage in Michigan basin. Lake Chicago outlets go dry.

Bowmanville low-water stage at 590.

Bowmanville outlet closed by readvance of eastern lobes.

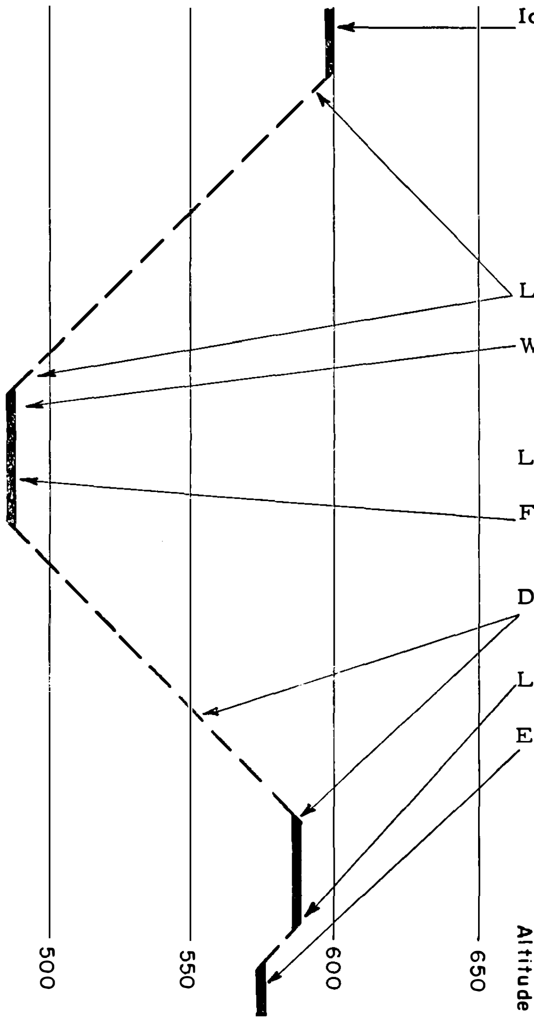
Lake Chicago rises to 620 feet and drains westward. Waves sweep sand and gravel up the slope of the Chicago plain to make the Calumet shore.

Calumet stage. Lake Wayne discharging to Mohawk and only Lake Chicago water using western channels. Little erosion in outlets.

Additional readvance of Huron and Erie lobes, closing Mohawk outlet and forming Lake Warren with discharge to Lake Chicago. Readvance of Michigan lobe to deposit Valders red drift. Beginning of Mankato substage.

Deepening of outlet-channels and lowering of Lake Chicago.

Bedrock reached in outlet-channel floors, deepening ceases. Lake Chicago at first-attained Toleston level.




Ice retreat in the east again opens Mohawk outlet. Lake Lundy (Dana) succeeds Lake Warren; western outlets again carry only Lake Chicago discharge. Further ice retreat creates Lake Algonquin of both Kirkfield and two-outlet stages. Hammond shore built.

Lake Algonquin lowered by opening of unknown low outlets from Huron basin.

Water in Michigan basin falls to 480 feet and drains eastward through Mackinac Strait River to lowest Algonquin (or Taylor Lakes) stage in Huron basin. Sag low-water stage.

Lake Chippewa (not shown in diagram).

Final withdrawal of ice barrier opens North Bay outlet to create early Lake Nipissing.

Differential uplift raises North Bay outlet and causes water-level in Michigan basin to rise to Englewood shore, 590 feet.

Lake Nipissing spills south through Port Huron outlet.

Erosion of Port Huron outlet lowers Nipissing to present levels of Lake Michigan and Lake Huron.

FIG. 51.—Changing levels in the Lake Michigan basin from the Glenwood stage to the present time. No attempt is made in this diagram to express relative duration of the different stages.

century (see p. 25),[41] and the Glenwood shore is here considered a unit.

The Glenwood shoreline, where definitely marked in the Chicago region, consists of alternating sea cliffs and beach deposits in almost equal proportions, there being a total of nearly 30 miles of each. Nineteen of the 30 miles of beach deposits are measured on spits that grew during the stage, not on original contacts of land and water. Glenwood waves had opportunities for erosional attack unequalled in the later stages when, except in one place, waves could reach and work only on the floor abandoned by Glenwood water. The exception is the east face of the Highland Park moraine, in the Highland Park and Evanston quadrangles (Maps 2, 5), where the record shows that the waves encroached on the land through all Lake Chicago and subsequent time. A vanished Glenwood sea cliff is recorded by the Wilmette spit, whose debris, derived from cliff-undercutting, was carried southward past the tip of the moraine and deposited on the shallow lake-floor in the Park Ridge and Evanston quadrangles (Maps 4, 5) to make the most intricate spit of the region. The spit is 5 miles long and has nine definite "fingers" built successively from north to south. The Glenwood cliff later was undercut and destroyed by Calumet waves, whose own sea cliff, recorded by the Rose Hill spit, was in turn destroyed by Toleston waves. The Toleston sea cliff, similarly recorded by the Graceland spit, was undercut and destroyed during later lake stages. The vanished cliffs probably were much more striking features than any which have survived from Lake Chicago time (fig. 57).

The growth of the Wilmette spit largely closed off the shallow Glenwood bay in Skokie Valley; in the warmer waters thus made possible lived the earliest-known animals to enter the region as the ice receded.[42] The remains are minute molluscan shells, ten species having been identified by F. C. Baker. "All the species, with one exception, are fresh-water shells," the exception by inference being a land form. Baker said that all are known in older (Pleistocene) deposits in middle Illinois.

Glenwood waves reached the southern end of the Park Ridge moraine with sufficient strength to cut a low sea cliff in its

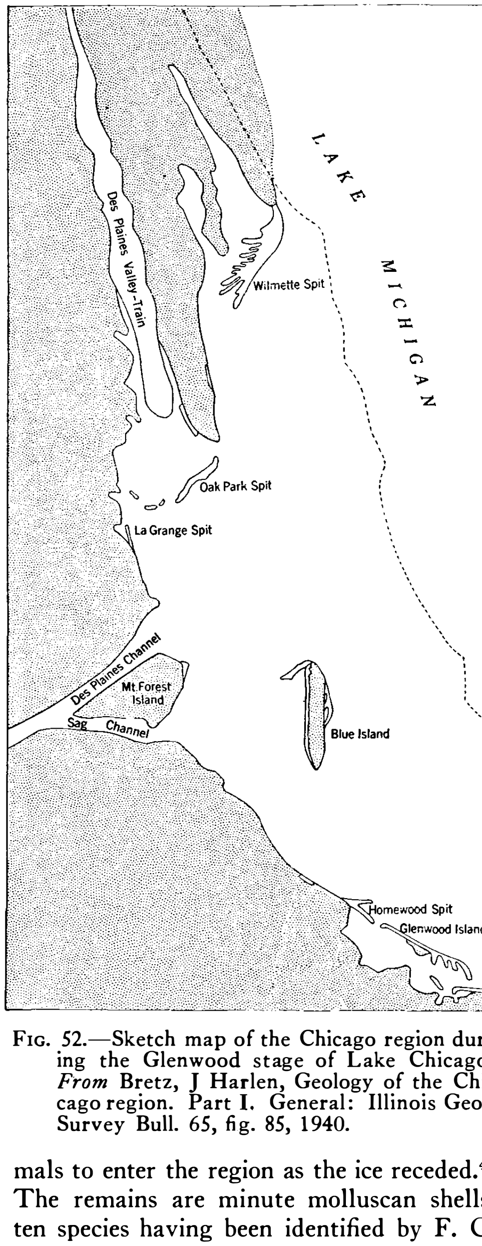



FIG. 52.—Sketch map of the Chicago region during the Glenwood stage of Lake Chicago. *From* Bretz, J Harlen, Geology of the Chicago region. Part I. General: Illinois Geol. Survey Bull. 65, fig. 85, 1940.

[41]Alden (Quaternary geology of southeastern Wisconsin: U.S. Geol. Survey Prof. Paper 106, p. 331, 1918) gave the largest range, 15 feet, although Goldthwait (The abandoned shorelines of eastern Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 17, p. 44, 1907) spoke of beach "ridges at many places which mark successive lowerings of the lake while the Chicago outlet was being cut down; and these extend the Glenwood series down to about 627 feet . . . only a few feet higher than the Calumet stage." Such ridges properly are not of Glenwood age: they belong to the interval of increased discharge which terminated and succeeded the Glenwood stage.

[42]Ball, J. R., and Powers, W. E., Evidence of aquatic life from the Glenwood stage of Lake Chicago: Science, vol. 70, 1929.

eastern side. A southward-moving littoral current built of its debris a simple spit ridge (the Oak Park spit in the River Forest and Berwyn quadrangles—Maps 7, 10), projecting 3.3 miles diagonally across the mouth of the bay which the glacial Des-Plaines River was filling, in early Glenwood time, with its valley train.

Margined on the east side by the lake and on the other two sides by outlet rivers, triangular Mt. Forest constituted the largest island of Glenwood time. Its area was more than 10 square miles, and its highest point, 752 above sea level, rose more than 100 feet above the lake.

The isolated portion of the Park Ridge moraine known as Blue Island (Blue Island quadrangle—Map 15) had an interesting Glenwood history. Its exposed eastern side was eroded by waves, but beach and dune deposits were built up on its western side. The longest belt of Lake Chicago dunes in the region is here, and beneath the dune sand is well-sorted, cross-bedded beach sand and gravel. A spit grew westward from the northern tip of the island's sea cliff, and at the end of the stage it projected almost two miles out into the protected water to the lee of the island.

Another large spit of Glenwood time grew more than 2 miles southeastward from a small island in the southern part of the Calumet City quadrangle (Map 20). Its stages of growth are shown by four southward-pointing fingers, the distal one, of course, being the youngest. Much of the sand in this spit must have been dragged up from the lake bottom, for the sea cliff on the island is too limited to have supplied all of it.

There are four separate beach accumulations of Glenwood age on the Calumet City and Dyer quadrangles (Maps 20, 24). The smallest of the four, about 2 miles west of Dyer, appears to have grown first and later to have been almost wholly cut off from further wave action by westward growth of the spit on which Dyer stands and by the southeastward growth of the Glenwood–Dyer four-fingered spit. Subsequent to the building of these successive beach deposits, Glenwood waves built an offshore bar in shallow water about 3 miles farther north, at Lansing, its gravel reaching 630 and 635 feet above sea level. This bar became the shoreline in the Calumet stage, hence the Calumet City map carries the symbol for both stages.

*The Bowmanville low-water stage.*—When the lake level lowered to within about 10 feet of Lake Michigan's present surface, a shallow bay lingered on the lake bottom in front of the Wilmette spit, apparently in a sag in the surface of the glacial till, perhaps protected from waves of the open lake by a spit or sand bar on the east, which was later destroyed as the water rose to the Calumet level. The silty, carbonaceous, and peaty sediments that accumulated in this bay to a maximum thickness of 40 inches during the Bowmanville stage entombed a variety of organic remains during their deposition, and buried a sand-and-gravel concentrate made by the waves at a depth of 50 feet on top of the subjacent glacial till. The remains indicate that forest trees had already invaded the region; oak, poplar, balsam fir, arbor vitae, spruce, and tamarack have been identified. The spruce (*Picea canadensis*) today ranges from southern Wisconsin north to Hudson Bay, and all the other trees are north-temperate to boreal species. The 36 molluscan species identified by Baker indicate a cold lake. Immediately overlying the Bowmanville fine sediments are 2 to 19 inches of sand and gravel without any organic material. This is taken to record the return of the lake to the Calumet level and the consequent disappearance of the protected little bay, whose depth did not exceed 10 feet.

Elsewhere, the Glenwood till floor of the lake, exposed to the air, dried out considerably. Otto found that this desiccated condition still persists under the heavy cover of Calumet beach deposits east of the Bowmanville bay.

*The Calumet stage.*—Aside from risers of a few feet, Calumet waves made no erosional shores in the region. Furthermore, at the top of all risers noted, there is a beach accumulation. Almost the only Calumet beach deposits that do not lie on the brink of a riser are spits. Thus, from these facts it appears that the Calumet stage terminated a period of rising water during which the waves eroded the till, and that the storm waves continuously tossed the beach aggregate ahead of them as they moved across the gently sloping plain. The Calumet beach material was already largely accumulated by the time the rising waters reached the outlet level. In the Chicago region, Calumet shores carry no notable accumulations of dune sand, although nearby Glenwood and Toleston shores may have relatively large dune deposits. This is another indication that the Calumet level was not long maintained—that lowering followed shortly after entrance of eastern glacial lake waters into Lake Chicago.

More time seems to be required for the building of the Rose Hill spit (Evanston and Chicago Loop quadrangles—Maps 5, 8). Its surviving length is 7 1/2 miles, it is nearly a mile wide in its distal portion, and it rises 10 to 15 feet above the lake bottom. It shuts off from the open lake a faint Calumet beach ridge at the foot of the Wilmette spit, and, unless the ridge was made by waves with a fetch of scarcely more than 2 miles, the Rose Hill spit must have grown after the little beach ridge was made, i.e., after the lake had risen to the Calumet level. But an adequate source for its material was the Calumet sea cliff, which had no wave-cut terrace at its foot (because of the relatively rapid rise of the lake) to damp down the wave attack from the deep open water. Therefore, only time for transportation is required. The growth of the Rose Hill spit may measure approximately the interval between reopening of Lake Chicago's westward discharge and the arrival of the overflow from eastern lake basins (Lake Warren).

Another plausible explanation for the Calumet ridge at the foot of the Wilmette spit is that it was made during the first lowering of water level when the outlets were being deepened below the Glenwood level, and that its final position records the first attainment of the Calumet level. By this view, it was then abruptly abandoned when the rapid fall to Bowmanville levels began, but became the shoreline of Wilmette Bay when Lake Chicago again

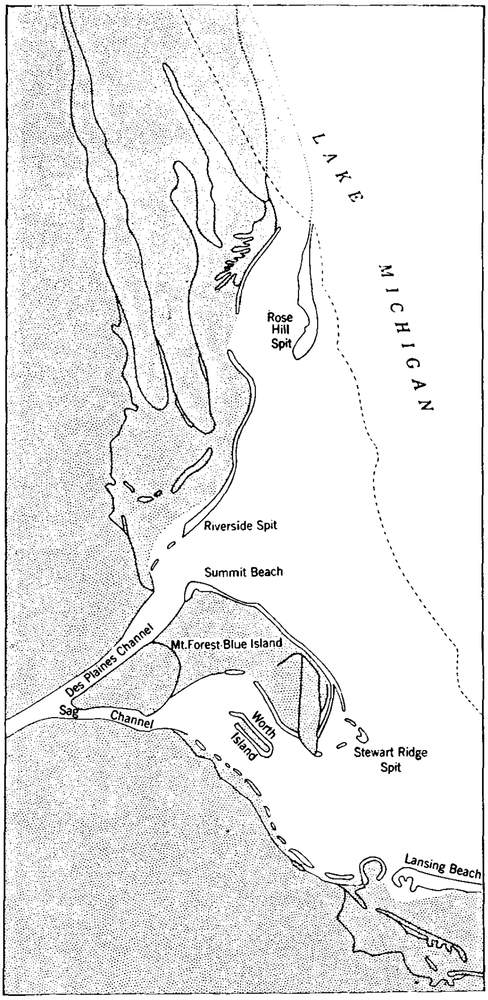



FIG. 53.—Sketch map of the Chicago region during the Calumet stage of Lake Chicago. *From* Bretz, J Harlen, Geology of the Chicago region. Part I. General: Illinois Geol. Survey Bull. 65, fig. 86, 1940.

rose to this level. This interpretation is furthered if the debris in the Rose Hill spit is considered as more largely carried onshore during the rising stage than transported southward from the Calumet sea cliff.

Two Calumet shorelines are shown on the Calumet City quadrangle (Map 20). The southern one is a faint beach ridge at the northern foot of the Glenwood–Dyer spit and cliff. The northern one, the Lansing–Munster beach ridge, is built against a Glenwood offshore bar and is a strong feature. The fainter southern ridge may be a record of waves in the bay between the two large beaches, or it may be a product of the earliest Calumet waves before the Lansing–Munster bar had grown beyond its Glenwood dimensions. East of Dyer for several miles the Glenwood dunes have a steep, straight northern front, as though they had been trimmed by good-sized Calumet waves. This feature favors the second explanation above.

Rising Calumet water did not surround Blue Island, although a group of beach ridges of this age was built a little out from the foot of the Glenwood sea cliff on the east side. On the west, Glenwood lake bottom had become land all the way from Blue Island to Mt. Forest Island; the Blue Island tract was the blunt end of a large peninsula projecting southeastward into the lake. A similarly aligned bay along the southern side of the peninsula extended northwestward to the head of the Sag outlet a little west of Worth. In the middle of the bay, another high area of about two square miles in the Glenwood lake bottom emerged to constitute Worth (Lanes) Island. A hairpin-shaped beach ridge outlines the larger portion of this Calumet island. The island was originally thickly strewn with boulders left behind by scour of the outlet stream before the Bowmanville stage.

The growth of the Rose Hill spit gave rise to a protected bay between it and the Calumet shore about 3 miles to the west. This was the Wilmette Bay[43] of Calumet time, larger than, and covering the site of, the Bowmanville bay. The shallow-water biota living in the Bowmanville bay was destroyed by the deepening Calumet lake, and not until the lake lowered considerably toward the Toleston level were shallow-water conditions restored. A fauna characterized by the "heavy Mississippi River type of mussels"[44] migrated into Wilmette Bay by the time it had shoaled to depths of 5 to 20 feet. Of 35 species, 30 are clams. Baker thought that larval forms (glochidia) attached themselves to fish and thus migrated up the lake outlet.

[43]Named by Goldthwait for the town of Wilmette, which is built largely on the floor of this bay. Atwood and Goldthwait, Bull. 7, p. 62.

[44]Baker, op. cit., p. 32.

MANKATO SUBAGE

*The second Calumet stage.*—Readvance of the Lake Michigan lobe with altered outlines and flow lines and deposition of the Valders red drift are here accepted as marking the inauguration of the Mankato subage. Because the southern part of this drift sheet in the lake basin carries a weak Calumet beach but no trace of a Glenwood shoreline, it is believed that eastern glacial lake water (Lake Warren) had risen from the Lake Wayne low level and was discharging again into Lake Chicago. This

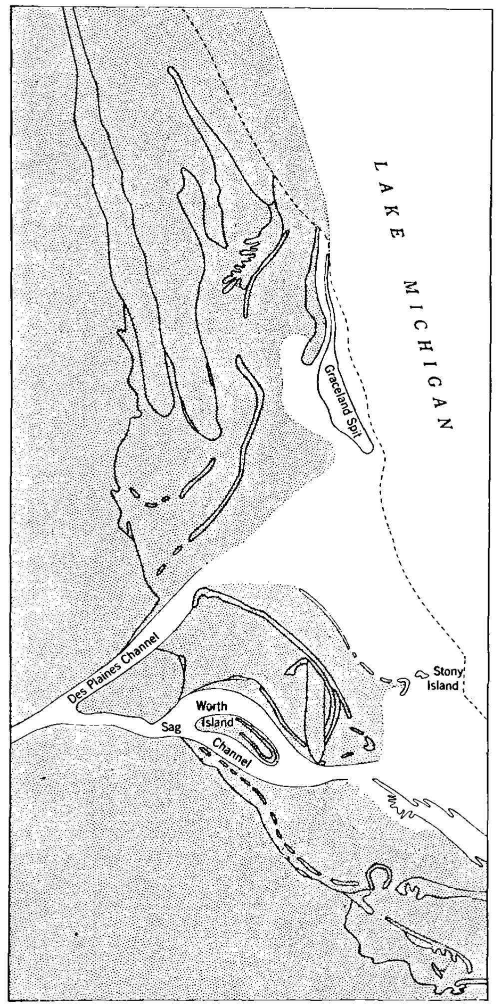



FIG. 54.—Sketch map of the Chicago region during the Toleston stage of Lake Chicago. *From* Bretz, J Harlen, Geology of the Chicago region. Part I. General: Illinois Geol. Survey Bull. 65, fig. 87, 1940.

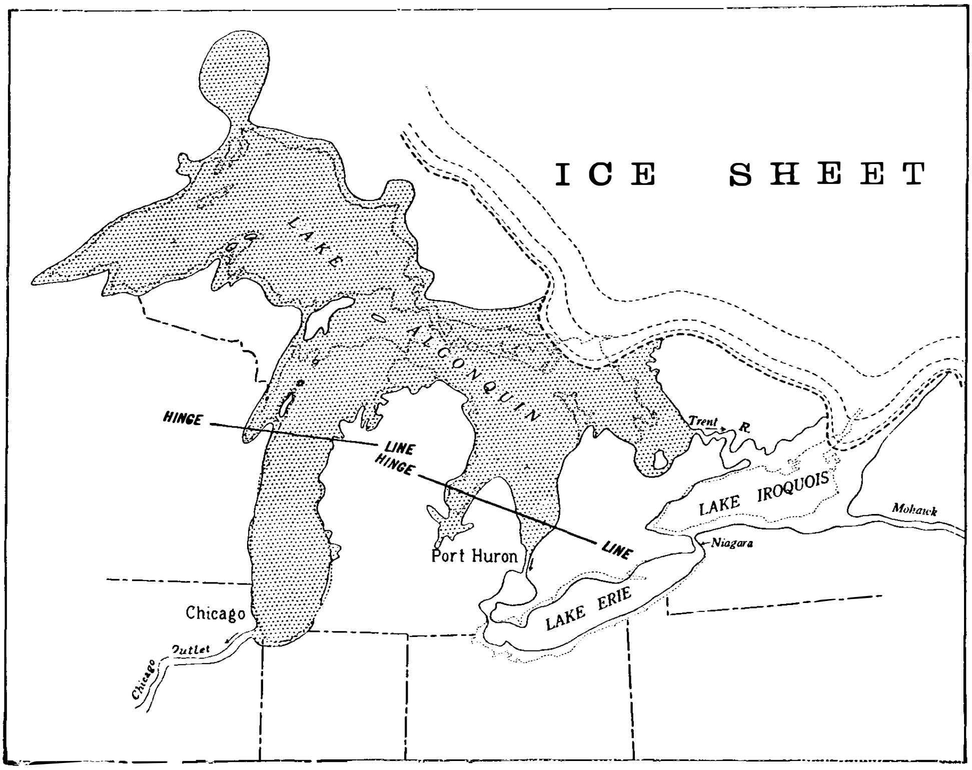



FIG. 55.—Lake Algonquin with three outlets. *From* Bretz, J Harlen, Geology of the Chicago region. Part I. General: Illinois Geol. Survey Bull. 65, fig. 89, 1940.

lake regained the level necessary for westward discharge before the Valders (Mankato) ice had more than begun to retreat from its maximum advance. Deepening of the western outlets came promptly on renewal of their functioning, and Lake Chicago as promptly began dropping from the second-attained Calumet level to the Toleston. There is no one stage in the lake's history to use as a marker for the opening of Mankato time. That geological moment came at some time between the Bowmanville low-water stage and the second-attained Calumet level. Deepening of the outlet and consequent lowering of the lake to the Toleston level are Mankato events.

*The Toleston stage.*—The Toleston stage of Lake Chicago has been thus far presented as a simple consequence of a simple cause: rock floors in the outlets determined a fixed low level of ponded water. In reality, the least understood part of the history of Lake Chicago took place after the Toleston outlet level was attained. Again, the complexity is caused by factors operating far to the east and northeast of the Chicago region and, because of them, it is not certain that the existing Toleston shoreline dates back to the original attainment of that outlet level.

Research, chiefly by Taylor, has shown that Lake Warren fell to the Lake Lundy (Dana) level when retreat of the ice in the Huron and Erie basins again opened a discharge route to the Mohawk. After Lake Lundy's time, still further recession of the ice front allowed a great expansion of glacial-lake water, which formed Lake Algonquin, bringing to a close the Lake Chicago episode. According to Leverett and Taylor, Lake Algonquin spread over the three combined basins of Superior, Huron, and Michigan, but recent research by Hough indicates that the Superior basin was still occupied by glacial ice and did not share in the Algonquin level. Discharge from this one large lake escaped from the southeast end of Georgian Bay by way of Trent River (Kirkfield or Fenelon Falls outlet) to a glacial lake (Iroquois) then occupying the Ontario basin.

The Trent River discharge so lowered the lake level that the western outlets went dry again. Baker thought the Sag low-water stage[45] may have been lower at Chicago than the present surface of Lake Michigan. Stanley[46] believed that if the combined lakes discharged through Trent Valley, this stage was "very considerably lower."

Differential northeastern uplift during the waning of the great ice sheet, because of the reduction of load on the crust, progressively raised the Trent outlet on the east. This caused Algonquin water to rise higher on all shores. Eventually it found another low place across which escape was possible, at Port Huron, down the St. Clair River. Opinion is general that this rise in water level also brought a return discharge to the Chicago outlet, which operated simultaneously with the initial Port Huron discharge. Thus, water in the Lake Michigan basin was now back to the Toleston level, and the existing Toleston beaches were added to or "overwhelmed and worked over entirely by Lake Algonquin waters."[47] The Port Huron spillway, however, was on glacial drift, and relatively rapid erosion there soon gave it all of Algonquin's discharge. The two-outlet[48] stage came to an end, and the rock-floored Chicago outlet probably has not been used since that time.

The ice barrier still lingering in the northeastern part of Georgian Bay covered low country which, when it finally became exposed by continued shrinkage of the ice, offered still lower escapeways eastward, probably to the Ottawa Valley; this caused a series of lowering levels of Lake Algonquin, and the Port Huron outlet in turn went dry. A submerged valley through Mackinac Straits[49] suggests that Lake Algonquin's level probably sank so low that the Michigan basin became dismembered and had its own outlet river to the Huron basin through the remainder of Algonquin time. Water in the Lake Michigan basin at the time of this lowest Algonquin level stood "about 100 feet"[50] lower than it does today.

Hough, in extensive coring of Lake Michigan sediments,[51] found that cores from less than 350 feet of water all had a layer of sand or sand with shells that was lacking in cores from deeper water. The shells were of gastropods and pelecypods that inhabit water from 1 to 15 feet deep. From this he concluded that Lake Michigan had had a low-water stage after Algonquin time but before the next (Nipissing) high level. He correlated this low-water stage with Stanley's Mackinac Straits River, and named the shrunken remnant in the Lake Michigan basin Lake Chippewa, and that in the Lake Huron basin Lake Stanley.

If a low-water level endured long enough and if the newly exposed bottom had sufficient slope, streams entering the lowered lake would erode valleys across the emerged floor and would deepen their pre-existing valleys. The ensuing rise of water would then cause drowning of the valleys and deposition in the drowned valleys. Several earlier writers[52] have discussed the filled channels and ponded lower courses of several Michigan rivers entering the lake, inclining to the view that a low-water stage is recorded but failing to date it closely. Stanley[53] more recently has cited borings in the Kalamazoo River channel near the mouth, through fine sand and peaty materials, to depths of 85 feet below lake-

[45]Baker, op. cit., p. 86.
[46]Stanley, G. M., personal communication.
[47]Taylor, F. B., The glacial and postglacial lakes of the Great Lakes region: Ann. Rept. Smithsonian Inst., p. 319, 1912. Baker (op. cit.) prefers to consider the Hammond beach as the record of the return of lake level to the two-outlet stage.
[48]During the shift from Trent to Port Huron and Chicago, three outlets functioned for a time.

[49]Stanley, G. M., The submerged valley through Mackinac Straits: Jour. Geol., vol. 46, pp. 966-974. 1938.
[50]Stanley, G. M., personal communication. For the lakes of this low-water stage, Antevs (Late Quaternary upwarpings of northeastern North America: Jour. Geol., vol. 47, p. 718, 1939) has proposed the name of "Taylor Lakes."
[51]Hough, J. L., Post-glacial low-water stage of Lake Michigan indicated by bottom sediments: Geol. Soc. Am. Bull., vol. 63, p. 1265 (abst.), 1952; and Pleistocene chronology of the Great Lakes region: Office of Naval Research. Project NR-018-122. 1953.
[52]Winchell, Alexander, Climate of the lake region: Harper's Magazine, vol. 43, July, p. 284, 1871.
Wooldridge, C. W., The river-lake system of western Michigan: Amer. Geol., vol. 1, p. 143, 1888.
Leverett, U.S.G.S. Mon. 38, pp. 440-442.
[53]Stanley, Jour. Geol., vol. 46, p. 974, 1938.

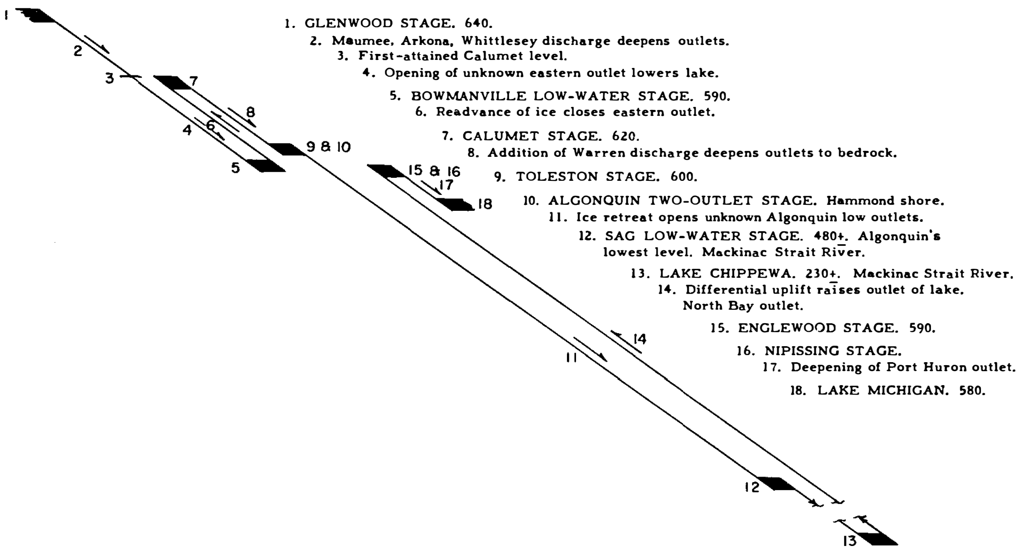



FIG. 56.—Diagrammatic cross section showing oscillations of the shoreline across the Chicago plain. The detached part of the diagram shows the relative position of Hough's Lake Chippewa.

level, and is convinced that "the river excavated its bed to this depth after the glacier withdrew from the region and during a period when its base level [Lake Michigan] was at least 75 or 80 feet lower than now." The writer would correlate this deep valley with the functioning of the Mackinac Straits River.

A low-water stage of Lake Chicago that followed the Calumet and preceded the Toleston stage has been argued by Leverett, Goldthwait, and Alden. Leverett's evidence[54] is the deep valley-fill along Black River near Holland, Mich., apparently younger than the Calumet beach and older than the Toleston beach at that place. A lowering of at least 50 feet below the present lake level is required for the erosion of this now-filled valley. Goldthwait's evidence[55] is peaty material beneath the gravel of a Toleston bar in Evanston. Alden's evidence is the occurrence of marsh deposits as much as 53 feet below Lake Michigan level, discovered in borings in Milwaukee River Valley. He dates the low-water interval necessary for the erosion of this deep valley as subsequent to the deposition of the red drift (i.e. post-Mankato).

[54]Leverett, U.S.G.S. Mon. 38, pp. 446 and 499.
[55]Atwood and Goldthwait, Bull. 7, p. 63.

In the Chicago region there are at least two minor filled stream valleys on the lake plain, both completely obliterated by beach sand at the Toleston level and known only from borings and excavations. One was 40 feet wide and had been eroded 16 feet deep in till before being buried in the beach sand.

But these datings are all subject to criticism. If Taylor is right in thinking that Lake Algonquin's two-outlet stage saw a remaking of the Toleston beaches, the evidence submitted for a low level by Leverett and Goldthwait may be used to support Baker's post-Toleston Sag low-water stage and Stanley's Mackinac Straits low-water level, which were also post-Toleston and appear to have been the same episode. If the writer is correct in dating the red drift as late Calumet or as post-Calumet but pre-Toleston (p. 111), Alden's low-water stage also is best dated as post-Toleston. The data now in our possession are not adequate to justify asserting or denying a post-Calumet, pre-Toleston low-water stage. It is not included in the diagrams of figures 51 and 56. Future investigations may clear up this doubtful point.

The Toleston shoreline is nowhere more than 6 miles back from the present shore, and in places in its northern stretches only a few blocks separate it and the lake today. It varies considerably in strength of development, being especially bulky in the northern and southern parts of the plain and almost completely lacking in the central part. The lack of well-marked beach ridges between the heavy shore accumulations may be related to the fact that the currents swept the beach-making materials into the outlets.

The largest spit of Lake Chicago in the region, the Graceland spit in the Evanston and Chicago Loop quadrangles (Maps 5, 8), grew southward from the sea cliffs on the Highland Park quadrangle at the Toleston level, its surviving length being 12 miles and its greatest width nearly 1 1/2 miles. Its northern half is a gravel ridge only two or three blocks wide, the great widening farther south strongly supporting the view that it is a spit rather than a simple beach ridge.

In the three high-water stages of Lake Chicago, three spits were built in the Evanston region almost alongside each other, successively lower and younger nearer the lake. Their material is believed to have come from the erosion of sea cliffs north of Kenilworth and Winnetka. Each spit was built after a drop of about 20 feet in water level, which shifted the new shore farther east. It is as though a fulcrum point had existed in the Kenilworth district, the successive spits shifting eastward as the successive sea cliffs were driven westward.

Extensive sand accumulations on the strong southern, or Dolton–Hammond Toleston beach (Calumet Lake and Calumet City quadrangles—Maps 16, 20), produced the largest area of dunes in the Chicago region. They appear to have continued to grow during the following Algonquin, and perhaps still later, lake stages. About 2 miles south of this beach, the Lansing–Munster Calumet beach has a small sea cliff cut at the northern foot, at the Toleston level. The cliff is probably an early Toleston feature, although it might be the result of waves generated on the bay between the two larger features. By either interpretation, the Dolton–Hammond beach must have grown up on an offshore bar.

Stony Island appeared in Lake Chicago at the Toleston stage and is unique in that it was the only island of bedrock in this region. Like Blue Island, it still is a sufficiently marked eminence in the Chicago plain to carry the popular designation of "island." Stony Island is in the north-central part of the Calumet Lake quadrangle (Map 16), about 1 1/4 miles long, one-third of a mile wide, and 15 to 20 feet higher than its surroundings. Like Worth Island, its surface originally carried an unusually large number of boulders, which here must be ascribed to wave erosion during earlier stages, to stranded icebergs, or both. A gravel beach ridge at Toleston level almost encircles the island.

The only Toleston cut-bank shore that deserves the name of sea cliff is traceable through Roseland and Kensington, south from about 103rd Street to 127th Street. Some of the debris eroded from it was moved southward and accumulated as a short, blunt spit at the south end, almost in the head of the Toleston outlet channel that led to the Sag. It has been exploited as a source of sand and is now largely removed.

With the drop in lake level to the Toleston stage, the outlet channels necessarily lengthened eastward across emerged Glenwood and Calumet lake bottom. The Sag channel was lengthened 10 miles; its new head was shifted as far east as Riverdale. Worth Island became more definitely outlined because the two Calumet channels divided by it were deepened by Toleston discharge.

*Post-Toleston, pre-Michigan time.*—In the Chicago region the Toleston shoreline is roughly paralleled by other, somewhat lower beach ridges closer to Lake Michigan and at two different levels. They have been variously called the lower Toleston beaches, the second and third Toleston, and the Hammond and Englewood beaches. It is not certain that the Toleston outlet functioned for these lower levels, although they are not records of any of the late Algonquin low-water levels above noted. To approach an understanding of conditions at these times, the entirety of the

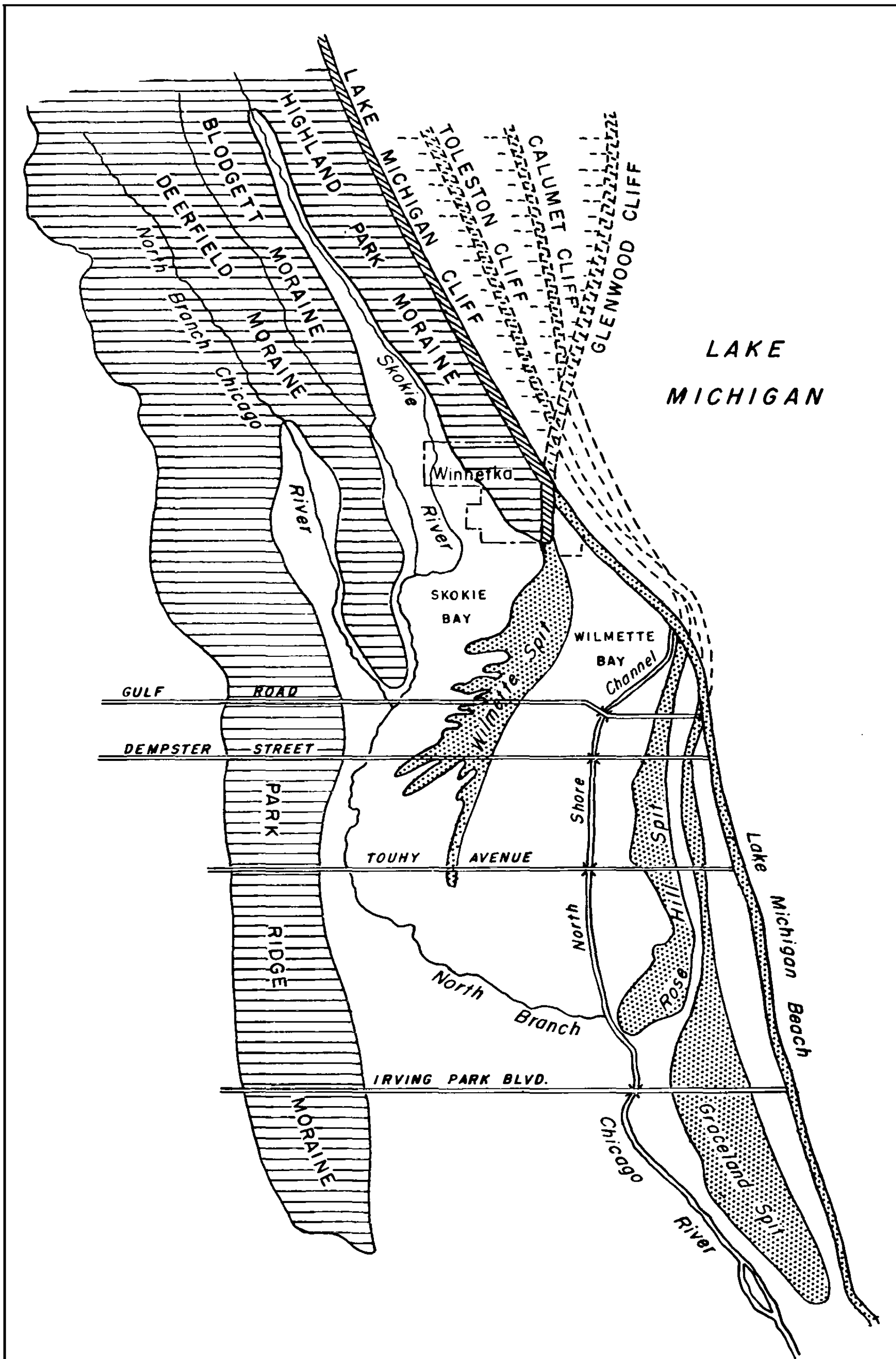



FIG. 57.—Reconstruction of the vanished sea cliffs and spit connections of the North Shore district.

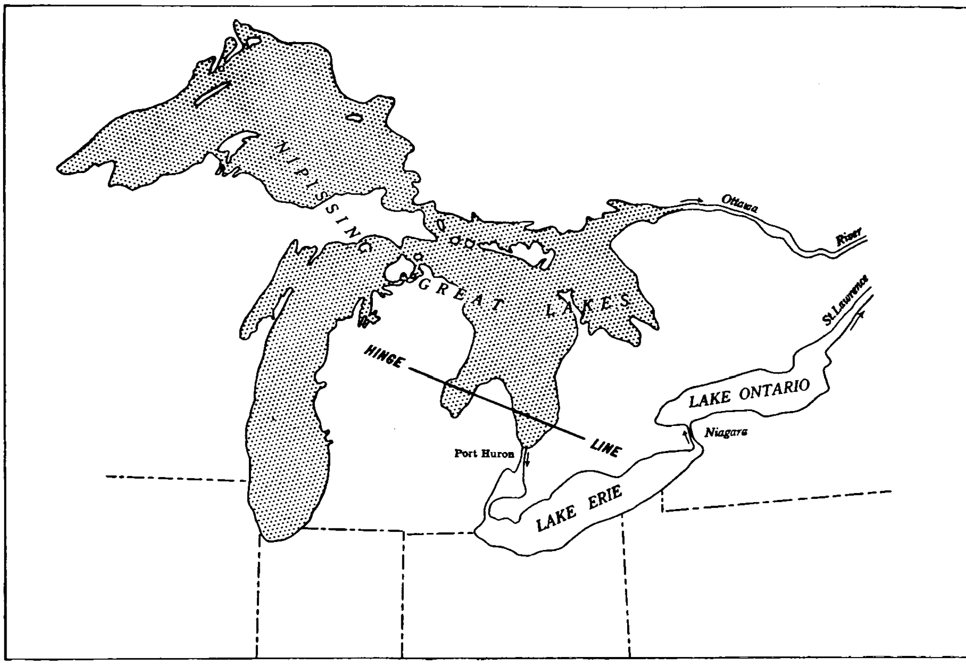



FIG. 58.—Nipissing Great Lakes. *From* Bretz, J Harlen, Geology of the Chicago region. Part I. General: Illinois Geol. Survey Bull. 65, fig. 90, 1940.

upper three lake basins again must be briefly considered.

Lake Algonquin levels, well recorded in the Georgian Bay region, must have made correlative shorelines in the southern part of the Lake Michigan basin. But today they are all superimposed on or built against the lakeward slope of the Toleston beaches.

Reduction of the load on the depressed crust of the region as the ice sheet retreated back into Ontario was causing continued uplift. The Algonquin beaches north of the hinge line are strikingly deformed, the amount of deformation increasing toward the northeast to a maximum of 6 feet to the mile. This warping must have occurred after the lake had constructed the shoreline, yet much of it had occurred before the ice front to the northeast ceased acting as a dam. The last stand of an ice dam appears to have been in the North Bay district of northeastern Georgian Bay.

When the ice retreated from the North Bay district, the lowest pass to the Mattawa–Ottawa River was opened and Lake Nipissing (or Nipissing Great Lakes) was formed, occupying most of the three upper lake basins. The formation of Lake Nipissing marks the close of glacial history and the opening of post-glacial time. Lake Nipissing was entirely surrounded by land; it had no glacial ice margin.

The initial North Bay–Mattawa–Ottawa spillway appears to have determined an early Lake Nipissing level that later rose as tilting continued to uplift the new outlet and added to the deformation of the Algonquin shores. Stanley[56] has found Nipissing marl overlying lower Algonquin beach gravels, proving that in the southern part of the Huron basin, the Nipissing level, because of the continuing uplift, eventually submerged some of the lower Algonquin levels.

Finally, the rising level of Lake Nipissing brought the Port Huron outlet into action again, the discharge out of North Bay ceased, and the stage was set for development of the modern lakes. Antevs[57] be-

[56]Stanley, G. M., Lower Algonquin beaches of Penetanguishene Peninsula: Geol. Soc. Am. Bull., vol. 47, pp. 1933-60, 1936.

[57]Antevs, Ernst, Late Quaternary unwarpings of northeastern North America: Jour. Geol., vol. 57, pp. 707-720, 1939.

lieved that there was a pause in uplift at this time and that North Bay and Port Huron long functioned simultaneously, constituting a two-outlet stage for Lake Nipissing.

In the southern and undeformed parts of Lake Algonquin, the main shoreline stands at about 607 feet above sea level,[58] which is not far from the Toleston level. The undeformed Nipissing shoreline, adjusted to the Port Huron outlet, is at about 596 feet,[59] and this stage may be represented by the Englewood[60] beach in the Chicago region.

Since the Port Huron discharge was restored, the North Bay outlet of Lake Nipissing has been raised by continuing differential uplift until it now stands 100 feet above the level of Lake Huron. Similarly, the Nipissing shoreline in the northern part of the Lake Michigan basin rises toward the northeast. Lake Superior, being entirely north of the hinge line, has all its glacial lake shorelines deformed. The bottom of the strait which in Nipissing time connected Superior with the rest of the three-basined lake has emerged entirely, making Superior a separate body of water 20 feet higher than Michigan and Huron and giving origin to the rapids in St. Marys River at Sault Ste. Marie.

The Hammond shoreline, according to Baker, is the same as the Toleston or is built up against it. In later Toleston time, Wilmette Bay received silt, sand, peat, and marl deposits above the heavy clam bed which marks the early Toleston bay, the deposits totalling a maximum of 6 feet. The upper part of the late Toleston sediments is crowded with shells which record a shallow-water environment. The upper surface of this stratigraphic unit has a yellow oxidized color with traces of crayfish burrows. Both the yellow color and the burrows record draining of the bay during the Sag low-water stage (Kirkfield stage of Lake Algonquin), an interval when the bay bottom became land.

[58]Goldthwait, J. W., An instrumental survey of the shorelines of the extinct lakes Algonquin and Nipissing in southwestern Ontario: Canada Geol. Survey Mem. 10, 1910.

[59]Goldthwait, Bull. 11.

[60]Baker, Univ. of Illinois Bull., vol. 17, no. 41, p. 93, 1920.

Above this land surface lie silt and peat beds of the Hammond stage, the two-outlet stage of Lake Algonquin. Wilmette Bay was very shallow at this time, partly because of the low level of the lake, partly because it was filled with these stratified deposits. The upper surface of the silt and peat beds, in turn, carries the same record of exposure (oxidized yellow color and crayfish burrows), dating from a low level following Lake Algonquin and preceding Lake Nipissing. At this time, Lake Michigan basin (containing Lake Chippewa) was drained by a river through Mackinac Straits.

Lifting of the North Bay outlet of Lake Nipissing brought the water level in the Chicago region back up as far as the Englewood level, about 690 to 695 feet, and silt and peat were deposited over the Hammond sediments in Wilmette Bay. Shallow-water molluscs characterize these deposits. When the Port Huron outlet was deepened, the bay was drained—just as it was when the first Europeans found it.

There was formerly a definite shoreline recording the Englewood stage, but it was faint and has largely disappeared beneath the city. Alden mapped it, and the Chicago region geological maps reproduce Alden's delineation with dotted outlines. It was a long beach ridge that reached originally from the tip of the Graceland spit (800 block North, West Chicago Avenue) south to 87th Street (Chicago Loop, Jackson Park, and Calumet Lake quadrangles—Maps 8, 12, 16), where it joined the Toleston beach. In its growth it blocked any possible drainage westward into the head of the DesPlaines outlet, and its existence is further evidence that the Chicago dischargeway was then dry.

East of the Toleston and Englewood beaches, the nearly flat plain carries a number of sand ridges on the Calumet Lake quadrangle (Map 16) that differ very little in altitude and that determine the outlines of Wolf Lake and Lake George. There were even more of them on the Jackson Park quadrangle, but they are no longer traceable. The ridges record the lowering from the Nipissing level to that of the

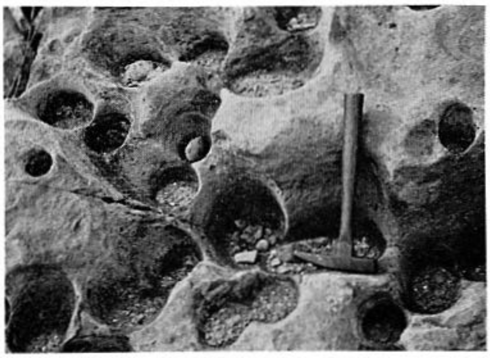


FIG. 59.—Potholes in floor of Toleston channel, near Lemont.

FIG. 60.—Water-worn grooves in floor of Toleston channel near Lemont.

present lake. Alden counted 90 of them, and figure 91 in Part I of this bulletin shows 68 in one photograph.

Quarrying in the DesPlaines valley bottom near Lemont has for many years provided almost continuous exposures of water-worn grooves and potholes in the bedrock floor. The marked elongation of the grooves early prompted the idea that they were ice-worn, but Leverett's statement that "they may be the product of the waters of the Chicago outlet"[61] suggests the correct explanation. Apparently the circular type shown in figure 59 was not exposed in the earlier quarrying. Some of the potholes are worn into cherty limestone, and the chert nodules are as cleanly cut as the limestone. Their production by the early postglacial DesPlaines seems out of the question; it is more likely that they were produced during the latest occupancy of the valley by glacial-lake discharge.

Deepening of stream valleys is likely to leave remnants of the valley floor of earlier stages as terraces on the lower slopes. But in the Lake Chicago outlet valley, the volume of discharge seems to have occupied the full width of the valley at all times and thus no terraces were built. Only one definite terrace is known, a remnant of the Tinley valley train (see p. 82), and it is protected in part by the projection of the Tinley moraine into the Sag Valley.

The history of Niagara Falls is intimately interwoven with, and almost as varied as, the late glacial and the postglacial history of the Great Lakes. The falls originated with the first emergence of the Niagara escarpment above the lowering water levels of glacial lakes in the Ontario basin, in early Lake Algonquin time. The cataract has retreated 7 1/2 miles back from its first position at the escarpment. Variations in the width of the gorge in different portions along the 7 1/2 miles are ascribed to variations in volume of discharge. When the Port Huron outlet was pouring the overflow of the Michigan, Huron, and Superior basins into Lake Erie the discharge was at its maximum; when Trent River or Mattawa River outlets were functioning and only Erie discharge was going over the falls it was at its minimum.

The correlation between Niagara Falls history and lake history which has been generally accepted for three decades[62] is based on the presence below the falls of three stretches of relatively wide gorge, separated by two stretches of narrow gorge. The wide stretch farthest upstream is being lengthened today by recession under the combined discharge of all four upper lakes. Its inception is dated back to the closing of the North Bay outlet. The narrow stretch downstream from it was formed during the life of early Lake Nipissing, which drained out of North Bay to the Mattawa and Ottawa rivers and allowed only Erie water to go over Niagara. The wide middle stretch is correlated with the Algonquin

[61] Leverett, Chicago Acad. Sci. Bull. 2, p. 53.

[62] Kindle, E. M., and Taylor, F. B., The Niagara folio (No. 190), U.S. Geol. Survey, 1913.

Port Huron discharge. The narrow stretch next downstream is a record of Erie discharge during the Trent River outlet stage of Lake Algonquin. The wide stretch at the lower end of the gorge is believed to record an early stage of Lake Algonquin, not previously referred to in this bulletin. It endured until the Trent River outlet was opened, and its discharge necessarily went into the Erie basin and thence over the falls.

Some refinements and revisions of this correlation are proposed by Antevs.[63] His revisions include a new estimate of 22,000 years for Niagara's total age, instead of Kindle and Taylor's figure of 25,000 to 30,000 years.

## RADIOCARBON DATING

In Part I the recession of Niagara Falls was called a "geological clock," and the Taylor and Kindle estimate of the age of the gorge, 25,000 to 30,000 years, was presented. This estimate is found in virtually every textbook on historical geology now in use, but it is more than twice the recent measurements made by a wholly different and far more precise method. Working with geological material, but using the laboratory methods and principles of physics and chemistry, we have been getting some surprising figures, in terms of years, for the age of the rocks in the geological record.

The amount of radioactive decomposition of uranium and thorium minerals in igneous rock has moved our estimate of the earth's beginning back in time more than two billion years. More recently, the amount of radioactive decomposition of an isotope of carbon, carbon 14, in wood and peat of late glacial age has demanded that we move these late events much nearer the present than the Taylor and Kindle estimates for Niagara.

The principles on which radiocarbon dating is based may be briefly outlined as follows. Cosmic ray neutrons, with very high specific energy, are constantly bombarding the earth's atmosphere. Nitrogen atoms are broken up by such bombardment to form carbon and hydrogen, the resulting carbon atom being radioactive with a half-life period of about 5600 years. These carbon atoms shortly combine with atmospheric oxygen to form carbon dioxide and to become a small part of the atmosphere's total amount of carbon dioxide. Because plants build their structures largely from carbon dioxide, all vegetable tissue, when formed, must contain the same proportion of radioactive carbon 14 and nonradioactive carbon 12.

Assuming a constancy of cosmic-ray reception by the earth during the recent geological past, there must now be a balance between the rate of disintegration of radioactive carbon and that of assimilation of new radiocarbon in all living matter. Input ceases when an organism dies, and the amount of carbon 14 begins to decline, becoming reduced to half its original amount in peat, wood, bone, or shell material in about 5600 years.

Because the proportion of carbon 14 to other carbon atoms in living organic material is known, it follows that buried wood or charcoal whose original carbon content has undergone no other alteration subsequent to burial may carry a record of time elapsed since the plant was alive.[64] Using this method of approach, determinations of the age of numerous samples of wood and peat of late glacial age[65] have given a correctly proportioned chronology back as far as about 20,000 years, which is the present limit of laboratory determination. The highest figure is for some wood buried in the loess of the earliest Wisconsin glaciation, more than a hundred miles southwest of Chicagoland (Farm Creek). There were 15 or more moraine-building episodes after the radiocarbon content of that wood began to decrease and before Lake Chicago's history began. Niagara Falls, born after Lake Chicago had ceased to exist, obviously cannot date back

[63]Antevs, Jour. Geol., vol. 47, pp. 719, 720, 1939.

[64]Some scientists doubt that the only alteration in C14 content since burial has been radioactive decay. Antevs, *in* Geochronology of the deglacial and neothermal ages, Jour. Geol., vol. 61, pp. 195-230, 1953, lists a considerable number of causes possible for other alterations.

[65]Libby, W. F., Radiocarbon dating: Univ. Chicago Press, 1952.

25,000 years if the radiocarbon method of dating is correct.

The discovery of wood buried in Lake Chicago deposits has made possible an approximate carbon 14 dating of some events in the lake's history. Wood has been found: (1) in and under the Dyer spit, itself undoubtedly of Glenwood age; (2) in an excavation on the campus of the University of Chicago, made in sand probably of Toleston age; (3) in an aggregate of beach ridges near Dolton that range from Toleston to Algonquin and perhaps Nipissing in age; and (4) in Plum Creek alluvial deposits, of indeterminate post-Calumet age.

A deposit of peaty debris, driftwood, and a few ice-rafted boulders underlies the sand and gravel of the Dyer spit, which itself can be no younger than latest Glenwood. The site of the deposit was exposed in early Glenwood time to waves from the open lake while a beach ridge was built on the landward side. Later growth of a barrier beach and of another spit (see p. 117) made the site a protected bay. Into this quiet water, plant debris was floated by a littoral current that still later brought in the sand and gravel of the spit. The organic material is indubitably of Glenwood age. Carbon 14 determinations made by two different laboratories have not yielded the same age in years, but both agree that the Dyer material is older than the Two Creeks buried forest.

In excavations on the University of Chicago campus, wood was found buried 14 feet deep in lake bottom sand below the level of the Toleston beach. It seems probable that this sand and the driftwood are of Toleston or later age. Its age was found to be 8,200 ± 480 years.

The driftwood log found under beach sand near Dolton was interpreted in Part I (p. 117) as probably Toleston in age. But the wide belt of beach ridges here must include Algonquin deposits and perhaps includes Nipissing deposits. The log was under the lakeward edge of the sand belt. Its age, 3469 ± 230 years, seems by comparison with the specimen from the excavation at the University of Chicago campus to be altogether too young for Toleston. It may be Algonquin or Nipissing.

Recent studies by Hough[67] indicate that in disagreement with some earlier interpretations of Nipissing history, Nipissing levels rose in the south end of Lake Michigan basin to the Algonquin level. Arnold and Libby in 1951 reported that peat from the Nipissing beach at Sand Island, Bayfield Co., Wis., is 3656 ± 640 years old.

The Plum Creek deposit was interpreted in Part I (p. 117) as at least post-Calumet, and accumulated because of the growth of an alluvial fan farther downstream after Lake Chicago was lowered from its Calumet shoreline. The wood is only 1850 ± 480 years old—younger than any glacial-lake stages of the Lake Michigan basin.

The North Shore Channel sections studied by Baker are no longer exposed. Baker reported peaty and woody material of Bowmanville, Calumet, and Toleston ages, but, until new excavations are made on the floor of the bay, the age of these lake deposits cannot be determined by the radiocarbon method.

The writer has correlated the Bowmanville low-water stage with the Two Creeks forest bed north of Manitowoc, Wis. Wood and peat from the deposit have been found to be 11,400 ± 350 years old, this figure being an average of several samples.[68] The rise to the second-attained Calumet level occurred because of the Valders (Mankato) advance, and a weak Calumet beach on the southern portion of the Valders red till sheet indicates that this lake level flooded back briefly when the Valders ice was beginning to retreat. The Calumet stage, therefore, did not persist much later than 11,000 years ago. Niagara Falls, dating from early Algonquin time, must be younger than this—younger even than the wood found in the excavations on the campus of the University of Chicago.

Final retreat of Wisconsin ice from any locality marks the beginning of that re-

[67]Hough, J. L., Pleistocene chronology of the Great Lakes region: Office of Naval Research, Project NR 018-122, 1953.

[68]In an elaborate study of glacial-lake varves and their correlative moraines in both North America and Europe, Antevs (loc. cit.) holds that the Two Creeks deposit is 19 000 years old and that all radiocarbon dates should be increased somewhat proportionately.

gion's postglacial history. Since the retreat was protracted, beginning thousands of years earlier on the oldest Cary moraine than it did on the youngest, the word *postglacial*, although a valuable adjective, is not a precise time name. Furthermore, the term has also been used to mean the duration of the present climate, to indicate the time since the transition from glacial to nonglacial stages of the Great Lakes, and to cover the time since final disappearance of the ice sheets from their centers of accumulation. A substitute term is *Recent age*, but unless arbitrarily defined, it is not much better than *postglacial*. The transition from Mankato to Recent was gradual.

The amount of oxidation and leaching of exposed calcareous Wisconsin till during the Recent age is slight compared with that on buried Illinoian and older tills and indicates the relative brevity of the age. Indeed, we may be living in the early part of another interglacial age instead of after the close of the Pleistocene glaciations. Therefore, in table 1 the Recent age is included in the Pleistocene epoch.

The immature soil profiles of the region are an expression of the geological shortness of Recent time, as are also the youthful stream valleys and the many enclosed depressions still incompletely filled or drained. The North Shore district has been the most severely eroded; both running water and waves have attacked the eastern slope of the Highland Park moraine. Each agency has accomplished a maximum performance here, and the tempo of the running-water work certainly increased because of the concomitant wave attack.

The rate of recession of the sea cliff here has been computed by several students at different times and from somewhat different data. Andrews[69] in 1870 found an average rate of 5.28 feet annually between Milwaukee and Evanston. Chamberlin[70] published in 1877 an estimate of 3.33 feet average annual recession in Racine County. Atwood and Goldthwait[71] reported in 1908 that the complete destruction of the site of the former village of St. Johns near Fort Sheridan indicated a recession of 100 to 400 feet since 1845, an average yearly recession of 1 1/2 feet for the smaller estimate and 6 feet per year for the larger. Ball and Powers[72] in 1930 measured the recession between 1918 and 1929 north of Kenosha as 12.33 feet per year.

Andrews called attention to a submerged terrace off this cliffed shore which he believed was a wave-cut beach, the correlative of the wave-cut cliff. Dividing the average rate of recession into the average width of the terrace gave him 2720 years elapsed time since the recession began. Leverett,[73] commenting on this estimate, notes that 4708 years is obtained by using Chamberlin's figures and that at best this method gives "only a rude approximation" of the duration of Lake Michigan. Johnson[74] in 1919 pointed out that the rate of terrace-cutting would not remain the same during all stages and that the full width of the terrace may not be the product of wave erosion. The net effect of Johnson's strictures would be to lower these estimates of the life of Lake Michigan.

Andrews[75] also attempted to obtain the relative life span of Lake Chicago and Lake Michigan from a comparison of the bulk of beach materials accumulated by each. Certain assumptions had to be made when numerical values could not be obtained, as for example the amount of Lake Chicago beach sand that was swept into the outlet heads and thus removed from possibility of measurement. His conclusions were that the combined bulk of the Lake Chicago beaches was nearly equal to that of the present beach, the proportions being 16 to 17. He attempted to estimate the time involved by measuring the amount of sand carried by shore agencies past certain piers in Chicago and in Michigan City, Ind., assuming that all movement was southward. His conclusion was that Lake Michigan had

[69]Andrews, op. cit.

[70]Chamberlin, T. C., Geology of Wisconsin: Wisconsin Geol. Survey, vol. 2, pp. 219-233.

[71]Atwood and Goldthwait, Bull. 7, p. 92.

[72]Ball, J. R., and Powers, W. E., Shore recession in southeastern Wisconsin: Ill. Acad. Sci. Trans., vol. 22, pp. 435-441, 1930.

[73]Leverett, U.S.G.S. Mon. 38, p. 459.

[74]Johnson, D. W., Shore processes and shoreline development: New York, John Wiley, p. 228, 1919.

[75]Andrews, op. cit.

existed about 3000 years. Leverett[76] comments that the shore currents apparently are changeable, reversing with reverses of wind direction, plainly implying that Andrews' estimate is too small. At present, therefore, no method of computing the duration of Recent time from phenomena in the Chicago region seems available.

Other specific changes of the Recent age which may be noted here are the accumulation of 10 feet of brown peat in the Sag Channel, the cutting down of outlets and consequent draining of the immediately postglacial lakes of Mt. Forest Island and the Orland–Palos district, and the piracy of Sawmill Creek.

Since the first recognition of warping in the glacial lake shorelines, the question has been debated as to whether that differential uplift is still continuing. Gilbert[77] gave us the first answer, in the affirmative. Spencer[78] denied Gilbert's conclusion, saying in effect that neglect of certain data vitiated Gilbert's affirmation—that it was possible to arrive at the opposite conclusion by selection of other tide-gauge records. Others have been in the controversy during the half century since the appearance of Gilbert's paper. Opinion today, based on more precise data which cover more time, seems settled on the affirmative.[79] Figure 61 graphically portrays the results of the latest computations. Not all the stresses engendered by the weight of the Labradorean ice sheet of the Wisconsin age have yet been relieved.

Aquatic mollusca in the Lake Michigan basin seem to have become very similar, by Nipissing time, to Lake Michigan's present fauna. The record of changes in the postglacial biota are better recorded by pollen statistics of bog deposits in morainic depressions. Voss[80] and others have shown

[76]Leverett, U.S.G.S. Mon. 38, p. 456.

[77]Gilbert, G. K., Recent earth movements in the Great Lakes region: U.S. Geol. Survey 18th Ann. Rept., pt. 2, p. 595, 1896-1897.

[78]Spencer, J. W., Postglacial earth movements about Lake Ontario and the St. Lawrence River: Geol. Soc. Am. Bull., vol. 24, p. 217, 1913.

[79]Moore, Sherman, Tilt of the earth in the Great Lakes region: Military Engineer, vol. 14, p. 151, May-June 1922.

Freeman, J. R., Regulation of the Great Lakes: Chicago Sanitary District, pp. 149-172, 1926.

Gutenberg, B., Tilting due to glacial melting: Jour. Geol., vol. 41, pp. 449-467, 1933.

[80]Voss, Ill. Acad. Sci. Trans., vol. 29, no. 2, 1936.

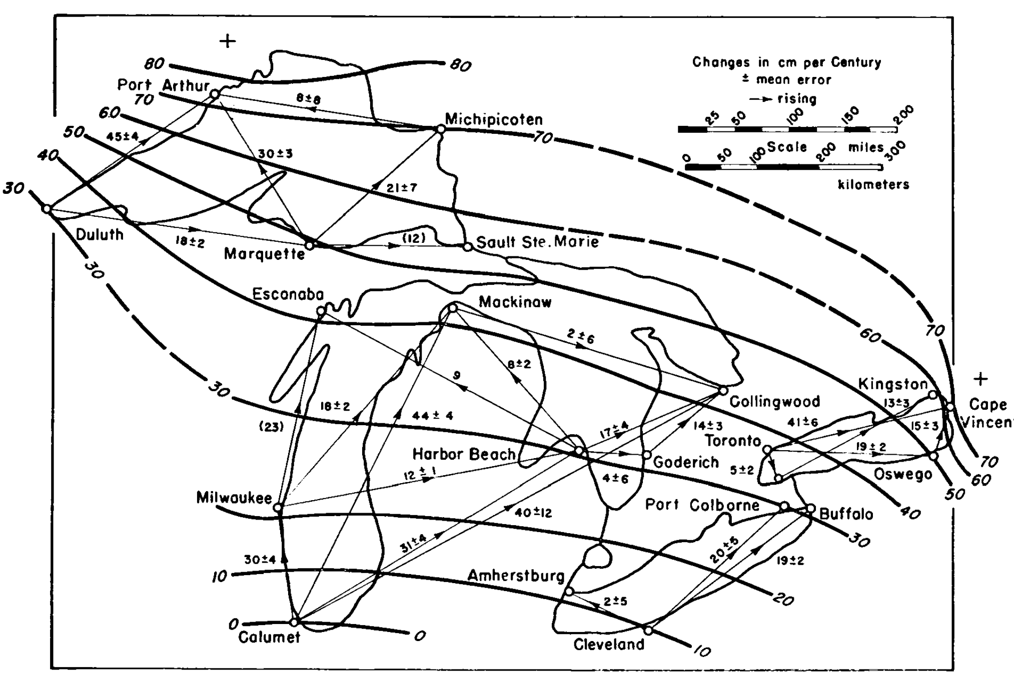



FIG. 61.—Changes in level in the Great Lakes region in centimeters per century. *After* Gutenberg, 1943. Arrows point in direction of uplift; lines of equal uplift from 10 to 80 cm.

that the balsam fir (Abies) was a prominent member of the earliest forests that repossessed the land in our region, and that it disappeared after something like 5000 to 6000 years. The spruce (Picea) was a contemporary of the fir and held its own for a somewhat longer time. Disappearance of both genera was gradual and coincided with a similarly gradual increase in oak (Quercus) and hickory (Carya). These changes were doubtless climatically determined.

Cooper,[81] reviewing a considerable literature on fossil pollen-grain stratigraphy of a larger area of glaciated North America, finds spruce and fir reported from all the lowest layers of postglacial peat, oak and pine (Pinus) in the middle layers, and spruce and fir again in the upper layers. It is a record of a mid-postglacial warm, dry time, followed by a return toward cool, moist conditions.

Matthes,[82] working with the records of alpine glaciers in the Cascades and Sierras, believes that these glaciers completely disappeared in a mid-postglacial warm, dry interval (comparable to that found by the botanists), and were formed again with the coming of cooler and more moist conditions some 4000 years ago. Since glacial shrinkage and retreat is now going on, the climate is judged to be shifting again, in a rhythmic fashion, toward another warm, dry interval. Matthes calls the time of regrowth of the Sierra and Cascade glaciers the "Little Ice Age." It did not reach the extremes necessary to initiate regrowth of the continental ice sheets.

The appearance of man in the local fauna is, for the Chicago region, an undated event. Although evidence strongly suggests that he was a pre-Wisconsin arrival in North America, there are no indications that he inhabited Chicagoland before the present climate and biota were well established. For many centuries after man entered the region, his presence had little influence on the biological and geological regimen. The early Indians exterminated no animal species and introduced few if any plant species that have since become established in nature. They made no alterations of the natural drainage routes. They did very little that altered nature's rates of slope-wash erosion. Their only interest in mineral resources was to secure hard stones for tools and clay for pottery.

White man's arrival was the signal for a series of notable changes in the equilibrium. Streams have been dredged or dammed or diverted. New waterways have been constructed and the drainage divide has been so shifted that the Mississippi has gained and the St. Lawrence has lost nearly 1200 square miles of contributing territory. Industrial and other wastes have polluted the larger streams and made great changes in their biota. Artificial draining has made many wet areas arable and has lowered the water table. Energy taken from stream flow, at Lockport, has been transformed into light and heat and mechanical work. Every geological deposit of the region has yielded raw material for man's use. Soil erosion has increased from clearing the forests and breaking the prairie sod for agriculture, and unwise cultivation has in many places unnecessarily damaged the soil. Many mammalian species have been forced to abandon the country and far too many undesirable plant species have entered. The lake-shore regimen has been extensively altered with construction of protecting walls, dredging of sand from offshore shallows, accumulation of "pocket" bathing beaches, and construction of harbors.

Some of man's changes have been partially detrimental because of uninformed interference with, and manipulation of, nature's forces. An understanding of the region's geological development should help to guide man into wiser cooperation with existing geological agencies and wiser utilization of those resources nature has been so long in accumulating.

[81]Cooper, W. S., Contributions of botanical science to the knowledge of postglacial climates: Jour. Geol., vol. 50, pp. 981-994. 1942.

[82]Matthes, F. E., Recent variations of glaciers viewed in their relation to the Pleistocene ice age; pp. 190-215 of Chap. 5, Hydrology, vol. 9, Physics of the earth: National Research Council. 1942.

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