XVI INTERNATIONAL GEOLOGICAL CONGRESS

Guidebook 26 - - - Excursion C-3

GLACIAL GEOLOGY OF THE CENTRAL STATES

International Geological Congress
XVI session
United States, 1933

Guidebook 26: Excursion C–3

GLACIAL GEOLOGY OF THE CENTRAL STATES

Prepared under the direction of

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U. S. GEOLOGICAL SURVEY

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1932

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - Price 10 cents

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This guidebook is published under the auspices of the United States Geological Survey, but it is not a part of the Geological Survey's regular series of publications, and the opinions expressed in it and the use of nomenclature do not necessarily conform to Geological Survey usage.

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Prepared under the direction of William C. Alden

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By W. C. Alden

INTRODUCTION

The classification of the Quaternary period in use at present by the United States Geological Survey is as follows, from latest to earliest:

Quaternary period:
- Recent epoch.
- Pleistocene epoch—
  - Wisconsin stage of glaciation.
  - Peorian stage of deglaciation.
  - Iowan stage of glaciation.[1]
  - Sangamon stage of deglaciation.
  - Illinoian stage of glaciation.
  - Yarmouth stage of deglaciation.
  - Kansan stage of glaciation.
  - Aftonian stage of deglaciation.
  - Nebraskan stage of glaciation.

In the studies leading to this classification numerous geologists took part, among the most prominent of whom were T. C. Chamberlin, Samuel Calvin, and Frank Leverett. Leverett, Kay, and Leighton have proposed certain changes in the general classification of the North American Pleistocene deposits, as noted in the following pages. Kay has urged that the several gumbotils (see p. 26) and the interglacial soils and weathered zones, all of which are the modified upper parts of the several till sheets (including also the several loesses, peat, and other non-glacial deposits), be more closely grouped with the glacial deposits in the classification, that four epochs be recognized in North America, and that they be named as subdivisions of a

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[1] By some geologists the Iowan is correlated with the Illinoian glaciation; by others it is regarded as earliest Wisconsin, and by them the Peorian stage of deglaciation is omitted. (See bibliography, pp. 52–54, Nos. 32, 21, 27.)

Pleistocene period from which Recent time would continue to be more or less arbitrarily separated.

Consideration of the Pleistocene faunas and floras is, for the most part, omitted from the following summary description.

PREGLACIAL CONDITIONS

Since Cretaceous time that part of the Mississippi Basin above the head of the Mississippi embayment (north of latitude about 37° 30′) has been land. In the region of the Great Plains extensive stream deposits with perhaps some of lacustrine origin were laid down in Tertiary time. Some high-level traces of Tertiary stream gravel are also found north and northeast of the head of the Mississippi embayment in southern Indiana and in adjacent parts of Illinois, Iowa, and Wisconsin. The Tertiary record in that region, however, is mostly one of stream erosion. The preglacial drainage in western Minnesota is thought to have been northward by way of the Red River Valley, as now. (See fig. 1.)

Studies in Iowa indicate that the land was reduced to a surface with gentle slopes and a relief of perhaps 200 feet (61 meters). Some authors have applied the name Dodgeville peneplain to small remnants of this surface preserved in and near southwestern Wisconsin. Remnants of a similar erosion surface about 200 feet (61 meters) lower in the same region have been designated the Lancaster peneplain. The northerly extension of these plains is not known. Martin (41) [2] has interpreted the configuration resulting from Tertiary erosion in Wisconsin as cuestas rather than distinct peneplains—that is, the more rapid erosion of the friable sandstones and shales left the more resistant beds standing as cuestas. The relations of these erosion surfaces indicate a moderate regional elevation in late Tertiary time. Over these and correlated surfaces came the first of the Pleistocene ice advances.

Some geologists (22, 51) think that the Mississippi River and its tributaries in and adjacent to northeastern Iowa and southwestern Wisconsin did not cut much, if any, below the old upland (the so-called Lancaster peneplain) until after the Nebraskan glaciation. There is now a relief of 500 to 600 feet (152 to 183 meters) below this "plain," and some of the streams are now flowing in places about 200 feet (61 meters) above buried rock floors. Some of these rock floors are thought to have been lowered at least 200 feet (61 meters) since Nebraskan time. Leverett (31), however, cites evidence from which he concludes that the Mississippi River and its tributaries in Minnesota, Wisconsin,

[2] Figures in parentheses refer to bibliography, pp. 52–54.

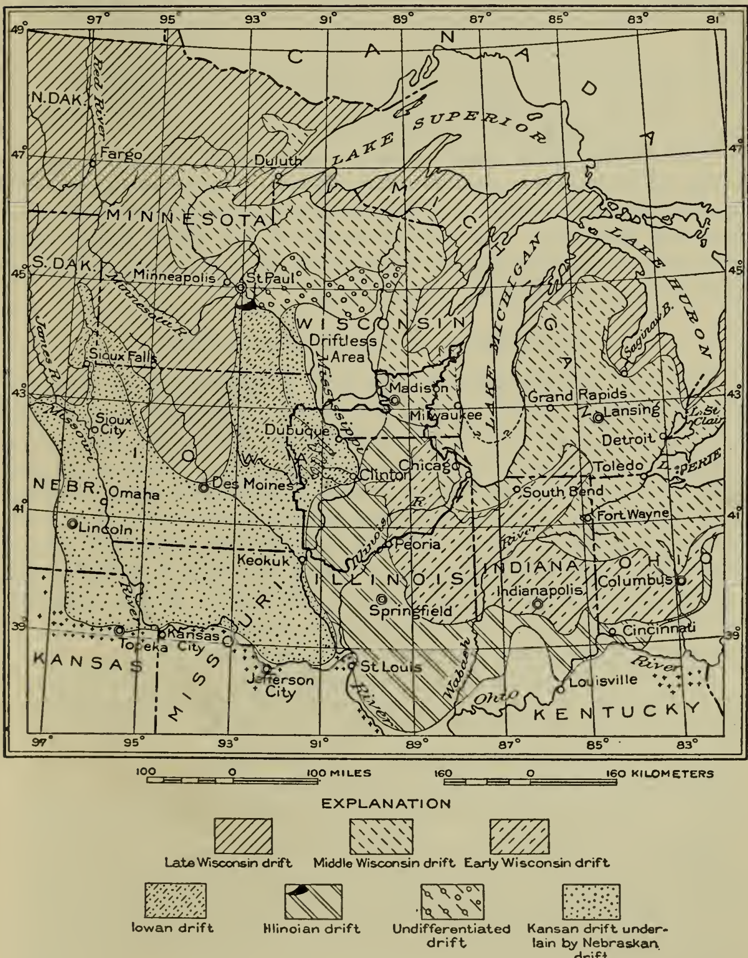

FIGURE 1.—Map of drift sheets in north-central United States, showing subdivisions of the Wisconsin drift. Crosses indicate outlying erratic boulders and patches of till. (After Leverett, 1931)

Iowa, and Illinois had cut valleys (some of which are now partly buried in drift) to their full depths, 100 to 200 feet (30 to 61 meters) or so below the present flood plains, before the first ice invasion. He traces the original course of the Mississippi River below Clinton, Iowa, southeastward to the bend in the Illinois Valley near Hennepin, Illinois. Thence southwestward nearly to its junction with the Missouri River the Mississippi followed the valley now occupied by the Illinois River. North of Hennepin it was joined by the preglacial Rock River.

The present Ohio River system is the result of a complicated series of changes, some of which seem to have antedated the earliest glaciation, but the main changes appear to date from that invasion (30, 34). The several basins of the Great Lakes were probably originally stream valleys which were later deepened and perhaps widened by glacial scour.

NEBRASKAN STAGE OF GLACIATION

The drift deposit made by the first or Nebraskan ice sheet in the Mississippi Valley is best exposed in Iowa (22) and is also found in adjacent parts of neighboring States (38, 46). The exposures are mostly small and occur at places where overlying later drift and loess have been removed artificially or by erosion. The Nebraskan drift has not been definitely identified in or west of the Dakotas. The ice making this deposit advanced southward from central Canada and reached the limit of glaciation in northeastern Kansas and central Missouri. Some outlying patches of till and boulders in these regions may perhaps be remnants of marginal parts of the Nebraskan drift.[3]

Drift of Nebraskan age has not yet been certainly identified in Illinois as the product of ice from the Labradorean center. Where found farther west the till is generally dense, compact calcareous stony clay of dark-gray or slate color. It is in many places cut by joints whose sides are bordered by rusty bands due to oxidation and in which considerable secondary calcium

[3] Deposits of drift exposed on Cape Cod, Massachusetts, the New England islands, and Long Island have been interpreted by M. L. Fuller and J. B. Woodworth as indicating that the ice of both the first and the second stages of glaciation advanced southward across the mainland of New England and reached the islands or their immediate vicinity. They also found evidence that a long time of deglaciation intervened between these two early ice invasions. R. D. Salisbury and his associates interpreted the extramorainal drift in New York, northern New Jersey, and northeastern Pennsylvania (called the Jerseyan drift) as indicating that these areas were also similarly affected by one or the other of these early glaciations. As the result of his recent studies in Pennsylvania and New Jersey, Leverett (personal communication, 1930) is inclined at present to regard the Jerseyan drift as the correlative of the second or Kansan drift of the Mississippi Valley.

carbonate has been deposited. Though thin in many places, Kay and Apfel (22) estimate that the average thickness in Iowa was originally more than 100 feet (30 meters). (See pl. 1, *A*.)

AFTONIAN STAGE OF DEGLACIATION

The Aftonian stage of deglaciation, which followed the melting of the Nebraskan ice, was so long that not only was the Nebraskan till greatly altered but its upper part, to an average depth of about 8 feet (2.4 meters), was thoroughly leached of soluble constituents. Limestone pebbles and boulders were removed by solution, and the granitic rocks were reduced to kaolin and sand, the whole residual layer becoming an ash-colored sticky clay, with sparse pebbles, very slippery when wet, to which Kay has given the name "gumbotil." Gumbotil was probably not everywhere developed on the Nebraskan till plain and in many places is not now preserved. In some places only an Aftonian soil is found, or an accumulation of peat or vegetal material, and in other places there is stream gravel. The famous "Aftonian gravel," including the fossiliferous gravel of western Iowa, is interpreted by Kay (22) not as interglacial but as partly of Nebraskan and partly of Kansan age. Calvin, Shimek, and Hay (18), who studied the mammalian fossils from the gravel of western Iowa, were of the opinion that these mammals could not have lived in the immediate vicinity of an ice sheet and that the gravel is of interglacial age. The pre-Kansan erosion of the Nebraskan till and underlying rock after the formation of the gumbotil was very considerable and in places extended to depths of 200 to 400(?) feet (61 to 122 meters), showing that the Aftonian stage of deglaciation was very long, probably more than 100,000 years.

KANSAN STAGE OF GLACIATION

At the Kansan stage of glaciation ice of vast extent spread from the Labrador and more westerly centers of accumulation. (See fig. 1.) From northwestern Pennsylvania to the Mississippi River the Kansan till is mostly covered by later drift. In Illinois there are numerous exposures of drift that is probably of Kansan age, and it is suggested (9) that ice centering in the Keewatin region west of Hudson Bay may perhaps have spread eastward in Illinois nearly as far as Peoria.

Northward along the west side of the Driftless Area, as far as Winona, Minnesota, the eastern limit of this drift is near and west of the Mississippi River gorge. North of the Driftless Area the Kansan drift probably came from the north or northeast. The southern limit of the Kansan drift in Missouri is near the Missouri River, and this drift is also present in northeastern Kansas and in the eastern counties in Nebraska (38).

In many places a thickness of 50 feet (15 meters) of Kansan drift is exposed. The combined thickness of the Kansan and Nebraskan deposits in southeastern South Dakota and adjacent parts of Minnesota and Iowa is, in some places, 300 to 500 feet (91 to 152 meters). In some localities the second drift appears to be thinner than the underlying Nebraskan till.

These two drift sheets, though showing local differences, are in general very similar in color, texture, composition, and degree of modification by weathering and erosion. In many places they can be distinguished from each other only by their relations to the interglacial soils, zones of weathering, or gumbotils (22).

The drainage of the combined upper Missouri and Yellowstone Basins, which is thought originally to have flowed northeastward to Hudson Bay, was permanently diverted southward by either the Nebraskan or the Kansan ice to join the lower Missouri in southeastern South Dakota (4, 5). There were also temporary diversions of the drainage farther south when the ice extended beyond the present river channel.

YARMOUTH STAGE OF DEGLACIATION

The Yarmouth stage of deglaciation was named by Leverett (29) from a village in southeastern Iowa, where, in digging a well, 12 feet (3.6 meters) of fossiliferous silt and 15 feet (4.5 meters) of peaty material were found between the Kansan drift and the overlapping Illinoian drift. Beneath this later drift in southeastern Iowa and Illinois gumbotil is also found in many places at the top of the Kansan. Elsewhere also the upper part of the Kansan till, to an average depth of about 11 feet (3.3 meters), was changed by weathering to gumbotil of similar character to that on the earlier drift. There was also much dissection of the nearly flat Kansan till plain before the deposition of the overlapping drift sheets and the loess (22). These features, together with the amount of pre-Illinoian erosion of the Kansan drift, show that the length of the interglacial stage was great and the climatic conditions were such as probably led to the total disappearance of the Kansan ice sheet.

The leached and eroded upper part of the Kansan till is, in places, especially in adjacent parts of eastern Nebraska and western Iowa, overlain by a wind-blown deposit, the Loveland loess, which is generally more reddish and shows evidence of greater age than the main deposit of buff loess. In places in southeastern Iowa and in Illinois loess or loesslike silt is found between the weathered top of the Kansan till and the base of the overlying Illinoian till (22).

ILLINOIAN STAGE OF GLACIATION

In southeastern Iowa and in Illinois the weathered and eroded Kansan till, the gumbotil, and the interglacial deposits are overlain by the Illinoian till, a drift sheet deposited by ice from the Labradorean center. (See fig. 1.) This ice reached 37° 35′ north latitude in southern Illinois and, invading Iowa a short distance, it temporarily shifted the Mississippi River to a channel west of its present course (29).

North of the Driftless Area in Wisconsin and in a small area south of St. Paul in Minnesota there is weathered reddish drift from the Lake Superior region, which Leverett (36) holds tentatively to be of Illinoian age. As indicated below, Leverett (32) is inclined to regard the Iowan drift of northeastern and northwestern Iowa as the contemporary of the Illinoian till.

The Illinoian is the uppermost glacial deposit throughout nearly two-thirds of the State of Illinois, and it has a thickness of 5 to 50 feet (1.5 to 15 meters) or more. This drift consists very largely of compact calcareous bluish-gray clayey till which has been oxidized to buff to depths of 15 feet (4.5 meters) or more. It is more or less thoroughly leached of the finer calcareous material to depths of 5 or 6 feet (1.5 to 1.8 meters), and in places the upper part is oxidized to rusty red. Where nearly flat remnants of the original till plain have been preserved alteration has gone so far as to develop ash-gray gumbotil 2 to 5 feet (0.6 to 1.5 meters) thick.

SANGAMON STAGE OF DEGLACIATION

The melting of the Illinoian ice sheet appears to have left a nearly flat plain of which remnants several square miles in extent are still preserved in interstream tracts. This plain was sharply incised and generally dissected to depths of 50 to 150 feet (15 to 46 meters) prior to the deposition of the Peorian loess, which now mantles the interstream upland tracts and the rather steep side slopes of the valleys.

Leverett early noted and recent studies in Illinois have differentiated a thin deposit of loess or loesslike silt overlying the gumbotil at the top of the Illinoian till and distinct from the overlying Peorian loess. It is separated from the calcareous Peorian loess by a soil and weathered zone, and in consequence Leverett (29) and more recently Leighton (27) concluded that the weathering and erosion of the Illinoian till, the deposition of this thin loess, and the development of the soil at its top were all features of the Sangamon interglacial stage. The indications are, however, that this stage of deglaciation, though long enough for the complete disappearance of the continental ice sheet from North America, was not nearly so long as the Yarmouth interglacial stage.

The Mississippi River appears to have assumed its present course between the south end of the Driftless Area and the mouth of the Illinois River some time after the front of the Illinoian ice sheet receded from Iowa (44).

IOWAN STAGE OF GLACIATION

The Iowan drift is a puzzling member of the glacial series in America. Although even its existence as a distinct deposit has been questioned, its presence has been established on sufficiently good evidence to warrant the continued use of Iowan drift and Iowan stage of glaciation as major subdivisions of the Pleistocene classification up to this time. If this Iowan drift is not the contemporary of the Illinoian drift, as several geologists think it is not, then there is little or no indication that ice of the Illinoian stage extended beyond the limits subsequently reached by the latest drift (late Wisconsin) in southern Minnesota and in Iowa, although it may perhaps have done so farther northwest. The Iowan and Illinoian drifts, as now mapped, occupy separate areas and do not overlap.

Critical study of the Iowan drift and its relations has continued since Alden and Leighton (6) reviewed the evidence in 1914–15, and apparently the time is approaching when some change should be made in its classification. There is not yet unanimity of opinion, however, as to what grouping affords the most usable classification. Reference of all the Pleistocene drift sheets to four major glaciations is growing in favor and may be found satisfactory. Even so, the exact status of the Iowan may not be permanently assured. In contrast with the idea that the Iowan drift is of Illinoian age are the interpretations recently proposed by Kay (21) and Leighton that the Iowan glaciation was not separated from the Wisconsin glaciation by any considerable interval of deglaciation, and by Leighton (27) that it may even be regarded as the initial ice invasion of Wisconsin time.

PEORIAN STAGE OF DEGLACIATION

Mantling the weathered and eroded surface of the Illinoian drift and the Sangamon loess and extending eastward under early Wisconsin till in Illinois is the deposit formerly called Iowan loess but more recently generally known as Peorian loess. This loess also extends westward over the weathered and eroded Kansan drift of eastern, southern, and western Iowa into Kansas and Nebraska and the borders of southeastern South Dakota. It overlaps the Driftless Area and the marginal parts of the Iowan drift in Iowa (fig. 1) and adjacent parts of Minnesota, and it extends under the late Wisconsin drift of the Des Moines lobe (pl. 1, *B*). There is difference of opinion as to the amount of erosion and length of time that were required to form the sparse accumulations of residual pebbles that are found on top of the Iowan till and beneath the loess, but to several geologists the time required does not seem to be long. Other conditions seem to indicate that the deposition of the Peorian loess followed the recession of the ice from the Iowan drift plain after a comparatively brief period. There was a moderate amount of leaching (4 to 5 feet, or 1.2 to 1.5 meters) and oxidation of the loess before it was overrun by the late Wisconsin ice of the Des Moines lobe. Leverett (29) and more recently Leighton (27) have found evidence of the development of a soil and of very moderate weathering of the Peorian loess before it was overrun by early Wisconsin ice, which formed the Shelbyville moraine. The Iowan drift is generally thin, and it has been little dissected, although subjected to sufficient erosion to account for the accumulation of residual pebbles. This drift where thin has about the same buff tint as the Peorian loess; where thicker the color shades into gray below the zone of oxidation. The calcareous material is present within 3 to 5 feet (0.9 to 1.5 meters) of the top and in many places up to the base of the overlapping loess.

The main deposit of loess, which is so generally present on the pre-Wisconsin drift south and east of southeastern South Dakota and in the Driftless Area, is now generally considered an eolian deposit. The included fossils appear to indicate climatic conditions not greatly different from those of Recent time. The fact that a goodly thickness extends under the Wisconsin drift in both Iowa and Illinois has led to its reference to the Peorian interglacial stage. There are thicknesses of 50 to 100 feet (15 to 30 meters) in many places in the bluffs bordering the Missouri and Mississippi Rivers and some of the tributary streams, but the deposit thins rapidly on the interstream areas with increasing distance from the alluvial flats, which appear, in large measure, to have been the local sources of supply for the dust.

Loess mantles the slopes and uplands in the Driftless Area; it borders the Ohio River eastward to West Virginia, and there is a broad belt adjoining the Mississippi lowland on the east in Kentucky, Tennessee, and Mississippi. It is present in southeastern Missouri and caps Crowleys Ridge, Arkansas, and a narrow belt borders the Black River lowland on the west about half the distance southwestward to Little Rock, Arkansas. The broad belt of loess extending westward from northeastern Kansas and eastern Nebraska to Colorado is not here under consideration.

WISCONSIN STAGE OF GLACIATION

The Wisconsin drift (fig. 1) is the product of the last stage of glaciation. On this drift most if not all of the various known types of glacial, glaciofluvial, and glaciolacustrine features and deposits have been developed somewhere, though not everywhere, within the area which it covers, and they have suffered relatively little modification either by weathering or by erosion. These features on the Wisconsin drift are particularly well developed in southeastern Wisconsin. Eolian deposits are represented locally by sand dunes of both Pleistocene and Recent ages and much of the marginal part of the early Wisconsin drift in Illinois is thinly mantled with loess.

At the earliest substage the Labrador ice spread southwestward across the Great Lakes region; it covered much of Ohio and Indiana and extended as far southwest as central Illinois. (See fig. 1.) A succession of notable moraines marks the oscillations of the ice front when receding from this limit (29, 30, 33, 37).[4]

It is not certain that there was a corresponding early Wisconsin invasion of the area between the Missouri and Mississippi Rivers from the Keewatin region west of Hudson Bay. Even the Iowan drift has generally been considered somewhat too old to be evidence of such an early Wisconsin ice advance. Some drift outside the late Wisconsin moraine in northwestern North Dakota and northeastern Montana is probably of either early Wisconsin or middle Wisconsin age (4, 5).

Leverett (36) has concluded, from the axial trend of the glacial lobes in Wisconsin, Illinois, and Michigan, that by middle Wisconsin time that part of the great Laurentide ice field in and near the Patricia district, west of James Bay, was gaining in relative importance as a center of dispersion. At the outer limit of this middle Wisconsin ice were formed the outer moraine of the Green Bay lobe and its correlatives in Wisconsin, the outer part of the Valparaiso morainic system of the Lake Michigan lobe in Illinois, the Kalamazoo moraine in Indiana and Michigan, and the Tekonsha moraine of the Saginaw lobe in southern Michigan. Farther south and east the Mississinawa

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[4] During some parts, at least, of the Wisconsin glacial stage New England, most of New York, and the adjacent parts of New Jersey and Pennsylvania were covered with ice from the Labrador peninsula.

morainic system and its correlatives mark the extent of the combined Maumee, Miami, Scioto, and Grand River lobes, which formed the Erie lobe of the Labrador ice field. Within these borders also is a series of recessional moraines. It is not known to what extent the ice fronts receded and readvanced to form these several moraines.

There is evidence of distinct readvance to the Port Huron morainic system and its correlatives at the late Wisconsin substage. This ice reached the south end of the Lake Huron basin and extended south of Milwaukee in the Lake Michigan basin (37). In eastern Wisconsin it deposited a reddish till on top of the earlier grayish Wisconsin till (3). The ice filled the Lake Superior basin but did not extend so far beyond the limits of that basin as in middle Wisconsin time.

From the relations of the moraines and outwash deposits in Wisconsin and Minnesota, Leverett (36) concludes that it was at this late Wisconsin substage that the accumulation of ice centering in the Keewatin region, west of Hudson Bay, became so great that it traversed the valleys of the Red and Minnesota Rivers and extended thence southward into north-central Iowa as the Des Moines lobe. (See fig. 1.) This lobe overran part of the Iowan drift and some of the Peorian loess. (See pl. 1, *B*.)

In eastern and northeastern Minnesota gray drift deposited by this late Wisconsin ice overlaps red drift deposited by the Patrician ice of the middle Wisconsin substage, showing that the front of the Patrician ice had receded into Canada before the Keewatin ice reached the limits of its advance at this substage. Still later, however, as shown by Tyrrell (52), there was a readvance of the Patrician ice over part of the area in Ontario from which the Keewatin ice front had finally receded.

So far as is now known, the Dakota lobe of the Wisconsin stage reached its greatest southerly extent at this late Wisconsin substage. Its limits are marked by what has been known as the Altamont moraine. At the west side of the lobe this moraine lies in part on the Coteau du Missouri, northeast of the Missouri River, and it enters Montana only in the extreme northeastern part of the State. It extends thence northwestward into Alberta, Canada.

Leverett [5] suggests that the final melting back of the ice border probably proceeded both northward and eastward in such a way as to separate the ice mass into a western (Keewatin) and an eastern (Labrador) ice sheet, each with its own radiating movements.

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[5] Unpublished manuscript.

GLACIAL LAKES

The recession of the Wisconsin ice fronts northward and northeastward across the divides caused ponding of water in the several basins up to the levels of spillways leading to tributaries of the Mississippi River. The outlet of glacial Lake Agassiz, in the basin of the Red River, led down the Minnesota River Valley; glacial Lake Duluth, in the Superior Basin, had an outlet southward by the St. Croix Valley; glacial Lake Chicago, in the Lake Michigan Basin, discharged to the Illinois River Valley; and glacial Lake Maumee found a spillway southwestward from the Erie Basin to the Wabash River. Later there were outlets eastward to the Hudson River Valley and the Ottawa River Valley when glacial Lakes Algonquin and Iroquois and the Nipissing Great Lakes occupied part of the basins. Deepening of outlets, opening of new ones, shifting of the ice fronts, and tilting of the basins, as indicated by the abandoned shore lines, differentiated stages of a complicated glaciolacustrine and postglacial lake history covering the Great Lakes basins (1, 2, 3, 17, 30, 33, 37, 54). The abandoned shore lines are horizontal in the southern half of the Lake Michigan Basin, but in the northern half they rise gradually in a north-northeasterly direction. Among the indications of a low-water stage of glacial Lake Chicago is a buried "forest bed" near Manitowoc, Wisconsin. There were also many other glacial lakes, some of them of considerable size.

DRIFTLESS AREA

An area of more than 10,000 square miles (2,590,000 hectares), embracing southwestern Wisconsin and small parts of the adjacent States, although entirely surrounded by glacial drift, shows no evidence of ever having been glaciated. (See fig. 1.) Its protection from ice invasion appears to have been due not to any greater elevation but to the general southerly trend of the axial movements of the ice lobes on the west, to limitations on the amount of ice available, and to diversion of axial flow by the elongated basins of Lakes Superior and Michigan on the north and east. Some fluvioglacial gravel was swept down the valleys, and bergs floating on glacial Lake Wisconsin and other ponded water dropped some erratic boulders on some of the lower slopes and lowlands. The slopes and uplands of the much dissected surface of the Driftless Area are generally mantled with loess.

GLACIAL DRIFT AND LOESS

A, Near Delmar Junction, northwest of Clinton, Iowa: *a*, Nebraskan till; *b*, Aftonian gravel; *c*, Kansan till; *d*, Peorian loess. *B*, Near Rhodes, northeast of Des Moines, Iowa: *a*, Kansan till; *b*, Kansan gumbotil; *c*, Peorian loess; *d*, late Wisconsin till. Photographs by William C. Alden.


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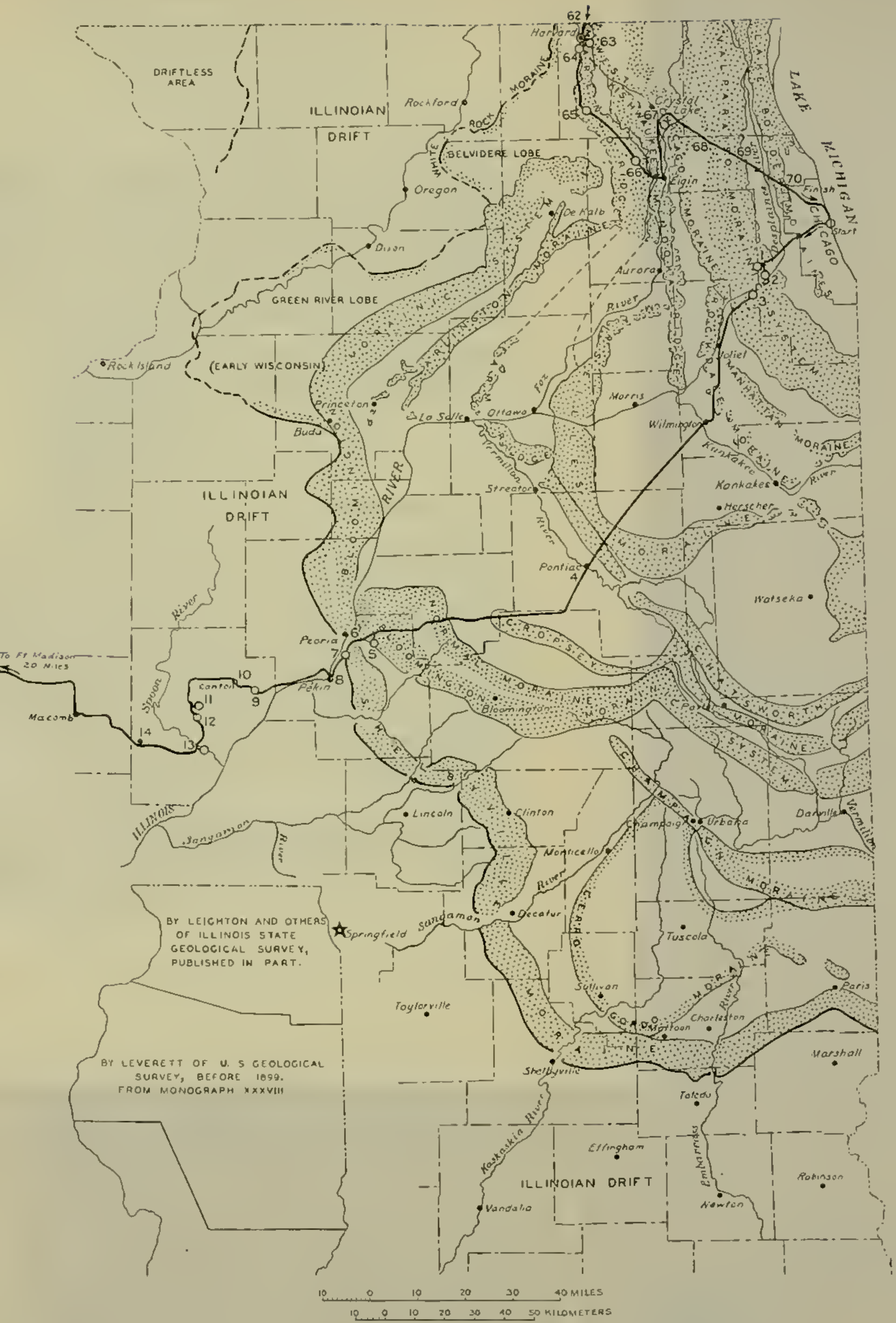

PRELIMINARY MAP OF GLACIAL MORAINES OF NORTHEASTERN ILLINOIS

Subject to revision according to studies in progress. Heavy line shows itinerary. Numbers indicate localities mentioned in text.

ANNOTATED GUIDE ACROSS ILLINOIS

By M. M. Leighton and G. E. Ekblaw

CHICAGO TO CANTON, ILLINOIS

INTRODUCTION

The excursion starts from Chicago (population 3,376,438) and passes through Joliet, Pontiac, Chenoa, East Peoria, and Pekin to Canton, Illinois. (See pl. 2.) On this section of the itinerary are seen features representing practically the entire succession of geologic events of the Wisconsin stage of glaciation in Illinois. The route crosses the plain of glacial Lake Chicago and some of its beaches; broad, flat rock-bottomed valleys through which its water escaped to the Illinois River; and nearly all the Wisconsin moraines in Illinois, which are, in succession from youngest to oldest:

Lake Border system of three moraines (not seen until return to Chicago).
Valparaiso morainic system, including Arlington Heights moraine on its inner border and West Chicago moraine on its outer border.
Manhattan and Rockdale moraines (closely related).
Marseilles morainic system.
Chatsworth morainic system.
Cropsey system of three moraines.
Normal moraine.
Bloomington moraine.
Champaign moraine (not seen on trip).
Cerro Gordo moraine (not seen as distinct from Shelbyville on this route).
Shelbyville moraine.

The moraines of central Illinois are generally smoother and much less gravelly than those in Wisconsin, lacking the ice-block basins and the kames and eskers of the territory farther north. The ground moraines are strikingly flat over large areas and gently undulatory elsewhere, with very few swamps and bogs. Loess mantles the earlier moraines, but there is little if any on the Marseilles and later moraines. The depth of leaching of the drifts, as controlled by permeability and topographic position, varies considerably. On the Valparaiso moraine it averages about 2½ to 3 feet (0.75 to 0.9 meter); the Marseilles till is very compact and shows no deeper leaching. Outside this moraine the loess is leached for 5 to 7 feet (1.5 to 2 meters), but near its sources of supply it is so thick that the underlying till is not leached.

Features of special interest to be seen are the plain developed by the Kankakee Torrent behind the Marseilles moraine and the sandbars in its channel, the Pleistocene type section on Farm Creek, the valley-train terraces on the Illinois River, and the late Illinoian drift plain.

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LAKE CHICAGO PLAIN

Glacial Lake Chicago lay between the Valparaiso moraine and the retreating margin of the Wisconsin glacier in the Lake Michigan Basin. Several lake levels have been recognized and named (1, 8, 10, 12, 29) as follows in order of age:

Westchester(?), altitude 655–670 feet (200–204 meters).
Glenwood, 635–640 feet (193–195 meters).
Bowmanville (low water), 590 feet (180 meters).
Calumet, 615–620 feet (187–189 meters).
Tolleston, 600–605 feet (183–184 meters).
Sag (low water), 590 feet (180 meters).
Hammond, 600 feet (183 meters).
North Bay (low water), 580 feet (177 meters).
Englewood, 592 feet (180 meters).
Present Lake Michigan, 580 feet (177 meters).

The levels of the lake were controlled by the altitude of the outlets at the respective stages. The lake plain, which is largely occupied by the city of Chicago and its suburbs, is remarkably flat except for local elevations of till and rock. In many places in the city the beaches have been destroyed by the work of man. The plain is developed mainly on glacial drift overlying the eroded surface of Niagara dolomite (Silurian), which has a maximum relief of about 300 feet (91 meters). At some places the rock lies so near the present surface that it can be quarried. At many places the till or lacustrine clays are used for brick and tile.

The Lake Chicago plain is traversed for nearly 14 miles (22 kilometers).

6 (9.6).[6] Margin of Tolleston stage, but shore line not perceptible here.

11 (18). The Des Plaines River is here cut in the plain of the Calumet stage. On the far side of the river is a bar built at the combined mouth of the Des Plaines River and Salt Creek during this stage. About 1 mile (1.6 kilometers) from the river the route descends the bar and approaches the Tolleston beach.

13 (21). Beginning ascent of slope at which were the margins of both the Calumet and Glenwood stages. Quarry of Consumers Co., on left (south), is in Niagara dolomite (Silurian), which probably controlled the extent of the lake at this point. Dolese & Shepard quarry is about half a mile (0.8 kilometer) farther on the left.

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[6] Approximate distances from starting point in Chicago, near the mouth of the Chicago River, are indicated in miles, with kilometers in parentheses.

VALPARAISO MORAINIC SYSTEM [7]

The Valparaiso morainic system is 20 to 30 miles (32 to 48 kilometers) wide and is composed of more or less distinct ridges. North of the Des Plaines River its outer member is the well-defined West Chicago moraine. Its inner member, west of Chicago, is the well-defined Arlington Heights moraine, which south of Chicago is known as the Tinley Park moraine. Recent studies by MacClintock and Bretz indicate that this moraine represents a readvance after a considerable retreat of the glacier front and should therefore be considered as distinct from the Valparaiso system. The outlets of Lake Chicago cut across this morainic system.

16 (26). Top of Arlington Heights moraine.

17 (27). Flag Creek Valley [1],[8] between the Arlington Heights moraine and the main Valparaiso moraine, served as the outlet for the Westchester stage of Lake Chicago. Route goes south.

20 (32). Deposits at gravel pit north of Des Plaines River [2] consist of 16 feet (4.8 meters) of brownish-gray calcareous till underlain by 50 feet (15 meters) of coarse gravel, cemented in upper part, beneath which is blue "clay" (probably till). This gravel pit is situated at the north side of the Des Plaines outlet of Lake Chicago. South of this place the route crosses this valley to Willow Springs. The succession of brown till, gravel, and blue till is exposed in road cuts along the slope, and in the bottom of the valley are many boulders, either ice-rafted or residual from eroded drift.

21 (34). For 4 miles (6.4 kilometers) the route follows the southeast side of the Des Plaines outlet of Lake Chicago. The slope on the left is composed of glacial drift, which has slumped wherever road cuts have been made. Through the trees on the right may be seen the spoil banks of Niagara dolomite (Silurian) excavated from the Sanitary and Ship Canal, part of the Lakes to Gulf waterway.

25 (41). Sag outlet of Lake Chicago, apparently contemporaneous with the main Des Plaines outlet. The floor of the valley is Niagara dolomite (Silurian), which was formerly quarried extensively. Striae on the bedrock indicate that the valley had been eroded to its

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[7] See topographic maps of Riverside, Des Plaines, Hinsdale, Sag Bridge, Wheaton, and Joliet quadrangles, Illinois.

[8] Figures in brackets refer to corresponding numbers showing locations on Plate 2.

present depth before the formation of the Valparaiso moraine and that the Lake Chicago waters removed only whatever drift had been left in the valley. The same dolomite is exposed in the south wall of the valley, beyond which for 9 miles (14 kilometers) the route goes southwest across the Valparaiso moraine.

35 (56). Lockport (altitude 602 feet, or 183 meters). From this place south through Joliet the route is not far west of the outer margin of the Valparaiso moraine, which forms a high slope on the east side of the Des Plaines River.

The Manhattan and Rockdale moraines (pl. 2) are low but distinct ridges with gentle slopes and broad undulations. The Manhattan moraine is narrow, but the Rockdale moraine is about 4 miles (6.4 kilometers) wide. They appear to be closely related and are distinct from the later Valparaiso system (16).

37 (59). Joliet (population 42,993; altitude of river surface 510 to 540 feet, or 155 to 165 meters).

42 (68). Inner margin of Manhattan moraine. National Stone Co.'s quarry in Niagara dolomite (Silurian) on right.

49 (79). Back slope of Rockdale moraine.

53 (86). Outer slope of Rockdale moraine.

KANKAKEE TORRENT FEATURES

The great volume of glacial water concentrated at the junctions of the Lake Michigan, Saginaw, and Erie lobes when the ice front was receding from the Valparaiso moraine was discharged through the Kankakee Valley, creating a torrential river, known to geologists as the Kankakee Torrent, 10 miles (16 kilometers) wide at some places (13). The torrent was checked by the narrow Illinois River gap in the Marseilles moraine, so that it formed an extended body of water in the Morris Basin (11),[9] reaching eastward as far as the Rockdale moraine. Where it was strongest the torrent washed away most of the drift, exposed bedrock over extensive areas in the Kankakee Valley and Morris Basin, eroded away a considerable part of the Minooka moraine, carried away fine material, built up coarser material, together with fragments of the local bedrock, into bars and beaches, and left boulders strewn over the plains. Along the margins there was little erosion, and silt was deposited.

From the Rockdale moraine the route crosses the Kankakee plain for nearly 30 miles (48 kilometers). Numerous bars of

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[9] See topographic maps of Wilmington, Morris, and Herscher quadrangles, Illinois.

sand, in places reworked by wind, and alternating swampy flats cover several miles southwest of the Kankakee River, which is crossed at Wilmington (altitude 540 feet, or 165 meters). The sandy, acidic character of the soil is indicated by the luxuriant growth of sorrel and by the absence of farms. The silt-mantled tracts are very favorable for agriculture. The bedrock is of Pennsylvanian age, and coal mining is a local industry. Former shaft mines have been abandoned, and several small towns are decadent. Recently a large strip mine has been opened and is operating where the torrential deposits are thin.

69 (111). Mazon River, along the lower course of which near Morris are well-known beds of fossiliferous concretions.
82 (132). Margin of Kankakee Torrent basin and inner margin of Marseilles moraine.

MARSEILLES MORAINE

The Marseilles moraine is a belt nearly 12 miles (19 kilometers) wide marked by broad, deep swells and swales with a relief of about 40 feet (12 meters). It consists of two ridges, separated by an intermorainic area which, in the vicinity of Odell, was occupied by a glacial lake. Broad mounds in the old lake bed are composed of laminated clays, which are believed to have been deposited in crevasses in a mass of stagnant or semistagnant ice.

88 (142). Odell lake bed.
93 (150). Outer margin of Marseilles moraine.

CHATSWORTH (FARM RIDGE) MORAINE

It has recently been determined by Ekblaw that the Chatsworth moraine, in Livingston County (29), is identical with the Farm Ridge moraine, in La Salle County, both named by Leverett. This moraine is almost overridden by the Marseilles moraine in northern Livingston County; the relations to the north and south are shown on Plate 2. Where the route crosses them, northeast of Pontiac, there is only about 1 mile (1.6 kilometers) of ground moraine between the two terminal moraines. The Chatsworth moraine is about 4 miles (6.4 kilometers) wide and consists of two distinct ridges. Considerable outwash was deposited along nearly every drainage line leading away from or along the moraine.

98 (157). Outer margin of Chatsworth moraine.
99 (160). Pontiac [4] (population 8,272; altitude 647 feet, or 197 meters) is on the Vermilion River.
105 (169). Small pits in outwash sand and gravel.

CROPSEY MORAINIC SYSTEM

The Cropsey Ridge (29) has recently been determined to be a comprehensive morainic system comprising in central Illinois three separate morainic ridges, each 30 to 40 feet (9 to 12 meters) high and each having two or three crests. Farther east in Illinois the system is combined into one broad belt, and in central-northern Illinois the component ridges lie close together.

106 (171). Inner slope of innermost ridge.
115 (186). Top of middle ridge. Crest of inner ridge appears 3 miles (4.8 kilometers) to right (north).
128 (206). Approximate outer margin of Cropsey moraine.

NORMAL MORAINE

The Normal moraine is about 8 miles (13 kilometers) wide. The highest part is near the outer margin and stands about 80 feet (24 meters) higher than the drift plain beyond. Behind the crest the surface lowers through a succession of recessional "steps," which appear like secondary ridges when approached from the inner side. Considerable outwash is associated with the Normal moraine. The total thickness of Wisconsin drift behind the Normal moraine is as little as 40 feet (12 meters), as shown by the exposure of the underlying Illinoian gumbotil in places.

131 (211). Road cut exposes Illinoian till and gumbotil beneath younger Pleistocene deposits.
139 (224). Top of Normal moraine. A subglacial channel on the right interrupts the continuity of the moraine.

BLOOMINGTON MORAINE

The Bloomington moraine is more than 12 miles (19 kilometers) wide. Like the Normal moraine, it has a crest near its outer margin, which is more than 150 feet (46 meters) above the outlying plain and decreases in height behind the crest through a succession of recessional "steps." There is an outwash apron along the foot of the moraine and outwash terrace remnants in all the valleys. Along the Illinois River Valley, particularly on the east side, both the outwash and the moraine are covered with loess 1 to 10 feet (0.3 to 3 meters) or more in thickness.

141 (226). Back slope of moraine.
154 (247). Outer margin of moraine.

About 4 miles (6.4 kilometers) west of the village of Washington, 152 miles (245 kilometers) from Chicago,[10] the route turns from the paved highway to a secondary road by which a notable Pleistocene section on Farm Creek may be approached (26, 27, 29). This section is in the south bank of Farm Creek and exposes the following beds:

Deposits on Farm Creek, 7 miles east of Peoria, Illinois

	Feet	Meters
Post-Bloomington substage of Wisconsin stage:		
Soil, loessial, light gray	1½	0.45
Loess, leached, brown	3½	1
Loess, calcareous, yellow	2½	.75
Bloomington substage: Outwash gravel	0–4	0–1.2
Shelbyville substage: Till, calcareous	32	9.7
Peorian stage: Loess, calcareous, fossiliferous; soil at top at west end but no profile of weathering	6	1.8
Sangamon stage:		
Old soil, loessial, noncalcareous	1½	.45
Loesslike silt, leached above, slightly calcareous in places in lower part	7–8	2.1–2.4
Weathering and erosion of underlying deposits.		
Illinoian stage:		
Mesotil,[11] chocolate-brown	4	1.2
Till, very calcareous	41	2.5

SHELBYVILLE MORAINE

The drift composing the Shelbyville moraine is the earliest known Wisconsin drift in Illinois, and east of the Illinois River and for a short distance west of the river the Shelbyville is the outer terminal moraine of the Wisconsin glaciation. This drift is covered by loess so thick near the Illinois River Valley that neither the lower part of the loess nor the underlying till has been leached. This is in contrast with the weathering of the Illinoian drift below the loess cover. Outwash of Shelbyville age is also mantled thickly with loess, calcareous in the lower part, and the gravel is unleached. The route returns to the highway and continues west.

159 (255). Drift overlying Pennsylvanian shale is seen on the left (east) side of the road.

160 (256). Near top of deep road cut, unleached till of the Shelbyville moraine is overlain by loess, leached at the top but calcareous and fossiliferous in the lower part.

161 (258). Shelbyville outwash plain, in front of the moraine.

[10] See topographic maps of Mackinaw and Peoria quandrangles, Illinois.

[11] Mesotil is till from which part of the colloidal material has been removed by weathering (28).

161 (260). At a road cut [6] the following deposits are exposed near the Illinois River:

	Feet	Meters
Wisconsin loess, leached brown	7	2
Wisconsin loess, calcareous, fossiliferous, gray and brown	2	.6
Outwash gravel	10	3

ILLINOIS RIVER VALLEY

The Illinois Valley below the bend at Hennepin, southeast of Princeton, is believed to be part of the preglacial valley of the Mississippi River. Its earlier history is obscure, but the presence of Illinoian till and gravel in it indicates that in Illinoian time it had nearly its present configuration. At the Wisconsin stage outwash from the ice front when it stood at the Shelbyville and Bloomington moraines filled the valley at Peoria (population 104,969) to a maximum height of about 650 feet (198 meters) above sea level. From this height near the Bloomington moraine the surface of the outwash lowers downstream. On a remnant of this early Wisconsin terrace west of the river is built the higher part of the city of Peoria. When the ice front retreated, water was impounded by the valley train and the morainal dam up to a level of 600 feet (183 meters) above sea level, forming Lake Illinois, which extended far up the valley as the ice front melted back. In bays and extending out into the lake coarse, angular outwash gravel, containing numerous till balls, derived from successive retreating and readvancing phases of the glacier, was deposited as deltas. The dam persisted until shortly after the retreat of the glacier from the Marseilles moraine, when the water was augmented by the Fox River torrent, and the valley train was greatly eroded. At the middle Wisconsin substage, when the ice front stood at the Valparaiso moraine, outwash formed a lower valley train, and later this was largely removed by the Kankakee Torrent and the outflow from Lake Chicago. As a result there are three terraces below the highest west of the river at Peoria—the one on which the greater part of the city is built, at an altitude of about 520 feet (158 meters), the next at about 460 feet (140 meters), and the lowest, the present flood plain, at about 440 feet (134 meters). The sand from the outwash has been reworked to some extent by the wind, and dunes are common, both on the terraces and on the margin of the upland to the east.

The finer material of the outwash also probably served as a source for much of the local loess of Wisconsin age. The walls of the valley below Peoria are about 170 feet (52 meters) high, above the valley flat, and are composed of Illinoian drift overlying Pennsylvanian strata.

163 (262). McGrath Sand & Gravel Co.'s pit is situated on Wisconsin outwash terrace, north of Pekin.
166 (267). Pekin [8] (population 16,129); cross the Illinois River (altitude 440 feet, or 134 meters) and flood plain and go southwest.
171 (275). Local gravel pit in middle terrace on north side of the valley.
173 (278). Large gravel plant half a mile (0.8 kilometer) to left (south) is situated on lowest terrace.
181 (291). Local coal mines in north wall of Illinois Valley.

ILLINOIAN DRIFT PLAIN [12]

Most of Illinois outside the limits of the Wisconsin drift is covered by Illinoian drift. (See fig. 1.) Recent studies have determined that a continuous moraine, lobate in outline, very prominent at some places and less so at others, divides the Illinoian into earlier and later substages. Leverett (29, pp. 74–76) applied the name Buffalo Hart to a prominent portion of the moraine, and that name is being used for the whole moraine as now mapped. The later Illinoian drift plain east of this moraine is nearly flat where not dissected by erosion, but more or less undulatory, in places with a relief of 30 to 40 feet (9 to 12 meters), generally only 10 to 20 feet (3 to 6 meters); the earlier Illinoian drift plain outside the moraine is also nearly flat over wide areas. In western Illinois the younger Illinoian drift differs also from the older in that more gravel is associated with it. The interval of time between the deposition of the earlier and that of the later Illinoian drift was not sufficient to make any appreciable difference in the amount of weathering that they have undergone. Both are mantled by loess deposits of at least two stages—late Sangamon and Wisconsin (including the Peorian, which the writers regard as also of Wisconsin age). The Sangamon loess overlies the soil and gumbotil developed on the Illinoian till and is itself leached and weathered so deeply that only where it is thickest is the lower part calcareous. The Wisconsin loess (including the Peorian) overlies the soil developed on the Sangamon loess. At some places the Peorian phase can be distinguished by texture or other physical features from the overlying loess, but the two are calcareous up to the leached zone of the present soil profile. The Illinoian drift overlies Kansan and Nebraskan drifts and the associated interglacial zones, which are exposed at several places in western and southern Illinois.

[12] See topographic maps of Glasford, Canton, Havana, Vermont, Good Hope, and La Harpe quadrangles, Illinois.

183 (293). Cut where road ascends from Illinois Valley to Illinoian upland [9] exposes the following beds:

Deposits 7 miles (11 kilometers) east of Canton, Illinois

	Feet	Meters
Soil	1	0.3
Wisconsin stage:		
Loess, leached, brown	5	1.5
Loess, calcareous, fossiliferous, gray and brown	4	1.2
Peorian stage: Loess, slightly calcareous, gray and brown	7	2.1
Late Sangamon stage: Loess, leached, reddish brown	6	1.8

187 (301). Gently undulatory plain of later Illinoian drift.

190 (309). City limits of Canton [10] (population 11,718; altitude 655 feet, or 200 meters).

CANTON, ILLINOIS, TO FORT MADISON, IOWA

On this section of the excursion (pl. 2, fig. 2) both the later and earlier Illinoian drift plains and the Buffalo Hart moraine are traversed, so that the contrast in topography may be noted. Mines exploiting the coal beds in the Pennsylvanian strata are seen in many places. The route leads west from Canton.[13]

5 (8). Local coal mines in sides of Putt Creek Valley; their high level shows how thin the glacial drift is.

7 (11). Fiatt (altitude 678 feet, or 207 meters); strip mine south of town. Go south past the village of Cuba (altitude 686 feet, or 209 meters).

15 (24). Side road on left (east) [11] shows the following section:

Deposits exposed at United Electric Co.'s strip mine

	Feet	Mete
Soil, light gray	1	0.3
Wisconsin stage (including Peorian stage):		
Loess, leached, brown	6	1.8
Loess, calcareous	3	.9
Sangamon stage:		
Soil	1	.3
Loess, leached, reddish brown	3	.9
Weathering of underlying deposits.		
Illinoian stage:		
Gumbotil	4	1.2
Till.		

17 (27). Road cut [12] shows same succession of strata, but secondary calcite has penetrated Sangamon loess and Illinoian gumbotil. A considerable thickness of fresh Illinoian till is exposed lower in the cut.

17 (28). Stream bluff across Big Creek Valley on right (south) exposes Pennsylvanian shales and sandstones.

[13] Approximate distance from Canton indicated in miles, with kilometers in parentheses.

21 (34). Lewistown (population 2,249; altitude 596 feet, or 182 meters).

25 (41). Follow secondary road on left (east) [13] across terrace in Spoon River Valley at altitude of 500 feet (152 meters) for half a mile (0.8 kilometer). The terrace is about 40 feet (12 meters) above the valley flat and is composed of fossiliferous reddish silt which was carried from the Illinois Valley when Bloomington outwash in that valley dammed the Spoon River. A road cut in the margin of the terrace exposes these beds, representing the early Wisconsin stage:

Deposits in Spoon River Valley

	Feet	Meters
Silt, leached, brown	2	0.6
Silt, calcareous, very fossiliferous, gray-brown	8	2.4
Silt, reddish, calcareous	30	9

26 (42). Cross the Spoon River (altitude 440 feet, or 134 meters) and go west.

38 (61). Back slope of Buffalo Hart moraine.

40 (64). Central square of Table Grove [14] (altitude 720 feet, or 219 meters) is situated on crest of Buffalo Hart moraine. Go northwest.

43 (69). Front slope of Buffalo Hart moraine, looking out over the flat plain of earlier Illinoian drift.

56 (91). Macomb (population 8,509; altitude 702 feet, or 214 meters). Go north. Farmsteads 7 miles (11 kilometers) away can be seen.

60 (97). Ridges and alternating longitudinal depressions [15] trending east-west are not undulations in drift plain but erosional irregularities of bedrock surface thinly mantled with drift. Go north through Good Hope, then west.

94 (151). From this point the route follows the south bank of the Mississippi River. In the river are stumps of trees killed by water impounded behind the Keokuk Dam, 20 miles (32 kilometers) downstream. The bluffs on the left are composed of the Keokuk and Warsaw formations (Mississippian) mantled by drift and loess.

102 (164). Abandoned gravel pit [16] in outwash terrace of undetermined age. Gravel lies on bedrock, which is exposed in road.

103 (166). Cross bridge over the Mississippi River (altitude 502-522 feet, or 153–159 meters) to Fort Madison, Iowa.

ANNOTATED GUIDE OF EASTERN IOWA

By George F. Kay

FORT MADISON TO IOWA CITY, IOWA

[See figs. 1 and 2]

North of Fort Madison [17] [14] (population 13,799; altitude 522 feet, or 159 meters) an exposure a few feet below the upland at the head of a ravine about 100 yards (91 meters) north of the edge of the bluff (23, p. 100) gives a section as follows:

Deposits near Fort Madison, Iowa

	Feet	Meters
Peorian interglacial stage: Loess, grayish yellow to buff-yellow, leached	7	2
Sangamon interglacial stage: Weathering and erosion of underlying deposits.		
Illinoian glacial stage:		
Gumbotil, drab to chocolate-brown or dark color, starchlike fracture, few pebbles, leached; grades into underlying till	4½	1.3
Glacial till, oxidized, leached	6	1.8
Glacial till, oxidized, unleached to base of gulch	15	4.5

NEBRASKAN, KANSAN, AND ILLINOIAN TILLS

The relations of the three oldest tills, the Nebraskan, Kansan, and Illinoian, are seen in cuts on the Chicago, Burlington & Quincy Railroad and in the slopes of valleys about 1 mile (1.6 kilometers) north of the city limits of Fort Madison (22, pp. 149–151). The upper part of a near-by railroad cut, where the upland is but a few feet above the top of the exposure and is underlain by loess, shows the following beds:

Deposits in railroad cut north of Fort Madison, Iowa

	Feet	Meter
Illinoian glacial stage:		
Gumbotil, gray to ashen on dry surface; dark gray mottled with brown on damp surface; starchy fracture with small polyhedral blocks; leached and contains siliceous pebbles, also a few secondary calcium carbonate concretions	4½	1.3
Till, oxidized and leached; brownish buff grading upward into gray; some pebbles and boulders; no concretions	5½	1.6
Till, oxidized and unleached; buff to brown with very few patches of gray; jointed; breaks into small irregular fragments; some larger fragments and pebbles in this zone	1	.3
Yarmouth interglacial stage: Weathering and erosion of underlying deposits.		

[14] Numbers in brackets refer to localities shown on Figure 2.

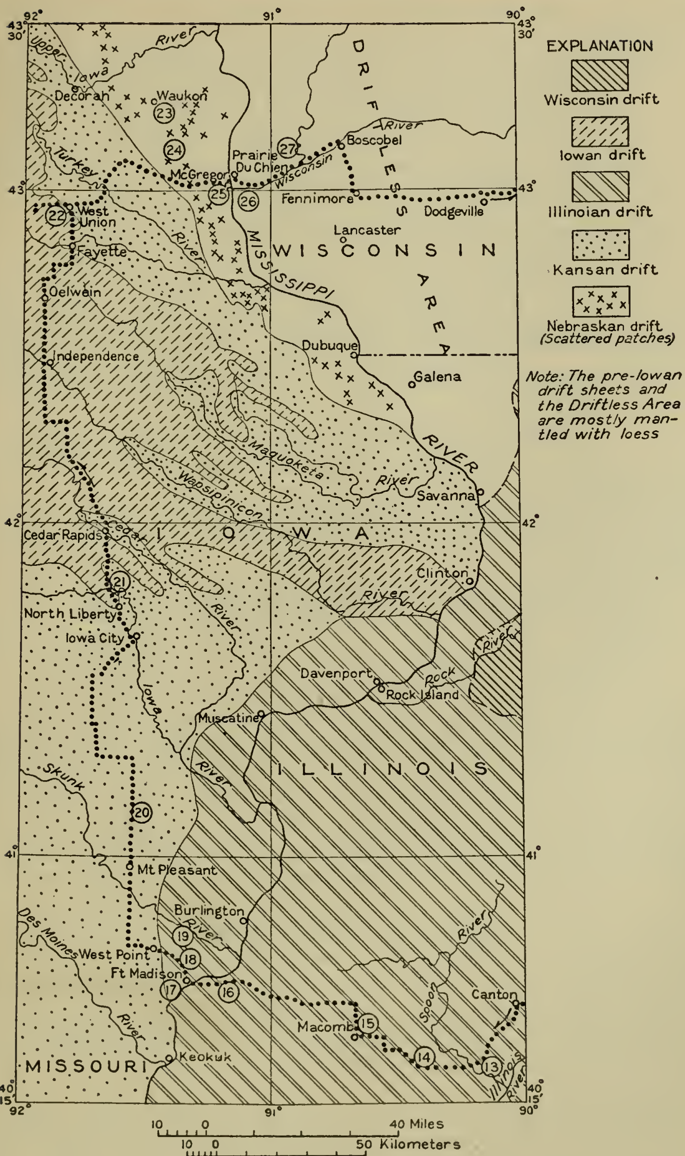

FIGURE 2.—Map of glacial deposits in adjacent parts of Iowa, Wisconsin, and Illinois. (Mainly by Iowa Geological Survey.) Dotted line shows itinerary. Figures in circles show localities mentioned in text

	Feet	Meters
Kansan glacial stage:		
Gumbotil, dark gray to drab in upper part, of lighter color lower; some patches of brown; starchy fracture; closely spaced joints in upper part, more widely spaced in lower, but the resulting fragments in each part are irregular and a few millimeters in diameter; leached; a few secondary concretions of calcium carbonate; calcareous zone around concretions usually very narrow	8½	2.6
Till, oxidized and leached; brownish-buff clay, with gray patches	5	1.5
Till, oxidized and unleached; yellowish brown; jointed; has calcareous concretions, especially in upper part	12	3.6

About one-fourth mile (0.4 kilometer) down the gully from the section just described there is, east of the railroad track [18], an exposure about 60 feet (18 meters) in depth on the face of a truncated spur on the valley wall. Here the following section is exposed:

Deposits in valley wall north of Fort Madison, Iowa

	Feet	Meters
Peorian interglacial stage: Loess, buff, leached; upper surface below the upland level	3	0.9
Illinoian glacial stage: Till, oxidized, unleached	8	2.4
Yarmouth interglacial stage: Weathering and erosion of underlying deposits.		
Kansan glacial stage:		
Gumbotil; a distinct dark zone extending across the face of the exposure; thoroughly leached clay with a few siliceous pebbles	12	3.6
Till, oxidized and unleached except in upper part; calcareous concretions to base of cut	37	11

About 400 yards (366 meters) still farther down the valley is exposed the transition zone between the oxidized and unleached Kansan till and the unoxidized and unleached Kansan till, which is here about 15 feet (4.5 meters) thick. Near the base of the unleached and unoxidized Kansan till there is much carbonaceous material, beneath which is a zone a few feet thick of leached sand and silt, the upper part of which is very carbonaceous. Included in the sand and silt are sticks and logs, some of which have a diameter of nearly 6 inches (15 centimeters). The leached sand and silt, which are interpreted to be of Aftonian interglacial age, are in marked contrast to the overlying unleached carbonaceous Kansan till. Beneath the Aftonian leached sand and silt is unoxidized and unleached till, which is interpreted as Nebraskan till. The Aftonian horizon is 600 feet (183meters) above sea level.

Less than 5 miles (8 kilometers) north of these sections, about 1½ miles (2.4 kilometers) south of Denmark [19], is an interesting exposure in the slopes along Lost Creek (22, p. 149), where the section is as follows:

Deposits south of Denmark, Iowa

	Feet	Meters
Peorian interglacial stage: Loess, light buff	5½	1.7
Yarmouth interglacial stage: Pebble band a few inches thick; a concentration of the larger material of the drift, due to erosion; also weathering of underlying deposits.		
Kansan glacial stage:		
Till, oxidized brownish and yellowish, leached	5	1.5
Till, oxidized and unleached; upper part has a zone of concretions which marks the base of the leached till; sand masses included in the till; oxidized till grades downward into unoxidized and unleached till	22	6.7
Till, unoxidized and unleached, very dark when moist, light gray on a dry surface; hard, tough, difficult to cut. Many joint planes along which oxidation has taken place	20	6
Aftonian interglacial stage: Erosion and weathering of underlying deposits.		
Nebraskan glacial stage: Till, oxidized, leached, distinctly reddish on surface but greenish-gray when freshly cut. The color is in striking contrast with that of the unoxidized and unleached till above; breaks into small irregular fragments; compact and uniform throughout, except for being more sandy near base	11	3.3

The Nebraskan in this section is interpreted to have been Nebraskan gumbotil from which much of the colloidal material was removed while the Nebraskan gumbotil plain was being eroded and before the advance of the Kansan ice sheet; the surface of the leached Nebraskan till is about 600 feet (183 meters) above sea level, the same altitude as that of the Aftonian leached sand and gravel farther south in the same township [18].

In this region the thickness of the Kansan drift is approximately 60 feet (18 meters), of the Illinoian drift 20 feet (6 meters), with less than 20 feet (6 meters) of loess. About 1 mile (1.6 kilometers) north of Denmark [19], which is 9 miles (14 kilometers) north of Fort Madison, there is a section in which sand and gravel at the same topographic position as the Kansan gumbotil of this area are leached to a depth of about 30 feet (9 meters). This weathering was accomplished during the Yarmouth interglacial stage.

ILLINOIAN TERMINAL MORAINE

West Point (altitude 755 feet, or 230 meters) is located on the Illinoian terminal moraine. Just west of the village the road enters a flat upland area of Kansan drift overlain by loess. In cuts on the road to Mount Pleasant, in Henry County, may be seen, beneath the loess, good sections of Kansan gumbotil, oxidized and leached Kansan till, and oxidized and unleached Kansan till. Only a few of the cuts are deep enough to expose the unoxidized and unleached Kansan till or the underlying Nebraskan drift.

ERODED KANSAN DRIFT PLAIN

South of Mount Pleasant (population 3,743; altitude 725 feet, or 221 meters) and north of this town to Washington and beyond erosional features of the Kansan drift mantled by loess are well seen. Here flat-topped divides are remnants of a former extensive glacial drift plain, which had a gentle slope from the Mississippi-Missouri divide eastward to the Mississippi River. A large part of the region traversed in Henry and Washington Counties and parts of adjacent counties shows only slight erosional modification of the former Kansan gumbotil plain. With the exception of the areas close to the main drainage lines, the valleys are broad and shallow; between these valleys the uplands are flat "tabular divides" and are drained along broad, shallow depressions which are the headward extensions of the valleys. The broad valleys, the very gentle slopes, and the completeness of the drainage indicate a long time of erosion, during which there has been developed almost perfect adjustment of the streams at grade.

At Wayne [20] (altitude 694 feet, or 212 meters), in the northern part of Henry County, a broad channel is crossed. This was occupied by the Mississippi River when displaced by the Illinoian ice sheet (29, p. 92).

From Ainsworth (altitude 700 feet, or 213 meters) to Iowa City the Kansan drift topography is more rugged than farther south, owing to the erosion of the Iowa River and its tributaries. Moreover, the loess thickens appreciably as far as the border of the Iowan drift north of Iowa City. South of Iowa City the road for several miles crosses the basin of the extinct Lake Calvin (44).

IOWA CITY, IOWA, TO PRAIRIE DU CHIEN, WISCONSIN

Iowa City (population 15,340; altitude 685 feet, or 209 meters) is the seat of the State University of Iowa, which was established in 1847 and now has an enrollment of nearly 10,000 students. The Iowa River Valley has been carved in glacial deposits and underlying indurated rocks of Upper Devonian age. Lying unconformably on the Devonian in places in this locality are outliers of shale and sandstone of Coal Measures (Pennsylvanian) age.

IOWAN DRIFT, LOVELAND LOESS, AND PEORIAN LOESS

Between Iowa City and North Liberty two distinct types of topography are observed. One is the fairly rugged mature topography of the Kansan drift mantled by thick loess; the other is the gently rolling, drift-mantled, erosional topography characteristic of areas that were invaded by the Iowan ice sheet. (See

p. 8.) Around the borders of the Iowan drift is thick Peorian loess, which genetically and in age appears to be related closely to the Iowan. There is only thin loess overlying the Iowan drift, and in places beneath this loess is a thin pebble band.

Just north of the area invaded by the North Liberty lobe of the Iowan ice sheet there is a deep road cut [21] within the Kansan drift area showing two distinct deposits of loess—the older one the Loveland loess, which is older than the Iowan drift, and the younger one the Peorian loess. Between this cut and Cedar Rapids the lobate tracts of Iowan drift and the intervening areas of Kansan drift exhibit marked contrasts in topography, including some paha (elliptical hills and elongated ridges composed of or mantled by loess). The relations of the late Wisconsin till of the Des Moines lobe to the Peorian loess and the underlying Kansan till and gumbotil are shown in Plate 1, *B*.

From Cedar Rapids (population 56,097; altitude 732 feet, or 223 meters) northward the characteristics of the Iowan drift are well displayed. The average thickness of this deposit is less than 10 feet (3 meters). In places Iowan till is seen overlying Kansan gumbotil.

Although in general the topography is of a drift-mantled, erosional type, there are small areas within which the Iowan drift is thick enough to produce distinct depositional features. In parts of the area the surface appears to be almost level. Many large granite boulders are seen on the surface of the Iowan drift. Since the retreat of the Iowan ice front there has not been sufficient time for the development of gumbotil. However, leaching of calcium carbonate has proceeded to a depth of somewhat more than 5 feet (1.5 meters) (22). The loess on the Iowan drift has an average thickness of less than 2 feet (0.6 meter).

IOWAN DRIFT BORDER

In the vicinity of Fayette, in Fayette County, outcrops of Upper Devonian limestone are seen. A short distance south of Fayette the route enters an area of Kansan drift mantled by thick loess. This extends less than 2 miles (3.2 kilometers) north of Fayette and is succeeded by typical Iowan drift. Just before reaching West Union (population 2,056; altitude 1,106 feet, or 337 meters) the route leaves the area of Iowan drift and enters another area of thin Kansan drift mantled by thick loess. The topography of this area resembles somewhat that of the Driftless Area.

KANSAN TILL AND IOWAN TILL

One of the best-known exposures of northeastern Iowa showing Kansan till and Iowan till separated by Kansan gumbotil is

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a road cut [22] 5 miles (8 kilometers) west of West Union (19, pp. 505–506), where the section is as follows:

Deposits west of West Union, Iowa

	Feet	Meters
Peorian interglacial stage: Loess, buff, mealy, unleached; some concretions; fossil shells	2	0.6
Iowan glacial stage: Till, dark buff on a dry surface, yellowish brown to brown when damp; cuts readily with a hoe; sandy; few if any concretions; all unleached	7	2.1
Sangamon(?) interglacial stage: Loess (Loveland?), gray with chocolate-colored stain, leached, laminated, puttylike when wet, free from grit; no pebbles found	2½	.7
Yarmouth interglacial stage: Erosion and weathering of underlying deposits.		
Kansan glacial stage:		
Gumbotil, dark gray on dry surface, leached; no concretions seen; few pebbles of any kind, and those present are siliceous; upper 1½ feet (0.45 meter) has much carbonaceous matter, which shows as a distinct soil band through the cut	5½	1.6
Till, oxidized and leached; grades into the gumbotil; exposed	4½	1.4

In this section the Iowan till is both underlain and overlain by loess. The Iowan drift of this region has a distinctly depositional topography.

From West Union to McGregor only a few road cuts show drift; the mantle material is Peorian loess. The erosional forms in this deeply dissected area have been developed almost entirely in Paleozoic rocks.

The topography of part of northeastern Iowa is similar to that of the Driftless Area, an unglaciated tract of more than 10,000 square miles (2,590,000 hectares) lying mostly in Wisconsin and including adjacent parts of Minnesota and Illinois but not of Iowa. (See p. 12.) Patches of till are so distributed within northeastern Iowa as to leave no doubt that an ice sheet advanced from the northwest as far, at least in most places, as the gorge of the Mississippi River.

Several of the large streams tributary to the Mississippi cross northeastern Iowa, and their valleys are at grade, hence the maximum relief of the surface under present conditions has been attained. This relief is about 400 feet (122 meters) locally and as much as 600 feet (183 meters) within distances of a few miles. The uniform rise of the steep slopes is broken in many places by cliffs of resistant bedrock formations. Chief of these are the Oneota dolomite, Platteville limestone, and Galena dolomite (all Ordovician) and the Niagara dolomite (Silurian). Where shale is at the surface the area has rolling dome and saddle topography indicative of maturity in stream dissection.[15]

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[15] See topographic maps of Elkader and Waukon quadrangles, Iowa.

DODGEVILLE PENEPLAIN AND LANCASTER PENEPLAIN

The traveler through the northeastern part of Iowa is strongly impressed by the even sky line as seen from the summits of the divides. Some of the upland areas are broad, with very gently rolling surfaces. Here and there rising steeply above the even sky line are knobs and secondary ridges whose summits also reach uniform heights. The two levels attained by different parts of the divides are strikingly consistent and have been interpreted by some geologists to be remnants of two old erosion surfaces. The upper level, called the Dodgeville peneplain, is between 1,200 and 1,300 feet (366 to 396 meters) above sea level. In the vicinity of Waukon [23], Church, Elon, and Rossville [24], in Allamakee County, Iowa, it consists of remnants in branching divides with flat tops. The much more extensive lower plain slopes from an altitude of about 1,100 feet (335 meters) at the Minnesota line to about 900 feet (274 meters) at Dubuque. The summits of many of the divides within 8 or 10 miles (12 to 16 kilometers) of the Mississippi River are remnants of this plain, which is known as the Lancaster peneplain (22, 51).

McGregor (population 1,299; altitude 627 feet, or 191 meters) is on the west bank of the Mississippi River opposite Prairie du Chien, Wisconsin, in the midst of beautiful scenic features. About 3 miles (4.8 kilometers) to the south is Pike's Hill [25], visited in 1673 by Sieur Joliet and Père Marquette.

ANNOTATED GUIDE OF SOUTHERN WISCONSIN

By E. F. Bean, F. T. Thwaites, and W. C. Alden

PRAIRIE DU CHIEN TO MADISON, WISCONSIN

[See figs. 1 and 2]

At Prairie du Chien (population 3,943; altitude 640 feet, or 195 meters), the flat bottom of the trenchlike gorge of the Mississippi River [16] between northeastern Iowa and southwestern Wisconsin is 500 to 600 feet (152 to 183 meters) below the adjacent upland ridge tops, and wells show the presence of 150 feet (46 meters) or more of filling in the rock gorge below the present level of the river (high water, 626 feet (191 meters) above sea level). The general southerly dip of the rock formations is steeper than the gradient of the stream, so that the gorge, which is 2 to 4 miles (3.2 to 6.4 kilometers) or more in width farther north, where cut in the Cambrian sandstone, narrows southward as the more resistant overlying "Lower Magnesian" dolomite (Ordovician) approaches the river level, and for some distance

[16] See topographic maps of Waukon and Elkader quadrangles.

south of the mouth of the Wisconsin River the towering walls of the gorge are but 1¼ to 1¾ miles (2 to 2.8 kilometers) apart. In consequence of the southwesterly dip of the rocks there is a similar downstream narrowing of the gorge of the Wisconsin River. Prairie du Chien stands on a low sandy terrace, which slopes northward from the mouth of the Wisconsin River as if part of a great alluvial fan built by that stream out into the Mississippi flood plain (41, p. 145) at the Wisconsin stage of glaciation.

Five miles (8 kilometers) southeast of Prairie du Chien the route goes up onto a terrace 100 to 200 feet (30 to 61 meters) above the river at Bridgeport [26][17] (altitude 700–800 feet, or 213–244 meters). This terrace was cut into the dolomite by the Wisconsin River at an early stage (pre-Wisconsin stage, perhaps early Pleistocene or late Tertiary). Later the river cut its narrow inner gorge, and the rock terrace was then dissected and finally mantled with 30 to 50 feet (9 to 15 meters) of bouldery drift and loess. MacClintock (39, p. 677) has suggested that the drift may have been deposited by a lobe of glacier ice from Iowa that crossed the Mississippi gorge and invaded the mouth of the Wisconsin Valley at the Kansan stage of glaciation. Thwaites (48, p. 631) believes that the erratics may have been carried on floating ice from the east and that the till-like appearance of the material is due to slope wash, slump, and weathering. The route continues eastward up the Wisconsin River Valley.

Several miles above Bridgeport, near Wauzeka [27] and the mouth of the Kickapoo River, is a terrace cut in Cambrian sandstone and mantled with glacial outwash 100 to 115 feet (30 to 35 meters) above the Wisconsin bottom land. The pebbles in the sand and gravel are largely of local rock, but with these are numerous erratics and pebbles of granite, quartzite, porphyry, basalt, etc., similar to those in the glacial drift to the east. MacClintock (39) regarded this material as outwash from the Kansan (?) drift on the Bridgeport terrace to the west. Bedding noted in one high-level gravel pit, however, dips westward. This and other pits on the lower flat furnish surfacing material for local roads. The drainage basin of the Kickapoo River, to the north, is entirely within the Driftless Area. In the Kickapoo Valley are the largest apple orchards in Wisconsin. At one place there are erratic boulders 60 feet (18 meters) above the flood plain, or 713 feet (217 meters) above sea level. MacClintock thinks that old glacial gravel on one sandstone terrace probably came from the east and may be of Nebraskan age.

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[17] Numbers in brackets refer to localities shown on pl. 3 and fig. 2.

At Boscobel (population 1,762; altitude 673 feet, or 205 meters) wells on the low terrace show 130 feet (40 meters) of sand and some gravel, and pre-Cambrian granite was encountered below the Cambrian sandstone at depths of 965 and 1,000 feet (294 and 305 meters). Leaving the river at Boscobel, the route runs south to the loess-mantled, driftless upland, going up over Cambrian sandstone and "Lower Magnesian," Platteville, and Galena dolomites (all of Ordovician age).

Fennimore [18] (population 1,341; altitude 1,196 feet, or 365 meters) is in the heart of a rich dairy region, with upland soil in part residual from weathering dolomite and in part loess. The top of Military Ridge, on which the route and the Chicago & Northwestern Railway run eastward, is part of an old southward-sloping erosion surface which has been called the Dodgeville peneplain (51, p. 64). Martin (41) and others regard the ridge as a northward-facing cuesta with maturely dissected slopes.

At Dodgeville (population 1,937; altitude 1,253 feet, or 382 meters) there are two active zinc mines and several that are worked out. This is part of the southwestern Wisconsin lead and zinc district, where mining began in 1824. The first ore mined was galena, which was close to the surface or cropped out upon the hillsides. Many of these old shallow workings are to be seen. Later mining developed the zinc sulphide, sphalerite. The ore occurs in the lower part of the Galena dolomite and the upper part of the Platteville dolomite (both of Ordovician age).

Near the village of Blue Mounds [28] (see pl. 3) (population 182; altitude 1,301 feet, or 397 meters) the top of the western one of the Blue Mounds has an altitude of 1,716 feet (523 meters) and is about 400 feet (122 meters) above the surrounding upland. The Blue Mounds are composed of Maquoketa shale (Ordovician) capped by an isolated outlier of the Niagara dolomite (Silurian) escarpment, which is 69 miles (111 kilometers) to the east in Wisconsin and 45 to 55 miles (72 to 88 kilometers) to the south and west in Illinois and Iowa.

East border of the Driftless Area: [19] Near the railway crossing 1.8 miles (3 kilometers) west of Verona [29] there is a little of the Illinoian glacial drift, which farther south, near the Illinois-Wisconsin State line, is spread over an area 50 to 60 miles (80 to 97 kilometers) wide outside the limit of the later drift. (See fig. 1.) The southwest front of the Green Bay lobe of the middle Wisconsin substage occupied a small valley about a

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[18] See topographic maps of Lancaster, Mineral Point, Richland Center, Blue Mounds, and Blanchardville quadrangles, Wisconsin.

[19] See topographic maps of New Glarus, Cross Plains, and Madison quadrangles, Wisconsin.

mile (1.6 kilometers) east of the railway crossing and left its terminal moraine (Johnstown moraine) crowded against the west slope, separated from it only by a sharp ravine, 35 to 40 feet (11 to 12 meters) in depth. One side of this ravine consists of nearly bare "Lower Magnesian" dolomite; the other is formed by the abrupt front of the moraine. In the next 1½ miles (2.4 kilometers) northward the moraine front rises abruptly 60 to 80 feet (18 to 24 meters) from a flat terrace to a well-marked ridge crest, back of which a belt half a mile to 2 miles (0.8 to 3.2 kilometers) in width, marked by gentle sags and swells and several ponds, extends to a very indefinite inner margin (3, p. 212).

For 25 miles (40 kilometers) north-northwest from Verona (population 1,062; altitude 981 feet, or 299 meters) to the Wisconsin River the relations of the outer margin of this glacial drift to the topography of the deeply dissected Driftless Area afford interesting studies.

The outermost moraine of the Green Bay lobe crosses Black Earth Creek obliquely, thus losing its relief in the general filling. Coarse outwash gravel from this moraine built up the valley train between Cross Plains and Black Earth, 6 miles (9.6 kilometers) to the northwest.[20]

When the ice front retreated past the narrow gaps 4 to 5 miles (6.4 to 8 kilometers) east of Cross Plains, and thence by stages eastward to the recessional moraine at the west end of Lake Mendota [30], the basin of Pheasant Branch was flooded, forming glacial Lake Middleton (Thwaites), and in this basin notable outwash deposits and morainal deposits were laid down (3, pp. 265–266). One well on the flat penetrated sand 100 feet (30 meters), peat 1 foot (0.3 meter), and clay 125 feet (38 meters) before reaching the rock bottom of the valley. Some of this filling was probably deposited at an earlier stage.

On the way from Middleton (population 983; altitude 931 feet, or 284 meters) to Madison glimpses of Lake Mendota may be had. This is the largest of the four lakes near Madison. These lakes occupy portions of the preglacial valley of the Yahara River, possibly somewhat broadened and deepened by glacial erosion in Cambrian sandstone.

At Madison (population 57,899; altitude of Lake Mendota 849 feet, or 259 meters) are the State capitol, the State university, the Forest Products Laboratory, and several manufacturing plants. The annual enrollment at the university is about 10,000.

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[20] Much gravel from the pits near Cross Plains is used for road surfacing. Local plants here and east of Cross Plains are equipped to crush, screen, and wash the gravel. The saving to the public by using local material amounts to $2,000 to $5,000 per mile ($1,250 to $3,125 per kilometer) of paving.

MADISON TO PLYMOUTH, WISCONSIN [21]

Along most of the route from Madison northwest to the Wisconsin River Valley there are alternating belts of recessional moraine and ground moraine mantling the eroded surface of the Upper Cambrian (St. Croixan) sandstone and the overlying "Lower Magnesian" dolomite (Ordovician).

At Sauk City (population 1,137; altitude 780 feet, or 238 meters) the route crosses the Wisconsin River (altitude 740 feet, or 226 meters).[22]

At Prairie du Sac (population 949; altitude 800 feet, or 244 meters) a dam on the river furnishes power to many places in southeastern Wisconsin. To the north the river cuts through a broad composite terminal moraine [31], which overlies older valley filling and which is bordered for miles on the west by a broad, high outwash terrace (Sauk Prairie). The villages stand on a lower terrace produced by erosion of the outwash. For 8 miles (13 kilometers) the route traverses these terraces a short distance west of the morainal front; farther west are driftless hills of Cambrian sandstone.

From the upper terrace the route runs up over a driftless part of the Baraboo Range [32], composed of folded and truncated pre-Cambrian (Huronian) quartzite, which projects 300 to 800 feet (91 to 244 meters) above the eroded surface of surrounding Paleozoic rocks. The South Range, 1 to 5 miles (1.6 to 8 kilometers) wide and 25 miles (40 kilometers) long, is joined at the ends by the less prominent North Range forming a synclinal basin through which the Baraboo River flows.

In preglacial time the Wisconsin River flowed through the North Range at the Lower Narrows on a valley bottom 200 feet (61 meters) below the present Baraboo River, then west and south through the Devils Lake gorge [32]. (See fig. 3, *a*.) The rock bottom of this gorge is thought to lie nearly 400 feet (122 meters) below the level of the lake, which is 963 feet (294 meters) above sea level. At the Wisconsin stage of glaciation the west front of the Green Bay lobe overrode the South Range to a point 4 miles east of this gorge. On the lower ground to the north and south it advanced farther west and blocked the gorge at both ends with morainal dams, thus inclosing the lake basin. (See fig. 3, *b*.) The lake has no inlet or outlet other than by

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[21] See topographic maps of Baraboo, Denzer, Dells, Briggsville, and Portage quadrangles, Wisconsin.

[22] Pitted and dissected outwash deposited at the western front of the Green Bay lobe borders the river for 2 miles (3.2 kilometers) southeast of Sauk City. By using this local gravel (80 per cent limestone) $22,000 was saved in paving 10.5 miles (17 kilometers) of highway; on gravel from another pit, $23,000 was saved on 7½ miles (12 kilometers).

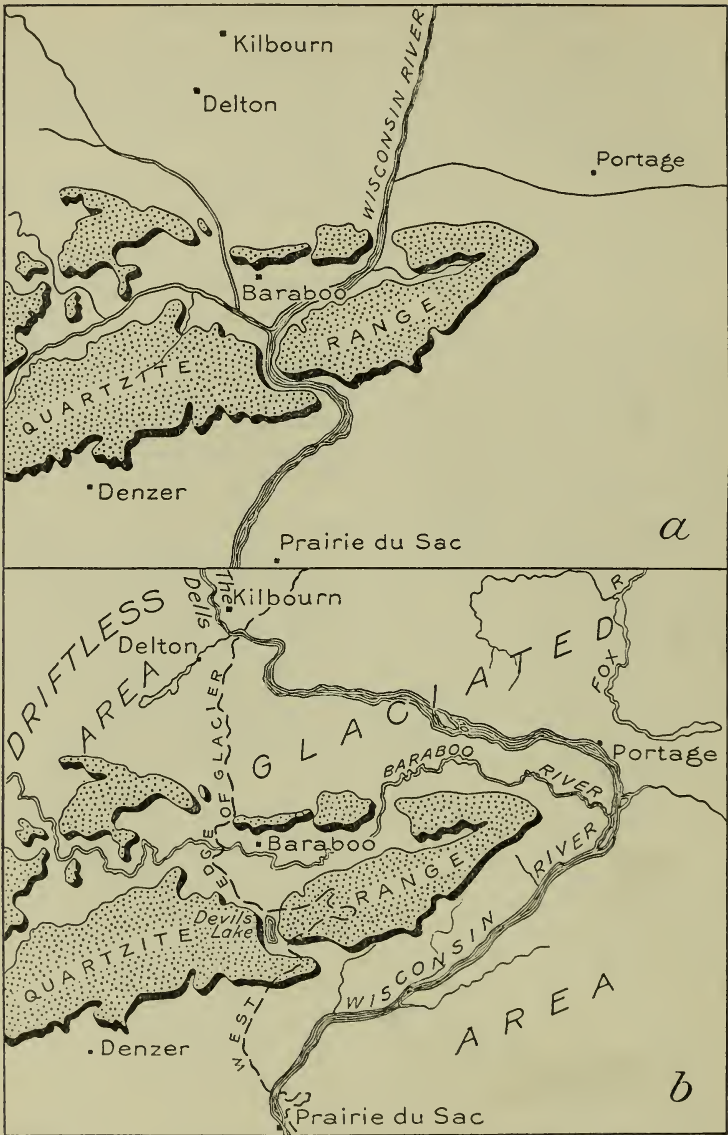

FIGURE 3.—*a*, Preglacial drainage lines across the Baraboo quartzite range; *b*, present courses of the Wisconsin, Baraboo, and Fox Rivers. (After Hotchkiss and Bean)

percolation. A talus of great quartzite blocks flanks the steep walls of the gorge. The route crosses the terminal moraine northwest and north of the lake.

The Green Bay Glacier blocked the Baraboo Valley at Baraboo, thus forming glacial Lake Baraboo. At the same time glacial Lake Wisconsin was formed in the lowland north of the Baraboo Range. Alden believes that the waters of these two lakes were confluent and that they rose to an altitude of at least 960 feet (293 meters). The waters discharged to the northwest into the East Fork of the Black River.

Baraboo (population 5,545; altitude 864 feet, or 263 meters) is located on the terminal moraine where the Baraboo River has cut through it. North from Baraboo the highway is on the outwash plain west of the Johnstown moraine. Much of this plain, which slopes gently westward, lies between 960 and 980 feet (293 and 299 meters) above sea level. It appears that much of the fill was deltaic. The upper part of the terrace, however, was built above the lake level.[23] A well on this terrace [33] penetrated 304 feet (93 meters) of sand, gravel, and lake clay, thus showing that an old southeastward-trending valley of Dell Creek lies buried beneath the terrace.

The recession of the west front of the Green Bay Glacier to a moraine near Portage cleared the Wisconsin Valley and permitted Glacial Lakes Wisconsin and Baraboo to be drained about the east end of the Baraboo Bluffs. The reestablishment of the drainage lines in new courses across the drift located the Wisconsin River across a broad buried ridge of Cambrian sandstone at Kilbourn, which is west of the broad preglacial valley. The erosion of the new channel, a narrow gorge cut in the cross-bedded sandstone, gave rise to The Dells [34], the most famous and beautiful feature of the Wisconsin Valley. (See pl. 4, *A*.)

The Baraboo River, instead of discharging to a stream flowing southward through the Lower Narrows and the Devils Lake gorge, as in preglacial time, now flows eastward through the Lower Narrows and joins the Wisconsin near Portage. (See fig. 3, *b*.)

At Kilbourn (population 1,489; altitude 903 feet, or 275 meters) a trip by boat enables visitors to see the Upper Dells.

From the outwash terrace east of Kilbourn the route runs eastward and again crosses the terminal moraine and also two recessional morainal tracts, between which are extensive marshes. The westward-dipping cross-bedded morainal gravel

[23] On paving 11.8 miles (19 kilometers) of this highway $55,000 was saved by using material from a gravel pit on this outwash terrace. Of this gravel 45 per cent is derived from the quartzite ranges and but 22 per cent from the limestone formations farther east.

appears to have been deposited in water ponded over the lowlands, forming a lake which Thwaites has called glacial Lake Oshkosh. As the ice front retreated this lake was extended north and east down the Fox River Valley. It persisted until the escarpment east of Green Bay was so far cleared of ice as to open a lower outlet eastward to the Lake Michigan Basin. When this lower outlet was again blocked by a readvance of the ice at the late Wisconsin substage, the lake waters again crossed the col at Portage, cutting it down from an altitude of 825 feet (251 meters) to 796 feet (243 meters).

At Portage (population 6,308; altitude 811 feet, or 247 meters) a monument marks the point where, in June, 1673, Sieur Joliet and Père Marquette launched their canoes on the Wisconsin River after their portage of "2,700 paces" across the flat from the Fox River. A levee now prevents the Wisconsin from overflowing to the Fox River at flood stages. For many years a canal and locks were maintained between the two streams, but the shifting sands in the channel of the Wisconsin and other conditions were not favorable to navigation.

East of Portage for a long distance the route traverses undulating ground moraine, which overlaps the dissected western parts of the Ordovician formations, the "Lower Magnesian" dolomite, the St. Peter sandstone, and the Beloit and Galena dolomites. The eroded edges of the dolomites do not everywhere form definite escarpments in this region. Between Portage and Montello, several miles north of this highway, some knobs of Archean granite, rhyolite, and porphyry rise above the eroded surface of the surrounding Cambrian sandstone.

A few miles east of Portage are small drumlins [35] parallel to the direction of the westward-moving ice. About 15 to 20 miles (24 to 32 kilometers) farther east the route passes a mile or so north of the margin of the main area of the famous Wisconsin drumlins. (See fig. 4.) The drumlins in this vicinity [36] trend southwesterly and were produced by the sector of the radially spreading Green Bay lobe which terminated south of the Baraboo Range.

At Fox Lake (population 901; altitude 885 feet, or 270 meters) the lake lies in a reentrant of the escarpment of Galena dolomite (Ordovician) and east of a narrow section of the Green Lake recessional moraine. Ten miles (16 kilometers) farther south the basin of Beaver Dam Lake is closed by a drumlin [37] (3, p. 41). Northeast of Fox Lake the ground moraine overlies the Galena dolomite.

At Waupun (population 5,768; altitude 888 feet, or 271 meters) one of the best examples of planed, polished, and striated surfaces of flat-lying limestone may be seen at Randall's quarry

[38]. On several streets in the town the walks are largely composed of these finely glaciated flagstones (3, p. 204).

North and east of the town are patchy deposits of recessional moraine, and to the southeast is the great Horicon Marsh, which occupies a basin closed at the south end by the Green Lake recessional moraine [39]. The innermost of the middle Wisconsin recessional moraines, the St. Anna moraine, is crossed east of the village of Lamartine [40].

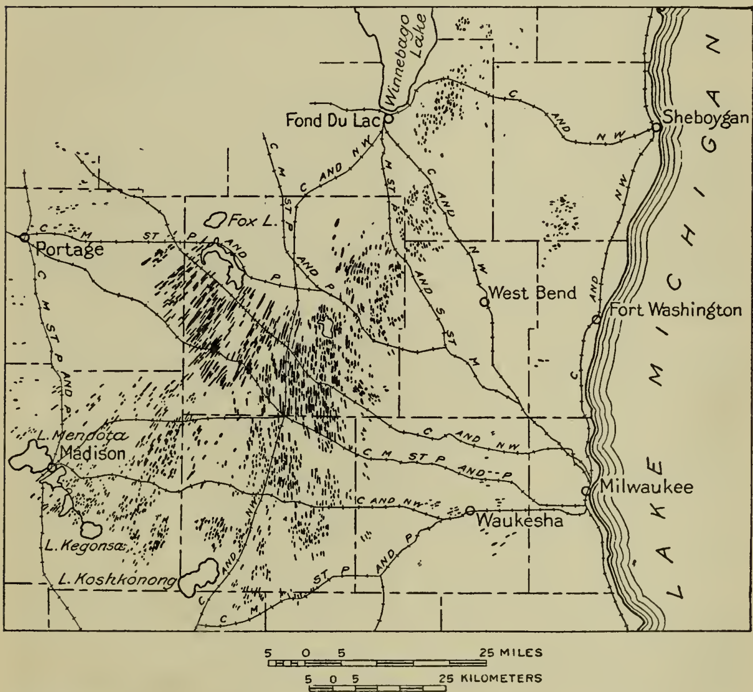

FIGURE 4.—Map of the drumlins of southeastern Wisconsin. Redrawn from John Millis's copy of W. C. Alden's map

After a further recession of the ice front and a lowering of glacial Lake Oshkosh (p. 38) there occurred a readvance of the ice at the late Wisconsin substage into the basins of Lake Winnebago and Lake Michigan (p. 11). The limit of the Green Bay lobe at this substage is marked by a low, somewhat pitted morainal ridge of reddish till overlying the middle Wisconsin grayish till. This ridge, which encircles the low plain adjacent to Lake Winnebago, is crossed by the highway 3 to 5 miles

(4.8 to 8 kilometers) northeast of Lamartine [41]. It was bordered on the south and west by a narrow glacial lake, and when the ice front again receded from the ridge the basin within it and also the Fox River Valley was reflooded by glacial Lake Oshkosh (see 3, pp. 324–325) up to the level of the col at Portage (796 feet, or 243 meters, above sea level). There are beaches at 795 to 825 feet (242 to 251 meters), but they are not everywhere conspicuous.

Fond du Lac [42] (population 26,449) stands on the lacustrine plain not far above the level of Lake Winnebago (altitude 747 feet, or 228 meters). The present lake, the largest in Wisconsin, is about 28 miles (45 kilometers) long from north to south and 10 miles (16 kilometers) in maximum width.[24] Adjacent wells indicate that the rock bottom of the ancient valley in which it lies is 100 to 300 feet (30 to 91 meters) below the surface, yet the lake is but 20 feet (6 meters) deep.

To the east is a drift-mantled escarpment, 200 to 300 feet (61 to 91 meters) in height, formed by the west edge of the Niagara dolomite (Silurian) and the underlying Maquoketa shale (Ordovician) (3, p. 39). This escarpment extends far to the north and south, and the trough at its base was followed by the axial movement of the asymmetric Green Bay lobe. The remarkable regularity of the escarpment here and to the north is probably due to glacial erosion (41, pp. 230–235). Farther south it is indented by several embayments due to preglacial erosion.

From the Lake Winnebago trough the ice of the Green Bay lobe crowded up over the Niagara escarpment and spread southeastward on the upland until it met the westward-moving ice of the Lake Michigan Glacier head-on, and there was formed the famous Kettle interlobate moraine. (See pl. 3.)

Two miles (3.2 kilometers) east of Fond du Lac is a spit (altitude 810 feet, or 247 meters) built out from the east shore of glacial Lake Oshkosh. The gray drift of the St. Anna moraine (middle Wisconsin) and the near-by margin of the red till (late Wisconsin) lie along the foot of the escarpment [43], rising gradually northward until they curve eastward onto the upland farther north.

The route eastward climbs to the upland [44] at an altitude of 1,000 to 1,100 feet (305 to 335 meters) and for 10 miles (16 kilometers) runs through a group of drumlins remarkable for the various and abnormal southwesterly trends of their axes and their unusual forms.[25] (See fig. 4.) Alden (3, p. 250) pointed out indications of a readvance of the ice over earlier drift ridges,

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[24] See topographic maps of Fond du Lac and Oshkosh quadrangles, Wisconsin.
[25] See topographic map of Fond du Lac quadrangle, Wisconsin.

some of them perhaps recessional moraines, with shifted direction of ice movement and partial reshaping of the ridges into their present forms. Thwaites suggested that the ice invading this tract west of the interlobate moraine at the early Wisconsin substage may have been that of the Lake Michigan Glacier, that the southwestward-trending ridges were due to its action, and that some of these ridges were reshaped by the southeastward-moving ice of the Green Bay lobe of the middle Wisconsin substage. A few drumlins seem to have escaped much alteration; others have had new tails built which trend south; some have two distinct tails; still others conform exactly to the later direction of movement.

Farther east is ground moraine with scattered patches of recessional deposits. At Greenbush [45] the famous Kettle interlobate moraine, which is largely wooded, is reached. The topography of this moraine is rugged in the extreme; knobs, ridges, and mounds with a relief of over 150 feet (46 meters) are interspersed with inclosed kettles. In many places the slope is that of the angle of repose of wet gravel, over 30°. Although this moraine is the highest land between Lake Michigan and the Fox-Winnebago lowland, it forms a water parting in but few places, for it has many breaks through which streams pass. When the margins of the two ice lobes stood close together, assortment of the material was not good, and coarse, ill-assorted bouldery gravel was deposited in the reentrant. When included ice masses and the supporting ice walls melted, irregular ridges, knolls, and cones of gravel (kames) were left. In a few places the conical hills may represent cones formed at the bottoms of moulins; elsewhere coarse gravel was doubtless deposited in open crevasses. When the interlobate angle between the ice fronts widened, new and lower outlets were opened for the melt water, and terraces of better-sorted gravel were formed. Many ice blocks still survived, buried in the sediments, and later melted to form terraces of pitted outwash (47). Several distinct terrace and drainage channel levels can be seen along the route on approaching Plymouth. Just west of the city a moraine, largely gravel, marks the west side of the Lake Michigan lobe at the time of formation of the lowest terraces.

PLYMOUTH TO WEST BEND, WISCONSIN

Plymouth (population 3,882; altitude 845 feet, or 258 meters) is at the western margin of the red till deposited by the Lake Michigan Glacier at the late Wisconsin readvance. The highway north to Elkhart Lake [46] (population 571; altitude 946 feet, or 288 meters) is on terraced and pitted outwash, with a gray drift moraine on the right. About 4 miles (6.4 kilometers) east of the village the area of the red drift is entered. At the top of the hill west of Franklin [47] a pit exposes the bright-red till overlying gravel of a middle Wisconsin recessional moraine. In places the older deposits were folded by the overriding late Wisconsin ice. The lower reddish drift of the ground moraine to the east is nearly flat. This flatness is due to several factors: (*a*) clay tills such as the red drift may flow when wet and form level plains; (*b*) much of the red drift overlies older outwash plains; (*c*) much of it overlies older lake deposits. The low pitted ridge that the road crosses east of Howards Grove [48] may be an older moraine merely mantled by the red drift.

After the recession of the Lake Michigan Glacier, of middle Wisconsin age, and both before and after the late Wisconsin re-advance and the deposition of the red till the waters of glacial Lake Chicago submerged a narrow strip of the present lake shore line up to the level of the highest or Glenwood Beach (640 feet, or 195 meters above sea level). The route runs northward near the west margin of this narrow lacustrine plain. Partly cemented, stratified gravel exposed below red till in gravel pits at Fisher Creek, north of St. Wendell [49], may represent the early Glenwood Beach of Lake Chicago, although the gravel may have been deposited in a higher local lake. The route continues north on the red till.

Manitowoc (population 22,963; altitude of Lake Michigan 581 feet, or 177 meters) is next reached. Owing to the absence of a well-marked shore line and the lack of topographic maps, the exact extent of the submergence at the Calumet stage (about 620 feet, or 189 meters above sea level) in this vicinity is not known. From the city north and northeast a large area was submerged by glacial lake waters.

Just north of the city several pits expose deltaic gravel deposits, probably made at the margin of the ice in Lake Chicago. Lake silt and clay, much disturbed by ice push, overlie the deposits, but no till is seen. In places percolating water has carried calcium carbonate from the clay down into the gravel, cementing it to conglomerate. In places also beach sand and gravel, probably of the Calumet stage, overlie the folded beds unconformably. The waters of later glacial Lake Chicago may have reworked such thin red till as was left on the top of the deltas.

The route follows the present lake shore northeastward. In places, where not adequately protected by breakwaters, the waves of Lake Michigan have caused very rapid recession of the cliffs composed of glacial and lacustrine deposits.

At Two Rivers (population 10,083) shores of glacial Lake Algonquin (altitude 607 feet, or 185 meters) and the Nipissing

Great Lakes are represented by cliffs and barrier beaches (17, pp. 57–59, 61–62). North from the city, much of which is built on sandy Nipissing lake bottom, the highway runs along a ridge of red till that locally resembles a weak terminal moraine. As no trace of the Calumet beach is known north of Two Rivers, this ridge may mark the position of the ice border at the maximum extent of that stage of Lake Chicago.

A buried forest bed is exposed in the lake cliff at Two Creeks (17, 56), where the following section may be seen:

Deposits exposed at Two Creeks, Wisconsin

	Feet	Meters
Glacial Lake Algonquin: Clay, red and yellowish gray, varved, calcareous, found up to about 25 feet above Lake Michigan	5	1.5
Late Wisconsin glacial stage:		
Till, red, clayey, calcareous; some wood	8–15	2.4–4.5
Silt and clay, red, calcareous; some shells	½	.15
Interglacial substage: Forest bed—peat, stumps, logs, branches, etc.	½	.15
Glenwood stage of glacial Lake Chicago: Red clay, sand, and gray silt; top part contains organic remains	7–12	2.1–3.6
Middle Wisconsin glacial stage: Till, clayey, gray, calcareous	3	.9

In the forest bed Wilson (56) found spruce and pollen of jack-pine, 19 species of mosses, and 7 of mollusks. Fungi, mites, beetle excavations on logs, and pollens of several upland plants were also collected. The flora and fauna indicate a colder climate than that of to-day, one like that of northern Minnesota at present.

A similar section is also exposed in the pit of the Manitowoc Portland Cement Co. at Manitowoc, except that no forest bed is present. The altitude of the clay here suggests that it was deposited in the Glenwood stage of Lake Chicago.

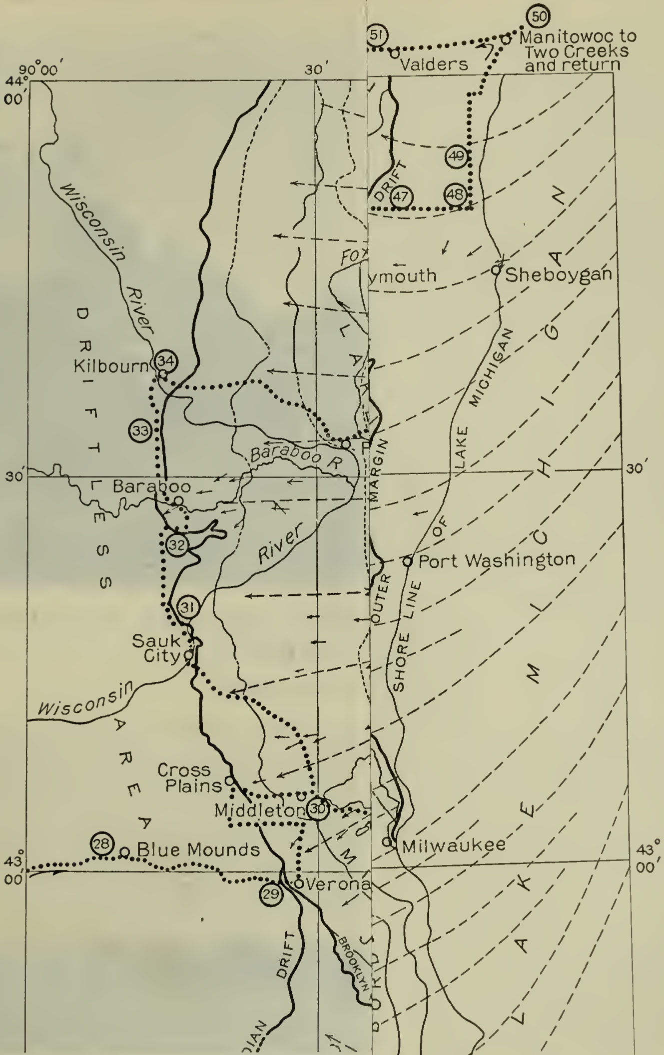
At these exposures the amount of disturbance due to the late Wisconsin ice varies widely. In places the underlying beds seem to have been buried by lake sediments and little disturbed by glacial push. A few feet away all the sediments below the red till are much folded and contorted. Great boulders of silt, clay, and gravel are found in the red till. Locally masses of vegetal remains have been intermingled, not only with the stratified beds, but even with the basal gray till. The surface on which the forest grew undulates considerably and both north and south of the exposures disappears below lake level. Besides being evidence of an interglacial substage, the forest bed seems to indicate that there was a low-water stage of Lake Chicago between the Glenwood and Calumet stages. (See 3, pp. 332–335.)

The route returns to Manitowoc and goes west over the red till, crossing a marked terminal moraine which is probably of middle Wisconsin age veneered with red till. Cuts in another moraine farther west show the underlying gray till.

At Valders (population 504; altitude 812 feet, or 248 meters) a quarry [51] shows the relations of the middle and late Wisconsin ice sheets. The hill is a reef of Niagara dolomite (Silurian) mantled with till 5 to 10 feet (1.5 to 3 meters) in thickness. At both the north and south ends of the opening gray till is found beneath the red; in the center only red till occurs. Where gray till is present the only striae trend approximately south; but where the red till rests directly upon the rock striae bearing west also occur and locally obliterate the older markings. The westerly striae demonstrate that the ice of the late Wisconsin readvance moved westward, for they are best developed on the eastward-facing sides of the older grooves. About 2 miles (3.2 kilometers) northwest of this point Alden (3, pp. 317–318) discovered striae beneath gray till which he thought indicated a southeasterly movement; in the light of the information now available at Valders, however, it is plausible to suppose that the movement was northwestward and that the ice of the late Wisconsin readvance of the Lake Michigan lobe extended several miles farther west than previously mapped. The thin edge of the late Wisconsin red till is difficult to trace, and its exact limits are hard to determine.

A prominent moraine which is crossed several miles west of Valders was mapped by Alden as a recessional of the Green Bay lobe, but he suggested (3, pp. 299, 309) that it may be part of the interlobate moraine. It contains very little if any material from the Galena dolomite to the west. Thwaites regards it as the interlobate moraine (middle Wisconsin). The route south to Elkhart Lake [46] passes through the same moraine. It is possible that this moraine where first seen has been overridden by the late Wisconsin ice, for red clay and red till are found in some of the kettle holes. Surveys by Thwaites have shown that similar overridden moraines near the border of the red till were little altered. North of Kiel the St. Anna moraine of the Green Bay lobe branches off to the southwest from this moraine. Two miles (3.2 kilometers) north of Kiel this is joined by an esker. (See pl. 4, *B*.)

From Elkhart Lake the route runs southwest over pitted outwash terraces to Glenbeulah (population 284; altitude 972 feet, or 296 meters). A large commercial pit at Glenbeulah appears to be in a deltaic kame formed in the reentrant between the Green Bay and Lake Michigan lobes. Southward to Greenbush [45] the route follows the foot of the west side of the Kettle interlobate moraine.


Manitowoc to
Two Creeks
and return
Valders
90°00′
30′
44°
00′
Wisconsin
River
DRIFTLESS AREA
Kilbourn
Baraboo R.
Baraboo
River
Sauk City
Wisconsin
Cross Plains
Middleton
Blue Mounds
Verona
43°
00′
DRIFT
BROOKLYN
Fox
ymouth
Sheboygan
LAKE MICHIGAN
OUTER MARGIN OF LAKE MICHIGAN
SHORE LINE
Port Washington
Milwaukee
30′
43°
00′
50
51
49
47
48
34
33
32
31
30
28
29

MAP OF GLACIAL DEPOSITS OF SOUTHEASTERN WISCONSIN

Numbers in circles indicate localities mentioned in text. By William C. Alden.

A. DELLS OF WISCONSIN RIVER, IN CAMBRIAN SANDSTONE, KILBOURN, WISCONSIN

Photograph by A. D. Hole.

B. ESKER NEAR FRANCIS CREEK, MANITOWOC COUNTY, WISCONSIN

Photograph by William C. Alden.

For 30 miles (48 kilometers) from Greenbush south to West Bend the route lies almost wholly in the interlobate moraine and its associated outwash terraces. (See p. 46; also 3, pp. 269–270, 283, 289–293, 308–309.) Some wells on the great moraine penetrate 200 to 275 feet (61 to 84 meters) of gravel and sand without reaching bedrock.

WEST BEND, WISCONSIN, TO HARVARD, ILLINOIS

For 35 to 40 miles (56 to 64 kilometers) the route southward from the vicinity of West Bend past Cedar Lake traverses the same Kettle interlobate morainal belt and associated terraces.[26]

Two high peaks, one of which is a kame that was probably deposited in a moulin some distance from the open part of the reentrant angle between the two ice fronts, may be seen. These are Sugar Loaf or Pulforts Peak (altitude 1,320 feet, or 402 meters), southeast of Hartford, and Holy Hill (1,361 feet, or 415 meters). South and southwest of North Lake is the Oconomowoc Lake region, which lies in a big embayment in the drift-covered Niagara escarpment due to preglacial erosion.

A gap of several miles in the moraine is due in large part to the fact that streams fed by the melting Lake Michigan lobe here crossed into the area just vacated by Green Bay ice. Farther south, east of Delafield (altitude 900 feet, or 274 meters), there are several abandoned stream channels. The one followed by the route carried water from the ice in the basin of Pewaukee Lake [53] west across a stagnant block in the basin of Lake Nagawicka, a tributary of the Rock River.

From this region [54] the route goes westward into the southeastern part of the great drumlin area. (See fig. 4.) The drumlins of this vicinity [55] trend east of south, for they were developed by the southeasterly quadrant of the Green Bay lobe, Alden (3, pp. 253–256)[27] has suggested that the remarkable radial spreading of the ice in the southern part of the Green Bay lobe may have been an important factor in the development of the drumlins. Few if any of the Wisconsin drumlins appear to be built over rock cores. Eskers may be seen in some places between the drumlins. Several poorly developed belts of recessional moraine deposits may be traced transversely across the drumlin area. Drumlins were not formed within several miles of the terminal and interlobate moraines, and no more are seen beyond a point a few miles south of Rome [56].

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[26] See topographic maps of West Bend, Hartford, Oconomowoc, Eagle, and Whitewater quadrangles, Wisconsin.

[27] See also Alden, W. C., Radiation of glacial flow as a factor in drumlin formation [abstract]: Geol. Soc. America Bull., vol. 22, pp. 733–734, 1911.

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From Palmyra (population 642; altitude 840 feet, or 256 meters) to Eagle (population 392; altitude 945 feet, or 288 meters) the Kettle interlobate moraine is recrossed. In digging a well near Eagle one of the few diamonds discovered in the drift of Wisconsin, a 15-karat stone, was found. The distribution of these and a few other diamonds found in the drift in Minnesota, Michigan, and Ohio and the directions of the glacial movements indicate that the source of these erratic gems was probably somewhere in the region of Hudson Bay.[28]

From Eagle southward extends a remarkable series of pitted outwash terraces, explained by Alden (3, pp. 267–269, 275–277)[29] as due to changes in drainage outlets as a result of ice recession. The highest terraces were formed when the melt water from the Green Bay and Lake Michigan fronts escaped southwestward to the Rock River by way of the Turtle Creek outlet [59]. Later terracing was due to erosion of this outlet and the successive uncovering of two lower outlets to the east by way of the Fox River of Illinois. Present-day exposures indicate that some parts of the moraines shown by Alden on his maps of this region are pitted and dissected terraces of sand and gravel, as is also indicated in his descriptions.

The route runs westward across the Elkhorn moraine, a recessional moraine of a minor lobe of the Lake Michigan glacier known as the Delavan lobe. Where the interlobate moraine is recrossed on this route its southeast side is buried beneath a great pitted outwash deposit, showing that here the Green Bay ice on the west lasted longer than the Lake Michigan Glacier on the east. Its northwest front is steep and 100 to 200 feet (30 to 61 meters) high. An abandoned railway cut traversed by the road to Whitewater exposes very stony till in the moraine. About 90 per cent of this material is of local derivation. Southwestward to the interlobate angle at Richmond the moraine is broader and more typical in character.

At Richmond two great terminal moraines of the middle Wisconsin substage diverge—the Johnstown moraine of the Green Bay lobe extends westward to and across the buried preglacial valley of the Rock River, and the Darien moraine extends southward in a broad easterly curve marking the limit of a minor lobe of the Lake Michigan glacier, known as the Delavan lobe. The outer fronts of both of these terminal moraines are bordered by extensive outwash deposits, somewhat trenched by erosion.

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[28] Hobbs, W. H., The diamond field of the Great Lakes: Jour. Geology, vol. 7, pp. 375–388, 1899.

[29] See also Alden, W. C., The Delavan lobe of the Lake Michigan glacier: U. S. Geol. Survey Prof. Paper 34, pp. 44–49, 57–62, 1904.

From Richmond southward the route closely follows the outer front of the Darien moraine and crosses the terraced valley of Turtle Creek, through which water from the retreating glacier front flowed westward. South and southwest of Darien [60] beyond the outwash terrace, is the rolling ground moraine of the Illinoian drift.

Records of wells penetrating more than 400 feet (122 meters) of glacial drift in places within the Darien moraine indicate that there is a broad and deep preglacial valley west of the drift-covered Niagara escarpment and extending southward between Darien and Elkhorn and under the outwash plain known as Bigfoot Prairie [61], south of Walworth. In another preglacial valley tributary to this lies the basin of Lake Geneva. One reason for the great thickness of drift where the Darien moraine crosses the old valley is that the northward extension of the early Wisconsin terminal moraine (the Marengo Ridge of northern Illinois) may be buried beneath the middle Wisconsin drift of the Delavan lobe. The route follows the west foot of this ridge southward to Harvard, Illinois [62]. (See pl. 2.)

ANNOTATED GUIDE ACROSS NORTHEASTERN ILLINOIS

By M. M. Leighton and G. E. Ekblaw

HARVARD TO CHICAGO, ILLINOIS

In this part of the itinerary the entire series of moraines of the Lake Michigan glacier, of Wisconsin age, and their associated outwash deposits in northeastern Illinois are studied, in the order of their formation—the Marengo Ridge or moraine, Gilberts morainic system, Minooka moraine, Kishwaukee (Marseilles) morainic system, West Chicago moraine, Valparaiso morainic system, and Lake Border morainic system. At first a side trip is taken to observe where the West Chicago moraine, after overriding other moraines, covers the back slope of the Marengo moraine near the State boundary.[30] (See pl. 2.)

MARENGO MORAINE

The Marengo moraine is 4 to 5 miles (6.4 to 8 kilometers) wide and as much as 250 feet (76 meters) high, standing prominently above an outwash plain on each side. Its surface is strongly undulatory, with a relief of 10 to 40 feet (3 to 12 meters). It appears to consist of a sloping marginal apron of till and outwash,

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[30] Unpublished data by Leighton. See topographic maps of Harvard, Elgin, Barrington, and Highwood quadrangles, Illinois.

above which a crest rises abruptly for about 100 feet (30 meters); these features may represent two distinct stages in the building of the moraine. The till composing the ridge is distinctly pinkish. The Marengo moraine is bordered on the west by a broad outwash deposit composed not only of its own outwash but also of that from subsequent glaciations. This outwash plain in the vicinity of Harvard [62] (population 2,988; altitude 966 feet, or 294 meters) is bounded on the west by the White Rock moraine, the earliest moraine of Wisconsin age in northern Illinois and correlated with the Champaign moraine in central Illinois.

The route goes through a gap in the Marengo moraine east of Harvard which is partly filled with outwash from the West Chicago moraine.

4 (6).[31] Top of West Chicago moraine [63], 50 feet (15 meters) high, overriding Marengo moraine. The kame and kettle topography with sharp relief of 10 to 20 feet (3 to 6 meters) and the gravelly drift are typical and are in contrast with the broader and deeper undulations and more clayey drift of the Marengo moraine.

5 (8). Top of Marengo moraine.

6 (10). From this point [64] for a distance of 12 miles (19 kilometers) southward the route follows the lower front slope of the Marengo moraine. The crest of the moraine is to the left (east), the broad outwash plain and the White Rock moraine in the distance to the right (west).

22 (35). The village of Marengo [65] is in one of three subglacial channels or gaps in the Marengo moraine; this one is traversed by the Kishwaukee River (altitude 796 feet, or 243 meters). The route runs in a southeasterly direction on the back slope of the ridge for 5 miles (8 kilometers), and numerous road cuts expose the pinkish till.

27 (43). Top of Marengo moraine, 150 feet (46 meters) above the outlying plain to the right (west). The route continues southeast.

GILBERTS MORAINIC SYSTEM

Recent detailed studies in the Elgin quadrangle by Leighton and Powers have differentiated several morainic systems which were formerly grouped in a "complex area." One of these, the Gilberts morainic system, is probably correlative with the Cropsey morainic system in central Illinois. The Gilberts system comprises several ridges, all of which merge with the east (back)

[31] Approximate distances from Harvard indicated in miles, with kilometers in parentheses.

margin of the Marengo moraine. However, the till in the Gilberts is light tan, in contrast with the pinkish till of the Marengo. The Gilberts moraine is also remarkable for its exaggerated kame and kettle topography and its gravelly drift. The coarser outwash was deposited as deltas and fans in a fore-glacial lake; the finer material was borne farther out into the lake.

32 (51). From this point for 5 miles (8 kilometers) the route crosses several ice-front deltas, fans, and intervening channels. The ice-block depressions behind the deltas persist as swamps and ponds.

37 (59). The profiles of deltas crossed may be seen from this point [66], and from a point a few rods farther east the profile of the ice-contact slope and the relations of deltas, ice-block depressions, and the hummocky moraine are evident.

39 (63). From this point for 5 miles (8 kilometers) southeastward the route crosses the Gilberts moraine, with typical kame and kettle topography. The kames are rudely alined, with irregular longitudinal depressions between, which suggest successive stands of the ice front. The abundance of gravel, indicated by the large number of pits, accounts for the good condition of all secondary roads.

44 (71). A shallow channel marks the break between the drift of the Gilberts moraine to the west and that of the Minooka moraine ahead (east) toward and into Elgin (population 35,929; altitude 717 feet, or 219 meters).

MINOOKA MORAINE

The Minooka moraine (pl. 2) is relatively flat-topped and gently undulatory, is about 3 miles (4.8 kilometers) wide and 80 feet (24 meters) high, and extends north and south. At the south it ends abruptly at the Illinois River, and at the north it is overridden by the West Chicago moraine just north of Elgin. Between Elgin and St. Charles, about 6 miles (9.6 kilometers) south, it overrides the outer Marseilles moraine.

A mile(1.6 kilometers) north from Elgin the road (790 feet, or 241 meters, above sea level) is on a terrace of outwash from the West Chicago moraine. The Minooka drift forms the upland at the left.

FOX RIVER VALLEY

The Fox River Valley has had a complicated history, of which the part prior to the formation of the Kishwaukee moraine (a probable correlative of the Marseilles moraine) is obscure. At that time the valley must have existed in almost its present status, inasmuch as remnants of post-Kishwaukee outwash found along its course indicate that the valley was filled to a level accordant with the outwash near Algonquin. The valley was partly reexcavated before it was crossed and dammed at the Minooka moraine by the glacier. During the Minooka stand the Fox River followed a course west of Elgin along the present Otter Creek Valley. On the recession of the ice front the river resumed its former course. Later, at the West Chicago substage, the glacier lay across the valley above Algonquin [67], and outwash gravel filled the valley to a maximum altitude of 820 feet (250 meters above sea level. In the melting back of the ice from the West Chicago moraine (pl. 2) enormous volumes of water were produced which deeply incised the valley train and also the adjacent outwash plains. When the ice front stood at Cary, southeast of Crystal Lake, bars of sandy gravel were formed in the wider portions of the Fox River Valley below Algonquin.

2 (3).[32] Outlet of abandoned oxbow cut in terrace of outwash gravel from the West Chicago moraine.

3 (5). Krahn-Krest farm, on south bank of inlet of abandoned oxbow. Gravel pit exposes stratified outwash gravel.

5 (8). Road descends from high-level West Chicago outwash to low-level Cary outwash. Upland on left consists of Kishwaukee moraine.

CRYSTAL LAKE OUTWASH PLAIN

North of Algonquin [67], to and beyond Crystal Lake, there is a broad plain mostly underlain by outwash gravel deposited presumably during the retreat of the ice front from the Kishwaukee moraine. This outwash gravel is partly covered by a sheet of outwash from the West Chicago moraine. Subsequent to the deposition of the former the plain was deeply trenched by the Fox River and small tributaries.

9 (15). The route ascends from the Fox River Valley near Algonquin to the Crystal Lake plain. Pit on left exposes coarse outwash gravel.

WEST CHICAGO MORAINE

The West Chicago moraine (pl. 2) is a distinct, well-developed, gravelly kame and kettle moraine, 2 to 3 miles (3.2 to 4.8 kilometers) wide, with a maximum relief of 100 feet (30 meters). It marks the outer border of the Valparaiso morainic system and overrides in succession, from Harvard to Joliet, the Marengo,

[32] Approximate distances from Elgin indicated in miles, with kilometers in parentheses.

Gilberts, Kishwaukee, Minooka, Rockdale, and Manhattan moraines.

10 (16). From the vicinity of Crystal Lake [67] southeastward, the West Chicago moraine may be traced by its knobby topography until it descends into and crosses the Fox River Valley. From its position in the valley the relative age of the valley, the moraine, and the other deposits may be determined.

11 (18). Outwash fans in front of West Chicago moraine are seen. American Sand & Gravel Co.'s pit in Crystal Lake plain. The West Chicago and older gravel deposits can be distinguished by the difference in bedding and texture. Locally, till marking the outermost advance of the ice at the West Chicago substage separates the two deposits of gravel.

15 (23). On the left (north) is the gravel plant of the Wisconsin Lime & Cement Co., exploiting kame and associated deposits of West Chicago age.

VALPARAISO MORAINIC SYSTEM

From the Fox River Valley the route continues southeastward and crosses the Valparaiso morainic system where more or less distinct ridges mark successive stands of the glacier in the vicinity of Fox River Grove, at Barrington [68], between Barrington and Palatine, at Palatine, and at Arlington Heights [69]. Kames and kettles are abundant near Cary. Swamps and peat bogs have developed in the morainic depressions, and in many of the bogs the material is so unstable that the highway across them has settled.

17 (28). Gravel pits in outwash near Cary.

21 (33). Exposure of Valparaiso till.

35 (57). Back slope of Arlington Heights moraine [69], the innermost member of the Valparaiso morainic system.

LAKE BORDER MORAINIC SYSTEM

The Lake Border morainic system consists of four moraines, nearly parallel to the west shore of Lake Michigan. They extend southward into the Lake Chicago plain, where they terminate and give way to beach ridges. They were deposited during the early stages of glacial Lake Chicago. The outer moraine is bordered by the Des Plaines valley train.

46 (73). Beach of Lake Chicago [70], developed on inner slope of outermost Lake Border moraine. The rest of the route, about 12 miles (19 kilometers), through the city of Chicago to the starting point of the tour, crosses the Lake Chicago plain.

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