CHAPTER II

PHYSICAL FEATURES AND CLIMATE OF SOUTHEASTERN WISCONSIN

The region with which this bulletin deals is a small part of the great central valley of the United States—an extensive plain most of which belongs to the basin of the Mississippi, but a small part of which is included in the drainage basin of the Great Lakes. The rain falling upon eastern Wisconsin finds its way both to the Gulf of Mexico and to the Gulf of St. Lawrence.

Geology of the Region

Deposition of sediments. The land of southeastern Wisconsin shares with the rest of the central plain of the United States a geological history that reaches far back into the past. More than once the waters of the sea have covered this plain, at times joining the Gulf of Mexico to the Arctic Ocean. For a part of the time at least they were warm waters, as revealed by the fact that colonies of coral-building polyps built extensive coral reefs which now make up parts of the limestone of eastern Wisconsin. The region was covered by the sea for an enormous length of time, as is indicated, for example, by a sandstone formation which is nearly a thousand feet thick; and a limestone formation which was probably built up very slowly, that is 300 or 400 feet thick. The evidence is conclusive that this corner of Wisconsin, like the region for hundreds of miles around, was under the sea and was receiving sediments brought from the land by streams for a very long period of time.

Uplift. Later, an uplift of this sea bottom occurred and the upper beds of sand and limy material—compacted into rock—were raised hundreds of feet above sea level and became part of the continent of North America. The great interior sea, which connected the Gulf with the Arctic Ocean, was forced to recede, and land took its place. But the uplift was relatively gentle, for the rocks still lie in nearly horizontal beds. This uplift took place a very long time ago, and a large proportion of the uppermost beds has been weathered and eroded away.

The history of the rocks underlying the region of southeastern Wisconsin, therefore, includes three principal events, each of long duration: (1) the deposition in the sea of the various kinds of sediments (sand, clay, limestone) which were slowly cemented into beds of solid rock; (2) the uplift of these above sea level, and (3) the prolonged weathering, erosion, and removal of the surface rocks, considerably reducing the general level of the land. This is the series of events through which practically all of the land surface of the earth has passed at one time or another, and, in many cases, several times.

In addition to these three processes, southeastern Wisconsin has passed through a fourth experience, namely, glaciation.

The Glacial Period

The most recent of the great geological events in North America was the glaciation of more than half of the continent. For some cause, yet unknown, the climate of northern North America became cold—probably as cold as southern Greenland is at present. The precipitation which now falls mainly as rain then fell in the form of snow, and even the summers were so cold that this snow did not all melt, but accumulated in enormous quantities. The piling up of the snow was particularly great in Canada, including Labrador and the region west of Hudson Bay, the centers from which the glaciers moved outward. Year after year and century after century the snow continued to accumulate here and in northern Europe, and also in the higher mountains all over the world. The snow on both sides of Hudson Bay is believed to have become several thousand feet deep. Its own weight, and possibly slight melting in summer, compressed the snow into ice, and under the tremendous weight of this ice the bottom layers were so pressed upon that they were forced to flow outward—especially southward where the temperature was milder and where melting along the margin of the glacier took place during the warmest months of the year. The movement of the glacial ice was very slow, possibly only a few yards or a few rods a year, as is now the case with the great glacier which covers Greenland.

Soil and loose rocks became frozen into the glacier and were slowly moved along with it. The glacier moved over hills and low mountains, through valleys and across plains, removing everything that was movable, scouring and grinding the rocks over which it passed, deepening some valleys, rounding off

hills and other eminences, and carrying along a prodigious amount of rock waste in the form of clay, sand, rock fragments and bowlders. Much of this debris was ground fine and forms the present soil. The hardest rocks resisted the grinding and are now found scattered over the surface of the ground as glacial bowlders, some of which weigh many tons.

In Canada the work of the glacier consisted mainly in the removal of all loose material. There large areas are almost entirely bare rock whose grooved and polished surfaces

Fig. 4—View of the surface of the Kettle Moraine which extends nearly north and south in eastern Wisconsin. It consists of hills of glacial drift attaining a height of 200 feet and more, and forming a range of hills from one mile to several miles wide. See Fig. 5.

show plainly the prolonged scouring action of the glacier. In the region now included in our northern states the ice did some eroding, but its most important work was that of *deposition.* The load of rock waste which the ice carried was spread unevenly over the surface of our northern states and now forms the soil and many of the hills of these states. As time is reckoned in geology the glacial period ended only yesterday. Many evidences suggest that the glacier melted away in southern Wisconsin not over 50,000 to 60,000 years ago, by no means a long time. The glacial period, as a whole, lasted hundreds of thousands of years. It was not a time of continuous cold, however, but rather an alternation of several cold periods—

during which the snow accumulated and the ice moved southward—and warmer, interglacial periods, during which the ice melted and the southern margin of the glacier receded toward the north—at least receded from the section of the continent including Wisconsin.*

The Origin of Lake Michigan

Lake Michigan and the other Great Lakes did not exist before the Glacial Period. The basin now occupied by the waters of Lake Michigan was a former river valley which was later deepened and broadened by glacial erosion. Before the Glacial Period a river of considerable size is believed to have flowed southward through this valley to join the Mississippi, and this valley offered an easy path of movement for the ice. There is complete evidence that one of the principal lobes of the great continental ice sheet occupied it, and that a great deal of glacial ice traversed the valley from north to south. A smaller lobe passed southward through the valley in which Green Bay and Lake Winnebago now lie. Other lobes of the glacier traversed the basins now occupied by the other Great Lakes, and deepened them by erosive action. (Figs. 6 and 7.)

Rivers do not erode their channels very much below sea level, but the bottom of Lake Michigan is, in the deepest place, nearly 300 feet below. The shape of the depression now occupied by the lake is exactly what we should expect of a basin deepened by ice erosion. There is good reason for believing that the glacier, by eroding the rock, deepened the old river valley to the extent of 500 to 900 feet† and thus made the rock basin in which Lake Michigan is now held.

Another phase of the work of the glacier also helped to make Lake Michigan. When the glacier melted, it released a large amount of clay, sand, and stones which it carried, and laid them down in the form of moraines. The most conspicuous of these are the terminal moraines which were built up along

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* For further discussion of this subject see the following:

Martin, Lawrence, The Physical Geography of Wisconsin, Wis. Geol. & Nat. Hist. Surv. Bull. XXXVI, pp. 221–254; also consult index.

Alden, W. C. The Quarternary Geology of Southeastern Wisconsin, U. S. Geol. Survey Professional Paper 106 (1918), Chaps. V–XI.

Alden, W. C. The Delavan Lobe of the Lake Michigan Glacier, U. S. Geol. Survey Professional Paper 34 (1904).

† For fuller details see Martin, Lawrence, Physical Geography of Wisconsin, Wis. Geol. & Nat. Hist. Survey, Bull. XXXVI, pp. 222–238.

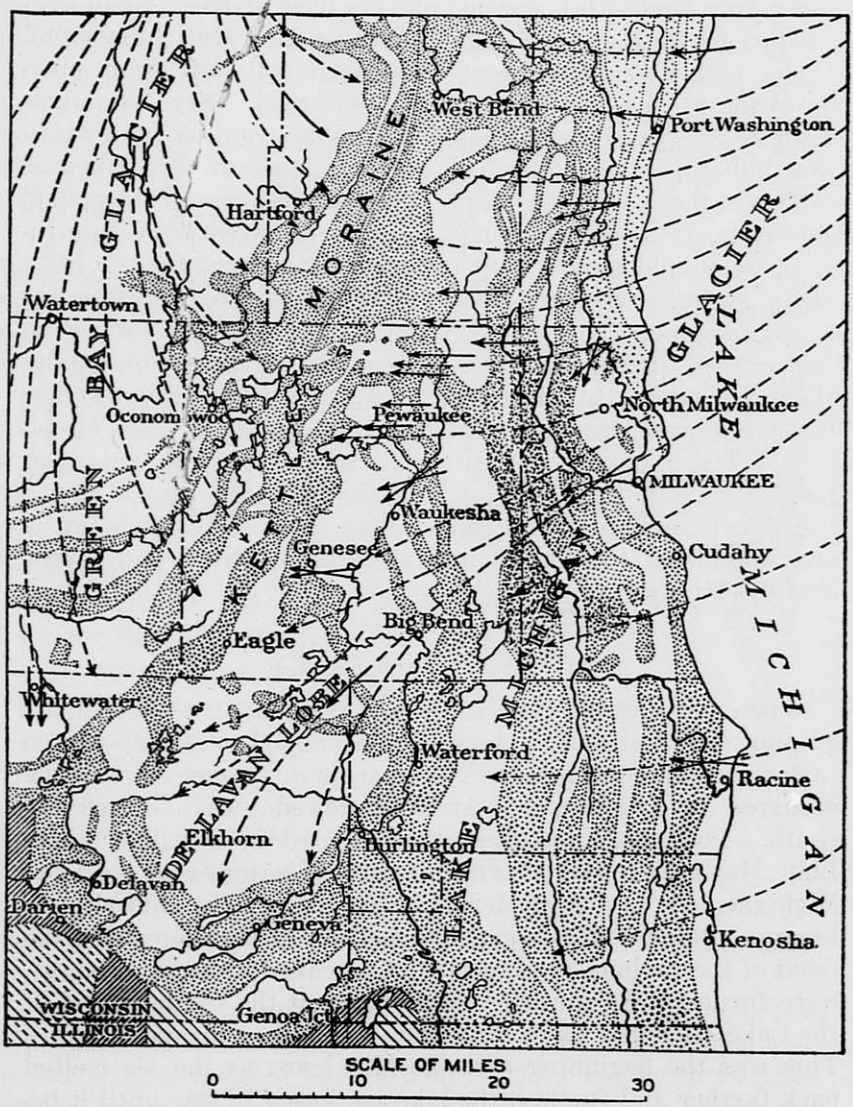

Fig. 5—Map showing the position of the glacial moraines in southeastern Wisconsin. Arrows indicate direction of ice movement and dotted arrows are the moraines. The Kettle moraine is the most conspicuous of these. (See also Figs. 4 and 47.)

the margin of the glacier when the ice front stood in one place for a long time, while the ice and its load of rock waste kept pushing forward and melting along this nearly stationary front. Under such a condition great heaps of glacial drift† were piled up in the form of mounds and hills (Fig. 4). Several ranges of these hills extend north and south in the counties with which this bulletin deals (Fig. 5). In fact, most of the hills and valleys in these counties are due to the unevenness of the glacial deposits. If the glacial drift were all removed from this region, we should have a very different landscape; for the hills, lakes, swamps, and prairies with which we are now familiar would be gone. There is scarcely a feature of the surface of the ground in southeastern Wisconsin which is not due to glaciers—mostly to glacial deposition. Fig. 5 shows how these moraines extend parallel to the shore of Lake Michigan. The extensive deposits of drift prevent the waters of Lake Michigan from draining southward. By means of the Chicago Drainage Canal, some water from Lake Michigan is now conducted southward into the Illinois River and thence into the Mississippi.

Lake Michigan in the Past

When the glacier advanced from the north, an arctic climate gripped this region, and the streams changed to ice and ceased to flow. Yet, along the southern margin of the glacier, melting occurred in summer, and streams flowed away toward the south. The river that flowed southward in a valley where Lake Michigan now is, carried away the water from the Lake Michigan lobe of the glacier (Fig. 6). When the cold climate became milder, and the gradual melting of the ice caused the front of the various lobes to retreat, so-called "marginal lakes" were formed. Such a lake was formed at the southern end of the Lake Michigan basin; it is known as Lake Chicago (Fig. 6). This was the beginning of Lake Michigan; as the ice melted back farther and farther, the lake increased in size until it became even larger than at present. During this period of enlargement, the lake had different outlets at different times. When the outlet was at Chicago, the lake surface stood at a somewhat higher level than the present surface of Lake Michigan, and low lands along the present margins of the lake were

† Glacial drift is the term applied to all kinds of rock waste deposited by glaciers when they melt. It is made up of clay, sand, gravel, bowlders, etc.

then covered by water.* The present sites of Chicago, Kenosha, and Racine, and the lowest ground in Milwaukee were all covered by the waters of Glacial Lake Chicago (Fig. 8).

At a later stage, the waters of Lake Michigan, along with those of the other Great Lakes, drained eastward to the Atlantic through New York State by way of the Mohawk and Hudson rivers. At other times other outlets were used (Figs. 6 and 7).

Evidences of the different levels at which the surface of Lake Michigan has stood are seen in the wave-cut cliffs, the long sand and gravel beaches, extending parallel to the present lake, and particularly in the shoreline of Glacial Lake Chicago still plainly visible in Kenosha and Racine counties (Fig. 8). This old shore line extends north and south through the western part of the city of Racine and is a little west of the city of Kenosha. On an average it is from one to two miles west of the present shore of Lake Michigan. The strip of land lying between the present lake and the old shore line of Lake Chicago is quite level.

This brief sketch of the history of Lake Michigan brings together the following facts that have been established by the field study of many geologists:

(1) Prior to the glacial period, there was a river which flowed southward to the Mississippi in a valley now occupied by Lake Michigan.

(2) This valley was further eroded to a depth of several hundred feet by a lobe of the great continental glacier.

(3) The gradual melting of this ice lobe at the southern end gave rise at first to a small lake near the present city of Chicago which increased in length as the ice lobe melted farther and farther back.

(4) This lake at one time drained southward through the Chicago, Desplaines, and Illinois rivers to the Mississippi; and at other times drained eastward by various routes to the Atlantic.

(5) This lake, at its highest stage, rose to a level 55 feet above the present surface of Lake Michigan, submerging the low land along its margin including the present sites of Chicago, Kenosha, Racine, and part of Milwaukee.

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* The surface of Lake Chicago was not at the same level at all times. At the highest (Glenwood) stage, it was 55 feet, and at the lowest, 23 feet above the present level of Lake Michigan.

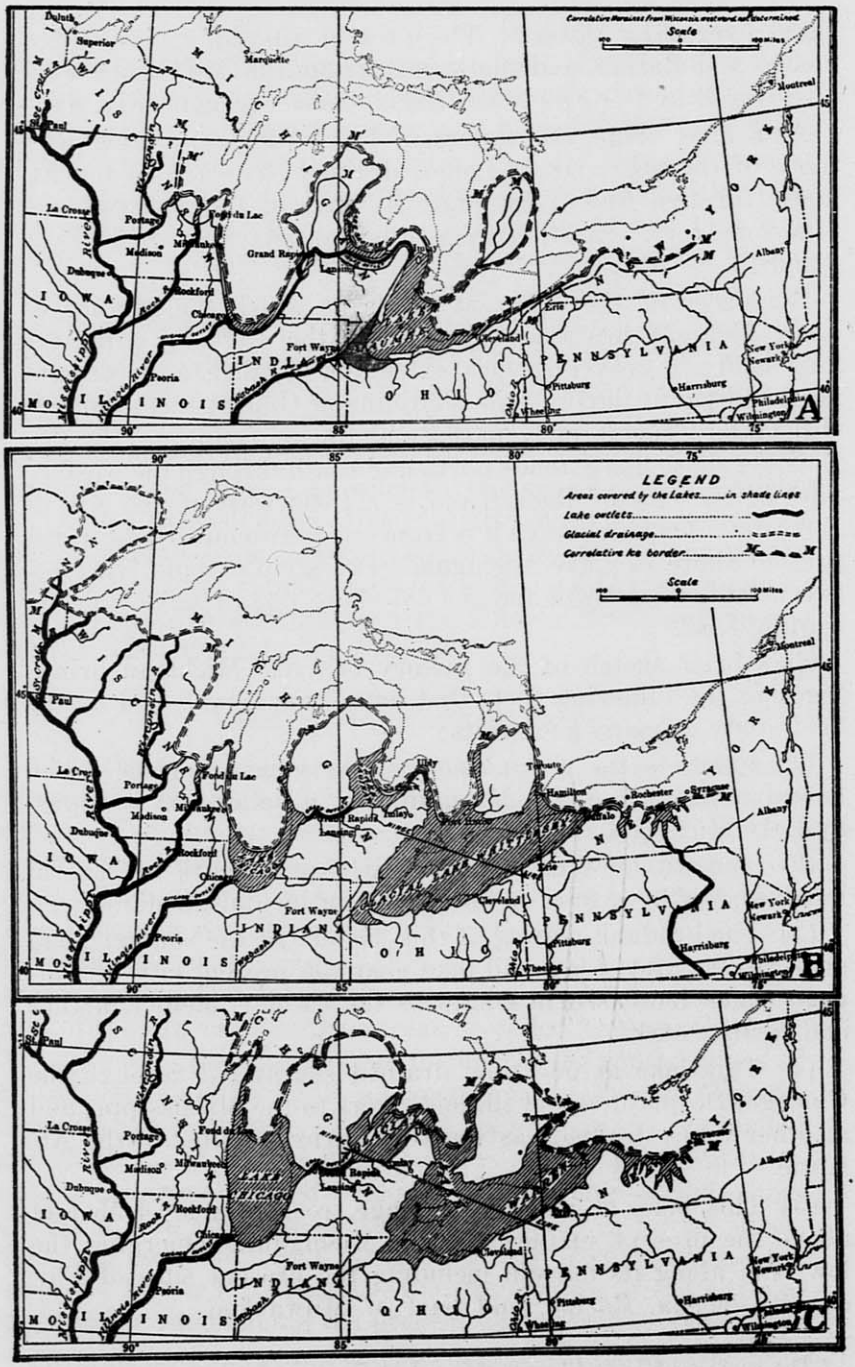

Fig. 6—Position of the glacial lakes at various stages in the development of the Great Lakes. Different outlets were used at different stages. Note the increase in the size of the lakes as the ice-front retreated northward. (Taylor and Leverett.)

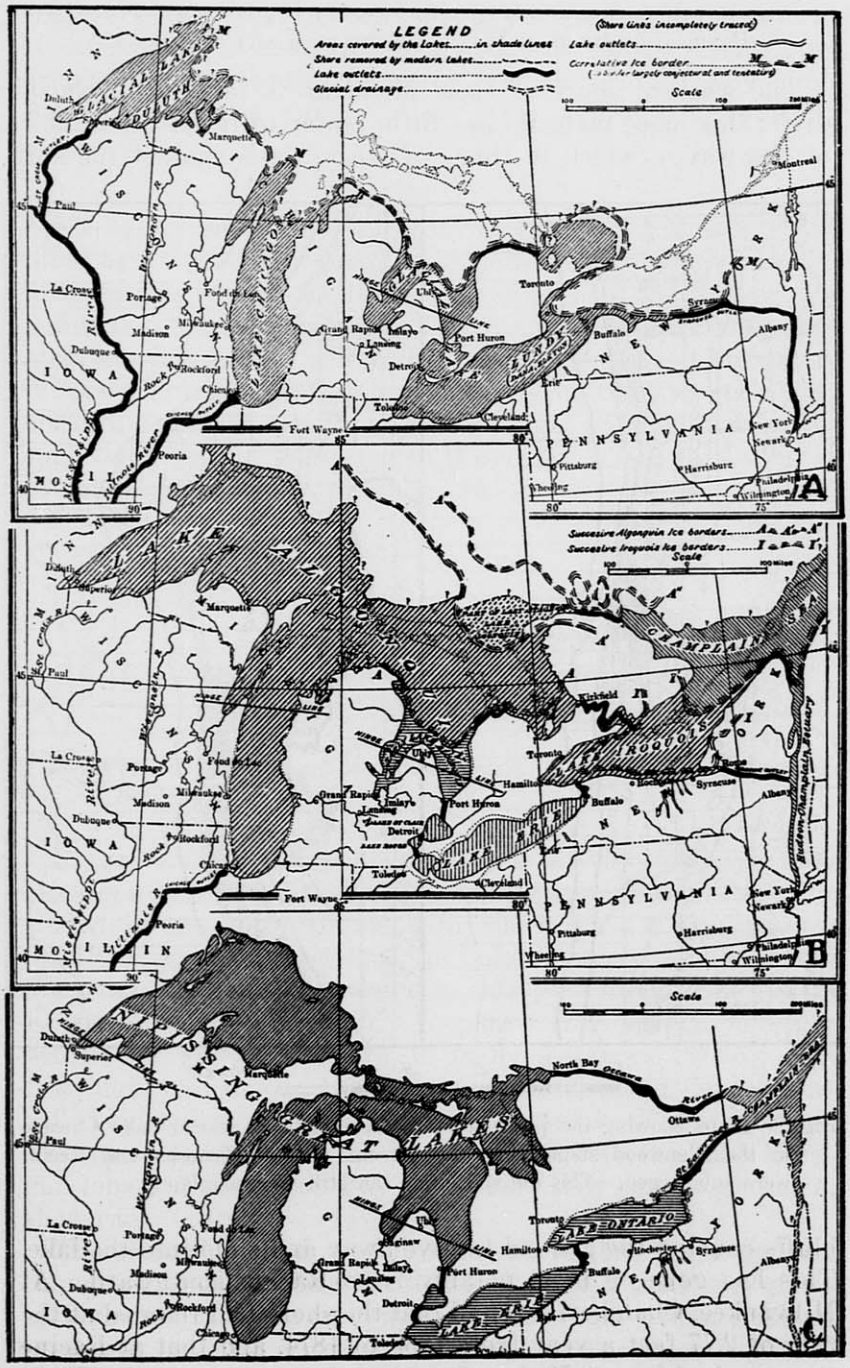

Fig. 7—The Great Lakes at later stages than those shown in Fig. 6. (Taylor and Leverett.)

Recession of the West Shore of Lake Michigan

The western shore of Lake Michigan is formed of glacial drift: this loose material has little power to resist the attacks of the waves, which in times of storm dash against the soft

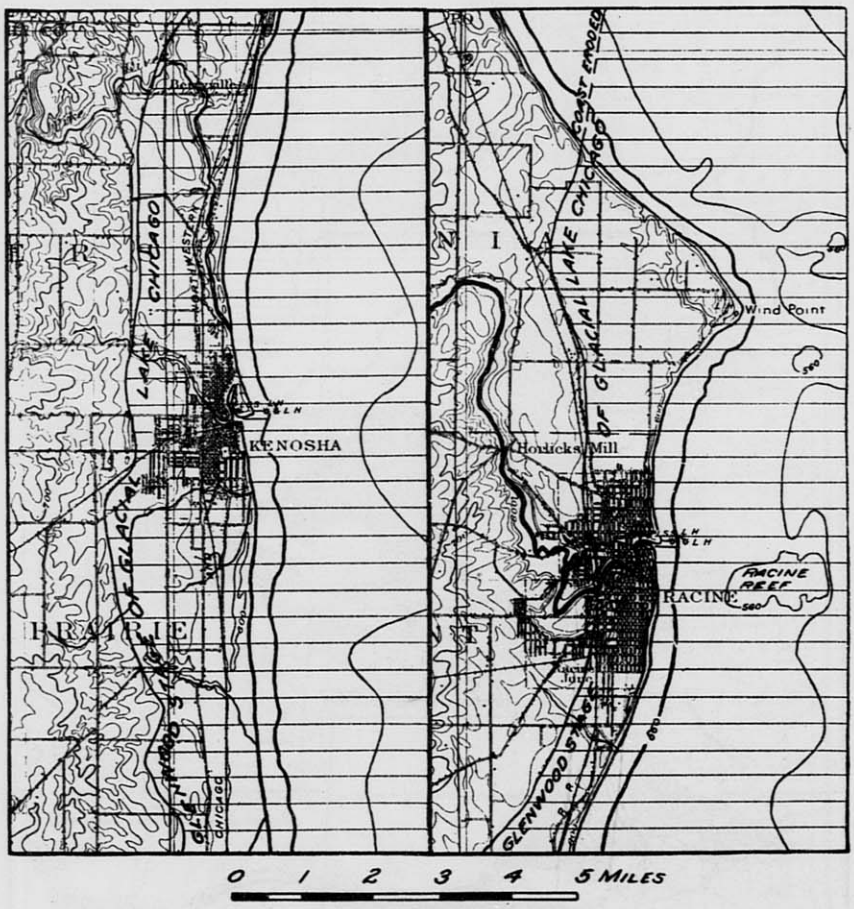

Fig. 8—Maps showing the position of the shore line of glacial Lake Chicago at the Glenwood stage when the present sites of Kenosha and Racine were submerged. This old shore line can still be seen plainly.

bluffs causing the ground to give away and slide into the lake. This has gone on most notably from Racine southward. At Milwaukee, Chamberlin found that the shore had receded at the rate of 2.77 feet a year from 1835 to 1874, and that at Racine the rate had been 9.73 feet for 24 years.* A report by U. S.

* Chamberlin, T. C., Geology of Wisconsin, Vol. II, p. 231.

engineers states that the recession of the coast at Racine was at times as much as 12 to 16 feet a year. At Racine efforts have been made to prevent further erosion of the shore line by building a concrete sea wall.†

Glacial Deposits

All of southeastern Wisconsin is covered with a variable thickness of glacial deposits of various sorts. Before glaciers invaded this region, the bed rock was covered with a layer of residual soil. Southwestern Wisconsin, which was not glaciated, has this kind of soil, called *residual* because it lies where it was originally formed by the decay of the bed rock. By observing surface conditions there, we get an idea of what the conditions were in southeastern Wisconsin before they were so completely changed by the glaciers.

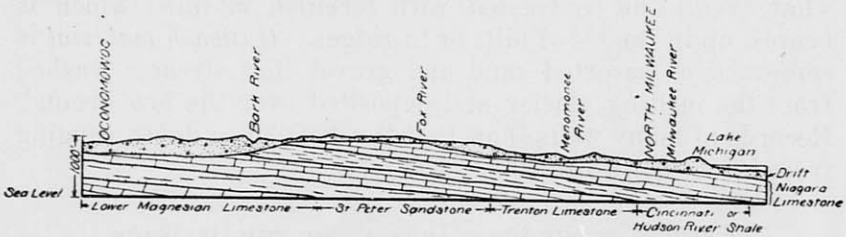

Fig. 9—The underlying rock-layers of eastern Wisconsin dip toward Lake Michigan.

Figure 5 shows that both the Green Bay lobe and the Lake Michigan lobe invaded this part of the state, but the area included in the five counties with which we are dealing was mostly covered by the ice of the Lake Michigan lobe. By far the most conspicuous moraine in this part of the state is the Kettle Moraine (Fig. 4). In places it is several miles in width; the glacial hills are, in many instances, 200 or more feet high, and among them are many undrained depressions, called kettle holes, whence came the name, the *Kettle Moraine*. This moraine is built of the deposits from both the Lake Michigan lobe and the Green Bay lobe where they came together as shown in Figure 5.

The Glacial Period was brought to an end by a gradual change of climate. The glaciers had pushed their way about as far south as the present Ohio and Missouri rivers, although

† See Alden, Wm. C., Professional Paper 106, U. S. Geological Survey (1918) pp. 338–340.

the last advance of the ice did not extend so far south as earlier advances had done. As the ice along the margins of the various lobes melted, terminal moraines were built up. As already explained, these moraines are ranges of hills of glacial drift extending for miles over the surface of the country; they mark the positions where the ice-front halted for a time, while ice from the rear advanced, melted, and dropped its load of drift. At least four ranges of these low, inconspicuous morainic hills extend in roughly parallel lines north and south across Kenosha and Racine counties (Fig. 5). Similar, but more confused, moraines exist in all of southeastern Wisconsin and cover nearly all of the five counties treated in this bulletin (Fig. 5). Between the terminal moraines are more or less level areas of *ground moraine* and of *outwash material.* The *ground moraine* is glacial drift that has been spread out somewhat evenly, as contrasted with *terminal moraine* which is heaped up in ranges of hills or in ridges. *Outwash material* is composed of assorted sand and gravel that streams washed from the melting glacier and deposited over the low ground. Records of many wells show that the drift has a depth ranging from a foot or two to 400 or 500 feet.

Effects of the Drift Deposits on the Drainage

The numerous lakes and swamps in southeastern Wisconsin are due to interference with the drainage caused by glacial deposits. In southwestern Wisconsin, which was not overspread by glaciers, there are no lakes and practically no swamps except small ones near streams. This same condition existed in southeastern Wisconsin before the Glacial Period; but after the glaciers had melted away, leaving the surface of the land covered with heaps and ridges of drift, the streams found their old channels, in some places, choked by moraines, and, in others, completely filled. In many localities the drift deposits formed dams across the valleys of the streams thus causing lakes. The deeper lakes still continue, but many of the shallow ones have been gradually filled by sediments and by vegetation, and have become swamps. However, not all of the present swamps were former lakes; probably the majority of them have been swamps from their beginnings. Between twelve and fifteen per cent of this area is covered with lakes, swamps, or land that has been swampy. Many of the lakes occupy depressions in the drift.

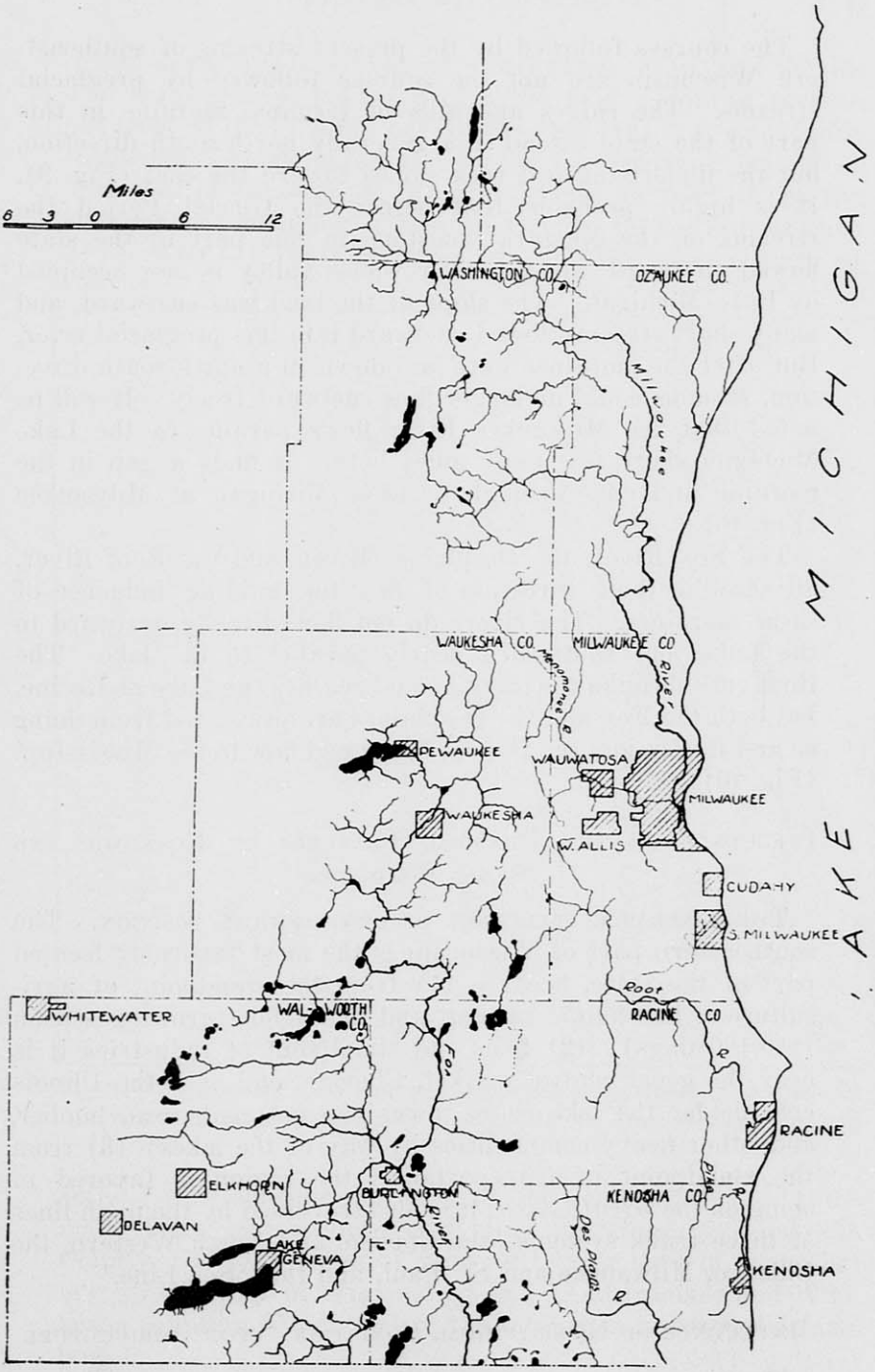

Fig. 10—Streams of southeastern Wisconsin which flow to Lake Michigan and to the Illinois River. Streams west of these flow to the Rock River and thence to the Mississippi. The divide between the two drainage systems consists of glacial moraines (see Fig. 5).

The courses followed by the present streams of southeastern Wisconsin are not the courses followed by preglacial streams. The ridges and hills of terminal moraine in this part of the state extend in a generally north-south direction, but the underlying bed rock slopes toward the east (Fig. 9). It is highly probable that before the Glacial Period the streams on the Niagara limestone in this part of the state flowed eastward into the river whose valley is now occupied by Lake Michigan. The slope of the land was eastward, and many short streams flowed eastward into this preglacial river. But after the moraines were laid down in a north-south direction, streams could no longer flow eastward freely. It will be noted that the Milwaukee River flows parallel to the Lake Michigan shore for many miles before it finds a gap in the moraine and cuts through to Lake Michigan at Milwaukee (Fig. 10).

The Fox River, the Desplaines River, and the Root River, all show in their direction of flow the guiding influence of these moraines. The rivers do not flow directly eastward to the Lake, but southward nearly parallel to the lake. The Root cuts through the moraine and reaches the Lake at Racine, but both the Fox and the Desplaines are prevented from doing so and finally join the Illinois River and flow to the Mississippi (Fig. 10).

Influence of the Physical Features on Economic and Social Conditions

The favorable influence of geographical position. The southeastern part of Wisconsin is the most favorably located part of the state, because (1) from the standpoint of agriculture it has ample rainfall and has a long growing season (150-160 days); (2) from the standpoint of industries it is near the great central market, Chicago, and near the Illinois coal fields; the lake shore towns can get coal, iron, lumber, and other heavy commodities by way of the lakes; (3) from the standpoint of transportation the region is favored in being on the Great Lakes; it is also traversed by the main lines of three trunk systems—the Chicago and North Western, the Chicago, Milwaukee and St. Paul, and the "Soo Line."

Influence of Geographical Conditions upon Agriculture

The favorable influence of surface features. The region has neither mountains nor high hills, and bare rock prac-

tically never appears; soil is everywhere deep and fertile. The many glacial moraines give the land a rolling surface, but most of the hills are not so steep but that they are readily cultivated. Small patches of woods are frequent, mainly on land that is unfavorable for cultivation. In four of the five counties, not including Milwaukee County, 90 per cent or more of the land is farm land. The cities of Milwaukee County oc-

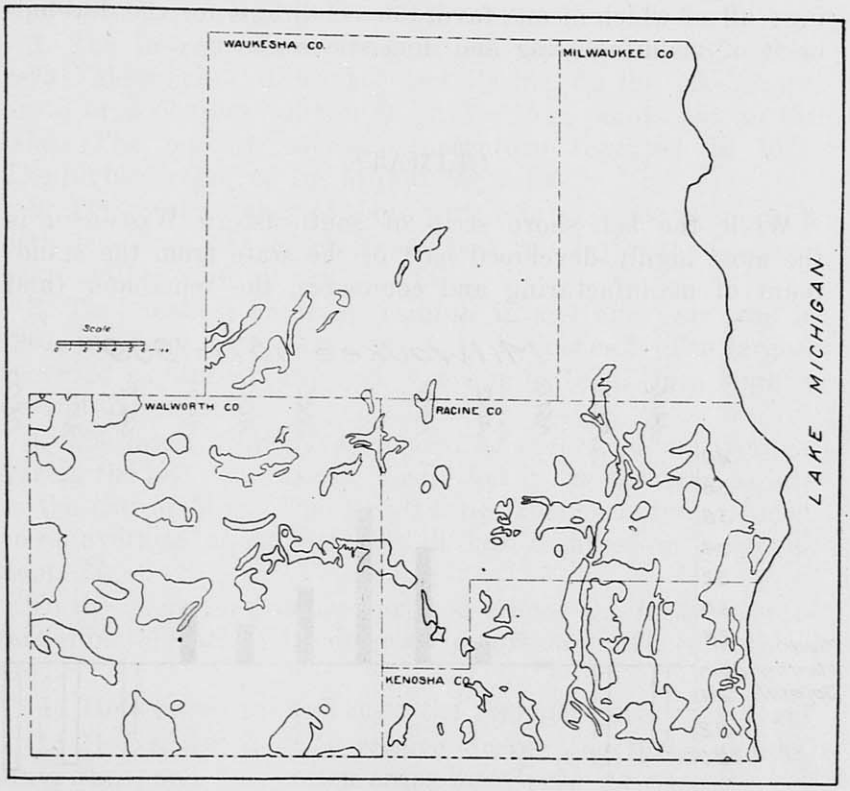

Fig. 11—The enclosed areas represent the principal "prairies" in southeastern Wisconsin as shown on a map published by the State Geological Survey in 1876.

cupy a very considerable area of the county. Owing to the many lakes and swamps and steep moraines in Waukesha County, the percentage of improved farm land is somewhat low for this part of Wisconsin. In both Milwaukee and Waukesha counties, 65 per cent of the total area is improved farm land.

Both the undulating surface and the rather high percentage of wet land encourage dairy farming, and these counties are among Wisconsin's leading dairying counties.

Railroads have found easy routes in all parts of the region, for there are no difficult grades or serious obstructions. Of the 59 townships in the five counties, 52 have railroads passing through them; four of the townships that have no railroads are in Walworth County. There is no township in either Waukesha or Milwaukee county without a railroad.

Taken as a whole, the region has a favorable topography for agriculture, for road construction, and for railway building; all of which means favorable conditions for the development of manufacturing and domestic commerce.

CLIMATE

While the lake-shore strip of southeastern Wisconsin is the most highly developed part of the state from the standpoint of manufacturing and commerce, the remainder (and

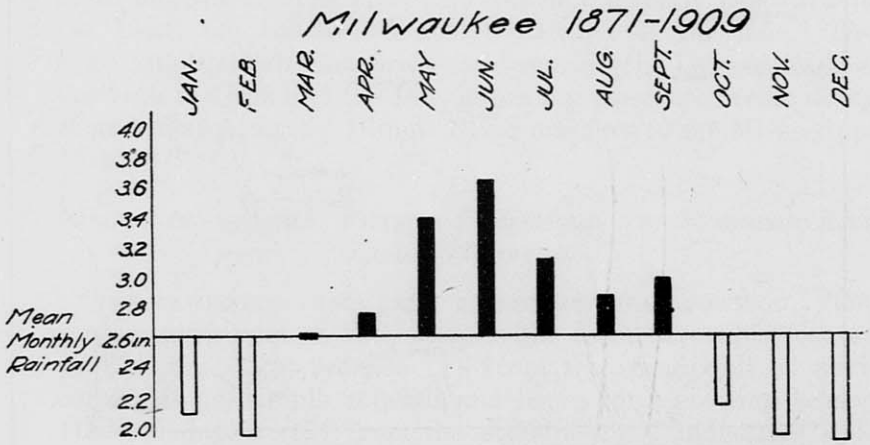

Fig. 12—Diagram showing the average monthly rainfall (in inches) at Milwaukee. Note that the spring and summer months have more than the mean, and the winter months less than the mean. This is highly favorable to agriculture.

the larger part) of the region is distinctly agricultural. The high degree of prosperity and the high level of wealth which characterize this section are the direct outgrowth of agriculture and dairying, which in turn, are intimately related to climate. If a region receives much less than 20 inches of rainfall a year, agriculture is seldom successful without artificial irrigation. Southeastern Wisconsin averages about 30

inches, and a complete crop failure on account of drought has never occurred. However, summers are sometimes too dry for the maximum production of crops, and it is probable that most summers have a period which is too dry for the highest welfare of crops. Occasionally the season or some part of it is too wet, as may be judged from Fig. 13.

SUMMARY OF CLIMATIC DATA covering the five southeastern counties of Wisconsin (Milwaukee, Waukesha, Racine, Kenosha, and Walworth).

1. The lowest official temperature reported is 28° below zero Fahrenheit. Milwaukee and Racine, on the lake shore, are 3 or 4 degrees warmer in winter than points not on the lake. The highest official temperature reported is 107°. The highest reported for Milwaukee is 100°.

2. The total number of days with rain or snow averages a little less than 100, which means that 265 days out of a year have neither rainfall nor snowfall.

3. The smallest recorded rainfall in any one year was in 1901, in which year there were only 17 inches.* The largest recorded rainfall in any one year was in 1876, when slightly over 50 inches fell†.

4. The latest killing frost in spring occurs, on an average, during the last few days of April; but it has occurred as late as the end of May. The first killing frost in autumn comes, on an average, about Oct. 12; it has occurred as early as Sept. 22.

To the men who produce our food crops—the farmers—certain climatic matters are of great importance. Three of these are:

(1) How much rainfall does the region receive in a year?

(2) How much does it receive during the three months, May, June, and July, when crops most need it?

(3) Is the rainfall during these months dependable, or does the amount fluctuate widely in different years?

Answer to No. 1. On an average, the farmer of southeastern Wisconsin can count upon 30 inches of rainfall a year. This is ample for crops if a sufficient proportion of it falls in the growing season (May, June, July).

Answer to No. 2. On an average southeastern Wisconsin receives slightly over 10 inches of rain during these three

* At Waukesha.
† At Milwaukee.

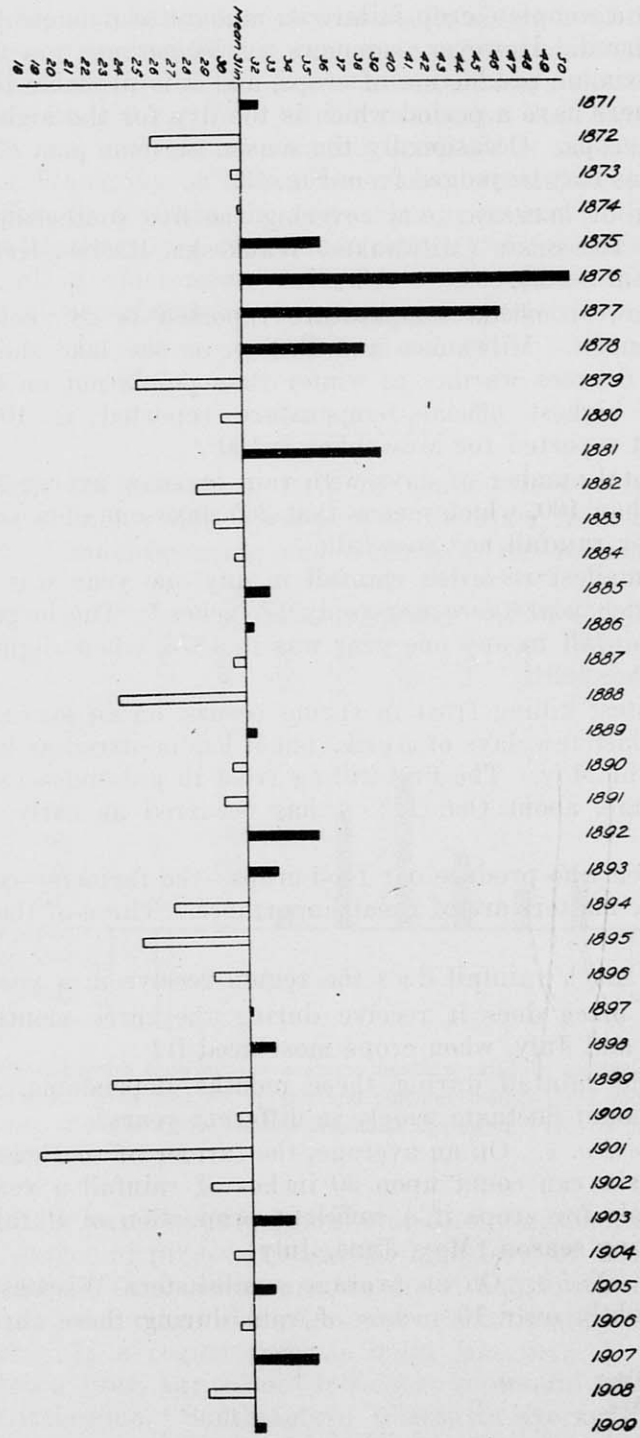

Fig. 13—Diagram showing the wide fluctuations in the annual rainfall of southeastern Wisconsin. Such a large rainfall as that of 1876 or 1877, and such a small rainfall as that of 1899 or 1901 are bad for agriculture.

months. If this is well distributed throughout the time, it is ample for crops, in fact nearly ideal.

Answer to question No. 3. The rainfall during these three months is *not* entirely dependable. Fortunately, May, June, and July are, on an average, the three rainiest months of the year, yet there is a very wide fluctuation in the amount of rainfall. Taking Waukesha County as an example, in July, 1902, nearly nine inches of rain fell; while in July, 1909, less than one-half of one inch fell.

If any of the three critical months (May, June, July) has less than 1 inch of rain, crops suffer seriously; or if the average for the three months is less than 6 inches, crops generally suffer. How often may either one of these two unfavorable conditions be expected to occur? The records of the U. S. weather bureau indicate that *on an average* about once in six years this serious deficiency of rainfall may be expected (Fig. 13). If the records are reliable, Racine County has suffered most frequently, and Walworth County least frequently from this deficiency of rainfall. However, the farmers of this section of Wisconsin have learned to diversify their crops so that anything like a complete crop failure is not known.

TABLE 1—CLIMATIC DATA

	Delavan	Milwaukee	Racine	Waukesha
Smallest annual rainfall recorded	26.87 in.	18.69 in.	20.00 in.	17.00 in.
Largest annual rainfall recorded	41.39 in.	50.36 in.	36.06 in.	38.30 in.
Mean annual rainfall	31.43 in.	31.19 in.	29.51 in.	28.96 in.
Number of years below the mean	6	23	6	9
Number of years above the mean	5	16	7	8
Lowest recorded temperature	—28°	—25°	—24°	—27°
Highest recorded temperature	101°	100°	107°	102°
Mean annual temperature	46°	45.6°	47.3°	45.9°
Average number of days with rain (.01 in. or more)	81	128	89	101
Average date of first killing frost in autumn	Oct. 16	Oct. 7	Oct. 13	Oct. 12
Earliest recorded killing frost in autumn	Sept. 22	Sept. 25	Sept. 30	Sept. 24
Average date of last killing frost in spring	April 20	April 28	April 28	April 28
Latest recorded killing frost in spring	May 31	May 29	May 31	May 31