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GEOLOGY OF THE GRAND CALUMET RIVER REGION

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ABSTRACT. The geology of the Calumet River region is briefly reviewed to provide a background for applied research in the area. The review relies heavily upon research conducted by scientists affiliated with the Indiana and Illinois Geological Surveys. At the end of the Late Wisconsinan glacial epoch, fluctuations in the Lake Michigan Lobe of the Laurentide Ice Sheet resulted in the formation of three moraine systems around the south end of the Lake Michigan basin: in decreasing age, the Valparaiso, Tinley and Lake Border ridges. High stands of ancestral Lake Michigan (also known as glacial Lake Chicago) are named the Glenwood, Calumet and Algonquin high phases that formed when the north end of the basin was blocked by ice. Retreat of the glacier from the basin caused the lake level to drop during the Two Creek low phase. The Chippewa low occurred at the beginning of the Holocene when ancestral Lake Michigan was as much as 107 m below modern levels. Lake level then rose in response to isostatic rebound of the outlet in southern Ontario until the Nipissing high was reached about 5000 years ago. At this time, the Toleston Beach in northern Indiana and Illinois was developing as a complex of sand dunes and more than 100 beach ridges. The Grand Calumet River came into existence about 2600 years ago as spits deflected the Little Calumet River eastwards upon closure of the Sag channel. Eastward migration of the Grand Calumet River ceased when the coastline was modified following European settlement in the late 19th century.

Keywords: Indiana, Lake Michigan, Grand Calumet River, geology

The geology of the Grand Calumet River region (hereafter referred to as 'the region') is closely tied to glacial events that began about 1,600,000 years ago. During the Pleistocene epoch ($\approx$1,600,000–10,000 years ago) the region was impacted by numerous glacial advances and retreats. Because successive glacial advances destroyed the evidence of previous advances, the number of glaciations is unknown. The presence of older glacial sediment throughout the Midwest beyond the limit of the late Wisconsinan glaciation (Fig. 1), which peaked about 20,000 years ago (Mickelson et al. 1983), is testament to earlier, more extensive glaciations. In the region there appears to be sedimentary evidence for only the most recent glacial episode (Brown et al. 1996), although there may be some uncertainty about this. The geology of the region is by no means only a result of glacial erosion and sedimentation. Much of the sediment in the region was deposited as littoral sand or offshore mud from various levels of glacial Lake Chicago and mid-Holocene age Lake Michigan. The variable levels of these lakes developed in response to the presence of ice in the Lake Michigan basin and isostatic rebound in Ontario.

Time (radiocarbon dates) within the text older than 6300 ybp (years before present [1950]) is in radiocarbon years, while dates younger than 6300 ybp are reported in calendar ybp.

GLACIAL AND GLACIAL LAKE HISTORY

The region is underlain by sediment deposited by glaciers and glacial lakes. The Grand Calumet River is located on lacustrine sediment of the Toleston Beach that is less than 6300 years old, which in turn lies upon older glacial, and finer-grained glaciolacustrine sediment. The distribution and character of this older sediment is best understood by linking the history of the recessional ice margin with glacial lakes in the Lake Michigan basin.

During the last ice age, known as the Wisconsinan in the Midwest, the Laurentide Ice Sheet advanced across much of Indiana, Illinois, and Ohio (Fig. 1); and the maximum extent of ice was reached about 20,000 ybp. Across Indiana, there are series of recessional moraines that record stationary ice-margins (Gray 1989) composed of glacigenic material (sand, gravel, and till). By about 14,000 ybp

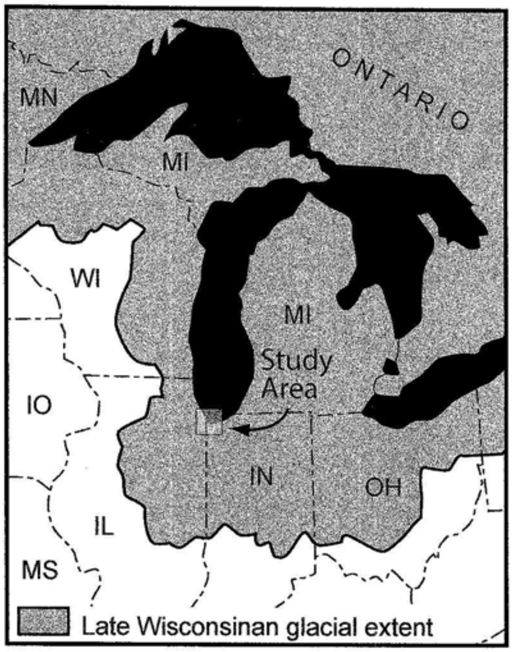
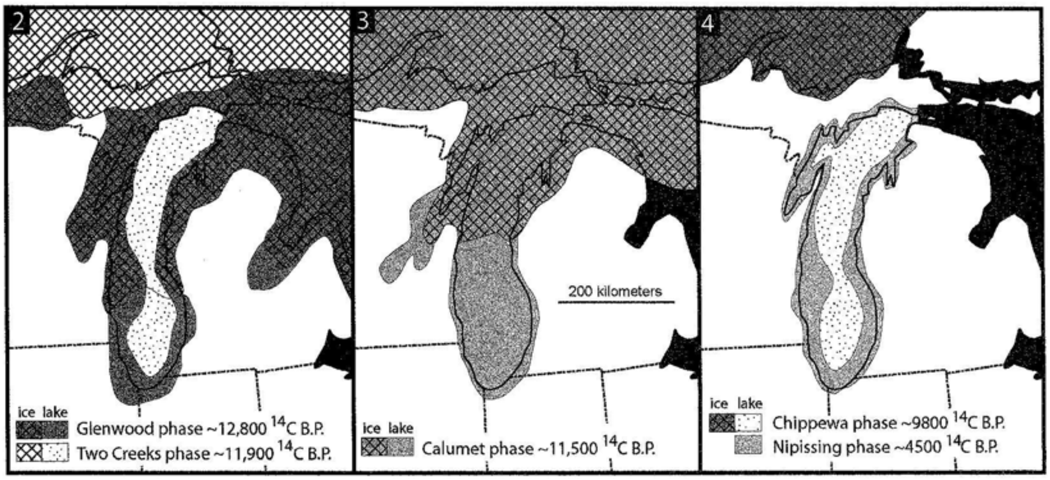


Figure 1.—Location of the Grand Calumet River region at the southern end of Lake Michigan, and the extent of Late Wisconsinan glaciation in the Great Lakes region.

(Hansel et al. 1985) much of the Laurentide Ice Sheet was confined to the Great Lake basins, giving a lobate pattern to the ice margin (e.g., Fig. 2). The Valparaiso Moraine wraps around the southern end of Lake Michigan, extending into Michigan and Wisconsin; and in Indiana, the moraine forms the sub-continental drainage divide between the St. Lawrence and Mississippi drainage systems. Set inside the Valparaiso Moraine are two other recessional moraines known as the Tinley and Lake Border Moraines. All three ridges were likely deposited in a short period of time around 14,000 ybp by successive and less extensive readvances (Fig. 5). Glacial lakes formed between the ice and the ridges as the glacier receded northwards, opening up the lake basin. Because the glaciers were in lake basins, they rested on fine-grained sediment well-lubricated with water, and this low-resistive state (Clarke 1987) likely aided the glaciers ability to respond quickly to variations in climatic conditions and/or glaciologic controls. These responses are illustrated in Figs. 2–4, where four different positions of the ice margin are illustrated. The dated phases are averages and simplifications. For example, the Glenwood phase has been interpreted to consist of two separate advances with a low-lake phase between them (Hansel et al. 1985). Figures 2–4 are designed to provide the reader with only an overview of late-glacial events.

When the Lake Michigan lobe of the Laurentide Ice Sheet occupied the lake basin, the Straits of Mackinac were blocked by ice. Glacial Lake Chicago was dammed by the glacier (hence the term: glacial lake) and the outlet



Figures 2–4.—Position of lake levels (phases) as controlled by ice margins. Note that lake phases are not drafted for the Lake Huron basin, other than for the Glenwood phase. Dates are averages and along with the figures are based on Hansel et al. (1985) and Eschman & Karrow (1985). Note that the ice margin fluctuated over hundreds of kilometers over relatively short periods of time.

was located on the lowest point of the drainage divide (Leverett 1897). During the Glenwood phase (Fig. 2), the Chicago outlet was active, with water flowing through the Sag and Des Plains channels. Once the glacier receded northwards enough to deglaciate the Straits of Mackinac or Indiana River lowlands, lake level dropped and was controlled by outlets to the northeast (Hansel et al. 1985). The Chicago outlet was abandoned at this time, and forests grew on the newly exposed lake plain between the Glenwood shoreline and the much lower lake of the Two Creeks phase (Fig. 2). The northeast outlets were glaciated once more during a readvance of the Lake Michigan lobe, causing the lake to rise to the Calumet level. The rising lake buried a forest at Two Creeks, Wisconsin (Broecker & Farrand 1963) and other woody material in the Chicago region (Hansel et al. 1985) and northwest Indiana (Schneider & Reshkin 1982; Schneider & Hansel 1990). The radiocarbon dates indicate flooding of the land started at about 11,800 ybp. The higher lake level is known as the Calumet phase, and the Chicago outlet was reoccupied (Fig. 3). By about 11,200 ybp the Lake Michigan lobe had begun to retreat northwards of the Straits of Mackinac, and Lakes Michigan and Huron were confluent. This lake is called glacial Lake Algonquin, and some contend that any evidence of it in the region was eroded by the subsequent mid-Holocene Nipissing high phase (Karrow 1980; Hansel et al. 1985). However, more recently Chrzastowski & Thompson (1994) and Capps et al. (2000) have described erosional scarps just below the Calumet level as evidence for an Algonquin beach in the region. With continued retreat of ice in southern Ontario, the North Bay outlet was exposed around 10,300 ybp (Larsen 1987). Ancestral Lake Michigan dropped to a low level known as the Chippewa low (Fig. 4), which may have been as much as 107 m below the modern lake level (Hough 1955). More recently, Coleman et al. (1994) have suggested only an ≈80 m lowering. At this time until the mid-Holocene, ancestral Lake Michigan drained through the North Bay outlet into the Ottawa River before entering the St. Lawrence east of Lake Ontario.

The distribution of the sediment deposited during ice recession was partly controlled by elevation. On Fig. 5, the diamond pattern indicates glacigenic sediment (tills, debris flows, sand and gravel, and ice-contact glacial lake sediment) of the Lake Border sequence (Tinley and Lake Border Moraines) and Valparaiso Megasequence (Brown et al. 1996). The Glenwood-age sediment consists of two main types. First, the most obvious landforms are the extensive spits that built across northwest Indiana by the westerly transport of sand by littoral currents. Although not shown on Fig. 5, Glenwood-age spits are prevalent in Illinois; and they indicate an easterly transport direction. The spits record migration of sand southward along both sides of the lake, focusing sediment to its southern end. The spits record a lake level between about 195–189 m suggesting that the Chicago outlet was slowly being eroded during Glenwood time. The second type of Glenwood sediment is fine-grained lacustrine sediment of laminated and massive silty-clay. This unit is mapped as part of the Lake Border sequence and consists of approximately 16 m of laminated clay, silt, and silty clay and fine-grained till over bedrock (Bleuer and Woodfield 1993; Brown & Thompson 1995; Brown et al. 1996).

There are no sediments mapped for the Two Creeks phase because the region was subaerially exposed at this time. It is during this time and the subsequent Chippewa phase that the region's rivers carved their valleys. This incision was in response to the lower lake level that increased the streams bed slope. Evidence for the low lake level is now beneath the lake. For example, divers off Chicago found a buried forest with oak stumps rooted in place beneath 25 m of water (Chrzastowski et al. 1991). Radiocarbon dates averaging 8300 ybp suggest that the lake had risen to that elevation by then and drowned the trees.

The next youngest sequence of sediment in the region is affiliated with the Calumet Phase. Two map units are shown on Fig. 5. Sand dunes form an arc parallel to, and south of, the Little Calumet River. On either side of the dunes, beach, lagoon, and shallow water, sand and mud is exposed at the surface today. The elevation of the lake was at approximately 189 m. Spits were also formed at this time, but are restricted to near the Illinois state line and further west. The Calumet-age sediment is grouped with the Glenwood dunes and littoral sediment as part of the Lake Michigan sequence because in the subsurface it is dif-

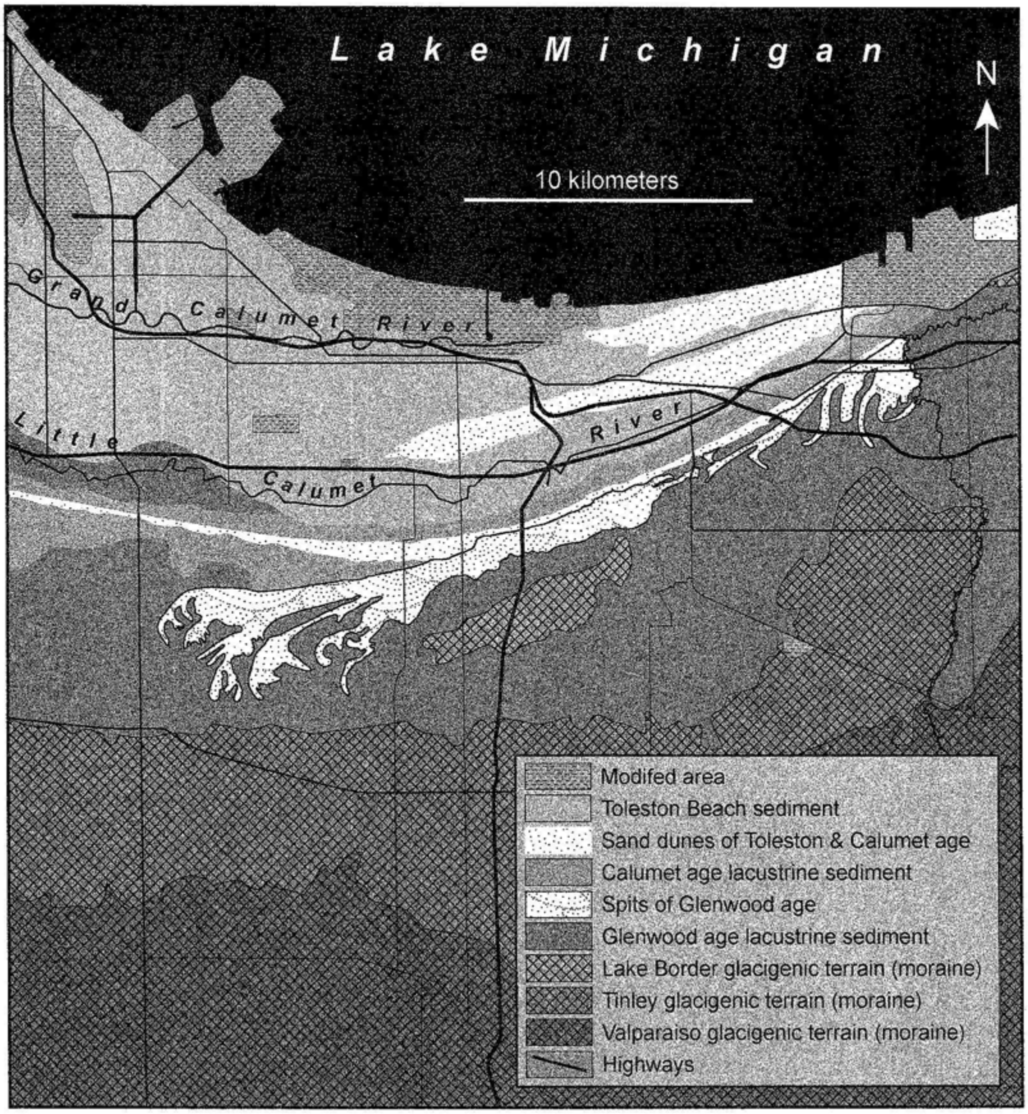


Figure 5.—Generalized Quaternary terrain map for northwest Indiana illustrating the inset relationship of moraines and beaches. As a general rule, the landscape becomes progressively younger from south to north. Modified from Brown et al. (1996).

ficult to differentiate between Glenwood and Calumet sediment (S.E. Brown pers. commun. 2002).

HOLOCENE CHANGES IN SOUTHERN LAKE MICHIGAN

Previously, the fluctuations in glacial Lake Chicago were explained by fluctuations in the ice margin of the Lake Michigan lobe: but interestingly, after the Lake Michigan lobe had retreated well north of the Great Lakes, the effect of the ice sheet was still felt in the Lake Michigan basin. A time lag exists between deglaciation and when the Earth's crust has reached its equilibrium elevation once the ice sheet load had been removed (slow isostatic rebound). As mentioned earlier for the Two Creeks phase, during the Chippewa phase, the outlet for the Great Lakes was the North Bay outlet rather than the modern outlet at Port Huron. During the Holocene, the North Bay outlet gradually rose causing Lakes Michigan and Huron to rise until they were confluent with Lake Superior (Larsen 1985). Lake

Michigan continued to rise until it reached two peaks at approximately 5300 (Larsen 1994) and 4700 ybp (Baedke & Thompson 2000) known as the Nipissing I and II high phases, respectively (Fig. 4). During the Nipissing phase the North Bay, Sag channel outlet (Chicago outlet), and Port Huron outlets were simultaneously active (Lewis 1969, 1970). With continued isostatic rebound, the North Bay outlet was abandoned; and there may have been a rapid drop in lake level that could be attributed to incision of the Port Huron outlet (Baedke & Thompson 2000). At around 2600 ybp the Sag channel was abandoned (Chrzastowski & Thompson 1992) leaving the Port Huron outlet as the sole outlet.

Since about 6300 ybp (Thompson & Baedke 1997), when the lake rose above the modern lake level from the Chippewa low to the Nipissing high, the 700 km^2 Toleston Beach began forming. A lake level curve going back to 4700 ybp was reconstructed based on the elevation of foreshore gravel deposits in beach ridges from the Lake Michigan basin since the Nipissing high (Baedke & Thompson 2000). Beach ridges record the high elevation of fluctuations in lake level, thus the curve (Fig. 6) is a smoothed record of high lake levels from the last 4700 years. It is interesting to note that Thompson (1992) and Thompson & Baedke (1995, 1997) were able to determine three scales of lake level fluctuations. There are 25–35, 140–160, and 500–600 yr cycles with a lake level elevation change of 0.5–0.6, 0.8–0.9, and 1.8–3.7 m, respectively.

The Toleston Beach has prograded basinward since the Nipissing high, and incorporates the Little and Grand Calumet Rivers. On Fig. 5 the Toleston-age sediment is shown in lightest gray. Sand dunes are stippled and dominate the eastern side of the Toleston Beach. The southern band of parabolic dunes had developed by 3200 ybp and point eastwards, reflecting westerly air flow. The younger, northern band of dunes contain parabolic dunes that point southeast and southwards recording a transition to more northerly air flow (Thompson 1992). Westward of the sand dunes, the Toleston Beach widens to where it contains over 100 beach ridges (Thompson & Baedke 1997).

The evolution of the Little and Grand Calumet Rivers is illustrated in Figs. 7–10 and was the result of three factors: 1) relative topographic gradients perpendicular to the shoreline, 2) littoral transport of sand from the northwest after about 3000 ybp, and 3) fluctuations in lake level. Along the eastern part of Fig. 5 the relative slope of the land into the off-shore zone is steeper than at the lake plain further west in the southwest corner of the lake. As a result, aeolian processes dominated, and dunes rather than beach ridges developed on the eastern side of the Toleston Beach. Further west, the southwest corner of the lake acted as a depositional sink; and beach ridges developed with only minor sand dune development.

Initially, the source of sand for most of the beach ridges in the Toleston Beach was from glacial deposits along the Michigan coastline. Bluff recession would have been particularly active during the rise in lake level from the Chippewa low to the Nipissing high. Recently, Loope & Arbogast (2000) demonstrated that the age of perched sand dunes along the western coast of Lower Michigan corresponds with high stands of Lake Michigan (see Fig. 6). Therefore, during these short-lived high stands, bluff recession would also increase sand supply for littoral transport. The paleogeographic reconstruction of Fig. 7 corresponds in time to about the Nipissing II peak. The lake has flooded the Sag Channel and the Calumet lagoon formed behind the early Toleston beach. Since the Nipissing II high, there was only westerly transport of sand to the southern end of the lake where beach ridges developed. The easterly transport of the sand did not reach the region until after 3000 ybp because the Chicago outlet embayment was trapping sediment (Chrzastowski & Thompson 1992). Figure 8 reflects a lowering of the lake level with continued beach and dune development. Note that by this time spits are building out from Stoney Island in Illinois across the outlet embayment, and beginning to deflect the Little Calumet River eastwards.

As the Calumet River turns east, it is referred to as the Grand Calumet River. Thus the Grand Calumet River came into existence just after 2600 ybp when the Sag Channel was abandoned (Chrzastowski & Thompson 1992). At about 1500 ybp all barriers to the south- and eastward transport of sand were removed (Fig. 9); and a large baymouth bar formed by spit growth, trapping an embayment of Lake Michigan to form Lake Calu-

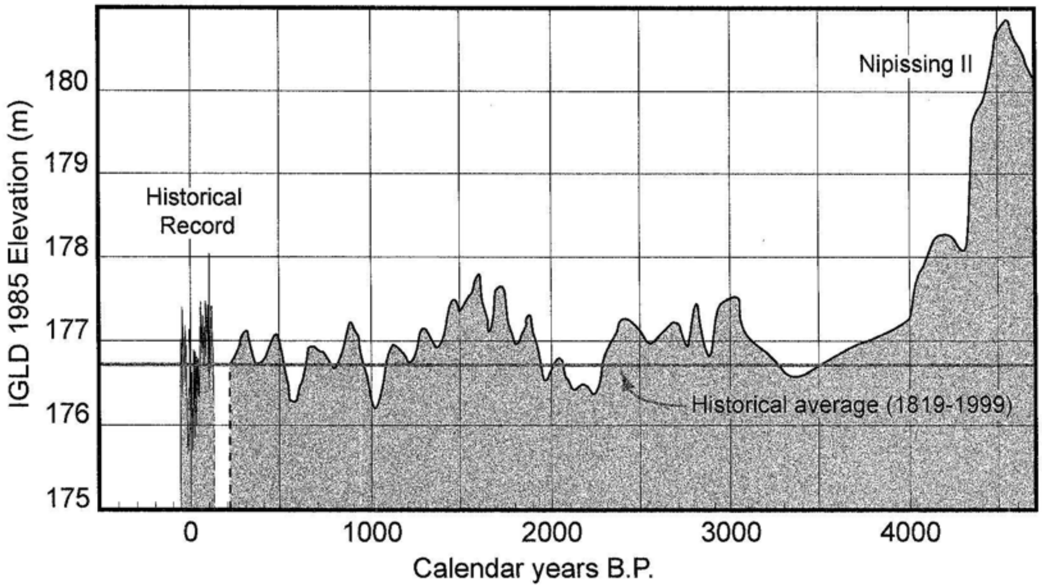


Figure 6.—A Fourier-smoothed lake level curve for Lake Michigan for the last 4700 years. Actual variations in lake level (peaks and troughs) are not shown. This curve combines data sets for around the Lake Michigan basin and illustrates the dramatic drop in lake level from the Nipissing II stage and multiple meter variations in lake level since 4000 ybp when the Toleston Beach was forming. IGLD–International Great Lake Datum. Modified from Baedke & Thompson (2000).

met. The Grand Calumet River entered Lake Calumet and was then continually deflected eastwards by spit growth at the mouth of the river. At about 1100 ybp continued spit growth had captured another part of ancestral Lake Michigan to form Wolf Lake (Fig. 10). The spit growth corresponds to high stages in Lake Michigan between 2000 and 1000 ybp (Fig. 6) and presumably increased sediment supply. The Toleston Beach continued to grow northward into the lake as beach ridges developed once every ≈30 years, while at the same time deflecting the Grand Calumet River further eastward. Development of the Toleston Beach had essentially stopped once European settlement in the area led to modification of the shoreline during the 19th and 20th centuries, although occasional beach ridges are still forming today on the eastern side of obstacles to littoral drift (Hunter et al. 1990). Shoreline positions for selected dates are superimposed on Fig. 10.

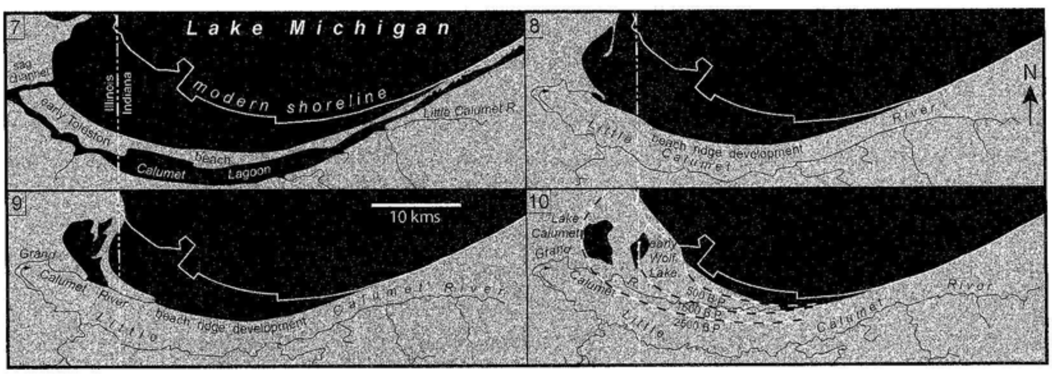


Figure 7–10.—The evolution of the Grand Calumet River was initiated by closing the Sag channel and deflection of the Little Calumet River eastwards by spit and beach ridge growth in the southwest corner of the lake. Figures modified from Chrzastowski & Thompson (1992) and Thompson (1992).

Sediments that underlie the region have been investigated by numerous researchers (Blueur & Woodfield 1993; Doss 1993; Brown & Thompson 1995; Brown et al. 1996). Beneath Lakes Calumet and Wolf, and the Grand Calumet River are 15–18.5 m of sand, gravel, and peat (Doss 1993) of the Lake Michigan sequence that is in turn underlain by finer grain sediment of the Lake Border sequence (Brown et al. 1996). Sand is the predominate sediment in the Toleston Beach, with minor amounts of gravel in the beach ridges; and organic material (peats) is found in swales between beach ridges and in the Calumet lagoon.

SUMMARY

The geology of the region is linked to the events of deglaciation and subsequent fluctuations in the levels of ancestral Lake Michigan. Glacial sediment of the Lake Border sequence and Valparaiso megasequence consists of tills and meltwater deposits from ice-marginal environments in the southern part of the region above 195 m elevation. Sometime around 14,000 ybp the glacier had receded northwards from Indiana and glacial Lake Chicago occupied the region in which fine-grained lacustrine sediment and spits were deposited during the Glenwood phase. Lake level dropped for about 500 years during the Two Creeks low phase until ice once again dammed the north end of the basin and the lake rose to the Calumet high phase, when another sandy beach with dunes formed. The lake dropped to the Chippewa low after final deglaciation of the Straits of Mackinac and North Bay outlet in Ontario. During the Chippewa phase when the lake was from 80–107 m lower than today, rivers eroded their valleys in the region in response to steeper streambed gradients. With the isostatic rise of the North Bay outlet, Lake Michigan became confluent with Lakes Superior and Huron during the Nipissing high; and the Port Huron outlet became the controlling outlet following abandonment of the North Bay and Chicago outlets. During the rise to the Nipissing high, the Toleston Beach began developing by 6300 ybp. The beach is dominated by sand dunes on its eastern edge and by more than 100 beach ridges further west where the Toleston Beach is up to 10 km wide. The Grand Calumet River developed once the Little Calumet River was deflected eastwards by spits at about 2600 ybp. Spits and beach ridges continued to grow until the end of the 19th century, which resulted in (1) capturing small embayments of Lake Michigan to form Calumet and Wolf Lakes, and (2) further deflecting of the Grand Calumet River eastward.

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