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HISTORY AND ARCHITECTURE OF WETLAND DEVELOPMENT IN THE INDIANA DUNES

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ABSTRACT: The coastal wetlands of the Great Lakes are formed and maintained by the interaction of biological, chemical, and physical processes. The initial development and early history of the wetlands are controlled by physical processes. The formative physical processes are important in creating the wetland basin, the predepositional topography of the basin, and the hydrologic connections within and between the wetland sediments and surrounding deposits. The early physical processes in coastal areas are primarily nearshore, eolian, and overwash transport and deposition. The formative processes and their impact on later biological and chemical processes in the wetland basin are poorly known.

Wetlands are common features in the coastal environments that border Lake Michigan and its ancestral equivalents. Most occur in interdunal and intradunal settings, but others occur between individual beach ridges and larger dune and beach complexes. The largest wetland in the area is the Great Marsh. The Great Marsh is a 22-km-long and 0.8- to 1.2-km-wide peatland, extending through the eastern part of the Indiana Dunes National Lakeshore and across the southern part of the Indiana Dunes State Park and Nature Preserve. The Great Marsh began to form about 6,300 years ago, during the final stages of the post-Chippewa Phase transgression, as a lagoon between the Calumet Beach and the early Toleston Beach. Over the next approximately 3,000 years, the wetland basin changed from a lagoon to a series of isolated ponds that accumulated freshwater carbonate, and finally, to an extensive peatland. This change was primarily controlled by the external influence of the water level in Lake Michigan, that reached its highest postglacial peak about 4,500 years ago before slowly falling to the elevation observed today. The southern margin of the Great Marsh is a simple onlapping of palustrine sediments over the nearshore deposits of the Calumet Beach, whereas the northern margin contains a complex stratigraphy consisting of interbedded lacustrine, palustrine, eolian, and washover sediments. The Great Marsh is locally recharged from the Calumet and Toleston Beaches, but the wetland also receives regional groundwater recharge from an artesian aquifer system discharging upward through breaks in the till and glacial-lake sediments below the peat.

West of the Great Marsh, the Toleston Beach changes from a series of coalesced parabolic dunes to more than 100 individual beach ridges, separated by narrow curvilinear wetlands. Study of the internal architecture and timing of beach-ridge development indicates that a shore-parallel beach ridge formed along the western Indiana shore about every 30 years. A wetland formed in the swales between ridges soon after the development of the beach ridge lakeward of it. Like the beach ridges, the wetlands are a chronosequence from the oldest wetlands in the landward part of the Toleston Beach to the youngest wetlands in the lakeward part. Similar to the Great Marsh, the wetlands are interbedded on their lakeward margin with eolian and overwash sediments. Although influenced by drainage divides, most wetlands are simple flow-through groundwater systems.

KEYWORDS: Coastal, Great Marsh, history, Indiana Dunes, lake level, Late Holocene, Toleston Beach, wetlands.

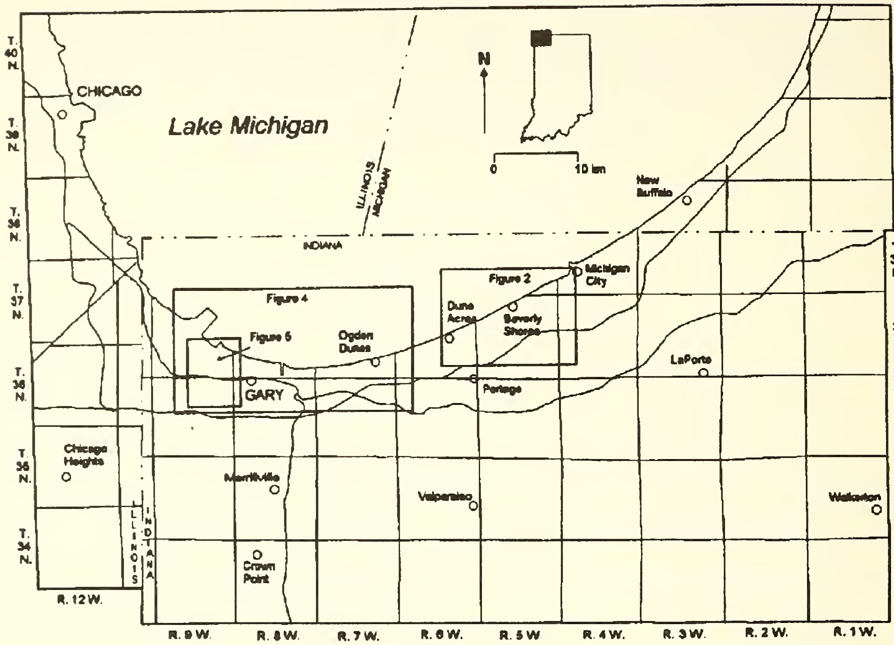

Figure 1. Map of the southern shore of Lake Michigan showing the areas discussed in the text.

INTRODUCTION

Wetlands are common features along many Great Lakes' shorelines. These coastal wetlands occur in all paralic settings and are formed and maintained by an interaction of biological, chemical, and physical processes. The initial development and early history of these wetlands are dominantly controlled by physical processes with the chemical and biological processes taking precedence later. The formative physical processes in coastal areas are primarily nearshore, eolian, and overwash transport and deposition; they are important in creating the wetland basin, the predepositional topography of the basin, and the hydrologic connections within and between the wetland sediments, the coast, and surrounding mainland deposits. The extended impact of these formative processes on biological and chemical processes in the wetland basin are poorly known.

Wetlands occur along Indiana's coast with Lake Michigan (Figure 1). They are found in interdunal and intradunal settings, and between individual beach ridges and larger dune and beach complexes. The largest extant coastal wetland in the area is called the Great Marsh, which is located in the eastern part of Indiana's coast. Other coastal wetlands occur in the swales between individual beach ridges within the central and western part of the Toleston Beach. My purpose in this paper is to summarize the developmental history of both wetland systems and to briefly discuss the importance of the formative physical processes on the sedimentological character of the wetland.

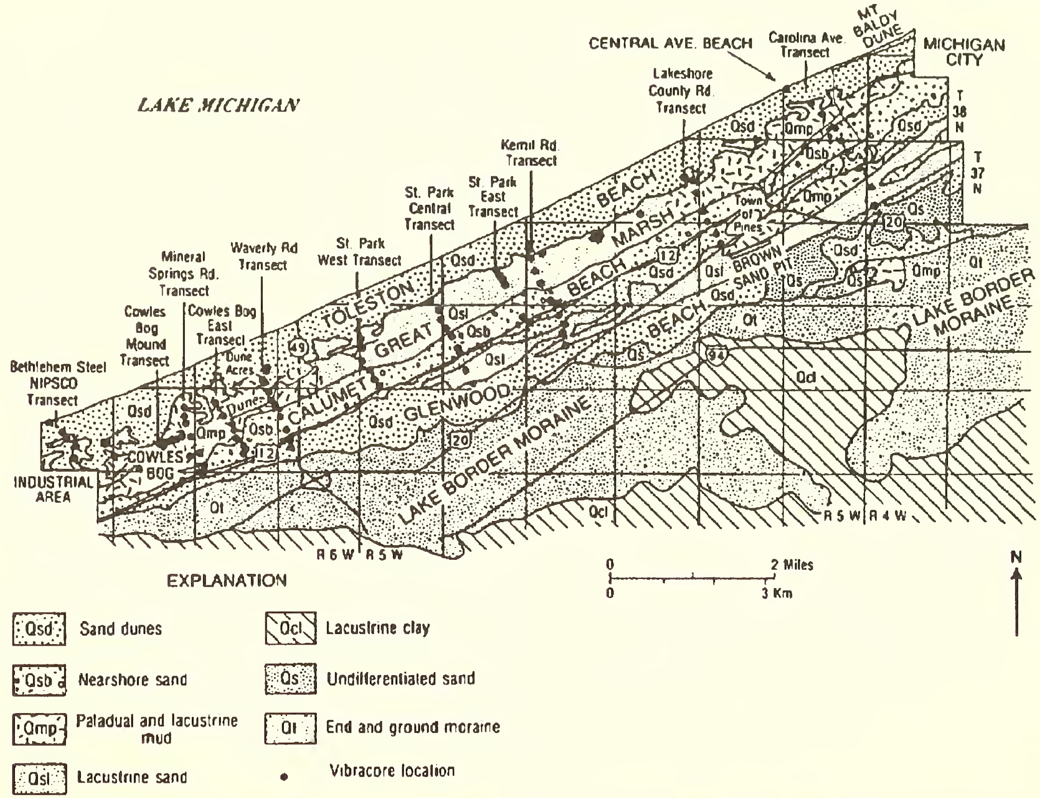

Figure 2. Map of the Great Marsh showing the major geomorphic and cultural features, vibracore sites, and the location of outcrops (from Thompson, 1987). The vibracores were used to construct 10 shore-perpendicular cross sections, illustrating the stratigraphic relationships between the Great Marsh and the Toleston and Calumet Beaches.

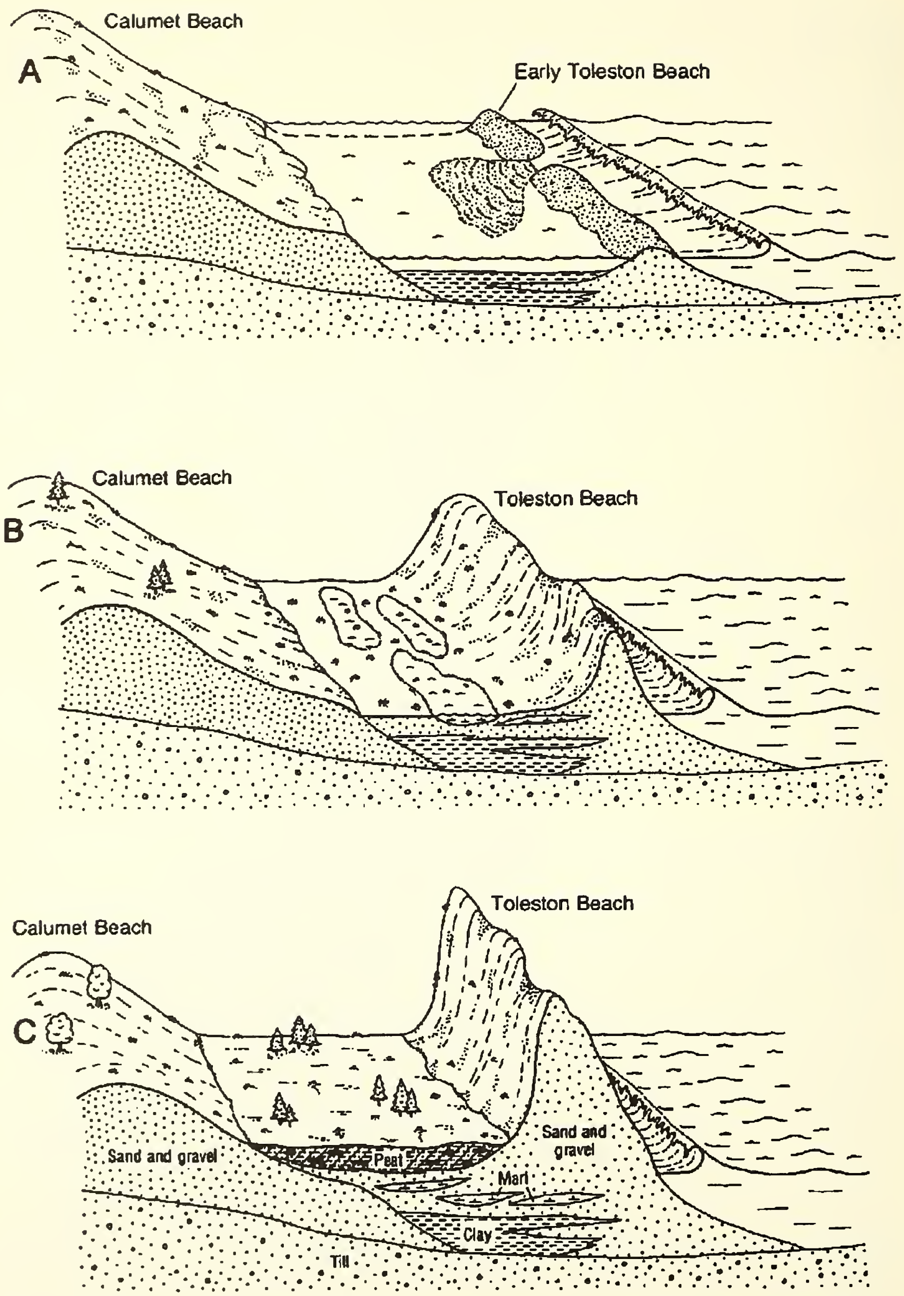

Figure 3. Schematic diagram of wetland development throughout the Late Holocene.

GREAT MARSH

The Great Marsh is a 22-km-long and 0.8- to 1.2-km-wide peatland (Figure 2), extending through the eastern units of the Indiana Dunes National

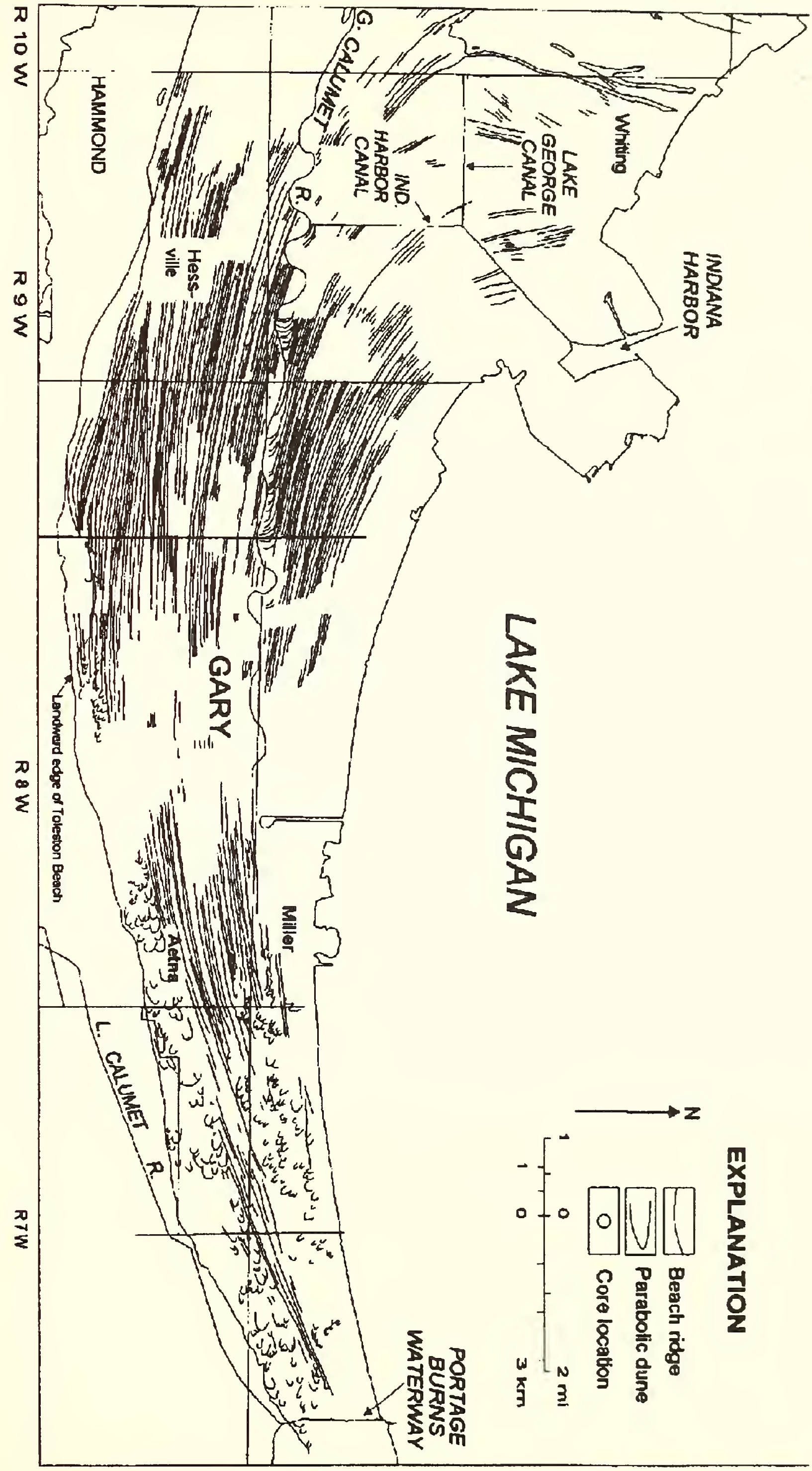

Figure 4. Map of Toleston Beach showing beach ridges and cultural features.

Figure 5. Aerial photograph of beach ridges in the Gary area in 1938. The light-colored arcs are beach ridges. Black areas are the wetlands between beach ridges. Mid to late 20th century urbanization has removed most of this ridge and swale topography from the landscape.

Lakeshore and across the southern part of the Indiana Dunes State Park and Nature Preserve. The Great Marsh is bounded on the south by the Calumet Beach, a spit that formed across the coast from 11,800 to about 10,200 years ago (Chrzastowski and Thompson, 1992). North of the Great Marsh is the Toleston Beach. The Toleston Beach began to form about 6,300 years ago, during the final stages of the post-Chippewa Phase transgression (Thompson,

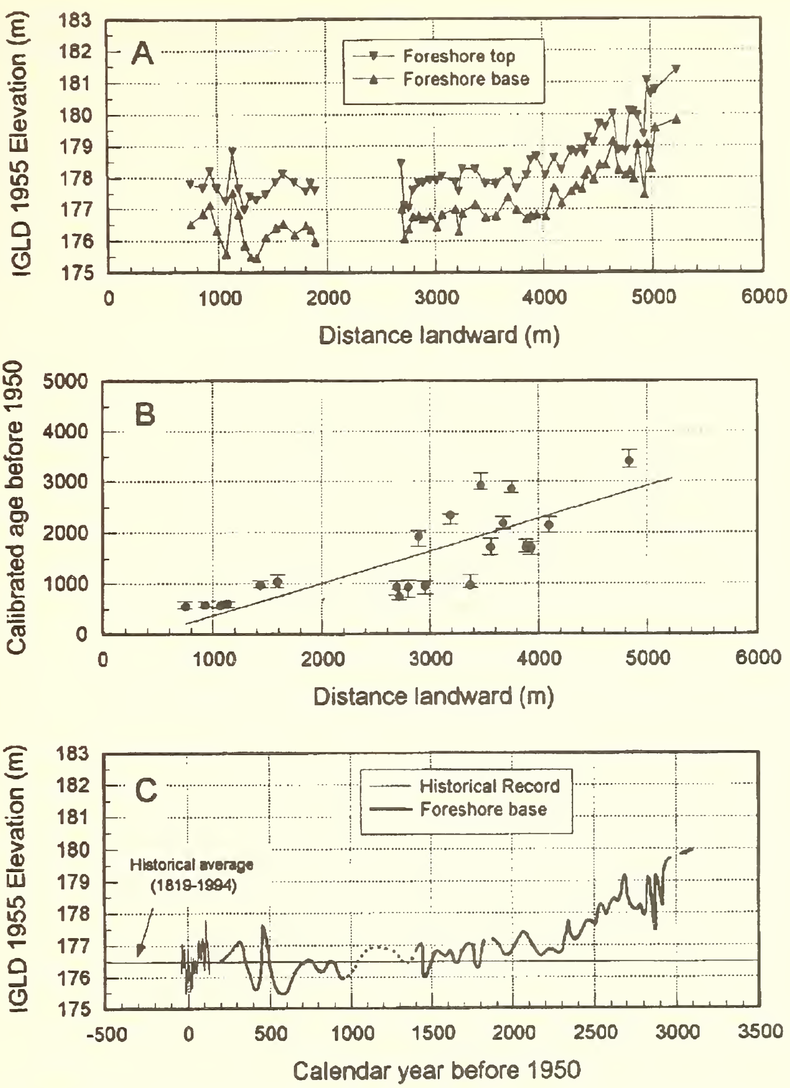

Figure 6. Graphs of: (**A**) foreshore elevation vs. distance landward from the originally surveyed shoreline; (**B**) calibrated radiocarbon age vs. distance landward; and (**C**) the Late Holocene lake level.

1989). The development of the Great Marsh is concurrent with the establishment and growth of the Toleston Beach.

To study the interrelationships between the Great Marsh and surrounding deposits, 98 vibracores were collected in the Great Marsh, Calumet Beach, and Toleston Beach (Figure 2), using the techniques of Thompson, *et al.* (1991b). In addition, several outcrops were measured along the coast near Michigan City. The vibracores and outcrops were used to create ten shore-perpendicular cross sections across the wetland (Figure 2). These cross sections define the stratigraphic relationships between the wetland and the marginal coastal sediments and long-term patterns of shoreline and wetland interaction.

These data indicate that the Great Marsh has undergone three stages of development (Figure 3). The first stage (6,000 to 5,500 yrs BP) was as a lagoon between the Calumet Beach and the early Toleston Beach (Figure 3A). At this time, the wetland basin was influenced by washover, eolian, and lacustrine processes that produced a calcareous clay layer that interfingers lakeward with washover and eolian sand (Thompson, 1987, 1989). Throughout this time period, the Toleston Beach was migrating landward by overwash and growing in height through nearshore and eolian accumulation. On the southern side of the wetland basin, the lacustrine sediments onlapped the lower shoreface and upper shoreface sediments of the Calumet Beach (Thompson, 1987).

Continued growth of the Toleston Beach (5,500 to 3,000 yrs BP) by eolian and nearshore processes systematically precluded overwash from going into the basin. Without a supply of clay from Lake Michigan and as accommodation space decreased, the lagoon changed into a series of isolated ponds accumulating freshwater carbonate (marl) surrounded by vegetation (Figure 3B). At this time, large parabolic dunes migrated off the back side of the Toleston Beach into the wetland basin, forcing the marl ponds to the southern side of the basin. Unpublished radiocarbon dates from the base of the wetlands in the interior of the parabolic dunes indicate that the dunes were active before 3,200 years BP.

Lake level in Lake Michigan reached a Late Holocene high at about 4,500 years BP and fell to a low about 2,600 years BP before entering a phase of lake-level variation that is similar to today (Thompson, *et al.,* 1991a; Thompson, 1992). The low external lake level and decreasing precipitation about 2,600 years ago caused the marl ponds in the Great Marsh to dry and to become covered with vegetation (Miller and Thompson, 1990). Essentially, the open-water phase of the wetland had ended, and conditions similar to the pre-settlement conditions in the area were established across the basin (Figure 3C).

WETLANDS IN THE STRANDPLAIN OF THE TOLESTON BEACH

The Toleston Beach north of the Great Marsh is a series of coalesced parabolic dunes overlying a gravel-beach core. Westward, however, the dune field and underlying nearshore deposits fan out into about 100 curvilinear beach ridges that arc across Indiana's coast (Figure 4). This strandplain is one of the largest in the Great Lakes basin. The western Toleston Beach is a record of lake-level fluctuations in Lake Michigan over the past 4,000 years, because beach-ridge development is related to rises and falls in lake level (Olson, 1958; Thompson, *et al.,* 1991; Thompson, 1992). Prior to the urbanization of this area, wetlands occurred between almost all of these beach ridges (Figure 5).

Jackson, *et al.* (1988) examined the vegetational history of the wetlands in the eastern part of the strandplain. They found no significant change in vegetation within and between ridges over the past 3,000 years. Consequently, paleobotanical studies yield little information on the developmental history of the coastal and wetland systems. An alternative source of information, the coastal geologic record, is needed to establish the developmental history of the wetlands.

To understand the change in lake level accompanying beach-ridge development and the timing of beach-ridge development, 61 vibracores crossing about 75 beach ridges were collected. The vibracores were taken along the lakeward margin of the beach ridges to collect foreshore (swash zone) sediments. The base of the foreshore is a close approximation of actual lake level when the beach ridge formed (Figure 6A). In addition, 23 radiocarbon dates were determined on basal wetland sediments (peat and organic sands) in the swales (Figure 6B). The radiocarbon dates are minimum ages of beach-ridge development. To reduce variability and assign ages to undated ridges, a least-squares linear regression was run through the data. Using the regression line as real time, a lake-level curve was constructed from the elevation and age data (Figure 6C).

These data suggest that a beach ridge was formed about every 30 years (Thompson, 1992). Consequently, a swale in which a wetland would develop was also formed behind the beach ridge during this time. Without the development of a new beach ridge along the Indiana shore, no swale accommodating the wetland would have been created. Because many of the beach ridges are low-relief features, overwash commonly overtopped the ridges and deposited discontinuous washover fans into the swales. Moreover, many ridges contained small parabolic dunes than migrated landward into the wetlands. Both processes create a complex stratigraphy along the lakeward side of the wetlands. This stratigraphy creates a direct hydrologic connection between the ridge and the swale only on the northern side of the wetland. Along the southern side of the wetland basin, palustrine deposits simply onlap the nearshore sediments of the next landward beach ridge.

DISCUSSION

Wetlands are formed and maintained by an interaction of biological, chemical, and physical conditions and processes. Most studies of wetlands have focused primarily on the effects of the chemical and biological processes on the wetland system. These effects are predominant in the later stages of wetland development. Few studies have focused on the formative physical processes that create the wetland basin and its hydrologic connectedness to surrounding sediments (Thompson, 1988). In coastal settings, physical processes can have an extended impact as the coastal system responds to the numerous factors that influence shoreline behavior.

In the Indiana Dunes, the Great Marsh and the small wetlands inside the Toleston Beach owe their existence to the development of beach ridges offshore of the area of the swale. In both cases, the formation of the beach ridge created the basin and the intrabasin topography in which the wetland developed. The Great Marsh began its existence as a lagoon landward of the Toleston Beach during the final stages of lake-level rise from the Chippewa Phase of ancestral Lake Michigan. The wetlands within the Toleston Beach, on the other hand, formed in the swales between beach ridges during a long-term fall in Late Holocene lake level, but they owe their existence to short-term fluctuations in lake level that produced the beach ridges. These fluctuations occur about every 30 years in response to climatic variations over Midwestern North America (Thompson, 1992).

In both settings, overwash and dune development were important processes imposed on the wetland system. Both processes produced beds of sand that extend from the nearshore and onshore deposits on the lakeward side of the wetland and pinch out into the wetland. The sand layers create hydrogeologic connections between the ridges and the wetland. This relationship does not occur on the landward side of the wetland, where the wetland sediments simply onlap the beach ridge.

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