HYDROLOGY AND CHRONOLOGY OF A PEAT MOUND IN DANE COUNTY, SOUTHERN WISCONSIN

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Abstract

This study describes the hydrologic conditions that have caused the formation of a three hectare peat mound. This wetland is elevated two meters above the adjacent 100 hectare Waubesa Wetlands and has developed at the transition area between upland and lowland.

Results from 37 hydrologic stations located on the mound indicate the existence of an artesian source of water beneath the peat. Because of the ability of clay layers to confine an aquifer more than silt and sand layers, the stratigraphy of the mineral soil beneath the peat may dictate the amount of vertical flow of water and thus the height to which the peat can accumulate. The rate of groundwater flow and the topography of the artesian site determine whether peat will accumulate. The beginning of peat formation at the mound is dated at 7500 ±80 years before present (WIS-1265).

INTRODUCTION

The purpose of this study is to describe the hydrologic conditions that have caused the development of a peat mound, an elevated wetland which has formed at the transition between upland and lowland. The study site is a three hectare portion of the 100 hectare Waubesa Wetlands located in Dane County, southern Wisconsin (Figure 1). In southern Wisconsin peatlands are typically located in local depressions of the landscape where water levels are relatively high throughout the year (Bedford, *et al.* 1974). They often form in a manner similar to the way the majority of Waubesa Wetlands formed, by the accumulation of organic matter in a shallow lake bay or lake (Friedman, *et al.* 1979). The peat mound examined in this study is different from the more typical basin-filled peatlands of the region in several respects.

First, its surface is elevated two meters above the adjacent basin-filled wetland. This is remarkable because for peat to accumulate the water level must be at or near the surface of the peat throughout the year. The high water levels retard the rate of decomposition, so that rate of productivity of organic matter exceeds the rate of decomposition. The difference in elevation between the mound and the basin-filled wetland implies a dramatic change in the elevation of the water table over a relatively short distance in the peatland. The water table, and hence the surface elevation of the peat, drops nearly two meters in less than 40 meters of horizontal distance (Figure 2). This is an exceedingly steep slope for peatlands in this region. Only blanket bogs in Great Britain and Ireland exhibit steeper slopes (Moore and Bellamy 1974).

Secondly, the three-dimensional shape of the peatland is convex, not flat or concave like a typical basin-filled wetland. In this respect the mound is more similar to raised *Sphagnum* bogs that occur 800 km to the north (Heinselman 1970).

Finally, although lake sediments (gyttja) underlie the basin-filled portion of Waubesa Wetlands, no lake sediments underlie the

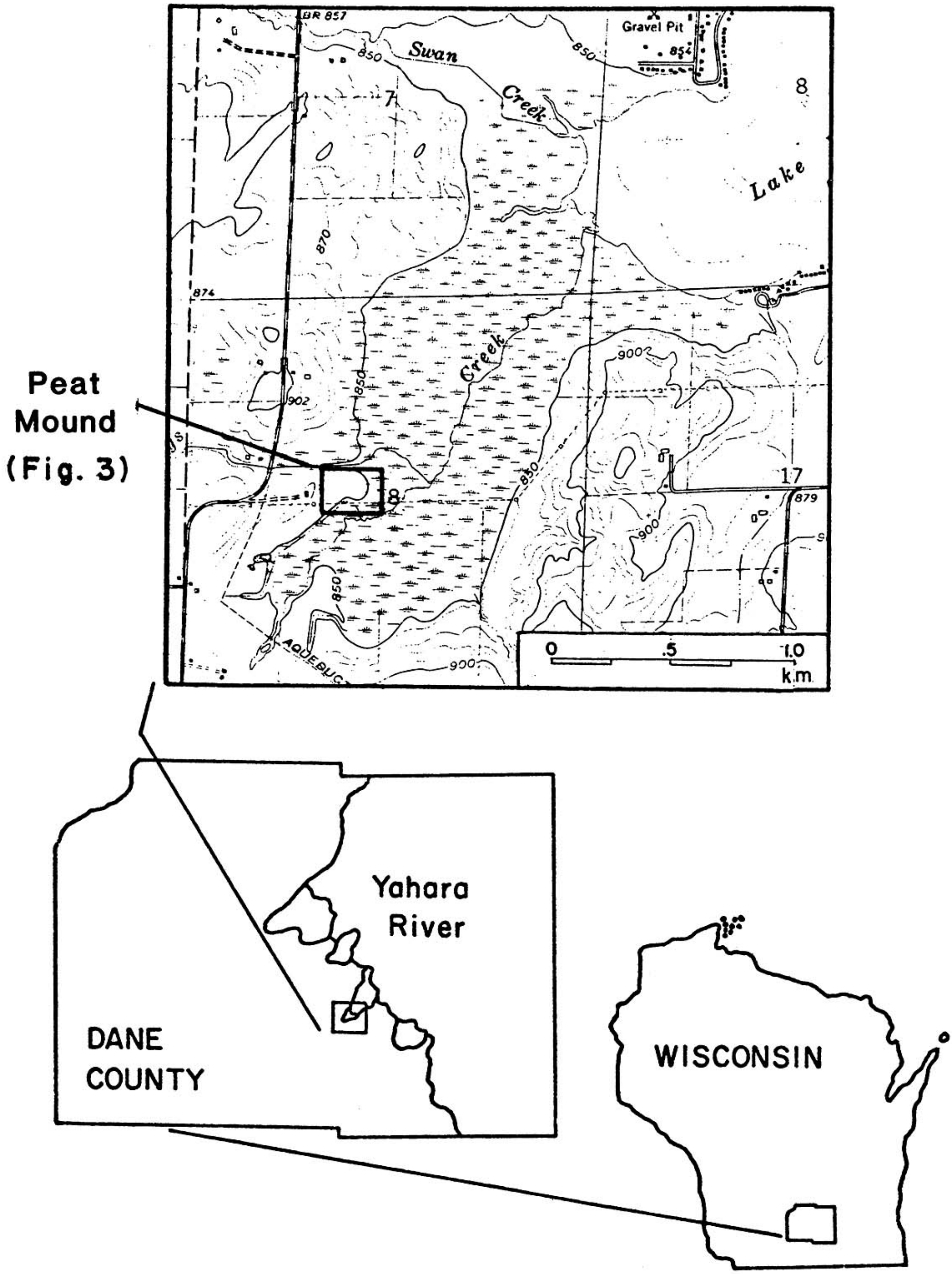

Fig. 1. Map of Waubesa Wetlands and its location in Wisconsin. The peat mound is shown in more detail in Figure 3.

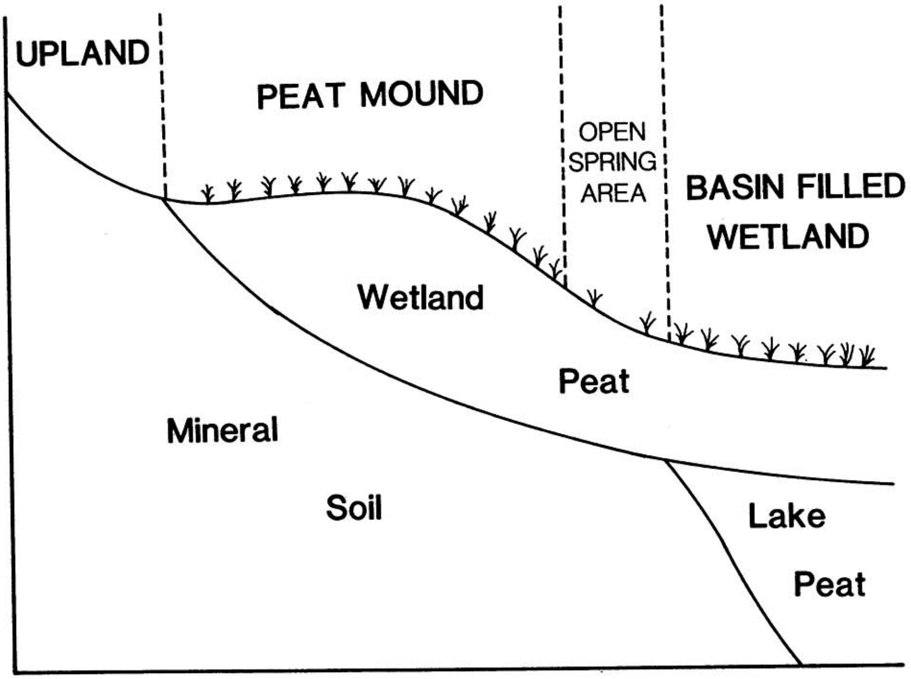

Fig. 2. Schematic diagram showing the relative positions of the peat mound and open spring area in relation to the upland and basin-filled wetland.

one to two meters of peat of the mound. The lack of underlying lake sediments implies that the peat did not form through a basin-filling process typical of many peatlands in the region.

This preliminary study provides a description of the physical conditions that have caused the development of the mound. Because the source, distribution, fluctuation and flow of water are central to the development of peatlands, we have taken a hydrological approach.

THE STUDY AREA

The site is near a terminal moraine that marks the extent of Wisconsin glaciation 13,000-17,000 years ago (Mickelson and McCartney 1979). A drumlin is located immediately next to the peat mound. Beneath the glacial till are layers of sandstone (Cline 1965). Artesian springs are common in the region, and occur at the base of the mound.

The vegetation was disturbed by plowing and the planting of reed canary grass, *Phalaris arundinacea,* about 50 years ago. The reed canary grass still dominates the site, and therefore the peatland is classified as a degraded fen (Curtis 1959). *Gentianopsis procera* occurs in comparative abundance in patches on the top of the peat mound (Burr 1980), and the groundwater is mineral rich. Other plants at the site which are characteristic of sedge meadows or wet prairies but are also found in fens are *Carex stricta, Andropogon gerardii,* and *Spartina pectinata* (Bedford, *et al.* 1974). *Cornus stolonifera* occurs in patches at both the top of the mound and in the basin-filled portion of the wetland, but not on the slopes, where *Phalaris* dominates.

One to two meters of fibrous sedge peat has accumulated in the study area. The top 50 cm is more decomposed than the deeper peat.

The site is owned by The Nature Conservancy.

METHODS

Surveying. We established a 50 × 50 meter grid system on the mound using wooden stakes to mark the intersection of the grid. From this grid we defined a coordinate system to allow horizontal control at the site. All positions on the mound can be located by two coordinates.

To determine relative elevations of the surface of the mound, we leveled approximately 200 points using a Leitz automatic level. We produced a contour map with 40 cm contour intervals using computer assisted two-dimensional interpolation and smoothing routines (Figure 3). Back-checking with actual data showed the interpolation and smoothing routines did not distort the data. Smoothing was necessary because of the high degree of microrelief on the mound, caused by sedge tussocks and ant hills.

Hydrology. Thirty-seven hydrologic stations were established on the peat mound. Thirty are located on a 25 meter grid system (Figure 3). The other seven are located 10 meters apart on a transect from the top of the mound down to the basin-filled wetland. Each station has a shallow open well (about 50 cm deep) and a piezometer. Each piezometer is a 1.1 cm diameter titanium pipe open at both ends. To prevent the pipe from clogging while it was being pushed through the peat, we placed a loosely fitting bolt into the lower end of the piezometer so that the head of the bolt completely covered the lower opening. After driving the piezometer to the proper depth we lifted the pipe 2 cm, opening the lower end. The bottom

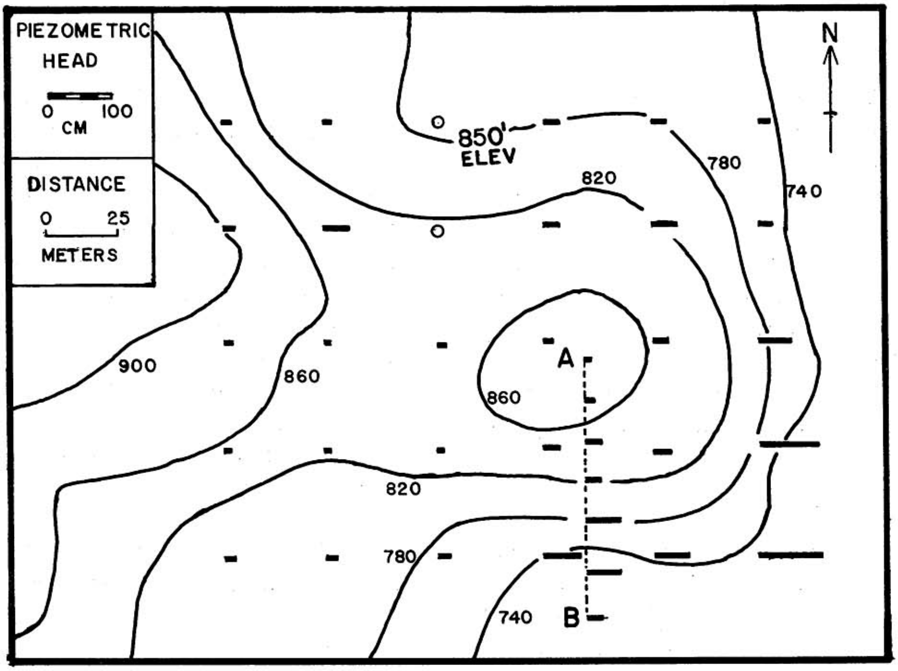

Fig. 3. Contour map of the peat mound showing the location of the piezometric head at the 37 hydrologic stations. Contour interval is 40 cm (relative to arbitrary base station); the 780 cm contour line coincides with the 850 ft. U.S.G.S. contour line (see Fig. 1). A-B marks the transect shown in Figure 4. Hollow circles indicate negative piezometric head (see text).

openings of the piezometers are in mineral soil three to four meters beneath the surface of the mound.

The level of the water in the piezometer measures the hydraulic head of the stratum at the bottom of the pipe. This was compared with the water level in the well. We call the difference between the two levels, the piezometric head. If the water level in the piezometer is higher than the water level in the open well, we arbitrarily called this a positive piezometric head. Water will tend to move upward. The surface elevation at each station is known and elevations are marked on each piezometer.

We measured the elevation of water in each well and piezometer using a wooden dipstick in a four hour period on 13 November 1979, and again on 25 October 1980. There were no substantial differences between the results. Our figures are based on the 13 November 1979 data. Dipstick displacement was calculated and accounted for in the results.

Stratigraphy. We determined the stratigraphy of the underlying sediments at several stations along the transect using Livingstone, Hiller, or Davis peat corers, as well as a standard soil auger.

Laboratory analysis. Pollen and charcoal analysis was done at the Center for Climatic Research. Pollen was scarce but at least 100 grains were counted at each level. Standard pollen analytical techniques were used (Faegri and Iverson 1964).

RESULTS AND DISCUSSION

The contour map of surface elevations of the mound shows the existence of a raised dome of peat (indicated by A in Figure 3)

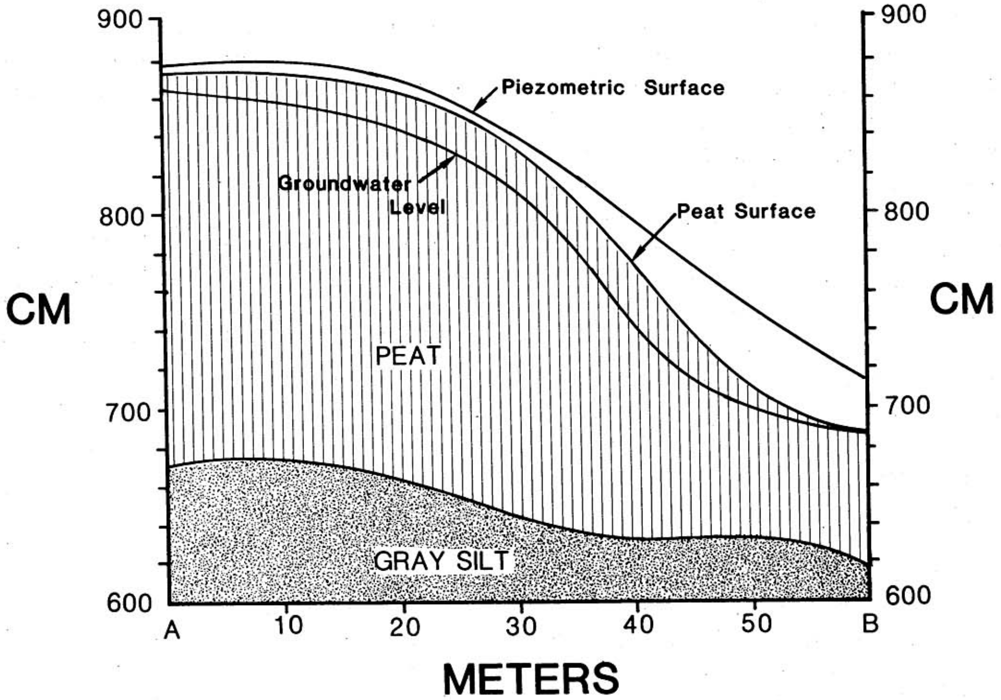

Fig. 4. Cross section of the peat mound, showing the relationship among the piezometric surface, peat surface, groundwater level, and mineral soil (gray silt). The location of the transect is shown in A-B in Figure 3.

nearly two meters above the surface of the basin-filled peatland. The water table closely follows the surface elevations, usually being within 30 cm of the surface. To determine the source of the water in the peat mound, we measured the piezometric head at 37 locations. Figure 3 shows that 35 of the 37 stations have a positive piezometric head, indicating an artesian source of water. We cannot fully explain the anomalous readings at the other two stations, although there may be a very localized perched water table near the two stations. In contrast to the positive piezometric head in the mound, a hydrologic station in the basin-filled portion of the wetland showed no difference in water levels between a piezometer and an open, shallow well. This indicates that the hydrology of the peat mound is qualitatively different than the hydrology of the basin-filled wetland.

The artesian source of water has allowed the peat to accumulate to an elevation nearly two meters above the surrounding basin-filled wetland. To investigate the reasons for the existence and location of the relatively steep slopes emanating in three directions from the raised dome of peat, we placed hydrologic stations ten meters apart along a transect from the top of the mound down to the basin-filled wetland (Figure 3). Figure 4 shows that although there is a good correlation among the piezometric surface, the surface of the peat, and the water table, the piezometric head is greater midway down the slope than on the top of the mound.

It might be expected that a region with a greater piezometric head would be able to supply water to a higher elevation, allowing the peat to accumulate to a greater height, than a region with a lesser piezometric head. The data refute this. Although the top of the mound has a high piezometric head, the slopes have higher heads. The highest piezometric heads are found at the base of the slopes near the open springs (Figure 3).

There are at least two reasons why the elevation of the peat is not positively correlated with the piezometric head. Under very high heads the vertical flow of water may be great enough to prevent any accumulation of peat. This would be the case if there were little resistance to flow in the substrate. Any excess organic matter is dislodged and washed away by the water. This is the most likely explanation of why the open spring area at the base of the mound (Figure 2) still exists after thousands of years of peat accumulation elsewhere in Waubesa Wetlands.

Secondly, if there is substantial resistance to vertical flow through the substrate, a high piezometric head need not be associated with an elevated water table and subsequent peat accumulation. To test this idea, we conducted a preliminary experiment to see if there is greater resistance on the top of the raised sedge meadow. Detailed stratigraphies were determined at both locations. In addition, at the midslope point seven piezometers were placed at various depths in various substrates according to the predetermined

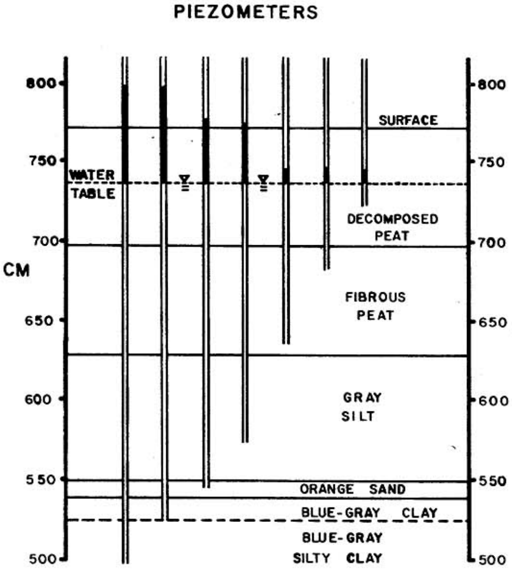

Fig. 5. Piezometric heads (dark lines) at seven levels in the stratigraphy at a midslope point. Note the three distinct levels of the piezometric heads.

stratigraphy. The results are shown in Figure 5.

Although the piezometers were placed at seven depths, there are only three distinct values of piezometric head. Two barriers to vertical flow are suggested by this result. The first is at the boundary between the blue-gray clay layer and the orange sand and the second is at the interface between the gray silt and the fibrous peat. The stratigraphy at the top of the mound differs from the stratigraphy midslope. At the top of the slope there is no blue-gray clay layer beneath the orange sand. Although we have not yet done the piezometric test, the lack of the clay layer probably affords greater vertical flow rates, allowing a higher water table and greater peat accumulation on the top of the mound. In addition, the sand lens may allow significant rates of horizontal flow from the mound to the basin-filled wetland, so that not only does vertical flow meet a greater resistance midslope, but horizontal flow is enhanced. The vertical extent of the water table is thus limited in the midslope region.

Chronology of the Peat Mound Development

The ages of the mineral soil strata and the peat underlying the top of the mound were estimated by correlating pollen spectra taken from various levels with published, radiocarbon-dated pollen diagrams (Friedman *et al.* 1979). The deposition of the mineral soil probably occurred rapidly after deglaciation. Although pollen grains are sparse, half of the grains counted from levels in the mineral soil are spruce. This suggests an age of about 12,500 years before present (L. Maher, Personal communication).

Peat sampled just above the mineral soil-peat interface from a core taken at the top of the mound has been radiocarbon dated at the University of Wisconsin-Madison (WIS-1265) by Dr. Margaret Bender. The date for the beginning of peat formation is 7500 ±80 years before present. This date indicates the beginning of the postglacial warm period in southcentral Wisconsin and the extension of the prairie into this area. It is a minimum date because of the charcoal layer at the transition between inorganic and organic sediment indicating a possibility of burned peat and therefore a hiatus in the core.

A decrease in groundwater supplies caused by a decrease in precipitation and an increase in temperature during this time might have decreased the piezometric head enough to allow peat to be produced and to begin to accumulate. A higher piezometric head would wash sediment away and a smaller head would be too intermittent to give a favorable production/decomposition ratio for build-up of peat. Once the peat begins to build up it acts like a sponge—raising the water table, and the peat acts also as a cap—slowing down the flow of water. The peat, then, accentuates the peat forming conditions and accelerates the accumulation of peat.

Other charcoal layers are common in the peat, suggesting that fires have swept over the landscape and have maintained oak-deciduous forest and prairie vegetation in the region to the present day. The peat mound itself may have also burned during dry periods in the past.

The Significance of Peat Mounds

Because of the importance of artesian sources of water to the hydrology and development of peat mounds, the ecological properties of the mound may differ substantially from other types of peatlands. For example, nutrient cycling, vegetation dynamics, and water relations in a wetland are all dependent to some degree on the hydrological properties of the wetland. Yet very little is known about the ecosystem dynamics of spring-dependent peatlands.

The occurrence of spring induced peat mounds in Jefferson County, southern Wisconsin has been reported by Milfred and Hole (1970) and Ciolkosz (1965). Van der Valk (1975) and Holte (1966, cited in Van der Valk) describe similar systems in northwestern Iowa. Although the vegetation of the

Iowan fens is different from that of Waubesa, the hydrologic setting is similar.

In Europe several authors discuss springs and their effects on peatland development (Hafsten and Salem 1976; Holdgate 1955a, b; Kirchner 1975; Lahermo *et al.* 1977; Moore and Bellamy, 1974; Wickman 1951). But because of differences in water flow, topography, climate, and water chemistry, the peatlands described in these studies are similar to our site only because springs are important in their development.

There is little knowledge of the regional distribution and abundance of peat mounds, but the geologic condition giving rise to these peatlands may not be rare (Ciolkosz 1965; G. B. Lee and J. H. Zimmerman, personal communications). Because these peatlands may often occupy the transition area between upland and more extensive wetlands, they are more subject to agricultural disturbances such as runoff, drainage, and tillage. The vegetation differences between the Iowa fens and the mound at Waubesa Wetlands may be a function of the land use history of each area as well as the climatic and geochemical differences of the area. The Excelsior fen complex in Iowa which has more than eleven peat mounds and associated spring terraces is badly degraded by cattle pasturing although the wetter areas still have *Lobelia kalmii, Eupatorium perfoliatum,* and *Parnassia glauca; Gentianopsis procera* was found at the nearby Silver Lake fen which is an Iowa Natural Area Conservation site (M. Winkler, personal observation).

Ecological processes taking place in this intermediate position in the landscape are important in the coupling of land and water systems (Hasler 1975).

CONCLUSIONS

An artesian source of water has allowed vertical accumulation of peat and development of a peat mound. Stratigraphy of mineral soil beneath the peat influences the amount of vertical flow of water and ultimate height of the peat. The mound may be approaching (or may already be at) an equilibrium height.

The peat mound, because of its location between the upland and basin-filled wetland, may act as an important buffer, intercepting runoff of nutrients from the upland. Also, because of their location at the upland-wetland interface, many peat mounds have probably been eliminated or degraded in some way. Because the ecological processes occurring in this kind of peatland are not well known, more detailed research needs to be done before the complexities of this hydrologically interesting ecosystem are understood.

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