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## Age and Developmental History of Iowa Fens

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Iowa fens are small, mineotrophic peatlands maintained by shallow groundwater. Eighteen fen sites located across northern Iowa were mapped and radiocarbon dated to assess the timing of initial peat accumulation. The radiocarbon ages span the Holocene, ranging from 1,240 to 10,900 B.P.; however most fens postdate 5,000 yr B.P. The dominance of late-Holocene ages suggests that Holocene climatic change may have strongly influenced the record of peat accumulation. During the mid-Holocene Iowa was warmer and drier than at present, and peat was degraded or accumulated slowly in fens. The range of ages also implies that the commencement and subsequent rate of peat accumulation depends on local variations in landscape development and resultant hydrology.

INDEX DESCRIPTORS: peat, fens, radiocarbon ages.

The developmental history of hillslope fens found in the Midwest and Prairie states of the USA is poorly understood. Peat in these fens is often highly degraded and pollen is usually not preserved. Thus, developmental history can be studied only by the use of stratigraphic and age-dating techniques. Fens are one of the rarest wetland communities in the United States. Their importance lies in the "disproportionately high number of rare, threatened, and endangered species" which occur in these wetlands (Eggers and Reed, 1990). An understanding of the geologic controls on fen development and maintenance is necessary to adequately address management concerns.

Fens are peatlands; however their definition and classification are complicated by the fact that there is a continuous gradation in peatland communities from bog to fen. In the simplest sense, a fen is a peatland that receives water which has passed through a mineral soil. This results in relatively high available nutrients and slightly acidic to basic water chemistry. Fens in the Midwest typically fall into the rich fen category because of their high nutrient levels, and have been referred to as prairie fens (Moran, 1981), calcareous fens (Carpenter, 1990; Reed, 1985), and spring fens (Nekola and Lammers, 1989). These are minerotrophic peatlands with circum-neutral or higher pH, and high calcium and magnesium content. Midwestern fens are mostly less than 4 hectares in extent and occur as mounds of peat, usually on a side-slope.

Theories of peatland evolution have always recognized that regional climate plays a significant role in the development and growth of peatlands (Heinselmann, 1970; Glaser et al., 1981; Ovenden, 1990). Recent research has suggested that local hydrologic conditions, which are in turn influenced by local geology and climate, also play a major role in peatland development (Miller and Furyma, 1987; Foster and Jacobson, 1990). This would appear to be particularly true for the small, groundwater-dominated fens found in Iowa and other parts of the Midwest.

Only a few radiocarbon ages are available from fens in the lower Midwest and Prairie states. Basal ages of  $9,340 \pm 200$  B.P. at Hughes Bog, Iowa (Hall, 1971), approximately 2,000 B.P. in Cowles Bog, Indiana (Wilcox et al., 1986), 4,400 B.P. at Tamarack Creek, Wisconsin (Davis, 1975), 4,790 B.P. at Denbigh Fen, North Dakota (Malterer and Bluemle, 1988), and ranging from 2,120 to 5,460 B.P. at a fen in northeastern Iowa (R.G. Baker, personal communication) indicate that peat accumulation in fens spans a wide interval of time, but most seems to have accumulated after 5,000 B.P.

The purpose of this study was to assess the timing of initiation of peat accumulation for Iowa fens. The geologic information as well as the radiocarbon ages that were collected for this study allow some preliminary theories regarding fen development in Iowa to be advanced. This information was gathered as part of a broader study to investigate the geologic setting, hydrology, and water chemistry of fens in Iowa (Thompson, 1993; Thompson et al., 1992).

### DESCRIPTION OF IOWA FENS

Fens are peatlands fed by shallow groundwater. They occur in all of

Iowa's landform regions, but are most prominent on the Iowan Surface and morainal margins of the Des Moines Lobe (Prior, 1991). These two landform regions are loess-free terrains with mostly glacial and glaciofluvial deposits at the land surface. The Des Moines Lobe is a constructional glacial landscape formed by a lobe of the Laurentide Ice Sheet between 14,000 and 12,000 years ago. The Iowan Surface is an erosional landscape formed under periglacial conditions during the last glacial maximum. It consists of a series of stepped erosion surfaces cut into Pre-Illinoian (>500,000 B.P.) glacial deposits. Glacial till on the Iowan Surface is usually more weathered and is oxidized to a greater depth than that on the Des Moines Lobe.

Iowa fens range from 0.4 to 10 hectares in extent, with most less than 4 hectares. Some occur as complexes, i.e., several fens clustered within a relatively small area. They occur primarily in sloping upland landscape positions; however some can be found in abandoned channels in valleys. Most are on sideslopes, and gradient on the fen surface ranges from 0.004 to 0.243, with 90% less than 0.1.

Surface features on fens are variable. The surface is often wet, but without standing water. Compression of the peat surface can lead to development of small shallow pools. Only a few Iowa fens have naturally occurring well-developed pool areas. One fen (Silver Lake) has surface patterning of alternate pools (flarks) and peat areas (strings) similar to fens in more northern climates, albeit on a much smaller scale. During drier years or extended periods without rain, the surface becomes drier, although the peat itself remains damp. In most cases, the permanent water table drops less than 0.3 meters below ground surface. Surface expression of groundwater discharge zones in the fens is not common. Some fens, particularly those with artesian water sources, have springs surrounded by well-developed mound areas. These mounds are underlain by fluidized peat, carbonate muck, and/or sand and are not particularly solid surfaces. Other areas of the fen where discharge occurs are buoyant, but can be walked on. Areas where water is discharged from the peat are often characterized by red flocs caused by bacterial oxidation of iron (Robbins, 1991).

Some fens show well-developed vegetative zoning with an outer area dominated by *Carex stricta* (hummock grass) and an inner area, referred to as a sedge-mat or lawn, dominated by *Rhynchospora capillacea* (capillary beakrush) and *Scleria verticillata* (low nut rush). A more detailed discussion of the vegetation on Iowa fens can be found in Pearson and Leoschke (1992). Hummocks are common on most Iowa fens. These are small structures, less than 0.3 meters across, about 0.1 to 0.3 meters tall (some are as tall as 0.6 meters), and usually about 0.1 to 0.3 meters apart.

### METHODS

Eighteen fens were selected for this study (Fig. 1). Stratigraphic information from each fen's surroundings was obtained with a Giddings hydraulic soil-coring machine which was also used to install wells for water sample collection. Each fen was surveyed with a theodolite; and a topographic map was prepared. Peat thicknesses

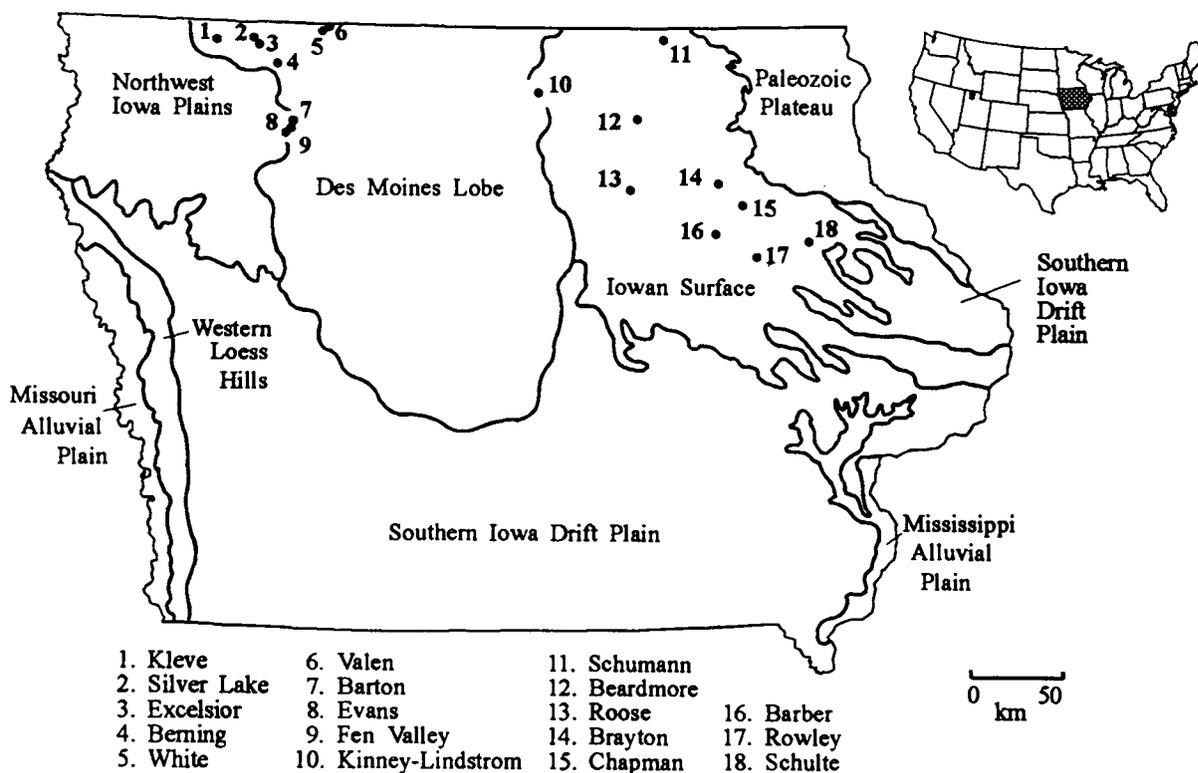


Fig. 1. Locations of studied fens in relation to landform regions of Iowa (after Prior, 1991).

were obtained along several transects through each fen using a 2.5 cm diameter hand probe. An attempt was made at every probing location to ascertain the nature of the substrate materials. Cores were collected from different parts of the fen using an Eijkelkamp peat sampler. The cores were wrapped, boxed, and described indoors using modified U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS) terminology (Soil Survey Staff, 1981). One sample for radiocarbon analysis from the base of the deepest core was obtained from each site. Radiocarbon analysis was performed on bulk samples of peat, picked of rootlets and dispersed in hot acid to remove carbonates, by Beta-Analytic, Inc. Additional information on soil type and shallow substrate composition in the vicinity of the fen was determined from published USDA-SCS county soil survey maps at a scale of 1:12,000.

## RESULTS

The peat in Iowa fens is normally a well-humified, sapric variety, although considerable variation occurs. By definition, peat has an organic content of at least 20 percent and an ash content of less than 50 percent (Crum, 1988). Not all organic deposits in Iowa fens are peat. It is not unusual for these fens to have layers of fibric peat interbedded with carbonate hash, tufa, or sapric muck. Such interbedding implies changes in hydrologic regime and/or allogenic factors during accumulation of the fen sediments. On the Von Post scale of humification Iowa's fen peats range from H6 to H10 (Crum, 1988).

Ash content measured at three sites ranges from 18 to 85% with the majority being less than 50%. The high values were obtained at a site dominated by carbonate-rich muck and carbonate hash (Silver Lake). Ash content varies not only with depth, but also with position in the fen. Based on visual examination the peat is more mineral-rich in the hummock areas and more organic-rich in the sedge-mat zones. In fens with no vegetative zoning, there is usually an area near the

middle of the fen with lower ash content that is probably related to upwelling flows. The areas with more or less constant water flow and consequently high stable water levels have less decomposition and develop less-humified peats than areas where flow and water levels are more variable (Boelter, 1969; Everett, 1983).

Peat thickness is also variable, with most Iowa fens having less than 1.3 meters across their extent. Maximum peat thickness observed was 4.5 meters. Areas of maximum peat thickness do not necessarily coincide with surface features on the fens. Areas of thickest peat are usually coincident with subsurface depressions or slope inflections on the sub-peat surface. This has important implications with regard to development and evolution of these sites.

Table 1 shows basal radiocarbon ages from the studied fens. The ages span the Holocene, although most postdate 5,000 B.P. There is no relationship between fen type (as defined in Thompson et al., 1992) and age, or between fen location and age (Fig. 2). The dates establish the commencement of peat accumulation. The groundwater in Iowa is usually saturated with respect to carbonate and the possibility exists that inert carbon could have affected the reported radiocarbon dates (hard-water error). However, organic-rich materials such as peat are generally unaffected by the incorporation of some inert carbon unless contamination levels are extremely high. No marly peat layers were used for dating. If contamination was present the reported ages would be too old. However, this would not change the conclusions reported in this paper.

## DISCUSSION

The assumption was made during collection of radiocarbon samples that the deepest part of the fen represents the point of initial peat accumulation. One possibility is that the peat expands from an initial accumulation at an inflection point in the subsurface. Such subsurface inflections were documented at several fens, particularly fens developed on terraces or on sand and gravel lenses exhumed from intert

Table 1. Radiocarbon ages for Iowa fens<sup>a</sup>

Site	Size (ha)	Lab#	Age (RCYBP)	Depth (cm)	Fen Type <sup>b</sup>	Landform Region <sup>c</sup>
Evans	0.4	B-42620	1,240 +/- 60	55-66	Intertill	DML
Berning	0.8	B-42617	1,570 +/- 60	178-188	Terrace	DML
Chapman	1.1	B-42619	2,130 +/- 60	168-185	Intertill	IS
Kinney-Lindstrom	0.9	B-48037	2,280 +/- 60	86-96	Intertill	IS
Kleve	0.5	B-42622	2,510 +/- 70	102-117	Outwash	DML
Excelsior	0.6	B-42621	2,550 +/- 80	249-267	Artesian	DML
Fen Valley	0.3	B-42623	2,720 +/- 80	254-264	Intertill	DML
Barton	4.3	B-42616	3,390 +/- 70	394-414	Outwash	NWIP
Schuman	2.6	B-48040	3,660 +/- 80	198-206	Intertill	IS
Silver Lake	0.5	B-42625	3,750 +/- 80	292-318	Artesian	DML
Schulte	5.5	B-48039	4,080 +/- 90	168-173	Intertill	IS
Rowley	2.6	B-42624	4,430 +/- 80	99-104	Ridge	IS
Roose	1.2	B-48038	4,990 +/- 90	160-173	Intertill	IS
Brayton	7.7	B-42618	5,940 +/- 70	272-284	Intertill	IS
Barber	2.9	B-42615	8,340 +/- 80	203-218	Intertill	IS
Valen	0.5	B-42626	8,780 +/- 90	259-267	Intertill	DML
White	0.5	B-42627	10,220 +/- 110	343-353	Terrace	DML
White	0.5	B-48041	10,750 +/- 110	330-343	Terrace	DML
Beardmore	6.5	B-48036	10,900 +/- 80	178-185	Intertill	IS

<sup>a</sup>all dated material was peat

<sup>b</sup>see Thompson et al., 1992 for a discussion of fen types

<sup>c</sup>DML Des Moines Lobe

NWIP Northwest Iowa Plains

IS Iowan Surface

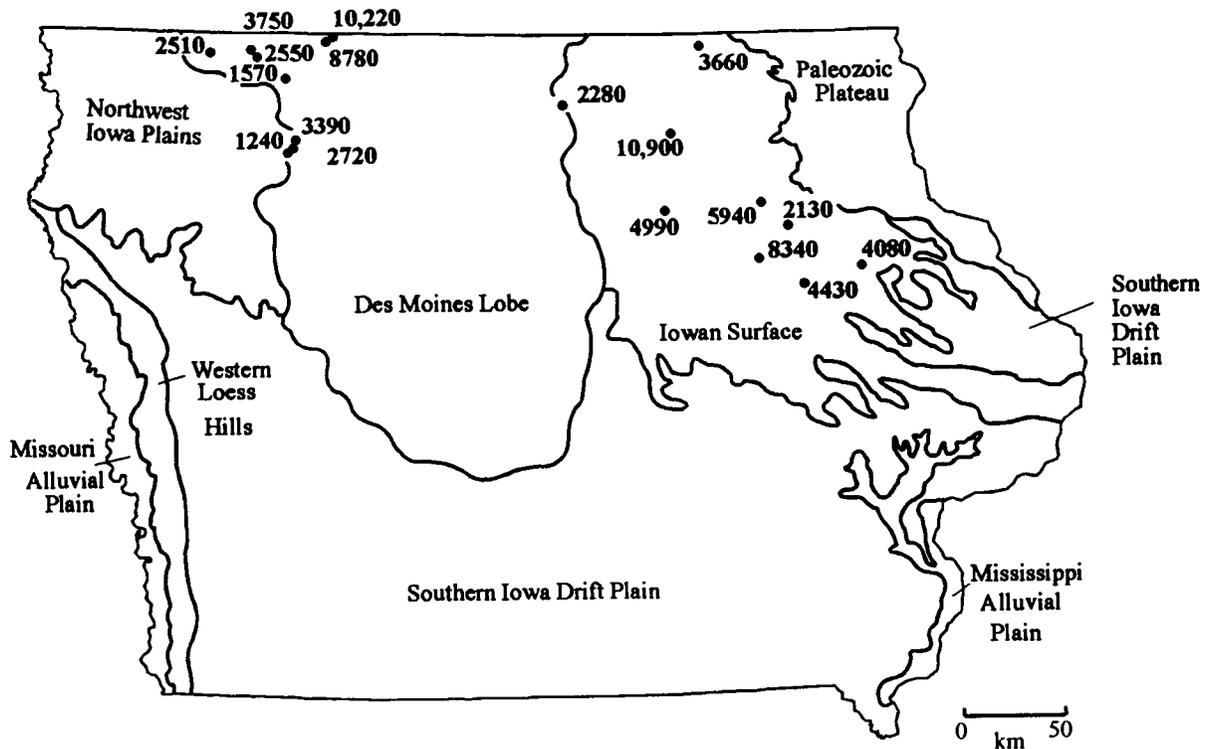


Fig. 2. Basal radiocarbon ages for Iowa fens.

positions. Invariably the thickest section of peat occurred at this subsurface inflection point (Fig. 3). However, analysis of subsurface topography shows that there is a great deal of variability. Therefore, the radiocarbon sample from each site may or may not have been collected from the area of initial peat accumulation. Until intensive dating within individual fens can be done, the nature of peat expansion in the fens will not be known.

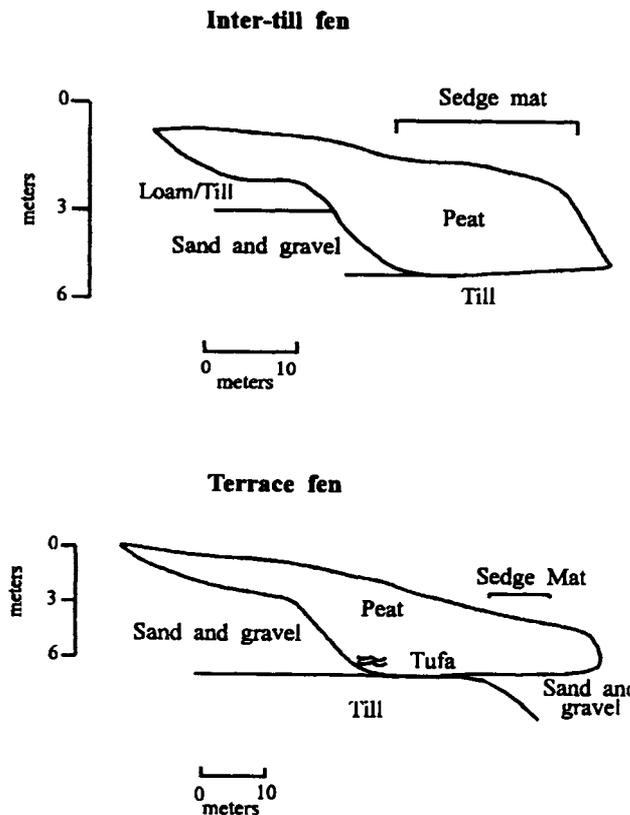


Fig. 3. Typical stratigraphy and subsurface configuration for inter-till and terrace fens in Iowa.

At first glance the radiocarbon ages suggest that initiation of peat accumulation was not synchronous, and may have been controlled by local variations in landscape and resultant hydrology at each site. The importance of local geologic and hydrologic conditions cannot be underestimated for Iowa fens. In most cases the recharge area for these fens is very small, probably less than 25 square kilometers. The local geology has a strong influence on the rate of infiltration and thus on the availability of water to the fen. Iowa fens respond individually to drought conditions. This behavior has been explained by reference to the variations in weathering and secondary fracture patterns of the geologic materials around each fen (Thompson et al., 1992). Fluctuations in water supply over time will affect the rate of peat accumulation by altering the ratio of decomposition to accumulation.

We suggest, however, that Holocene climatic change may also have strongly influenced the record of peat accumulation in these fens. Of the 18 fens with radiocarbon ages, 13 have a basal age less than 5000 B.P. The middle Holocene in the Midcontinent USA was warmer and drier than at present (Bartlein et al., 1984). Several studies put the period of maximum dryness in central and western Iowa sometime between 6300 and 5000 B.P. (Baker et al., 1990; Van Zant, 1979; Van Zant and Hallberg, 1976). During this period water levels of lakes and marshes were significantly lower than at pre-

sent (Van Zant, 1979; Baker et al., 1990; Keen and Shane, 1990) and, by inference, shallow groundwater levels were also lower. Investigations at lakes in Minnesota have shown that several periods of extended or recurrent drought occurred during the middle Holocene (Bryson et al., 1970; Dean et al., 1984; Forester et al., 1987; Keen and Shane, 1990). Drought conditions accompanied by depressed levels of shallow groundwater would not have been favorable for peat accumulation. It seems likely that peat accumulation in fens was very reduced during the Middle Holocene; and that in most cases net degradation of earlier-formed peat occurred. When viewed in this light, the dominance of post-5,000 B.P. basal ages from Iowa fens probably indicates the time at which long-term local shallow groundwater levels rose and peat accumulation resumed following the droughty Middle Holocene. Pre-5,000 B.P. ages probably indicate that at these fens (or at least in these locations in the fens) local hydrologic conditions were sufficient to overcome regional drought conditions, and all the pre-Middle Holocene peat was not degraded. It is also worth noting that fens with pre-Middle Holocene basal ages may contain a hiatus in peat accumulation that is not macroscopically visible in cores. Such a hiatus occurs at Sumner Bog in eastern Iowa (Van Zant and Hallberg, 1976), Postville Bog in northeastern Iowa (R.G. Baker, personal communication), and may be present at other localities where dramatic changes in pollen composition and radiocarbon age occur over very short intervals (e.g. Kim, 1986; Nations et al., 1989). Radiocarbon dating of selected intervals within single peat cores would allow testing of this hypothesis. Testing cores at closely spaced intervals for ash content may help identify zones of slower peat accumulation, or increased inputs of mineral sediment, and thus provide a more selective approach for picking the intervals to date.

It is clear that the rate of peat accumulation in fens has varied throughout the Holocene. Plant communities at these sites probably also varied in response to changing hydrologic conditions. However, pollen is not generally preserved in these fens, making it more difficult to assess vegetation changes. Analysis of plant macrofossils preserved in the fen's organic deposits may shed light on the Holocene evolution of vegetation communities at these sites.

It is important to recognize that fens harbor dynamic plant and animal communities dependent on shallow groundwater for their existence. Data from this study indicate that hydrologic conditions that control the rate of peat accumulation at Iowa fens have varied significantly during the Holocene. This has implications with regard to management and persistence of fen habitats. Management plans need to address both long- and short-term stability of water sources. Especially important is a better understanding of recharge mechanisms and development of techniques for accurately delineating recharge areas. Increased temperatures and/or greater seasonal variability of precipitation in the midcontinent USA may be part of the near future's human-induced climate change. These shifts in climate may alter groundwater conditions and foster the degradation of some fens, or cause changes in species composition. Improved assessments of fens' hydrogeologic systems should make it possible to rank fens on the basis of the stability of their water source and thus their ability to withstand the effects of future climate change.

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