

BOGS: A WEB PRESENTATION

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ES767 Quaternary Geology

Introduction

Bogs are unique ecological communities found in most climatic zones of the world from the high latitudes to the equatorial region. Many existing bogs have supported an active flora community since shortly after the end of the last period of glaciation. In fact, geologic and hydrologic conditions resulting from the advance and retreat of the ice sheet and the associated changes in sea level created conditions favorable to the formation of bogs in both the cold and tropical regions.

The word "bog" has been used as a definition of soft, spongy ground since prior to 1450 (Barnhart, 1988). Barnhart (1988) reports the word to be of Irish and Gaelic origin. The term "bog" can be used to describe either a landform or a plant community. Bates and Jackson (1984) give definitions based on being a landform and a plant community; Parker (1989) defines a bog as a plant community with a permanently waterlogged peat substrate. Damman and French (1987) give a good definition that begins to show the interrelationship between the land and the vegetation. They define a bog as; *"a nutrient-poor, acid peatland with a vegetation in which peat mosses, ericaceous shrubs, and sedges play a prominent role"*. From these definitions, it becomes apparent that vegetation and water are critical and interrelated requirements for a bog environment. A third requirement for the formation of a bog is a suitable geologic setting.

As a bog matures peat begins to accumulate. This peat layer is formed by the semi-consolidated remains of plant material. Peat exists in a water logged region where chemical and physical conditions prevent rapid degradation. Peat is a precursor to coal and when dried and burned, peat can be a significant energy source. Recognizing that peat is a precursor to coal, also suggests something about potential bog environments that must have been common in the Carboniferous Period in coal producing regions.

Methods for Classifying Bogs

Introduction

There are several methods that can be used to classify bogs. Damman and French (1987) discuss three methods for the classification of bogs. These classification methods are:

- Classification based on the method of water supply;
- Classification based on the landforms where the bog development occurs; and
- Classification based on the landform produced by the bog.

Classification Based on Source of Water

All bogs depend on water for their existence and the first determination that must be made in the classification of a bog is the means by which the bog receives water. Bogs that receive water only from precipitation are classified as ombrotrophic. Bogs that receive moisture from surface water or groundwater are called minerotrophic bogs. The flux of nutrients and minerals in a minerotrophic bog is much greater than in an ombrotrophic bog.

Classification Based on the Landforms in Which Development Occurs

Bogs can also be classified based on the landforms in which they develop (Damman and French, 1987). On this basis, they divide bogs into ombrogenous, topogenous, limnogenous, and soligenous.

Ombrogenous Bogs

Ombrogenous bogs initially form in surface depressions. As peat begins to accumulate, the surface of the bog raises above the level of the surrounding land surface, cutting the vegetation off from sources of water other than precipitation. These types of bogs are limited in geographic range to humid, temperate climates (Damman and French, 1987).

Topogenous Bogs

Topogenous bogs form in topographic depressions where water accumulates and the bogs are maintained by groundwater (Damman and French, 1987). More than 300 topogenous bogs, which range in area from 25 acres to less than one acre, are present in the formerly glaciated regions of Iowa (Anderson, 1998). Anderson (1998) describes six typical landscape positions in which bogs are found in the formerly glaciated regions. The landscapes given by Anderson (1998) are:

- Valley walls where sand and gravel deposits occurs between glacial tills;
- Hummocky settings along the margins of the Des Moines Lobe where sand and gravel bodies occur within glacial till;
- The lower slopes of exhumed sand and gravel deposits of the Iowan Surface;
- The base of alluvial terraces or outwash deposits;
- Bedrock aquifers that are exposed at the land surface; and
- Sand and gravel deposits in abandoned stream channels.

Kettle holes are also common depressions favorable to bog formation (Hansen, 1941).

Topogenous bogs are not confined to a particular climatic region, their locations range from the tropics to the arctic (Damman and French, 1987).

Limnogenous Bogs

Limnogenous bogs can develop along lakes and slow moving streams (Damman and French, 1987). These types of bogs may also be referred to as swamps or marshes. Limnogenous bogs can form under a diverse range of climatic conditions (Damman and French, 1987). Where an inflow of water is present, a potential for a supply of nutrients is also present.

Soligenous Bogs

Soligenous bogs form on slopes that are provided moisture by means of seepage from the layers that form the slope. Soligenous bogs are generally restricted to those climatic regions where precipitation is greater than evapotranspiration (Damman and French, 1987). As with limnogenous bogs, the potential exists for nutrients and minerals to be supplied as a result of the inflow of water.

Classification Based on the Landscape Produced

Bogs may be classified based on the landforms they produce. Damman and French (1987), identify four landforms produced by bog development. These landforms are peat bog lake systems, perched water peatland systems, peat bog stream systems, and ombrogenous peatland systems. There can also be composite-type bogs. Damman and French (1987) give the example of a perched water bog adjoined by a lake fill bog for a composite type bog. An obvious advantage to this classification system is that a visual surface reconnaissance is adequate to gather sufficient information to allow classification.

Peat Bog Lake Systems

Peat bog lake systems are topogenous peatlands. In formerly glaciation regions, peat bog lake systems are most common in kettle lakes. Damman and French (1987) divide peat bog lake systems into three types based on the configuration of the bog mat. These types are lake fill bogs, moat bogs, and pond bordering bogs. The lake fill bog is the first stage in the filling of an oligotrophic lake. The lake is completely covered by either a grounded or quaking mat. The vegetative cover ranges from conifers and deciduous trees to dwarf shrubs. In a moat bog, an area of open water separates the bog from the surrounding shoreline. The moat bog is a floating or quaking bog with vegetation similar to that of the lake fill bog. Pond border bogs have vegetation around the pond shoreline. The width of this vegetative zone may only be a narrow area around the shoreline or it may extend to near the center of the pond. The bog is floating near its inner terminus and grounded along the shoreline.

Perched Water Bog Systems

Perched water bogs occur in depressions and valleys where a perched groundwater table is present that can provide water for bog development. (Damman and French, 1987). Glacial till is a common lower confining unit for the perched water table (Damman and French, 1987). Since the water is supplied by a shallow perched water table, mineral and nutrient concentrations are low. Soligenous bogs are another type of perched water table bog (Damman and French, 1987).

Soligenous bogs can form on slopes in climates where precipitation exceeds evapotranspiration. The reason for classification of soligenous bogs as perched water table bogs appears to be that the seepage water that supplies water to the bog is seepage from a perched water table. Soligenous bogs vary widely in size and type of dominant vegetation.

Peat Bog Stream Systems

This type of bog forms along a slow moving stream system. Flooding may occur during periods of heavy stream flow (Damman and French, 1987). The mineral and nutrient flow is variable. Damman and French (1987) reports that streams that supply water to bog stream systems can be low in nutrients, in which case *Sphagnum* is the dominant vegetative cover.

Ombrogenous Bog Systems

This type of bog is also referred to as a raised bog. The border around the raised portion of the ombrogenous bog may be minerotrophic (Damman and French, 1987). The vegetation in the raised portion of the bog is dominated by *Sphagnum*. Raised bogs can exist over a wide range of climatic regions. They are found in Newfoundland, and Canada (Damman and French, 1987) and in tropical regions such as Sumatra (Neuzil, 1993).

Sequence of Bog Formation

Introduction

Lakes are an important element in the formation of bogs. An indication of this importance is given by Lowe (1997) who states; "*Given sufficient time, all lakes become infilled with sediment to form mires and bogs.*" A review of the landscapes where bogs form shows potential formation sites not directly related to lakes. Soligenous bogs may form on hill slopes where groundwater seeps are present. Peat bog stream systems form along the bed of slow moving streams. While all lakes may, given time, evolve into bogs, not all bogs are formed in lake environments.

Lake Origins

Lakes may develop in response to many physical and biological activities. Lowe (1997) classifies eleven lake types based on the activities leading to their development. These lake types are summarized in the following table.

Lake Classifications Data Source: Lowe, 1997	
Lake Type	Example Lake Formation Activities
Tectonic lakes	Epeirogenic movements Crustal tilting, folding, or warping
Volcanic lakes	Caldera and crater lakes Damming of drainage by volcanic materials

Landslide lakes	Damming or topographic depressions formed by landslides
Glacial lakes	Kettles lakes Impoundments created by glacial deposits
Solution lakes	Solution of underground materials (sink holes)
Fluvial lakes	Delta formation Changes in stream course (oxbow lakes) Deposit of natural levee systems
Aeolian lakes	Deflation Damming by aeolian deposits
Shoreline lakes	Damming by materials deposited by longshore currents Formation of recursive spits
Organic lakes	Vegetative damming Damming by beavers Coral growth
Anthropogenic lakes	Construction of dams Excavation
Meteorite lakes	Meteorite impacts

The transition from lake to bog begins with the accumulation of sediment. These sediments may be allochthonous or autochthonous (Lowe, 1997). The initial types of deposits depend on the limnology of the lake. Lowe (1997) provides a descriptions of deposit characteristics based on lake limnology. These descriptions are summarized in the following table.

Lakes Sediment Types Based on Limnology Data Source: Lowe, 1997	
Limnologic Condition	Resulting Deposits
High nutrient concentration, noncalcareous, abundant flora	Organic rich sediment called nekron mud or gyttja in the near shore environment, grading into finer sediment in deeper water
High nutrient concentration, calcareous, biological community contains organisms that mediate the precipitation of lime	Cream-colored sediment with high clay content (marl)
Low nutrient concentration, low biological production	Inwash materials clastic in nature: Coarse clastics (sand) near shore, then silts grading into clay in deeper water Inwash materials organic in nature: Lake water has brownish color and colloids may precipitate to form a mud known as dy
Abundant diatoms, nutrient level may be high to low determining the species of diatom present	White siliceous mud formed from diatom frustules (diatomite)

Progression from Lake to Bog

The progression from lake to bog starts when plants begin to encroach into perimeter of the lake and the sediments begin to change from clasts to peats (Lowe, 1997). There are three general categories of peat identified by Lowe (1997) that contribute to the accumulating peat. These peat categories are limnic peats, telmatic peats, and terrestrial peats. Limnic peats form below the water level from plant material transported into the water or from native plant material. Telmatic peats form in the swamp zone. Terrestrial peats accumulate at or above the high water level.

Limnic peat begins to accumulate along with silts in the lake as plants start to invade the lake. Limnic peat forms a layer at the bottom of the lake. Telmatic peats begin to accumulate around the lake's perimeter. As the telmatic peat begins to accumulate, the region around the lake's perimeter grows shallower providing additional area for the growth of more vegetation. The area of open water grows smaller until the lake is filled with telmatic peat. Mixed vegetation such as grasses, sedges, shrubs, and deciduous trees may then root and grow over the now filled lake. As terrestrial peats begin to accumulate, the deciduous trees begin to dwarf and conifers start to dominate. The change from deciduous trees to conifers is probably a result of the increasing acidity of the bog as the terrestrial peat accumulates. As the doming of the bog continues, the environment changes such that conifers can no longer survive and the vegetation is then dominated by *Sphagnum*.

The Transition from Vegetal Matter to Peat

Peat is produced from plant matter. The type of peat produced depends on the type of plant matter from which the peat was formed. Vascular plant material is added as plants die. Examples of material contributed by vascular plants include leaf litter, dead roots, branches, and stems (Damman and French, 1987). *Sphagnum*, grows at the surface and dies at the bottom; therefore, it is a steady contributor to peat formation (Damman and French, 1987).

Peat can be classified on the type of plant material from which it was derived. Damman and French (1987) recognize five types of peat based on their vegetal origin. The types of peat are:

- *Sphagnum* peat, which consists primarily of *Sphagnum* with minor amounts of vascular plant material;
- Moss and moss-sedge peat, which is primarily derived from mosses;
- Reed and sedge peat, which is derived from a mixture of reeds, cattails, and large sedges;
- Wood peat, originates in forested peatlands and contains wood in various stages of decay; and
- Limnic peat, develops in lakes as a result of the deposition of organic matter from aquatic organisms.

As decay and compaction occur, the peat becomes more humified. Humification is a measure of the degree of decomposition that has occurred. The degree of humification is often reported

using the von Post's Humification Scale, which was developed by Von Post and Granlund in 1926. The von Post Humification Scale is given in the following table.

von Post Humification Scale Table Source: Damman and French, 1987	
Scale	Peat Characteristics
H1	Completely undecomposed peat; only clear water can be squeezed from peat
H2	Almost undecomposed; mud free peat; water squeezed from peat is almost clear and colorless
H3	Very little decomposition; very slightly muddy peat; water squeezed from peat is muddy; no peat passes through fingers when squeezed; residue retains structure of peat
H4	Poorly decomposed; somewhat muddy peat; water squeezed from peat is muddy; residue is muddy but it shows structure of peat
H5	Somewhat decomposed; muddy; growth structure discernible but indistinct; when squeezed some peat passes through fingers but most muddy water passes through fingers; compressed residue is muddy
H6	Somewhat decomposed; muddy; growth structure indistinct; less than one-third of peat passes through fingers when squeezed; residue very muddy
H7	Well decomposed; very muddy, growth structure indistinct; about one-half of peat passes through fingers when squeezed; exuded liquid has a "pudding-like" consistency
H8	Well decomposed; growth structure very indistinct; about two-thirds of peat passes through fingers when squeezed; residue consists mainly of roots and resistant fibers
H9	Almost completely decomposed; peat is mud-like; almost no growth structure can be seen; almost all of peat passes through the fingers when squeezed
H10	Completely decomposed; no discernible growth structure; entire peat mass passes through fingers when squeezed

The Chemical Environment of Bogs

Bogs have unique chemical environments. Damman and French (1987) define two peat horizons. The horizon identified as the acrotelm is the peat above the low water table elevation and the horizon identified as the catotelm is the horizon that is permanently saturated. This section focuses on the aqueous chemistry of the catotelm. The catotelm is saturated with water that has a low dissolved oxygen content and is reducing with respect to most redox reactions. The water also has a low pH and is nutrient poor.

The amount of oxygen that can be dissolved in water can be calculated using the Henry's law constant for oxygen. Oxygen has a Henry's law constant (K) of $1.28 \times 10^{-3} \text{ mol / l} \cdot \text{atm}$ at 25 degrees C. Since oxygen constitutes about 21 percent of air, the partial pressure of oxygen (P_{O_2}) is 0.21 atmospheres. At equilibrium, the oxygen content of water in contact with air at a temperature of 25 degrees C can be calculated as follows:

$$[O_2] = P_{O_2} \cdot K = 0.21 \text{ atm} \cdot 1.28 \times 10^{-3} \text{ mol / l} \cdot \text{atm} = 2.69 \times 10^{-4} \text{ mol } O_2 \text{ / l } H_2O$$

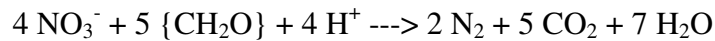
Since diatomic oxygen (O_2) has a molar mass of 32 grams per mole:

$$2.69 \times 10^{-4} \text{ mol } O_2 \text{ / l } H_2O \cdot 32 \text{ grams } O_2 \text{ / mol } O_2 = 0.0086 \text{ grams or } 8.6 \text{ mg } O_2 \text{ / l } H_2O$$

Water that is saturated with oxygen has an oxygen concentration of about 8.6 milligram per liter (mg/l). Since the Henry's law constant is temperature dependent, the saturated oxygen concentration varies with temperature in an inverse manner. Numerous factors can cause the oxygen content of water to be less than the saturation concentration. The oxidation of contaminations (natural or anthropogenic) can take oxygen from the water. Aerobic or facultative bacteria can consume oxygen from water faster than it can be replenished. The consumption of oxygen by aerobic bacteria is self regulating to an extent, as the oxygen content of the water decreases so does the rate of growth of the bacteria. Facultative bacteria are a different matter, as the oxygen content decreases these bacteria use other materials as electron acceptors.

The three primary nutrients needed by plants are nitrogen, phosphorus, and potassium. In most ecosystems these nutrients are recycled. They are leached from decaying vegetation and the soluble nutrients are then again available to the currently active vegetation. In bog environments nutrient recycling is limited by the chemical and biological properties of the bog. Decay and leaching occur slowly in the bog.

An example of the incomplete recycling of nutrients is what happens to nitrogen in a bog environment after it becomes aqueous. The most common form of nitrogen available for plant uptake is the ion nitrate (NO_3^-). In the absence of oxygen, facultative bacteria (e.g. certain species of *Pseudomonas*) begin to use nitrate as an electron acceptor (Chapelle, 2001). With an adequate source of carbon to serve as an energy source for the bacteria, the nitrate can be reduced to nitrogen gas in accordance with the following reaction (Manahan, 1991). The carbon source is represented by a simple carbohydrate given as $\{CH_2O\}$.



The nitrogen gas (N₂) and carbon dioxide (CO₂) are lost to the atmosphere. The reaction can only occur in an anaerobic reducing environment. Vegetation provides the required carbon for energy. The reaction is thermodynamically favorable and readily occurs when the appropriate bacteria are present to mediate the reaction.

The water contained in bogs generally has a low pH which is somewhere around 5.5. The pH scale is logarithmic so a change of one pH unit represents a 10-fold change. There are several factors that may contribute to the low pH. Davis (1946) states that the growth of mosses decrease the pH of the water but does not provide a mechanism by which the pH is lowered. Decaying vegetation produces humic and fulvic acids which would decrease the pH of the water. Dissolved carbon dioxide in the water forms carbonic acid. Carbon dioxide is produced by many reactions including the reduction of nitrate to nitrogen gas. In the northeast, rainwater may have a low pH due to atmospheric sulfur combining with the rain water to form sulfuric acid. The brown color common in bogs is mostly due to tannins released from vegetation. These tannins can also lower the pH.

The above discussions should provide a sense of the complexity of the water chemistry in bog environments. It should also be noted that each element and reaction is interrelated to other elements and reactions. There are other important chemical processes such as carbon absorption and cation exchange that create and stabilize the environment.

Bog Flora

Introduction

The types of vegetation associated with a bog depends on the available water source, climatic conditions and stage of bog development (Damman and French, 1987). As a lake begins the transition to a bog, the first plants that begin to allow the accumulation of organic material are those that encroach from the shoreline and free-floating plants. Organic matter continues to accumulate until infilling of the lake is complete. Deciduous trees, shrubs, and sedges then become the dominant vegetation. *Sphagnum* begins to accumulate starts the formation of a convex surface. Conifers and dwarf shrub displace the deciduous trees in this environment. As the *Sphagnum* continues the doming process, the conifers can not survive.

Transitional Vegetation

Plants that begin to encroach into a lake at the beginning of the transition from lake to bog include cattails, rushes, sedges, and bulrushes. Cattails (*Typha spp.*) are common around the borders of most lakes and ditches. Cattails can grow in water that is less than about 1 meter deep. Cattails grow in dense stands that limit the growth of other plants (Eastman, 1995). Cattails can spread rapidly. One spike produces an average of 220,000 seeds (Eastman, 1995). These seeds mainly serve to allow the dispersal of seeds to new areas. Cattails have creeping rhizomes that cause the propagation of new plants in the existing stands (Eastman, 1995). Cattails are easily

recognized by their large sausage-shaped seed spikes. They reach heights of one to three meters. The geographic range for cattails in North America is from Alaska to Mexico (Niering, 1998).



**Dormant cattails along a shoreline
McPherson County, Kansas**

Rushes (*Juncus spp.*) grow in shallow water and along shorelines (Eastman, 1995). Rushes grow in colonies and their dense growth impedes other plants from encroachment (Eastman, 1995). Rushes range in height from about 0.5 to 1.5 meters (Niering, 1998). Rushes have spike-like rounded stems and produce small flowers (about 4 mm) when leaves are present, they are rounded (Eastman, 1995; Niering, 1998). In North America, rushes are common in Canada and the northern United States (Niering, 1998).

Sedges (*Carex spp.*) are related to grasses. A main diagnostic features given by Eastman (1995) to differentiate grasses from sedges based on visual observation is; "*grasses are round, sedges have edges*", which refers to the characteristic of the stem. There are over 200 species of sedges (Eastman, 1995). Sedges form thick mats that advance from the shoreline (Eastman, 1995). Eastman (1995) reports that the decomposition of these mats lowers the water pH which in turns establishes conditions favorable to subsequent vegetation. Sedges may form circular mounds that extend 75 or more centimeters above the water surface.

Bulrushes (*Scirpus spp.*) are members of the sedge family and are not rushes. Bulrushes are tall emergent herbs that grow along shorelines or in dense off-shore patches (Eastman, 1995). Bulrushes can grow in water up to 1.5 meters in depth and can serve to dissipate wave energy allowing less hardy plants to grow closer to shore (Eastman, 1995). In North America, bulrushes have a geographic range beginning in Canada and extending south to Texas (Niering, 1998).

Vegetation of the Filled Lake

As the lake becomes filled with organic matter, the vegetation undergoes a change from aquatic plants of terrestrial plants. Typical examples of these terrestrial plants include deciduous trees such as tamarack, red maple and black ash and shrubs like leatherleaf and poison sumac

(Niering, 1998). Many species of sedges also find this a suitable environment. *Sphagnum* begins to play an important role at this stage of development.

Tamarack (*Larix laricina*) is a conifer in the pine family and is the only northern conifer that drops all of its needles in the fall (Eastman, 1995). Tamarack is able to tolerate low pH and nutrient levels. These trees can grow quickly and reach a height of over 20 meters within 40 or 50 years after which their rate of growth decreases (Eastman, 1995). Tamaracks have a geographic range from Canada south to the Great Lakes region of the United States (Niering, 1998).

Red maple (*Acer rubrum*) thrives under wet soil conditions from southern Canada to the Gulf of Mexico (Niering, 1998). They reach heights of 18 to 27 meters (Niering, 1998). The branches of red maples are brittle and can be broken by wind and ice (Eastman, 1995). Black ash (*Fraxinus nigra*) are often found in the same types of environments as red maple; however, their geographic range extends south only to about West Virginia (Eastman, 1995; Niering, 1998). Black ash trees mature with heights of 9 to 15 meters (Niering, 1998).

Shrubs are also inhabitants at this stage of bog development. Two common shrubs in this environment are leatherleaf (*Chamaedaphne calyculata*) and poison sumac (*Toxicodendron vernix*). Leatherleaf is an evergreen member of the heath family. This shrub grows around the lake margin prior to establishment of *Sphagnum*. Once *Sphagnum* accumulates the shrub grows in the peat deposits of the *Sphagnum*. Leatherleaf is found from southern Canada south to Iowa and along the east coast of the United States south to Georgia (Niering, 1998). Poison sumac can grow either as a shrub or small tree and may reach a height of 7.5 meters (Niering, 1998). This plant has poisons which cause skin irritation. Poison sumac is found along the Atlantic coast from southern Canada to Florida with its western range extending to Iowa (Niering, 1998).

A variety of species from the genus *Sphagnum* are common plants associated with bogs. *Sphagnum* is a member of the Bryophyta phylum, which includes mosses, liverworts, and hornworts. Members of the Bryophyta phylum lack true roots, stems, and leaves (Parker, 1989). Bryophytes evolved in the Carboniferous Period. They grow in areas that are moist at least part of the year. They can become desiccated during dry periods and revive upon later rehydration (Starr and Taggart, 1992). Starr and Taggart (1992) list three salient features of bryophytes that allow them to survive under cyclic moisture conditions. These features are:

- Above ground parts have a water conserving cuticle;
- A protective cellular jacket surrounds key reproductive parts to prevent them from drying out; and
- The sporophyte begins development in the protective environment of the tissues of the female gametophyte.

When hydrated, *sphagnum* can hold large amounts of water. *Sphagnum* moss can hold up to 1,500 percent water (Davis, 1946). [Note: water content is calculated by dividing the wet mass of moss by the oven dried mass.]

Species of *sphagnum* can survive under most climatic conditions. Examples of North American climatic zones in which *sphagnum* is abundant include; the northeast United States (Damman and French, 1987), the coastal region of Oregon (Hansen, 1941), and the Florida Everglades (Davis, 1946).

Vegetation of the Domed Bog

As the bog begins to dome from the accumulation of peat, the vegetative layer rises about the level of the water. The plant species change to become dominated by conifers such as black spruce (*Picea mariana*). Black spruce can grow in the soft peat; however, as it grows and gains mass it sinks into the peat (Eastman, 1995). The sunken limbs can clone to establish new trees (Eastman, 1995). This tree can reach heights between 6 and 18 meters (Niering, 1998). Black spruce trees are found through out Canada, Alaska, and the northern United States.

As the mounding continues, even the conifers can not survive the low nutrient levels, cyclic water conditions, and soft ground. The vegetation becomes dominated by *Sphagnum* as the bog reaches maturity.

Scientific, Economic, and Cultural Benefits Gained From Bogs

Bogs are a source of scientific, economic, and cultural resource. Scientifically, bogs are a source of information about Quaternary conditions. Bogs are a valuable economic resource both for the products derived from them and for their capacity to sequester carbon. European bogs have yielded many artifacts and bodies that provide an insight to past cultures.

Quaternary Conditions Recorded in Bog Environments

Climatic trends and vegetation regimes since the last period of glaciation are recorded in bogs. Bogs are particularly valuable sites for researching Quaternary conditions. Absolute age of peat can be determined by carbon-14 dating. The type of vegetation is recorded by pollen deposited in the peat. The pollen record can be used to determine climatic conditions and vegetation regimes. The diverse geographic distribution of bogs allows correlations and differences to have a spatial element to the accompany the temporal element.

Carbon-14 dating is useful for dating organic materials less than about 40,000 years old (Eicher, 1976). Carbon-14 is created in the upper atmosphere when nitrogen-14 gains a neutron in response to cosmic ray bombardment (Eicher, 1976). This carbon-14 then combines with two atoms of oxygen to form carbon dioxide, with is incorporated in the terrestrial carbon cycle. Carbon-14 has a half-life of 5,730 years. Thus, after 5,730 years half of the original carbon-14 in organic material has decayed back to nitrogen-14. After the living matter dies, it no longer absorbs carbon dioxide. By measuring the ratio of carbon-14 to all the other carbon isotopes, the absolute age of the material can be determined.

Pollen grains are well preserved in bog environments (Lowe, 1997). Scientist can study pollen assemblages to determine vegetation regimes. Since pollen is transported by wind, the pollen collected from bogs records not only the bog or bog precursor vegetation regime but also the upwind wind vegetation regime. The collection of carbonaceous materials from the same strata as the pollen assemblage provides material for carbon-14 dating.

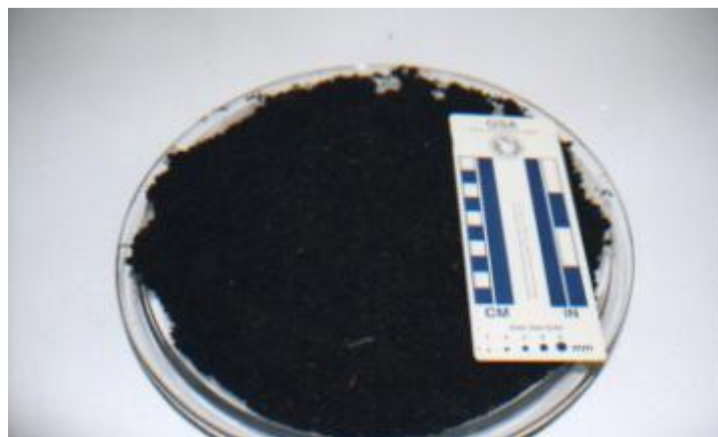
Economic Products Derived for Bog Materials

Peat and *Sphagnum* are important economic resources. Peat is the humified remains of plant material of all types. The term peat moss is used commercially to identify humified or partially humified *Sphagnum*.

In the United States, the principle use for peat and peat moss are as soil amendments which are used to enhance the texture and water holding capacity of agricultural soils. Peat is used as a domestic and industrial fuel source in Ireland and Sweden (Cady, 1984). Montan wax (a wax used in the manufacture of wax and candles) is extracted from peat in Germany (Cady, 1984).



Typical Retail Packaging for Peat



Commercial Peat for Garden Use



Typical Retail Package for Sphagnum



Commercial Sphagnum for Horticultural Use

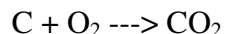
Davis (1946) lists numerous potential economic uses for peat. While most of these potential uses did not come to large-scale production they give a sense of the robustness of the potential value of peat. Some examples of the uses suggest by Davis (1946) include:

- The manufacture of activated carbon;
- The extraction of volatile gas products for fuel;
- The manufacture of paper;
- Use in insulation, medical dressings, and life preservers; and
- Fermentation to manufacture alcohols.

Carbon Sequestration in Bogs

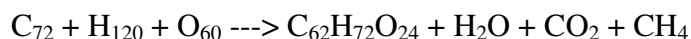
The earth receives energy from the sun in the form of shortwave radiation centered around 0.5 micrometers and reflects energy in the form of longer wave radiation centered around 10 micrometers (Mackenzie, 1998). The transmittance of longwave (outgoing) radiation is inhibited by the presence of greenhouse gasses in the atmosphere; whereas, shortwave (incoming) radiation is not appreciably attenuated by these gasses. Greenhouse gasses affect the energy flux and allow more energy to be retained on the earth which in turn causes the mean

temperature to increase. The most common greenhouse gas is carbon dioxide. Whenever carbonaceous materials are oxidized a stoichiometric quantity of carbon dioxide is generated.

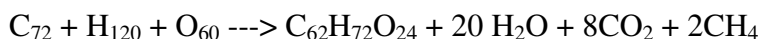


This means that for every mole of carbon oxidized, one mole of carbon dioxide is produced. Oxidation can occur rapidly, as in the combustion of fossil fuels or less rapidly as in biological metabolism. Gravimetrically, for every gram of carbon oxidized, approximately 3.75 grams of carbon dioxide are produced. It is now recognized that achieving an appropriate level atmospheric carbon dioxide is requisite to preventing anthropogenically induced climate change. A mass balance analysis requires the identification of all the sources and sinks within the system being studied. Peat bogs may be an important sink for carbon dioxide.

Bogs are a sink for carbon. Davis (1946) gives the following equation for the conversion of cellulose to peat.



When stoichiometrically balanced this equation becomes:



For every mole of cellulose (1 mole of cellulose equals 1,944 grams of cellulose) converted to peat, 8 moles of carbon dioxide (352 grams), 2 moles methane (32 grams), and 20 moles of water (360 grams) are generated, leaving 744 grams of carbon sequestered in the peat. Based on this simplified analysis, at maturity, dried peat would have a maximum organic carbon content of about 38%.

Archaeological Finds in Bogs

People in northwest Europe have cut peat for use as fuel for more than 2,000 years (Glob, 1965). During World War II and the years following the war, fuel was in short supply leading to an increase in the cutting of peat for fuel.

The archaeological record in northern Europe records evidence and details of man's interaction with the bog environment since before the birth of Christ (Menon, 1997; Glob, 1965). Menon (1997) reports that 1,000 or so bodies or body parts have been found in Iron Age peat, while Glob (1965) enumerates the discovery of 529 bog bodies found in the Iron Age peat of northwest Europe with 161 found through the remainder of Europe.

The state of preservation of many of these bodies was so good that the discoverers often thought the bodies to be those of recent murder victims. The anoxic acidic conditions found in bogs serve to preserve organic materials. Bacterial activity is minimal under these conditions and the anoxic conditions inhibit the oxidation of carbonaceous organic materials such as plant materials, flesh, and internal organs (Menon, 1997). Preservation of internal organs may depend on the prevailing temperatures at the time the body was placed in the bog. Under warm conditions, bacteria

present in the gut at the time of death, can cause severe degradation of the internal organs (Menon, 1997). Further preservation of flesh occurs where tannins are present, which cause the flesh to be preserved through a natural tanning process (Menon, 1997). Bones may or may not be preserved depending on the pH of the bog water (Glob, 1965). Glob (1965) cites an incident of a body found in a bog in Damendorf where the skin was "*so well preserved that it might have been taken from a living man.*" The body from the bog at Damendorf, however had no bones remaining.

Many of the bodies found in the bogs appear to have been murdered and certain elements indicate that the bodies may be the result of human sacrifice (Glob, 1965). Most of the bodies discovered in bogs date from about 2,000 years ago (Glob, 1965; Menon, 1997).

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