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DEVELOPMENT OF A *SPHAGNUM* BOG ON THE FLOOR OF A SANDSTONE QUARRY IN NORTHEASTERN OHIO[1]

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ABSTRACT. The vegetation and selected groundwater characteristics of Silica Sand Quarry Bog, a pioneer bog forming in an abandoned sandstone quarry, were examined. After 70 years of development the bog mat measures 0.75 km in diameter and contains 35 species of vascular plants and 5 species of *Sphagnum*. Six species of vascular plants from the bog are on Ohio's rare plant list. The herbaceous layer is the best developed stratum and contains 33% of the total plant species. Importance values indicate *Betula populifolia, Vaccinium corymbosum, V. macrocarpon* and *Sphagnum teres* to be the dominant species. Vegetational analysis indicates that the *Sphagnum* mat is expanding by encroaching on the extant vegetation, with *Vaccinium macrocarpon* and *Typha latifolia* serving as substrates. *Sphagnum teres* and *S. recurvum* are the major consolidating species. Analysis of the groundwater indicates that the community is best classified as a weakly minerotrophic swamp. Silica Sand Quarry provides an opportunity to study early stages of bog succession and development in a minerotrophic system.

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INTRODUCTION

In his comprehensive survey of peat deposits in Ohio, Dachnowski (1912) estimated that approximately 74,000 ha, or about 0.6% of Ohio's land surface was peat. He also noted that "the present bog and marsh societies are being destroyed so rapidly that some historical record is indeed of primary importance." Since Dachnowski's survey, Ohio's peat deposits have been depleted further by mining, draining, clearing, and development. Intensive field surveys conducted by the senior author between 1976 and 1980 revealed that fewer than 10 undisturbed acidic bogs remain (Andreas 1980).

Ohio's peat deposits, like those of West Virginia and Pennsylvania, provide habitats for rare plant species. Approximately 142 (24%) of the native plant species listed as potentially threatened, threatened or endangered on Ohio's list of "Rare Species of Native Ohio Wild Plants" (Division of Natural Areas and Preserves 1982), are located in peatland habitats. Twenty-two of the 96 native plant species presumed extirpated from Ohio formerly grew in bogs.

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Ten endangered bog plant species are currently known from only one locality.

Ohio's peat deposits are associated with 2 types of bogs. Fens (calcareous bogs) occur throughout glaciated Ohio. Acidic bogs primarily are confined to the Glaciated Allegheny Plateau and are most frequent in the kame and esker region (Goldthwait et al. 1967).

While none have been reported from Ohio, the formation of peat deposits in situations unrelated to glaciation is well documented (Darlington 1943, Rigg and Strausbaugh 1949, Montgomery and Fairbrothers 1963, Swan and Gill 1970, Wieder et al. 1981). This paper describes the formation and vegetation of a pioneer bog that has developed on the floor of a sandstone quarry in less than 70 years.

STUDY SITE

Silica Sand Quarry Bog is located in northeastern Portage County, Ohio (41° 16′ N, 81° W). The area lies within the Glaciated Allegheny Plateau section of the Appalachian Plateau (Fenneman 1938). The area was last glaciated by the Late Woodfordian (Hiram) ice margin which deposited a rather thin layer of Hiram Till (White 1979).

Climate of the region is generally classified as humid temperate, hot summer (Trewartha 1968). Climatic data (Ruffner 1980), based on records collected over a 23-year period at the Hiram, Ohio, weather station 11.3 km northwest of the study area, follow: mean January temperature −3.5 C; mean July temperature 21.6 C; annual mean temperature 9.6 C; average length of frost-free season 165 days; mean annual precipitation 103.83 cm; mean annual snowfall 154.68 cm.

Based on a 1907 Garrettsville topographic quadrangle, the quarry site prior to mining was an upland with a gentle slope to the east and a maximum elevation of 300 m above sea level. An oak-hickory forest presently covers the remaining undisturbed upland, and presumably that same vegetation occurred throughout the area prior to mining.

Excavation of the Pennsylvanian-age Sharon Conglomerate began in 1911 (Fuller 1955, 1965). With an increase in the demand for high grade silica sand during World War II, the direction of the quarry activity changed from a north-northwest orientation to a northwest-west direction (Fuller 1965). Mining activity at Silica Sand Quarry ceased in 1980, and the quarry was officially closed in 1981. The best developed sphagnous area occurs in the area excavated between 1911 and the mid-1940s.

Today the quarry is approximately 1.0 km in diameter. The north and west walls reach a height of 20 m above the quarry floor, and on the south and east, 7 m. The uneven quarry floor is the result of the nonconformable surface between the Pennsylvanian- and Mississippian-age rocks (Fuller 1965).

Water percolating through the porous sandstone walls enters the quarry as seeps in the floor and walls. Drainage from the quarry is through a manmade channel in the northeast corner (fig. 1). This channel periodically is blocked by beavers, and the water table in the quarry has fluctuated as much as 40 cm during the last 7 years.

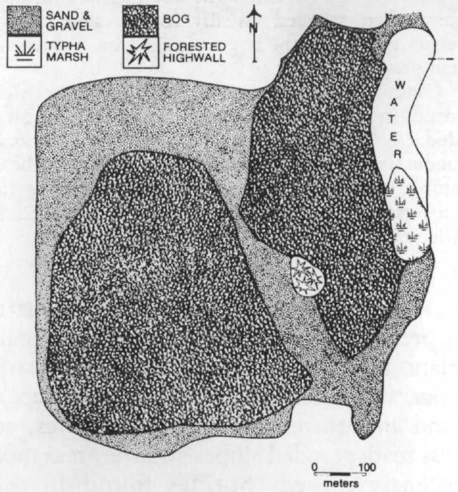

FIGURE 1. Vegetation map of Silica Sand Quarry, Portage County, Ohio (line in upper right quadrant indicates a manmade channel).

The mining of a sister quarry, located about 1.0 km to the south, began in 1941 and continued until the mid-1970s. Although this quarry is from the same rock formation, is provided with an adequate water supply, and contains some *Sphagnum* spp., the remaining bog plant association has not developed.

METHODS AND MATERIALS

The vegetation of Silica Sand Quarry Bog was sampled during spring and summer of 1982 with nested plots. The bog mat was divided into study areas, and individual sample plots were located within the areas by random numbers. Tree and shrub layers were sampled with 10 × 10-m plots and the herbaceous and ground layers were sampled with 1 × 1-m plots. Following Beaman and Andresen (1966) and Crow (1969), percentage frequency and mean percentage cover were compiled and combined to give importance values (I. V.) for each vascular plant and bryophyte species present in the plots. These results are presented in table 1.

Complete vascular plant species inventories were made from 1975 through 1981 for the entire quarry floor and surrounding highwall. Bryophytes were surveyed from 1980 through 1982 from the quarry floor. Voucher specimens for all species collected are deposited in the Kent State University Herbarium, Kent, Ohio. Unless otherwise indicated, nomenclature for the vascular plants follows Fernald (1950), and the nomenclature for the bryophytes follows Crum and Anderson (1981).

Water chemistry data were collected from samples taken between April 1981 and April 1982, from a depth of 15–25 cm below the water surface. Sample points were selected visually to represent the diversity present in the bog as judged by the vegetation present.

Conductivity, pH and temperature were measured in the field with a Hydrolab Digital Model . .4041. Calcium, Fe, Mg and additional conductivity values were measured within 12 hr of sample collection by the BioTest Laboratory at the University of Akron using methods described in Allen et al. (1974).

DISCUSSION

A vegetation map of Silica Sand Quarry is presented in figure 1. There are 3 main plant associations present on the quarry floor. The area indicated on the map as sand and gravel includes gravel piles, access roads, eroded slopes and the areas most recently mined. Species found in this area are typically present in recently disturbed acidic soils and include *Andropogon virginicus* L., *Danthonia spicata* (L.) Beauv.,

TABLE 1

Vegetation of the bog mat at Silica Sand Quarry, Portage County, Ohio.

	% cover	% frequency	Importance value
Tree Layer			
Betula populifolia	5.64	90.91	79.17
Acer rubrum	1.81	63.64	38.48
Quercus palustris	2.90	36.36	36.77
Populus tremuloides	1.36	36.36	24.56
Populus grandidentata	0.73	27.27	16.12
Nyssa sylvatica	0.18	9.09	4.88
Shrub Layer			
Vaccinium corymbosum	10.18	90.91	105.38
Vaccinium angustifolium	4.73	36.36	46.02
Spiraea tomentosa	1.36	36.36	26.18
Amelanchier arborea	0.18	18.18	10.15
Pyrus melanocarpa	0.45	9.09	7.19
Rhus vernix	0.09	9.09	5.07
Herbaceous Layer			
Vaccinium macrocarpon	38.75	81.82	108.76
Scirpus cyperinus	4.43	36.36	23.43
Carex canescens	1.61	25.00	13.32
Drosera rotundifolia	0.52	29.55	13.05
Juncus effusus	1.86	20.45	11.95
Juncus canadensis	1.41	13.63	8.29
Andropogon virginicus	1.66	11.36	7.86
Carex sp.	0.45	6.81	3.63
Lycopodium inundatum	0.45	6.81	3.63
Carex lacustris	0.23	4.55	2.30
Typha latifolia	0.14	4.55	2.12
Leersia oryzoides	0.23	2.27	1.37
Hypericum virginicum	0.02	2.27	0.96
Ground Layer			
Sphagnum teres	11.14	34.09	59.19
Polytrichum commune	9.27	31.82	51.49
Sphagnum recurvum	3.68	27.27	29.92
Drepanocladus fluitans	4.00	9.09	19.21
Cladonia spp.	1.09	20.45	16.86
Sphagnum capillifolium	0.43	18.18	13.19
Aulacomnium palustre	0.34	11.36	8.48
Sphagnum fuscum	0.05	2.27	1.64

Vaccinium corymbosum L., *Vaccinium angustifolium* Ait., *Lycopodium flabelliforme* (Fern.) Blanchard [*L. complanatum* of Fernald (1950)], *L. clavatum* L., *L. tristachyum* Pursh, and the mosses *Polytrichum piliferum* Hedw. and *Ceratadon purpureus* (Hedw.) Brid. In moister areas, *Juncus effusus* L., *Scirpus cyperinus* (L.) Kunth, and *Leersia oryzoides* (L.) Sw. are abundant.

An almost homogeneous stand of *Typha latifolia* L. occurs at the edge of the open water and along the east wall (fig. 1). Dead clumps of *Vaccinium corymbosum* scattered among the cattails indicate that this area was drier, and the inundation by beaver dams has allowed the expansion of cattails into *Vaccinium corymbosum.*

Approximately 56 ha (.75 km × .75 km) of the quarry floor are covered with a dense mat of bog vegetation comprised largely of *Sphagnum* spp., *Polytrichum commune* Hedw., and *Vaccinium macrocarpon* Ait. This study area, termed a bog by Andreas (1980), follows Curtis' (1959) definition, the criteria of which include a nearly continuous carpet of sphagnum moss and a predominately shrubby vegetation (50–60%) dominated by members of the Ericaceae and Cyperaceae.

Quantitative vegetational data collected from the bog mat are presented in table 1. Tree layer species with high importance values include *Betula populifolia* Marsh. (I. V. 79.17), *Acer rubrum* L. (I. V. 38.49), and *Quercus palustris* Muenchh. (I. V. 36.77). *Acer rubrum* commonly is found in northeastern Ohio bogs along the lagg zone and scattered throughout the open mat zone. *Betula populifolia* is not a typical bog species (Small 1972) and in Ohio is most often found in wet fields and woods and on the floor of abandoned sandstone and limestone quarries (Andreas 1980). Swan and Gill (1970) list it as a species found on the hummocks in a bog developing in a manmade lake in Massachusetts. *Quercus palustris* typically is found in Ohio on flat, poorly drained swamp forests and on the borders of swamps (Braun 1961).

Shrub layer species with high importance value indices include *Vaccinium corymbosum* (I. V. 105.38) and *Vaccinium angustifolium* (I. V. 46.02). *V. corymbosum* has a wide habitat tolerance and is found on dry hillsides and in kettle-hole bogs. *Vaccinium angustifolium* commonly grows on dry, rocky, wooded hillsides, and in Silica Sand Quarry Bog this species is confined to the drier "ridges" of sand piles scattered throughout the bog mat. *Spiraea tomentosa* L. (I. V. 26.18) occurs in marshes and swamps (Aldrich 1943).

With the exception of *Vaccinium macrocarpon,* the herbaceous layer is dominated by species characteristic of swamps. *Scirpus cyperinus* (I. V. 2.43) and *Carex canescens* L. (I. V. 13.32) frequently occur in bogs and forests recovering from inundation or in minerotrophic waters (Aldrich 1943, Schwintzer 1979, Whitney 1981). *Vaccinium macrocarpon,* in Ohio, is restricted to sphagnous mats and is not associated with swamps (Braun 1961).

Dominant ground layer species include *Sphagnum teres* (Schimp.) Angstr. ex. E. Hartm. (I. V. 59.19), *Polytrichum commune* Hedw. (I. V. 51.49), *Sphagnum recurvum* Beauv. (I. V. 29.92), and *Drepanocladus fluitans* (Hedw.) Warnst (I. V. 19.21). The 2 dominant moss species are typical of wet, minerotrophic habitats (Vitt and Slack 1975, Crum and Anderson 1981). *Polytrichum commune* occurs in wet habitats such as bog margins, coniferous swamps and meadows (Crum and Anderson 1981). *Drepanocladus fluitans* typically grows in bogs and wet meadows (Crum and Anderson 1981). Additional moss species, which are minor components of the vegetation, include *Sphagnum capillifolium* (Ehrh.) Hedw., *S. fuscum* (Schimp.) Klinggr., and *S. magellanicum* Brid. These species are characterisitic of slightly drier conditions and are found growing near the summit of the more acidic sphagnous hummocks.

Bog species collected from the quarry which did not appear in a sample plot include *Bartonia virginica* (L.) BSP., *Gaylussacia baccata* (Wang.) K. Koch, and

Thelypteris palustris (Salisb.) Schott. Of the 35 species of vascular plants collected from the quarry floor, 6 are listed as potentially threatened species on the "Rare Species of Native Ohio Wild Plants" (Division of Natural Areas and Preserves 1982). These are *Bartonia virginica, Betula populifolia, Drosera rotundifolia, Lycopodium inundatum* L., *Rhus vernix* L., and *Vaccinium macrocarpon*.

Several vascular plant species that are characteristic of Ohio bogs, such as *Chamaedaphne calyculata* (L.) Moench, *Ilex verticillata* (L.) Gray, *Carex trisperma* Dew., and *Carex howei* Mackenz., are not present at Silica Sand Quarry Bog. The absence of several of the more common bog species could be a function of the relatively short time species have had to colonize the mat.

Water chemistry data are presented in table 2. For the most part, these data are consistent with those found in other Ohio bogs. July water temperatures at Silica Sand Quarry Bog are high due to the shallowness of the water level. April and October water temperatures range between 11.1 and 11.6 C. These are consistent with Buchanan's (1982) spring and fall temperatures for Triangle Lake Bog. Higher summer temperatures may be a limiting factor to some bog species colonizing the mat.

Measurements for pH, Ca and Mg are higher than expected for the vascular plant vegetation found at the study area. Using these measurements, Silica Sand Quarry Bog falls within the classification of a weakly minerotrophic swamp (Heinselman 1970). The high conductivity level probably is due not to elements present in the sandstone (Fuller 1967), but is due instead to leaching of minerals from the Hiram Till which forms a 3–5-m cover over the bedrock (Ritchie and Powell 1973).

Heinselman (1970) and Vitt and Slack (1975) emphasize that *Sphagnum* species are important indicators of bog classification and play an important part in the successional direction of bog development. The species of *Sphagnum* present at Silica Sand Quarry Bog support the classification of a weakly minerotrophic swamp. A typical weakly minerotrophic swamp supports a greater vascular plant species richness than

TABLE 2

Chemical and physical characteristics of Silica Sand Quarry Bog and other Ohio and Michigan bogs. Values ±1 SE.

Location	pH	Conductivity umhos/m	Ca mg/1	Mg mg/1	NO_3-N mg/1	Fe mg/1	Average July temperature C
Silica Sand Quarry Bog, Portage Co., Ohio	5.24±0.2	167.8±12.9	13.7±0.48	6.0±0.8	0.8±0.15	0.74±0.03	27.3±0.75
Triangle Lake Bog, Portage Co., Ohio	3.77±0.2	37.0±7.0	4.0±0	0.54±0.14	0.6±0.2	0.52±0.22	22.5*
Brown's Lake Bog, Wayne Co., Ohio**	4.20±0.1	26.6±1.4	4.0±0.01	2.2±0.1	0.55±0.13	—	—
Average of 6 northern lower Michigan bogs***	4.1±0.4	58.0±3.4	3.2±2.5	0.7±0.7	8.2±11.5	1.1±0.8	—

*Buchanan 1982
**Whitney 1981
***Schwintzer 1978

is exhibited at the study area (Vitt and Slack 1975). The low species richness at Silica Sand Quarry Bog may be a factor of its relatively young age.

From field investigations we are proposing that the mat is expanding in a pattern similar to that of bogs which develop in open waters where *Sphagnum* spp. encroach upon already established vegetation (Rigg and Strausbaugh 1949). Forerunner species (purchases) often include *Carex* spp., *Menyanthes trifoliata* L., *Chamaedaphne calyculata* and *Decodon verticillatus* (L.) Ell. (Conway 1949, Dansereau and Segadas-Vianna 1952, Swan and Gill 1970). At Silica Sand Quarry Bog, primarily 2 vascular plant species are serving as substrates. These are *Vaccinium macrocarpon* on the drier sites, and *Typha latifolia* in standing water. Conway (1949) mentions both species assuming the purchase role in Minnesota bogs. *Sphagnum recurvum* is the only moss species found invading *Typha latifolia,* whereas both *S. recurvum* and *S. teres* are found among the branches of *Vaccinium macrocarpon. Sphagnum capillifolium, S. fuscum* and *S. recurvum,* all present at Silica Sand Quarry Bog, are mentioned by Swan and Gill (1970) as pioneer mat-forming species. However, *Sphagnum cuspidatum* Ehrh. ex Hoffm., not located at the study area, is mentioned by Swan and Gill as the predominant mat-forming species in the development of a sphagnous bog in a manmade lake in Massachusetts.

The depth of the mat at Silica Sand Quarry varies from several centimeters to a maximum depth of 60 centimeters. The mean depth is approximately 30 cm. Depth varies with the unevenness of the quarry floor and the depth of the water table. The estimated rate of peat accumulation is as great as 0.43 cm per year. This rate is high when compared to the estimation by Sears and Janson (1933) of 0.08–0.12 cm per year for the Great Lakes region, and is high when compared to Leisman's (1953) rate of between 100–800 years per 30.48 cm for Minnesota bogs. Heinselman (1970) reports a rate of between 4.6–13.6 cm per 100 years for Minnesota bogs and states that the rate of accumulation appears to vary with environmental conditions since the last period of glaciation. Estimations of the rates of peat accumulations provided by the above authors are based on consolidated peat which has accumulated for thousands of years, whereas our rate is based on unconsolidated peat which has accumulated in less than 70 years. Silica Sand Quarry Bog provides an opportunity to monitor the long-term rate of peat accumulation.

The origin of the propagules colonizing Silica Sand Quarry Bog is uncertain. The study area lies within 14 km of a known bog with similar vegetation (Andreas 1980). In his notes, Almon Rood, a noted amateur botanist in northeastern Ohio during the first 3 decades of this century (Cooperrider and Hobbs 1978), mentions a now destroyed tamarack bog that occurred within 2.6 km of the quarry. We are proposing that this tamarack bog may have been a major source for some of the propagules. Usher (1979) discusses the colonization of quarries and states that the species available for colonizing are dependent "upon the nature of the land use surrounding the quarry and the vagility of the species situated farther away." Many of the species present at Silica Sand Quarry (*Bartonia virginica, Drosera rotundifolia, Betula populifolia,* for example) produce small, wind-dispersed seeds. Other species, such as *Vaccinium corymbosum* and *V. macrocarpon*, produce seeds that are disseminated by animals. Whatever the source of the propagules, it is noteworthy to mention that the sister quarry 1.0 km south of the study area, which is 30 years younger, has not yet been colonized by bog species.

Silica Sand Quarry Bog, already disturbed in the sense that it is a manmade habitat, can serve an active role in preserving Ohio's native bog plants. Presently 6 "rare species" have become established naturally in the quarry floor. Through introduction, this area could function as a refuge for rare Ohio bog species whose native habitat cannot be saved. However, introductions need to be recorded, monitored and managed. Other disturbed areas such as borrow pits and abandoned sandstone and limestone quarries (Herrick 1974) harbor selected rare Ohio plants.

Silica Sand Quarry Bog also can serve as a study area to monitor bog succession. The ecology of bogs in glaciated areas has been studied by numerous authors (Rigg 1940, Aldrich 1943, Conway 1949, Dansereau and Segadas-Vianna 1952). Silica Sand Quarry Bog provides a unique opportunity to study early stages of bog succession unrelated to glaciation and to study the rate of peat accumulation.

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