GEOLOGIC CONDITIONS ESSENTIAL FOR THE PERPETUATION OF CEDAR BOG, CHAMPAIGN COUNTY, OHIO[1]

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ABSTRACT

Cedar Bog, a unique boreal relict area, is situated on the Mad River Valley Train (outwash) four miles southwest of Urbana, Ohio. The unusual plants present here are maintained by a continuous flow, at the surface, of cool high-lime ground water, which emerges as springs along the base of a low escarpment on the east edge of the Bog.

Regionally the water table in the Mad River Valley Train lies only about 10 feet below the surface, but it is too deep to create such springs. However, ground water moving through a higher outwash level, the Urbana Outwash, to the northeast, provides so much additional ground water, at the place where this outwash has been truncated by the lateral erosion of the Mad River, that the water table in the Mad River Valley Train is locally raised enough to reach the land surface and produce these springs. Contours drawn on the water table near the Bog demonstrate that the main source of ground water feeding the Bog is the Urbana Outwash (this water becomes superimposed on the moving down through the Mad River Valley Train) and not the very deeply buried fill of the preglacial Teays valley, which lies almost directly below the Bog.

In the past, drainage ditches have lowered the level of the water table enough to reduce the earlier greater extent of the Bog, but fortunately have not completely drained it. It is hoped that no additional lowering of the water table, no warming of the water (by addition of sun-warmed surface water), and no addition of any deleterious materials (salt, mud, etc.), any of which could greatly damage or even destroy the Bog, will be permitted, so that Ohio's only alkaline fen, Cedar Bog, may be preserved.

One of Ohio's most famous natural areas is Cedar Bog, a boreal fen located in the Mad River valley four miles southwest of Urbana, Ohio (latitude 40°03′N, longitude 83°47½′W) (fig. 1). Known variously in the past as Cedar Swamp, Dallas Bog, and Urbana Bog, this area (which is technically not a true bog, but a swamp, with a "raised bog"—created by a strong upward flow of ground water—at its center) has been famous for many years (Dachnowski, 1912). Continuously seeping ground water emerges along the base of a low escarpment along the east side of the Bog, creating a perpetually cool moist microclimate, which maintains the unique Bog flora (figs. 2, 3, 4), composed of many species normally found

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FIGURE 1. Aerial photograph of Cedar Bog. East-west road in center of Bog is Woodburn Road, and other east-west road, at base of picture, half a mile south of Woodburn Road, is Dallas Road. Escarpment lies along easternmost edge of vegetated area of Bog. Photograph courtesy of Richard H. Durrell.

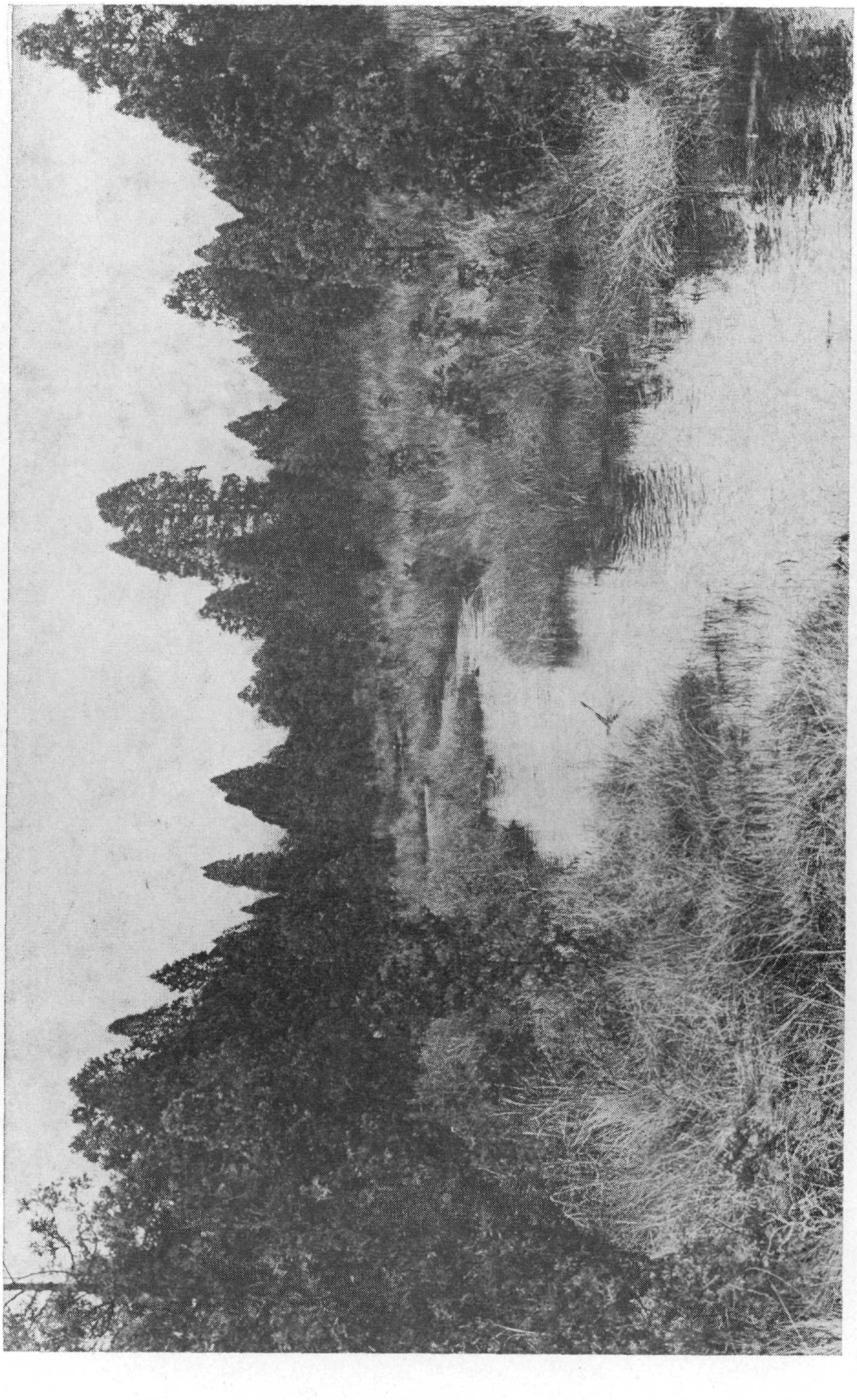

FIGURE 2. Typical view in Cedar Bog. Cedar Run, main stream carrying flow of spring water south through Cedar Bog, is shown, surrounded by sedges and white cedar trees. Photograph courtesy of Richard H. Durrell.

only much farther north, in northern Michigan or Canada (Frederick, 1974). Presumably such boreal species have persisted in this locally cool microclimate since early postglacial times (Dachnowski, 1912; Frederick, 1974). In addition, because of the high alkalinity of the spring water, a condition of "simulated drouth" exists for some species, encouraging the survival of some western prairie forms (Clarke County Audubon Society, 1972).

FIGURE 3. Cedar Run in Cedar Bog, just north of bridge on Woodburn Road (visible in distance). Sedges show on left (east), cedar logs lie across Cedar Run, and swamp forest, with scattered white cedars and tuliptrees (with pointed crowns, in right distance), occurs on right. Photograph courtesy of John Gallagher.

All of these unusual species in Cedar Bog owe their existence to springs which continuously discharge cool ground water, and thus to the geologic setting which produces these springs. The purpose of this paper is to describe the geologic conditions in which the Bog occurs and which are essential for its perpetuation. Unfortunately, some misinformation on this subject has been distributed, so that some people, in a sincere effort to preserve the Bog, may instead find themselves destroying it. With a sound understanding of the true situation, perhaps it may be possible to preserve this unique feature of Ohio's landscape.

FIGURE 4. Typical view in swamp forest at Cedar Bog. Photograph courtesy of John Gallagher.

The basic geology presented here has been drawn from the work of Dr. Goldthwait and his students (Goldthwait, 1955; Janssens, 1964; Quinn, 1972). It is the use of this geology to determine the source of the ground water maintaining the Bog that is my contribution, although subsequent studies by a Wright State University student (Craig Smith, working under Dr. Ben Richard, in 1966) and, more professionally, by George Robinson (Robinson and McComas, 1973; Environmental Control Corporation, 1973) have both served to corroborate my earlier hypothesis.

Cedar Bog is located on a thick filling of glacial outwash gravel in the Mad River valley, a deposit named the Mad River Valley Train by Goldthwait (Goldthwait, 1955; Janssens, 1964; Quinn, 1972). This valley train is very extensive, heading in a number of valleys to the north, in central Logan County (Forsyth, 1956), and extending south down the Mad River valley to Dayton and, from there, down the Great Miami River valley to the Ohio River.

Two other outwash deposits occur in the Urbana area, east of the main Mad River valley (Goldthwait, 1955; Janssens, 1965; Quinn, 1972). These deposits are older and occur at higher elevations than does the Mad River Valley Train, but they are composed basically of the same sort of material—fairly coarse, very permeable, carbonate-rich gravel (pebbles mostly of dolomite, with some limestone—Michael J. Quinn, personal communication, 1974). The higher and more eastern of these two deposits, the Kennard Outwash (Goldthwait, 1955; Janssens, 1964; Quinn, 1972), lies about three miles east of Urbana and extends from southern Logan County (north of Champaign County) (Forsyth, 1956) south to Clifton Gorge (three miles east of Yellow Springs). The carbonate-rich gravel composing this outwash extends westward beneath the till of the Springfield Moraine perhaps as far as the east edge of the other, lower outwash (Michael J. Quinn, personal communication, 1974), so that both deposits probably form one hydraulic unit (Herbert B. Eagon, Jr., personal communication, 1974). The lower of these two deposits is called the Intermediate, or Urbana Outwash (Goldthwait, 1955; Janssens, 1964; Quinn, 1972). It underlies much of the city of Urbana, but to the south has been truncated by the lateral erosion that widened the Mad River valley, so that this outwash now terminates at a critical position in the bluff of the present Mad River valley—just one mile northeast of Cedar Bog. Ground water draining from this high truncated gravel deposit and derived both from the Urbana Outwash to the north and in part from the Kennard Outwash to the east, I believe plays an essential role in the maintenance of the Bog.

Everywhere else in the area—on the segments of higher land between the Mad River Valley Train and the Urbana Outwash and the Kennard Outwash and on the higher land west of the Mad River valley—glacial till is present, in the form of end moraine to the east and ground moraine to the west of the Mad River valley. Surface drainage off these less permeable deposits certainly makes some contribution to the ground water in the Bog area and all the outwash deposits, but this contribution is far less than that coming from the gravel reservoirs. In addition, this surface water is more subject to evaporation, so that this contribution diminishes significantly during long dry periods. A map showing all of these deposits (except the Kennard Outwash) is included, based on the work of Goldthwait and his students (Goldthwait, 1955; Janssens, 1964; Quinn, 1972) (fig. 5).

Gravel is among the most permeable of all geologic materials. Precipitation, falling on gravel deposits, almost immediately soaks down into the ground (unless some heavy clay-rich impermeable material forms a cap over the gravel), so that relatively little of the water is lost to evaporation or to surface runoff. Once beneath the ground, the water seeps downward to the water table and then slowly moves, more or less horizontally, with the rest of the ground water, in the direction of the hydraulic gradient. This direction of flow, in any extensive area of perme-

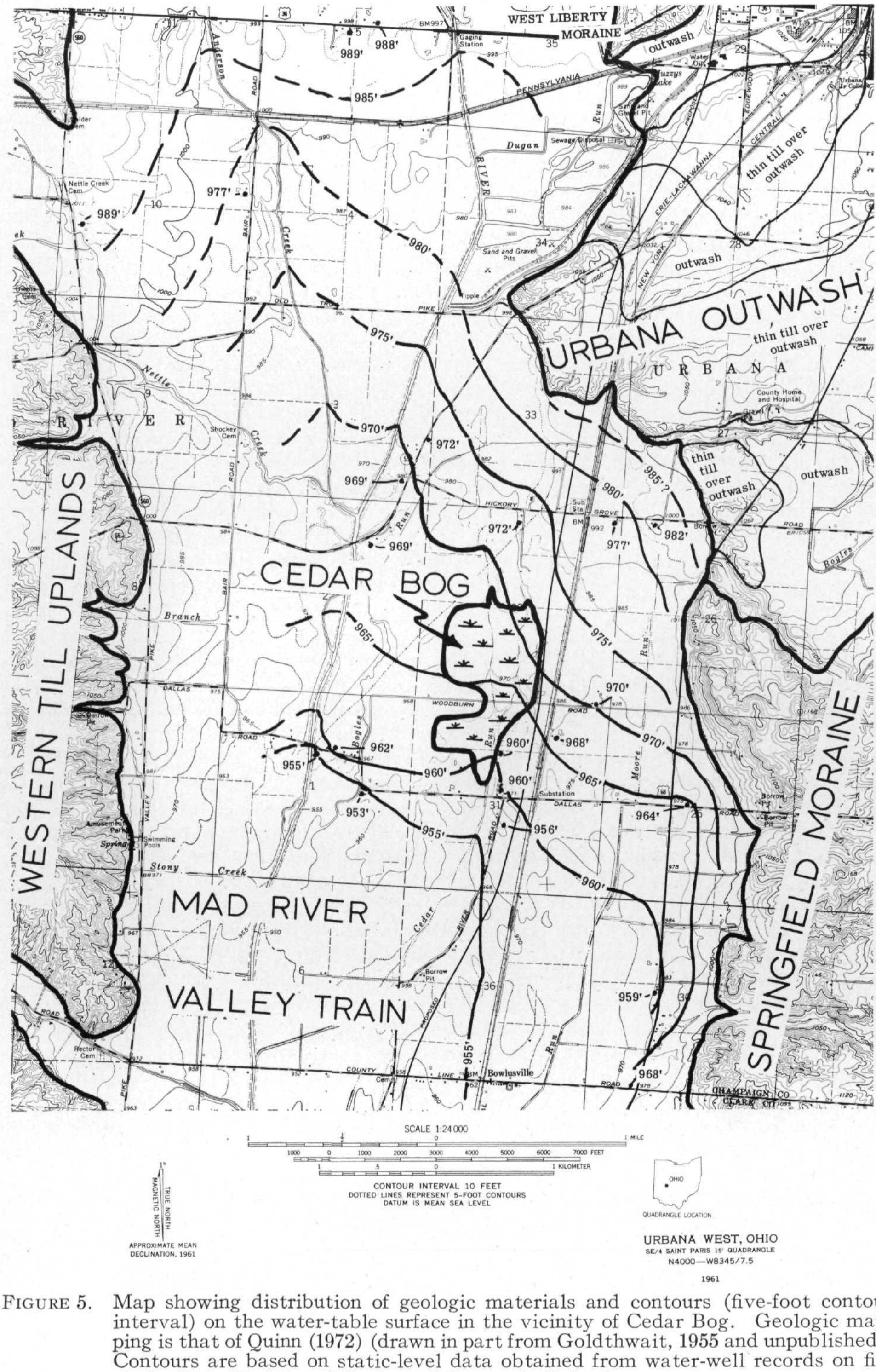

FIGURE 5. Map showing distribution of geologic materials and contours (five-foot contour interval) on the water-table surface in the vicinity of Cedar Bog. Geologic mapping is that of Quinn (1972) (drawn in part from Goldthwait, 1955 and unpublished). Contours are based on static-level data obtained from water-well records on file at the Ohio Division of Geological Survey in Columbus.

able material, is determined by the slope of the water table, which in turn is determined by the slope of the valley in which the gravel occurs and by the relative location of any discharge areas, natural or manmade (drainage ditches or wells). The Mad River valley slopes southward, so the movement of the ground water down in the Mad River Valley Train is southward down the valley. The level of the water table is relatively high (generally less than 10 feet deep near the Bog), except where ground water is lost to wells, drainage ditches, or the Mad River (Kaser, 1962; Norris and Eagon, 1971).

Water that infiltrates the Urbana (Intermediate) Outwash near Urbana, above and northeast of Cedar Bog, also flows southward, within that higher level outwash deposit, through its truncated edge and down into the lower Mad River Valley Train. Here it merges with the ground water already present and moving southward through that lower deposit. However, because of the considerable volume of ground water added to that in the Mad River Valley Train here, the level of the water table in the Mad River Valley Train, for about a mile from the foot of the bluff, is unusually high, 10 to 15 feet higher than out in the main part of the valley (as shown by the water-table elevations in figure 1, taken from water-well records on file in the offices of the Ohio Division of Geological Survey in Columbus).

Contouring of this water-table surface, which provides a measure of both the direction and the rate of ground-water flow, shows that the upper levels of ground water at Cedar Bog are moving, not from the north (down the Mad River valley), but from the east—from the truncated edge of the higher level Urbana Outwash (fig. 5). Clearly, water from this deposit, where it combines with the ground water in the Mad River Valley Train, raises the water table enough, in the Cedar Bog area, for ground-water discharge to occur at the surface—the springs which maintain the Bog. This is also the conclusion of Robinson and McComas (1973), who state that "The existence of the Bog is due to the superposition of a shallow groundwater flow system, recharged locally by gravel terraces, over a regional groundwater flow system recharged in the uplands and discharging in the Mad River floodplain. . . . Cedar Bog is recharged by water infiltrating locally through a gravelly terrace east of Cedar Bog, and by a regional, deep flow system partially defined by the Mad River valley."

In the past, before the water table had been lowered by any manmade drainage ditches, flow from the springs in the Bog must have been far greater than at present, creating a much larger area of cool moist microclimate and leading to a much more extensive occurrence of the Bog's unusual plants (Frederick, 1974). At that time, the force of the water coming from the ground in the Bog area was apparently enough actually to erode or undermine some of the gravel, a process technically called sapping. This sapping is interpreted to have been extensive enough to have created a very low escarpment along the east side of the Bog and a lower area at the foot of the escarpment, permitting more ground water to escape and thus to increase the effects of the sapping, so that a 10-foot escarpment finally resulted. This is the escarpment visible today along the east side of the Bog, at the base of which occur the springs that maintain the Bog. When drainage ditches subsequently lowered the water table here, it was only in the low area at the foot of the escarpment that ground water could still seep out at the surface, thus maintaining the critical microclimate essential for perpetrating the unique flora of the Bog. Had this drainage lowered the water table just a little more, this seepage might have ceased, and the unique plants might all have been lost.

This interpretation is based entirely on hydrologic conditions at or near the water-table level. There has been considerable discussion concerning the possible influence on Cedar Bog of a deep buried valley that underlies the Mad River and the Bog. This is the valley of the preglacial Teays River, which had its origin in the Appalachian highlands and flowed northwest across Ohio into Indiana (Ver

Steeg, 1946). The trunk valley of this ancient stream almost directly underlies that of the modern Mad River here, though it bends to the west about five miles to the north (Norris and Spicer, 1958; Cummins, 1959; Environmental Control Corporation, 1973) and is joined by a tributary valley from the southwest about five miles south of the Bog (Kaser, 1962). According to Kaser (1962, p. 13–14), the bottoms of these valleys, both the trunk stream and the tributary, were sites of ice-dammed lakes and contain clay. This is in contradiction to the interpretation of Richard (1973), who suggests that deltaic sands and gravels occur at the mouth of the tributary, though he acknowledges the presence of lacustrine silt and/or clay in the main valley. Richard (1973) contends that artesian water from these deep deltaic gravels provides at least a component of the ground water maintaining Cedar Bog, though there is no explanation for how these deltaic deposits could be recharged, in light of their position several hundred feet deep and surrounded by impermeable Ordovician shale bedrock (Kaser, 1962). Even if a recharge area could be identified, it seems very unlikely to me that such a limited deposit at so great a depth could have any significant effect either in creating or in maintaining Cedar Bog. In contrast, the steep rise of the water-table surface from the Bog to the northeast, toward the truncated edge of the Urbana Outwash aquifer, is enough to bring the water table up to (and slightly above) the ground surface, so that cool alkaline ground water can seep out at the surface continually, thus providing the particular microclimate essential for maintaining the unique Bog flora.

This flora is maintained not only by the presence of the ground water, but by its uniform coolness and its continuous flow. Either addition of sun-warmed surface water or reduction in the flow of this spring water could destroy the unusual plants that make Cedar Bog unique. All water that flows from underground tends to have a relatively uniform temperature year-round, just as do caves, because the underground area is so deep that it is neither warmed by the summer sun nor cooled by winter's storms. Such water is relatively cool in the summertime, the critical time—the growing season—for plants, and is relatively warm in winter (Frederick, 1974, points out that, even though Cedar Bog boreal plants are maintained by coolness, the water in the center of the Bog seldom freezes even during the coldest winter). The continuous flow of the water is a result of the very extensive area of gravel outwash that serves as a reservoir for the ground water feeding the Bog. With such a large supply of ground water to feed the springs in the Bog, flow is continuous and uniform throughout the year.

The other characteristic of Cedar Bog water, that of high alkalinity, or lime, is demonstrated by the accumulation of marl in the Bog (Dachnowski, 1912; Frederick, 1974) and by the presence of some plants characteristically found in high-lime sites (Frederick, 1974; Dr. T. Richard Fisher, personal communication, 1974). This alkalinity is due to solution, by the ground water, of part of the many carbonate pebbles forming the gravel. Gravels throughout this area tend to be composed of about 90 percent carbonate pebbles, according to pebble counts made by Goldthwait (1955, p. 62, 63, 64), so that lime is available to the ground water throughout all the gravel-outwash deposits.

The unusual flora of Cedar Bog, therefore, is the result of a unique local microclimatic condition, produced by augmentation of the ground water in the Mad River Valley Train by that from the higher Urbana Outwash to the northeast, so that the water table is raised to and above the ground surface, resulting in a continuous year-round flow of cool uniform-temperature high-lime water. Boreal plant species are maintained by the relative coolness (during the summer) of this water, while prairie species persist because of the "simulated drouth" created by the high alkalinity (Clarke County Audubon Society, 1972). The once-greater extent of Cedar Bog (Dachnowski, 1912, Frederick, 1974) presumably dates from a time when the water table had not yet been lowered by manmade drainage; the small size of the Bog at present indicates the precarious nature of this unique site—a slightly greater lowering of the water table, produced by slightly deeper and/or more extensive drainage ditches or wells, might completely eliminate the flow that now maintains the Bog, thus destroying forever the only remaining alkaline bog in Ohio. Hopefully, with a better appreciation of the hydrologic conditions essential to the maintenance of the Bog, future activities of man in this area may be so governed that the water table will not be allowed to lower, nor the quality of the water be allowed to become contaminated (by salt, mud, or warming by addition of sun-warmed surface water, etc.), so that the unique area that is Cedar Bog may be preserved.

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