THE ALTONA FLAT ROCK JACK PINE BARRENS: A LEGACY OF FIRE AND ICE

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Introduction

Altona Flat Rock is the largest (approximately 32 km^2) of a discontinuous, 5-kilometer wide belt of bare sandstone areas that extend approximately 30 km southeastward into the Champlain Valley from Covey Hill, near Hemmingford, Québec (Fig. 1). Created by catastrophic floods from the drainage of glacial Lake Iroquois and younger post-Iroquois proglacial lakes in the St. Lawrence Lowland more than 12,000 years ago (Denny, 1974; Clark and Karrow, 1984; Pair et al., 1988), the exposed sandstone today provides habitat for one of the largest jack pine *(Pinus banksiana)* barrens in the eastern United States. The relatively low-diversity jack pine community is maintained by fire, which has an important role in ecosystem regeneration in this nutrient-poor, drought-prone environment.

We will visit several sites in the southeastern portion of Altona Flat Rock on property owned by the William H. Miner Agricultural Research Institute. The area contains the remains of the "Million-Dollar Dam," part of a failed hydroelectric project begun by William Miner in 1910. This trip will address on-going efforts to understand the linkages between the hydrogeology and ecology of the jack pine barrens and will document the recent history of anthropogenic development in this unique ecosystem.

Geological Setting

Physiography

Altona Flat Rock, located in the northwestern Champlain Valley (Fig. 1), is entirely underlain by flat-lying Potsdam Sandstone (Cambrian). The lithology of the Potsdam ranges from orange-pink to pale red, very coarse to medium-grained, cross-laminated arkose with quartzitic green shale and conglomeratic interbeds to pinkish gray to very pale orange, well sorted, fine to medium-grained quartz sandstone (Fisher, 1968). The exposed rock surface slopes north and east from an elevation of more than 300 meters a.s.l. (above sea level) to below 200 meters a.s.l. where it passes beneath surficial deposits in the Champlain Lowland (Denny, 1974). The sloping surface is broken into a series of stairlike bedrock treads separated by risers that range from a few decimeters to tens of meters in height (Fig. 2). The tread surfaces have little local relief except near stream channels and risers. The eroded edges of truncated trough cross-beds, ripple marks, and solution pits are common minor surface features. Shoreline deposits from the highstand of glacial Lake Vermont (Fort Ann Stage) (Chapman, 1937; Denny, 1970, 1974) lap onto the northern and eastern margins of Altona Flat Rock.

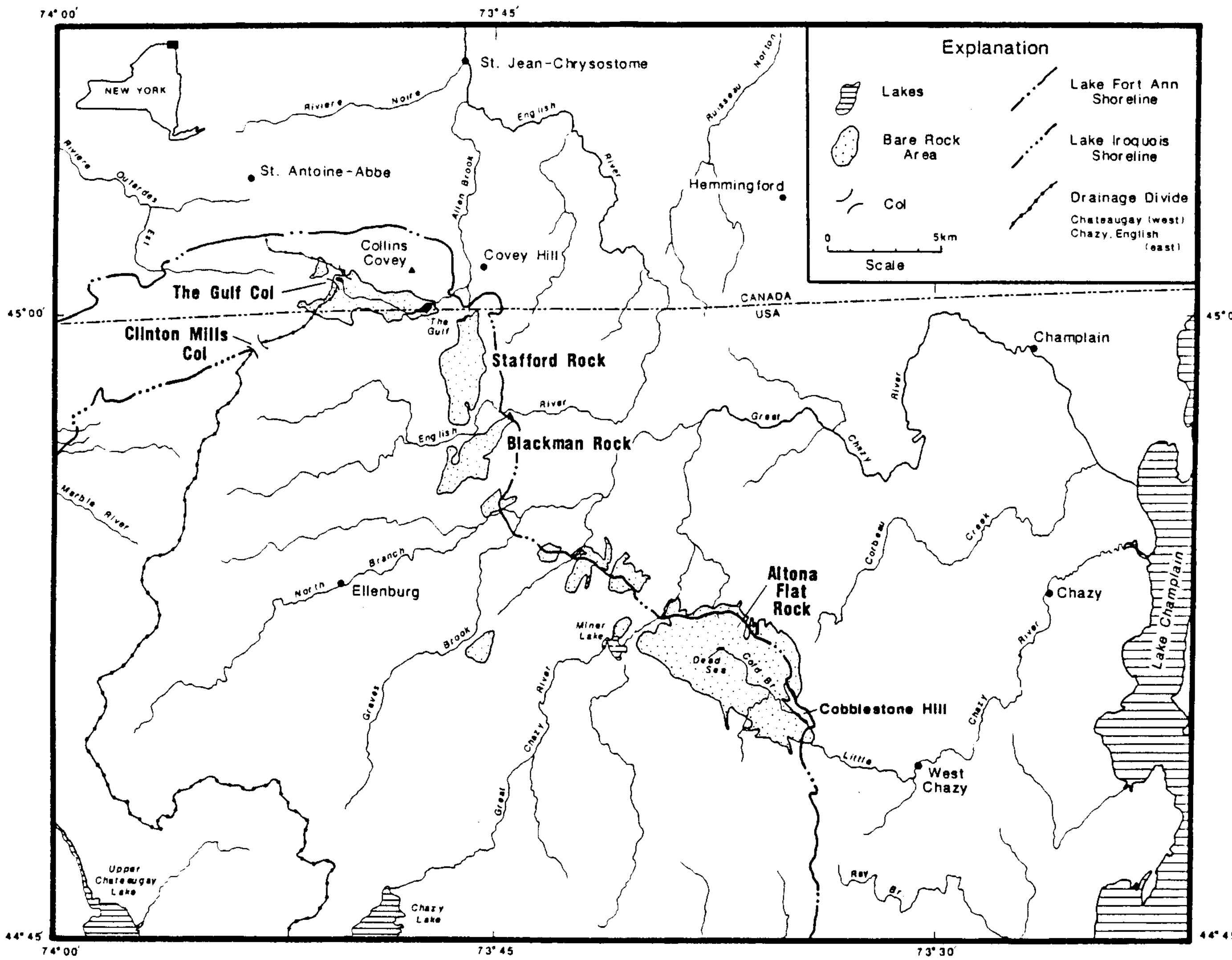

Figure 1. Location map showing the principal bare rock areas east of the divide between the Chateaugay (west) and Chazy and English (east) river watersheds in northeastern New York and adjacent parts of Canada (from Woodworth, 1905a; Denny, 1974; LaSalle, 1985).

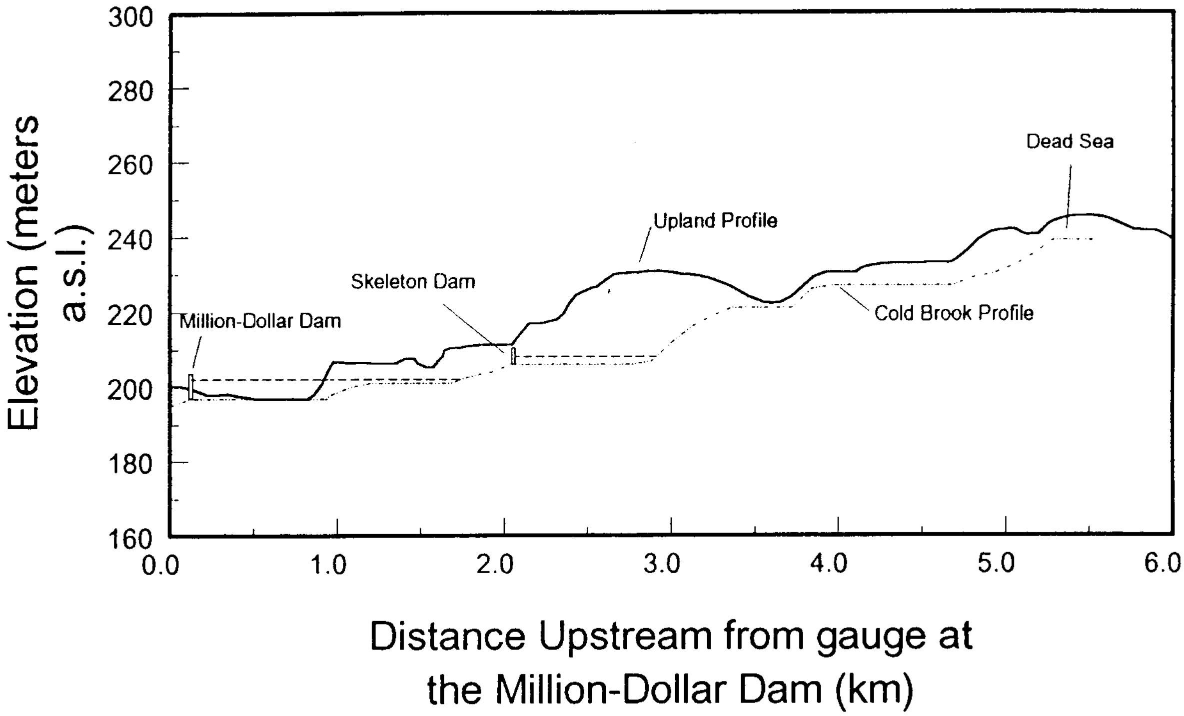

Figure 2. Topographic profile of Cold Brook and adjacent uplands on Altona Flat Rock showing the location of the Million-Dollar and Skeleton Dams and the approximate design pool elevations of their respective reservoirs. The upland profile represents the maximum land surface elevation within 0.5 kilometers of a line oriented N40°W through the Cold Brook Valley.

The central portion of Altona Flat Rock is drained by Cold Brook, a principal headwater tributary of the Little Chazy River that originates at the Dead Sea (Fig. 1). Cold Brook is an underfit stream that occupies a bedrock channel that may locally be more than 200 meters wide and 25 meters deep. The greatest channel incision generally occurs where the stream cuts across prominent southeast-facing bedrock risers. The generally southeastward drainage of Cold Brook is characterized by a subtle rectangular channel pattern that is probably related to bedrock fracture patterns.

Cobblestone Hill is a conspicuous, elongate ridge on the northern flank of Cold Brook at the southeastern margin of Altona Flat Rock. The ridge is more than 15 meters high, 500 m wide, and 2.5 kilometers long and is composed of angular boulders, almost exclusively Potsdam Sandstone, that range from 0.5 to 3 meters in diameter. The average size of surface boulders decreases to the southeast. Boulder and gravel terraces on the northeast flank of Cobblestone Hill represent beach ridges formed in Lake Vermont (Woodworth, 1905a; Chapman, 1937; Denny, 1974).

Geological History

The exposure of large areas of sandstone in the northwestern Champlain Lowland occurred more than 12,000 years before present by the erosional effects of ice-marginal streams during the catastrophic drainage of glacial Lake Iroquois and younger post-Iroquois lakes (Woodworth, 1905a, 1905b; Coleman, 1937; Denny, 1974; Clark and Karrow, 1984; Pair et al., 1988). Lake Iroquois occupied the Ontario Lowland and drained eastward across an outlet threshold near Rome in the western Mohawk Lowland (Coleman, 1937). The lake expanded northeastward into the St. Lawrence Lowland during deglaciation between the Adirondack Uplands to the south and the waning Laurentide Ice Sheet margin to the north. The former water level probably stood at a present elevation between 329 and 332 meters a.s.l. near Covey Hill, Québec (Fig. 1) (Denny, 1974; Clark and Karrow, 1984; Pair et al., 1988).

Eastward drainage of Lake Iroquois began as lower outlets were exhumed along the drainage divide between the Champlain and St. Lawrence drainage systems southwest of Covey Hill during ice recession. The initial drainage may have occurred through a channel approximately 1 km north of Clinton Mills (Fig. 1) that was controlled by a threshold between 329 and 332 meters a.s.l. (Clark and Karrow, 1984). The falling levels of proglacial lakes in the St. Lawrence and Ontario lowlands temporarily stabilized at the glacial Lake Frontenac level (308-311meters a.s.l.) as the ice margin receded northward and the col at The Gulf was uncovered (Clark and Karrow, 1984; Pair et al., 1988). Outflow from these lakes was directed southeastward along the ice margin where it crossed the English, North Branch and Great Chazy watersheds before eventually emptying into Lake Fort Ann which occupied the Champlain Lowland at an elevation between 225 and 228 meters a.s.l. (Denny, 1974). The outflow streams stripped large areas of their surficial cover and cut deep bedrock channels and plunge pools into the Potsdam Sandstone (Fig. 1), *e.g.* The Gulf (MacClintock and Terasme, 1960) and the Dead Sea (Woodworth, 1905a; Denny, 1974). The most intense scour (e.g. Stafford Rock, Blackman Rock, and Altona Flat Rock) generally occurred on major watershed divides. Cobblestone Hill (Fig. 1) is an accumulation of bouldery debris washed from the exposed rock areas by glacial lake outflow floods (Woodworth, 1905a; Denny, 1974).

The scour of the areas southeast of the St. Lawrence-Champlain divide continued as ice recession caused the drainage of Lake Frontenac around the northern flank of Covey Hill. Denny (1974) suggested that the ice margin may have oscillated in the area around Covey Hill causing the lakes in the eastern St. Lawrence Lowland to refill and empty several times. The lake-drainage episodes ended when the ice front receded from the northern flank of Covey Hill for the last time and the proglacial lake in the St. Lawrence Lowland, Lake Belleville, was lowered to the level of Lake Fort Ann in the Champlain Lowland (Pair et al., 1988).

The Jack Pine Barrens

The large areas of exposed bedrock on Altona Flat Rock (Fig. 3) provide habitat for one of the largest jack pine *(Pinus banksiana)* barrens in the eastern United States (Woehr, 1980). The Natural Heritage Program (NHP) classifies this barrens as a sandstone-pavement barrens. With fewer than 20 known sites in the world the NHP ranks the jack pine sandstone pavement barrens as a globally rare ecosystem (Reschke, 1990). The William H. Miner Agricultural Research Institute owns almost 1000 ha (hectares) of barrens on Altona Flat Rock and an additional 600 ha is owned by New York State.

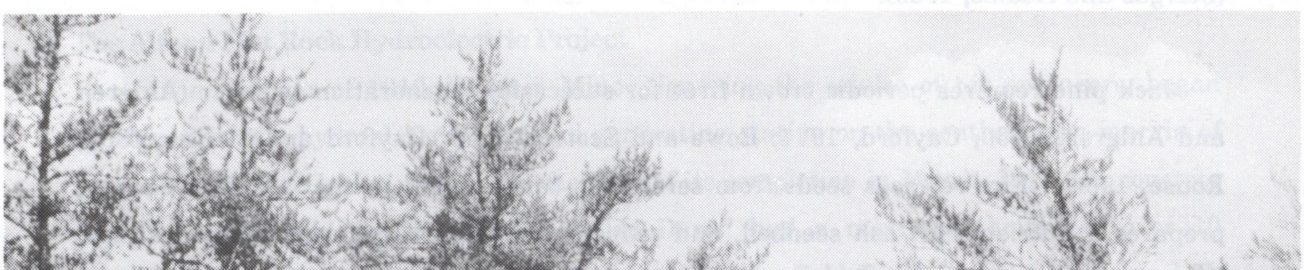

Figure 3. Photograph of "typical" jack pine barrens on Altona Flat Rock.

Jack pine is a relatively short-lived (<150 years), shade-intolerant, boreal species that has maintained a relic community at Altona Flat Rock because of its adaptations to fire and ability to survive in an area with thin (or absent), nutrient-poor soils (Fig. 3). The Altona Flat Rock pine barrens is near the southern limit of the present natural range of jack pine (Burns and Honkala, 1990; Harlow, et al., 1991).

The relatively low species diversity in the barrens reflects low seasonal water availability and the thin, nutrient-poor soils on Altona Flat Rock. The barrens consists essentially of a single tree species, jack pine, with virtually no subcanopy or understory trees. The understory shrubs are predominantly lowbush blueberry *(Vaccinium angustifolium)*, black huckleberry *(Gaylussacia baccata)*, black chokeberry *(Pyrus melanocarpa)*, sweetfern *(Comptonia peregrina)*, and sheep laurel *(Kalmia angustifolia)*. Ground cover is primarily reindeer lichen *(Cladonia rangiferina)*, haircap moss *(Polytrichum commune)*, bracken fern *(Pteridium aquilinum)*, and *Sphagnum spp.* (Stergas and Adams, 1989).

Jack pine requires periodic crown fires for successful regeneration to occur (Ahlgren and Ahlgren, 1960; Cayford, 1971; Rowe and Scotter, 1973; Cayford and McRae, 1983; Rouse, 1986). Fire releases seeds from serotinous cones stored in the jack pine canopy, prepares a nutrient-rich ash seedbed, and reduces competition for the young seedlings. Since this barrens is a fire-dependent ecosystem, fire exclusion will ultimately cause the local extinction of jack pine and the deterioration of the major heath plants, blueberry and huckleberry.

The pine barrens community is well adapted for the Altona Flat Rock environment. Mean annual precipitation from meteorological records for a 27-year period between July, 1963 to August, 1992 at the Miner Institute in Chazy, New York is approximately 80 cm. Mean monthly air temperature ranges from -11^{o}C in January to 20^{o} C in July (Stergas and Adams, 1989). Summer air temperature in bare rock areas, however, may be as much as 16^{o}C higher than in the surrounding areas, and midday temperatures commonly exceed 38^{o}C (Woehr, 1980). Preliminary data from observation wells on Altona Flat Rock indicate that, in many places, the water table lies well below the depth of root penetration.

The combined effects of anomalously high summer air temperature, low seasonal water availability, and flammable foliage produce a fire-prone environment at Altona Flat Rock. There have been four stand-replacing wildfires at Altona Flat Rock during this century (1919, 1940, 1957 and 1965). The oldest jack pine stand at Altona Flat Rock (ca. 73 years) is beginning to show signs of decline. Nearly 40 percent of the trees in this stand (1919 burn area) are dead (Hawver, 1992). The accumulation of dead tree biomass increases the probability of another fire in this stand. A fire management plan, that includes both planned-ignition and natural-ignition fires, is needed for the entire barrens.

The exclusion of fire from a fire-dependent ecosystem such as the jack pine barrens can result in a loss of biodiversity. At the landscape level, the complex mosaic of habitat types created and maintained by fire can benefit many species of plants and animals. The use of prescribed fire to preserve biodiversity in the barrens, however, will require several more years of ecological research and careful planning and coordination with local fire-control agencies and the New York Department of Environmental Conservation.

The Altona Flat Rock Hydroelectric Project

In the summer of 1910, William Miner, ignoring the advice of his engineers, began construction of a hydroelectric dam and generating station on the southeastern margin of Altona Flat Rock (Gooley, 1980). By the time of its completion in March, 1913, the concrete dam, known locally as the "Million-Dollar Dam," had a maximum height of over 10 meters and stretched more than 700 meters across the Cold Brook valley (Figs. 4 and 5). The design capacity of the reservoir was more than 3.5 million cubic meters. A second dam, the Skeleton Dam (Gooley, 1980), was constructed upstream to provide supplemental flow to the main impoundment (Fig. 2).

The dam and generating station were completed in 1913 but it took almost two years to fill the reservoir to near capacity. The inadequate flow of Cold Brook and ground water seepage through Cobblestone Hill, which formed the eastern flank of the reservoir, proved to be major design flaws. At one point, seepage beneath the dam was so great that it caused severe damage to the Stephen LaPierre residence, approximately 600 meters east of the dam (Gooley, 1980). A 10 to 15 cm thick layer of concrete grout was spread over more than 100,000 m^2 along the southwestern flank of Cobblestone Hill to mitigate the seepage loss (Figs. 4 and 6). A deep trench was excavated in the sandstone at the base of Cobblestone Hill behind the dam. A grout curtain was poured into this trench, presumably sealing the northeastern flank of the reservoir. The grouting effort was partially successful and the power generating plant began operation on January 21, 1915, more than four years from the beginning of the project (Gooley, 1980). The power plant produced electricity intermittently for seven years before mechanical problems forced the abandonment of the project.

Figure 4. Oblique aerial photograph showing the Million-Dollar Dam and the northwestern flank of Cobblestone Hill (lower right) where it was covered with a concrete veneer to reduce seepage from the former reservoir. The grout-curtain trench can be seen on the right side of the photo.

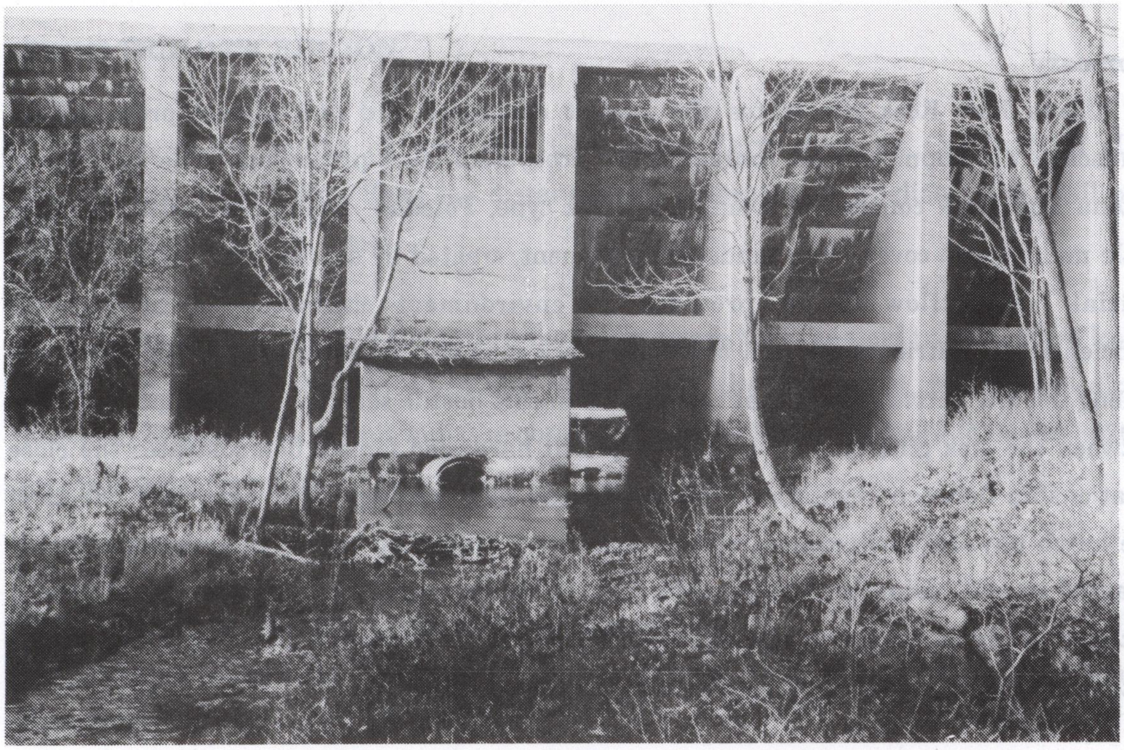

Figure 5. The Million-Dollar Dam looking northwest from the reservoir outlet.

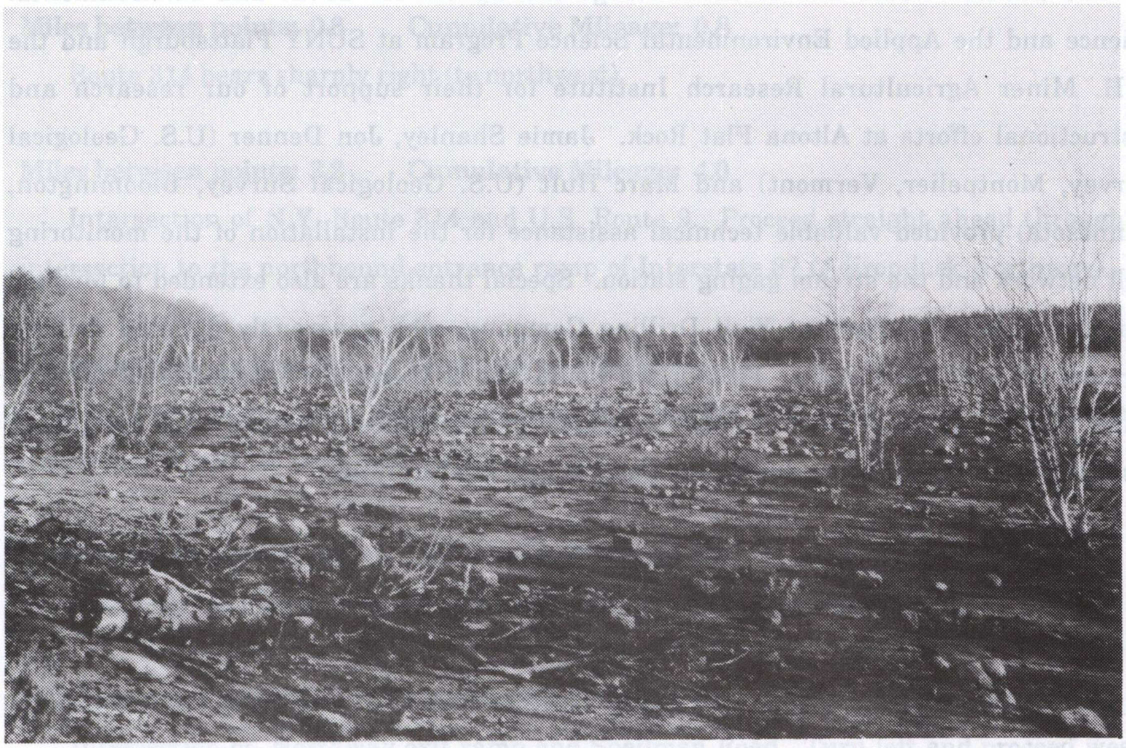

Figure 6. The Scarpit.

Summary

Altona Flat Rock illustrates the impact of glacial and post-glacial processes on landscape development and contemporary ecosystem-level processes. The geology at Altona Flat Rock consists of a single bedrock type, Potsdam Sandstone, with relatively little mineral-soil cover. The sandstone pavement, created by erosion associated with late glacial lake-outflow floods, provides an environment characterized by extreme deficiencies in nutrients and soil moisture. Jack pine and its associated heath plants are among the few native species that can survive in this hostile setting. The abrupt transition between the jack pine barrens and the adjacent hardwood forests demonstrates the close relationship between vegetation distribution and hydrogeology. The combined effects of the harsh physical environment and its associated vegetation create an ecosystem that is adapted to and maintained by periodic fire. A fire-management program, based upon a detailed study of ecosystem dynamics and function, is needed if the uniqueness of the Altona Flat Rock jack pine barrens is to be preserved.

Acknowledgments

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FIELD TRIP DESCRIPTION

The road log begins at the Lake Champlain Ferry dock on Cumberland Head, Plattsburgh, New York. Road log distances are presented in English units. All other measurement are in SI units.

Persons using this log in the future should be aware that the field trip stops are located on private property that is owned and patrolled by the William H. Miner Agricultural Research Institute. A permit must be obtained from the Miner Institute (518-846-8020) to access this property.

START

Miles between points: 0.0 Cumulative Mileage: 0.0

Assemble in the Lake Champlain Ferry parking lot at Cumberland Head, Plattsburgh, New York.

Proceed west on N.Y. Route 314 toward Plattsburgh.

Miles between points: 0.8 Cumulative Mileage: 0.8

Route 314 bears sharply right (to northwest).

Miles between points: 3.2 Cumulative Mileage: 4.0

Intersection of N.Y. Route 314 and U.S. Route 9. Proceed straight ahead through the intersection to the northbound entrance ramp of Interstate 87 (Adirondack Northway).

Miles between points: 0.1 Cumulative Mileage: 4.1

Northbound entrance ramp. Turn right (north) and proceed to Interchange 40 (Spellman Road) in Beekmantown.

Miles between points: 3.8 Cumulative Mileage: 7.9

Exit ramp at Interchange 40. Exit right and proceed to Spellman Road.

Miles between points: 0.1 Cumulative Mileage: 8.0

Intersection of Northway exit ramp and Spellman Road. Turn left and proceed west to Beekmantown Corners.

Miles between points: 2.7 Cumulative Mileage: 10.7

Intersection of Spellman Road and U.S. Route 22. Turn right and proceed north on U.S. Route 22.

Miles between points: 3.4 Cumulative Mileage: 14.1

Intersection of U.S. Route 22, N.Y. Route 348, and West Church Street in West Chazy. Turn left and proceed west on West Church Street.

Miles between points: 0.7 Cumulative Mileage: 14.8

Intersection of West Church Street, Parker Road, and O'Neil Road. Bear left then right to remain on West Church Street.

Miles between points: 0.8 Cumulative Mileage: 15.6

Intersection of West Church Street and Barnaby Road. Turn right and proceed north on Barnaby Road.

Miles between points: 1.0 Cumulative Mileage: 16.6

Barnaby Road changes to a gravel surface at the farm just north of Slosson Road intersection.

STOP 1: LAKE FORT ANN BEACH RIDGES

Miles between points: 1.0 Cumulative Mileage: 17.6

Park at the gate at the entrance of the Miner Institute property and continue northward on foot along Barnaby Road approximately 100 meters (320 ft). Turn left into woods and proceed west for 150 to 200 meters (500–750 ft) up the eastern flank of Cobblestone Hill (Fig. 7). The beach ridges occur at elevations between 175 and 205 meters (580 and 670 ft) above sea level (Denny, 1974).

The beach ridges on Cobblestone Hill were first described by Woodworth (1905a) and later by Denny (1974). The beaches consist predominantly of moderately rounded to well rounded, pebble to cobble gravel that is deposited in multiple, elongate, low-relief ridges that extend along the northern and eastern flanks of Cobblestone Hill between 175 and 205 meters a.s.l. (Fig. 7). Individual deposits are typically as much as 1 meter high and 30 meters wide, and often extend laterally for more than 400 meters (Denny, 1974). The

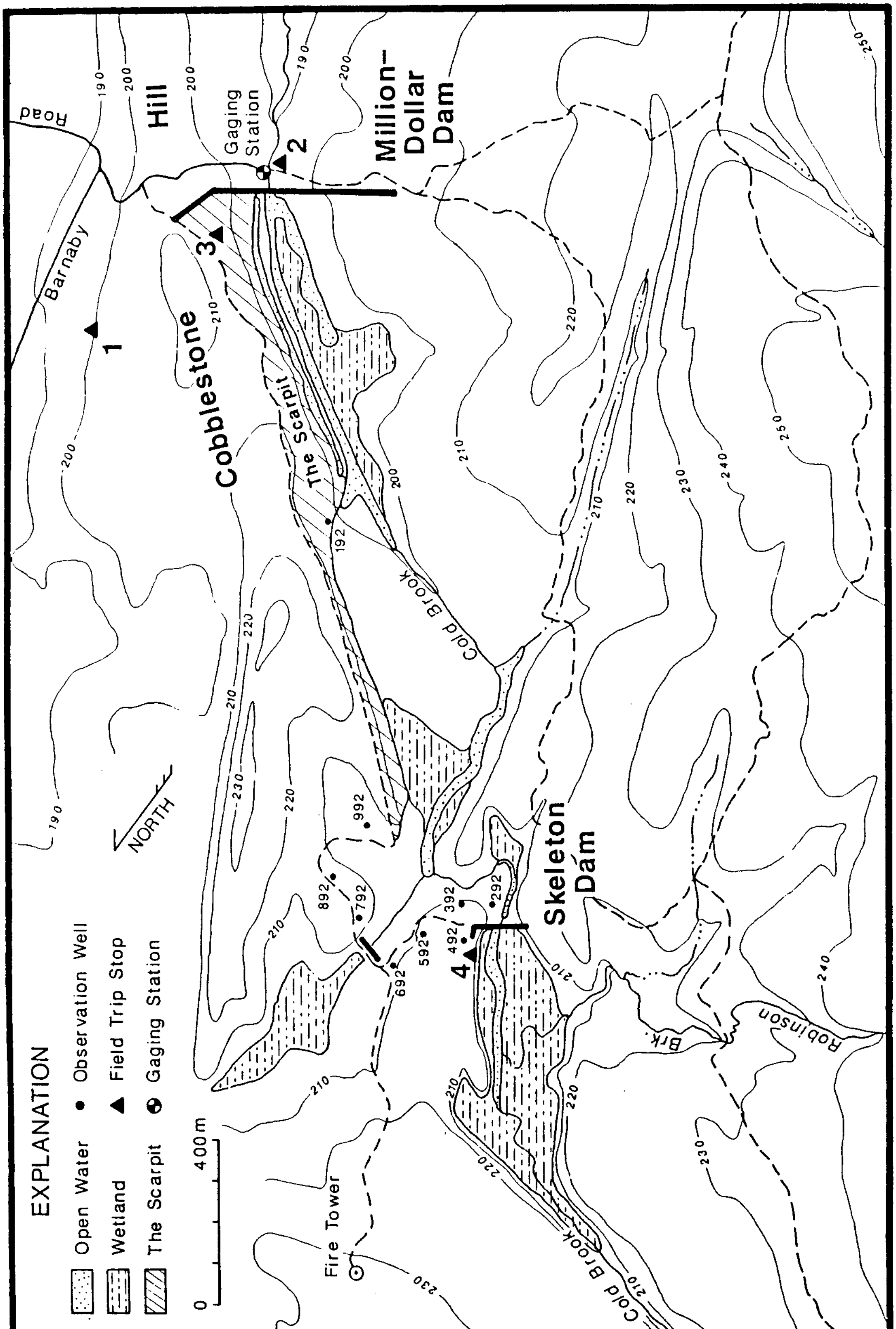

Figure 7. Topographic map of the southeastern portion of Altona Flat Rock showing locations referred to in text. (Topographic base from West Chazy Quadrangle, U.S. Geological Survey 7.5-Minute Series)

gravel is almost exclusively composed of Potsdam Sandstone that was presumably derived from the alluvial cobble to boulder gravel that composes Cobblestone Hill.

Return to the vehicles at the gate after the discussion at this stop.

Proceed through the entrance gate. Low roadside excavations approximately 75 meters (250 ft) west of the gate expose the cobble gravel that comprises the Lake Fort Ann beach ridges. Near the crest of the ridge the angular, 0.3 to 1.2 meter (1 to 4 ft) diameter boulders that comprise the core of Cobblestone Hill can be observed at the surface. The remains of the "Million-Dollar Dam" can be seen on the right just southwest of the hill crest.

STOP 2: THE "MILLION-DOLLAR DAM"

Miles between points: 0.3 Cumulative Mileage: 17.9

The "Million-Dollar Dam" and hydroelectric generation plant was completed on 11 March, 1913 and operated intermittently from 21 January, 1915 until its closure in 1922. A large hole was blasted in the dam shortly after William Miner's death in 1930 to permit Cold Brook to drain freely through the former reservoir. The Altona Flat Rock sandstone pavement is exposed southwest of Cold Brook. The change from mixed deciduous, primarily oak, forest on Cobblestone Hill to jack pine barrens on Altona Flat Rock is characteristically sharp at this location.

A gaging station was constructed at the reservoir outlet in the fall of 1992 to continuously monitor surface-water discharge (Fig. 7). The gaging station is part of a joint initiative by the Center for Earth and Environmental Science and the Applied Environmental Science Program at the SUNY Plattsburgh and the W.H. Miner Agricultural Research Institute to establish an instrumented field station for undergraduate research and instruction in geology and environmental science at the Miner Dam site. A monitoring-well network, consisting of nine wells ranging in depth from 10 to 25 meters, was completed in May, 1992 between the northeastern portion of the former Million-Dollar dam reservoir and the Skeleton Dam (Fig. 7). Water-level measurements were begun in late July, 1992 (Fig. 8). Future plans include the installation of a weather station, an inflow stream gaging station, and expansion of the monitoring-well network. The field station will provide an important linkage between traditional and applied educational opportunities that addresses some of the unique geological and ecological aspects of the Altona Flat Rock region.

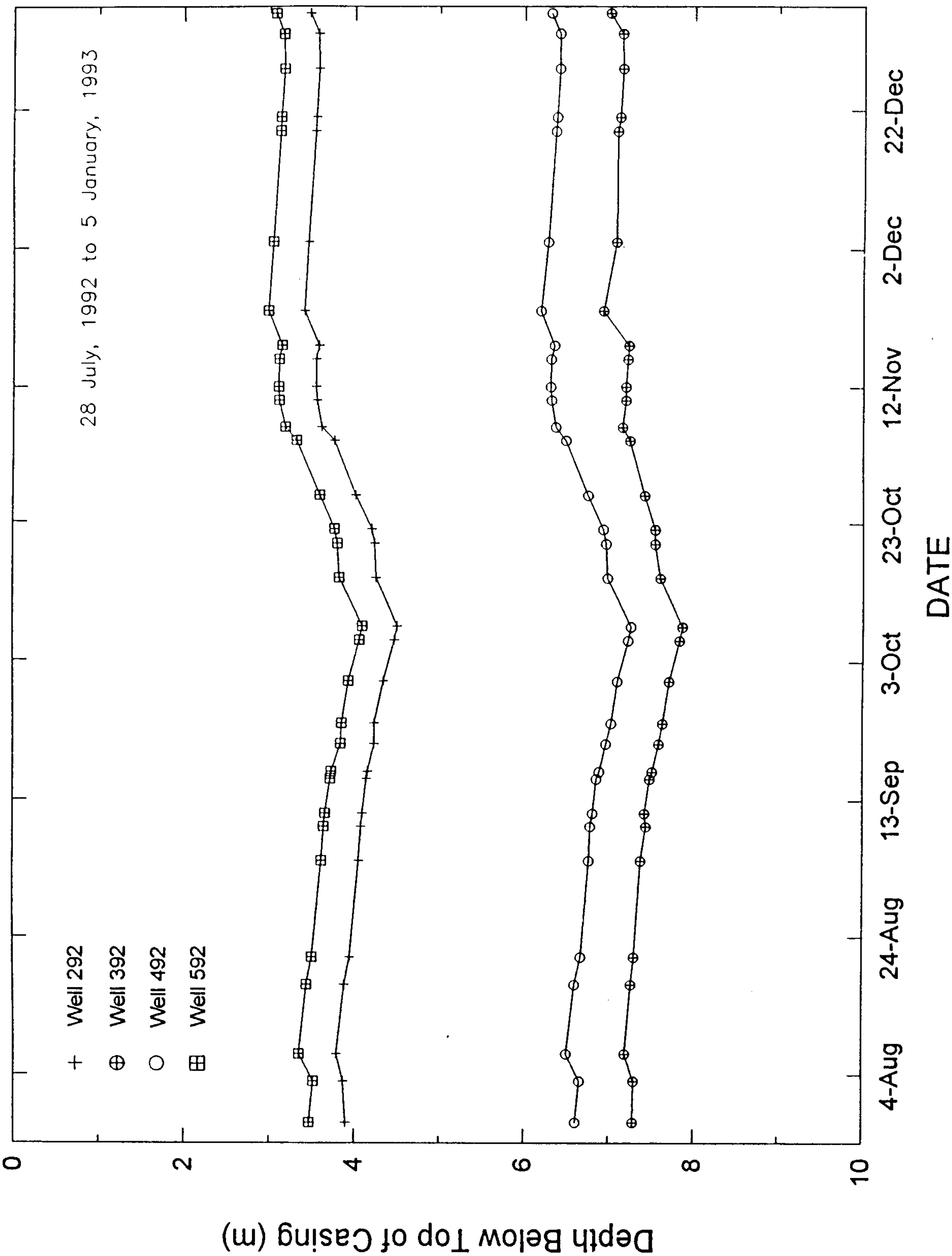

Figure 8. Hydrographs for monitoring wells near the Skeleton Dam.

Return to the vechicles following the discussions at this stop and proceed eastward toward Cobblestone Hill. Turn left onto a small road near the crest of the hill that leads northwestward along the flank of the former reservoir (Fig. 7).

STOP 3: THE "THE SCARPIT"

Miles between points: 0.2 Cumulative Mileage: 18.1

The "scarpit" is the local name given to the desolate landscape created by efforts to grout the porous boulder gravel slope of Cobblestone Hill (Figs. 6 and 7). The surface consists of a thin (1.2 to 2.5 cm) layer of cement that was poured and raked between large boulders composed predominantly of Potsdam Sandstone. The trench that was dug for the grout curtain (Fig. 4) can be observed approximately 100 meters west of the concrete road that parallels the former shoreline of the reservoir.

Return to the vehicles following the discussions at this stop and proceed northwestward on the concrete road.

Miles between points: 0.5 Cumulative Mileage: 18.6

The first of nine observation wells drilled in May 1992 can be observed to the left near the treeline at the edge of the grout surface. The wooded area beyond the well is part of minor southeast-facing bedrock riser. The slope of Cobblestone Hill steepens and the boulder size increases to the northwest.

Miles between points: 0.5 Cumulative Mileage: 19.1

The concrete road ends and the access road bears sharply northeast and continues on the bedrock surface through the jack pine barrens.

Miles between points: 0.1 Cumulative Mileage: 19.2

The road crosses a surface-water supported wetland. The road bed is deeply rutted where it crosses a wetland that contains 0.2 to 1.0 meters of organic soil. Observation wells located approximately 50 meters northeast and 70 meters southwest of the wetland indicate that the water table is more than 7.5 meters below the surface.

Miles between points: 0.2 Cumulative Mileage: 19.4

The road crosses a small channel that contains a large wetland. A concrete wall on the left (south) side of the road was constructed to prevent water impounded behind the "Million-Dollar Dam" to escape northward through this channel (Fig. 7).

The access road forks immediately west of the channel. The right fork leads to an abandoned fire tower on the top of Pine Ridge. Bear left and proceed southward.

STOP 4: THE "SKELETON DAM" & CHASM LAKE

Miles between points: 0.2 Cumulative Mileage: 19.6

The partially completed "Skeleton Dam" was designed to augment flow to the reservoir impounded behind the "Million-Dollar Dam" (Figs. 7 and 8). The dam impounds "Chasm Lake" (Gooley, 1980), presumably named for the deep gorge cut into a prominent sandstone riser at its northwestern edge.

The water level of Chasm Lake dropped more than 2 meters below the spillway of the Skeleton Dam during the summers of 1991 and 1992. What little surface flow reached the basin during the summer months was lost by evaporation and ground-water seepage from the basin. Water level measurements from nearby observation wells since late July, 1992 indicate that steep, eastwardly directed hydraulic gradients exist at the southeastern flank of Chasm Lake, providing support for the hypothesis that some water is being lost from the reservoir by groundwater seepage.

Return to vehicles after the discussion at this stop and follow the rod log in reverse order to the Lake Champlain Ferry dock at Cumberland Head.

Miles between points: 19.6 Cumulative Mileage: 39.2

Lake Champlain Ferry dock.

End of road log.

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