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POSTGLACIAL CHRONOLOGY AND THE ORIGIN OF DEEP LAKE BASINS IN PRINCE EDWARD COUNTY, ONTARIO

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Abstract. Draining of glacial Lake Iroquois to low-level Admiralty Lake occurred rapidly with temporary halts about 11,000 years ago. Uplift in the eastern end of the Lake Ontario basin initiated the present Lake Ontario stage shortly thereafter, some 10,200 years ago. Lake on the Mountain, Roblin, and Fish Lakes occupy bedrock basins that are thought to be sink holes which developed prior to the last glaciation in the area, possibly in pre-Pleistocene time. These lakes were isolated between the Iroquois and Ontario lake stages as waters receded in the Lake Ontario basin.

INTRODUCTION

The origin of the deep bedrock basins presently occupied by Lake on the Mountain, Roblin Lake, and Fish Lake is an intriguing aspect of the surficial geology of the region mapped recently by Mirynech. Echo sounding, SCUBA diving, and investigations of bottom sediments were conducted in 1961 and 1962 in an attempt to solve the problem presented by these deep basins. This phase of the study was followed by a drilling program during the winter of 1963. Unconsolidated sediments and bedrock were cored through the ice of Lake on the Mountain and Roblin Lake by means of a truck-mounted Boyles soil testing rig, model 1A. Continuous 2-in. Shelby tube samples of the unconsolidated deposits were obtained for laboratory analysis.

Roblin Lake, Lake on the Mountain, and the neighbouring Fish Lake (Fig. 1) have long held the attention of geologists and geomorphologists because of their rather unique position relative to adjacent high limestone escarpments and to the Bay of Quinte, an arm of Lake Ontario. The lakes are situated near the edge of a limestone tableland that stands high above the Bay. They are all rock-rimmed and occur in a region where drift overlying the bedrock surface is very thin. Roblin and Fish Lakes are relatively shallow but Lake on the Mountain is 98 ft deep. Roblin Lake contains the thickest sequence (68 ft) of unconsolidated sediments; however, Fish Lake remains to be cored. Roblin Lake and Lake on the Mountain both contain glacial deposits which are overlain by glacio-lacustrine and lacustrine sediments (Fig. 2). The latter document part of the late-

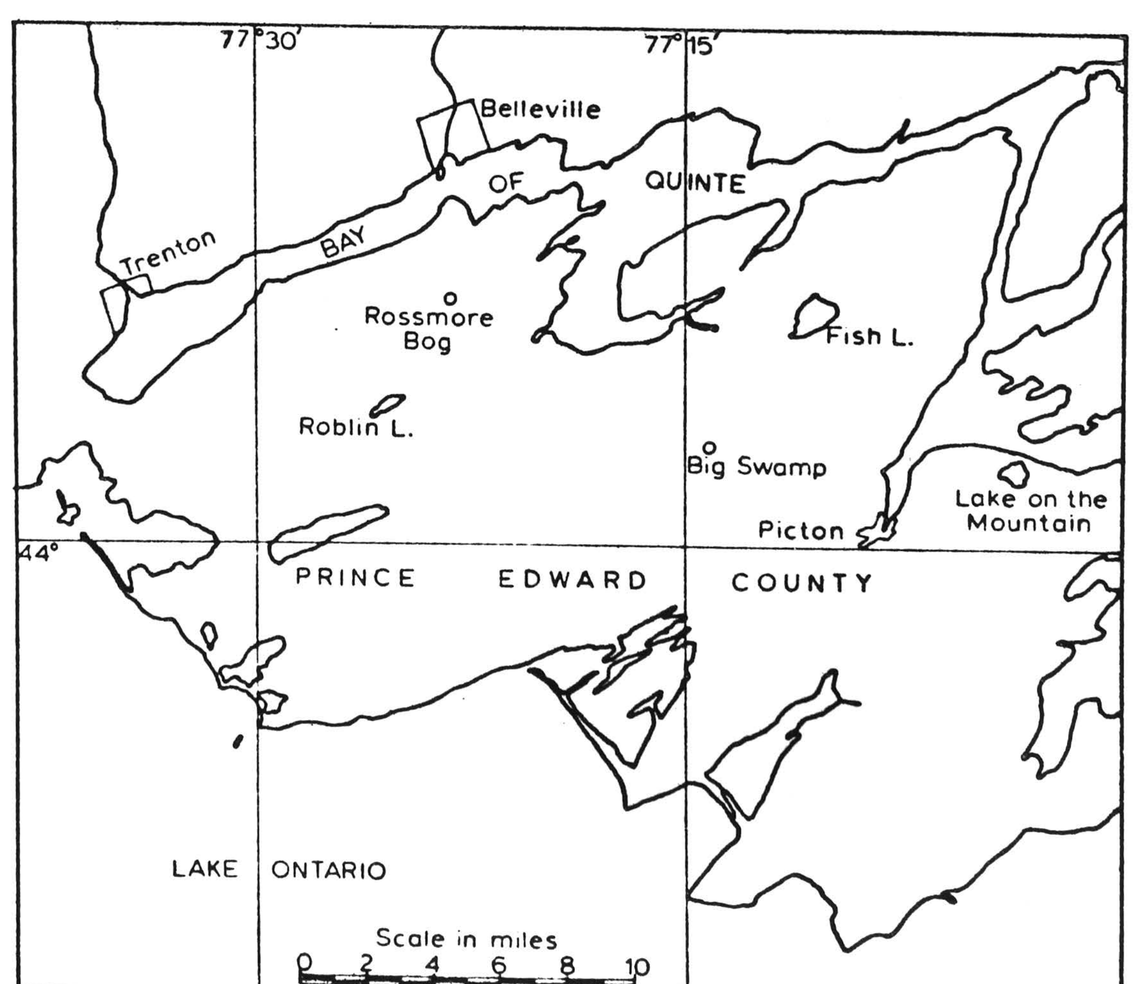

Fig. 1. Index map showing location of sites studied.

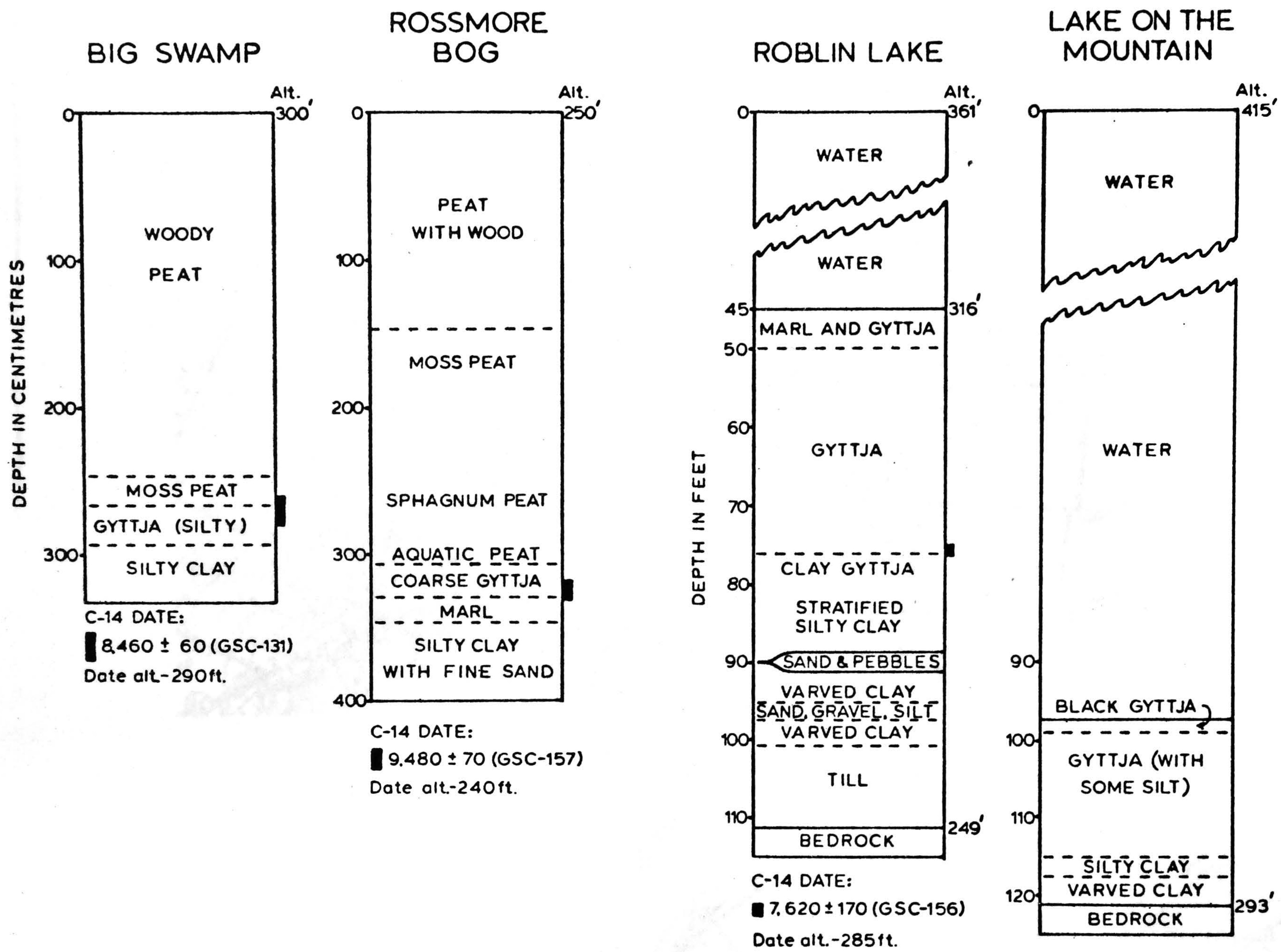

Fig. 2. Sediment sequences and C-14 dates at the sites studied.

glacial and postglacial history of the Lake Ontario basin.

The Prince Edward County region (Fig. 1) lay several hundred feet beneath the surface of the Glacial Lake Iroquois, the highest proglacial lake that occupied the Lake Ontario basin. Approximately 11,500 years ago retreat of the barrier ice dam from the head of the St. Lawrence valley caused lowering of this glacial lake to a sub-Lake Ontario level, the Admiralty Lake stage (Coleman 1922). The tableland emerged and Lake on the Mountain, Roblin Lake, and Fish Lake successively were left above the receding water plane. The initial phase of emergence (drainage of the glacial lake) was instigated by adoption of successively lower outlets in the St. Lawrence Valley to the eastward. However, regional uplift was in progress well before the draining of Lake Iroquois commenced. Emergence since the end of the brief Admiralty Lake stage has continued at a decelerating rate in response to rebound. The net result of this crustal movement has been the elevation of the eastern end of the Lake Ontario basin and drowning of the western end.

During the Lake Iroquois stage varved sediments accumulated in the bedrock basins considered and buried pre-existing glacial deposits. These glaciolacustrine sediments grade upward into stratified silt which is overlain by stratified organic deposits (gyttja and marl) (Fig. 2). Changes in both the regional climate and the local sedimentary environment are clearly recorded in the sedimentary sequences studied.

PHYSIOGRAPHY

Roblin Lake, rectangular in shape because of the limestone jointing pattern, is approximately 1 mile long and 0.3 miles wide. The present Lake on

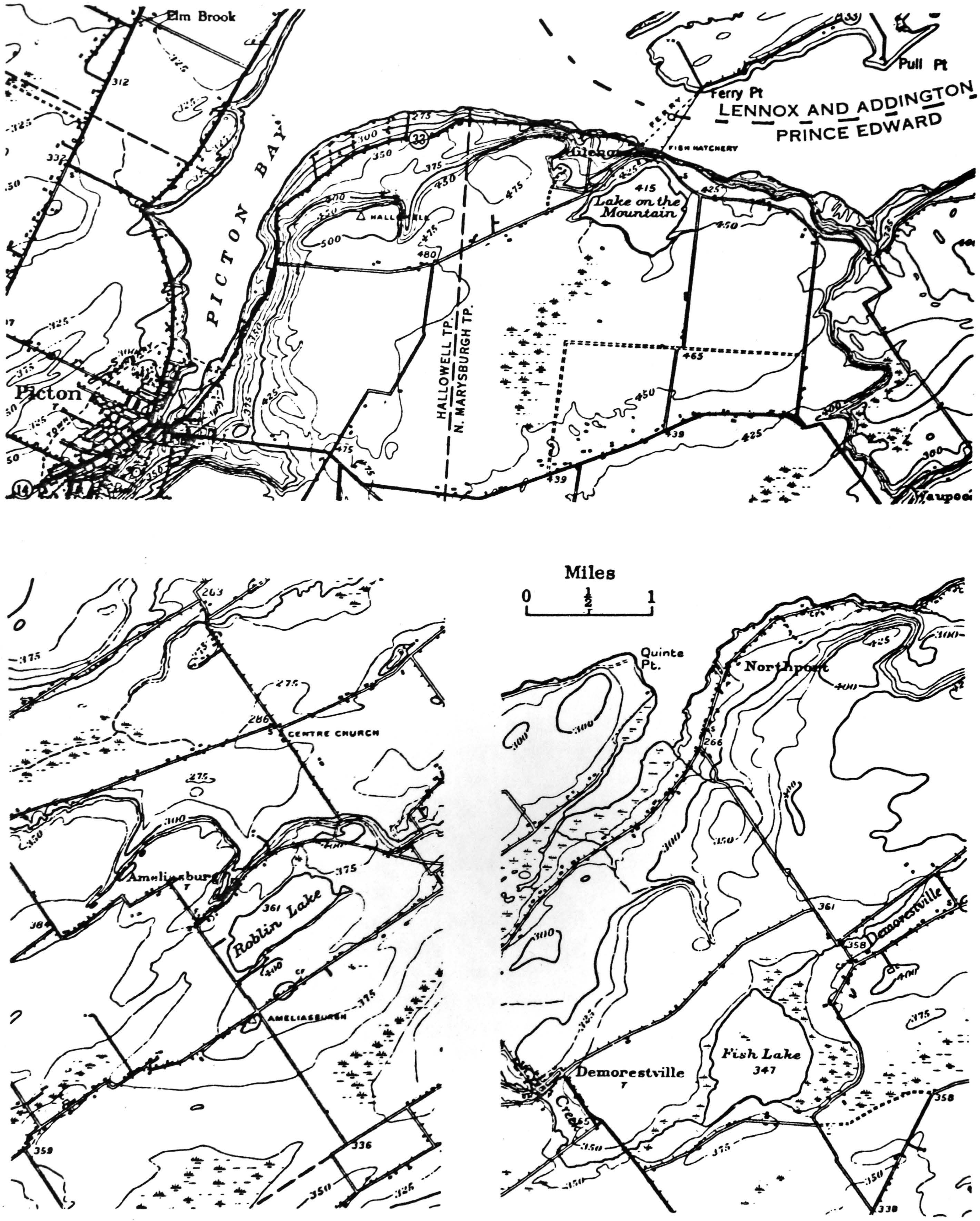

Fig. 3. Location and topographic setting of the lakes studied.

the Mountain is roughly square-shaped, about 0.5 miles on a side, but originally it was semicircular with a radius of 0.3 miles. The lake was raised about 10 ft by construction of a retaining wall across the outlet channel. Fish lake, the most irregular in shape, is 1.2 miles long and 0.8 miles wide. The surface of Lake on the Mountain, 415 ft above sea level, lies 54 ft above that of Roblin Lake (361 ft above sea level) and 68 ft above Fish Lake (347 ft above sea level). Each lake level is well above that of the Bay of Quinte (245 ft above sea level): Lake on the Mountain 170 ft, Roblin Lake 116 ft, and Fish Lake 102 ft.

The lakes each receive considerable surface drainage from the surrounding country in the spring, but Fish Lake alone receives stream drainage. Summer surface drainage is intermittent because it depends on rainfall; nevertheless, the lake levels remain relatively constant because of substantial influxes of ground water below lake level. Ground water flows from neighbouring marshy areas through subsurface joints, bedding planes, and fissures.

Roblin Lake's only outlet is a broad shallow spillway that runs northward over flatlying limestone, from the west end of the lake to the escarpment at Ameliasburg. Only minor volumes of water can leave the basin through this spillway, even in the spring when run-off is greatest. The present outlet of Lake on the Mountain coincides with the original one and drainage is carried northward through a shallow bedrock channel from the northeast corner of the lake. The outlet stream flows several hundred feet to the edge of the Glenora escarpment and drops nearly 100 ft down its face. A machine shop and grist mill utilized this water prior to the present Fisheries Research Station. A sluice was built to carry the water to the mill and a retaining wall was constructed to maintain a high lake level. Present runoff from Lake on the Mountain is intermittent in the summer months. Fish Lake drains west and then north through Demorestville to Muscote bay. Flowage in the outlet stream virtually ceases in mid summer.

As shown in Fig. 3, both Roblin Lake and Lake on the Mountain are situated close to local escarpments at points where prominent re-entrants cut these escarpments. At first glance Fish Lake does not appear to be so situated; however, its outlet passes through a broad, shallow re-entrant cut in a local low escarpment. The latter is situated a short distance east of a major escarpment that passes through Demorestville. The Ameliasburg re-entrant (near Roblin Lake) is longer, narrower, and deeper than that at Glenora (near Lake on the Mountain). Bedrock faces within the re-entrant usually exceed 50 ft in height and are steep, often vertical.

The lake basins are almost completely rock rimmed by thin-bedded Middle Ordovician limestone (Liberty 1960). The limestone is overlain by a thin veneer of black muck in the northeast corner of Roblin Lake, and more than 50% of Fish Lake's shoreline is formed by such deposits. While little or no muck occurs along the Lake on the Mountain shoreline, glacial till forms short segments, particularly along the northwest side of the lake (Coleman 1937; Dwight 1954). In this locality till appears to fill a northwest trending bedrock depression, possibly a former channel that once connected the lake basin with the adjacent Glenora re-entrant. When the shoreline was 10 ft lower in altitude the peripheral limestone shelf, evident on aerial photographs, must have been very near to the lake level.

ORIGIN OF THE LAKE BASINS

As Coleman (1937) stated, the origin of Roblin Lake and Lake on the Mountain presents an intriguing problem. During the 1961 field season echo soundings were made on the lakes with the cooperation of R. E. Deane, Great Lakes Institute. An accurate topographic picture of bottom contours of both lakes was obtained (Figs. 4, 5) which confirmed the previous chain-sounding data collected for Lake on the Mountain by the Glenora Fisheries Research Station (Dwight 1954).

In the winter of 1963 series of bore holes were drilled in Roblin Lake and Lake on the Mountain to obtain further data concerning both the origin of these lakes and the general late- and postglacial history of the Lake Ontario basin. Maximum depths in both lakes are associated with holes situated along the south sides of their basins. Basin walls of both lakes are high on the

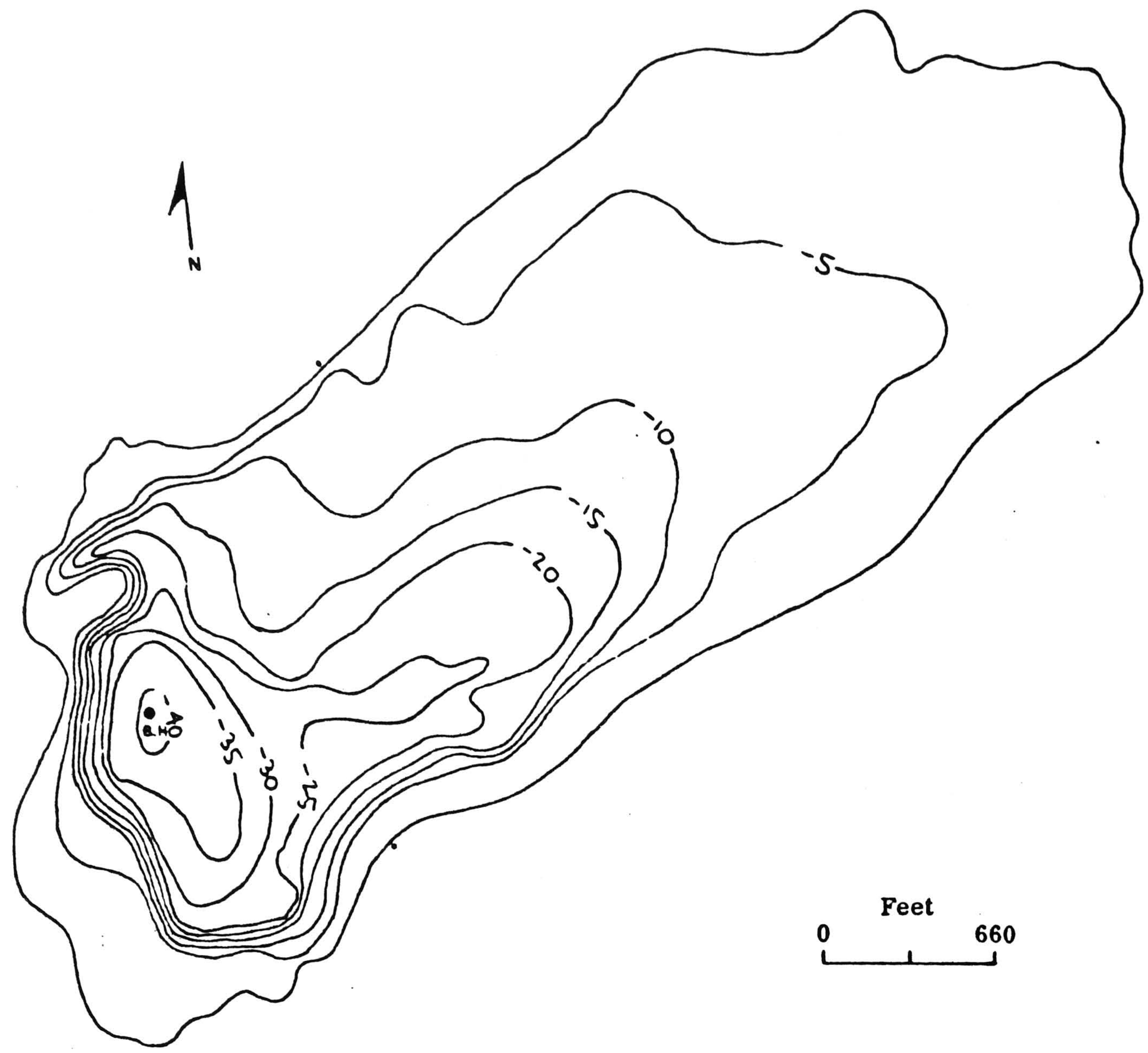

Fig. 4. Bottom configuration of Roblin Lake (depth in feet) and borehole location.

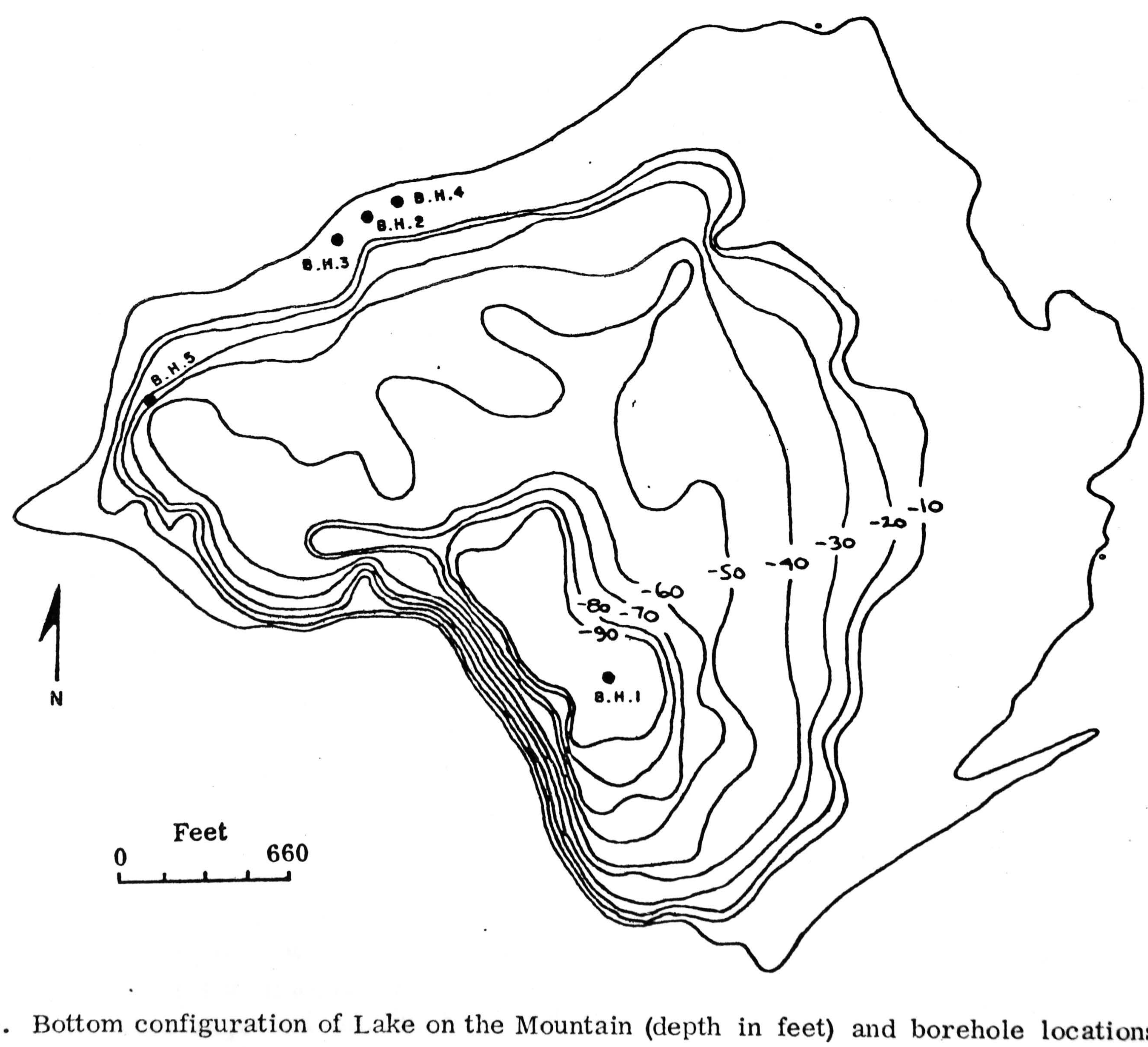

Fig. 5. Bottom configuration of Lake on the Mountain (depth in feet) and borehole locations.

south and nearly vertical, while northern walls are distinctly benched and have a gentler slope. As described earlier, a shallow peripheral bedrock shelf can be traced around each lake both on aerial photographs and in the field. Beyond the shelf the limestone in Roblin Lake steps regularly down to the flat floor in a southwest direction. At Lake on the Mountain the limestone descends to a depth of nearly 60 ft in steps but then it drops almost vertically the remaining 37 ft to a flat bottom. The trenched character of the deepest part of each lake is obvious. These trenches are short and terminate abruptly at both ends. Echosounding records strongly suggest the trench walls are bedrock, whereas the flat floors are composed of soft sediments. Minor submerged channels descend into the Lake on the Mountain trench from the northwest and southwest. These, together with a broader channel entering from the east, appear to be incised in bedrock. Similar submerged channels descend to the bottom of Roblin Lake from the north and northeast. The configuration of both lake basins indicates all gradients are in the direction of the trenches.

In an effort to substantiate conclusions formed on the basis of preliminary work, the Ameliasburg and Glenora re-entrants were mapped in detail, and boreholes were drilled to bedrock on the northwest side of Lake on the Mountain to determine the thickness of the till "plug" which Coleman (1937) and Dwight (1954) had postulated. Mapping revealed no trace of a buried bedrock channel joining the Roblin Lake basin to the Ameliasburg re-entrant, but it permitted more precise delineation of the Lake on the Mountain till "plug." The till is thickest, about 40 ft, in the shallow saddle 0.4 miles southwest of the Glenora fish hatchery. Approximately 30 ft of fresh till is exposed on the south side of the new Lake on the Mountain road above the embankment, but limestone crops out in the south ditch at the southwest corner of the same exposure and discontinuously along the ridge flank along the head of the re-entrant.

The boreholes at Lake on the Mountain (Fig. 4) were drilled 50-60 ft offshore through 14 inches of ice. Three feet of till overlying the thin-bedded Trenton limestone was found 5 ft below the ice surface in boreholes 2 and 3. In borehole 4, 15 ft of till overlies the limestone beneath a similar depth of ice and water. Although the till is thicker at this site, it is far thinner than the 113 ft (the difference in elevation between the lake and bedrock surfaces) necessary if the lake basin is indeed a plugged stream-cut ravine. Borehole 5 was located at the southwest corner of Lake on the Mountain at a point where the peripheral bedrock shelf is narrowest and where the bedrock barrier separating the lake from the re-entrant is also very narrow. Furthermore, the site is near the head of a lake-bottom channel which descends southeast into the Lake on the Mountain trench. Ten feet of fossiliferous marl lies 33 ft beneath the ice surface. The marl lies on 1 ft of stony till which overlies limestone.

Mapping and drilling data now at hand cast serious doubt on the presence of any buried outlet ravines at either Lake on the Mountain or Roblin Lake. Thus the bedrock basins, whose bottom altitudes are now known to be at least 293 and 248 ft above sea level respectively (Lake Ontario level is at 245 ft a.s.l.), are not believed to have formed as the result of stream erosion, and there is no apparent relation between lake basin morphology and their topographic locations. Past discussions regarding the origin of these lake basins invariably involved glaciation, particularly erosion at the base of a moulin. Basin size and configuration contradict such a hypothesis. Furthermore, it is unlikely that a retreating glacier would remain in a fixed position for a protracted period of time, that would permit erosion of a depression in the soft Trenton limestones of the magnitude required. Meteorite impact theories of basin origin are also rejected on the basis of basin configuration and geological structure.

Both Roblin Lake and Lake on the Mountain bedrock basins pre-date the last glaciation in this area, because till covers the bedrock floor of the basins. They probably developed prior to the Pleistocene epoch. However, the writers have no fully satisfactory answer to the question why no older Pleistocene deposits than those of the last glaciation were not found in these basins. As there is no apparent relation between basin morphology and local drainage development, it is possible that the basins developed prior to the Bay of Quinte trenches, at a time when the limestone strata were more continuous northward and eastward. They appear to have been formed on a relatively flat well-jointed limestone surface. This surface presently bears little evidence of chemical weathering although the most plausible hypothesis of the origin is related to such weathering. The lack of karst topography in this area does not exclude the possibility that the basins are sink holes. Its absence might be attributed to glacial erosion which was relatively severe along the St. Lawrence valley - Lake Ontario basin corridor. It is remarkable, perhaps, that the Lake on the Mountain and Roblin lake basins were not completely filled with glacial drift in view of their location within the corridor. However, the bulk of the debris was effectively removed from advancing glaciers by the adjacent escarpments. By impeding the basal, debris-laden ice the escarpments prevented filling of the lake basins.

PALYNOLOGICAL STUDIES AND POSTGLACIAL CHRONOLOGY

Mapping and stratigraphic studies of surficial deposits in the Belleville area (Prince Edward County) were supported by an investigation of glacio-lacustrine and lacustrine sediments and peat deposits at selected sites (Fig. 1) for the purpose of documenting the late- and postglacial sequence of events. This investigation proceeded along three different lines: 1) the sediments were cored and described in detail, 2) their fossil content was studied, and 3) radiocarbon dating of certain samples provided an absolute time scale. The results obtained clearly indicate that no single approach can provide the complete story, but, when combined, a reasonably continuous chronological sequence of events can be established for late-glacial and postglacial time. Stratigraphic sections at the sites studied are shown in Fig. 2, which also shows the stratigraphic position of the samples dated by the radiocarbon method.

Description of Sites

Big Swamp (Fig. 1) developed in a shallow rock basin which first was occupied by a lake and later was filled with organic sediments. Pollen bearing, inorganic sediments extend beneath the radiocarbon dated depth, and it is inferred that oligotrophic environment in this lake existed for a long time after it was isolated from the Glacial Lake Iroquois.

The Rossmore Bog, too, developed from a shallow lake (formed after drainage of Lake Iroquois) which was filled first with organic sediments. The lacustrine sediments are overlain by peat. At the beginning of peat accumulation a fen vegetation is inferred from the abundant remains of grass, sedge and moss. A gradual change to an acid environment favoured bog development as indicated by the presence of *Sphagnum* peat. However, the rising lake level in the Lake Ontario basin slowly flooded the bog and replaced it with a forest swamp environment. In recent time, some 100-150 years ago, the forested swamp was destroyed, probably owing to further rise of the Lake Ontario level, and the present extensive cat-tail (*Typha*) swamp developed.

In the Roblin Lake basin the near ice-marginal conditions during existence of Glacial Lake Iroquois lasted only for a short time, as indicated by the small thickness and rapid thinning of the varves of the glacio-lacustrine sediments overlying till (Fig. 5). The coarse-textured layer overlying varved clay can be interpreted as having been deposited by wave wash when glacial lake waters in the Lake Ontario basin dropped below the altitude of Roblin Lake. The stratified silty clay represents deposition in late-glacial and early post-glacial time, when oligotrophic conditions prevailed in this lake. The onset of the deposition of marl and the later rapid accumulation of algal gyttja, beginning some 7600 years ago, is attributed to a climatic change which provided environmental conditions favourable for increased productivity of the lake.

Lake on the Mountain is a meromictic lake at the present time, as indicated by the black gyttja deposit in the deep part of the lake and other limnological features. Light coloured marl is characteristic of the shallower parts in Lake on the Mountain. In general, the sedimentary sequence in this lake is similar to that in Roblin Lake, although the total thickness of sediment, particularly of algal gyttja, is considerably less.

Interpretation of the Results Obtained

Preliminary palynological studies of the drill cores and a correlation of the pollen sequences obtained with other pollen diagrams of the region, which have radiocarbon control for significant pollen-stratigraphic levels, has led to the conclusion that there is no large age difference between the earliest pollen bearing sediments at the highest and the lowest sites (Fig. 6). All these pollen sequences, with the possible exception of Big Swamp, date back to little more than 10,000 years B.P.

This evidence indicates rather clearly that the glacial lake in the Lake Ontario basin drained rapidly from the Lake Iroquois level, some 11,500 years ago, to the Admiralty level (lower than that of the present Lake Ontario) some 10,500 years ago. However, there is sufficient evidence to indicate that minor halts occurred in the recession of lake levels. It is pertinent here to note that the above reasoning leads to the conclusion that drainage of Glacial Lake

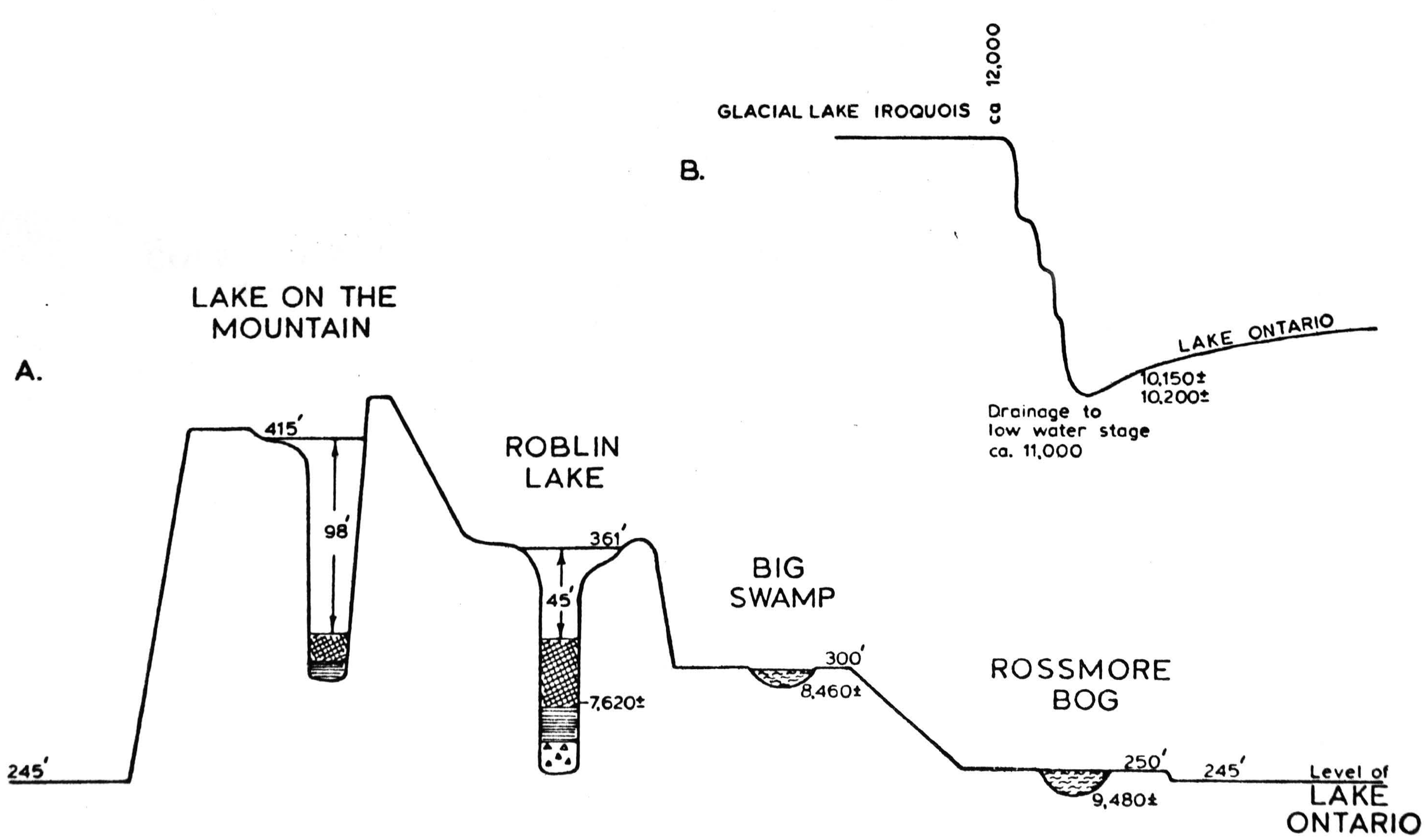

Fig. 6. A. Altitudes of sampling sites, C-14 dates and sediment thicknesses. B. Lake level changes in late-glacial time.

Iroquois occurred during the Two Creeks interval, possibly early in that interval.

The water level in the Lake Ontario basin was already rising from the Admiralty stage more than 10,000 years ago, as indicated by radiocarbon dates at Hamilton (10,150 ± 450 I(GSC)-11), discussed by Karrow et al. (1961), and at Kingston (10,200 ± 500 I-1223). Furthermore, these radiocarbon dates support the earlier assumptions that the eastern end of the Lake Ontario basin has been uplifted some 200 ft more than the western end at Hamilton in postglacial time.

Another study related to this investigation deserves mention. Site investigations for harbour facilities at Picton (Fig. 1) had indicated the presence of fossiliferous sediments at some depth beneath the present level of Lake Ontario. A coring of sediments at this site by the writers confirmed the presence of the fossiliferous beds. All the fossils found indicated freshwater environment. In several reports published some years ago it was assumed that the marine invasion of the St. Lawrence-Ottawa Valleys (the Champlain Sea) also extended into the Lake Ontario basin. To date the writers have examined numerous exposures and some cores in the Belleville-Kingston area without finding any evidence of marine environment. It would seem that glacial lake waters in the Lake Ontario basin drained to the low-water Admiralty stage at a time when rapid uplift was in progress at the eastern end of the basin, and hence, the Champlain Sea was excluded from it.

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