POST-IROQUOIS LAKE STAGES AND SHORELINE SEDIMENTATION IN EASTERN ONTARIO BASIN[1]

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ABSTRACT

Four distinct post-Iroquois stillstands are recognized in the coastal and upland areas of the eastern Ontario basin: the Sandy Creek (10,150 years B.P.), Skinner Creek, Dune (5,000 years B.P.), and North Pond stages. The tilt rate for the Sandy Creek–Dune stage interval was five times greater than Dune stage to present. During the Sandy Creek–Dune stage interval, the water level fell along the eastern shore area due to erosion of glacial deposits in the Saint Lawrence Valley and rapidly rose in the western end of the lake due to differential tilting. From Dune stage to present, both the eastern and southern nearshore areas were slowly flooded due to differential tilting. Prior to Dune stage time, erosion of the emerging eastern basin produced much of the lake sand and gravel in that area. Following the Dune stage, local sediment contributions diminished because of flooding, but extensive erosion of the southern lake shelf contributed proportionally larger amounts of sand from submerged tills. Easterly flowing nearshore currents were responsible for producing lag gravels along the southern shore and transporting sands to the eastern shore.

INTRODUCTION

The eastern nearshore area of Lake Ontario is characterized by numerous shallow bays, ponds, and streams bordered by an extensive offshore sand deposit (Sutton et al. 1970). In order to explain the presence of the offshore sand accumulation, we studied the coastal and upland surficial geology of the eastern shore in 1970 (fig. 1). North Pond, the largest of the bays, was extensively sampled (fig. 2). Shallower ponds, beaches, and baymouth and offshore bars were also cored and sampled. Former high-water strands recorded as beaches, bars, and wave-cut benches were studied below an elevation of 600 feet covering an area from Henderson Harbor and Stony Point at the north to Mexico Bay on the south.

The results of this study led to the establishment of a chronological order of events of the area which provides an explanation for the origin of the extensive offshore sand accumulations, and suggests a new sequence of lake-level changes in Ontario basin.

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GEOLOGIC SETTING

Poorly resistant siltstones and shales of the Ordovician Lorraine Group underlie the pond area along the eastern shore. Comparatively more resistant formations surround the pond area to the north, east, and south. These include older limestones of the Black River and Trenton Groups in the Henderson area, the younger Oswego, Queenston, and Medina strata to the east, and the Oswego Sandstone in the vicinity of Mexico Bay.

The bedrock surface is covered by glacial deposits that have been modified by lakes and streams related to former lake levels. Drumlins, kames, and kettles characterize the higher elevations (300–500 feet) a few miles east of the present shoreline. From the 300-foot elevation to the present lake level (246 feet) glacial features have been modified or buried beneath the younger lacustrine and fluvial deposits. Many drumlins have been truncated and benched, while others have been nearly obliterated with only a low boulder terrain outlining their location.

The present shoreline consists of bars enclosing lagoon-like ponds into which numerous small westerly flowing streams empty. The ponds are ringed by swamps where plant growth has taken over after the prograding streams partially filled the shallow basins behind the bars.

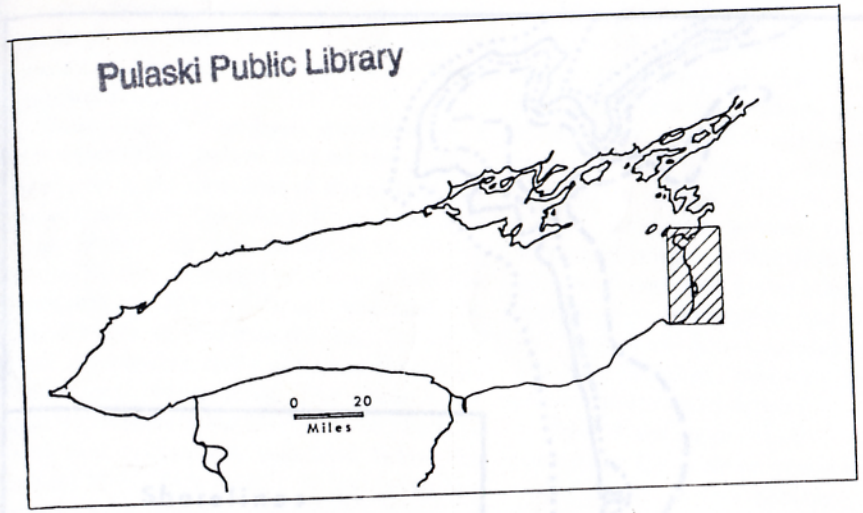

FIG. 1.—Index map showing study area

In places, dunes up to a height of 50 feet line the bars. On the lakeward side, a narrow beach composed of fine-grained sand with varying amounts of pebbles and cobbles extends almost continuously from Mexico Bay to Stony Point. The lake bottom is composed of fine-grained sand, and it dips lakeward at 30 feet per mile. During summer months, a low offshore bar cresting at a depth of 2 feet, may be observed approximately 100 feet from the strand line.

CHRONOLOGY OF LAKE STAGES

Four distinct lake levels can be recognized in the vicinity of North Pond, which represent times of post-Iroquois stillstands in the Ontario basin. Stage names for these levels have been assigned from areas where the best evidence was observed. The stages are classified in chronological order.

Following the retreat of the ice front from the eastern part of the Ontario basin, the drumlin and kame topography was inundated by one or more glacial lakes, of which Lake Iroquois (12,000 years B.P.) (Goldthwait et al. 1965) is best known (fig. 3). The Iroquois beaches have been identified on hills 4 miles east of the present lake at an elevation of 600 feet. For a detailed description of these shoreline features, see Stewart (1958, p. 55–64). A subsequent fall of lake level left a few scattered beaches on the drumlins and kames at 450- and 350-foot levels. Almost all of the North Pond area was under water during this time. Only a few of the drumlins projected above water level, and the features were slightly modified by wave or stream action.

Sandy Creek stage.—Evidence for a second stillstand occurs 3 miles east of the lake and trends parallel to the present shoreline from Henderson Bay to Mexico Bay (fig. 3). This stillstand, marked by benches, beach sands, and dunes at the 290–300-foot elevation, was named Gilbert Gulf by Fairchild (1906). Coleman (1936) criticized Fairchild's use of the word "gulf" which implied the presence of marine water. The term "Sandy Creek" is proposed here in order to avoid the same criticism.

The Sandy Creek stage is named for the extensive sand and gravel deposits forming a broad terrace between Sandy Creek and South Sandy Creek (fig. 4*a*). Here the sand and gravel deposits are interpreted as the remnants of the lake bed formed during Sandy Creek time. During the Sandy Creek stage, North Pond was the site of a large open bay. The shoreline was irregular, with some drumlins extending as wave-cut

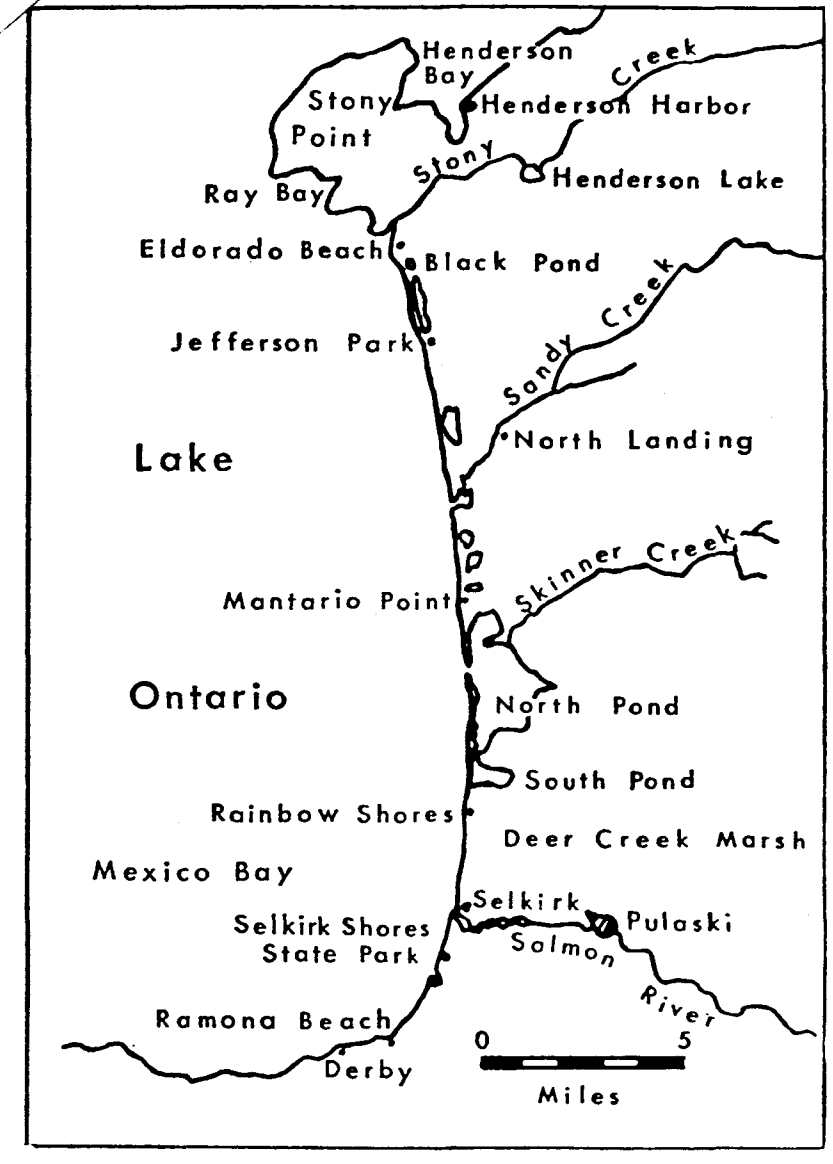

FIG. 2.—Geographic localities along the eastern shore

prominences and others forming islands just offshore. Numerous north-south ridges are interpreted as offshore sand and gravel bars. Streams trending in the same direction as those existing today drained the drumlin topography from the east.

Skinner Creek stage.—Following the Sandy Creek stage, the lake level dropped to an elevation of 255 feet where it remained for some time (fig. 4*b*). The Skinner Creek stage, representing this new level, is named from an exposure of well-sorted sands in the bank of Skinner Creek at Weaver Road.

During Skinner Creek time, extensive benching and terracing took place in a zone from 1 to 2 miles east of the present shoreline. This is particularly well documented by terraces that almost completely surround North Pond. In addition, a bar formed at the site of the present North Pond bar which embayed waters to the east. Remnants of the Skinner Creek bar may still be observed in the low cliffs beneath the dune sands on the modern bar. The Skinner Creek bar deposits consist of beach sands that are strikingly similar to the modern beach deposits. In both deposits, the bedding has a low-angled dip and heavy mineral zones contrasting with the overlying high-angle, cross-bedded dune sands lacking heavy mineral zones.

The Skinner Creek beach is marked by a terrace extending from Renshaw Bay south for 1.5 miles to the present outlet (*D*) and from a point (*B*) south to South Pond as shown in figure 4*b*. At the same time, the

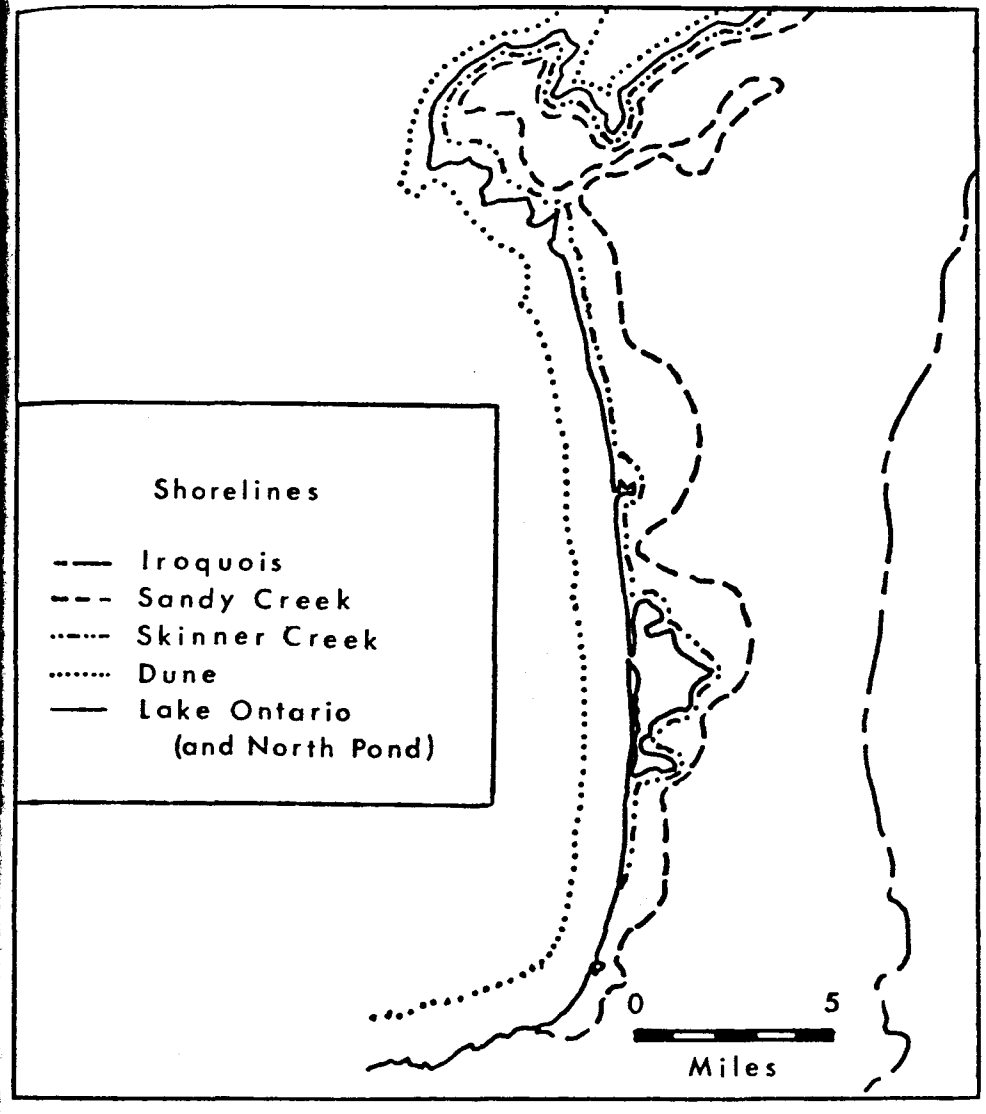

FIG. 3.—Position of Iroquois and post-Iroquois shorelines

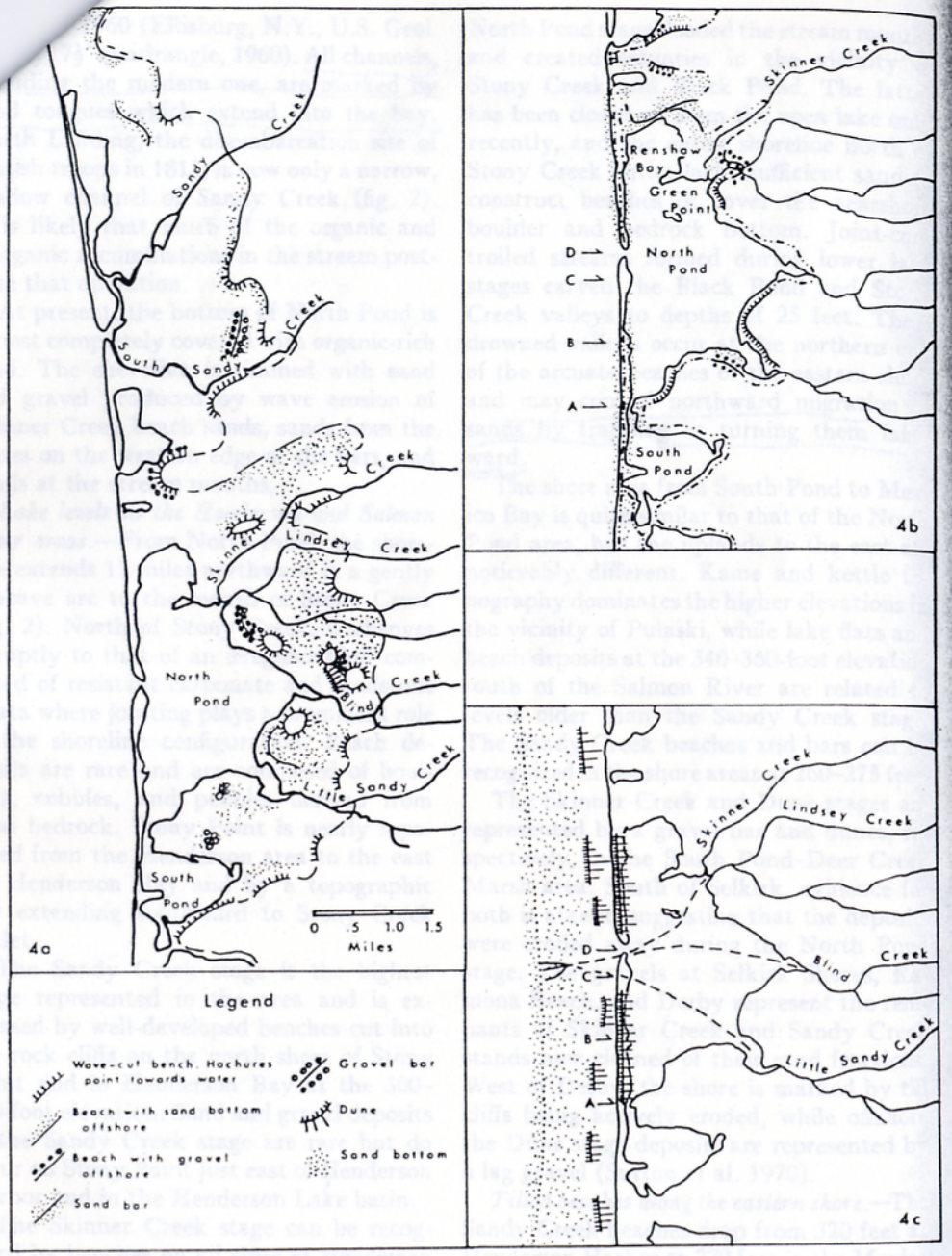

FIG. 4.—*a*, Relict shoreline features of the Sandy Creek stage; *b*, relict shoreline features of the Skinner Creek stage; *c*, location of shoreline, dunes, and stream channels during Dune stage.

streams draining from the east cut through much of the older Sandy Creek lake deposits and adjusted in part to the new lower base level.

Dune stage.—The basic evidence for a low-water stage below that of the present lake level is the existence of dunes that line more than half the shore from Selkirk to Stony Point (fig. 4*c*). Many of the dunes exceed 50 feet in height and cover both the remnants of Skinner Creek bar and the entire width of the modern bar. Dunes of these dimensions could not have formed at the present water level. The Dune stage then represents a further drop of the lake level and subsequent stillstand below the present level. This level is 30 feet below the present lake, thereby providing a beach of sufficient width to serve as an adequate subaerial source for the dune sands on the windward side of their present site. In Mexico Bay, the shoreline is marked by a 10-foot clay cliff topped by peat at a depth of 40 feet. At the northern edge of the sand blanket are two drowned valleys, one at Black Pond and a second at the mouth of Stony Creek. Both valleys extend to a depth of 25 feet and are interpreted as marking the shoreline of the Dune stage in that area.

At North Pond, evidence for the shoreline is less direct. The pond is less than 15 feet deep and is covered with mud for the most part. This mud can be traced into coves where streams now enter the pond. There, coring revealed that the mud overlies sand and gravel and is overlain, in turn, by a thin veneer of sand. The lowermost sands and gravels represent deposits from streams of higher gradient formed during Dune stage. The mud was deposited when the lake level was higher than present (North Pond stage), and the upper thin sand is the maximum-sized material transported at the present time.

During Dune stage time, streams extended across probable swamplands in North Pond. The general directions of several of those streams—including Skinner, Lindsey, Blind, and Little Sandy Creeks—may be projected to a theoretical junction in the vicinity of the Skinner Creek bar (fig. 4*c*, *B-D*). It is reasoned that the gap in the bar, which started forming during Skinner Creek time, was extensively developed by stream erosion during the Dune stage. Boulder-strewn islands in North Pond represent former drumlins leveled by meandering streams during receding levels between the Skinner Creek and Dune stages. Had wave erosion been responsible, the nearby shoreline should be less irregular and the tills similarly modified. Stream erosion best explains the localized erosion.

North Pond stage.—Lake waters rose following the Dune stage, resulting in gradual transgression of the beaches, drowning of the lower parts of the stream valleys, and destruction of an unknown number of dunes and nearshore beach and barrier features. Although the *B-D* gap in the Skinner Creek bar may have been produced at this time, the presence of peat throughout much of the area at 245 feet suggests that the ponds were enclosed by bars allowing vegetation to flourish.

Transgression proceeded until the water level reached 248 feet, or 2 feet above the present lake level. This level is the minimum required to explain a peat bed at 247 feet elevation in an excavation on Greene Point in North Pond. Had the transgression exceeded 248 feet, it is doubtful that the Skinner Creek terraces and dune sands would have survived the wave action on the lake side of the bars.

Present stage.—The drop of Lake Ontario to its present level is responsible for several changes in the North Pond area. Stream gradients were increased and sands were distributed over the peat and mud formed during the North Pond stage. Small dunes formed on the North Pond bar (fig. 4*b*, *B-D*). Longshore currents supplied with additional sand from the shallowed lake bottom closed a channel at *A* sometime after 1893 (Pulaski, N.Y., U.S. Geol. Survey, 15′ quadrangle 1895). The channel at *B* had already been closed prior to that date. A second channel at *C* during the 1940s was

...y 1960 (Ellisburg, N.Y., U.S. Geol. ...rvey, 7½′ quadrangle, 1960). All channels, including the modern one, are marked by sand tongues which extend into the bay. North Landing, the disembarcation site of British troops in 1813, is now only a narrow, shallow channel of Sandy Creek (fig. 2). It is likely that much of the organic and inorganic accumulations in the stream post-date that operation.

At present, the bottom of North Pond is almost completely covered with organic-rich mud. The shoreline is rimmed with sand and gravel produced by wave erosion of Skinner Creek beach sands, sands from the dunes on the western edge of the bars, and sands at the stream mouths.

Lake levels in the Henderson and Salmon River areas.—From North Pond, the shoreline extends 11 miles northward in a gently concave arc to the mouth of Stony Creek (fig. 2). North of Stony Creek, it changes abruptly to that of an irregular bluff composed of resistant carbonate and sandstone strata where jointing plays a prominent role in the shoreline configuration. Beach deposits are rare and are composed of boulders, cobbles, and pebbles derived from local bedrock. Stony Point is nearly separated from the Henderson area to the east by Henderson Bay and by a topographic low extending southward to Stony Creek outlet.

The Sandy Creek stage is the highest stage represented in the area and is expressed by well-developed benches cut into the rock cliffs on the north shore of Stony Point and in Henderson Bay at the 300–320-foot elevation. Sand and gravel deposits of the Sandy Creek stage are rare but do occur on Stony Point just east of Henderson Harbor and in the Henderson Lake basin.

The Skinner Creek stage can be recognized by benches on all sides of Henderson Bay at the 255–260-foot elevation, by gravel bars at Eldorado Beach and Henderson Harbor, and in pits at the north end of Ray Bay (fig. 2). The Dune stage is represented by 50-foot dunes on the Skinner Creek bar in the vicinity of Black Pond. The rise of lake level culminating in the North Pond stage flooded the stream mouths and created estuaries in the vicinity of Stony Creek and Black Pond. The latter has been closed off from the open lake only recently, and the entire shoreline north of Stony Creek outlet lacks sufficient sand to construct beaches or cover the nearshore boulder and bedrock bottom. Joint-controlled streams formed during lower lake stages carved the Black Pond and Stony Creek valleys to depths of 25 feet. These drowned valleys occur at the northern end of the arcuate beaches of the eastern shore and may control northward migration of sands by trapping or turning them lakeward.

The shore area from South Pond to Mexico Bay is quite similar to that of the North Pond area, but the uplands to the east are noticeably different. Kame and kettle topography dominates the higher elevations in the vicinity of Pulaski, while lake flats and beach deposits at the 340–360-foot elevation south of the Salmon River are related to levels older than the Sandy Creek stage. The Sandy Creek beaches and bars can be recognized in the shore areas at 260–275 feet.

The Skinner Creek and Dune stages are represented by a gravel bar and dunes, respectively, in the South Pond–Deer Creek Marsh area. South of Selkirk, evidence for both is absent, suggesting that the deposits were eroded away during the North Pond stage. The gravels at Selkirk Shores, Ramona Beach, and Derby represent the remnants of Skinner Creek and Sandy Creek stands now cleaned of their sand fractions. West of Derby, the shore is marked by till cliffs being actively eroded, while offshore the Dune stage deposits are represented by a lag gravel (Sutton et al. 1970).

Tilted beaches along the eastern shore.—The Sandy Creek beaches drop from 320 feet at Henderson Harbor to 270 feet in the Mexico Bay area, a drop that almost exactly parallels the change in the Iroquois shoreline located 320 feet higher (fig. 5). This parallelism indicates rapid fall of the lake level. This fall is in response to the disappearance of ice from the Saint Lawrence valley. In addition, the remarkable preservation of

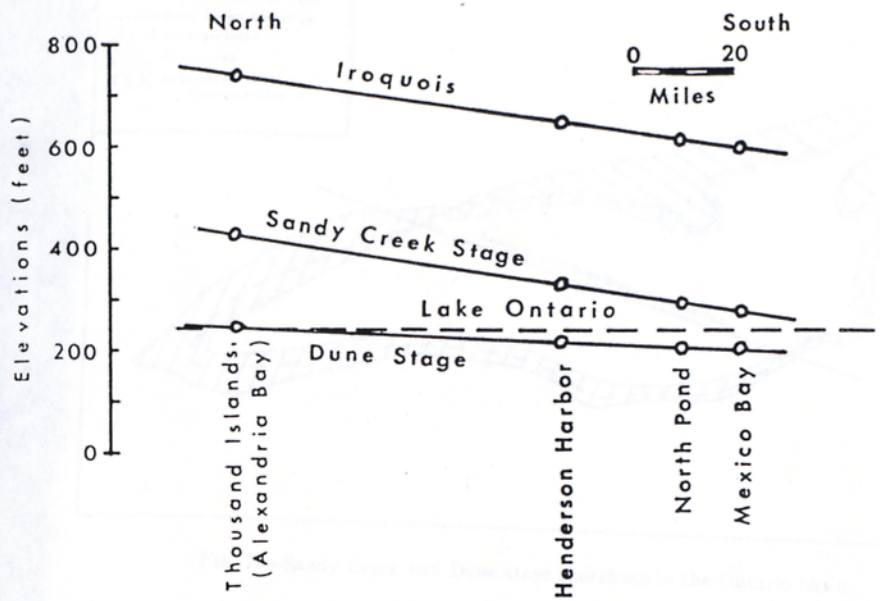

FIG. 5.—Lake profiles in the eastern Ontario basin

the drumlins, kames, and other features between the beaches can be explained by a lack of time for effective wave erosion.

The drop from the Sandy Creek stage to the Dune stage, with an intermediate stillstand at Skinner Creek time, took much longer for precisely the opposite reasons. Good evidence of wave modification of topographic forms and wave-built features suggest considerable lengths of time between these stillstands. The low-water stand (Dune stage) represented by peat 40 feet deep in Mexico Bay, the sand flat 30 feet deep off North Pond, and the extensions of Stony Creek to the north 25 feet deep gives a tilt of the Dune stage level of 0.5 feet per mile. This figure, compared with 2 feet per mile for the Sandy Creek and Iroquois beaches, demonstrates convergence of Sandy Creek and Dune stage levels.

RELATION BETWEEN EASTERN SHORE STAGES AND LAKE-LEVEL CHRONOLOGY IN THE ONTARIO BASIN

The dating of Lake Iroquois and its shoreline has been studied in detail by many authors during past decades. An excellent account of the basin history from Lake Iroquois to the present for the Hamilton, Ontario, area has been given by Karrow et al. (1961). They date Lake Iroquois as 11,510 years B.P. and cite strong evidence of a low-water stage more than 10,000 years ago, following the draining of Iroquois. Since then, the lake level has risen at a steadily declining rate due to differential uplift of the basin.

We theorize that the 320-foot drop from the Iroquois to the Sandy Creek stage at North Pond temporally coincided with the 330-foot drop from Iroquois to the low-water stage at Hamilton, Ontario. Further, these stages are represented in the Ogdensburg-Potsdam-Malone, New York, area where the Gilbert Gulf beaches lie 320 feet below the Iroquois beaches as described by MacClintock and Stewart (1965, p. 95–96), confirming Fairchild's (1906) earlier identifications. When projected to the Alexandria Bay area, the Iroquois and Sandy Creek levels in figure 5 intersect the levels constructed between Hamilton, Ontario, and the Ogdensburg-Potsdam area (fig. 6). The justification for these projections lies in the identification of the Iroquois beaches at Hamilton, North Pond, and Potsdam, the

...e coincidence of dates. Karrow ...00) reported a date of 10,150 years ... for the low-water stage. Recently, Karrow indicated the date is now thought to have been 11,000–12,000 years ago (personal communication). These dates agree with those assigned to the Gilbert Gulf–Champlain Sea by MacClintock and Stewart (1965, p. 47).

In a similar manner, the Dune stage shoreline near North Pond (fig. 5) can be projected into the Alexandria Bay area, where its elevation rests at or just above river level (fig. 6). The Dune stage is dated as 4,810 ± 180 years B.P. (S-83-B) from a wood sample in the subaqueous cliff in Mexico Bay. This date permits a correlation of the Alexandria Bay projection with the lake elevations determined by Karrow et al. (1961, p. 665, fig. 4) for a similar date at Hamilton, Ontario (fig. 6). When the Dune stage level is projected into the Ogdensburg area, it is found to coincide with a river terrace at 280 feet.

Supplied with two sets of intersecting

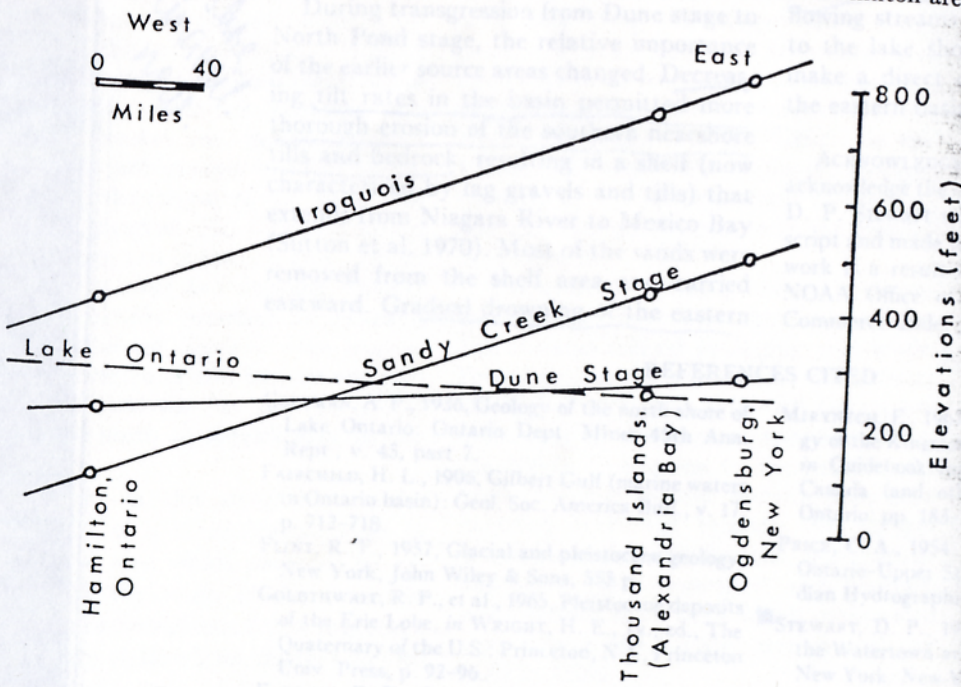

FIG. 6.—Lake profiles from Hamilton, Ontario to Ogdensburg, N.Y.

it is possible to construct planes representing their lake surfaces (fig. 7). These planes were found to intersect at a 50-foot depth along a line that extends from the southern New York shore southwest of Oswego to the Ontario shoreline east of Oshawa. More important is the fact that the trend of the line of intersection is parallel to the trend of the isobases of the Iroquois strand line as shown by Flint (1957, fig. 14-6).

The lake stages should correlate with those described by Mirynech (1967) along the northern shore. Whether the Sandy Creek stage correlates with the Belleville or the Trenton beach and the Dune stage with the Trenton or Admiralty beach is not known at this time. Until these and other questions are answered, the names proposed will have to suffice.

It is possible to speculate on the cause of the stillstand at Dune stage time, since the ages and positions of each surface are known. From Sandy Creek time to Dune stage, the water level lowered in the eastern shore area, whereas in the Hamilton area it

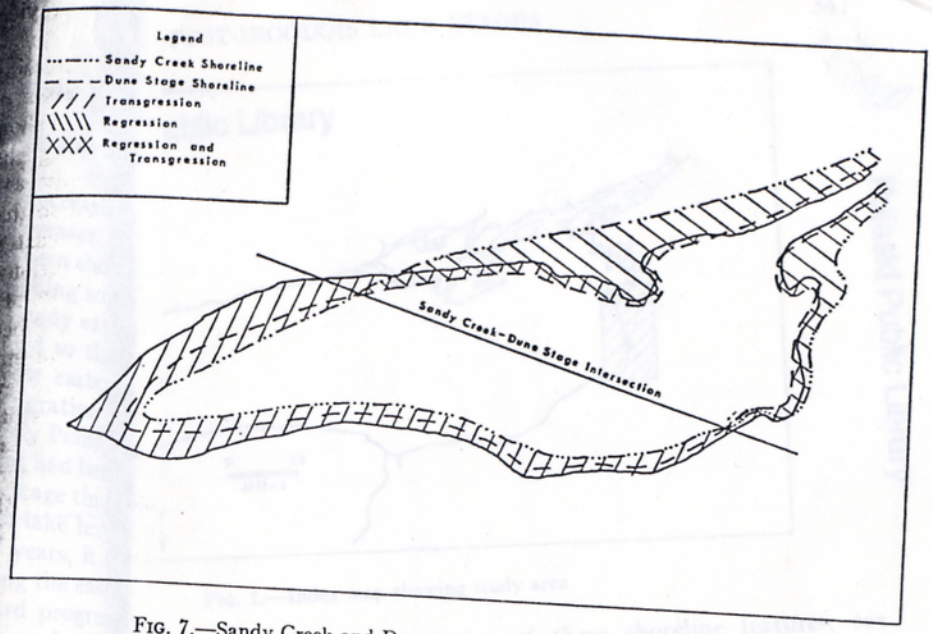

FIG. 7.—Sandy Creek and Dune stage shorelines in the Ontario basin

rose resulting in a pattern that can be partially explained by a tilting of the basin due to differential uplift. Tilting alone does not explain the drop in lake level on the eastern shore and at the outlet in the Saint Lawrence Valley. It is reasoned that the water level was controlled by sea level and/or by glacial deposits in the Saint Lawrence Valley. The expected rapid removal of the glacial deposits did not occur because sea level rise kept pace with uplift (MacClintock and Stewart, 1965, p. 47, fig. 12). The stillstand at the Dune stage was reached when the fall of the water level reached resistant rocks in the Thousand Islands.

From Dune stage (5,000 years B.P.) to the present, the water level in the basin was controlled by rock sills in the Saint Lawrence Valley. The slow erosion rate of the rock has been more than offset by differential uplift of the basin. It is estimated that the Thousand Island area, if compared with the Hamilton area, has been differentially uplifted 1.4 feet per century during the past 5,000 years. This value is in general agreement with the declining uplift rate of Karrow et al. (1961, fig. 4) and tilt rate of 1.18 feet between Hamilton and Prescott during the past 100 years (Price 1954). Although general flooding took place in the southern and western parts of the basin, the amount was less in the eastern shore areas.

Computation of tilting rates before and after the Dune stage, over a uniform distance and time interval, indicate the Sandy Creek–Dune stage interval has a differential rise from 2.8 feet per century per 100 miles compared with Dune stage–present differential rise of 0.7 feet per century per 100 miles. The effect of this slower rise during the past 5,000 years has been to permit a more thorough erosion of the southern lake shore and produce the boulder-strewn shelf described by Sutton et al. (1970). Post-Dune stage flooding has produced numerous bays and ponds where stream valleys were flooded.

ORIGIN OF EASTERN LAKE DEPOSITS

Following the rapid fall of lake waters from Iroquois time to Sandy Creek time, a large portion of the Ontario basin was exposed to erosion by streams. In the eastern basin, this resulted in a large volume of clastics being carried to the Sandy Creek shoreline. Following Sandy Creek time, rapid

tilting resulted in emergence of the eastern shore and drowning of the western shore of the basin. Sandy Creek beaches along the western perimeter were carried below the zone of effective wave and current action, removing these deposits as sources of sand for transport toward the eastern end of the lake. The emergence of Sandy Creek beaches along the eastern shore permitted continued erosion of these sands and gravels and their deposition along the eastern shore. By Dune stage, a broad sand flat had accumulated along and off the beach strand which resulted from sediment supply off the eastern shore and, to a lesser extent by easterly currents sweeping sands from southern shore sources. Gravels were carried by streams off the eastern shore and accumulated in the lake. Sands were selectively sorted by wind off the sand flat, blown eastward, and piled into high dunes.

During transgression from Dune stage to North Pond stage, the relative importance of the earlier source areas changed. Decreasing tilt rates in the basin permitted more thorough erosion of the southern nearshore tills and bedrock, resulting in a shelf (now characterized by lag gravels and tills) that extends from Niagara River to Mexico Bay (Sutton et al. 1970). Most of the sands were removed from the shelf area and carried eastward. Gradual drowning of the eastern shore caused streams in that area to provide proportionally less sand.

Since North Pond time, the decreasing tilt rate with corresponding decreases of eastern shore emergence and southern shore submergence resulted in a diminishing supply of sands from all sources. A steady eastward migration of sands continued so that now they are concentrated at the eastern end of the lake. The northward migration of material from Mexico Bay to Stony Point is presently exposing lag gravels that had been concentrated there during Dune stage time.

Unless a significant change in lake level occurs in the next few hundred years, it is likely that the sand deposits along the eastern shore will migrate northward progressively, uncovering Dune stage gravels that generally would remain as lag deposits. The eastern shore ponds and marshes will be filled with muds and sands. The westward-flowing streams will develop their channels to the lake shore where they would then make a direct contribution of detritals to the eastern basin.

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