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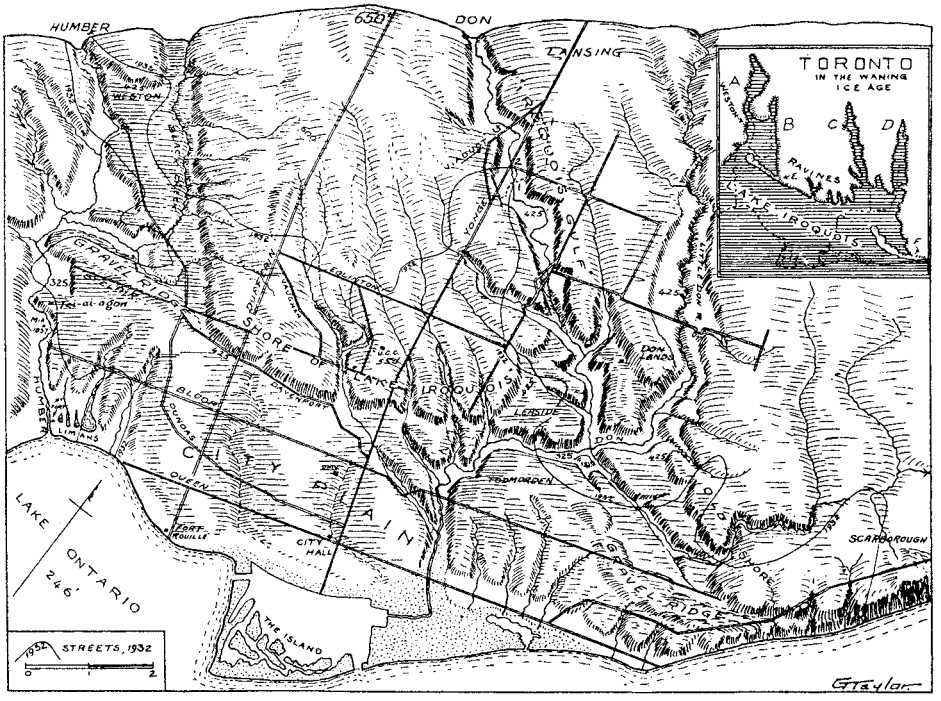
# Ravines, lagoons, cliffs and spits: The ups and downs of Lake Ontario

The bedrock basins now occupied by the Great Lakes are probably at least 2 million years old, the product of repeated phases of glacial erosion by successive ice sheets. In contrast, the lakes that fill these basins rise and fall with changing climate. The oldest water body we have direct geological evidence of is Lake Coleman, which formed some time after 80,000 years ago, when the climate in the Toronto area was subarctic and an ice sheet was beginning to expand across Canada. Lake Coleman was likely covered year-round by ice and infested by icebergs that plowed into its floor. By at least 40,000 years ago, ice had swept across all of southern Ontario, and lake waters may have survived only as subglacial lakes under the ice sheet, similar to those below the Antarctic Ice Sheet today. As the ice retreated after 12,500 years ago, another deep lake (glacial Lake Iroquois) was dammed up before abruptly draining, when ice finally left, into a much smaller lake (Lake Admiralty). The abrupt drainage of glacial Lake Iroquois gave rise to the characteristic feature of the Toronto lakeshore – its many ravines [1]. Lake Ontario came into existence about 8,000 years ago, as the basin refilled. Lake levels are still rising (albeit slowly), but much of the shoreline has now been engineered to prevent erosion and reclaim new land.

## RAVINES AS RECORDS OF CHANGES IN CLIMATE AND LAKE LEVELS

Toronto's topography is widely perceived as being flat when it is actually cut by many deep ravines that drain into Lake Ontario. Rivers and small creeks flow to the lake, imprisoned at the bottom of steep-sided, narrow valleys. Slippery side walls of muddy glacial sediments were an obstacle to early settlers and railways. Today, residences backing onto ravines are much sought after, and they are significant refuges for fauna and flora lost to urban development on the surrounding tablelands.

The ravines are of special scientific interest because they tell a remarkable story of abrupt changes in climate and lake levels during the closing stages of the last ice age. At that time, much of Canada lay entombed under the white shroud of a continental ice sheet, mammoth and bison still roamed southern Ontario and early Paleo-Indians were making their first appearance in eastern North America.

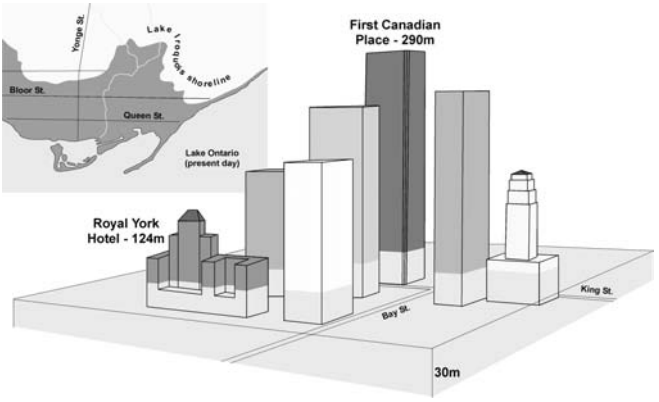



1 *Griffith Taylor's 1936 sketch of the Toronto area showing the principal ravines and the shoreline of glacial Lake Iroquois.*

Some 12,500 years ago, the last great North American glacier – the Laurentide Ice Sheet – began leaving the Toronto area. The ice sheet's margin retreated northward back to its source areas in Labrador and Quebec, where it finally thinned and melted some 6,000 years later. Ponded in front of the ice margin was glacial Lake Iroquois, which flooded much of the Toronto area. This very deep lake drained to the Atlantic Ocean not via the still-ice-blocked St. Lawrence Valley, but through the ice-free Hudson River Valley in upper New York State. At this time, downtown Toronto would have been under some sixty metres of water (the height of a twenty-storey building), in which drifting icebergs floated after having calved from the ice front [2].

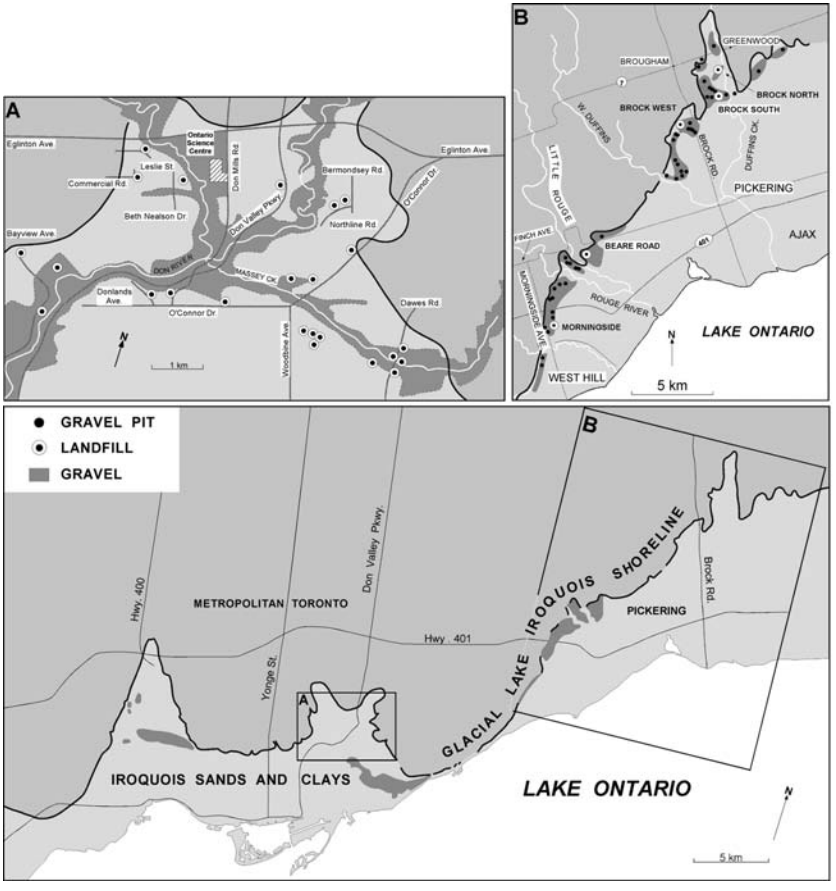
Glacial Lake Iroquois cut a prominent shore bluff and beaches that can be mapped all the way around Lake Ontario and that record the previous high-water mark. Casa Loma, one of Toronto's best-known landmarks, sits prominently atop the Iroquois bluff, gazing out over the city below; early settlers used cableways to ascend and descend the steep slope.[1] At the foot of the Iroquois bluff there are beach gravels and sands

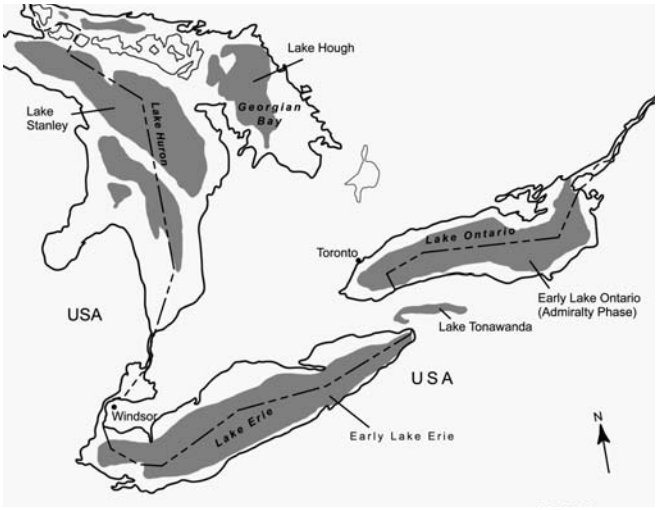
1 The lake was so named in reference to the use of the beach as a track by the Iroquois before the arrival of Europeans.




2 RIGHT *The depth of glacial Lake Iroquois relative to some modern Toronto buildings.*

3 BELOW *Modern gravel pits and lakefill sites in relation to glacial Lake Iroquois's shoreline and lake bed deposits.*






4 *Lakes Ontario, Erie and Huron today and 10,000 years ago. In its Admiralty phase, Lake Ontario's shoreline was five kilometres south of Toronto.*

that, once quarried, left large pits that were later filled with waste. The extent of the Iroquois shoreline around Toronto can be mapped with reference to the many hills created by landfilling [3].

As the ice front slowly melted back northeastward, the outlet to the St. Lawrence Valley, roughly where Kingston is today, suddenly opened. This opening had the effect of a plug being removed from a bathtub, causing Lake Iroquois to abruptly drain about 12,200 years ago. At this time, however, southern Ontario and Quebec were tilted eastward under the great weight of the thick ice sheet (an effect called 'glacioisostatic depression'), and sea level was some 100 metres below where it is today because enormous amounts of fresh water were still locked up in the ice sheet. In combination, the eastward tilt and low sea level meant that the early Great Lakes drained almost entirely, leaving small remnant lakes: imagine a tilted bathtub whose waters flow unimpeded from the plughole. Rivers that had drained to glacial Lake Iroquois now flowed out many tens of kilometres to the distant shoreline of a much smaller early Lake Ontario – the Admiralty phase of Lake Ontario [4]. In flowing to a much lower lake level, the rivers were 'reactivated,' and energetically cut down into the glacial sediments left by the ice sheet, excavating a huge amount of sediment. This is the origin of Toronto's many ravines: they are an exceptional record of the low lake levels that existed many thousands of years ago, and the deep erosion caused by rivers.

### THE LAST 8,000 YEARS

Low lake levels persisted in the Great Lake basins until at least 8,000 years ago, when the east-tilted crust began to rapidly recover in a process geologists call 'postglacial rebound.' The raised sill at the east end of Lake Ontario resulted in slowly rising water levels in the lake basin. This eastward-increasing crustal rebound is still taking place today, only much more slowly. Lake depths are increasing at the western end of Lake Ontario at Hamilton as the Kingston area slowly continues to rise. In a few thousand years, this readjustment process will end (and the next glaciation may start!).

A cliff line recently found some five kilometres offshore of the modern shoreline of Lake Ontario marks the early postglacial Admiralty phase. This feature is easily recognized on bathymetric charts (the submerged equivalent of an above-water topographic map) and is known locally as the 'Toronto Scarp.' It is a favourite spot for salmon that like deep, cold waters. By allowing intake pipes to reach icy cold water in a relatively short distance, it is also a feature that has made Enwave's deep-lake water-cooling project possible.

### RISING LAKE LEVELS AND DROWNED RAVINES

Rising lake levels in Lake Ontario over the past 8,000 years have bequeathed another landscape feature now found at the lakeward ends of the ravines. The mouths of the ravines are being slowly drowned, trapping wetlands and lagoons behind sandy spits. Hamilton Harbour, Cootes Paradise, Grenadier Pond and the many lagoons that dot the shoreline of Lake Ontario from Niagara-on-the-Lake to Cobourg record the landward movement (or 'transgression') of the shoreline over the past few thousands of years [5]. This also explains why there were large wetlands at the mouths of rivers such as the Humber and Don.

There is some evidence of an accelerated rise in the level of Lake Ontario some 4,000 years ago, but the origins of this rise are not clear. This time does broadly coincide with a short-lived phase of global cooling geologists call the 'Neoglaciation' because it saw the regrowth of glaciers in the Canadian Rockies and elsewhere and may have been a time of wetter climate in the Great Lakes. On the other hand, some have suggested that the slow rise in the crust to the northeast of the Great Lakes had the effect of diverting waters to the southwest back toward the lakes.

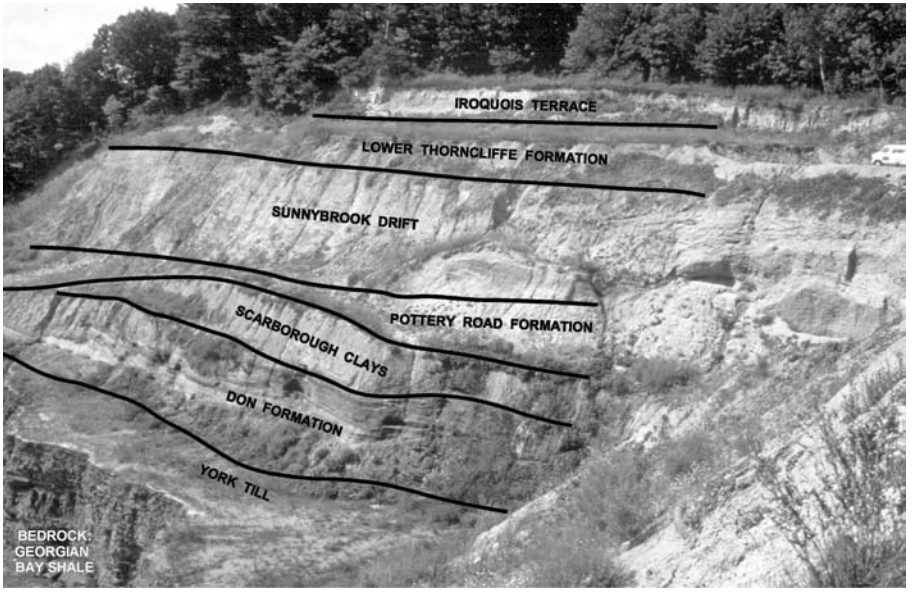
5 *The spit-and-lagoon formation at Frenchman's Bay, just east of Toronto.*

### RISING LAKE LEVELS AND COASTAL EROSION

The prominent cliffs seen at the Scarborough Bluffs are the result of the shoreline moving inland by eroding into soft glacial sediments. The cliffs at Scarborough once lay some five kilometres offshore, and have retreated landward over the past 8,000 years as the level of Lake Ontario has slowly risen. Historically, this has occurred at a rate of about one metre per year, but it has slowed in the last twenty years. Over the past 8,000 years, enormous volumes of sand, eroded from the bluffs and moved westward by strong lakeshore currents as a consequence of the shoreline being extensively eroded, have fed the growth of the Toronto Islands, which are, in essence, large spits. Today, these bold cliffs have been straitjacketed by engineers, greatly reducing erosion and the supply of sand. The prominent marina at Bluffers Park, where Brimley Road meets the lake, traps sand on its up-current (east) side but starves beaches down-current. The desire to protect private property from erosion has also armoured much of the coastline under a layer of asphalt and rip-rap, except for a small portion at Dutch Church, the most dramatic geological feature of the bluffs. These towering cliffs have long been the trademark of Scarborough, and explain why the area was so named by Elizabeth Simcoe in 1793, in recognition of similar cliffs in Scarborough, England.

6 RIGHT *The Scarborough Bluffs at Sylvan Park, 1999. Much of the shoreline has been armoured, and precious outcrops of sediments recording past climates have been lost to study.*

7 BELOW *Geological layers at the Don Valley Brick Works, 1985. The bedrock quarry has since been filled in. The York Till records the penultimate glaciation (the Illinoian), and the Don Beds the warm interglacial period that followed some time around 110,000 years ago. Younger overlying sediments record the last glaciation (the Wisconsinan). The flat terraced top of the outcrop was cut by glacial Lake Iroquois when the last ice sheet left the Toronto area shortly before 12,000 years ago.*



Unfortunately, these cliffs will disappear as the temptation to build a waterfront trail at their foot becomes too much for the Toronto and Region Conservation Authority (TRCA). The cliffs will slowly disintegrate and become vegetated, as has happened to the east and west. This is potentially a great loss, not only of a historic landmark, but of an internationally significant record of climate change [6].

Man-made changes have been no less dramatic elsewhere. Wetlands have been drained and lagoons infilled across Toronto. The size and shallowness of Ashbridge's Bay at the mouth of the Don River have made it desirable and relatively easy to reclaim land in the area now known as the Port Lands.

Across Toronto, the glacial Lake Iroquois shore bluff played a key role in acting as a source of springs. These fed the numerous creeks that flowed south across the downtown and midtown areas. Sadly, these have been crossed by roads and filled with waste to make new land for development. Their rivers have been straightened and imprisoned within pipes and channels, and their gravel floors mined to make concrete for the growing city.

The story of human intervention along the creeks and shorelines is not entirely bad, however. Clay excavations along the banks of the Don River for brick-making in the 1890s revealed ancient sediments from a warm climate episode (an interglacial) older than the last glaciation. The Don Valley Brick Works is now known to be among the best preserved interglacial records found anywhere in northern North America [7]. Most famously, it preserves the remains (mostly teeth) of the extinct giant beaver. This animal is a fitting symbol of the remarkable ups and downs of lake levels in the Great Lakes.