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Ice and water

In the beginning was the ice.

It crept down the continent as far as the present state of Kansas, advancing, retreating, and advancing again over a period that lasted for two million years. The remnants of that ice are still with us in the glaciers that overhang the Gulf of Alaska, in the Columbia ice fields in the Rocky Mountains, and in the Barnes Icecap that sprawls over the mountain spine of Baffin Island. Its claw marks are everywhere.

The ice destroyed the drainage pattern of eons. It blanketed the weathered Precambrian surface of the North so that wherever it reached vast layers of soil as much as forty yards deep were washed or carried away. It dammed and diverted great rivers, gouged out new inland seas, smothered jungles, buried forests, and crawled up mountainsides, grinding everything in its path – a chill and glittering wall as much as two miles thick.

Twenty times this monstrous frozen barrier slowly built up, inch by inch, and oozed south. Twenty times it shrank and retreated, leaving behind vast ponds of meltwater, the ancestors of the Great Lakes. We know little about the earlier advances because the evidence was obliterated by the ice itself. But we do know something about the last one. Niagara Falls was the child of that most recent incursion, a mere fifteen thousand years ago.

The Niagara is a young river, barely twelve thousand years old, a mere blink in geological history. But the Niagara Escarpment, through which it gnaws its way, is far more ancient, the product of millions and millions of years of geological transformation, first by the laying down of countless layers of sedimentary rocks and then by the slow erosion of ice and water. It is the presence of this ragged cliff of dolostone and shale over which the river plunges that has made possible the second-largest cataract in the world. Victoria Falls, hidden in the heart of

Africa, is vaster but remote, while Niagara Falls is the great Mecca of North America, at the very crossroads of the continent.

Straddling the international border in the industrial heartland of North America – a heartland created largely by its own presence – the Falls in the summer months attracts upwards of twelve million people, more than are to be found in all of Greece. This mass of humanity – kings and princes, presidents and poets, movie stars, painters, honeymooners, would-be suicides, and just plain people – is crammed together in an area that covers no more than twenty-five square miles.

One-fifth of all the fresh water on the planet lies in the reservoir of the four upper Great Lakes – Superior, Huron, Michigan, and Erie. All the outflow is destined to enter the Niagara River and plunge over the Falls. The geography here can be confusing. The Niagara flows north from Lake Erie, not the typical direction of flow in this part of Canada, while the Falls erodes its way south. And the Niagara is more like a strait than a river; it has no valley below the Falls, only a series of spectacular gorges through which the water races on its northward dash from Erie to Lake Ontario. It does not swell in size from source to mouth as other streams do, for there are scarcely any tributaries to feed it. The same amount of water that enters it from Erie pours from its mouth, thirty-four miles downstream.

It is a deceptive watercourse. Its average flow at Queenston is greater than that of much vaster streams such as those western rivers, the Columbia and Fraser, that daunted the early explorers. But there is another, more dramatic aspect to Niagara. The land between the lakes does not slope at an even grade but suffers, instead, an abrupt and spectacular drop, the height of a twenty-storey building, at the Niagara Escarpment. Thus, through a geological accident, Niagara Falls was created.

Its genesis goes back more than 450 million years to a time when much of the Precambrian Shield was submerged beneath

ancient seas. Slowly, eon after eon, the debris of the ages was deposited on the ocean floor – a monstrous geological rubbish heap formed from the mounting silt and the myriad shells of small ocean creatures. Layer upon layer of these sediments were compressed and cemented together by chemical action and the pressure of their own weight – forming a sandwich of shales, dolostones, limestones, and sandstones. The various strata of this sedimentary sandwich may be seen today on the exposed face of the Niagara Gorge, the softer shales capped by a hard, uncompromising layer of dolostone, a form of limestone in which some of the calcium has been replaced by magnesium.

When the seas retreated and the water level dropped, the surface of the new land was exposed as a flat, unbroken plain. Little by little, the land began to tilt, spurred on by forces deep within the earth's crust. Down those featureless slopes the rainwater drained, forming streams and rivers that began to erode the rock. As the tilting continued, the plain, now riven by valleys and gorges, became a *cuesta*: a landform that slopes gently back from a steep cliff. In Ontario that cliff is the Niagara Escarpment. Two million years ago it was buried under a creeping blanket of ice.

An ice age begins slowly, almost imperceptibly, when the average temperature drops by a few degrees. Snow falls and lingers. Spring comes later; summers are shorter; winters stretch out. At last the time arrives when the snows of one year do not melt but are carried over to the next winter. As the snow accumulates from that little boreal patch, growing inexorably year after year, gargantuan ice sheets begin to form.

Just as the pressure of the sand and mud piled up over the centuries cemented the geological debris of the Escarpment into stone, so the mounting snowfields, compacted by their own weight, were metamorphosed into ice. Like pitch poured from a spout, the ice was forced by the pressure to radiate out

from a central core, overriding and wrecking the old drainage pattern.

As the sun's heat waned and then grew warmer again, the ice sheets advanced and retreated, rearranging the shapes of ancient rivers and lakes. The last of these great sheets clawed its way south about one hundred thousand years ago, ripping up the land, choking the basins of earlier lakes, and burying the entire Niagara Escarpment under tons of ice. One tentacle probed almost as far south as the site of Chicago. Then, about eighteen thousand years ago, the weather mysteriously turned warmer, and once again the ice began its long retreat. Perhaps in some future era it will return.

In the wake of this vanishing rampart, great lakes – greater than those we know today – formed and reformed from the glacial meltwater. Early Lake Erie and its sister, Iroquois, the ancestor of modern Lake Ontario, became separate bodies of water. At the same time, another lake – Tonawanda – a vast, shallow pond, no deeper than thirty feet, lay between the two, just south of and parallel to the Niagara Escarpment.

Tonawanda's outflow spilled over the Escarpment and tumbled into Lake Iroquois from five different passages. Lake Iroquois then reached the foot of the cliff at the present site of Queenston. As the ice withdrew and the land, released from its pressure, slowly rose, Tonawanda's waters pooled at the western end of its bed, and all the spillways except the one at the Queenston site disappeared. That one, 12,500 years ago, became Niagara Falls, seven miles below its present position. Lake Tonawanda continued to shrink to become the Niagara River as it is now seen in the flatland above the site of the Falls.

The cataract dug out a pool at its base, now known as Cataract Basin. Then it began the slow process of undercutting the top layer of the Escarpment that produced the present Niagara gorges. Shale when wet is harder and more impervious to erosion than when dry. So it was that the shales immediately under

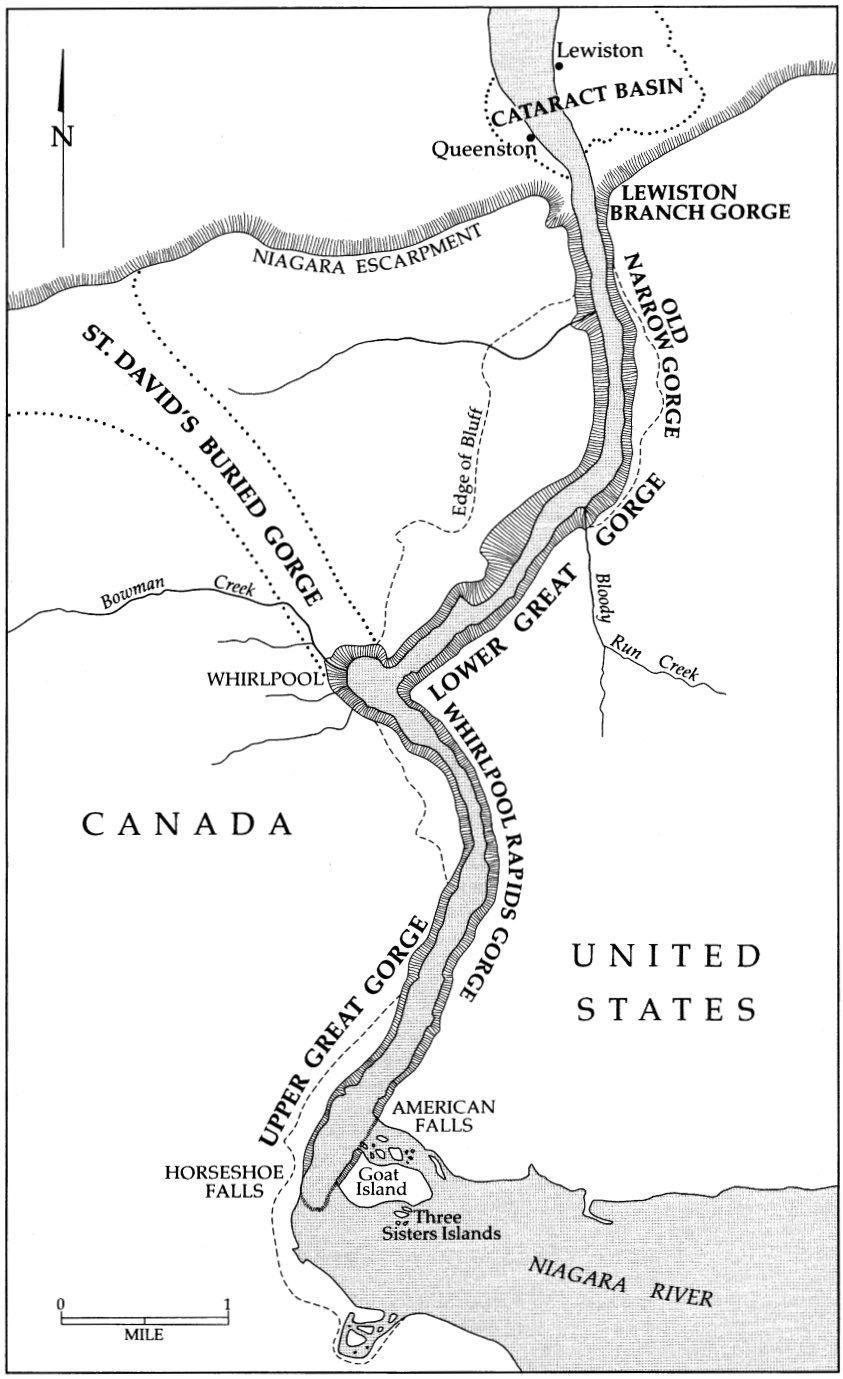
the protective cap of dolostones began to flake off during the annual cycle of freezing and thawing, encouraged by seepage from the river above working through the cracks and fissures. As the substructure fell away over the years, the ledge of dolostone became so top-heavy that great chunks broke off and plunged into the waters.

That process has continued to this day. The most spectacular modern example is that of Table Rock, a huge platform of dolostone several acres in size that once hung over the gorge near the lip of the Horseshoe Falls. In the last century it was a favourite vantage point for tourists and photographers. Over the years, as the rock beneath it weathered and crumbled, vast slabs of it tumbled away until, bit by bit, Table Rock disappeared.

The same fate befell Prospect Point, directly across from Table Rock beside the American Falls, another popular vantage point, most of which tumbled into the river in 1954. Another much-frequented tourist area, the Cave of the Winds at the foot of the Bridal Veil, or Luna, Falls has been totally altered. Here, another overhanging ledge of dolostone protected visitors, allowing them to walk directly behind the falling water. In 1955 it became so dangerous it had to be dynamited.

Through the process of erosion, the great cataract has created five distinct gorges through which the Niagara River has flowed between Queenston and the present site. That wearing away cannot be halted. All that human beings can do is to try to slow it down.

The shape of each gorge derives from the different volumes of water that once flowed out of old Lake Erie at varying speeds during the retreat of the last ice sheet. These were not constant. Sometimes the ice acted as a dam, changing the direction of flow from the Great Lakes Basin to the sea. There were times when most of the water spilled northeast toward the St. Lawrence. There were other times when it flowed southeast to



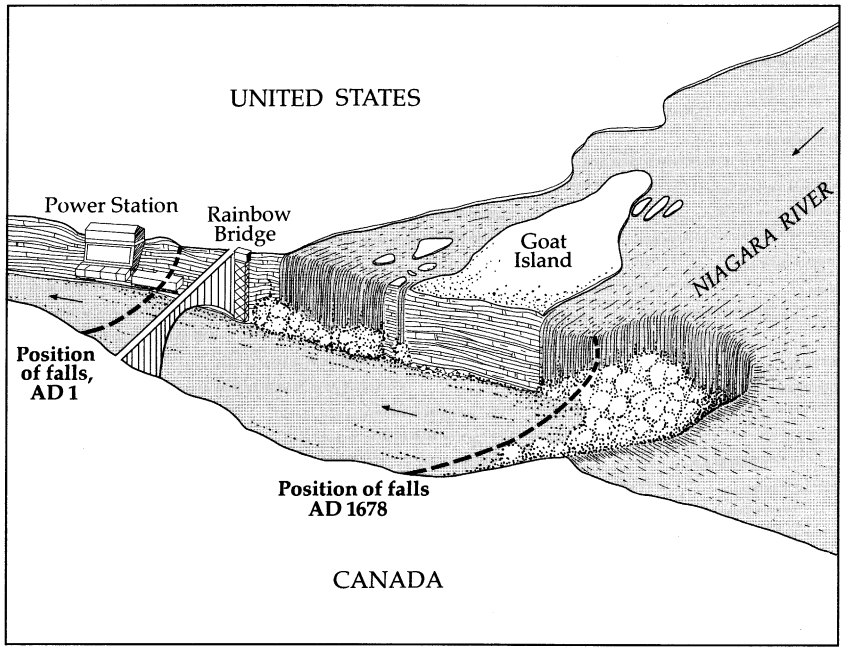
The five gorges of the Niagara River

the valley of the Hudson. When Erie was thus isolated, only a small amount of water poured over the Falls, digging out a narrow gorge, but when the entire flow from the Great Lakes filled the Niagara, a broader passage was created.

The first gorge to be chiselled out by the cataract, known today as the Lewiston Branch Gorge, was a canyon that ran upstream for two thousand feet before it changed character. When the Falls reached that point, the volume of water lessened. The eastern side of Lake Tonawanda had dried up when Lake Erie could no longer supply as much water as formerly. The main flow from the vast inland ocean known as Lake Algonquin (it covered three of the present Great Lakes) followed a different route through the region of the Trent River valley to Lake Iroquois, bypassing ancestral Lake Erie and reaching the sea by way of the Hudson. Erie became temporarily independent of its sister lakes. With so little water available, the Falls carved out a much narrower gorge (called the Old Narrow Gorge). The surrounding land, released slowly from the crushing pressure of the retreating ice, rose and tilted imperceptibly, and the drainage took new directions. Eventually, the Algonquin waters that had once flowed east and north flowed again into Erie. This increased volume produced the broad channel known today as the Lower Great Gorge. And here the cataract, fighting its way slowly upstream, encountered the subterranean remains of a much older watercourse.

A few thousand years before the last advance of ice smothered the Escarpment, an earlier Niagara River flowed northwest, gnawing out a gorge all the way back from the site of the town of St. Davids to the head of the present Whirlpool Rapids Gorge. Re-advancing ice had filled this channel with the usual debris of broken rocks and soil so that it was hidden beneath a mantle of earth and vegetation until the Falls, working upstream from the edge of the Escarpment above Queenston, collided with it.

The softer debris in the buried gorge offered less resistance



Goat Island

than did the hard dolostones of the Lower Great Gorge. The Niagara River could then quickly tumble over the wall of the glacial rubble and scour out the soft clays and sands, creating the Whirlpool Basin and re-excavating the Whirlpool Rapids Gorge. The fascinating Whirlpool Basin marks the intersection of the older and the younger channels of the Niagara River. The evidence is in the northeast wall for all to see.

The retreat of the ice led to the draining of Lake Iroquois and the lowering of the water level of the subsequent Lake Ontario. A new route east through the valleys of the Mattawa and Ottawa rivers acted as drainage for Lake Algonquin, lowering its level and drying up its outlet through Lake Erie.

The land around the Great Lakes, continuing its recovery from the crushing pressure of the ice, slowly tilted south, changing the drainage pattern so that once again the waters of Algonquin flowed out into Lake Erie and surged into the Niagara. As the volume increased, the erosion of the canyon

accelerated and widened. The cataract, moving at a rate that may have reached six feet a year, continued to work its way upstream. Thus was begun, at the time of the building of the pyramids, the broader chasm known as the Upper Great Gorge that leads to the present site of Niagara Falls.

Here, some five hundred years ago, the river encountered an obstacle that caused it to split into two channels. This was Goat Island, created of silts and clays that had originally lain on the bottom of the vanished Lake Tonawanda. On the eastern side of the island, the American Falls took shape, on the western side, where the river makes an abrupt, ninety-degree turn, the Horseshoe. The island's sheer northwestern face, rising 170 feet from the basin below the furious waters, divides the two cascades.

The waters immediately surrounding Goat Island are relatively shallow and studded with small islets and large isolated rocks, many of them the scenes of dramatic rescues and rescue attempts. Goat Island is so close to the American shore that only a small amount of Niagara's flow plunges over the edge on that side. As a result, the American Falls are not as effective at erosion as the Horseshoe. The channel here is broken by well-known landmarks such as Bath Island, long used as an anchor for the bridge to Goat. Luna Island divides the American cataract, forming a third waterfall, slender and shimmering, variously known as Luna Falls, Iris Falls, or Bridal Veil Falls.

On the Canadian side of Goat Island, several historic pinpoints of rock stand out from the shore, washed by the spray of the racing river. The Three Sisters islands at the southwest end of the island are the best known, but at one time the Terrapin Rocks, so called because they resembled gigantic tortoises, were equally famous. The water here was so shallow that a slender bridge was constructed out to the rocks and a stone tower built on the very lip of the Horseshoe Falls. The tower did not last out the nineteenth century; the danger from erosion caused the owners to destroy it. But Terrapin Point remains. In 1955 the area was permanently drained of water and

back-filled to create an artificial viewing space, perhaps the best of all the vantage points. Here, on the western rim of Goat Island, thousands of visitors look down over the cataract at the very point where the waters hurl themselves over the precipice, 170 feet to the vortex below.

Farther out from Goat Island toward the Canadian shore, the river deepens. Here the current is so strong that the shape of the cataract is constantly changing. Since the first white man, Father Hennepin, reported on the Falls more than three centuries ago, the waterfall has moved about a third of a mile upriver and changed from a gentle curve to a horseshoe bend to today's gigantic inverted V with it point upstream, where the tumbling waters, tearing away at the dolostone, have created a deep notch. It will change again, for it appears to have oscillated between horseshoe-shape and notch-shape over the centuries depending on the rate of recession.

The shape of the American Falls is also changing. Once this fall was likened to a gigantic weir, its crest a straight line between Goat Island and the opposite shore. But once again the implacable river, tearing out the softer shale, has caused the hard dolostone cap to crumble, leaving a familiar V-shaped notch at the western side to destroy the symmetry.

So powerful is the thrust of the water plunging off the Horseshoe that it has gouged out a hollow beneath the level of the riverbed some two hundred feet deep. On the American side, the pressure of the water is not strong enough to move the piles of talus – broken rock – that are heaped up to more than half the cataract's height.

The Falls can never be totally controlled, even though modern engineers have come close. The cataract can now be turned off at the pull of a lever. And even at the peak tourist periods in the daylight hours of summer, Niagara Falls is not quite what it once was. Today less than half the river's flow (and even less than that in the dark of winter) pours over the precipice. The remainder is carefully channelled into tunnels and canals to