

The exposed portions of the Onondaga Escarpment form local features of note. These include the exposures just north of Port Colborne on the West Side Road that marks the boundary of the Wainfleet Bog, and Highway 140 at Chippawa Road. Further east it provides the route of the scenic Ridge Road north of Ridgeway and the Battle of Ridgeway exposure on Highway 3. Where the escarpment is exposed the overburden is thin to absent but thickens southward in the direction the rocks dip.

The Bois Blanc Formation is quarried for crushed stone in operations on both the east and west sides of Port Colborne. Along with the active operations there are many abandoned quarries along the escarpment.

The bedrock formations have a general northeast to southwest dip of 3.75 to 9 metres per kilometer towards a low point known as the Michigan Basin.

2.1.2 SURFACE GEOLOGY

The surface geology consists of glacial and post-glacial deposits. During the retreat of the last continental ice sheet the study area was inundated by a series of post glacial lakes beginning 12,900 years ago with the formation of post-glacial Lake Warren. It had a height of 204 metres a.s.l. (above sea level). It was followed by two lower phases known as Lakes Grassmere and Lundy at 195 and 189 metres a.s.l.

With the retreat of the ice into the Lake Ontario Basin about 12,500 years ago Lake Warren and its lower levels drained northward over the Niagara Escarpment via a short lived lake known as Lake Tonawanda. Below and north of the Niagara Escarpment the basin was filled by Lake Iroquois that reached a height of 102 metres a.s.l.

When Lake Warren drained away to become early Lake Erie some remnants of its waters were trapped between the land rising to the Niagara Escarpment in the north and the face of the Onondaga Escarpment to the south. These entrapments became the present day Wainfleet Bog, Humberstone Marsh, Willoughby Marsh and numerous other small wetlands. Prior to the construction of the Welland Canals drainage from these wetlands was eastward toward the Niagara River.

Once the Welland Canals and the Feeder Canal were constructed drainage out of the Wainfleet Bog was accelerated and rerouted into the canals. Drainage projects to facilitate agriculture further reduced the extent of the wetlands. Today, only areas east of the canal now drain to the Niagara River. Those west of the canal drain either into it or down the power canal in Niagara Falls via the Welland River. South of the Onondaga Escarpment a few short streams drain into Lake Erie.

Today, those areas of the former bed of Lake Warren that completely drained away several thousand years ago are covered with deep clay deposits characteristic of a lake bottom. They are referred to as the Haldimand Clay plain.

In the north portions of the Haldimand Clay Plain the soils are described as Pedalfer (formerly Grey Brown Podzols).

Those areas that were the remnant wetlands of Lake Warren are covered by organic soils derived from deposits of peat and other vegetation characteristic of bogs and marshes. The post-glacial clay deposits are buried beneath them. The depths of the

deposits vary in thickness but in general are deepest just north of the Onondaga Escarpment, thinning as they extend northward.

The soils that developed on the poorly drained areas in the southeast portion of the study area are Humic Gleysols.

West of the Wainfleet Bog is an extensive sand plain extending all the way to the Grand River.

Along stretches of the Lake Erie shore are sand dunes, notably in the areas east and west of the entrance to the Welland Canal and at Point Abino. The sand dunes are a result of materials blowing out of the exposed bed of a smaller early phase of Lake Erie. These dunes have migrated inland ahead of the expanding lake. They have been stabilized by vegetation and their highest point today is known as Sugarloaf Hill.

Beaches along the Lake Erie shoreline consist of sand in some areas and exposed bedrock in others. Generally the sand beaches are located in the bays while the intervening headlands are bedrock. This is the result of wave action by the lake waters. Numerous large boulders can often be found sitting on the surface of the bedrock beaches. These are glacial erratics left behind by the retreating glacier. The surface of the exposed bedrock shows long linear scratches extending from northeast to southwest. These are the result of gouging by rocks frozen into the ice as the glacier advanced.

In all areas the present day soils sit unconformably on the bedrock surface. They are derived from transported materials and do not exhibit the C horizon gradation from bedrock to regolith characteristic of soils which have developed "in situ". Instead the C horizon is derived from glacial till.

2.2 Northern Portion of the Study Area

2.2.1 BEDROCK GEOLOGY

The northern portion of the peninsula is underlain by sedimentary rocks laid down in shallow seas during the Ordovician and Silurian periods (505 to 409 million years ago). The lowest formation is known as the Queenston Shale and underlies the portion of the peninsula from the base of the Niagara Escarpment northward to Lake Ontario. It is a red shale with thin limestone interbeds which forms the uppermost Ordovician strata in the area. The width of the outcrop, now buried under post glacial deposits, varies from 3.2 to 19.3 kilometres. At the Niagara River the strata is approximately 260 metres thick, thinning to 180 metres thick at Hamilton.

The Niagara Escarpment is formed from Silurian strata which overlie the Queenston Shale. The strata are composed of sandstone, shale, limestone and dolostone formations. At the Niagara River these layers can best be observed and consist of, from bottom to top, the Whirlpool Sandstone, Power Glen Shales and Sandstones, Grimsby Shales and Sandstones, Thorold Sandstone, Neahga Shale, Reynales Dolostone, Irondequoit Limestone, Rochester Shale, Decew Dolostone and Lockport Dolostone.

It is the hardness of the Lockport and Decew strata overlying softer shales and the Irondequoit and Reynales strata overlying softer shales and sandstones that resulted in the erosional feature known as the Niagara Escarpment. Because the backslope dips at an angle less than the face of the escarpment this feature is sometimes identified as the Niagara Questa. The escarpment is a continuous feature running in Ontario from Queenston to the tip of the Bruce Peninsula at Tobermory. In some places there are deep indentations which represent the sites of former river valleys now mantled by post glacial deposits, particularly in the St. David's and Short Hills areas. In most sections the upper layer of Lockport Dolostone forms a cliff face that gives way to a scree slope beginning at the top of the Rochester Shale.

South of the brow of the escarpment the Guelph Formation overlies the Lockport Formation. It appears in the wall of the Niagara Gorge about the site of the Rainbow Bridge and forms the upper rapids above the waterfall. The Guelph Formation is between 30 and 60 metres thick but does not outcrop anywhere else in the peninsula, being buried beneath post glacial deposits.

2.2.2 SURFACE GEOLOGY

Except for the Niagara Escarpment the bedrock geology of the area is hidden beneath post glacial deposits. A layer of basal till was deposited directly on the bedrock as the last phase of continental glaciation waned. The till was then buried beneath lacustrine deposits of a series of post glacial lakes. The most pronounced and longest lasting of these was post glacial Lake Iroquois which existed from 12,400 to 11,900 years ago. This lake, at a height of 102 metres a.s.l., occupied what is now the Lake Ontario basin to a southern limit that varied between a few hundred metres and several kilometres from the escarpment. The beach thus formed exists now as a well-defined feature along which runs Regional Road 81 (formerly Hwy 8). Between the beach and present day Lake Ontario deposits of silt were laid down over the 500 - 600 year life of the lake. In some areas sand deposits were laid down.

Rivers entering into Lake Iroquois flowed from south to north and cut through the beach deposits. At present day Homer (South east St. Catharines), a large baymouth bar was developed.

When Lake Iroquois drained away with the opening of the St. Lawrence River the water level dropped, exposing the flat lying silts of the lake bed and is referred to by some as The Fruit Belt. The positioning of lacustrine silt over the basal till can best be seen in the bluffs that now form the southern shoreline of Lake Ontario. The existing rivers began to downcut again to reach the new lower level of the lake. Twelve Mile Creek is an example of this. Where the rivers enter into Lake Ontario baymouth bars have developed with lagoons such as Martindale Pond trapped behind them.

Above the escarpment is evidence of an older post glacial lake called Lake Warren which had a height of 204 metres a.s.l. It existed while the ice still topped the escarpment and drained southward to the Mississippi River. Its bed is known today as the Haldimand Clay Plain. Running parallel to the escarpment and just to the south is a ridge of unconsolidated material known as the Vinemount Moraine. It is best seen as one travels northward on Regional Road 24.

One feature of note is the Fonthill Kame Delta which was developed in Lake Warren by a river running off the ice. The delta has its highest point at Lookout Point where the river exited the ice. It grades southwest to a point near Fenwick where the edge can be determined by the sandy nature of the soil.

The post glacial clays of the Haldimand Clay Plain deepen southward toward the Wainfleet Bog and Onondaga Escarpment. An appreciation of their depth can be felt as one descends into the tunnel that passes under the Welland Canal on Townline Road. Here the sharp contact between the bedrock of the Salina Formation and the overlying till can be seen.

2.3 A DESCRIPTION OF GEOLOGIC FEATURES WITHIN THE STUDY AREA

As was described in the geologic overview of the Niagara Peninsula, there are a number of features that are locally significant. These will be described in more detail here.

2.3.1 THE ONONDAGA ESCARPMENT

The first of these features, the Onondaga Escarpment, is described both in detail of present day form and origin because the geologic events described here are important to understanding the formation of other features as well.

Although not nearly as evident or striking as the Niagara Escarpment, the Onondaga Escarpment is the most obvious geologic feature in the southern portion of the peninsula. The escarpment is composed of two rock layers; the lower is the Bertie Formation (of Silurian age) and the upper the Bois Blanc Formation (of Devonian Age).

The rocks are sedimentary in origin and represent periods of time between 410 and 350 million years ago when this area was covered by warm, shallow seas. The Bertie Formation, consisting of thick beds of brown dolostone and minor beds of shaley dolomite, rests on top of the Salina Formation which forms a buried band of rock 9.5 to 26 kilometres wide south of the Welland River. (The importance of the Salina Formation in the development of the present day Onondaga Escarpment will be seen shortly)

The Bois Blanc Formation is a highly fossiliferous limestone with inclusion of chert (also called flint) and represents the formation of reefs during the Devonian period about 350 million years ago. At that time, because of continental drift, our area was located about 20 degrees south of the equator.

All of the above bedrock layers have a dip of 3.75 to 9 metres per kilometre down to the southwest.

With the retreat of the seas the area was subjected to a long period of erosion. During this time the resistant beds of the Bertie and Bois Blanc formation formed a low escarpment with a north face and a gentle southern back slope. Soils evolved from the bedrock and a drainage system was created.

The major river through the area flowed eastward in what is now the Lake Erie bed and eventually found a way northward through a low spot in the Onondaga Escarpment at

present day Lowbanks. This river continued northward cutting its valley into the Salina Formation and out through the Niagara Escarpment at present day Short Hills Park.

About two million years ago this area was overridden by the first of four major continental glaciers. The advancing ice (coming from the northeast to the southwest) acted like a bulldozer, scraping away the soils, gouging into the bedrock and modifying the shape of river valleys. This process was repeated three more times and in our area only evidence of the last glacial period, the Wisconsin, is found. Evidence of the direction of ice movement is preserved in scratches on the surface of the Bois Blanc Formation and can be clearly seen in the old Cement Plant Quarry at Quarry Road in Wainfleet.

The softer beds of the Salina Formation were deeply eroded but the harder Bertie and Bois Blanc Formations resisted the impact of the ice. About 25 thousand years ago the ice reached its maximum extent and began to melt away. Large amounts of meltwater were released to form a series of post-glacial lakes south of the ice front. As the ice thinned it also lost its ability to erode deeply into the bedrock and began to deposit material beneath the ice as a mixture of clay to boulders called a basal till. The entire southern portion of the Niagara Peninsula is covered by such a till known as the Wentworth Till, underlying the Haldimand Clay Plain, which is thinnest near the top of the Niagara Escarpment and thickest just north of the Onondaga Escarpment where it reaches depths of 30 to 45 metres (100 to 150 feet). On top of the Onondaga Escarpment the till is again thin near the edge and deepens to the south.

As the ice front retreated to a point near the brow of the Niagara Escarpment 12,900 years ago, the entire area to the south, including the Onondaga Escarpment, was covered by the waters of a post-glacial lake named Lake Warren. It was bounded on the south by the Portage Escarpment in New York and Pennsylvania and reached an elevation of 200 metres above present sea level. The waters of Lake Warren drained away westward to the Mississippi River. Layers of sand and clay were deposited in the lake covering the underlying till in most places. As the ice retreated in stages ridges of material called recessional moraines were deposited at the ice front but beneath the waters of the lake. One of these is seen along Bertie Street, Fort Erie in the area of the Douglas Memorial Hospital today. The largest is the Vinemount Moraine south of the crest of the Niagara Escarpment.

About 12,500 years ago the ice finally retreated into the present day Lake Ontario Basin. Lake Warren drained away over the Niagara Escarpment and the waters eventually reached the Atlantic Ocean via the Mohawk and Hudson River valleys. A remnant of the lake was retained in the shallow depression south of the Onondaga Escarpment. This lake, which reached a height of 140 metres above sea level, was early Lake Erie. Its waters drained northward into another remnant of Lake Warren called Lake Tonawanda. From Lake Tonawanda the waters escaped over the Niagara Escarpment by way of six outlets. The largest of these was called the Lewiston Outlet and it is today known as the Niagara River.

Small remnants of the lake were also trapped directly in front of and to the north of the Onondaga Escarpment. The rise of the land to the north and the escarpment face to the south forced the drainage from these areas to move from west to east. The areas became waterlogged and marshy. Deposits of peat accumulated on top of the lake deposits thus developed the Wainfleet and Humberstone Marshes.

Over time the size of Lake Erie expanded to its present extent. The bedrock of the escarpment now forms the headlands that extend out into the lake as such features as Morgan's Point. The shallow dip of the rocks means that the water deepens very slowly in this lake. In the bays wind and current have caused the accumulation of sand beaches.

Today the Onondaga Escarpment forms a discontinuous feature a few metres in height from Fort Erie to beyond Dunnville. In many places it is buried beneath glacial or post-glacial lake deposits. In others it forms local features of note. The most obvious of these is the outcrop along the West Side Road as it nears Port Colborne from Welland. Other notable sites are "the ridge" at Ridgeway where the escarpment is followed northeast by Ridge Road to Bowen Road and as the outcrop now designated the Shagbark Trail.

The presence of the escarpment is also identified by the numerous active and abandoned quarries along its length. These include those west of Port Colborne along Highway 3 near Cement Plant and Quarry Roads, east of Port Colborne along Chippawa Road and East Main Street (Hwy 3), and in Fort Erie at Ridgemount Road. The escarpment rocks are also seen at Fort Erie in the railroad cut at the intersection of Bowen and Thompson Roads.

Where the Onondaga Escarpment is prominent the bedrock surface tends to be exposed or thinly covered by soil near its edge. The soil deepens to the south reaching depths of up to 15 metres before the shore of Lake Erie is reached. In some areas deep deposits of sand in the form of dunes cover the bedrock near the shore.

A few short streams flow north to south above the Onondaga Escarpment to enter Lake Erie. As a result there are no waterfalls of note flowing over the Onondaga Escarpment as there are with the Niagara Escarpment. Most rivers in the peninsula north of the escarpment flow west to east. One exception is the Grand River which crosses the rocks of the Onondaga Escarpment from north to south at a low point near Dunnville.

2.3.2 THE WAINFLEET BOG AND HUMBERSTONE MARSH

The bulldozing effect of the Wisconsin Glacier cut deeply into the soft rocks of the Salina Formation which underlie the southern portion of the Niagara Peninsula. Directly in front of the Onondaga Escarpment and east of the Welland Canal this depth to bedrock reached 15 to 20 metres below the present soil surface. To the west of the Welland Canal, the depth is even greater, averaging 30 to 45 metres directly north of the escarpment. In the area of Lowbanks the action of the ice deepened and smoothed the pre-glacial river valley known today as the Erigan Canyon.

As the ice melted away, still moving from northeast to southwest, it lost its erosive power and began to deposit materials on the bedrock in what is known as a basal till. Then, as the area was freed from the ice it flooded beneath the water of Lake Warren and further deposits of layered sands and clays, known as lacustrine deposits, were laid down over the till. These deposits show stratification (layering). The waters finally drained away, first through two lower lake levels and then completely about 12,500 years ago when the retreat of the ice opened drainage channels over the Niagara Escarpment. The result was essentially a flat plain with deep deposits of clay and a few localized features such

as gravel or sand bars. Some of these features show beach lines where they had emerged as islands in the draining lake.

In the areas immediately north of the Onondaga Escarpment remnants of the lake were trapped between the escarpment to the south and the gentle rise of the landscape to the north. The climate was much colder immediately after the retreat of the ice and these remnants of the lake became extensive bogs with the growth of sphagnum moss. Over the centuries dead organic materials accumulated in parts of the bogs to form thick layers of peat. In some places ponds of water persisted, and as the climate warmed there was a succession of plant types in the area. Water that did escape the area flowed slowly from west to east in a series of streams that eventually entered the Niagara River.

Had man not interfered this would still be the situation today. However, the construction of a series of Welland Ship Canals beginning in the mid 19th century, including the ill-fated Feeder Canal, disrupted the natural drainage pattern. The area west of the canals now drained into them. The canals were deeper than the bogs and so the water table was lowered. Many of the ponds began to dry up. Clearing of large areas of the bog for agriculture with subsequent drainage ditches accelerated the process. During the mid 20th century these areas became so dry in many summers that smoldering peat fires would burn for months, being extinguished only by the winter snows. East of the Welland Canal the areas of bog and marsh are known as the Humberstone Marsh. They continue to drain eastward via shallow streams to the Niagara River.

2.3.3 THE HALDIMAND CLAY PLAIN

In general the entire area of the Niagara Peninsula south of the Niagara Escarpment is referred to as part of the Haldimand Clay plain. It is composed of glacial till and overlying lacustrine deposits from post-glacial Lake Warren. The depth of material is generally less than 15 metres near the lip of the Niagara Escarpment and thickens southward to maximum depths of about 45 metres just in front of the Onondaga Escarpment. South of the Onondaga the clays again increase southward in depth from less than a metre to about 3 to 15 metres along the Lake Erie shoreline.

Like the Wainfleet Bog and Humberstone Marsh (which are part of this clay plain) the remainder of the study area is poorly drained due to the heavy nature of the clays. Drainage moves from west to east in a few large streams, including the Welland River, Grand River and Twenty Mile Creek. This is a result of the downward dip of the bedrock to a structural low occupied by the Niagara River.

The plain is very level with only a few local features to break the topography. The most notable of these is the Fonthill Kame Delta Complex. In the southern part of the plain local features such as Doan's Ridge or the Fort Erie Moraine rise only a few metres above the general landscape.

In the north portions of the Haldimand Clay Plain the soils are described as Pedalfer (formerly Grey Brown Podzols). They are characterized by a dark surface layer grading down to a light lower A horizon. The B horizon contains materials leached from the A horizon and are usually brown to reddish from the accumulation of iron oxides and or clays. Both horizons are slightly acidic in their pH. The C horizon is partially decomposed parent material and may be partially cemented by calcium carbonate which

has dissolved out of the upper horizons. The material of the C horizon is derived from unaltered till below.

The soils that developed on the poorly drained areas in the southeast portion of the study area are Humic Gleysols. The A horizon is dark coloured due to the humus present. The B horizon is mottled in colour. Leaching may or may not have occurred from the A horizon due to a high water table.

2.3.4 THE LAKE ERIE SHORELINE

Due to the gentle southerly dip of the rocks of the Onondaga Escarpment Lake Erie exhibits relatively wide beaches and extensive shallows along its north shore. The lake came into being about 12,500 years ago with the draining away of the much larger post-glacial Lake Warren. Due to the weight of thousands of years of glacial ice the entire area had been depressed. When early Lake Erie formed it was much smaller than it is today.

Slowly the land rose through a process called isostatic rebound. This process continues even today with the brow of the Niagara Escarpment rising at a rate of 20 cm/century. However, in the center of Lake Erie the rise is now 0 cm/century. As a result the level of the lake must rise 20 cm/century to continue flowing at the same rate into the Niagara River.

The present shoreline of Lake Erie is a result of the thousands of years of isostatic rebound. Prevailing winds and currents move sand from west to east in the lake. In some areas this creates long hooked spits such as Turkey Point. In other areas the sand is removed from points of land into the intervening bays. Here it is also piled into dunes by the wind.

Early in its history, Lake Erie was actively growing in size. As a result the shoreline kept moving northward. Since vegetation could not get a permanent hold on the shore the beaches moved inland just ahead of the water and the sand dunes migrated ahead of the beaches. Over time the isostatic rebound decreased until the lake almost stabilized at its present size. This allowed vegetation to gain a foothold on the sand dunes, stabilizing them and preventing further movement by the wind. For the most part the tops of the sand dunes appear to be at a constant elevation but some are locally higher. The highest sand dune in the area is Sugarloaf Hill just west of Port Colborne.

Sand dunes form long sections of the Lake Erie shoreline. They have been extensively built on for summer cottages and year round homes. Unfortunately these areas represent the very edge of the active zone of the lake. In rare but severe storms with high waves the dunes can be attacked and severely damaged. Remedial action such as the building of breakwalls, groynes or rip rapping can slow the action of erosion. However, the lake is continuing to refill and eventually will overpower these structures.

One area where large sand dunes are conspicuously absent is at Lowbanks. This is the opening into the Erigan Canyon, the pre glacial river valley. The valley runs northward across the Haldimand Clay Plain, beneath the Fonthill Kame and out through the Short Hills. It is filled with post-glacial debris and shows itself on the surface only as a slight depression in the landscape, visible only from a distance by observing the treelines that cross it.

On the headlands wave action eats away at the cover of glacial till exposing the bedrock. The layers are highly fossiliferous and also show numerous chert nodules. There is a joint pattern in the rocks that divides the surface into large blocks. Wave action attacks these areas of weakness and wears the bedrock layers into a stepped pattern at the water's edge.

There were numerous rounded pieces of rock trapped in the glacial till, ranging in size from pebbles to boulders. As the finer clay and sand particles were winnowed out by wave action the rocks, called glacial erratics, were left behind. In some places they, and the broken pieces from the Onondaga, form pebble beaches. Larger erratics sit stranded upon the surface of the bedrock, conspicuous by their colour and shape. The accumulation of pebble beaches is most likely to develop on the eastern side of headlands.

2.3.5 THE ERIGAN CHANNEL

The Onondaga Escarpment forms a discontinuous feature running east-west across the southern portion of the Haldimand Clay Plain. In the area of Lowbanks the escarpment is absent. This site is the beginning of a pre-glacial channel known as the Erigan Channel. The channel, completely buried by glacial till and the lacustrine deposits of Lake Warren, is a pre-Niagara drainage channel.

The channel was first identified in 1907 by J.W. Spencer. It begins just east of Lowbanks and runs northward across the peninsula to a point west of Fonthill, exiting through the Niagara Escarpment in the area of the Short Hills. North of the escarpment there is no present evidence of the channel. Several side channels have been identified, including one possibly beginning at Dunnville, another running east to west beneath the Wainfleet Bog and a third called the Falls-Chippawa Valley that begins at the site of the present Niagara Falls and enters the Erigan Channel beneath Fonthill. It has been suggested that this channel was active several times as the outlet for water from melting glacial ice prior to the last advance of the continental ice sheet.

Other than the absence of the Onondaga Escarpment at its source and the Short Hills at its terminus the only physical evidence of the channel on the landscape is a slight dip in the topography that can best be seen looking southwest from a vantage point near the intersection of Hwy #20 and Effingham Road on the Fonthill Kame. Where the channel exists there can be observed a slight dip in the treelines. This indicates a shallow depression in the landscape.

At Lowbanks the channel is about three kilometers wide and it maintains this width throughout most of its length. At St. Johns West it narrows to about two kilometers in width.

Since the channel predates the present great lakes there must have been an extension north of the Niagara Escarpment into a river that flowed in what is the present day Lake Ontario Basin. However no evidence of this northerly extension across the present day Lake Iroquois bench or plain is indicated on maps produced by current researchers.

2.3.6 POST GLACIAL LAKE WAINFLEET

Approximately 13,000 years ago the southern portion of the peninsula was covered by the waters of Lake Warren. Since the Lake Ontario basin was filled by glacial ice which extended up over the Niagara Escarpment the waters of Lake Warren drained away west and southward to the Mississippi River. When the ice cleared, the escarpment Lake Warren drained northward via the Niagara River and Lake Tonawanda (as described in the section titled "The Niagara River"). Two phases in the reduction of Lake Warren are identified as Lakes Grassmere and Lundy. A beach line for Lake Lundy is evident on the Niagara Falls Moraine.

For several thousand years thereafter the amount of water discharged through the Niagara River was controlled largely by the melting of glacial ice in the Lake Huron and Superior Basins. Several phases of this melting produced large volumes of water that can be identified by the width of sections of the Niagara Gorge. High water volumes between 11,000 and 10,500 years ago inundated southern portions of the peninsula in a phase referred to by some authors as Lake Wainfleet. This lake would have expanded and waned in size dependent upon the outflow from the upper lake basins. This lake persisted until about 10,200 years ago.

Evidence of these late phase floodings, including Lake Wainfleet have been identified as strand lines or beaches evident on other features within the area. For example, there is a strand line evident on the long sand bar between Ridgeway and Sherkston. At Doan's Ridge there is a faint beach line on a gravel bar. Another faint beach line is seen near Lodba's Corners in Wainfleet.

When water volumes were high there were probably several channels from Lake Erie into Lake Wainfleet across the Onondaga Escarpment. The old Erikan Channel would have been one. Ultimately the waters would have escaped northward via the Welland and Niagara Rivers.

During low levels the area north of the Onondaga Escarpment would have contained a series of connected ponds. As isostatic rebound raised the land the ponds would have drained eastward back into the Niagara. Today the remnants of some of these are represented by the poorly drained areas of the Wainfleet Bog, Humberstone Marsh and Willoughby Marsh as well as many smaller sites.

2.3.7 THE DUNNVILLE SAND PLAIN

A late stage of Lake Warren called Lake Lundy saw water levels drop to expose most of the peninsula south of the Niagara Escarpment. Drainage from this lake was northward through the present day St. Clair River into an early stage of Lake Huron called Early Lake Algonquin. At one point in time the area immediately to the east of Dunnville was flooded. The Grand River built a sandy delta into this embayment at a height of about 180 metres a.s.l.

Eventually the ice cleared the Niagara Escarpment allowing Lake Iroquois to form and causing the drainage to now flow from the Lake Erie basin northward through the Lewiston Spillway. The drop in water level was enough to change the outlet of the Grand River to its present position. The sandy delta was abandoned and exists today as a sand plain extending from the Grand River as far eastward as the Wainfleet Bog. It

terminates to the south at Lake Erie and along a northern perimeter that begins at the Grand River about twelve kilometers from the lake.

In all the sand plain covers an area of over 300 square kilometers.

The two main branches of Big Forks Creek arise from this sand area.

2.3.8 DRAINAGE ON THE HALDIMAND CLAY PLAIN

The three largest streams that drain the Haldimand Clay Plain are the Grand River, Welland River and Twenty Mile Creek. They meander west to east across the plain.

The Grand River enters Lake Erie at Port Maitland having been controlled by the location of the Onondaga Escarpment and ultimately finding a low notch through which it enters the lake.

The Welland River (also known as the Chippawa Creek) enters the Niagara River at Chippawa. In fact it once did this but now the last 6 kilometres has been reversed to provide the intake for the Chippawa-Queenston power canal. In addition the river has been diverted under the Welland Ship Canal via large siphons at Welland and Port Robinson.

The Twenty Mile Creek enters Lake Ontario via a notch in the Niagara Escarpment at Ball's Falls.

The topography of the clay plain is very flat and the rivers meander sluggishly across it. The Welland River only drops seventy-three metres in one hundred and sixteen kilometers from its source to its mouth. Of this drop sixty metres occurs in the first twenty-four kilometres of its length. As a result the gradient for the remainder is less than fifteen centimeters per kilometre. The river has few large tributaries, notably Lyons Creek and Big Forks Creek. It carries a high sediment load derived from the lacustrine deposits of the plain. The slip-off slopes on the inside of meanders are low and broad and during spring runoff considerable inundations of the flood plain can occur. Natural levees are very faint. Several cut off meanders can be observed from aerial photographs and on the ground are observed as shallow sloughs.

The major control for the west east flow of this river is the slight drop in elevation from west to east caused by the bedrock topography which dips down to the low of the Niagara River channel. Other local controls are subtle features such as beaches formed by the various levels of Lake Warren and poorly defined recessional moraines.

The Twenty Mile Creek is similar to the Welland River in that it flows from west to east across a very low gradient. However a major control to the north is the long low Vinemount Moraine that occurs just south of the crest of the Niagara Escarpment. This moraine was deposited by the retreating glaciers in the waters of Lake Warren. The river parallels it and finally finds a way to break through to the north via the channel at Ball's Falls. This creek drains an area of only 300 square kilometers. The remainder of the clay plain is drained primarily by the Welland and Grand Rivers.

The Onondaga Escarpment controls the southern limit of drainage into the Welland River. Just north of the escarpment the drainage is poor, creating a series of wet areas

including the Wainfleet Bog, Humberstone Marsh and Willoughby Marsh. A few short streams such as Baker's Creek and Frenchman's Creek drain eastward to the Niagara River. Above the escarpment the dip down to Lake Erie creates a series of short streams flowing to the south.

2.3.9 THE NIAGARA RIVER

Approximately 12,500 years ago the retreat of glacial ice reached the present day Lake Ontario Basin. With the freeing of the Niagara Escarpment from the ice post-glacial Lake Warren drained away to the north, leaving a small remnant behind called Early Lake Erie. The flow of glacial meltwater from this lake northward created a channel that began between present day Fort Erie and Buffalo. Before reaching the escarpment the waters filled a long east-west depression to form a narrow lake in the location of present day Tonawanda Creek. This lake, approximately 100 kilometres long, was known as Lake Tonawanda. It had six outlets over the escarpment into a new post-glacial lake known as Lake Iroquois. From east to west they are known as the Holley, Medina, Gasport, Lockport, Devil's Hole and Lewiston Outlets.

Over time isostatic rebound caused the land to slowly rise and gradually each outlet dried up as Lake Tonawanda shrank toward the low of the Lewiston Outlet. Each outlet produced a gorge extending back from the lip of the escarpment and since the Lewiston existed for the longest period of time and had the major flow of water over it, that gorge became the largest. Its original waterfall was at Queenston.

The retreat of the waterfall was at a rate of about a metre a year. It was also controlled by a series of joints in the caprock of the Niagara Escarpment known as the Lockport Dolostone. Today, that gorge is approximately eleven kilometers long and its waterfalls are now known as the Horseshoe and American Falls. The outlet is now more commonly known by a different name – the Niagara River.

With the melting away of the continental glaciers the flow of water in the Lewiston Outlet fluctuated over time. During periods of high water the gorge width was wide, and at other times it was narrow. Eventually the flow of water decreased to reflect only the volume supplied by the annual water cycle. The channel above the waterfall reflected this decrease by becoming more narrow, abandoning its original banks. These abandoned banks can be observed in many places such as in Fort Erie where a conspicuous drop occurs on all east west streets approaching the river. It is also very noticeable parallel to the present day Niagara Gorge on both sides of the river.

It might be argued that the Niagara River should still be referred to as the Lewiston Spillway because it lacks many of the features associated with a river. There is little change in volume between its source and its mouth. It has few tributaries, the Welland River being the only one of significance. Its change in yearly volume is only by a factor of two, whereas most rivers show a marked increase and decrease in volume related to the seasons. It does not meander across the Haldimand Clay Plain in a fashion seen by most rivers. It is also very short, joining two lakes over a distance of only about 45 kilometres.

2.3.10 THE FORT ERIE MORAINE

The process of freeing the peninsula from the grip of the continental glacier was not measured in a constant number of metres per year. Variations in the climate resulted in some periods when the ice retreated, some periods when there were minor advances and others where the ice front remained static for some time. During periods when the front remained static summer meltwater would deposit materials released from the ice as a long ridge along its margin. These features are called recessional moraines. Three such features are recognized within the peninsula. They are the Vinemount, Niagara Falls and Fort Erie moraines.

The Fort Erie moraine is located on the back slope of the Onondaga Escarpment. Some authors suggest that the moraine extended across what is now the course of the Niagara River about 12,500 years ago. When the waters of Lake Warren drained over the escarpment to expose the peninsula as dry land and create early Lake Erie the moraine would have acted as a dam. This would have caused early Lake Erie to rise several metres in order to overcome this obstacle to its outflow. Only when the moraine had been eroded did the lake drop to its current level.

Being the furthest south, the Fort Erie moraine is the oldest but also one of the most poorly defined. It is best seen as a low ridge running westward from the Niagara River along Bertie Street in Fort Erie. Since the moraine was deposited in the waters of Lake Warren its surface features are smooth and do not exhibit the hummocky features of moraines deposited above water. The north face of the moraine is more pronounced than the south face. This can be best seen on Bertie Street in the area of the Douglas Memorial Hospital. The moraine creates a rise in the landscape a few metres high and up to a kilometre in width. Moraine materials are poorly sorted and contain all particle sizes from clay to glacial erratics. The moraine terminates at a western point about eight kilometers from the Niagara River.

The Fort Erie moraine has been extensively built upon and the initial section of the Queen Elizabeth Way crosses it.

Attempts have been made to correlate this moraine with an east west moraine feature about fifteen kilometres long south of Hamilton. In their publication "The Physiography of Southern Ontario, Third Edition, Chapman and Putman identify both these features as parts of the Fort Erie moraine. However there is a complete absence of the moraine between Ridgeway and Binbrook.

2.3.11 THE VINEMOUNT, FORT ERIE AND NIAGARA FALLS MORAINES

Three east west trending moraines are found on the Haldimand Clay Plain above the Niagara Escarpment. These are recessional moraines resulting from times when the ice front stabilized for a period. The rate of advance equaled the rate of melt and as a result materials being transported by the ice were released and accumulated along the static ice front. Of the other two, the most prominent is the Vinemount Moraine. It is located just south of the brow of the escarpment and is recognized as a low ridge of clayey till. This moraine was deposited into the waters of a late stage of Lake Warren. As a result it is a low, linear feature recognizable at a distance, but without sharp contrast to the surrounding landscape. Its northern limit extends almost to the brow of the escarpment. Directly to the south of the moraine are lacustrine deposits overlying the glacial till.

The Vinemount Moraine can be traced westward beyond Waterdown and in this area it is a distinct ridge of silty, stony till. It extends eastward as far as the Niagara River and then into New York State. In some places it is interrupted by local features such as the Short Hills and St. David's Buried Gorge.

The Niagara Falls Moraine, further south, is a much more subdued feature, a mere swell in the clay plain east of the Welland Canal. Only in the area of Lundy's Lane where it is topped by a gravel bar is it truly distinct.

The most southerly of the three, the Fort Erie Moraine has already been described for that section near Fort Erie itself. South of Hamilton a low ridge of clayey material extends for several kilometers south of the Twenty Mile Creek. Binbrook and Mount Hope are both set on its crest. Eight kilometers east of Binbrook it becomes indistinct but still has enough relief to serve as the drainage divide between the Welland River and the Twenty Mile Creek. Although this has been identified as an extension of the Fort Erie Moraine by authors such as Chapman and Putnam, there is a large gap of over forty kilometers between the east and west sections.

In the area around Smithville, along Hwy 20 the landscape shows low hills, ridges and indented stream valley, uncharacteristic of the flat landscape further east. This is the area where the Niagara Falls Moraine to the north and the Fort Erie Moraine to the south created a narrow zone through which flows the Twenty Mile Creek.

The Vinemount Moraine also has an influence on the flow of area streams, particularly the Twenty Mile Creek. This feature and the eastward slope of the landscape causes the Twenty Mile Creek to flow sluggishly across the clay plain south of the moraine from west to east. In the area of Vineland the stream finally finds a point where it cuts northward through the moraine, crossing the escarpment at Ball's Falls. The stream then enters Lake Ontario via the lagoon at Jordan Harbour.

2.3.12 THE FONTHILL KAME-DELTA

The most noticeable feature found on the Haldimand Clay Plain is the Fonthill Kame-Delta. It is a northeast to southwest trending structure with its highest elevation in the north and sloping southward to a terminus near Fenwick. The highest point is near the intersection of Effingham and Tice Roads at an elevation of 260 metres a.s.l.

The kame-delta is an ice front feature that resulted from meltwater pouring off the ice and depositing material into the waters of Lake Warren. As the lake level rose over several years the kame-delta also rose keeping its upper surface at about the level of the lake. The deposits are primarily of sand and gravel and there are evidences of distributaries near its upper level. Generally speaking the materials are sorted with the largest particles, boulders to gravel, at the north end grading down to sand farther south. Intermingled beds of sand and gravel would indicate yearly changes in outflow from the melting ice. Localized deposits with unique characteristics are also seen. For example, at the northern tip of the feature, just west of North Pelham Street was a deposit of fine sand that was mined out in the early 1900's for molding sand.

The northern terminus of the kame-delta was supported by the ice and when the glacier finally receded the north side collapsed creating the steep slope seen at Lookout Point.

The Fonthill Kame-Delta is the catchment area for rainwater that ultimately enters into tributaries of both the Twelve Mile Creek, the Welland River, Fifteen, Sixteen and Eighteen Mile Creeks, and Singers Drain. Rainwater exits from the north side of the kame-delta via a series of springs that create streams to cut deeply into the landscape ultimately flowing through the Short Hills area to the Twelve Mile Creek. On the south side of the kame-delta the springs create marshy areas in the clays of the Haldimand Clay Plain and ultimately reach the Welland River. It is these springs that gave Fonthill its original name (from "Fountain Hill").

Beach lines of two lower levels of Lake Warren, Lakes Grassmere (195 m. a.s.l.) and Lundy (189 m. a.s.l.) are found on the sides of the kame-delta. The kame-delta sits at the upper end of the portion of the Eriqan Channel that is now occupied by the Short Hills.

In its higher elevations the kame-delta has been extensively mined in the past for deposits of sand and gravel. Numerous small pits are still in evidence. Larger operations have been rehabilitated such as the one that now encompasses Peninsula Lakes Golf Course. One pit is still in production. These operations plus the removal of the original forest cover has had an impact on the water regimen of the area. Spring runoff is high but many streams still do flow in the drier summer months.

The town of Fonthill occupies the northeast section of the kame-delta. Extensive tender fruit farming once occurred over much of the remaining surface, but is now replaced by urban development. The limit of the sand deposits of the kame-delta to the south can be determined largely by the limit of tender fruit cultivation.

2.3.13 THE SHORT HILLS

The Short Hills occupy the notch (called a re-entrant) in the Niagara Escarpment created by the Eriqan Channel. They are bounded by the Fonthill Kame-Delta to the south. More than half of the area is now within the boundary of Short Hills Provincial Park. Contrary to their name, the Short Hills do not rise up above the surrounding Haldimand Clay Plain but rather sit down within the escarpment re-entrant.

During the last period of glacial advance the re-entrant was scoured and modified by the ice. As the ice retreated glacial till was deposited in the re-entrant and then covered by a layer of lacustrine material released from the ice and deposited in the waters of a late stage of Lake Warren. When the lake drained away a dendritic drainage pattern was established on these deposits and cut deeply into the unconsolidated materials. The ultimate direction of flow was northward into the channel of the Twelve Mile Creek. This process continues today. The Short Hills are the remnants of the original surface now deeply dissected by ravines and valleys.

Where streams entered into the feature from the east or west, they ultimately had to cross over the Niagara Escarpment. Waterfalls were created which then began to erode back into the escarpment creating gorges. The largest of these waterfalls is Swayze Falls which drains a western branch of the stream system into the valley. A similar, but somewhat less impressive, waterfall known as Terrace Creek Falls drains a major stream from the east. Throughout the short hills there are numerous other small

cataracts which form where bedrock is exposed along the rim of the surrounding escarpment.

Today the area is largely forested except on the remnants of the upper surface where farming has continued until the present. Some of these farm fields have been replanted in reforestation projects beginning in the late 1970's and 80's. There is ample evidence of farming in the short hills even in areas that have now returned to forest. This includes abandoned farm lanes, old farm machinery and old orchards.

The original settlers to the area in the early 19th century capitalized on the year round flow of streams and the steep stream gradients by setting up mills utilizing waterpower. On the east side of the short hills the historic community of St. Johns West once had twelve mills utilizing the stream. Remnants of mill-races and dams to create millponds can still be seen. Similar remnants can be seen on the west side of the short hills in the area of Effingham.

Many of the streams in the Short Hills are ephemeral today, that is to say they flow only after a rainfall or at the time of the spring thaw. During these times the streams are still actively eroding the post-glacial deposits. Major streams run year round, in some cases augmented by springs such as one just north of the St. Johns Outdoor Studies Centre. The most active scene of erosion today is an area known as the land-slip which is located about a kilometre south of the Pelham Road parking lot of the Provincial Park. This huge slump probably began to develop in the 1940's or 50's when the meander of the stream began to undercut the slope. It continues today and is more than a hundred metres wide.

2.3.14 THE LAKE IROQUOIS PLAIN AND BENCH

Lake Iroquois was perhaps the most famous of the post-glacial lakes to cover parts of the peninsula. It covered all of the present day Lake Ontario basin and rose to a height of 102 metres a.s.l before finding an outlet by way of the Mohawk Valley at present day Rome, New York. Lake Iroquois formed about 12,500 years ago when the glacial retreat reached a line north of Toronto. The lake received water from above the escarpment via six outlets, the most westerly of which was called the Lewiston Outlet and is today known as the Niagara River. Ice still plugged the St. Lawrence and for this reason the lake rose to a high level.

Lake Iroquois existed for a period of 500 to 600 years. During that time thick deposits of lacustrine silt were laid down over the glacial till forming the lake bottom. The settling out of silty material on the lake bottom created a flat landscape with little relief. Here and there are large boulders called glacial erratics that were released from the melting ice, or from ice chunks that broke off and floated out into the lake. These exposed lake deposits, up to five metres thick, are known today as the Niagara Fruit Belt.

The till in turn sits unconformably on the Queenston Shale.

The lake developed a prominent beach that now runs across the peninsula from the Niagara River, right around Lake Ontario to Trenton. In the Peninsula the beach lies 3 to 12 kilometres from the present lake. Between St. Catharines and Hamilton much of Regional Road 81 follows the beach.

Between the beach and the Niagara Escarpment the landform is known as the Lake Iroquois Bench. It is predominantly glacial till. Streams entering Lake Iroquois from the north cut valleys into the bench and created baymouth bars across the beach openings. The largest of these bars is the Homer Bar now covered by residences and cemeteries in St. Catharines.

When Lake Iroquois drained with the opening of the St. Lawrence 11,800 years ago the lake bottom was laid bare. The initial phase of Lake Ontario was only slightly above sea level (8 metres a.s.l.). The streams entering this lake reactivated their downward erosion. As a result the valleys crossing the bench were extensively deepened. When these streams reached the bed of Lake Iroquois they began downcutting to reach the new base level of Early Lake Ontario. At present Regional Road 81 (formerly Hwy 8) descends into some of the larger stream valleys that have cut through the Lake Iroquois Bench via a steep gradient to accommodate the depth of the valley. This is particularly true of the valley of the Twenty Mile Creek.

2.3.15 THE LAKE ONTARIO BLUFFS

Unlike Lake Erie the shoreline of Lake Ontario has no well-developed, wide beaches. Instead, the edge of the lake has a gravel beach only a few metres wide which ends at a bluff consisting of unconsolidated till overlain by lacustrine deposits of predominantly fine silt. The bluff varies in height up to 10 metres in some places.

The cause of this feature is essentially isostatic rebound in the Lake Ontario Basin and St. Lawrence River. When Lake Iroquois drained away with the opening of the St. Lawrence about 11,800 years ago the continent had been depressed by the mass of the ice which once reached a thickness in our area of up to two kilometers. As a result the earliest stage of Lake Ontario (called the Admiralty Phase) was only 8 metres above sea level and filled only about three quarters of its present basin. The western end of this early lake was approximately even with present day St. Catharines. The entire St. Lawrence Valley was inundated by the ocean to form the Champlain Sea. The land then began to "bounce back" and the rise of the bed of the St. Lawrence in the area of the Thousand Islands caused water to pond in the Lake Ontario Basin. This process continues today with isostatic rebound in the St. Lawrence rising at 40 cm/century while the Lake Ontario Basin is rising at 20 cm/century.

The deposits forming the bed of Lake Iroquois once extended further to the north. But as the lake basin refilled the water wave action began to attack the deposits. The unconsolidated materials were easily eroded and continue to do so today.

Over time the area of the lake expanded to eventually encompass its present size by 9,000 years ago.

The rate at which these bluffs are being destroyed varies from year to year. When lake levels are low the small beach that is formed is enough to protect the bluffs. During periods of high water the erosion is much greater. In 1972, during a period of high water, some areas of the bluffs were eroded back by tens of metres.

Evidence of erosion can be seen in the area of Charles Daley Park where there are remnants of concrete abutments out in the lake. These are the remains of a bridge which crossed the Fifteen Mile Creek at a time when there was an east west road

running along the top of the bluff. The entire structure and road are now gone as a result of the retreat of the bluffs.

The Lake Ontario Basin continues to fill at a rate of 20 centimetres/century. Add to this the projection that the Great Lakes Basin could receive 25% more precipitation as a result of climate change. The result is that the Lake Ontario bluffs will continue to be destroyed by the lake.

2.3.16 THE LAKE ONTARIO BAYMOUTH BARS AND LAGOONS

With the exception of the Niagara River all other streams entering Lake Ontario have at their mouth a lagoon which is separated from the lake by a baymouth bar. This is a low structure consisting primarily of gravel with some sand that extends from the west side of the lagoon toward the east. There is an opening on the east side of the bar which allows water to drain into the lake.

These features are a result of two actions. The first of these is the rise in the level of Lake Ontario. When the lake first formed at its level of 8 metres a.s.l. the streams flowing into the former Lake Iroquois were forced to begin downcutting through the lacustrine and till deposits to reach the new lake. Over time the rise in the lake level drowned these river mouths.

The second action is called the longshore drift. The movement of water along the south side of Lake Ontario in the area west of the Niagara River is from west to east. This water can move fine materials. At the same time wave action is primarily perpendicular to the shoreline. As a result a wave will drive material up the narrow beach and the returning water, influenced by the longshore drift will drag the materials slightly to the east.

When a river mouth is encountered the longshore drift will begin to deposit material at the extreme western edge of the stream. Over time the action of wave and longshore drift will extend this material eastward to form a baymouth bar. Water will pond behind this obstruction to form a lagoon. If the stream has little flow the water will escape from the lagoon by infiltrating through the bar. However if there is enough flow the stream will escape from the eastern extreme of the bar by cutting a channel.

This diversion of water to the eastern side of the lagoon increases the rate of erosion of the bluff on this side. The lagoon begins to extend itself eastward and the baymouth bar keeps pace.

The reason there is no baymouth bar at the mouth of the Niagara River is because of the high rate of flow of this body. There is too much force in the current of the river as it enters the lake for a bar to form. Instead the materials are swept away.

Periodically the baymouth bars have been destroyed by high lake levels and wave action. In 1972 the baymouth bar across the Fifteen Mile Creek was almost entirely destroyed and the western section that remained was overtopped by the waves. Within two years time the lake had completely rebuilt the baymouth bar.

2.3.17 THE ST. DAVID'S BURIED GORGE

The most recent period of glaciation, known as the Wisconsin Period, actually overrode the Niagara region more than once. A major advance that began over 100,000 years ago went through a period of retreat that saw the region ice-free again about 70,000 year ago. At that time a river formed where the upper Niagara River flows today. However its outlet over the escarpment was at a point above the village of St. David's.

The retreat of the waterfall created a gorge from that point southward to about where the Lower Rapids Bridge is today. Then, about 50,000 years ago the ice returned.

When the final melting of the ice 12,000 years ago reached this area the pre-existing gorge had been completely filled with glacial debris. The river, now reformed, as the Lewiston Spillway flowed over the top of this debris to a point where the Niagara Whirlpool is today. Then, for some reason, it turned ninety degrees eastward and flowed ultimately over the escarpment at Queenston.

For the next several thousand years the waterfall retreated upstream, reaching the site of the previous gorge about 6 – 7,000 years ago. When the erosion of the escarpment caprock broke through into the pre-existing gorge the force of the river began to flush out the sands and gravels it contained. The section from the whirlpool to the upper Rapids Bridge may have been completely flushed out of debris in a matter of a few weeks.

For some reason the river did not flush out the debris north of the whirlpool. Instead, when the waters entered this area they swirled around counter-clockwise and then continued downstream to exit at Queenston. The whirlpool had been formed.

What remained of the unopened old gorge is called the St. David's Buried Gorge. Early settlers recognized the area as a valuable deposit of sand and gravel. A sand pit was opened and a road (St. Paul Ave.) built down through the notch in the escarpment. Numerous glacial erratics were uncovered during the excavation of the sands. One in particular, the size of a bus, had clear evidence of glacial erosion on its upper surface.

The existence of the buried gorge caused problems with the building of both H.E.P.C. canals in that the absence of bedrock in the area forced the builders to use concrete rip rapping to prevent the canal walls from collapsing.

When the sand pit was finally exhausted of its material it was converted into a golf course and residential housing.

2.3.18 THE NIAGARA GORGE AND GLEN

The present Niagara River formed about 12,500 years ago when the retreating glacier finally cleared the Niagara Escarpment. A waterfall that was originally about 10 metres high formed at what is now Queenston. Over time the erosive power of the water cut into the bedrock creating a gorge that retreated upstream at a rate of about a metre a year.

Since the amount of water coming through the system varied at different times depending upon the melting of the ice and the various other channels that allowed water to flow from other post-glacial lakes this gorge also varied in width.

An observer today would note that the present Niagara Gorge that is about eleven kilometers long is actually composed of a number of linear sections with sharp angular turns that lead into the next one. Near Queenston the gorge is referred to as the First Gorge and it becomes the Old Narrow Gorge as one moves upstream. The next section is called the Devil's Hole Gorge and it is located just south of the Sir Adam Beck Hydro Plants. The notch in the American side of the gorge called the Devil's Hole is one of the other spillways that drained water from post-glacial Lake Tonawanda. Here there is a change in direction to a southeasterly lineation.

Above this point the gorge becomes quite wide until it reaches the Niagara Glen. The Glen is a unique feature. The waterfall had reached this point about 8,000 years ago. It was a wide torrent as indicated by the width of the gorge. Erosion of the waterfall began to create a U-shaped structure with the major flow of water now directed toward the American side of the river. Over time less water flowed over the western side and as a result blocks of Lockport Dolostone eroded from the gorge wall fell into the river here but were not swept away by the current. These blocks created a talus slope which reached as high as the contact between the dolostone and the underlying softer Rochester Shale.

Soon the flow was unable to cut through both the Lockport Dolostone and the Irondequoit Limestone layer beneath the shale with the same intensity. As a result the waterfall began to assume a stepped appearance falling first from the upper level of the river to the top of the Irondequoit and then over this sill to the gorge below. Eventually the accelerated retreat of the main waterfall caused the crest on the Canadian side to intersect the river channel and the whole of the west side of the waterfall went dry. The talus pile is what is known as the Niagara Glen today. A plunge pool at the upper end of the Glen is known as Cripp's Eddy.

Erosion continued upstream until the retreat of the waterfall intersected the older buried gorge at what is now the whirlpool (previously described) and for a period of perhaps a few weeks the waterfall disappeared, replaced by a raging torrent filled with sands and gravel. The waterfall reformed as soon as the debris had been flushed out of the old channel. The gorge had also taken another sharp turn and was retreating almost south again.

The retreat continued until about 900 years ago when the waterfall was at the location of the present day American Falls. At this point the river flowed almost due west and went around Goat Island in two channels. The majority of the water went south of the island and the increased rate of erosion caused the water to separate into two cataracts at this point. The larger one, now known as the Horseshoe or Canadian Falls, continued its retreat upstream. The other was to suffer the same fate as had occurred thousands of years before at the Glen. Not enough water flowed over the crest to wash out the broken rock. It piled up to cover the shale and erosion ceased. It has been estimated that the Canadian Falls will reach the upper end of Goat Island in about 1,500 years and when this happens the American Falls will go dry.

The cataract has now encountered another formation of hard limestone called the Guelph Formation that sits atop the Lockport Dolostone. This formation is about seventeen metres thick. The water cascading over the various layers in the Guelph Formation caused the upper rapids above the waterfall.

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