Ancient seas, glaciers and waterfalls: the geologic history of the Niagara Escarpment

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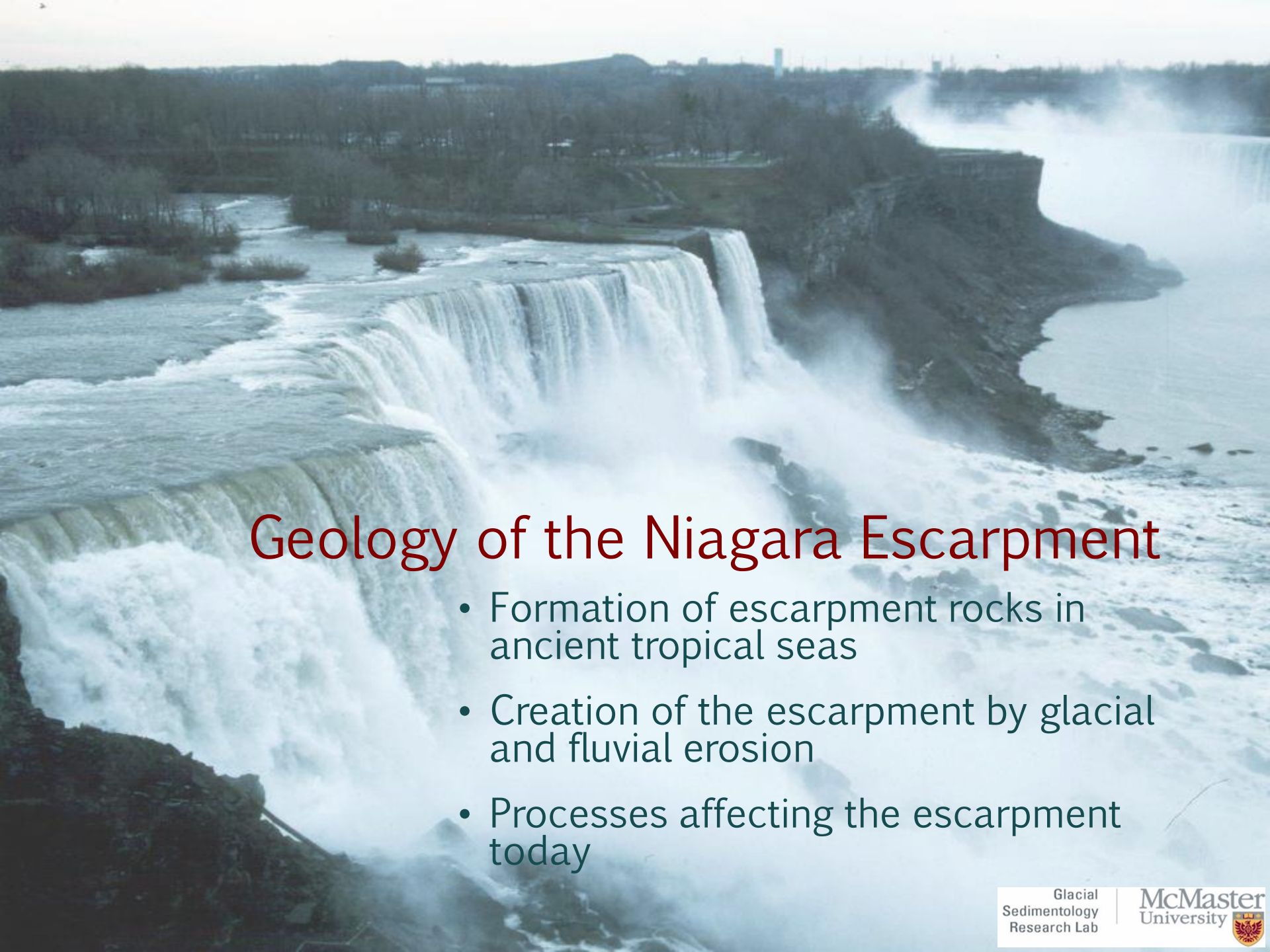

Geology of the Niagara Escarpment

- Formation of escarpment rocks in ancient tropical seas
- Creation of the escarpment by glacial and fluvial erosion
- Processes affecting the escarpment today

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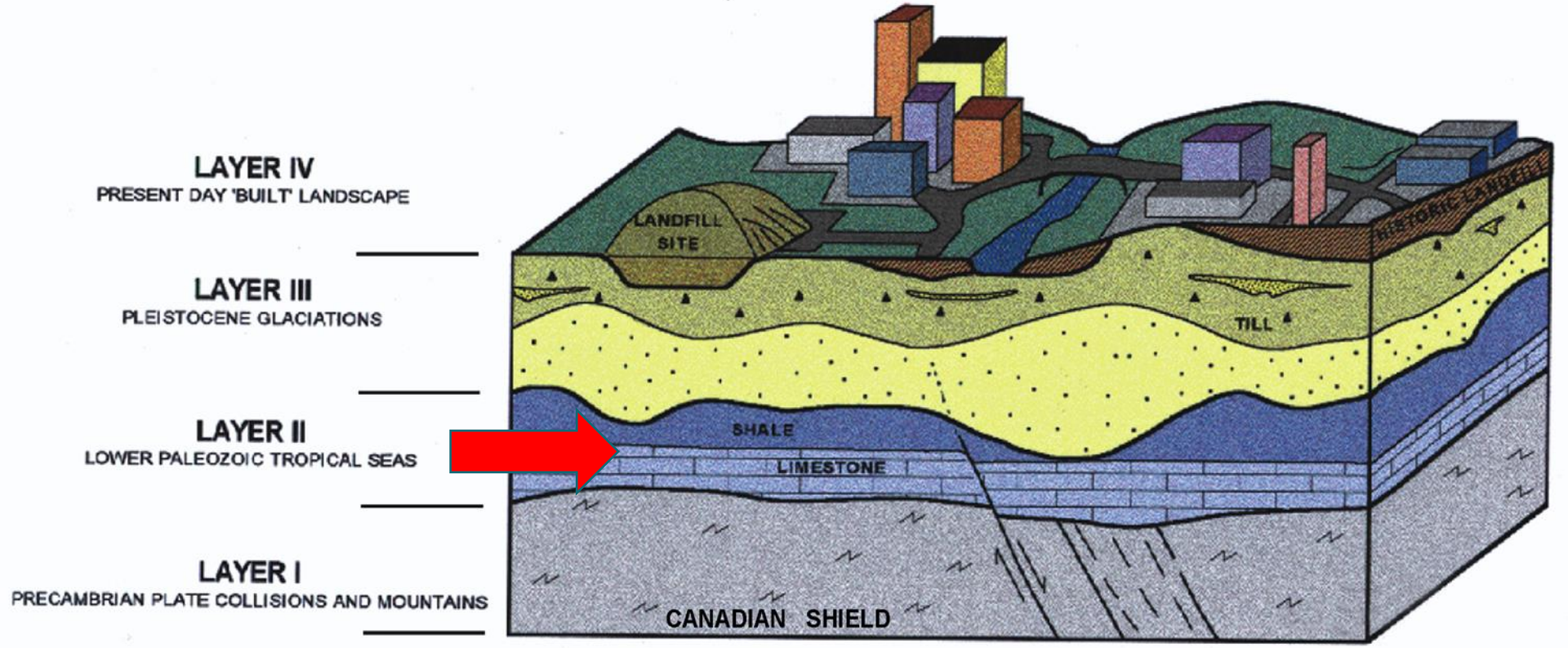
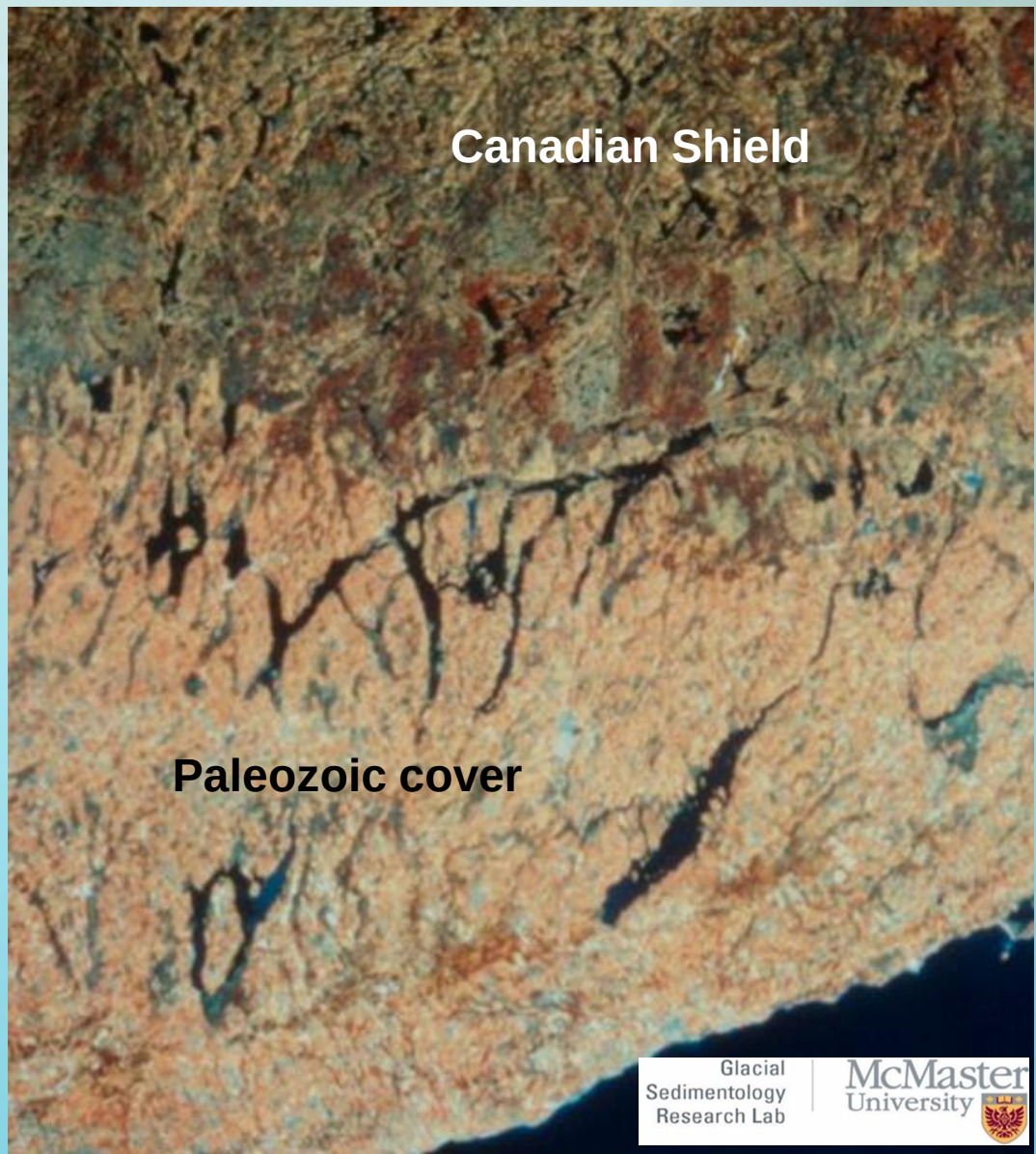
Geology of Ontario

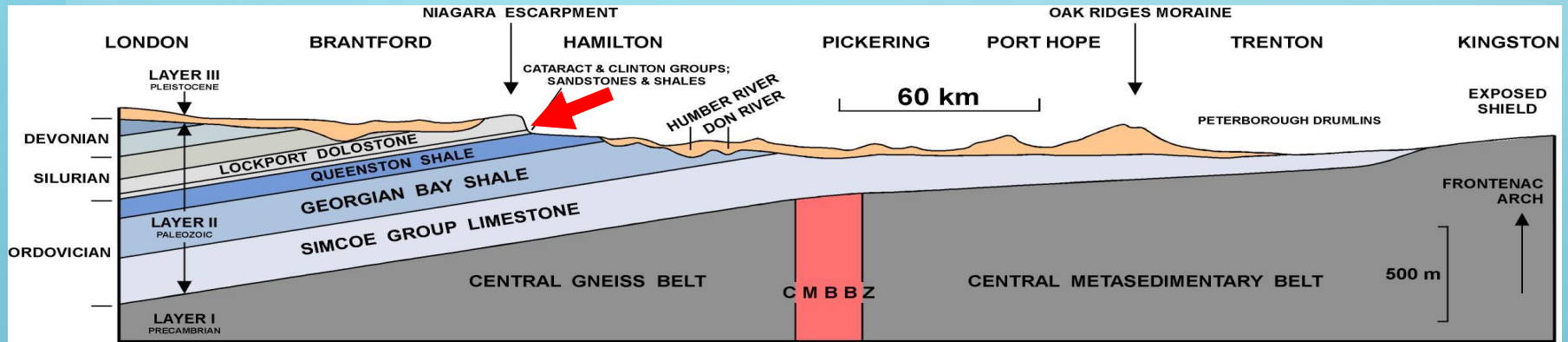


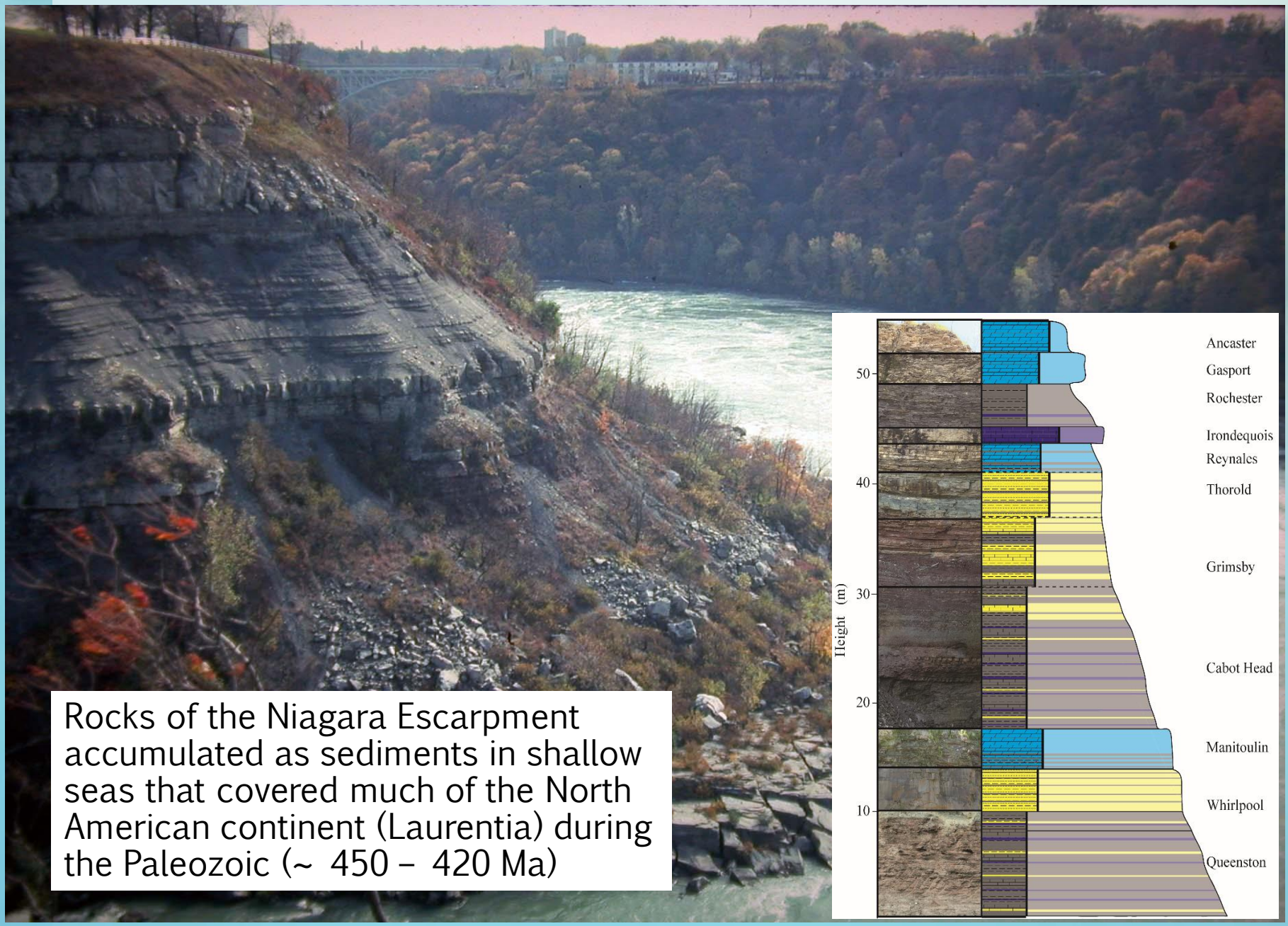
Paleozoic Sedimentary Rocks

- Deposited 600-350 million years ago
- Cover older Precambrian rocks of the North American craton (Canadian Shield) across much of southern Ontario



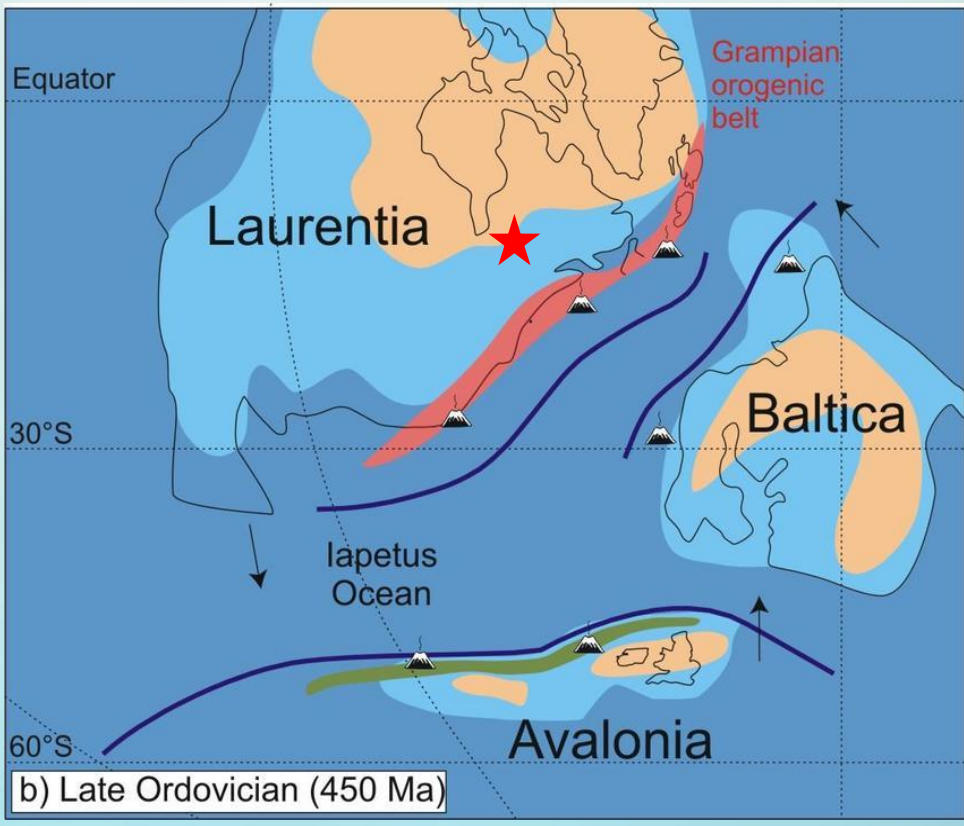

Shield
Paleozoic cover
CMBBZ
LAKE ONTARIO
MUSKOKA
SIMCOE
VICTORIA
DUFFERIN
DURHAM RM
YORK RM
NORTHUMBERLAND
PRINCE EDWARD
PETERBOROUGH
HASTINGS
LENNOX
ADDINGTON
Barrie
Newmarket
Aurora
Richmond Hill
Markham
Whitby
OSHAWA
Pickering
Port Hope
Cobourg
Peterborough
Lindsay
Bellville
SCARBOROUGH
EAST YORK
METROPOLITAN TORONTO RM
TORONTO
ETOBICOKE
MISSISSAUGA
BRAMPTON
Guelph
WATERLOO RM
KITCHENER
Cambridge
Oakville
BURLINGTON
HAMILTON
ST. CATHARINES
Niagara-On-The-Lake
Niagara Falls
LEGEND
ORDOVICIAN
UPPER ORDOVICIAN


NIAGARA ESCARPMENT
OAK RIDGES MORAINE
LONDON
BRANTFORD
HAMILTON
PICKERING
PORT HOPE
TRENTON
KINGSTON
LAYER III
PLEISTOCENE
CATARACT & CLINTON GROUPS; SANDSTONES & SHALES
HUMBER RIVER
DON RIVER
60 km
EXPOSED SHIELD
PETERBOROUGH DRUMLINS
DEVONIAN
SILURIAN
ORDOVICIAN
LOCKPORT DOLOSTONE
QUEENSTON SHALE
GEORGIAN BAY SHALE
SIMCOE GROUP LIMESTONE
LAYER II
PALEOZOIC
FRONTENAC ARCH
CENTRAL GNEISS BELT
C M B B Z
CENTRAL METASEDIMENTARY BELT
500 m
LAYER I
PRECAMBRIAN

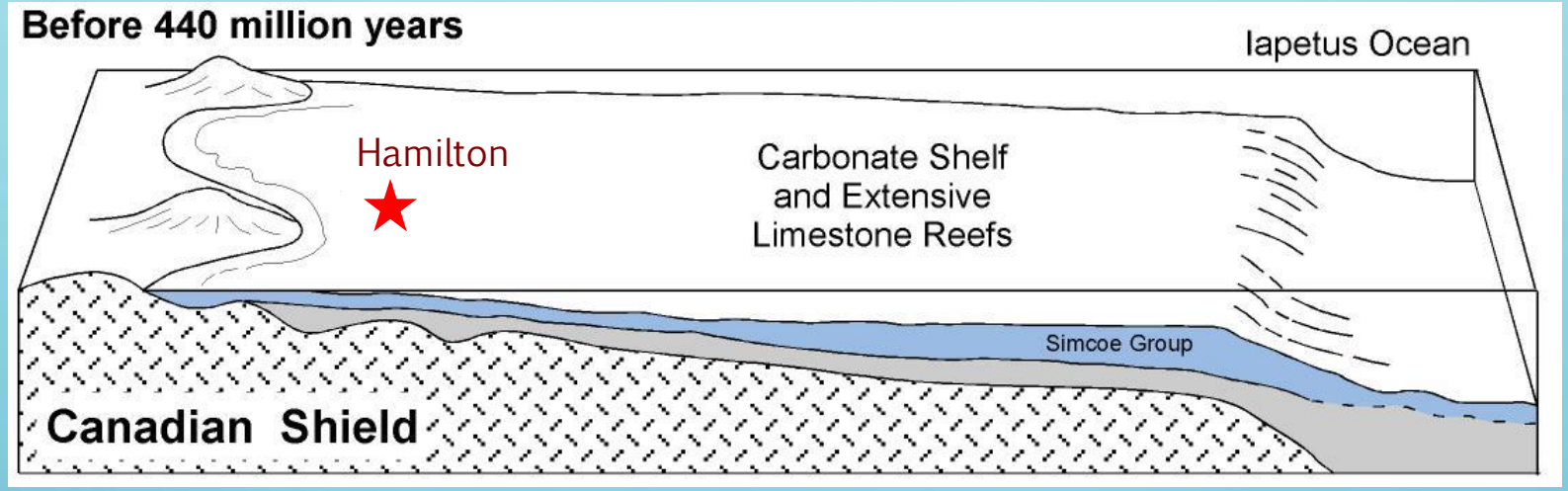


Rocks of the Niagara Escarpment accumulated as sediments in shallow seas that covered much of the North American continent (Laurentia) during the Paleozoic (~ 450 – 420 Ma)

- Before about 440 million years ago, carbonate reefs thrived in a tropical ocean that covered the area
- Now form limestones of the Simcoe Group



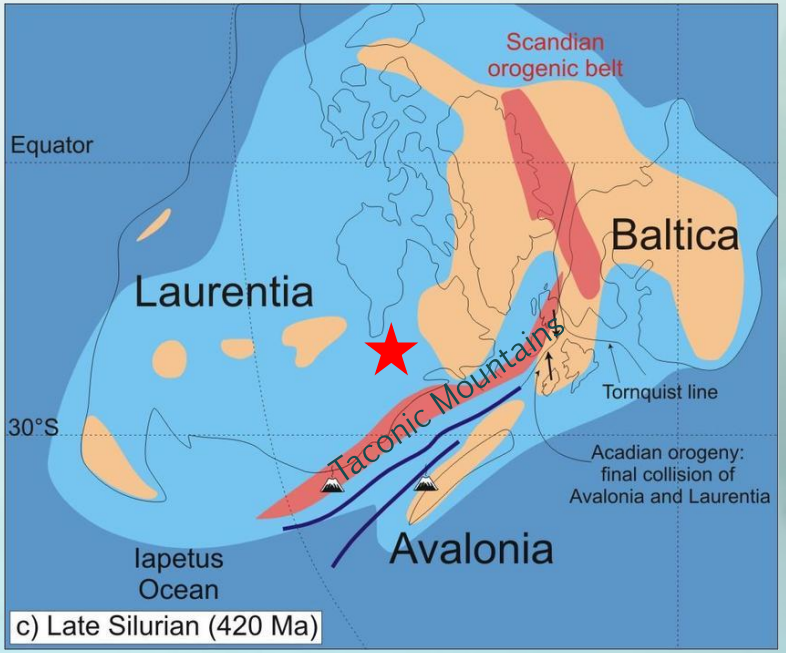
Note: Baltica moving toward Laurentia

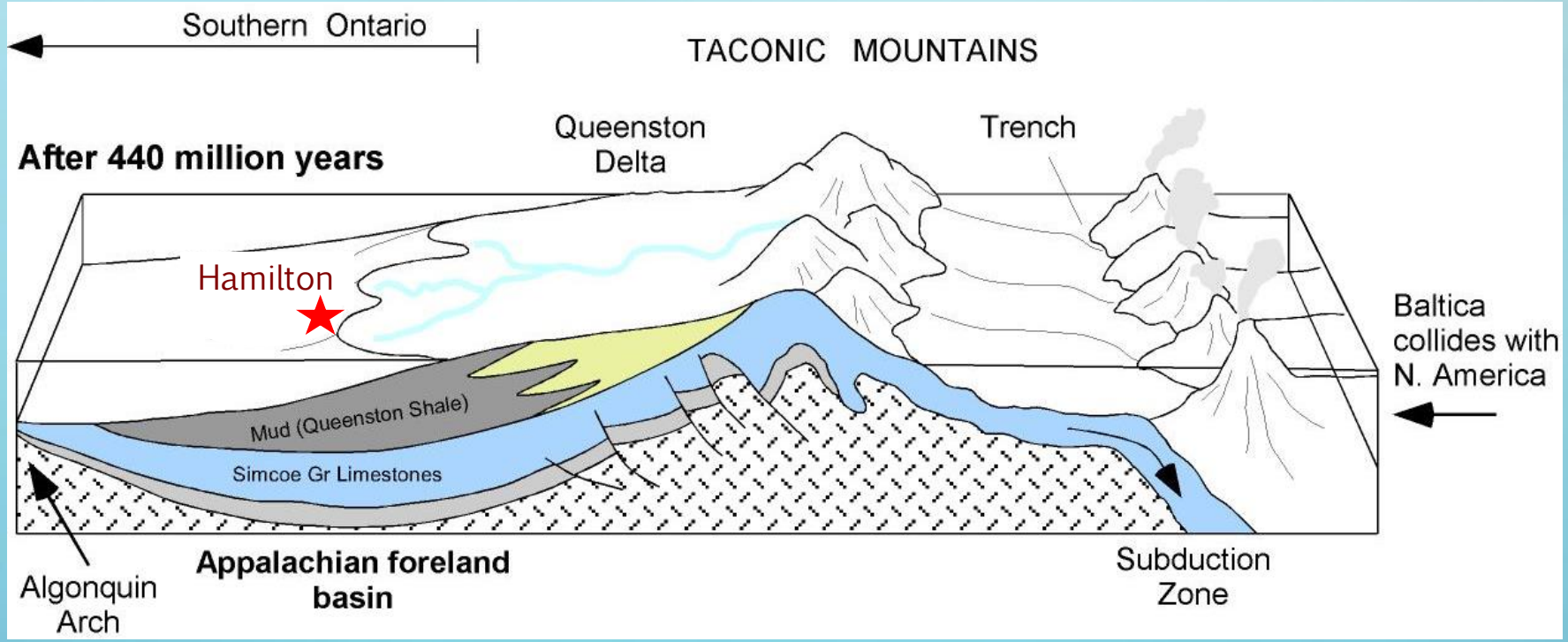


Baltica collides with Laurentia and forms the Taconic Mountains

An inland sea forms to the west

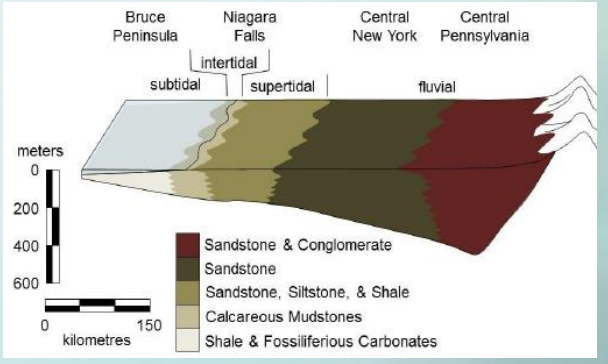
Sediments from the eroding mountains form an extensive muddy delta (Queenston Delta)

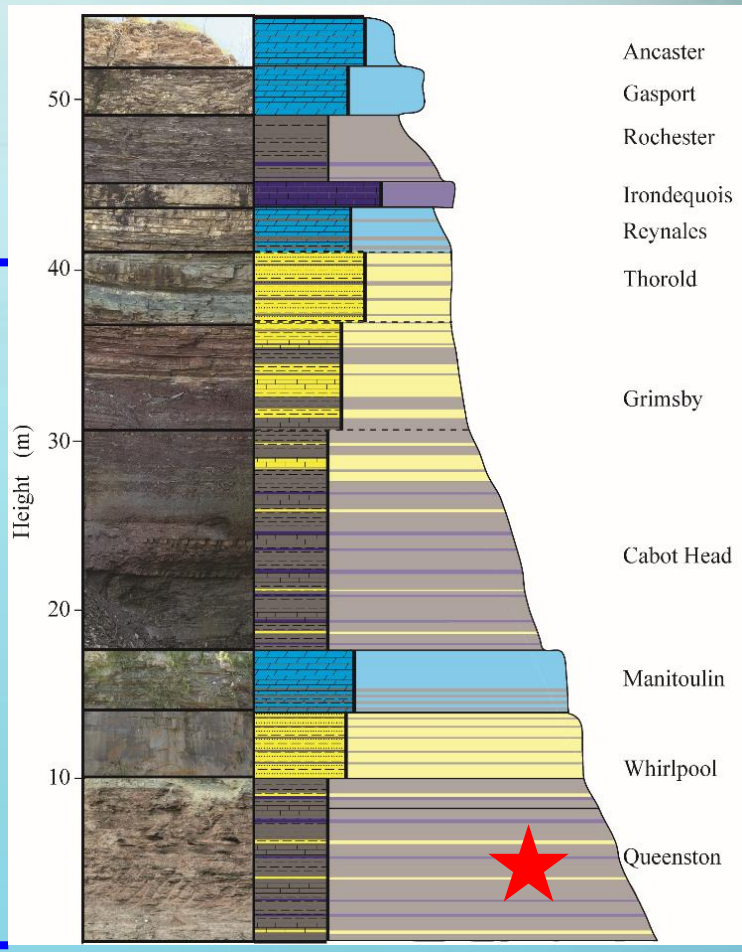




Queenston Clastic Wedge

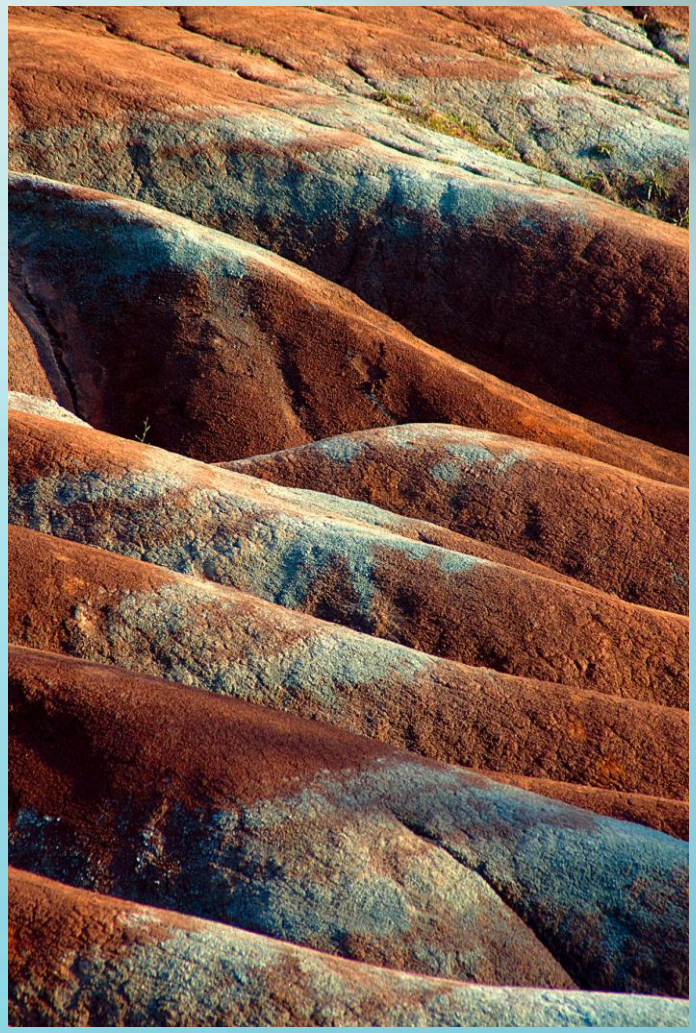
- Queenston clastic wedge is recorded in the Niagara Escarpment by:
  - Queenston shale, Whirlpool sandstone, Grimsby shale, Thorold sandstone





Queenston Shale – deposition on a muddy delta

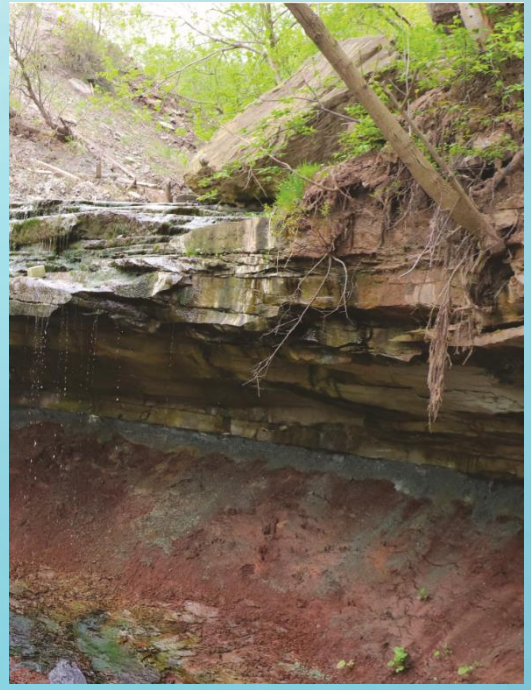
- Red and grey shales with interbeds of siltstone, limestone and sandstone
- Well exposed at:
  - Devil's Punchbowl (lower)
  - Caledon Badlands
  - Big Bay



https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Cheltenham_Badlands_closeup.jpg/1200px-

Whirlpool Sandstone:

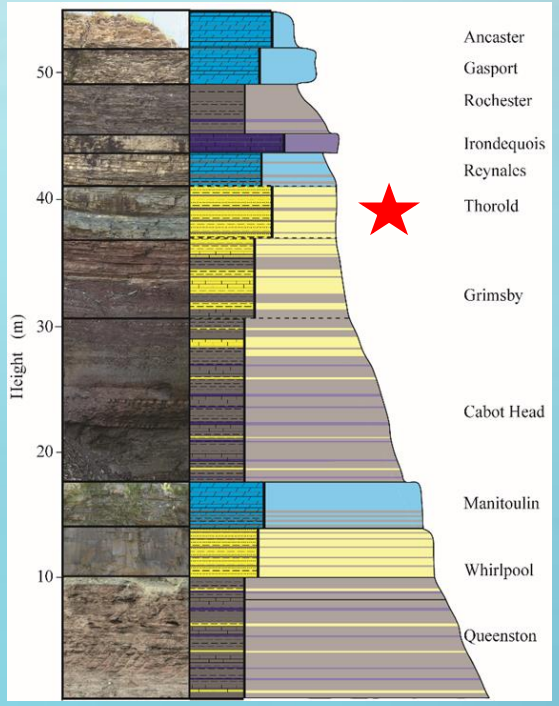
- Overlying Whirlpool Sandstone formed under higher energy fluvial (river) conditions
  - channelized sandstones, cross beds
- Well exposed at:
  - Niagara Gorge, Devil's Punchbowl



Ancient earthquakes?

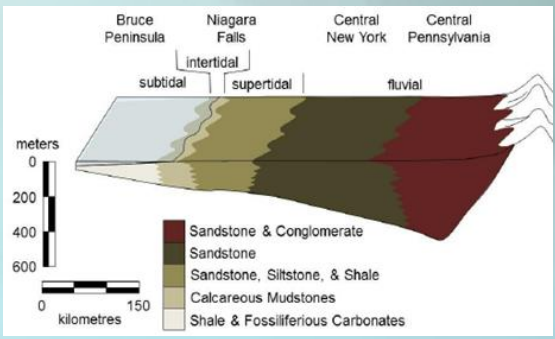
- Thorold Formation –
  - horizon of deformed sandstone pillows
  - caused by seismic disturbance of the seafloor

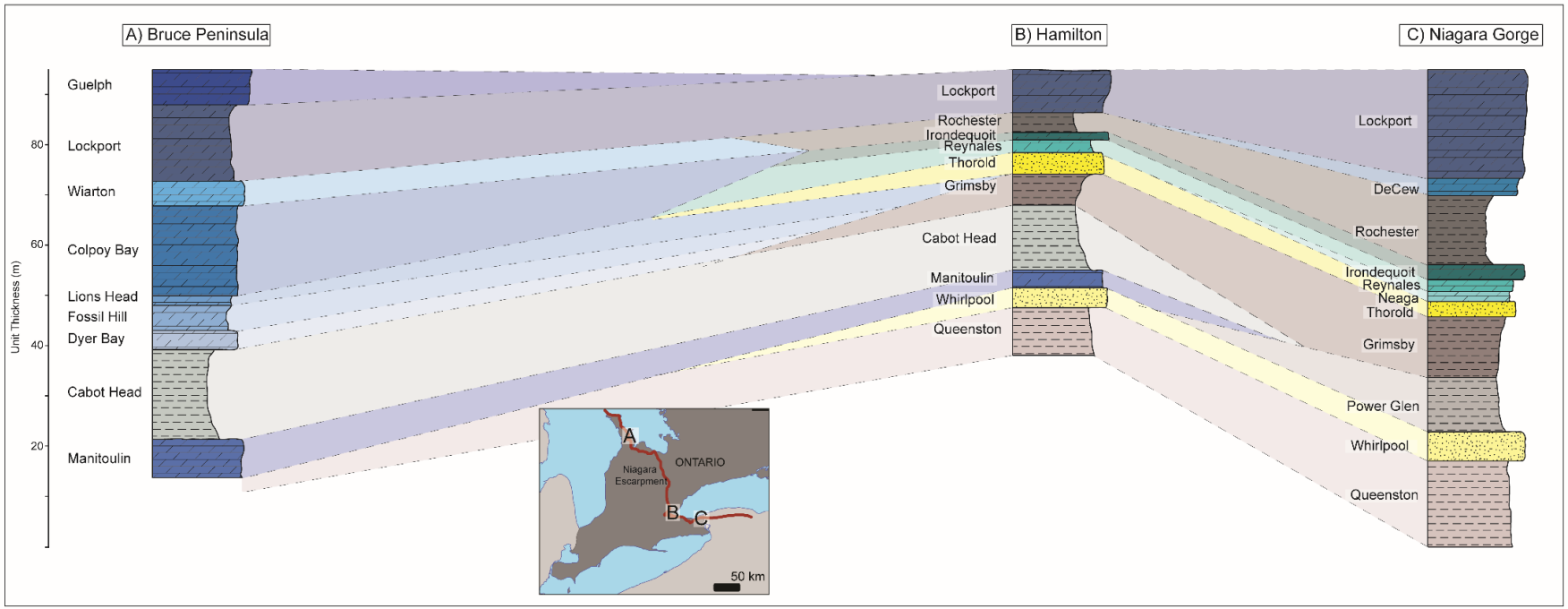
- Seismite
  - well exposed at the Jolly Cut, Devil's Punchbowl, Hamilton



Niagara Escarpment: Bruce Peninsula

- Changes from Niagara to Bruce Peninsula
  - less sandstone/mudstone (further away from source of deltaic sediments)
  - limestone units formed in clear, clean water (Dyer Bay, Lions Head, Colpoy Bay, Wiarton)
  - Guelph Fm. preserved as cap rock (part of Lockport Group)





Uplift of Taconic Mountains ceased around 430 Ma

- Sand and muddy sediment no longer supplied
- Clear warm waters – carbonate reefs developed

Depositional Environments (~430 Ma)

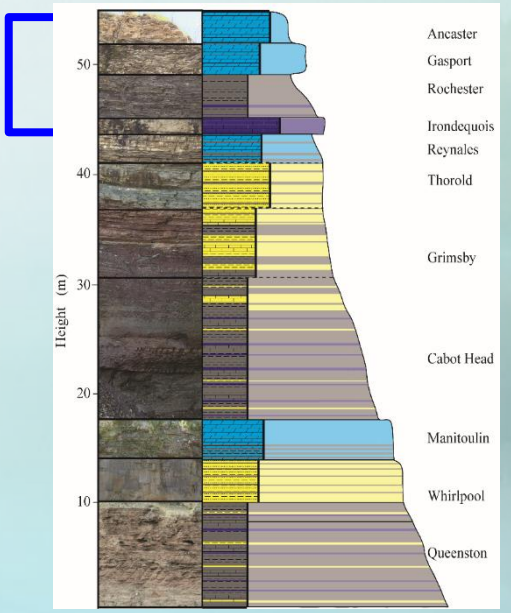
Limestones deposited in shallow (< 10 m) tropical seas

- formed at 0 to 30S latitude; warm climate
- local ‘patch reefs’ and extensive carbonate platforms

Tropical seas…

Recorded in Niagara Escarpment by:

- limestones and dolostones (Lockport, Irondequoit)



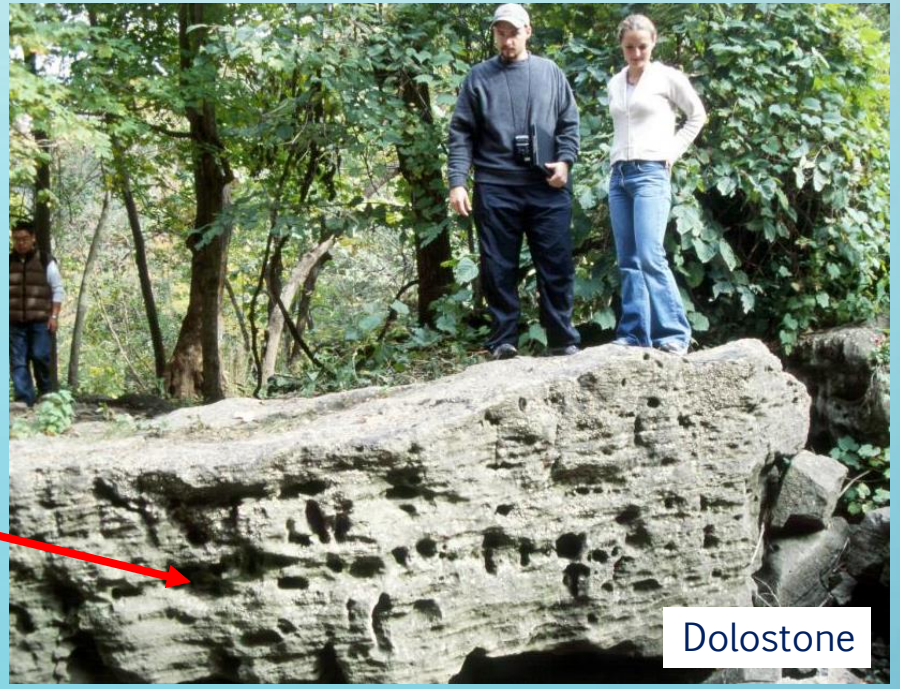
- some mud deposition (Rochester Shale)

What is the difference between limestone and dolostone?

- Limestone
  - calcium carbonate $CaCO_3$
- Dolostone
  - calcium magnesium carbonate $CaMg(CO_3)_2$

When limestone changes to dolostone – volume reduction

- **vugs** (cavities) produced



Life in Paleozoic seas


brachiopods

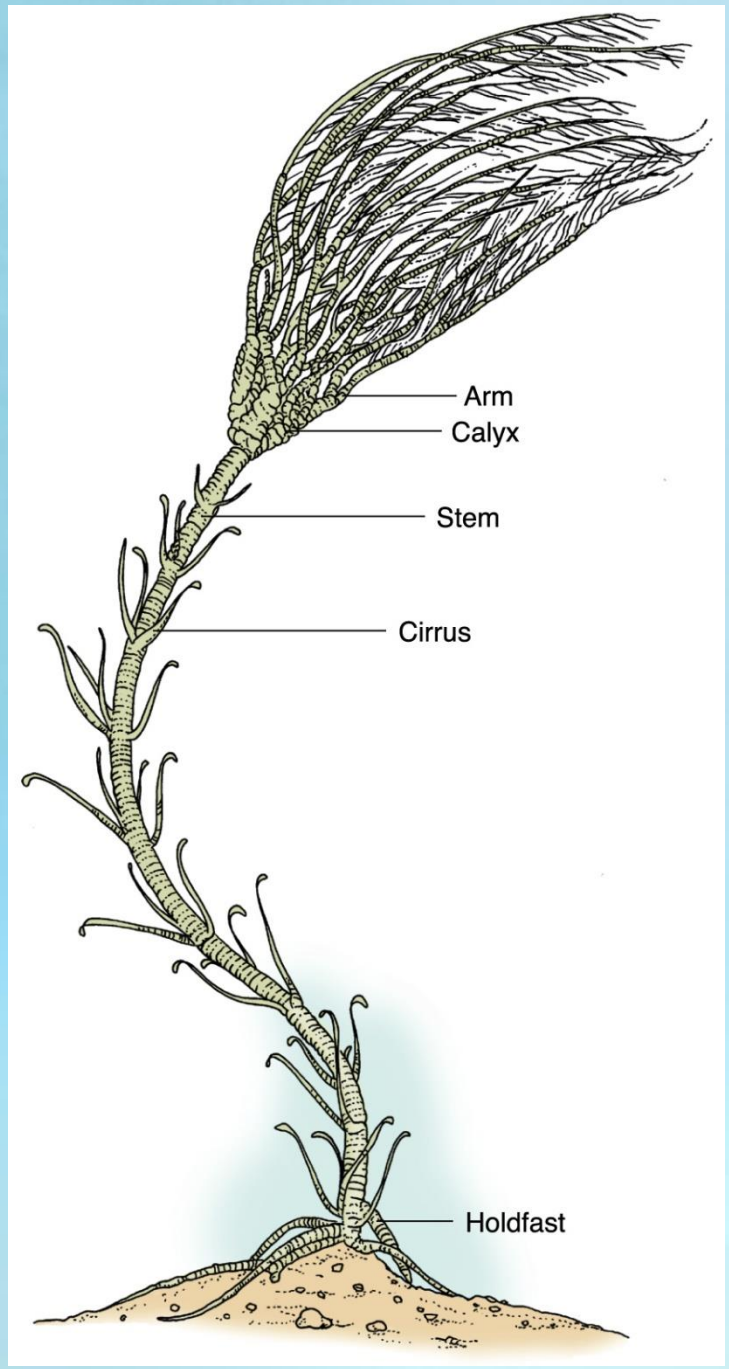

corals


eurypterids


Now preserved as fossils


trilobites


cephalopods



Crinoids (sea lilies)

- animals - attached to seafloor
- arms gather food particles from water
- stem consists of plates that fall apart when the animal dies – ***ossicles***

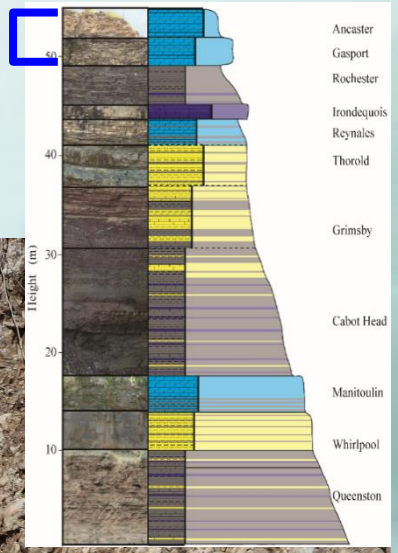
ossicles

Lockport Formation (Cap rock)

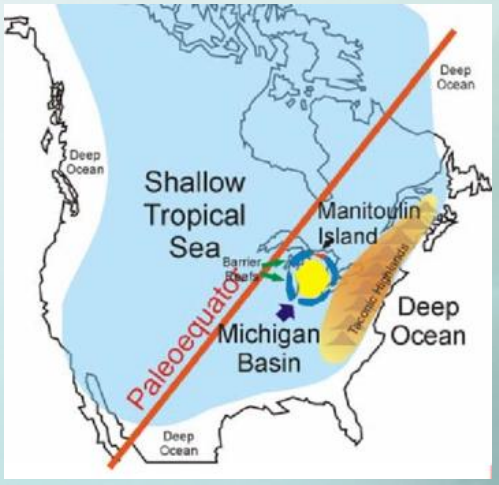
- Two members:

- Ancaster (upper)
  - thin beds
  - highly fractured
  - contains chert nodules

- Gasport (lower)
  - thicker beds
  - fewer fractures
  - less chert
  - (Amabel equivalent)



Demise of the Reefs

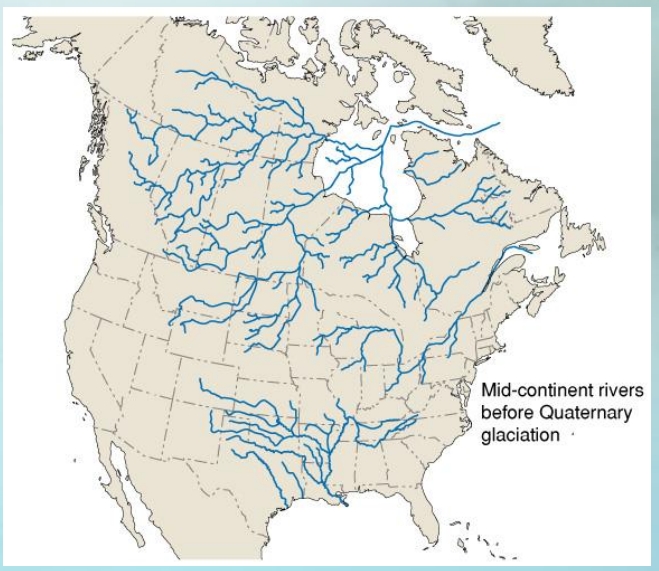


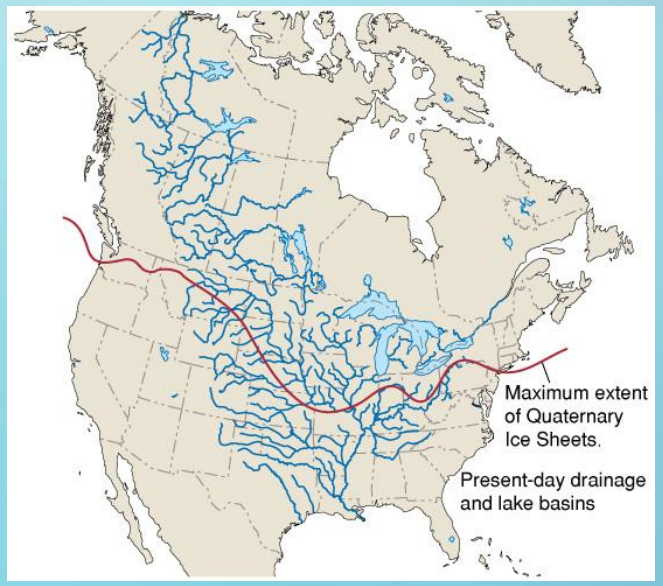
- By approximately 420 Ma….
  - climate became warmer and more arid
  - sea shallowed exposing reefs - reefs died
  - extensive tidal flats or ‘sabkhas’ formed

This resulted in….salt deposition

Between ~ 400 Ma and 3 Ma the eastern part of North America was exposed…

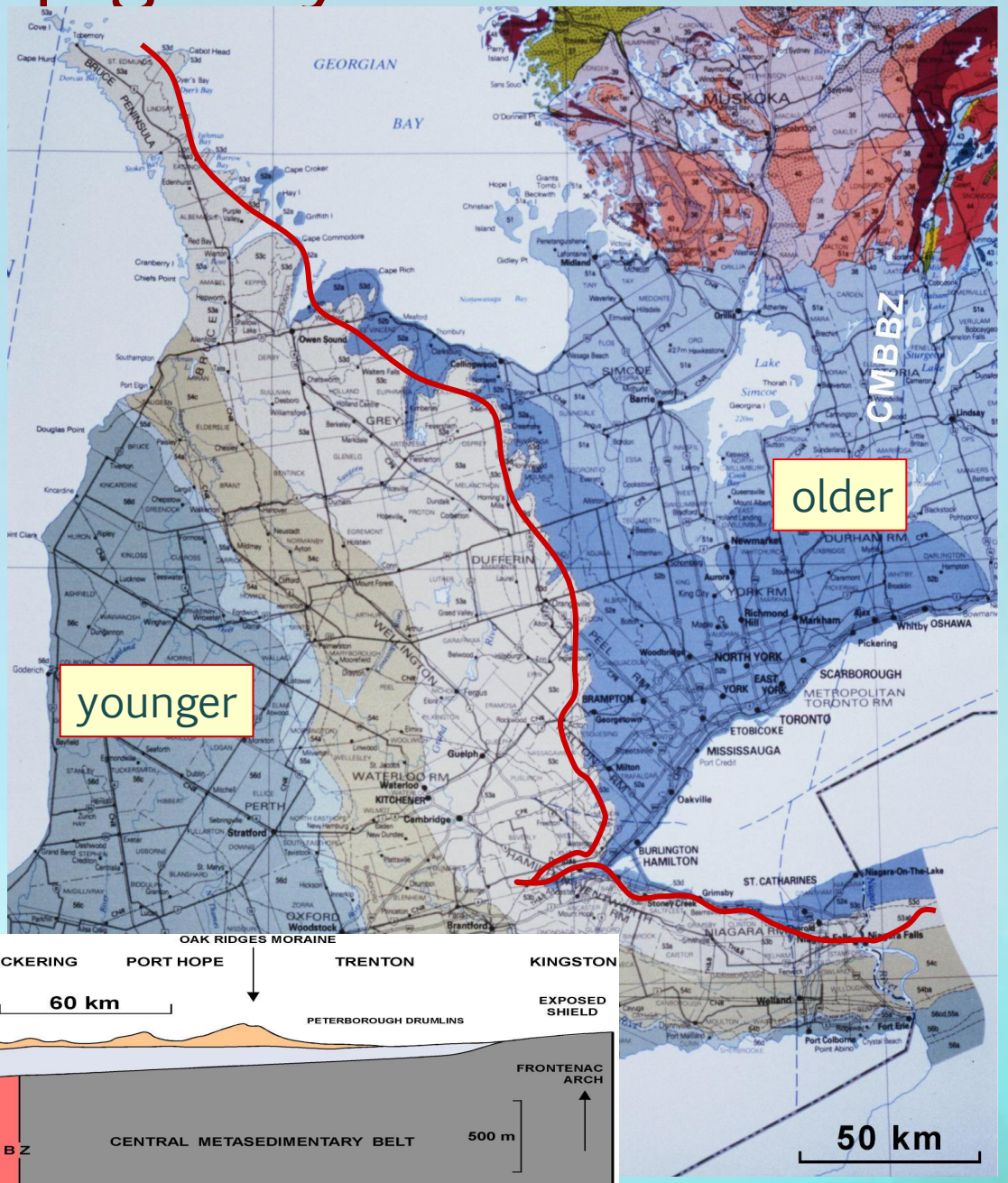
- No record of sedimentation
- Erosion of the Paleozoic rocks
  - by fluvial processes (e.g. Bell River)
- After ~ 3 Ma
  - by glacial processes

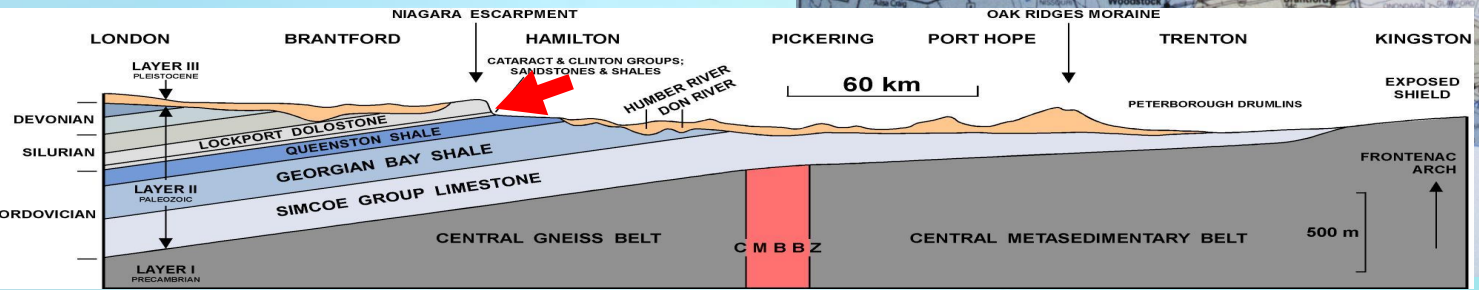




Paleozoic rocks dip gently to SW

- Erosion and removal of Paleozoic rocks from northeast to southwest
- Resistant Silurian limestones and dolostones form the Niagara Escarpment





Formation of the Niagara Escarpment

- Erosion of the dipping Paleozoic rocks has created the steep face of the Niagara Escarpment
- Although the rocks are old…. the escarpment as a landform is young!

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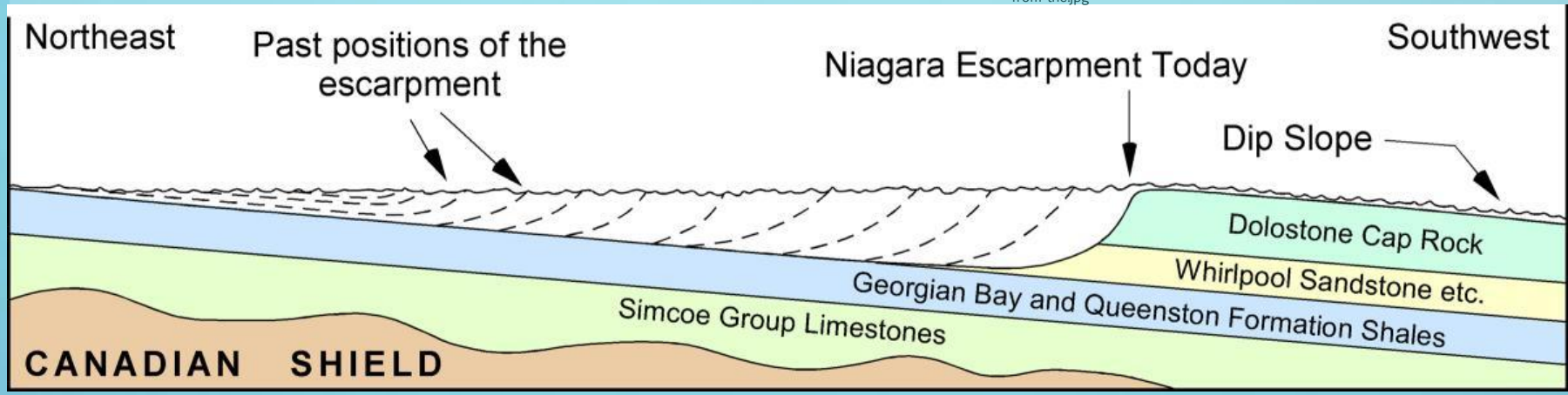
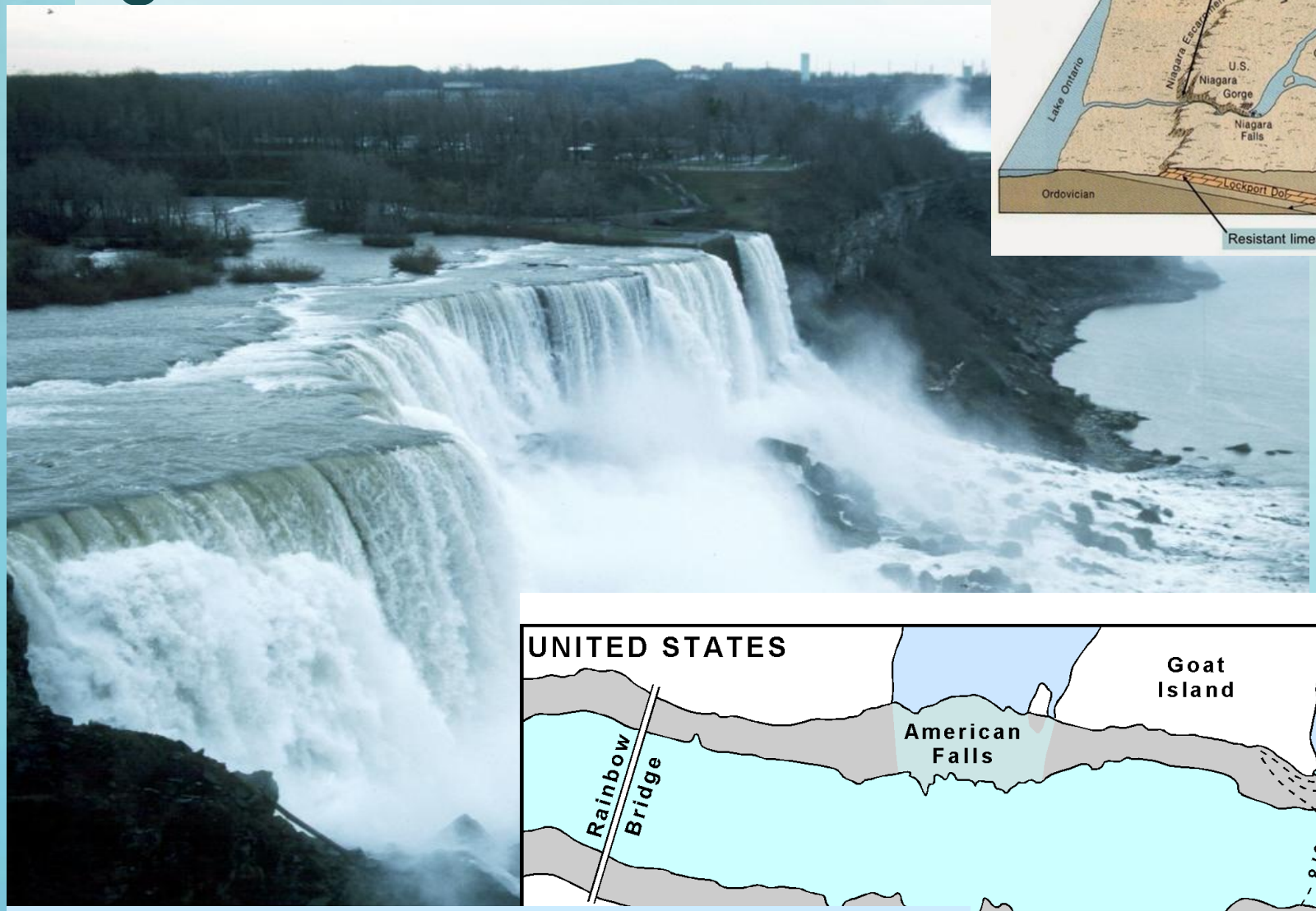
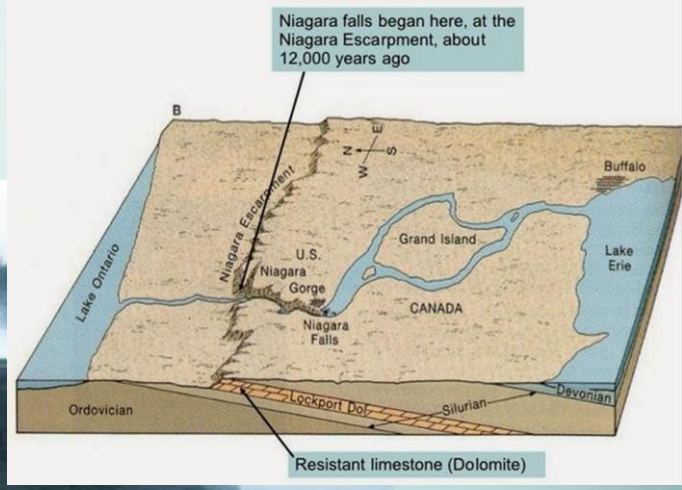


Niagara Falls



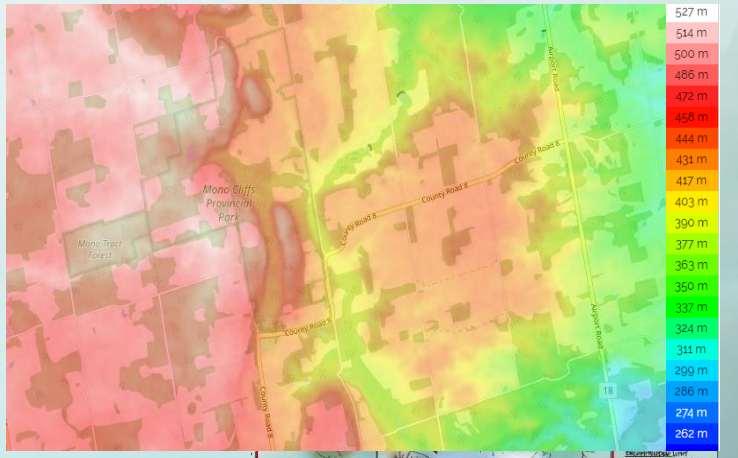


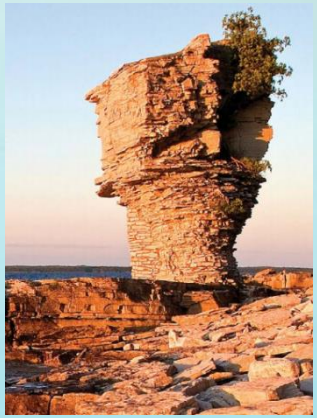
~10 km erosion over 12,500 years

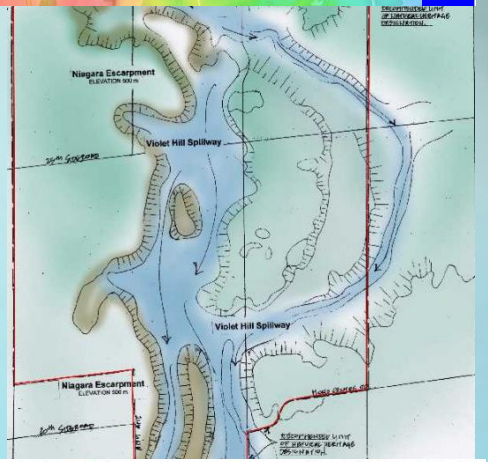
Similar processes have produced waterfalls and valleys in Hamilton area e.g. Tiffany Falls

Outliers

- Areas of particularly resistant rock
- e.g. Mono Cliffs – north of Orangeville, Milton Outlier, Flowerpots
- At Mono - escarpment has been cut by a large meltwater channel (Violet Hill Meltwater Channel ~13,000 years ago)
- Outlier of escarpment rocks protected by a resistant cap of Amabel Dolostone (Gasport equivalent)



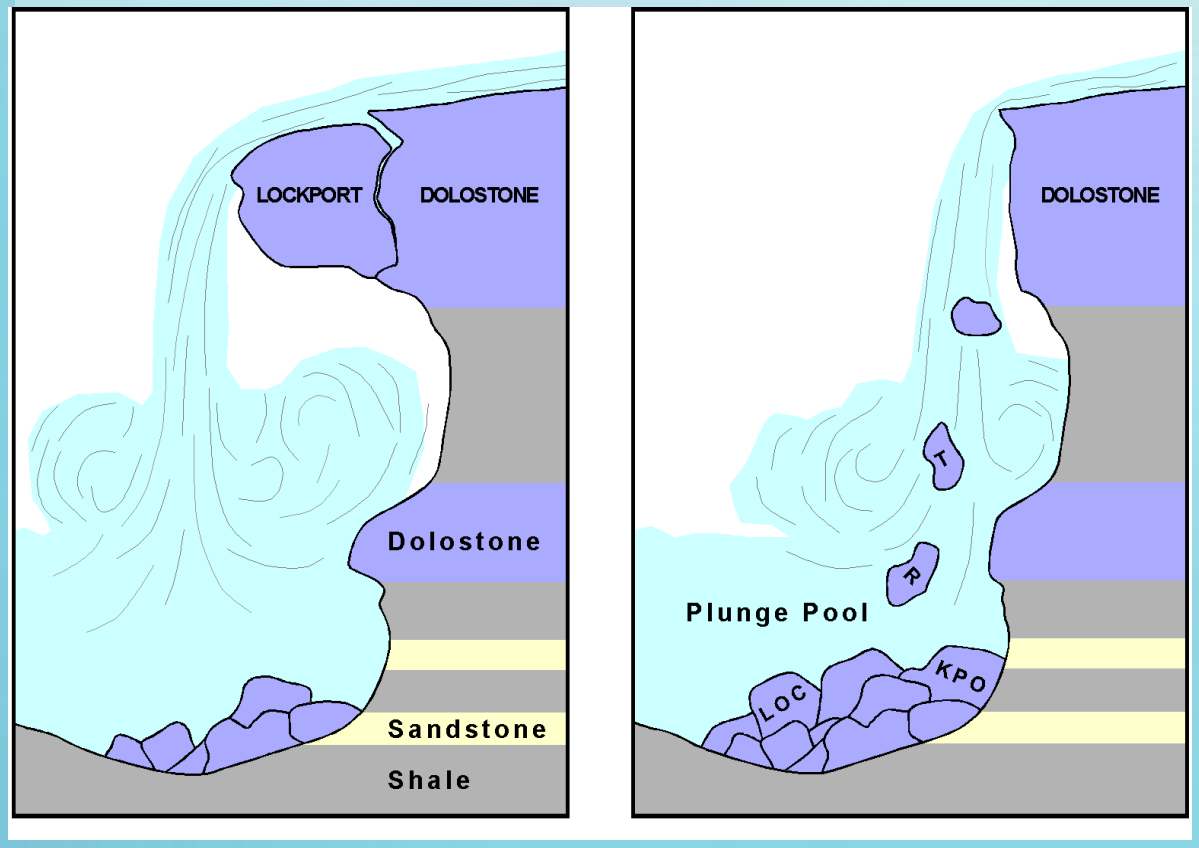




Erosion processes affecting the escarpment…

- Movement of water over escarpment rocks

- Undercutting: Niagara Escarpment has a resistant 'cap rock'
  - Lockport Dolostone



More easily eroded rocks below
- Rochester Shale

Undercutting causes significant retreat of the falls/ escarpment

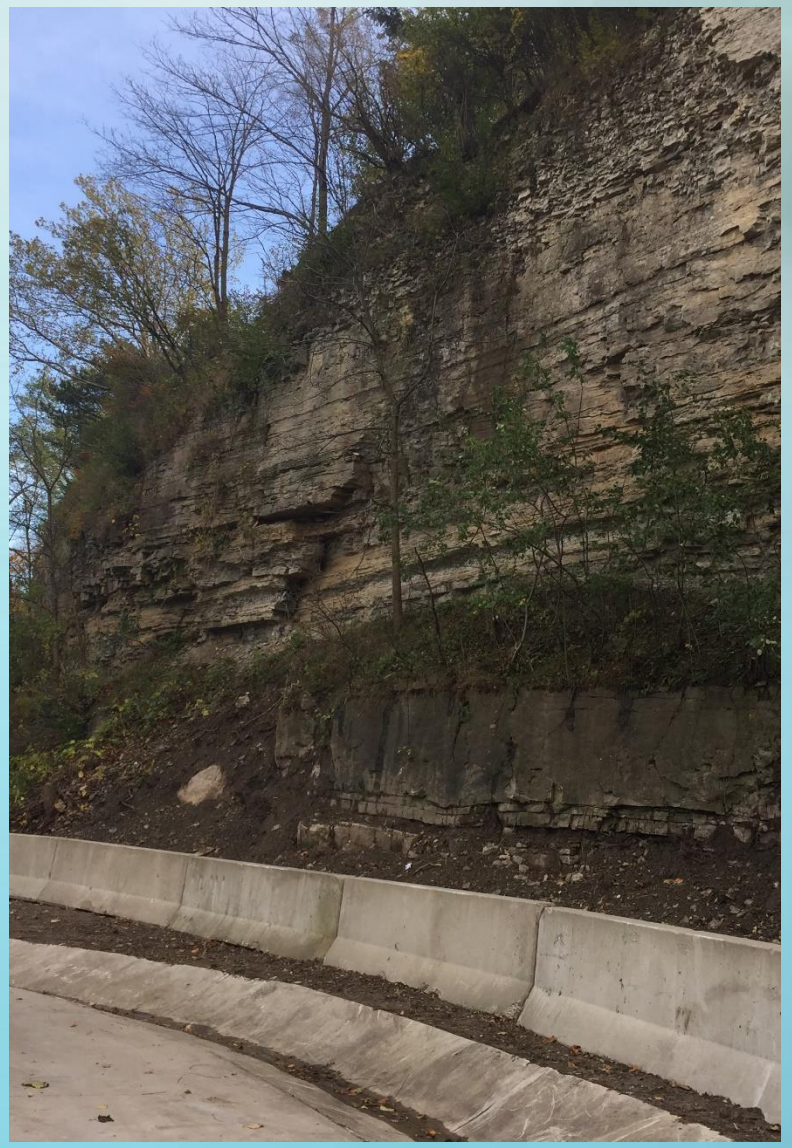
Erosion processes affecting the escarpment…..

- Movement of water through escarpment rocks
  - Summer – vegetation growth
  - Winter – ice growth

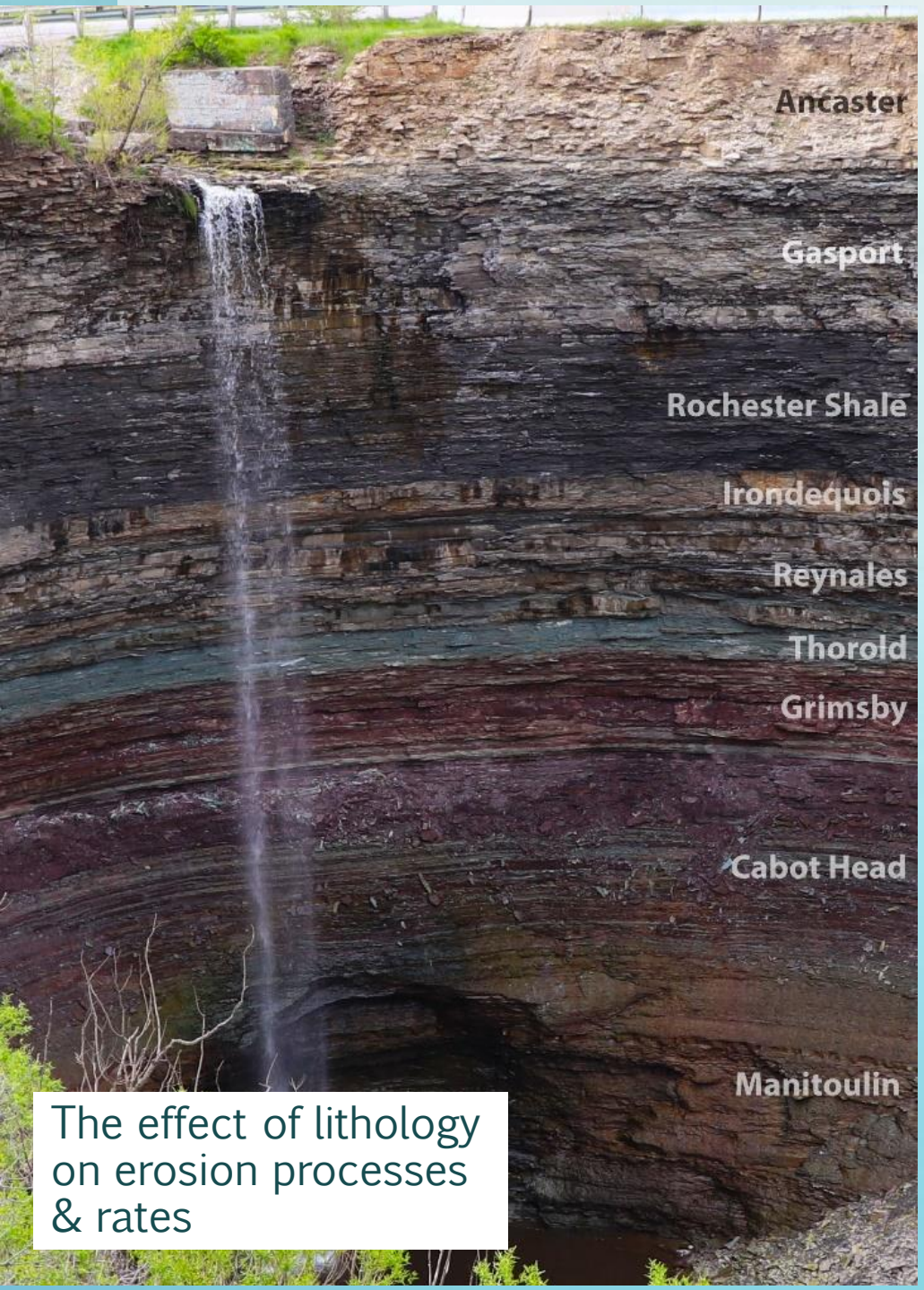
- Freeze-thaw weathering
  - water expands when it freezes in cracks
  - breaks rocks apart
  - loosens blocks from rock face

What we don't know….

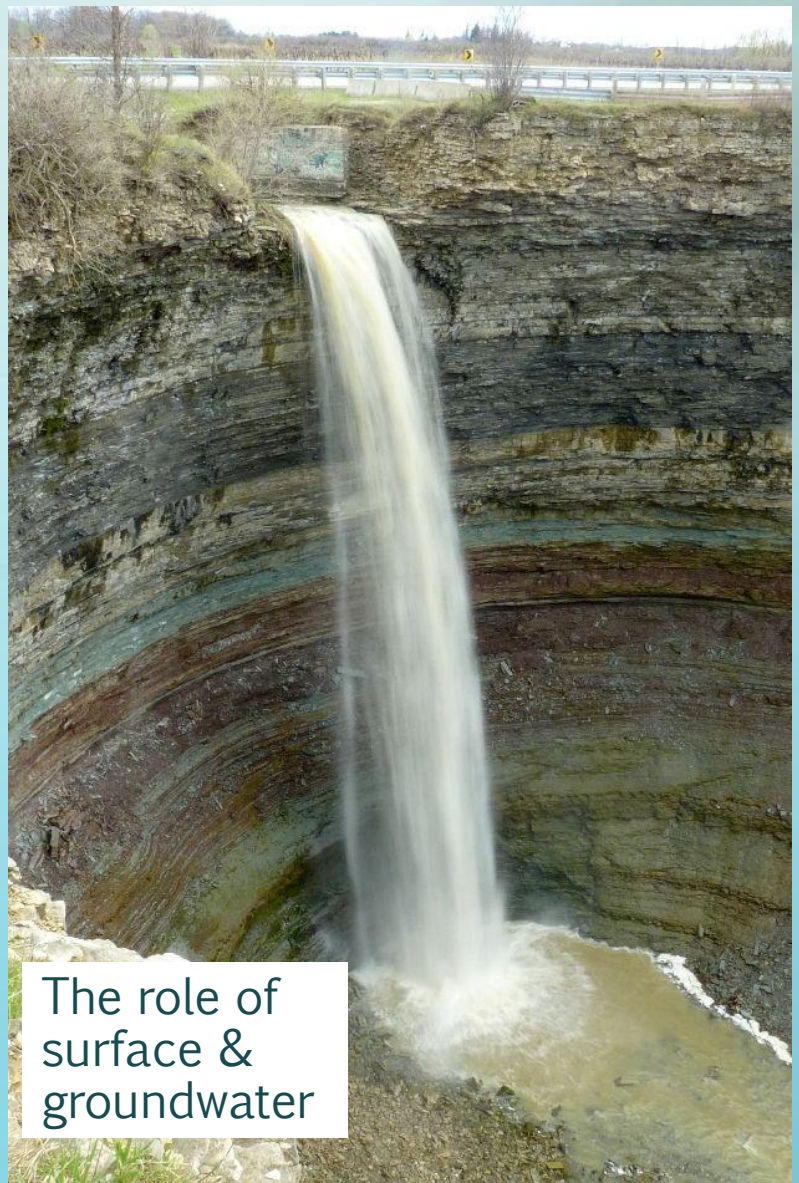
- How quickly the escarpment is eroding?
- What factors affect erosion processes and rates?
- How processes and rates vary along the escarpment?
- Which areas of the escarpment are most susceptible to erosion?
- Will climate change affect erosion processes and rates?



What we are studying…..



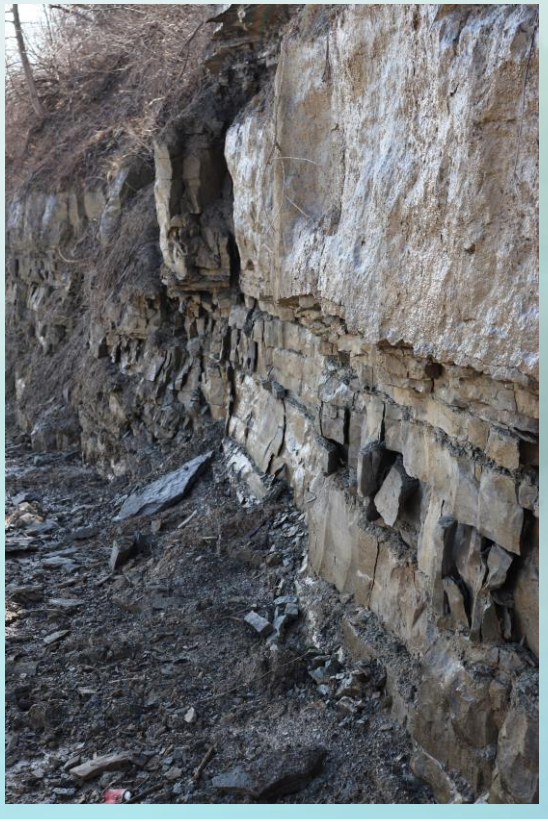
The effect of lithology on erosion processes & rates

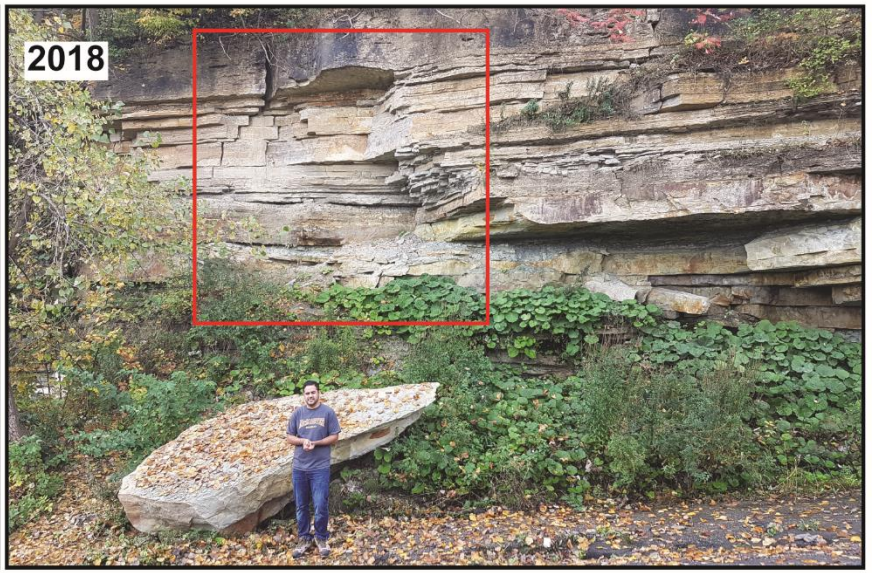


The role of surface & groundwater

What we are studying…

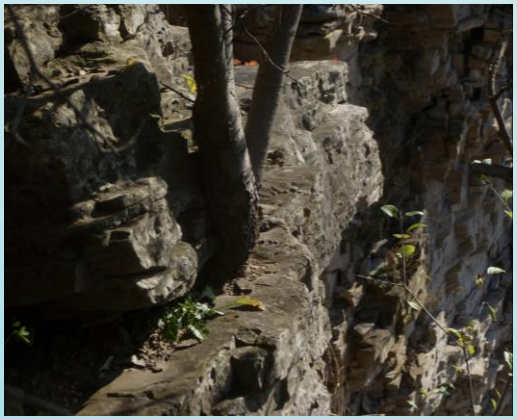
- How factures in the rock affect erosion processes and rates

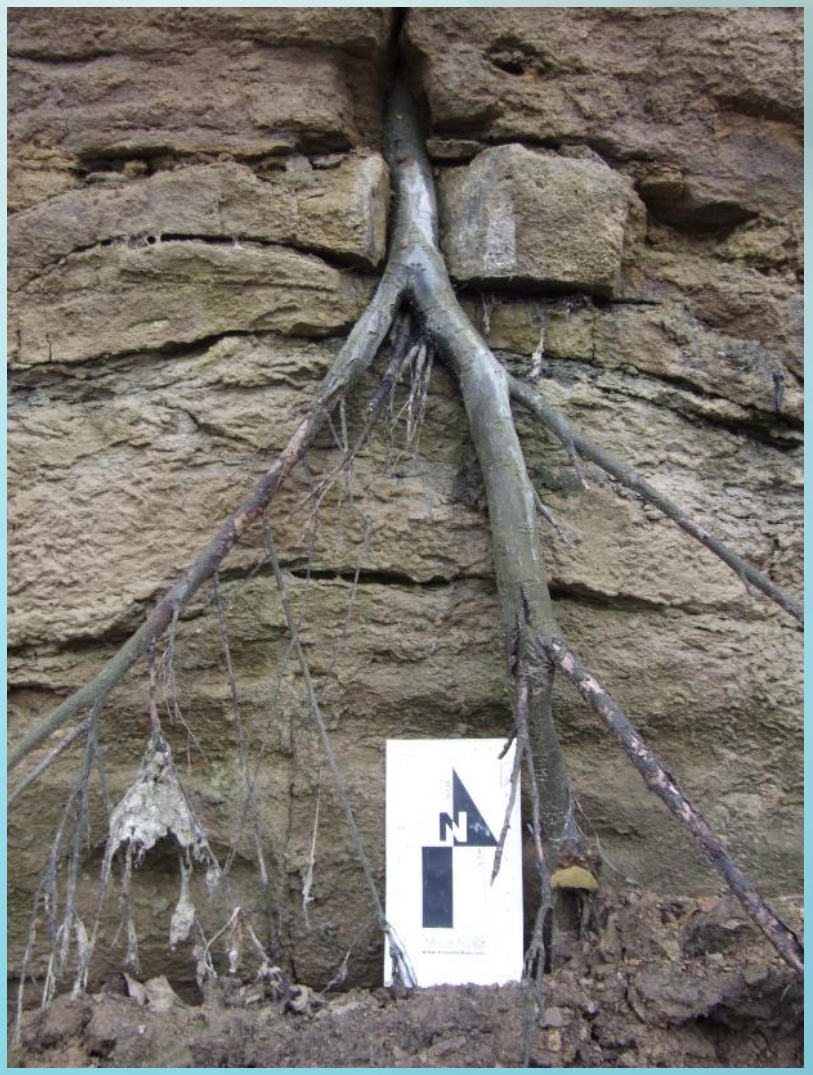




What we are studying…..

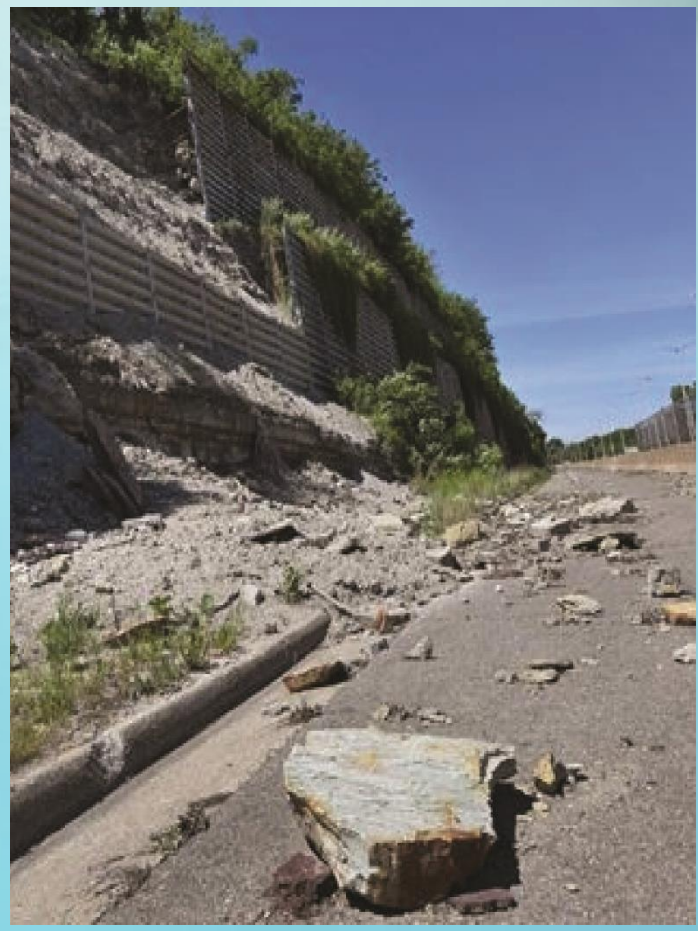
- The impact of vegetation on erosion processes and rates





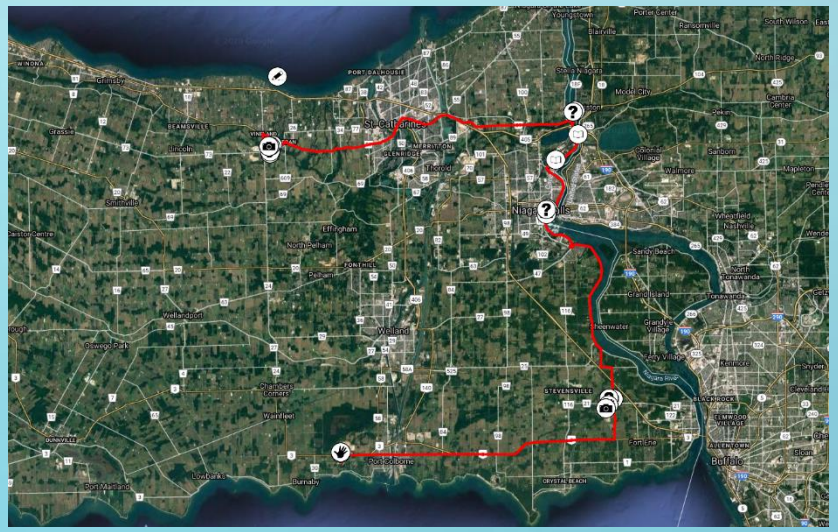
Outcomes…

- Better understanding of geological history of the escarpment
- Better understanding of processes affecting escarpment today
- Identification of areas of ‘high risk’
- Identification of mitigation measures



Most importantly….

- Provide information to public (in collaboration with BTC and APGO Education Foundation)
  - Create - Virtual Field Trips
  - Create - Geotrails
  - www.geoscienceinfo.com
- We need your help:
  - Information/questions about interesting/unusual geological features along the trail
  - Photos of any collapse features or anything looking unstable (with location)
  - Older photographs showing changes along the trail
  - Please apply to Citizen Science (mcroll@brucetrail.org)



THANK YOU

Questions?

Karst in Beaver Valley

- Karst is a product of the dissolution of carbonate bedrock by acidic rainwater
- Karst map of southern Ontario
  http://www.geologyontario.mndm.gov.on.ca/mndmfiles/pub/data/imaging/GRS005//karst-map.pdf

(Banks & Brunton, 2017)