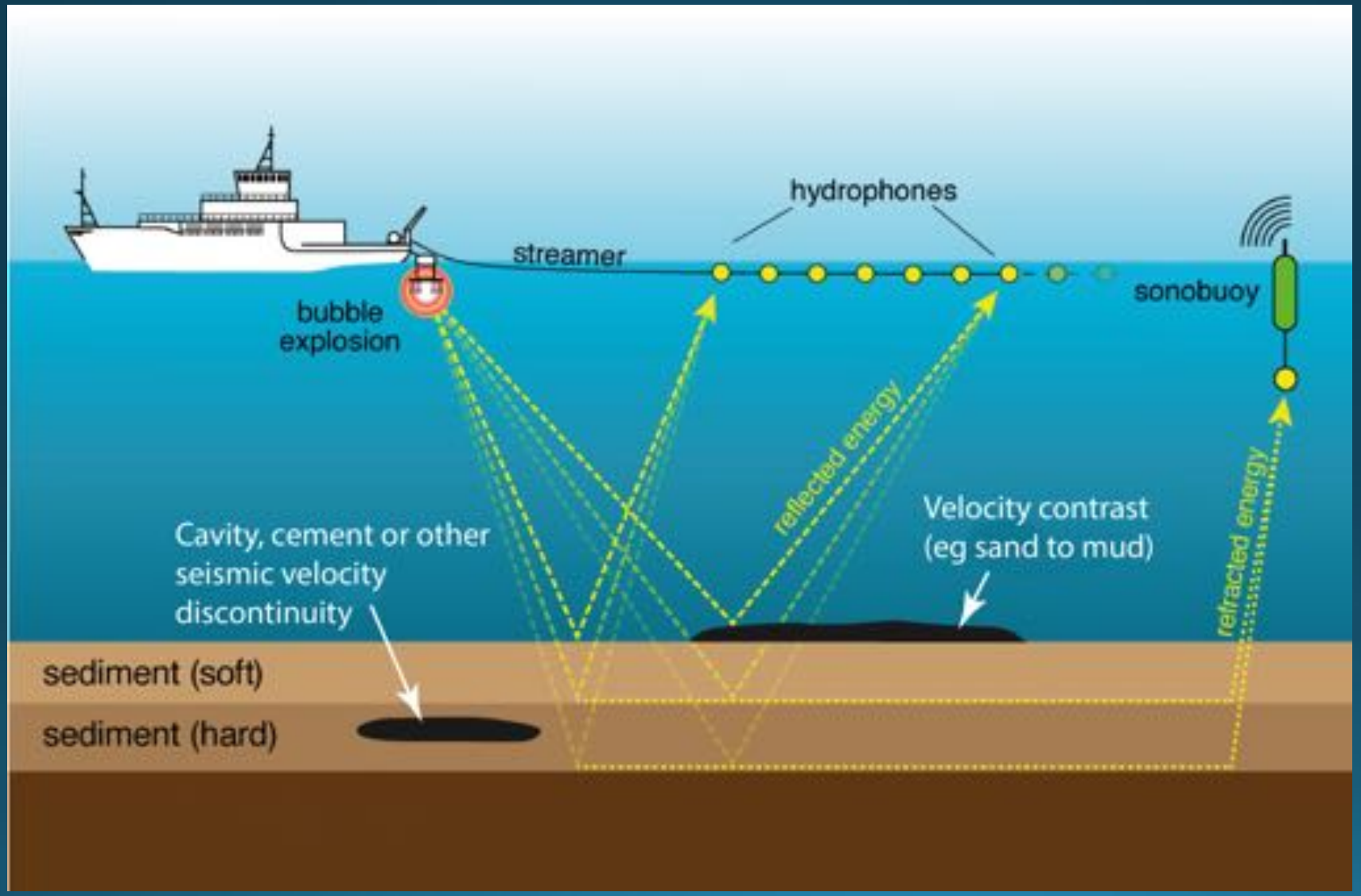
Angus Ferguson and John Warren

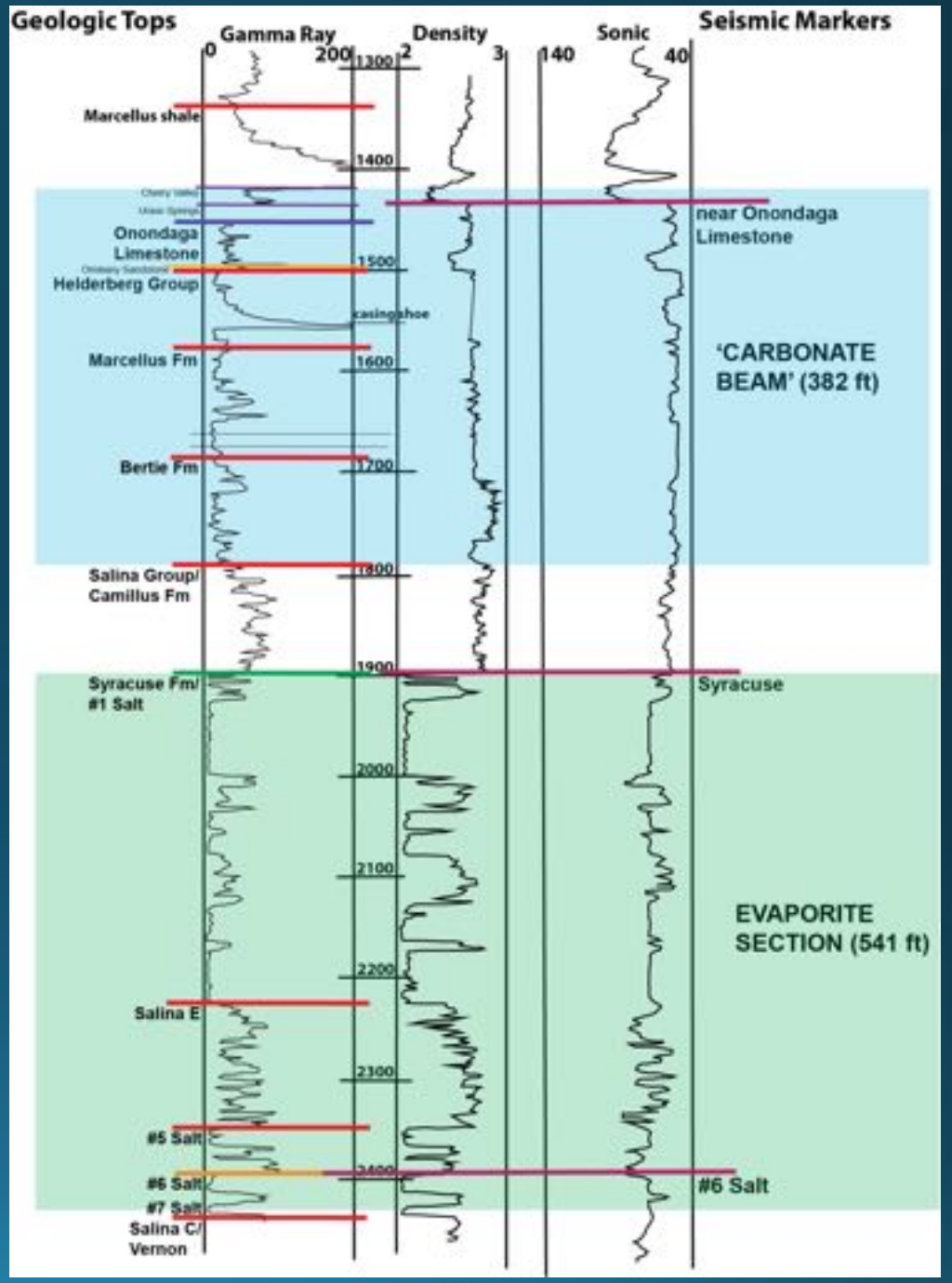
Seismic and Salt

What is seismic?



Seismic Units

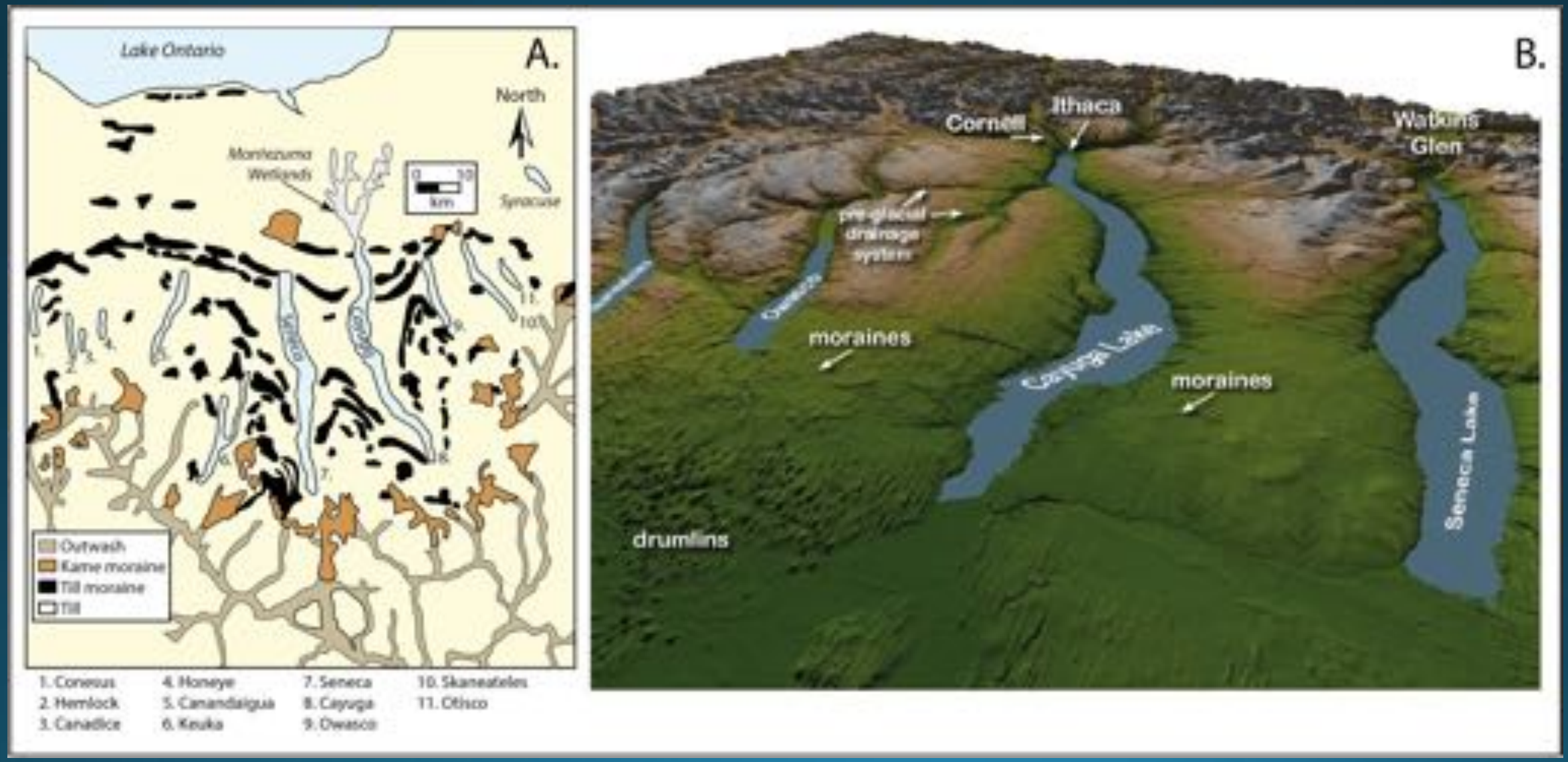
- Seismic reflectors and attributes define coarser-scale geologic units compared to Borehole 18 data
- Carbonate Beam dominated by brittle carbonates
- Evaporite Section made up of combination of evaporite, shale and dolomite beds
- Note the change in dominant sonic signature style at the top of the Syracuse Formation that defines the boundary between the two seismic-scale units (indicated by a red line).



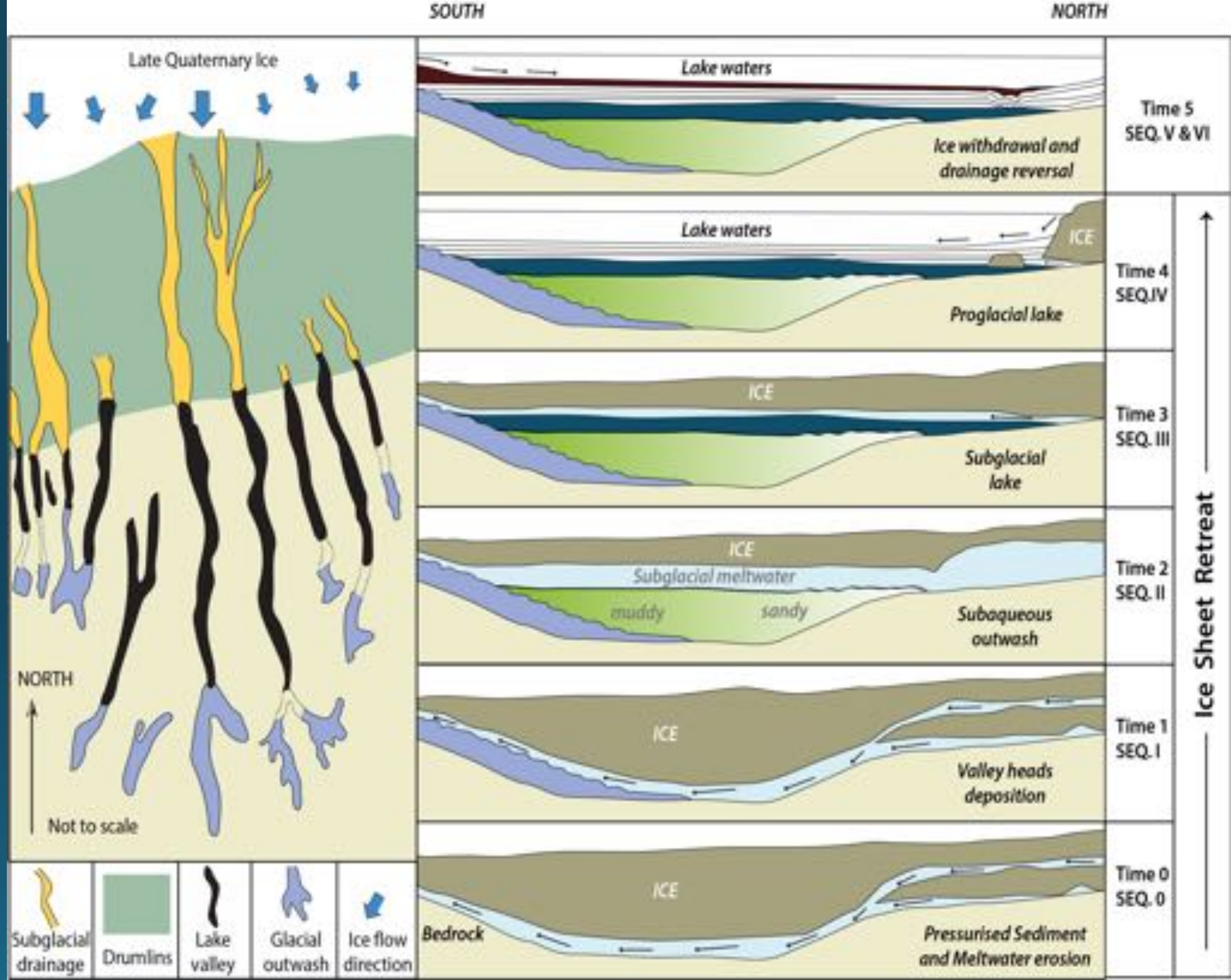
Seismic documents downcutting into the Carbonate Beam

- Basin depression that now hosts Cayuga Lake was formed by Pleistocene glacial scouring cutting into the bedrock
- Later the valley was partially filled with glacial sediments
- Where the Carbonate Beam is eroded there is a Pleistocene connection to the underlying Evaporite Section aquifer
- When loaded by an ice sheet, the rocks below the beam were at times subjected to fracturing and inflows of variably-pressurized, salt-undersaturated waters

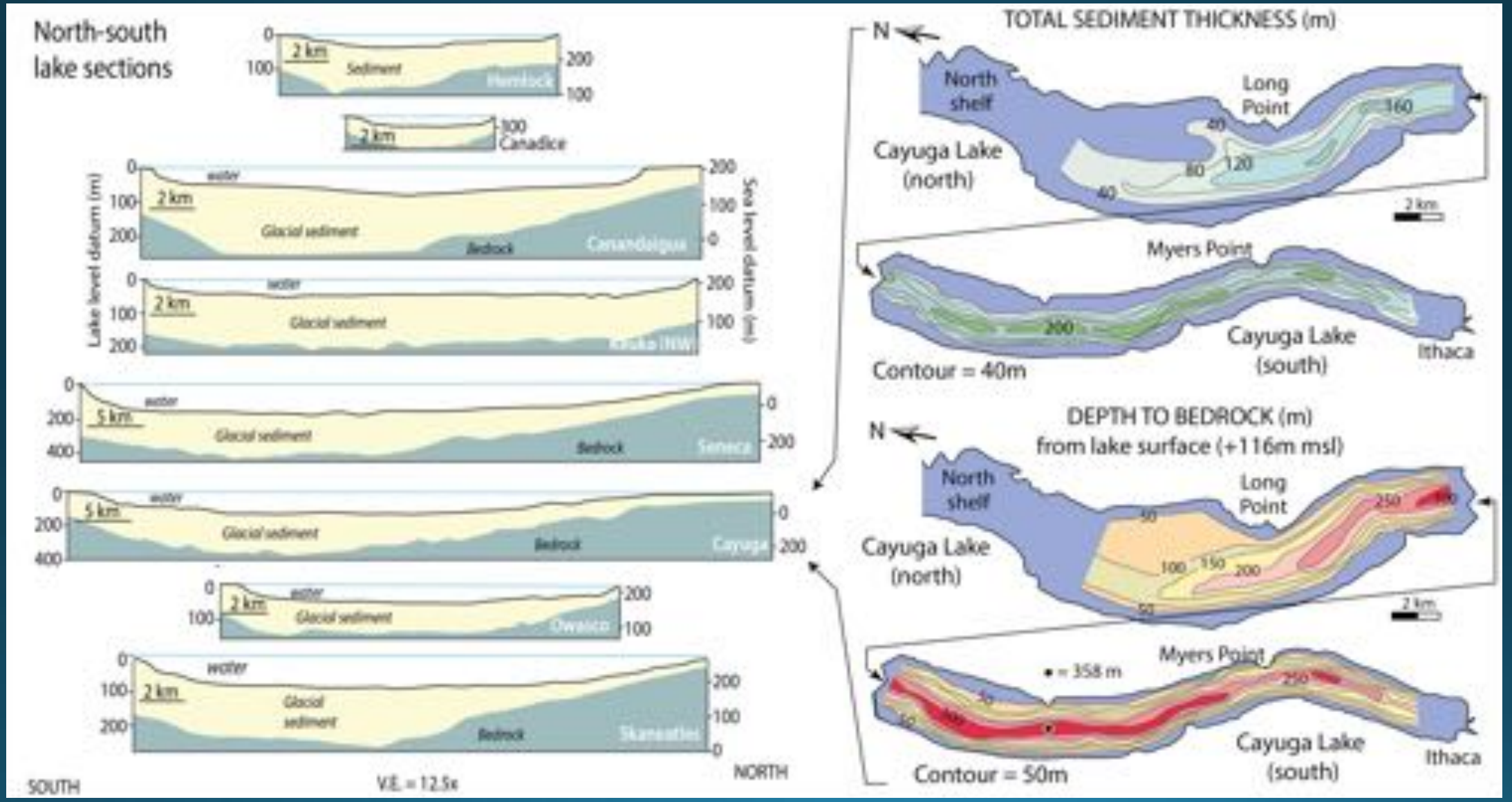
Pleistocene geology of Finger Lakes

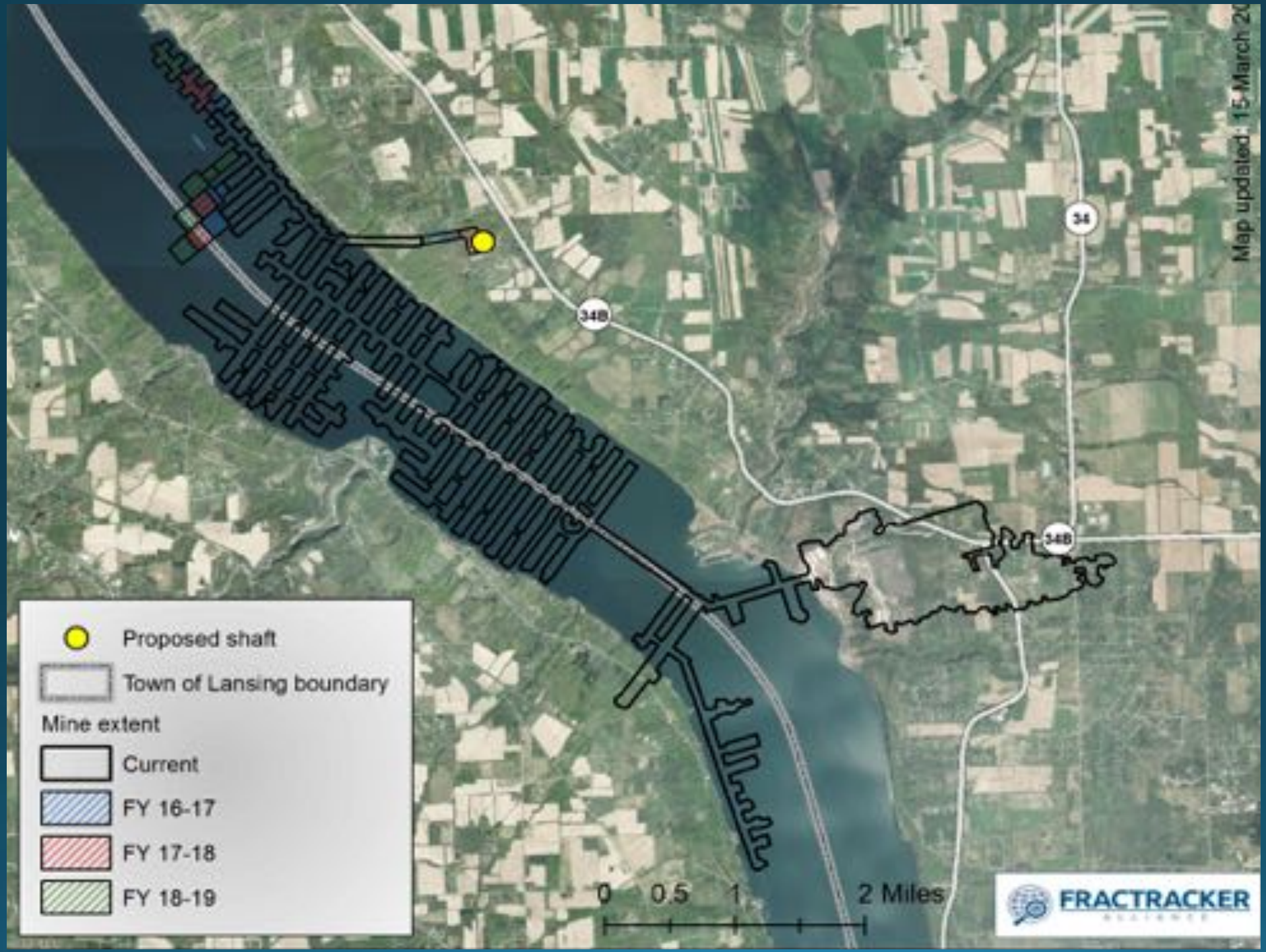


Subglacial lake valleys with a fill of variably porous Pleistocene sediments (aquifers)



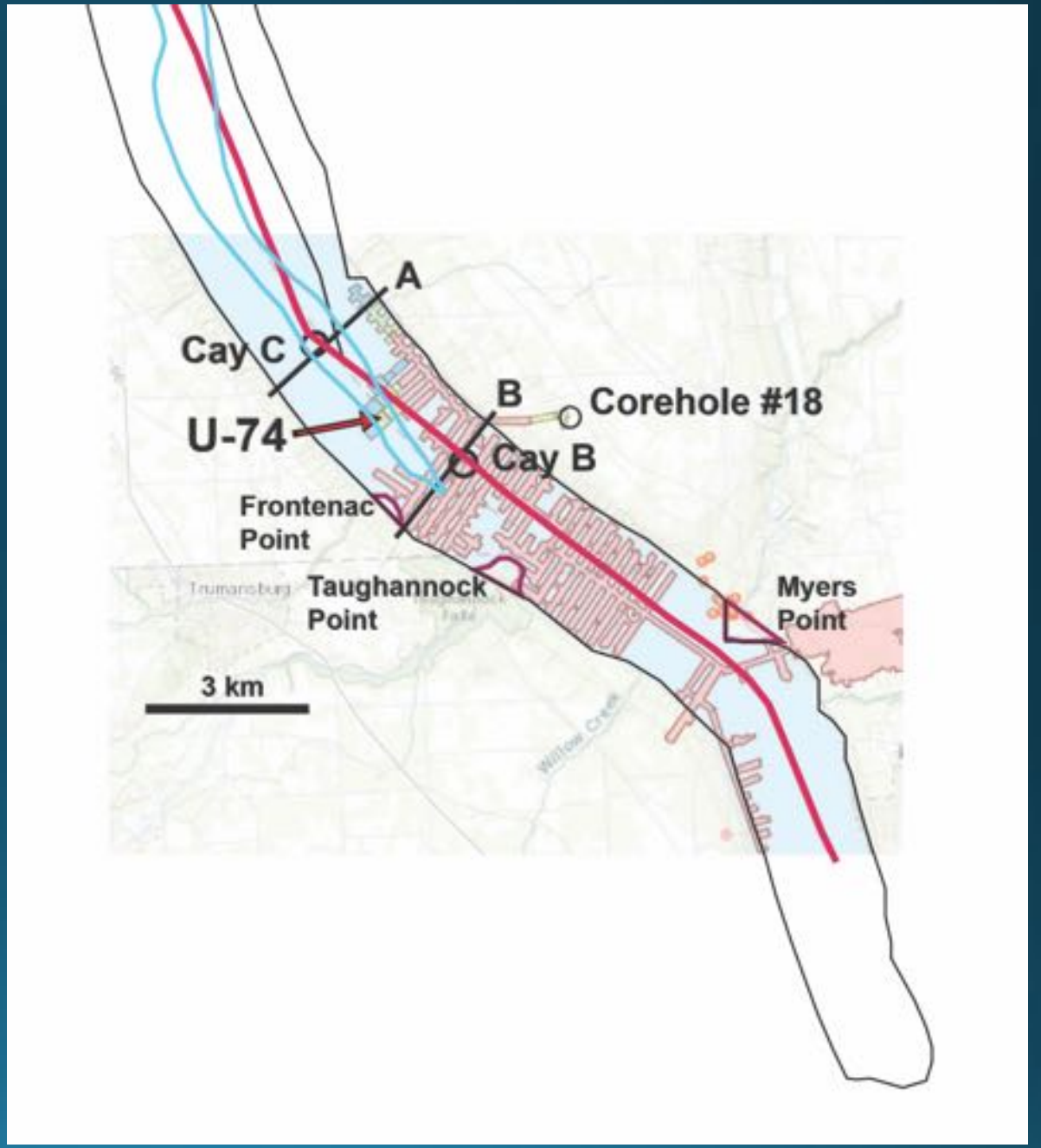
Sediment thickness in valley-downcuts



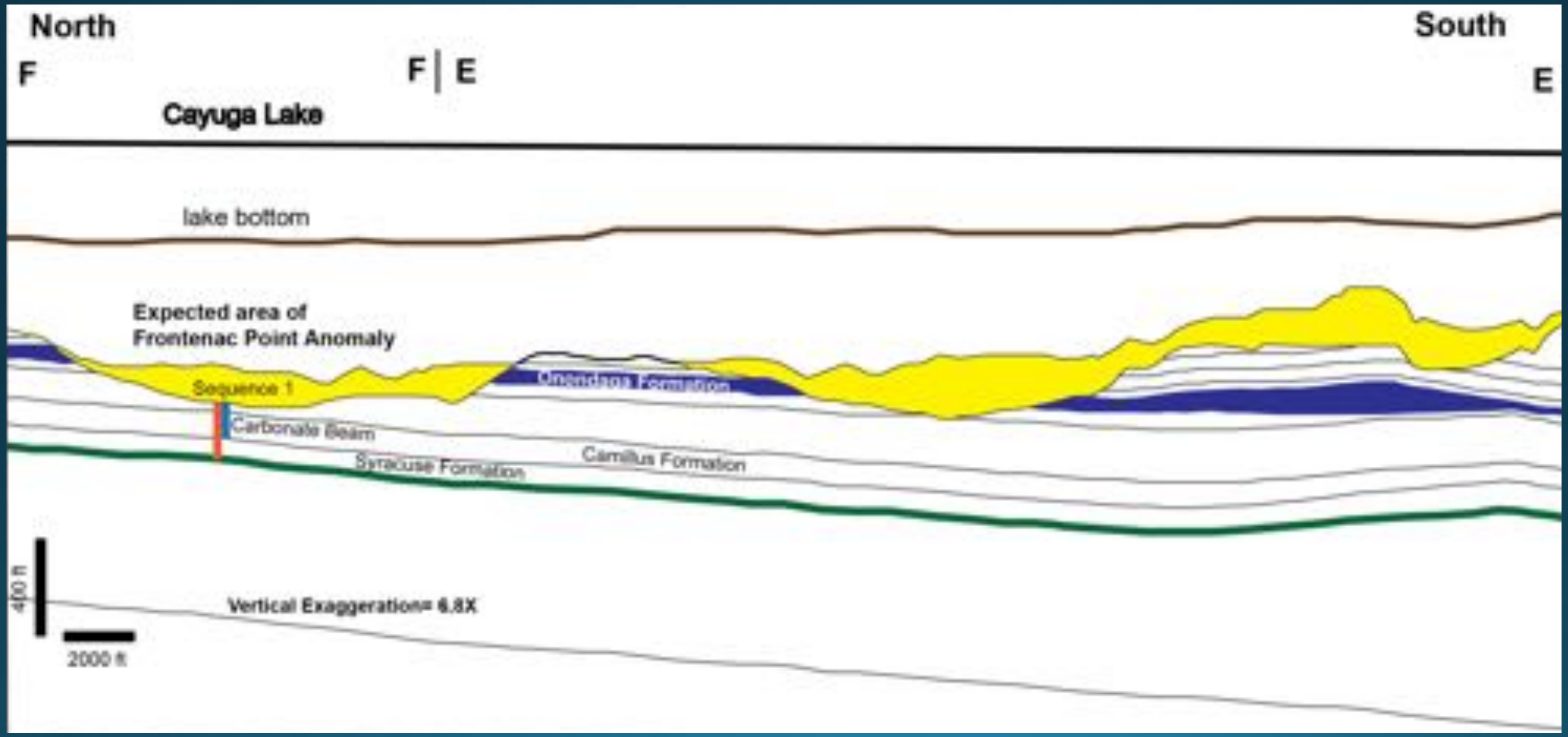

Map updated: 15 March 20
34
34B
34B
Proposed shaft
Town of Lansing boundary
Mine extent
Current
FY 16-17
FY 17-18
FY 18-19
0 0.5 1 2 Miles
FRACTRACKER

Seismic Interpretation - Method 1

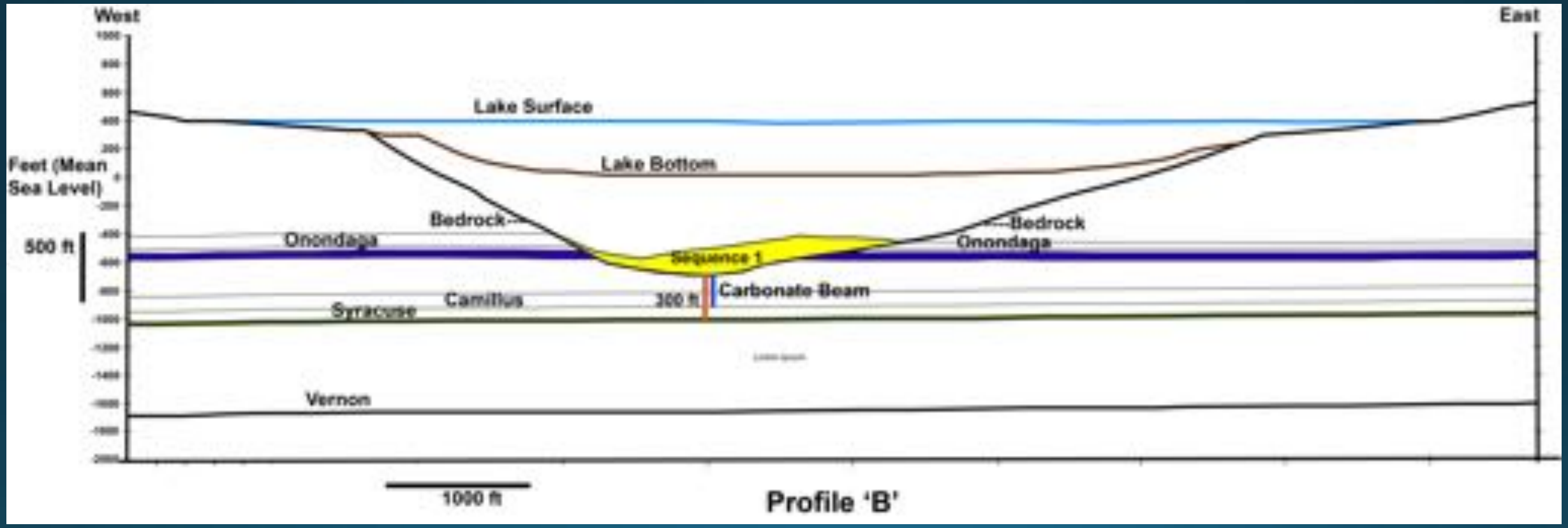
- Use seismic data to map the outcrop of the Onondaga Limestone on the Cayuga Lake floor
- Region where the Onondaga crops out and intersects sediment-covered lake floor is indicated by position of blue line
- Inside the area outlined in blue the Onondaga has been breached by glacial erosion (this is region of deepest valley floor = thalweg) and is today covered by thick beds of glacial sediment, which are dead weight providing no structural support



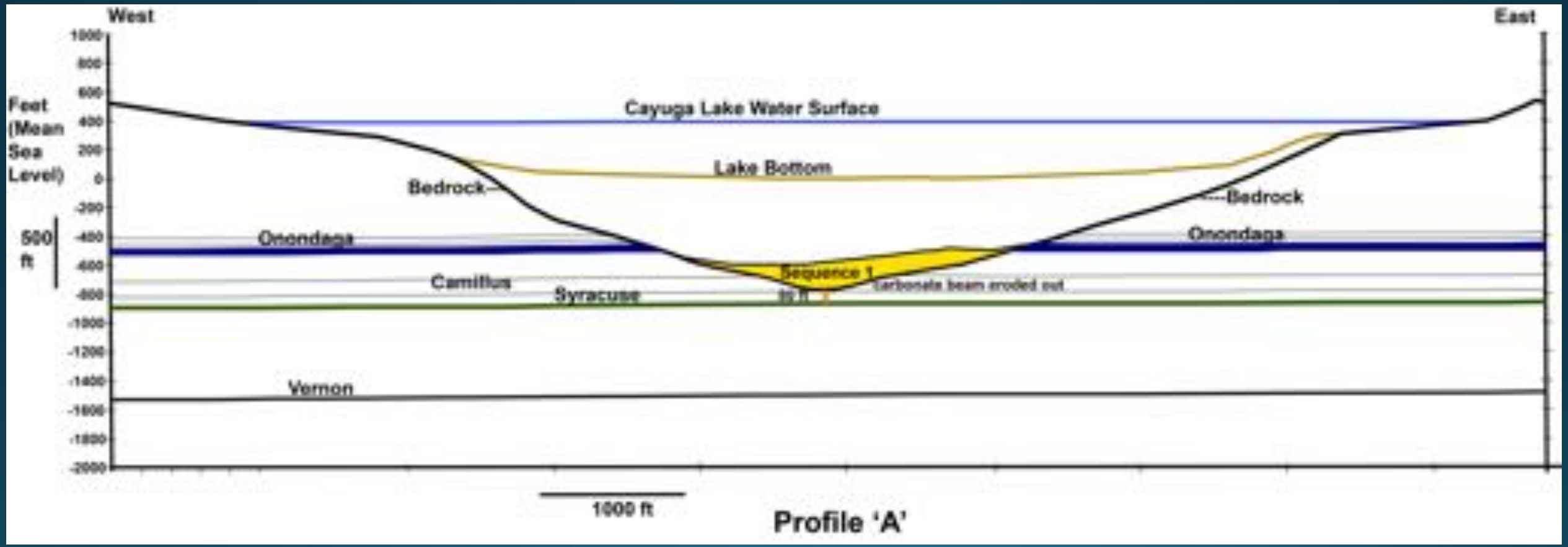
Seismic Interpretation - Method 2 (FE)



Method 2 - Profile B: 300 ft

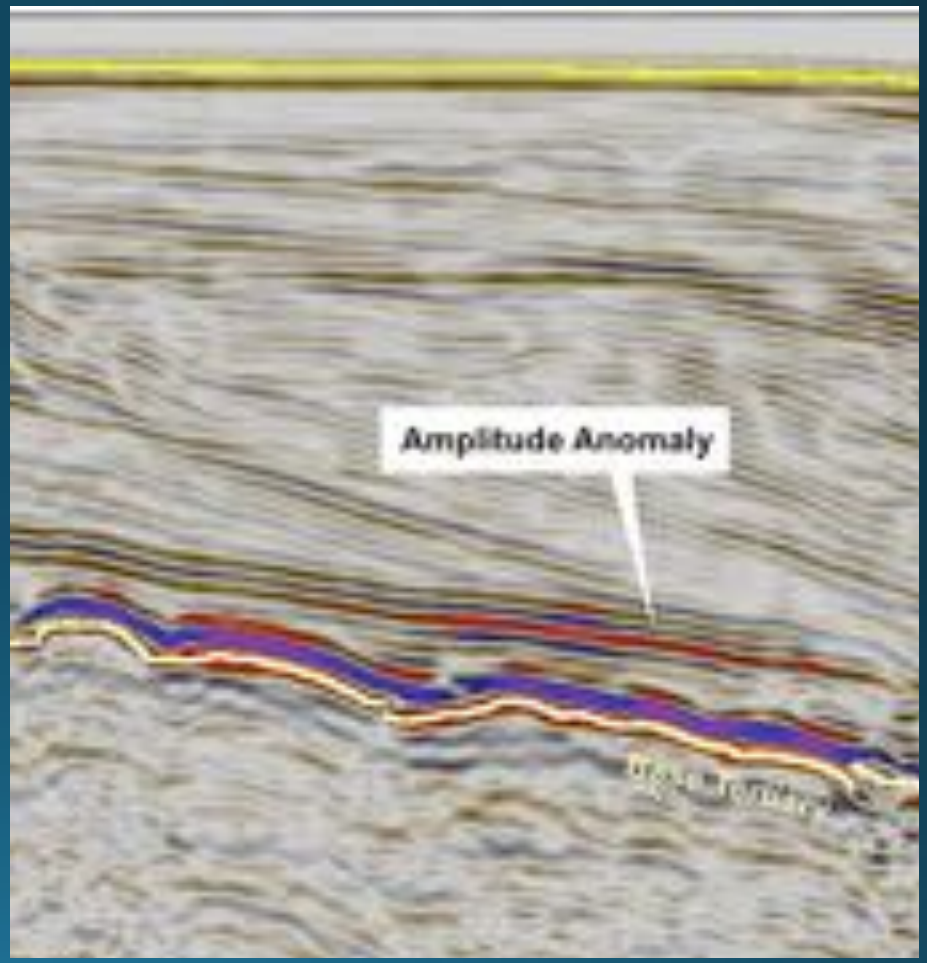


Method 2 - Profile A: 80 ft



What is a Seismic Anomaly? – Method 3

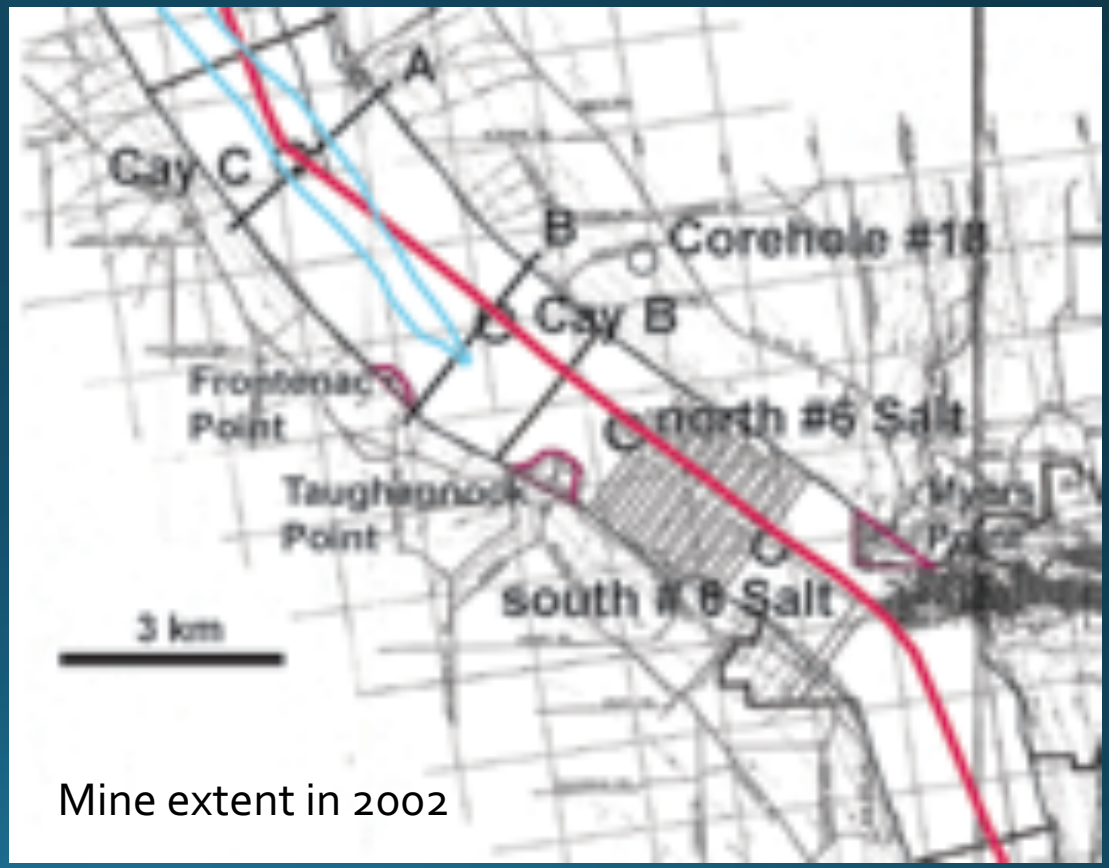
- A seismic anomaly indicates the unexpected
- Generally, it is due to an unexpected change in the velocity of sound waves passing though, or reflecting off, various rock layers
- Sometimes an anomaly indicates the changes in rock velocities in a zone of pores and cracks filled with gas
  - Hydrocarbons stored in pore space between sand grains (illustrated opposite)
  - Fluids in a zone of fractured rock
  - The anthropogenic cavity created in a rock such as an air-filled mine cavity in salt (this study)



Offshore Australia, east coast

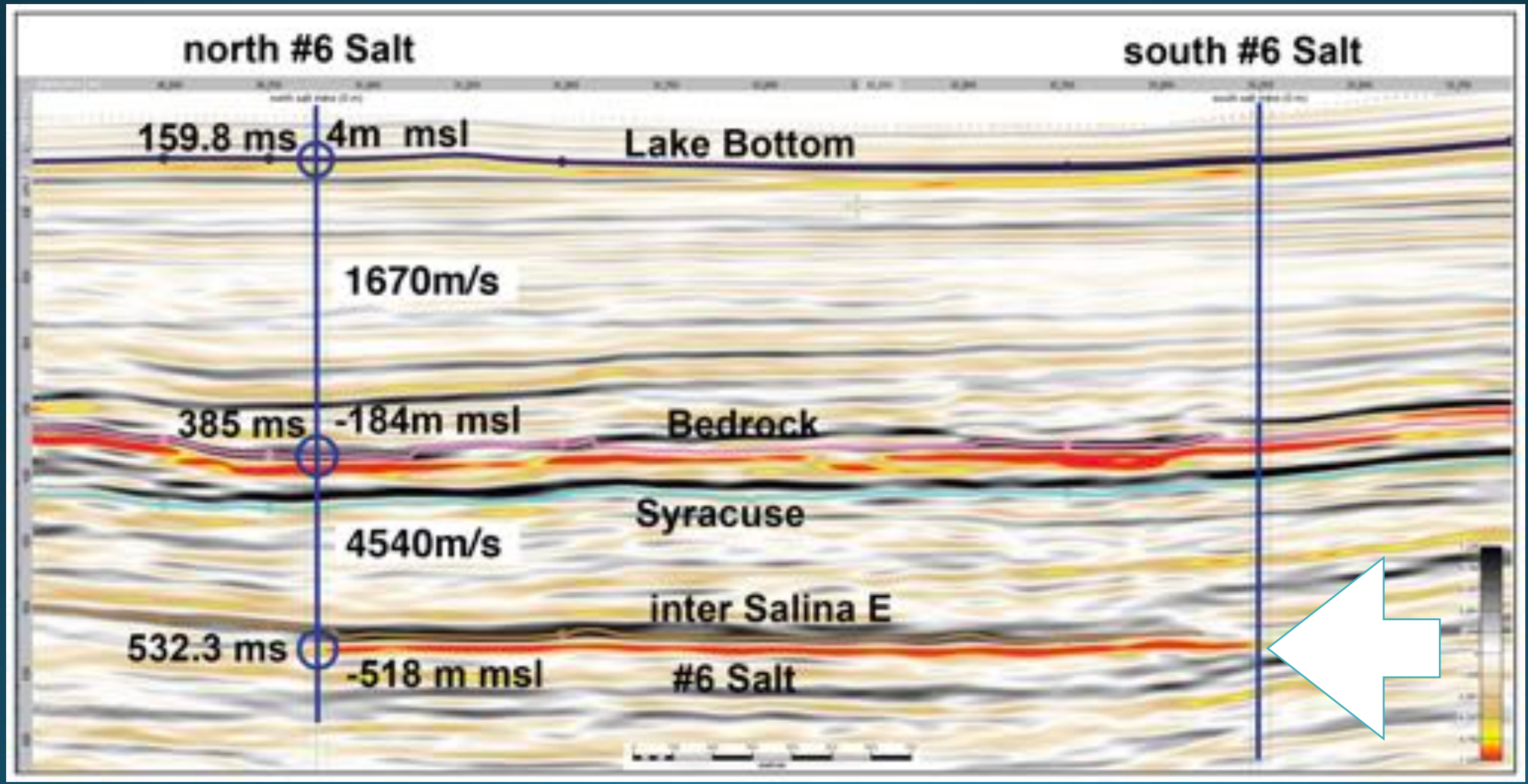
Existing and future seismic anomalies

- Seismic anomaly extent labelled as south #6 salt and north # 6 salt. Map shows in red shaded area indicate planned #6 salt mining level from 1998-2003.
- Superposition of this map on workstation-loaded seismic shows an anomaly that is the position of mine cavity in 2002 when the seismic was shot
- This is a new observation for the public realm, indicates the mine workings can be seen in seismic and so related to geologic features visible in seismic (thalweg, bedding, thicker and thinner salt regions)
- The next step is to relate seismic anomalies to salt anomalies (a mine safety indicator)
    - The two anomalies show similar extents, but are not the same. Implications for roof stability as mine moves north, are documented in upcoming Ferguson and Warren report

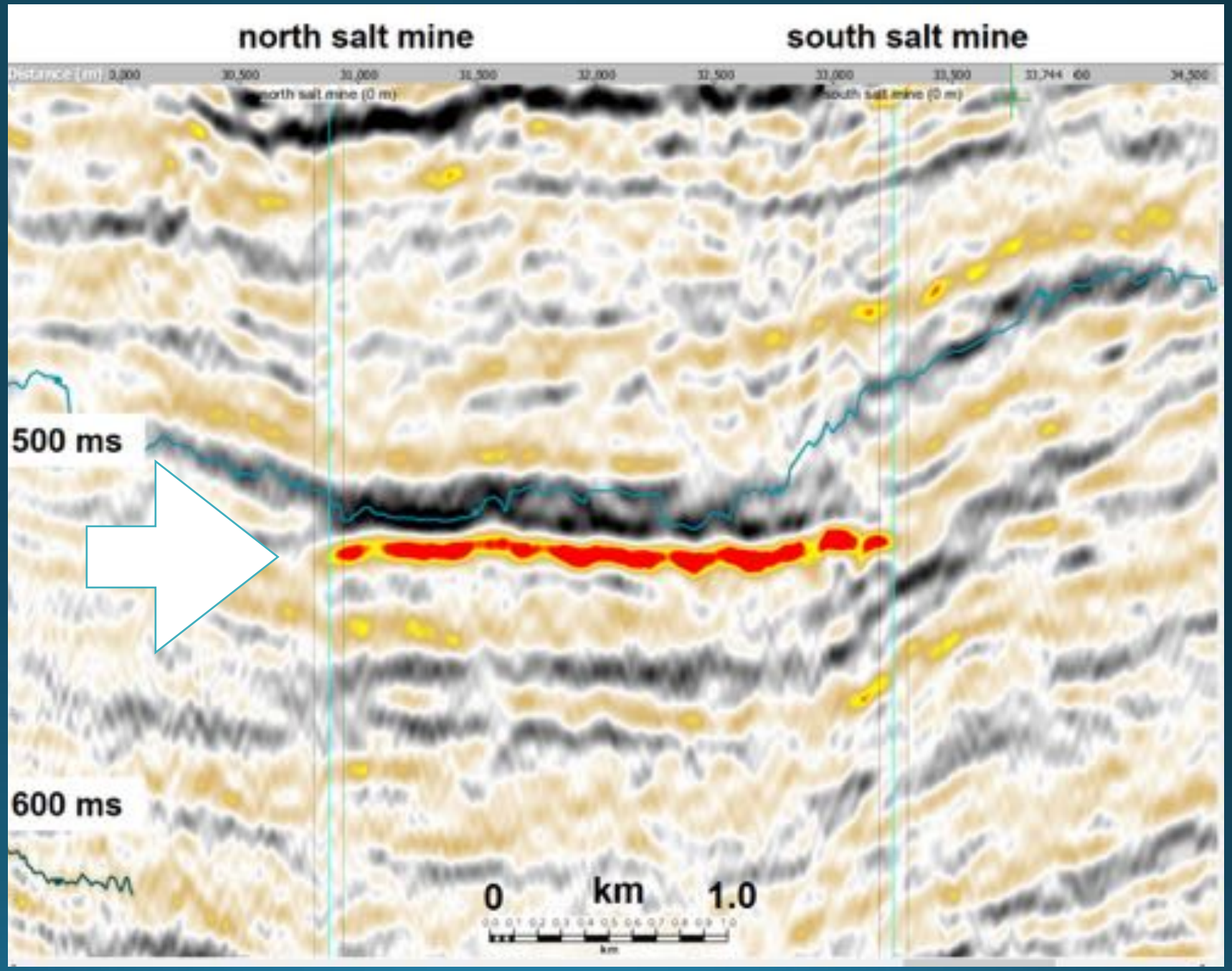


Mine extent in 2002

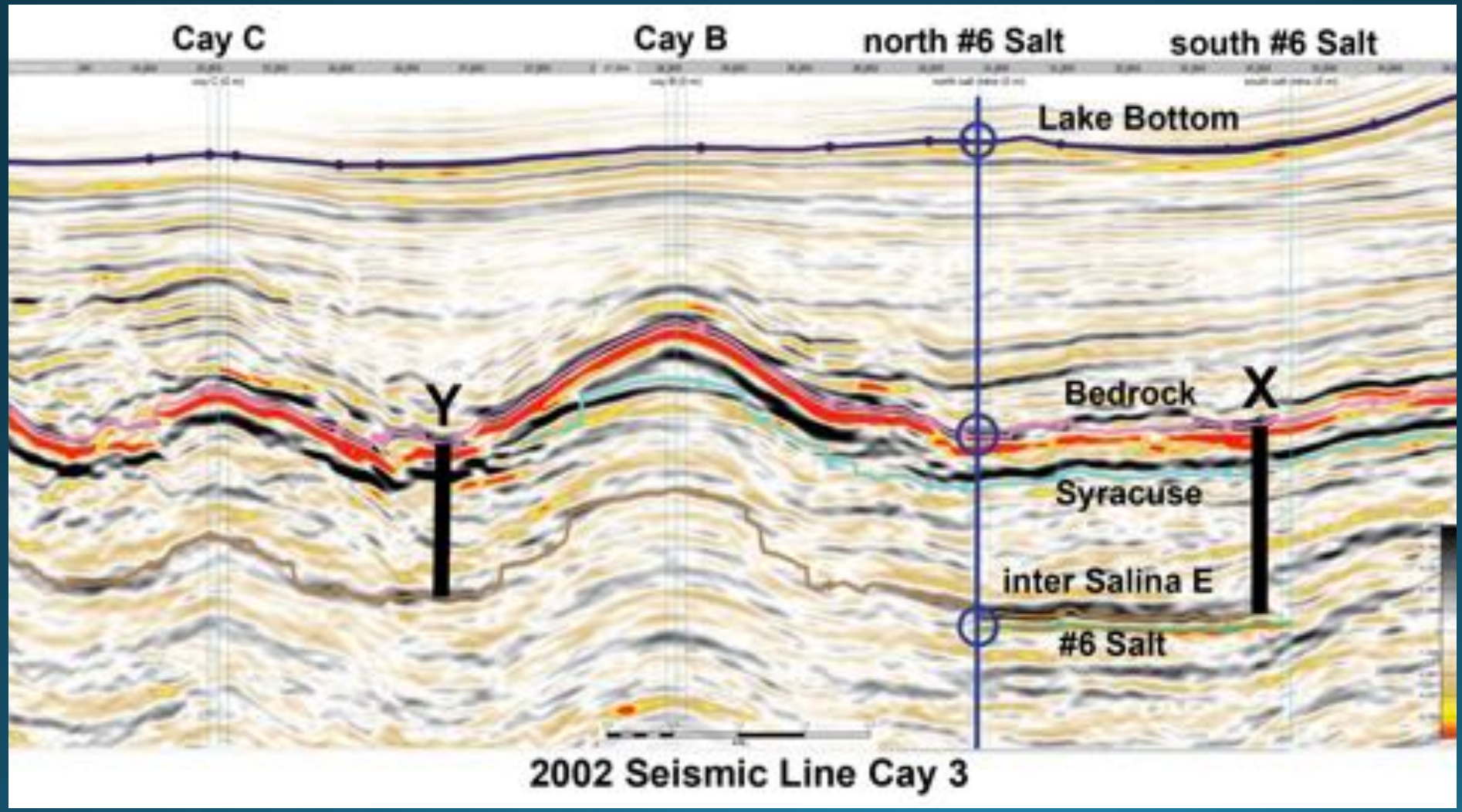
Cayuga 2002 mine extent (anomaly in red)



Mine extent in 2002 - detailed view



Method 3- Seismic with horizons shows thinning of carbonate beam to north and partial loss of Syracuse Formation layers



What does the seismic (2002) indicate?

- Below Cayuga Lake there is a significant thinning of the bedrock to top Salina E from the south to north of the lake.
- Agrees with the previous two methods and confirms a thinning of the carbonate beam overlying the evaporite unit in a northern direction.
- Exact thinning is difficult to calculate due to the general velocity values used. The amount of thinning is 27 ms in seismic two-way time. This would roughly calculate as 130-200 feet using a 4950 m/s interval velocity.
- Accuracy of these values can be greatly improved if the seismic velocity data become available, or more seismic surveys are used (a quantified velocity profile has not been released into the public realm, even for 2002 data).

Integrate seismic (2002) with known geology (Ferguson and Warren June 2017 report)

- Extension of the current Cayuga Mine to the north and east will encounter a thinned section of the carbonate rock that is considered when not erosionally thinned to be the more mechanically-stable stack of formations overlying the Salina Group.
- This thinning will result in more unstable geological conditions for the mining operations tied to penetration of undersaturated pressurised waters deeper into the targeted evaporite section.
  - Greater likelihood of icesheet-related pressure pumping and fracturing that forced undersaturated water into Syracuse Formation and drove pervasive salt dissolution.
  - This ice-sheet related set of processes created much of the roof instability in the now-abandoned and flooded Himrod and Retsof Mines.
- Currently the influence of roof-rock degradation on mine stability and safety in the region north and west of the current workings is underestimated.

Recommendations

- The NYS Department of Environmental Conservation should consider immediately halting any further exploitation of this thinning bedrock zone until the following have been completed:
- 1) A 3-D seismic survey, or detailed 2-D survey, with acquisition parameters focused on mapping the glacial valley floor and the degree of downcutting in the Carbonate Beam, the Camillus Shale, and the underlying Evaporite Section.
- 2) The same survey should be used to construct a salt anomaly map that defines the position of known and future mine workings with respect to the glacial valley thalweg.
- 3) The salt core at Corehole 18 is re-logged using current understandings of the significance of textures and vein structures in salt core, with a view to defining the degree, if any, of ice-flexure driven penetration by undersaturated groundwaters.