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Seismic Reflection Profiles and their Contribution to the Development of a Geological Model of the Oak Ridges Moraine area, southern Ontario

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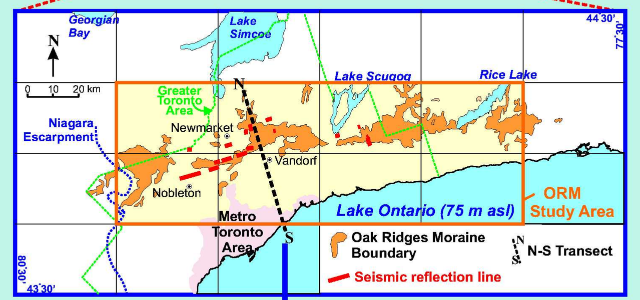
Canada
Natural Resources Canada
Ressources naturelles Canada

Oak Ridges Moraine (ORM)

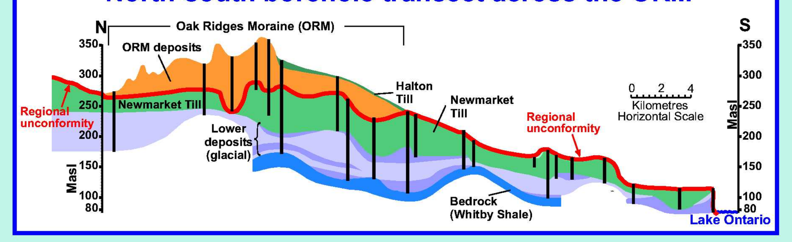
- ORM is a sandy, glaciofluvial-glaciolacustrine landform complex, deposited near margin of Laurentide Ice Sheet ~12,000 years BP
- 160 km long, up to 20 km wide, ~200 m thick in places
- ORM and underlying sediments form an extensive Quaternary aquifer complex that supplies groundwater to >200,000 people within the Greater Toronto Area
- area sought after for recreation, housing and aggregate resources
- seismic program was designed to map architecture of ORM and adjacent strata to evaluate which geological structures influence groundwater flow




Regional forests / recreation


Housing development

North-south borehole transect across the ORM

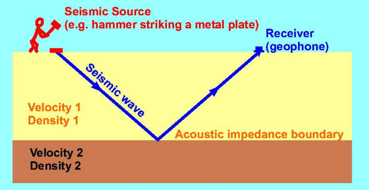



Aggregate resources

Shallow Seismic Reflection Method

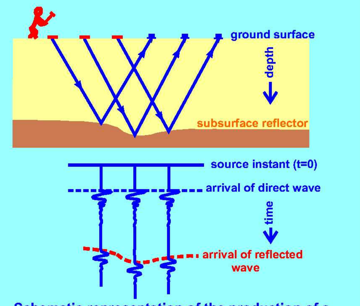
- geophysical method for delineating the structure of subsurface sediments

1. Basic Principles



Basic premise of seismic reflection methods. Seismic energy produced on the ground surface travels from the source down to an acoustic boundary, where it is reflected back towards the surface and recorded by a receiver (geophone).

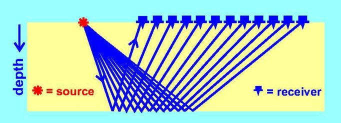
2. Seismic Profile



Schematic representation of the production of a two-way travel-time seismic section by acquiring data continuously along a survey line.

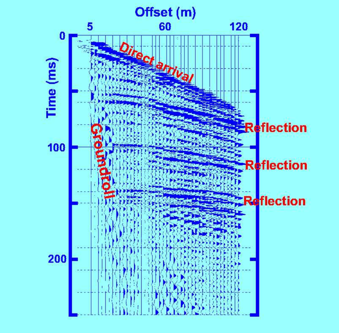
3. Common shot gather

(Field record)



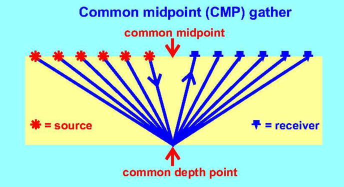
Schematic diagram showing the subsurface travel paths of reflections on a field record.

4. Field Record



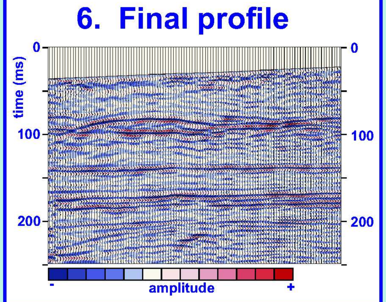
Field record showing excellent reflection energy.

5. CMP gathers



Schematic diagram showing the subsurface travel paths of reflections that have been sorted into a common-midpoint (CMP) gather. The traces in a CMP gather are processed and stacked together to form a single trace on a final CMP section.

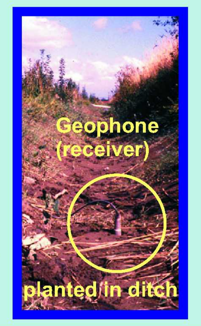
6. Final profile



ORM Data Acquisition and Processing

Recording Parameters

Seismograph:	*various 24- (or 48-)channel (e.g. Geometrics ES-2401, R-24 Strataview, OYO DAS-1)*
Receivers:	*single 50 Hz vertical geophones*
Receiver spacing:	*5 m*
Seismic source:	*12-gauge in-hole shotgun*
Source offset:	*5 m*
Nominal CMP fold:	*12 (or 24)*
Total line length:	*~ 50 km*



Processing steps applied:

Convert data format
Edit geometry
Interactive manual trace edit (e.g. kill bad traces)
First break picking - refraction analysis and statics
Automatic gain control (large window)
Bandpass (BP) filter
Groundroll and airwave mute as required
CMP sort
Velocity analysis
Normal moveout corrections with stretch mute
Residual statics
Stack
Spectral balancing (zero phase decon. and BP filter)
Statics os a datum plane (elevation corrections)
Migration (phase-shift method)
Depth conversion
Plot section

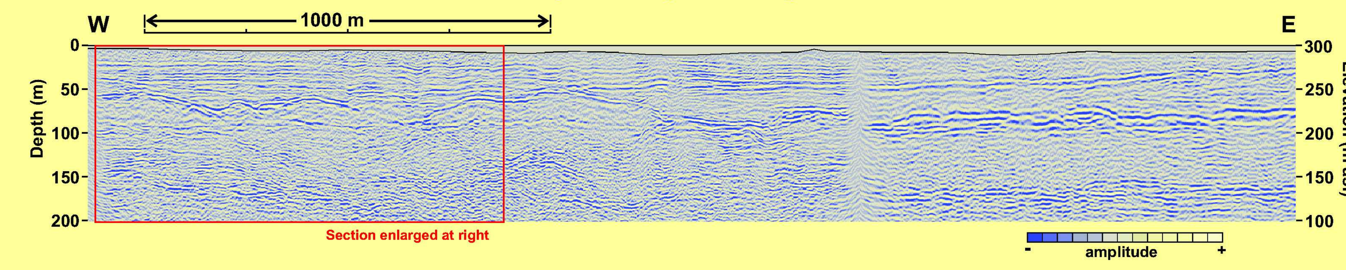
Processing carried out on a PC using Eavesdropper (Winseis) and VISTA software supplemented with author's (Pugin) routines.

- analysis of ~50 line-km of land-based, shallow, seismic reflection profiles has provided means of investigating subsurface architecture and stratigraphic relationships of glacial deposits in and beneath the Oak Ridges Moraine (ORM)
- poster highlights the role seismic surveys have played in development and refinement of a well-constrained, regional, geological model of the subsurface stratigraphy
- large area and thickness of overburden materials (>100m) mean that surface and borehole geophysical surveys play critical role in subsurface investigations
- seismic reflection data complements extensive 3-D database of water-well records supplemented with high-quality boreholes and surface mapping, allowing well-constrained interpretation of seismic stratigraphy

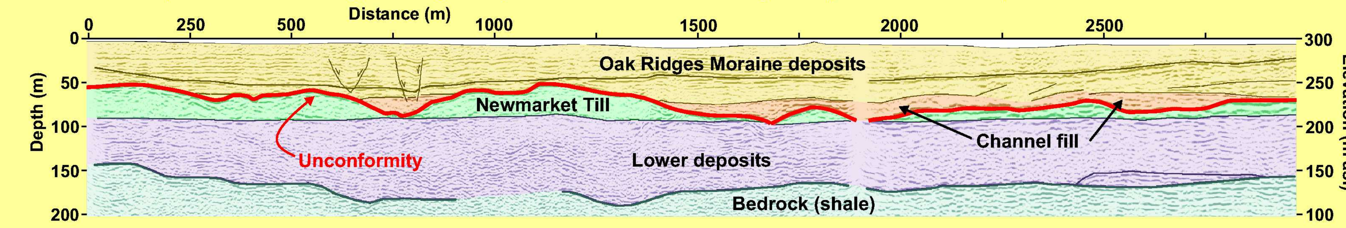
Regional Sedimentary Architecture

Newmarket Till

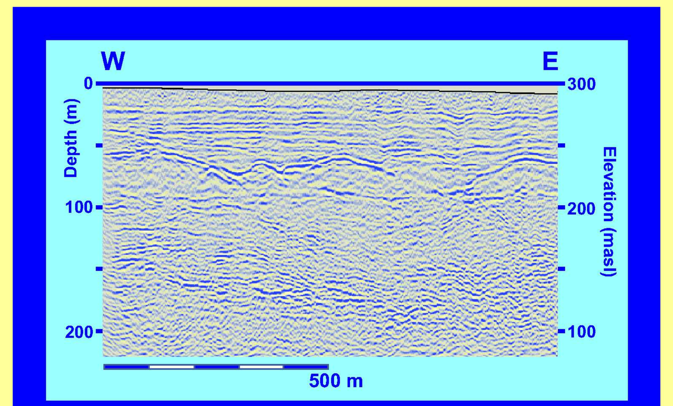
East-west profile acquired along 15th Sideroad.



Interpretation showing the regional, erosional unconformity interpreted as the top of the Newmarket Till.



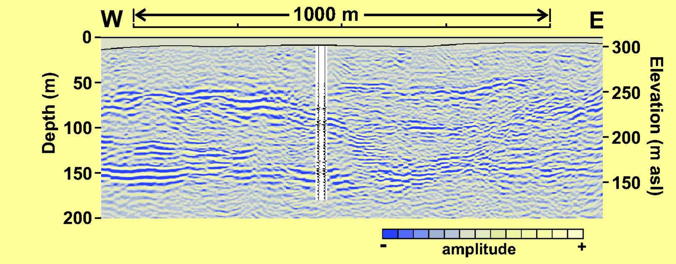
- seismo-stratigraphic unit interpreted on all seismic profiles
- highly variable in thickness, not always continuous across profiles
- characterized by highly reflective surface with considerable topography, little internal structure, and a flat-lying, low-amplitude base
- surface of Newmarket Till is interpreted as a major regional unconformity



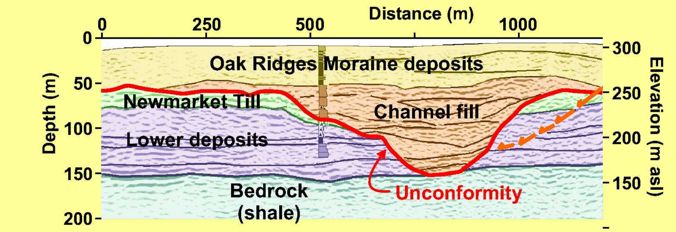
Portion of 15th Sideroad profile showing the undulating, erosional surface of the Newmarket Till, and it's characteristically flat, low-amplitude base.

Channels

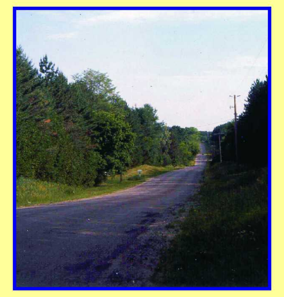
East-west profile acquired near Vandorf.



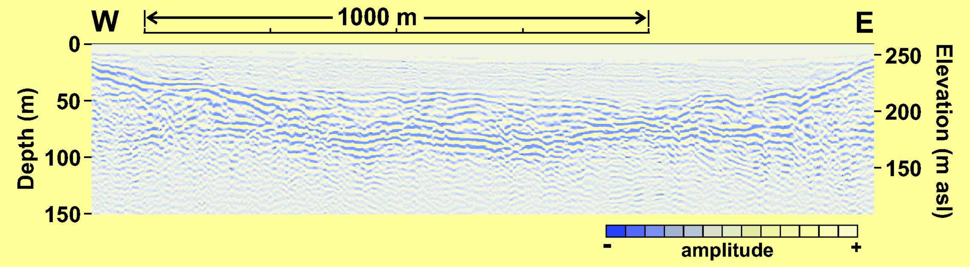
Interpretation showing deep, steep-sided erosional channel feature that cuts through the Newmarket Till and lower deposits.



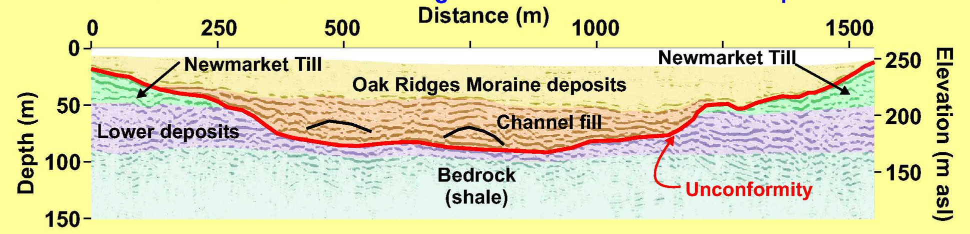
- profiles show many erosional features beneath ORM deposits which cut into or through the Newmarket Till (see left)
- seismic data show that surface channels north of the ORM are actually only muted expression of much larger buried channels (see right)
- channels have cross-sectional forms varying from narrow (~0.5 km) with steep and partially failed sides (e.g. see left), to broad (1-2 km) with low-angle sides and slopes (e.g. see right)


Surface expression of channel north of ORM.

East-west profile acquired north of ORM across surface channel feature.

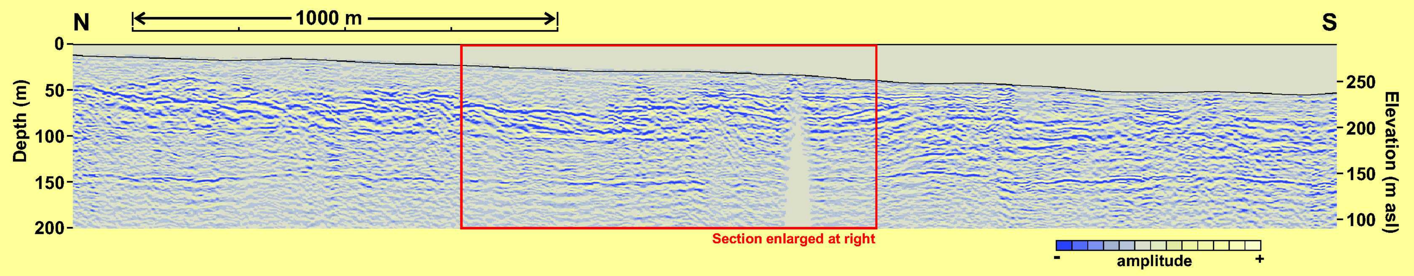


Interpretation showing extension of surface feature into subsurface. Broad channel cuts 80 m through Newmarket Till and lower deposits.

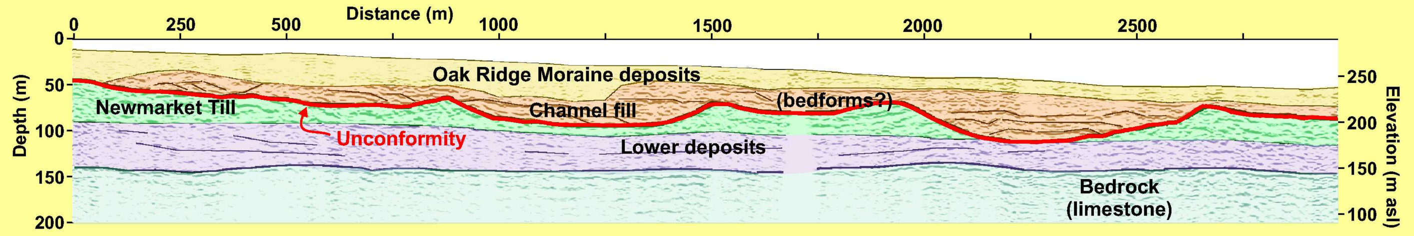


Channel Fills

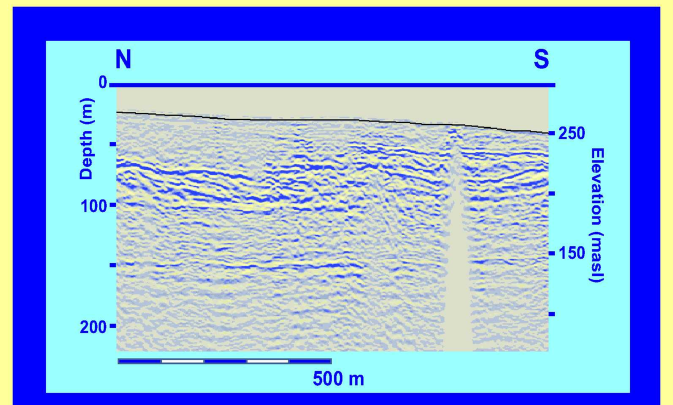
North-south profile acquired on south flank of the moraine near Port Perry.



Interpretation showing the complex structure of channel fill deposits lying on a heavily eroded Newmarket Till.



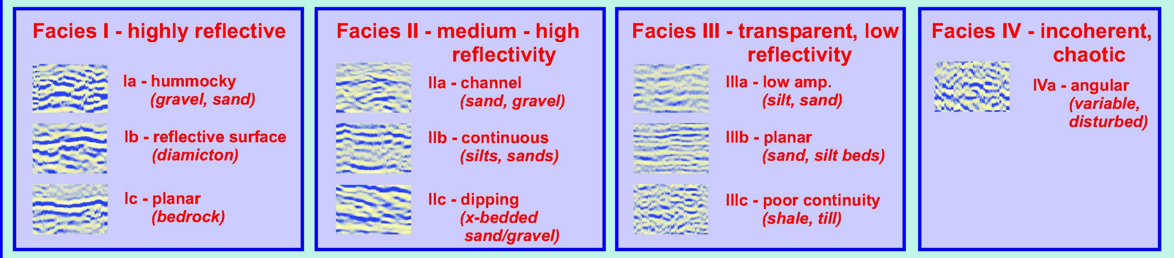
- stratified fills, up to >100 m thick, are seen in channels with surface expression north of the ORM (above right), and in channels buried beneath ORM deposits (this panel)
- fills have potential as high-yield aquifers
- seismic reflections surveys have role in exploration for such groundwater prospects



Portion of Grasshopper Park Road profile showing the coarse-grained (high amplitude) channel fill deposits on the eroded Newmarket Till surface. These deposits are interpreted to show large-scale cross-bedding and inferred to have been deposited rapidly by high-energy, subglacial meltwater.

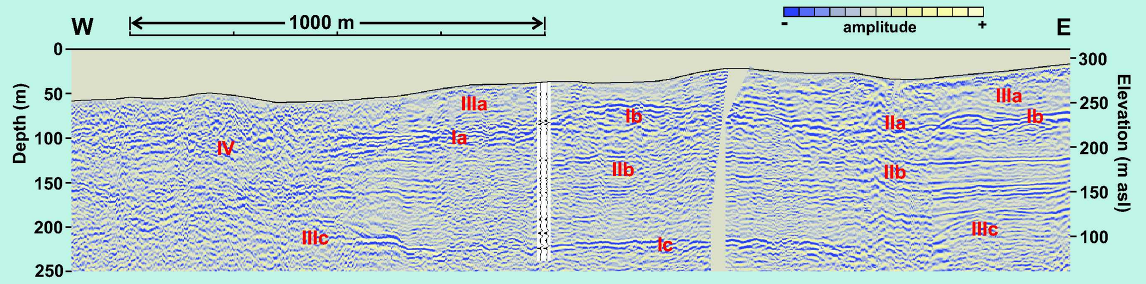
Seismic Facies

- major seismic facies (I-IV) defined primarily on reflection amplitude
- subfacies (a-c) indicate varying configurations or continuity of reflections

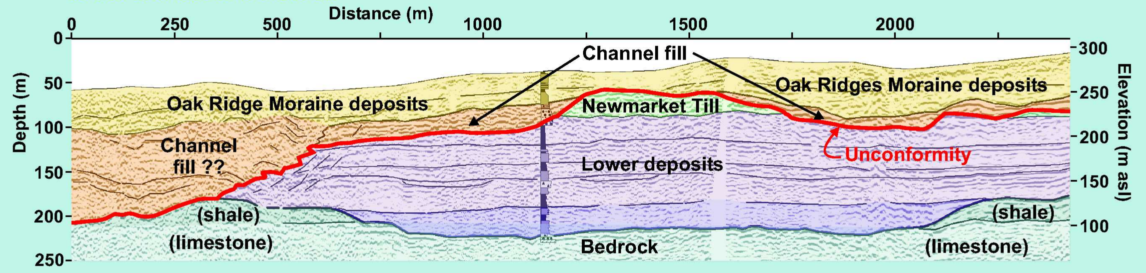


Type Seismic Profile

Type seismic reflection profile acquired near the town of Nobleton in the western region of the ORM. A corridor stack computed from downhole seismic data is superimposed at the location of a borehole to bedrock. The seismic facies are indicated by the bold characters.

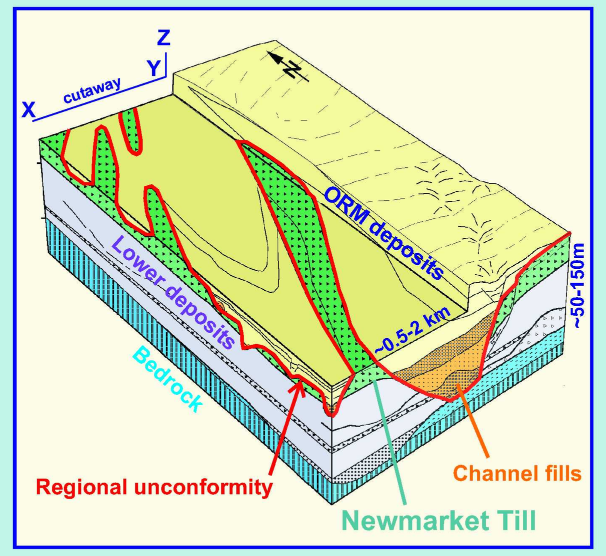


An interpretation of the profile in terms of the architecture of seismo-stratigraphic units. Heavy lines indicate regional unconformities. A schematic lithological log is superimposed at the borehole location.



Seismo-stratigraphic Model

Schematic diagram showing the major elements of a seismo-stratigraphic model of the ORM.



Channels
Channel fills
Newmarket Till
Lower deposits
Bedrock

- seismo-stratigraphic units based on interpretation of seismic facies in conjunction with subsurface architecture and stratigraphic relationships
- seismic stratigraphy outlines the regional architectural elements of the ORM area

Summary

- seismic profiles are interpreted in terms of their seismic facies, seismic stratigraphy, and the regional sedimentary architecture
- model illustrates the major architectural elements identified on the seismic profiles and their interrelationships in the subsurface
- borehole and geological mapping allow the seismo-stratigraphy to be interpreted in terms of a geological model (development and refinement of model)
- high-quality, land-based, shallow seismic reflection surveys have the resolution necessary to improve our understanding of sedimentary processes and environments in and beneath glacial sedimentary complexes

For further information see:
Pugin, A., Pullan, S.E., and Sharpe, D.R. 1999. Seismic facies and regional architecture of the Oak Ridges Moraine area, southern Ontario, Canadian Journal of Earth Sciences, v. 36, p. 409-432.

Adapted from poster presented at GSA'99 (Geological Society of America Annual Meeting), October 24-28, 1999, Denver, CO.

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