3-D Geological Modelling at the OGS – Products and Applications

or....

I made a model!!! Now what?

Abigail Burt
Andy Bajc
Riley Mulligan
Desmond Rainsford
John Dodge
Meet the team

Abigail Burt

Andy Bajc

Riley Mulligan

John Dodge

Desmond Rainsford
Our clients

Internal (OGS geoscientists)

Conservation authorities

Industry / Consultants

Other government ministries (Ministry of Environment and Climate Change)

Academia
What and Where

- Reconstruct the regional Quaternary history
- Construct a 3-D model of key sediment packages
- Characterize the properties of the modelled sediment packages
Life-cycle of a 3-D Project

- Project Initiation
- Reconnaissance
- Acquire legacy data
- Drill (that’s the fun part)
- Model
- Final products
Products: Guiding Principles

- Standardized from one project area to the next

- Terminology and geologic conceptualizations need to be standardized to allow for merging of models

- Products need to be useable by a wide range of clients

- Need to release products that eliminate the need for high-end computers or software to use the data.
Reconnaissance
• Improve our understanding of late-glacial history
• Verify existing surficial mapping (identify problem areas)
• Log exposures
• Auger and probe....
• Meet potential partners
Product: Summary Report

- Field descriptions
- Preliminary interpretation of landform-sediment assemblages
- Compilation of existing mapping
- Summary logs

38. Project Unit 13-018. The Niagara Peninsula Study: A New Three-Dimensional Quaternary Geology Mapping Project

A.K. Bert

INTRODUCTION

The May 2001 Walkerton tragedy and resulting Clean Water Act focused the attention of conservation authorities, all levels of government and members of the public on the importance of protecting Ontario’s groundwater resources. A critical component of evaluating the resource is having a thorough understanding of the three-dimensional (3-D) distribution of Quaternary (surficial) sediments. Accurate 3-D models will improve volumetric estimations of the provincial groundwater resource, may allow undiscovered aquifers to be located and will improve our understanding of groundwater recharge and discharge zones. Equally important is the use of the models to identify aquifers susceptible to contamination and potential pathways for contaminants.

The Ontario Geological Survey (OGS) has initiated a new 3-D mapping project, encompassing the Niagara Peninsula and extending seaward to the city of Brantford (Figure 38.1). This project is in response to both a recent gap analysis meeting held in the fall of 2012 and project proposals submitted as part of the 2012 project planning cycle. Several gaps in geoscience knowledge were identified during this process: 1) there is currently limited information available regarding the subsurface distribution of aquifers and aquitards in the Niagara Peninsula; 2) there is a need for a regional stratigraphic framework identifying key lithostratigraphic units; 3) there is an incomplete understanding of the location and geometry of the buried-bedrock valley network as well as the nature of the underlying sediments hindering hydrogeological studies; 4) there is an absence of a regional-scale 3-D model providing the scientific results to inform policy development, aquifer sustainability, and use, provincial instruments (e.g., Permits to Take Water), management of contaminated sites, optimization of deactivating systems, management of conservation areas and possibly, protection of coastal wetlands; 5) there is a need to identify new groundwater resources for rural applications, such as agriculture (irrigation), golf courses and domestic supply; and 6) because of high groundwater demand and vulnerability, the Lake Erie north shore area has been designated as a priority area for enhanced groundwater monitoring as part of the Canadian Coral Lakes Water Quality Agreement and Canada-Ontario Agreement (CDOA) respecting the Great Lakes basin ecosystem. Additional subsurface information and groundwater monitoring is required to effectively proceed with this project.

The goal of the Niagara Peninsula project is to build an interactive 3-D model of Quaternary deposits that form both regional and local aquifers and aquitards. Key objectives are: 1) reconstruction of the regional Quaternary history, 2) development of a 3-D model of Quaternary sediments and 3) development of the properties of the modelled sediment parcels. The model will be built on the interpretation of natural and man-made exposures, existing subsurface records (e.g., water wells, geophysical records) and new drilling and geophysical data.

38-1
Usage and Feedback...

Traditional view is that nobody reads them.

Consultants and Conservation Authorities

- See where we are starting new projects and get routine updates.
- Used as a source for baseline understanding of the geology in a given area.
- In recent years these reports have been completed on a finer-scale than the regional Quaternary geology reports previously used to understand glacial history.
- No one has much knowledge of summary articles. Their existence is poorly known and are generally viewed as a flag that work is on-going.

Internal

- Get it down before you forget!
Legacy Data
Dealing with data

- Acquire data
- Standardize
- QUALITY!!!!

Subsurface database is released as part of the final groundwater resources study
Geophysics

[Image of two individuals working on equipment in a field]
Ground-based gravity surveys

- Target areas with known or suspected buried bedrock valleys
- Guide drilling and monitoring well targets
Seismic surveys
- Collaboration with the GSC
- Continuous data
- Mixed results
- Up to 200 m depth penetration

Airborne Time-Domain Electromagnetics
- Continuous data
- Transmitter flown 30-40m above ground (prepare for phone calls!)
- Depth penetration of up to 200 m
- Cultural interference is a huge problem
Products

- Lots of maps (.pdf)
- Geophysical datasets
  - Databases
  - Grids
  - Survey lines and/or stations
  - Images
  - Contours
  - Logistics and processing reports
Usage and Feedback...

Consulting Companies
- Data is seen as contributing to the overall understanding of the area.
- Geophysical data outlining the buried valleys is very useful in modelling studies.

Conservation Authorities
- I don’t think we have the computing power to use the geophysical tools.

Internal
- Most of the geophysical surveys are designed to help find buried bedrock valleys before we drill (gravity surveys) or improve our understanding of surfaces.

Municipal Engineers
- Used results of a gravity survey to check on some dodgy drill logs.
Drill

“Our Goal Is Your Hole”
Monitoring wells

- Collaboration with municipal and conservation authority partners
- We provide the hole, they install the well

Downhole geophysics

- Collaboration with the GSC
- Determine seismic velocities of lithological units (convert profiles to true depths)
- Fingerprint tills
**Product: Summary Report**

- Hot off the drill field descriptions
- Preliminary interpretations
- Summary logs
- Text and graphics (.pdf)

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**Composite Log**

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<th>Stratigraphic Unit</th>
<th>Depositional Environment and Primary Sediments</th>
<th>Example Photo</th>
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**Erian Channel - Fonthill Ice Contact Delta Complex Area**

**Legend**
- Gilt to clay diamicton
- Gilt to sand diamicton
- Clay
- Silt and clay
- Silt
- Silt to very fine sand
- Sand
- Sand and gravel
- Gravel to boulders
- Silurian bedrock
- Ordovician bedrock
- Interbedded
- Laminated, rhythmically-beded
- Devonian bedrock
- Cambrian bedrock
- Silurian bedrock
- Ordovician bedrock
- No Recovery

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**GLACIAL LAKE IROQUOIS SEDIMENTS**

As Halton ice retreated north of the escarpment and lake levels continued to drop, the Onondaga and Niagara escarpments created distinct lake basins. Glacial Lake Iroquois formed between the Niagara Escarpment and the retreating ice front. Water levels in the newly formed Lake Iroquois dropped then rose again to the main stand in response to rapid isostatic rebound of the eastern Lake Ontario basin. There are extensive deposits of Lake Iroquois nearshore sands near Lake Ontario. Deeper water Lake Iroquois sediments are found at surface around Niagara-on-the-Lake and north of the main Lake Iroquois shore bluff.

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*Fig. Each pictured core (Photos 32 A to 32F) is 45 cm long and the clay (a) covering the slightly laminated slightly silty clay and clay silt. c) Rhythmically bedded silt and laminated clay. a) Sharp halton unit diamicton. b) Rhythmically bedded upper glaciolacustrine 3 large slump field in glaciolacustrine sediments.*
Usage and Feedback...

Conservation Authorities

- Great, thank you. When do we get your interpretations?
- Do you keep track of fractures?

Consulting Companies

- Good morning Abigail. I just downloaded your latest summary and wondered if I could run something by you.....

Internal

- Take a deep breath and THINK
Product: Interactive Borehole Data Release

- Index map (.pdf)
- Graphic borehole log (.pdf)
Graphic borehole logs are linked to...

- Written logs (.pdf)
- Analytical results database (.mdb)
- Spreadsheet (.xls)
- Photos (.jpg)
Usage and Feedback...

Conservation Authorities
• We use the logs for holes with monitoring wells.
• I don’t need the details, just show me the aquifers!

Consulting Companies
• I like to see the detailed logs so I can be confident in your interpretations (and summary logs).
• We use the boreholes as golden spikes to extrapolate the geologic units outwards.
• Particularly useful as you drill in areas with little or only poor quality data.
• Saves us (clients) money as we don’t have to drill.
• Only useful if boreholes are close to a site or area of interest – this rarely appears to be the case
• Downhole geophysics isn’t of much interest

Engineer
• Asked for additional parameters (numbers make them happy)

Other ministries
• Soil scientists like the way the drill data is displayed.
Product: New Interactive Borehole Map

- Project information
- Conceptual model
- Maps
- Slideshow
- Graphic logs
- Printable maps

Interactive Graphic Borehole Logs and Stratigraphic Correlations, Orangeville–Fergus Three-Dimensional Map Area

A.K. Burt
J. E. Chartrand

1. Borehole location map
2. Borehole map
3. Hydrostratigraphic map
4. Bedrock map

Orange borders indicate interactive elements. Click on the circles to navigate through the contents of the pdf.
Distribution of hydrostratigraphic units

- Clickable map (.pdf)
- Links to database (.mdb, .xls)
- GIS project (.mxd)
Borehole map

- Interactive (clickable) map (.pdf)
- Links to database (.mdb, .xls)
- Link to printable borehole log (.pdf)
Graphic logs

- View on screen or print
- Not everyone needs / wants the detailed version
- Database (.mdb) and spreadsheet (.xls) contain depth information
Printable maps

- Full and cropped versions (.pdf)
Usage and Feedback...

Conservation Authorities
- We are using your new map to try and figure out which aquifer our monitoring wells are screened in.

Other ministries
- Our GIS staff like the drill log layouts
- Envy! We had a request to train their support staff in creating a similar product.

Internal
- I used the borehole map as a quick reference tool while modelling.
- I used spatial distribution map to quickly see which boreholes to reference during the report writing stage.
**Model**

1. **Plot borehole traces**
2. **Add picks**
3. **Create 3-D wireframe surfaces**
4. **Fill spaces with blocks**

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*3-D Workshop 2015*
Report

- Executive summary
- Regional setting
- Construction of a 3-D geologic model (the abbreviated version)
- Synthesis and interpretation of modelled units
- Discussion of aquifer vulnerability and recharge
- Explanatory notes for accompanying datasets and products
- Appendices
  - Detailed discussion of data acquisition
  - Detailed discussion of modelling protocols
  - Outputs and products including links to previous releases
Synthesis and interpretation - discussion of modelled units

- Location, thickness, structural contour
- Stratigraphic context, age
- Sediment characteristics (range in grain sizes, trends)
- Interpreted depositional environment
Aquifer vulnerability and recharge

- Depth to first aquifer
- Aquifer ID
- Elevation
Usage and Feedback...

Consulting Companies

- A present in a present in a present
- Saved us a lot of time and effort (money)
- Stratigraphic interpretations are used to construct our conceptual model
- We rely on your geologic information and interpretations
- It gives the wrong impression to use the term ‘aquifer’ in the unsaturated zones.
- We don’t need you to focus on hydrogeologic interpretations. That’s our job. Just make sure you give us detailed GEOLOGIC interpretations!

Conservation Authorities

- Suspiciously silent on the topic...

General

- Work and products are regarded as being of high scientific quality by those in other government agencies and the private sector
Technical Products

Model output files
- Continuous and discontinuous surfaces
- X, Y, and Z coordinates on a 100 m grid
- Designed for easy import into groundwater modelling software
- Comma-delimited data files (.csv)

Subsurface database
- Location, formation and 3-D picks tables
- Database (.mdb)
- Too big for a spreadsheet

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Usage and Feedback...

Model Surfaces

- Used as a foundation for our flow models
- Most useful in the deep overburden where our information is lacking.
- We need you to model aquifers where monitoring wells are screened.
- Cost benefits are substantial in both the short and longer terms.
- An excellent starting point. I get really annoyed when people describe early efforts as crap. We just need to be able to tweak the model.
- Use the model, but add local refinement to fit our borehole data.

This highlights a major weakness in the process – we don’t get access to most consultant’s data so our models are inaccurate in the very places they are most important. Obvious???? One would have thought so.
Classic Example of the ‘Merged Model’

Geologically accurate and streamlined the modelling process

Unfortunately...

• Was very difficult to use as an input for flow models
• Required extra processing
• Providing the clipping surface would have resolved most of the problems

Even more unfortunately...

• The consultants didn’t pick up the phone and ask for clipping surface, even when another major client suggested it.
**GIS grids**

- GIS Raster datasets
- Structural contours, isopach and aquifer vulnerability maps

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### Surficial Geology

- **Paleozoic sediments**
  - Igneous sediments
  - Metasediments
  - Metamorphic sediments
  - Metasedimentary deposits
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**Ontario**

3-D Workshop 2015
Usage and Feedback...

Consulting Companies

- Use the maps and grids to help build our hydrostratigraphic model
- Import the grids into flow modelling software
- Some have used ALL our layers, other merge the layers

Internal

- Display grids from multiple project areas to improve our interpretation of the Quaternary history
- The grids facilitate the report writing process
Non-technical Products

Section viewer
- Displays cross-sections along user defined lines
- Save then view in Google Earth™
- Microsoft® Virtual Earth™ executable (SectionViewer.exe)
Google Earth™ as a viewing platform

- Eliminates need for clients to have expensive software
- Isopach and structural contour maps
- Excerpts from seamless geology maps
- Aquifer vulnerability maps
- Google Earth™ (.kml, .kmz) and graphic (.png) files
• Query the standardized legacy database
• View new high quality data (perhaps the SUMMARY lithology would be better)
• Import previously saved cross-sections
• Allows user-defined fence diagrams
Usage and Feedback...

Conservation Authorities

- Use the section viewer to determine which aquifer their monitoring wells are screened in.
- I mostly use the online Google Earth OGS tool for hydrostratigraphic and geological purposes along with the various layers associated with it.
- Can you resend me the link?

Other Feedback

- It looks great, but what am I supposed to DO with it?
OVERALL ASSESSMENT

Summary reports and borehole releases
- Mixed reviews – some can’t wait, others barely register their existence.

Geophysics
- Valley delineation is used, the rest is largely ignored.

Final Products
- This is what folks download and use as a reference and employ as a data source.

My take on it
- Each product has a different fan group
- This means that we have succeeded in our mission to provide products useable by a wide range of clients.
- Suspect that the auditors like interim products more than our clients do.