UNIVERSITY OF WATERLOO
FACULTY OF SCIENCE

USING THE NEW 3D DIGITAL MODEL OF ONTARIO'S PALEOZOIC GEOLOGY TO BRIDGE GAPS IN THE TRADITIONAL EDUCATION FRAMEWORK

UNIVERSITY OF WATERLOO
EARTH AND ENV SCI

Jeremy Kamutzki, Quinn Worthington, and John Johnston, Department of Earth and Environmental Sciences, University of Waterloo, 200 University Avenue West, Waterloo, ON N2L 3G1 (jakamutzki@edu.uwaterloo.ca)

ABSTRACT

The demand for competent geoscientists and engineers is high, and the development of a new resource has addressed a gap in the traditional education framework. Spatial understanding is a key component of geoscience competency, but it has proven to be difficult for students to grasp 3D concepts using 2D teaching media. A new 3D digital model of Ontario's Paleozoic Geology created in partnership by the Geological Survey of Canada, Ontario Geological Survey, Ministry of Natural Resources and Forestry, Oil Gas and Salt Resources Library, and Carter Geologic (Carter et. al, 2019) has the potential to effectively compliment the existing teaching resources and vastly improve an education framework for geoscientists and engineers. The Department of Earth and Environmental Sciences at the University of Waterloo has been developing a teaching framework for this revolutionary new resource in undergraduate theses. Applying this new 3D digital geological model in the class called Earth 235: Stratigraphic approaches to understanding Earth History has helped bridge the dimensional and interactive gaps that exist with the traditional education framework. To interpret the detail shown in the 3D geological model, the new Paleozoic lithostratigraphic chart for southern Ontario was used in conjunction with the 3D model. By examining the 3D model and lithostratigraphic chart as well as enlisting the help of students and professionals, a list of the 'Top 10 Important Aspects of Ontario's Paleozoic Geology' is being compiled to help guide development of a new education framework. This list is helping to define educational learning objectives that connect to professional competencies, provide a focus on certain features and resources that are hidden in the wealth of information in the 3D model, and link key features to core geologic concepts that could be transferred to other sedimentary basins.

PREVIOUS WORK

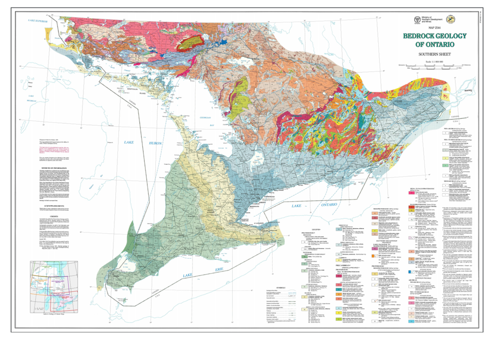
The Model: From Concept to Completion

The impetus for creating the 3D Paleozoic bedrock model for southern Ontario was from a gap analysis at the Regional-Scale Groundwater Geoscience in Southern Ontario Open House (Russell et al. 2015). After many years of collaborative efforts between the partners highlighted below, a 3D digital model was released (Carter et al. 2019).

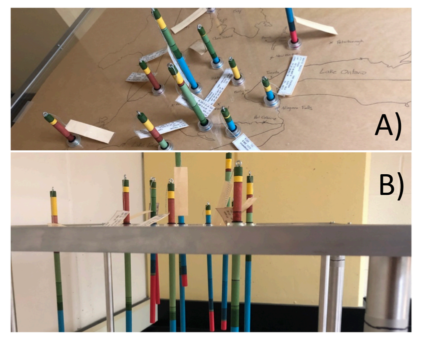
GSC – Project Lead & Modelling
OGS – Field Work & Bedrock map
MNRF – Field Work
OGSRL – Database & Geology QA
Carter Geologic – Project Lead

Quinn Worthington's Undergraduate Thesis (2019)

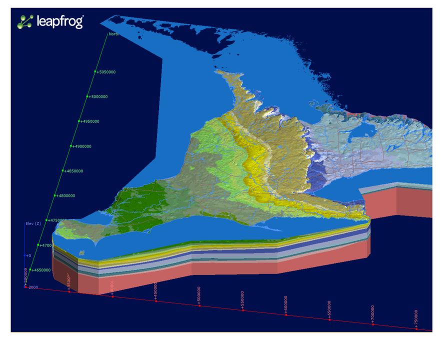
Quinn Worthington was provided access to a preliminary version of the 3D model by the GSC. For her undergraduate thesis, she compared the effectiveness of three different teaching mediums used in the second year course 'Stratigraphy and Earth History' (Earth 235): paper maps, a 3D physical model, and the preliminary 3D digital model. Quinn found that each medium that was tested had unique strengths, and that students had a high level of natural interest in the digital model. However, they found it difficult to navigate and understand in a single lab period due to its intrinsic complexity, with 56 layers and ~25,000 boreholes. Overall, she recommended that further work be done to implement the model into the lab portion of the course with a learning framework that enhanced students ability to link the content of the model to learning Ontario's geology.



2D Paper Map (OGS, 1991)



3D Physical Model (UW, 2018)
A) Top view, B) Side view



3D Digital Model (GSC, 2019)

GOALS AND OBJECTIVES

Enhance Student Learning

The overarching goal of this thesis project is to enhance the learning experience of students at the University of Waterloo in the 'Earth 235: Stratigraphy and Earth History' lab. This course is a fundamental knowledge-base requirement for professional geoscientist accreditation in Ontario. Students have traditionally had difficulty developing 3D spatial thinking skills from paper maps, but when they are able to extract the full educational value from the new 3D digital model, they are accelerated along this component of their path to geoscience competency.

Develop a Learning Framework

Worthington (2019) found that the digital model has so much detail that students were overwhelmed by its capability. In order to implement the model in an effective manner, a learning framework was developed that uses key features and concepts to direct students on a path of discovery through the model.

Unite Students with the 3D Digital Model

The developed framework will be considered successful if students are able to do the following. First, they can efficiently use the Leapfrog Viewer® software to navigate through the model. Second, they make concept connections that didn't occur with other learning media. Third, they develop core skills that can be applied in other sedimentary basins throughout the world.

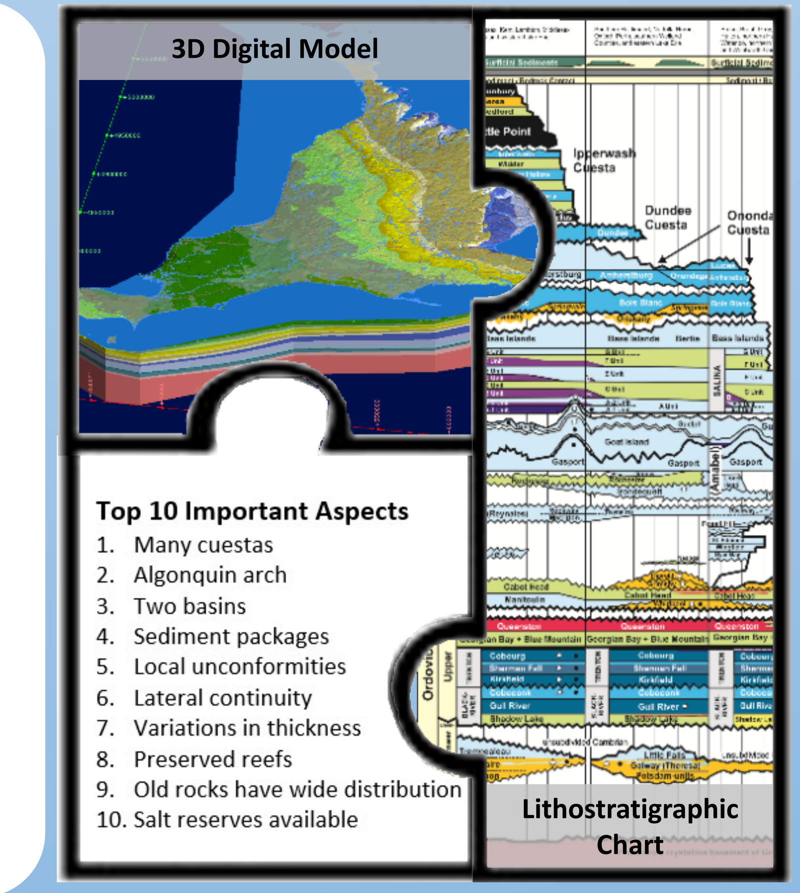
THE PROCESS

Students per Lab Section	Week 1 Topics	Week 2 Topics	Week 3 Topics	Week 4 Topics
23 12 30 Total of 65 Students	• Precambrian Geology (Paper Map) • Phanerozoic Geology (Paper Map) • Phanerozoic Geology (Lithostratigraphic Chart) • Wrap-up question to summarize Ontario's geology	• Introduction to Leapfrog Viewer® (3D Digital Model) • Cuestas, arches, and basins (3D Digital Model)	• Unconformities and lateral distribution of Paleozoic rocks (3D Digital Model) • Resources found in Paleozoic rocks (3D Digital Model) • Wrap-up questions to collect feedback on the functionality of the digital model and framework	Post-lab survey to collect qualitative feedback on how well students thought the model worked, and to collect recommendations on any changes that should be made to the learning framework

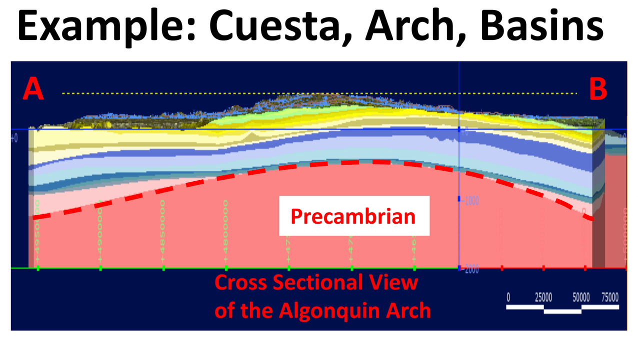
Combined Three Resources

In order to develop a robust education framework, students were provided with the following three resources:

- Unpublished version of the new 3D digital model of Ontario's Paleozoic provided by the GSC (Carter, 2019)
- The current Lithostratigraphic chart (Brunton, 2017). It provided a 3D sense when working with the paper maps, and simplified the abundant info in the 3D digital model
- A 'Top 10' list of the important concepts and features of Ontario's Paleozoic geology that was created as a learning framework for the model. The list helps define learning objectives and provides a focus for the many observable features in the digital model

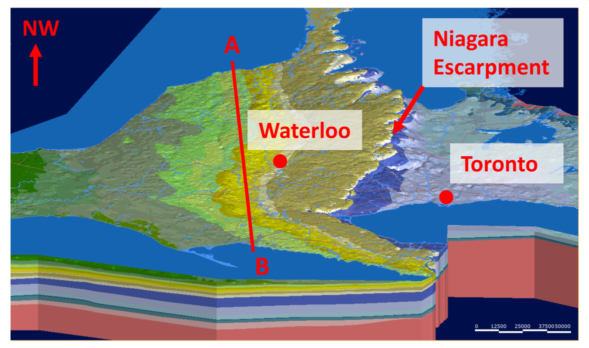


Example: Cuesta, Arch, Basins



Right: An oblique view of the 3D digital model showing the surface expression of the Algonquin arch, as well as the Niagara Escarpment.

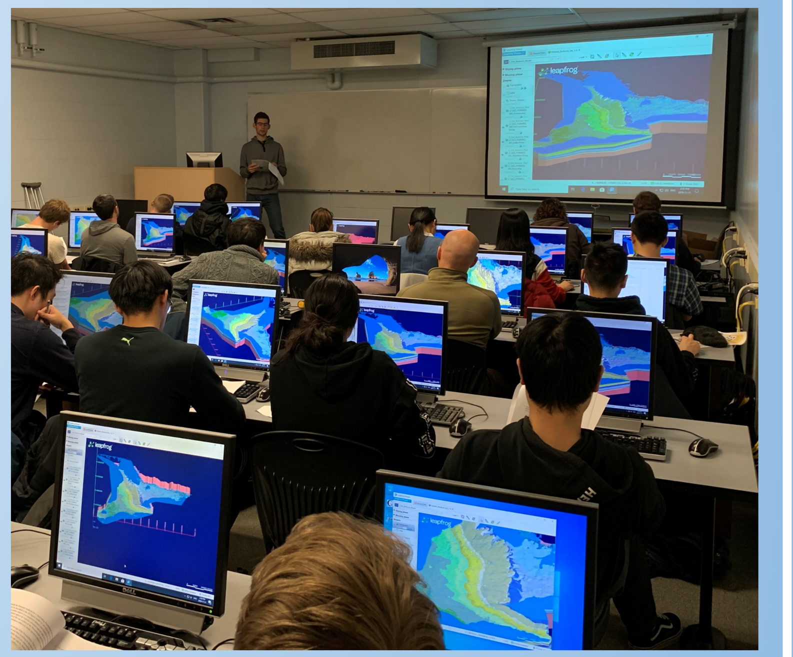
Left: A cross sectional view of the Algonquin arch showing the Paleozoic bedrock sitting atop the Precambrian craton. Note that the bedrock dips into the Michigan basin toward 'A' and the Appalachian basin toward 'B'



PRELIMINARY OUTCOME

High Student Engagement

Students were excited to work with the model, provided positive feedback on the model during the labs, and high quality qualitative feedback in a post lab survey.



Effective Framework

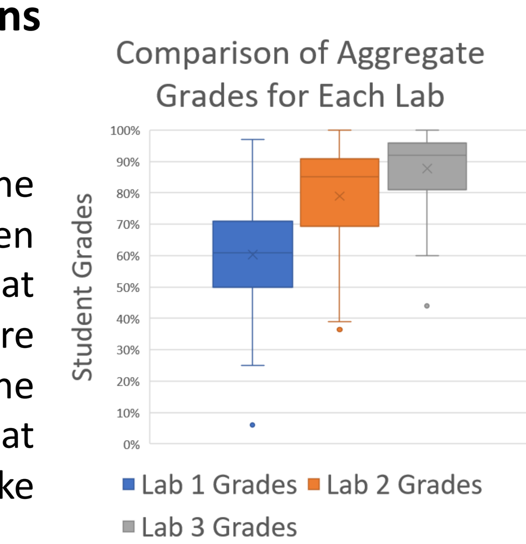
88% of students who responded to the post-lab survey said that the Top 10 framework helped them understand the model better.

Consistency Between Lab Sections

Because grades between all lab sections were statistically similar, the lab groups can be treated as an aggregate grade. This was the expected result, as significant effort was taken to make sure that student experience was consistent between lab sections

Concept Connections Improved from Week 1 to 3

A statistical increase in the average grade between labs 1 and 3 confirm that students became more proficient in using the software, and improved at using the model to make concept connections



Leapfrog is an Efficient Tool for University Students

Students were able to learn how to use Leapfrog Viewer® proficiently with twenty minutes of instruction and approximately 30 minutes of practice with the 'Learning Leapfrog' topic on the second lab. With this focused introduction time, students were then able to proficiently use Leapfrog Viewer® to make concept connections.

KEY TAKEAWAYS

Enhance Student Learning

- There was a statistical increase in grades when using the digital model
- Students were motivated and engaged in their learning
- New concept connections were frequently made while using the model (ie, visualizing the Algonquin Arch in 3D helped explain the 2D surface expression)

Develop a Learning Framework

- In a post-lab survey, 88% of respondents stated that the 'Top 10' learning framework helped them understand the model better
- Students were engaged in dialogue about the 'Top 10' list, and provided valuable input to refine and clarify the items on it

Unite Students with the 3D Digital Model

- By its very nature, the 3D digital model did a better job than the paper map at helping students understand data limitations, locate specific information, and make accurate predictions of subsurface geologic features

Help Shape the Next Generation of Geoscientists

We want to hear from you! The final part of Jeremy's undergraduate thesis is to get input from Open House attendees. In your professional experience, what is most important about Ontario's Paleozoic geology? Please tell Jeremy your 'Top 3, 5 or 10' most important features or concepts that future new hires should know about Ontario's Paleozoic geology. Then Jeremy will investigate to see if the items on your list have been or can be incorporated into the educational framework, and explained in the 3D digital model.

REFERENCES AND ACKNOWLEDGEMENTS

Thank you Earth 235 teaching assistants (Siyu, Sarah, and Emma) for their support, and students for their excitement about the model, and permission to use student responses to improve Earth 235 course. Thank you Stephen Markan for setting the model up on the lab computers. And thank you Hazen Russell from the GSC for providing an unpublished version of the 3D digital model, so I could develop a learning framework to best prepare upcoming professional geoscientists and engineers in Earth 235.

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