



Geological Survey of Canada
Scientific Presentation 153

Canada in 3D - National Geological Surveys Committee update report

E.A. de Kemp[1]

[1]Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario

2023

Presented at: Canada in 3D - National Geological Surveys Committee update meeting

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Ottawa, Canada

June 22, 2022

Welcome to Canada 3D! A National Geological Survey's Committee project to develop a 2D and 3D geological map of Canada. We urge our participants and others from the Provinces and Territories, and all stakeholders from abroad, academia, industry and other geoscience agencies to see our recent version of the C3D Portal, (See https://canada3d.geosciences.ca/) and click on the 'about' button.

There you will see our collective vision for moving forward to undertake this daunting task. We have summarized herein the presentations summarizing recent C3D activities, which include important compilations, data integration and 3D modelling activities. In addition, we transcribed comments made by the participants in this project update meeting that should be helpful to those who could not attend.

As I said in a recent GAC-MAC meeting in Halifax-2022; one thing that the Covid-19 pandemic experience has taught us is that we can do things differently. I suggest that at this time, we think of ways to do C3D differently, perhaps with better ways to collaborate and new ways to organize ourselves in order to move the C3D vision forward. I hope this will involve more communication, hammering out common goals and sharing of resources to move from vision to operational practice.

As mentioned in this NGSC-C3D update meeting our leader, Boyan Brodaric, is on leave unfortunately for health reasons. I am serving as best I can to move our vision toward implementation, trying to engage each of our jurisdictions. I look forward to continuing to serve you all and to enjoy doing things in ways we never thought possible!

Sincerely,

Eric A. de Kemp

3D Interpretation Specialist / Acting Head C3D

Geological Survey of Canada

Ottawa, Canada

22 juin 2022

Bienvenue à Canada 3D ! Un projet du Comité national des commissions géologiques visant à élaborer une carte géologique 2D et 3D du Canada. Nous invitons nos participants et d'autres personnes des provinces et des territoires, ainsi que tous les intervenants de l'étranger, du milieu universitaire, de l'industrie et d'autres organismes géoscientifiques à consulter notre récente version du portail C3D (voir https://canada3d.geosciences.ca/) et à cliquer sur le bouton " à propos ".

Vous y verrez notre vision collective pour aller de l'avant et entreprendre cette tâche colossale. Nous avons résumé dans ce document les présentations résumant les activités récentes de C3D, qui comprennent d'importantes compilations, l'intégration de données et des activités de modélisation 3D. De plus, nous avons transcrit les commentaires faits par les participants à cette réunion de mise à jour du projet qui devraient être utiles à ceux qui n'ont pas pu y assister.

Comme je l'ai dit lors d'une récente réunion du GAC-MAC à Halifax-2022 ; une chose que l'expérience de la pandémie de Covid-19 nous a appris est que nous pouvons faire les choses différemment. Je suggère qu'en ce moment, nous réfléchissions à des façons de faire le C3D différemment, peut-être avec de meilleures façons de collaborer et de nouvelles façons de nous organiser afin de faire avancer la vision du C3D. J'espère que cela impliquera plus de communication, l'élaboration d'objectifs communs et le partage des ressources pour passer de la vision à la pratique opérationnelle.

Comme mentionné dans cette réunion de mise à jour du NGSC-C3D, notre chef, Boyan Brodaric, est malheureusement en congé pour des raisons de santé. Je fais de mon mieux pour faire avancer notre vision vers la mise en œuvre, en essayant d'impliquer chacune de nos juridictions. Je me réjouis de continuer à vous servir tous et de prendre plaisir à faire les choses d'une manière que nous n'aurions jamais cru possible !

Sincèrement,

Eric A. de Kemp

Spécialiste de l'interprétation 3D / Chef intérimaire C3D

Commission géologique du Canada

Agenda

Introduction

- C3D in Transition Within the GSC: Geneviève Marquis
- C3D Portal: Dianne Paul

P&T Presentations (5 min)

- British Columbia – Yao Cui
- Alberta – Kelsey MacCormack
- Saskatchewan – Sean Boseman
- Manitoba – Greg Keller
- Ontario – Mike Easton
- Quebec – Patrice Roy
- New Brunswick – Dustin Dahn
- Nova Scotia – absent
- Prince Edward Island – Qing Li
- Newfoundland – Sara Jenkins
- Yukon – Maurice Colpron
- Northwest Territories – Viktor Terlaky, Kelly Pierce
- Nunavut – absent

GSC

- Collaborative Model Development – Karine Bédard
- Data Exchange – Éric Boisvert
- Methods – Mike Hillier

Discussion

Canada 3D June 6th meeting: Provincial participants

NGSC National Geological Surveys Committee

BC

Yao Cui

AB

Paulina Branscombe

Simon Haynes

Kelsey MacCormack

SK

Sean Boseman

Arden Marsh

Tyler Music

MB

Greg Keller

ON

Mike Easton

QC

Patrice Roy

NB

Dustin Dahn

NS

Mark Deptuck

Diane Webber

PE

Qing Li

NL

Alana Hinchey

Sara Jenkins

YT

Maurice Colpron

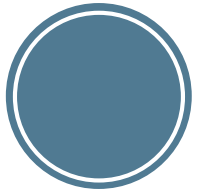
NT

Viktor Terlaky

Scott Cairns

Canada 3D June 6th meeting: GSC participants

NGSC National Geological Surveys Committee

Calgary	Ottawa					Quebec City	Halifax	Nunavut
 Andy Mort	 Sonya Banal	 Boyan Brodaric	 Michael Hillier	 Eric De Kemp	 Christopher Lawley	 Charles Logan	 Karine Bedard	 Calvin Campbell	 Linda Ham
	 Miren Lorente	 Genevieve Marquis	 Glen Newton	 Dianne Paul	 Alain Plouffe	 Michel Plouffe	 Eric Boisvert	 Brian Todd	 Catherine Gilbert
	 Hazen Russell	 Ernst Schetselaar	 David Snyder	 Marc St-Onge	 Victoria Tschirhart	 Don White			

Canada in 3 dimensions in a changing world

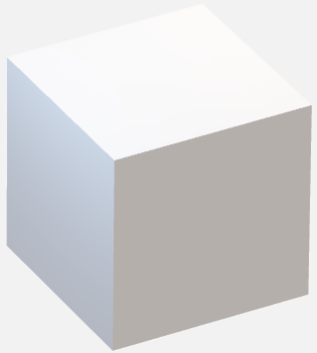
By Geneviève Marquis, GSC, June 6, 2022

The vision

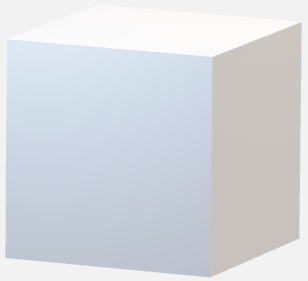
“The Canada-3D project is a national collaboration involving the provincial and territorial geological surveys and the Geological Survey of Canada (GSC), operating under the auspices of the National Geological Surveys Committee (NGSC).”

Some aspects of C3D

P&Ts
Collaboration

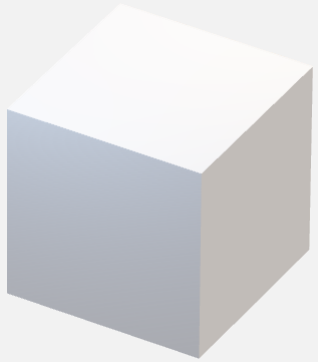


Data
Standards



GEM
Publications

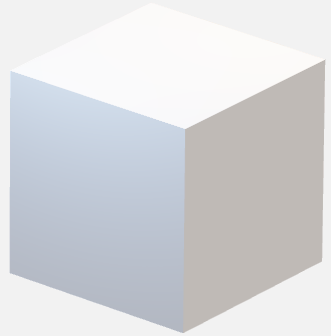
Ground
Water



International
Collaboration

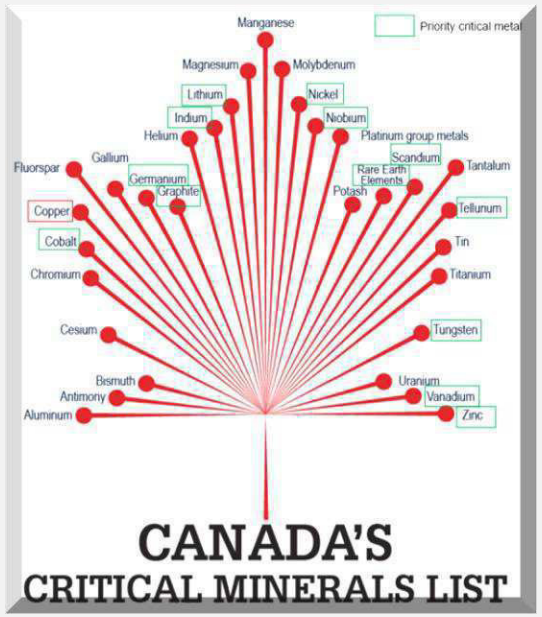
Predictive
Analytics &
Modelling

Data
Visualization &
Communication



Critical
Minerals

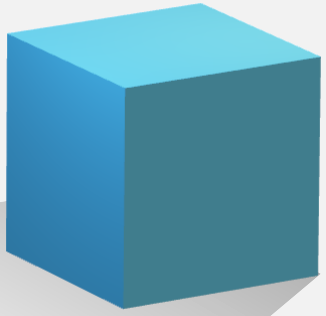
A new data approach with the Critical Minerals Geoscience and Data (CMGD) program



CMGD

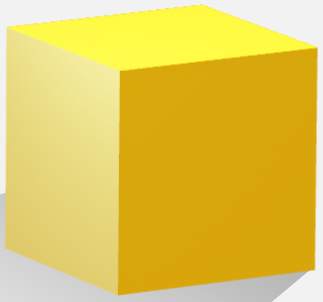
Predictive geoscience to accelerate the top 14 critical minerals to support the transition to a low-carbon future.

New data layers needed, new vision for C3D.



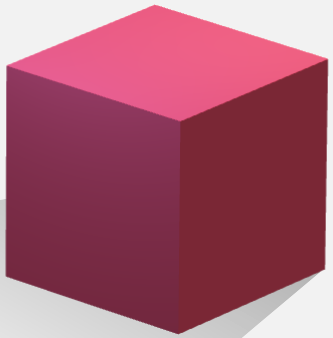
Critical Minerals Knowledge Based

What do we know about these top critical minerals?



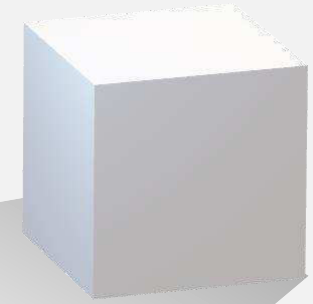
ESG values

Environmental, Social and Governance values



Bedrock Mosaic

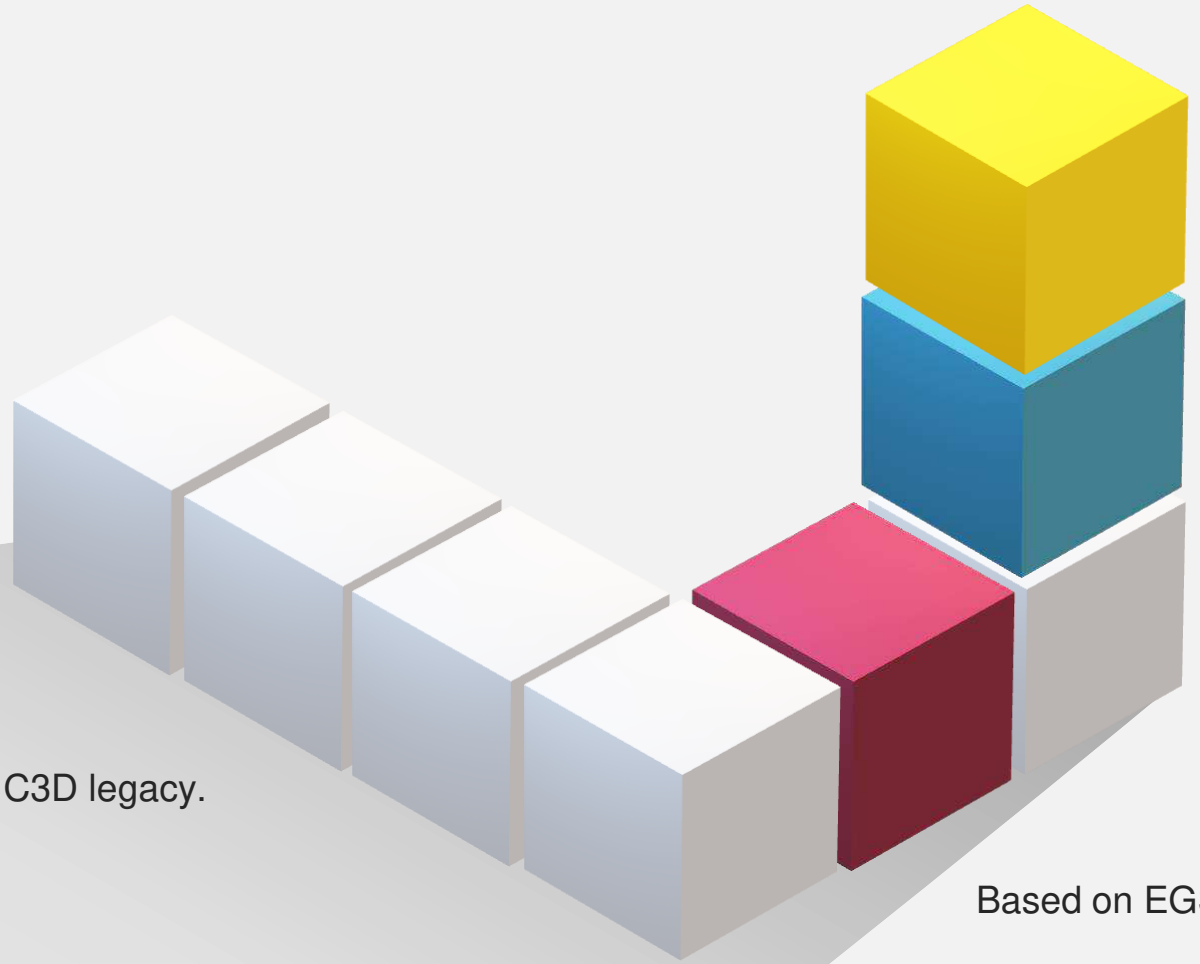
Can C3D contribute this this first requirement?



Analytics tools for Critical Minerals

Inspired from C3D accomplishments in the past.

The Future of C3D is to be built together, because it won’t stay “as-is”.



One important driver for 3D geological research is critical minerals;

Implementing a new culture of equity, diversity and inclusion.

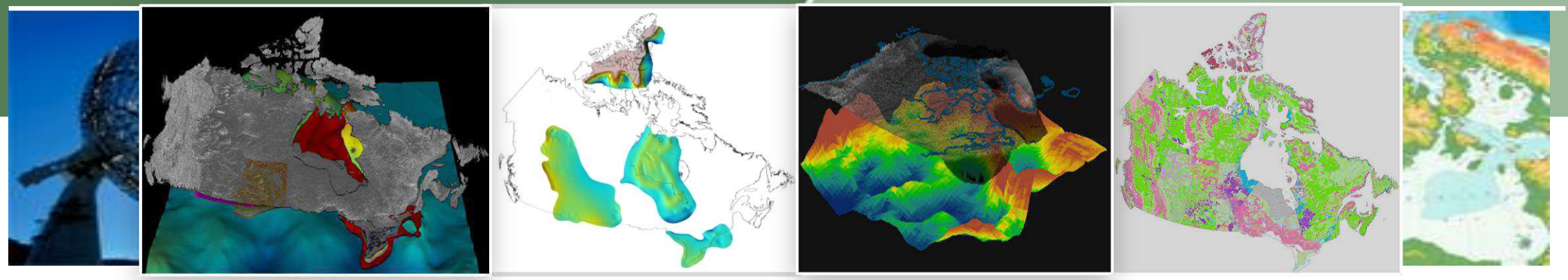
Traditional C3D legacy.

Based on EGS values

Conclusion

C3D

More discussion and engagement require to find the new C3D equilibrium.



Canada-3D Portal

Dianne Paul, Eric de Kemp and Marc St-Onge
on behalf of the C3D team
Geological Survey of Canada

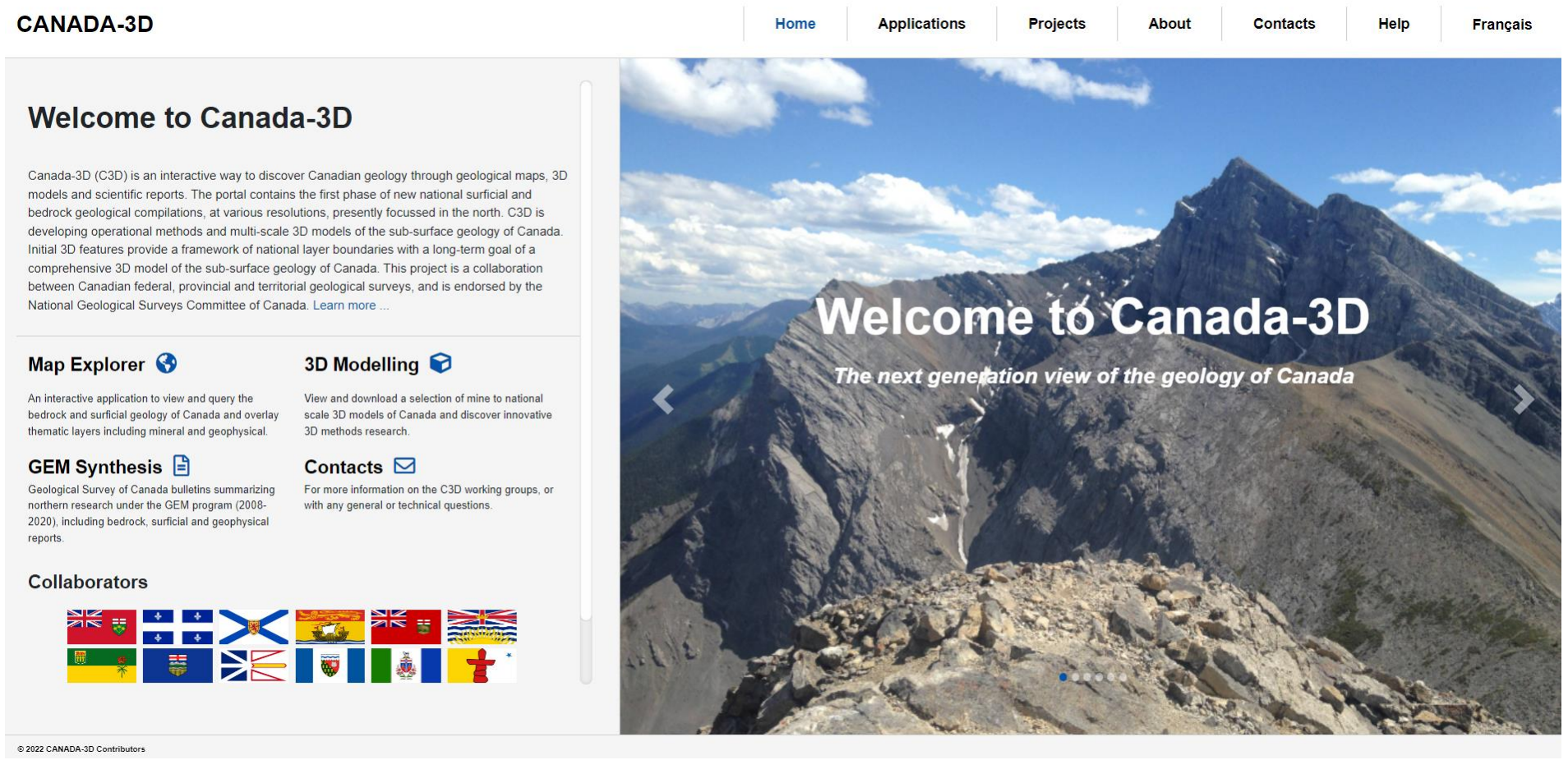
Canada

NGSC
National Geological
Surveys Committee

Canada 3D

Canada-3D Web Portal

https://canada3d.geosciences.ca



Goals & Outputs

To put the portal in context, the Canada-3D project goals and outputs include:

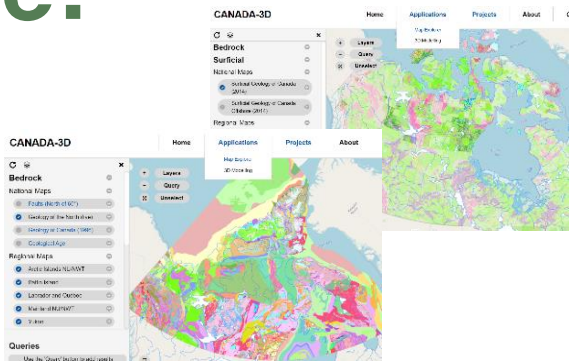
- Consolidated and increased knowledge of the geology of Canada through enhanced access to information through collaboration across provincial, territorial and federal geological surveys.

Achieved by:

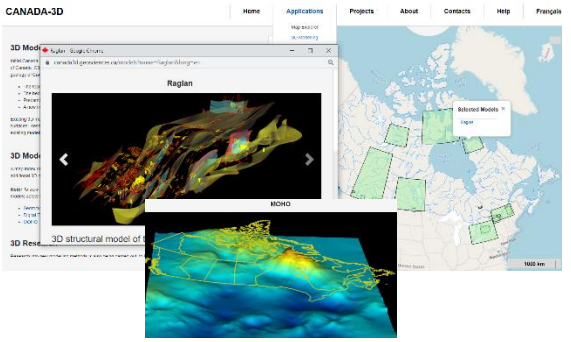
- Developing a national 3D model, from surface through mantle
- Creating new national-scale 2D surface bedrock and surficial geology maps for Canada (*Replace 20+ year old legacy maps*)
- Providing these through a web portal for public online delivery and use.

Major deliverables include:

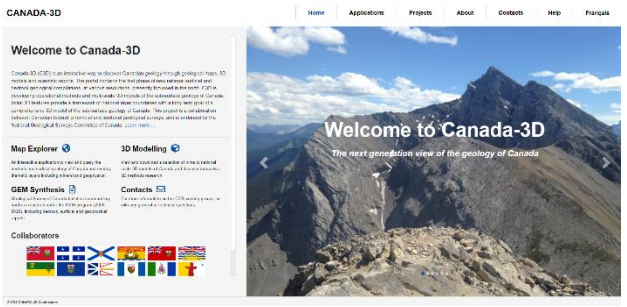
- New 2D bedrock and surficial compilations and source maps within the Map Explorer
  - Current focus north of 60°
  - Preliminary work started south of 60°



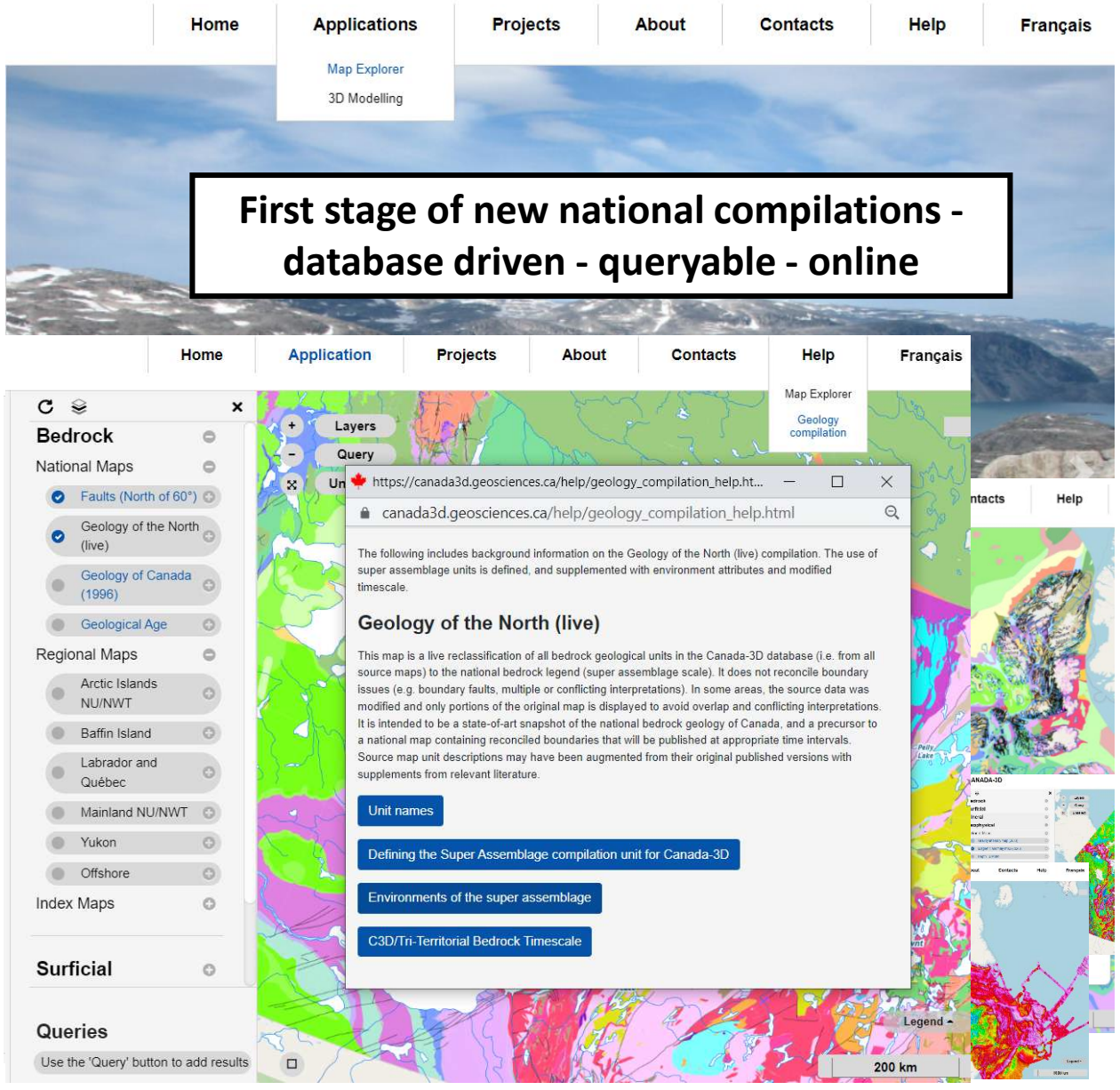
- 3D model for the geology of Canada
  - built on existing information and models
  - highly variable in its resolution and coverage, horizontally and vertically in space



- A web portal for their public online delivery and use
  - viewing and download of 3D models and 2D map queries
  - With ‘live’ online products, updated incrementally as new source materials available



Canada-3D: Map Explorer



ME allows users to discover the geology north of 60° through detailed querying of features within and across maps in the C3D database.

Currently focussed on the north, it represents the evolving national bedrock and surficial compilations of Canada.

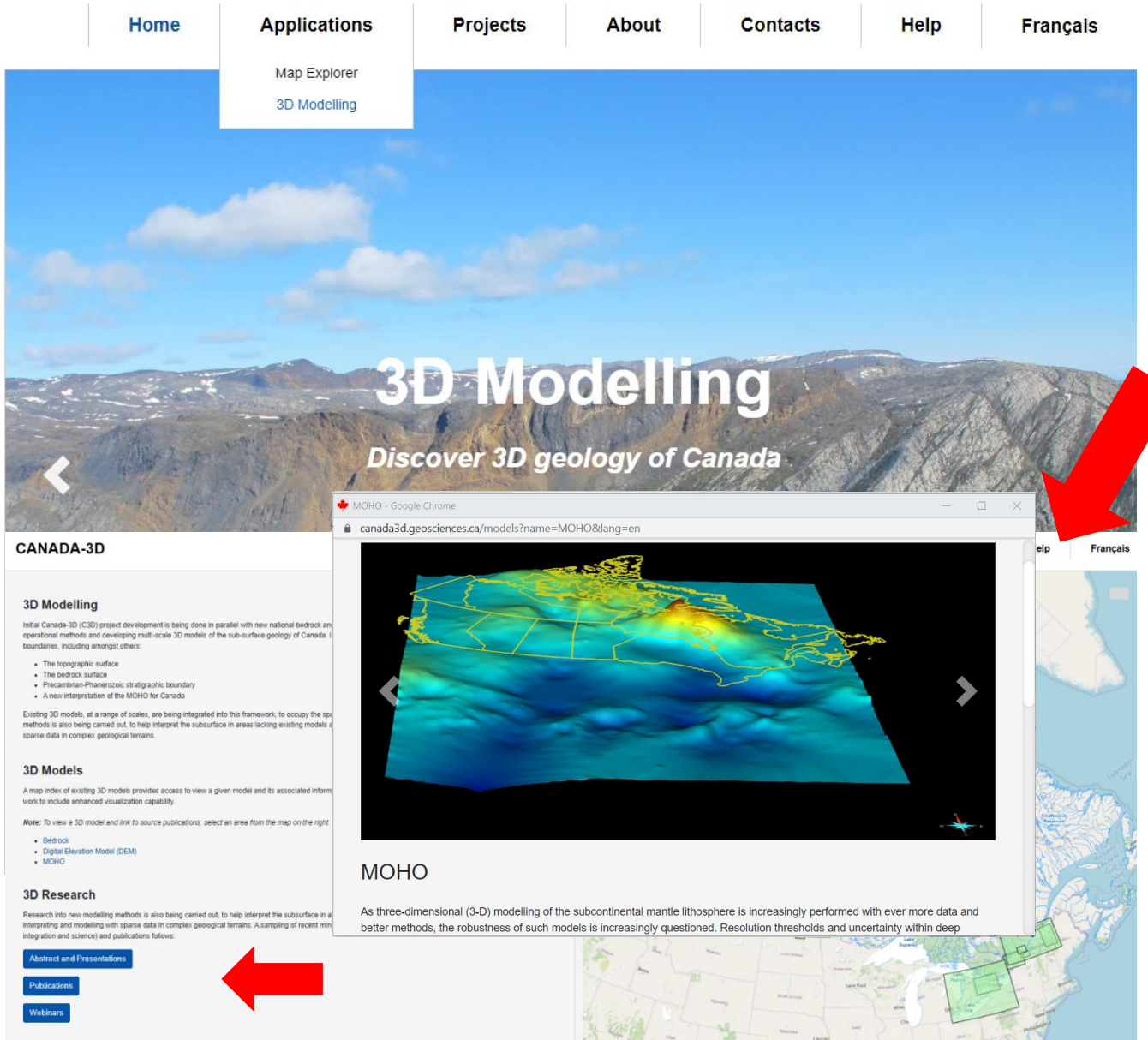
National scale geophysical and mineral layers available to view and overlay with geology layers.

Help files provide information for using the ME application from its National to Regional layer content to querying and displaying map units and attributes.

A separate help file provides background information on the Geology of the North compilation.

This map is a live reclassification of all bedrock geological units in the Canada-3D database (i.e. from all 70+ source maps) to the national bedrock legend (super assemblage scale).

Canada-3D: 3D Modelling

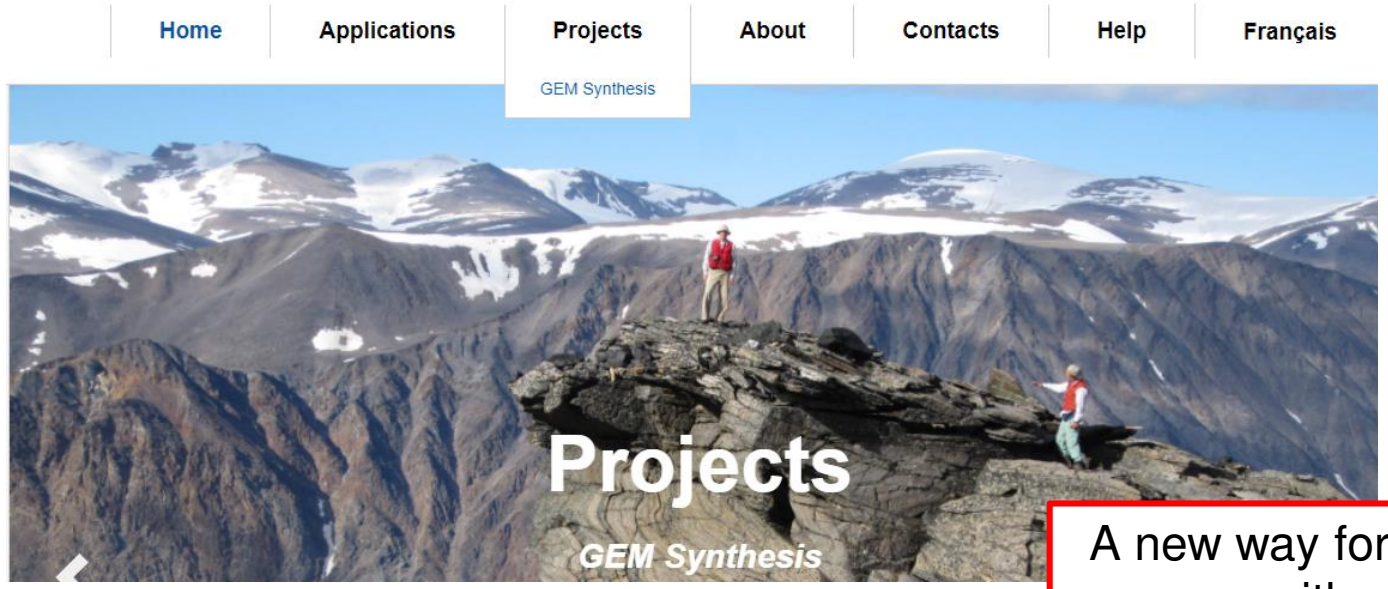


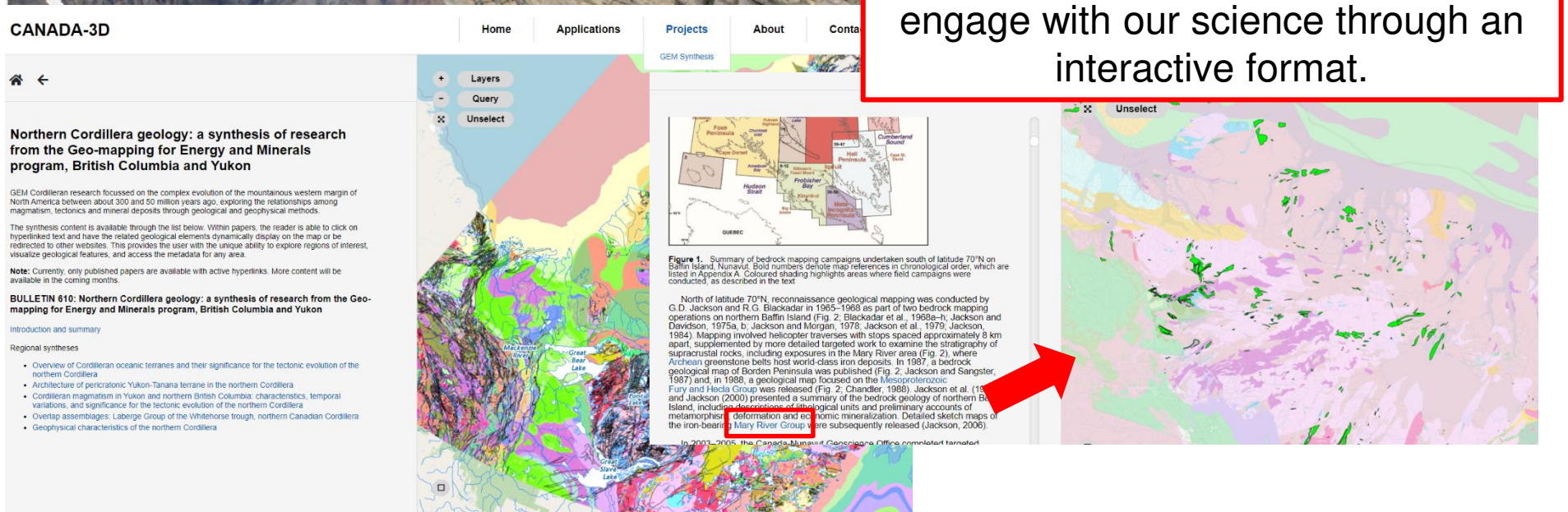
An index of existing 3D models, at a range of scales, provides access to view any given model as well as source publications describing the model and the associated data.

Research into new modelling methods are available through a referenced list of recent 3D modelling activities, from mine to national scale.

Canada-3D: GEM Synthesis

Discovery through interactive text-map content





GSC bulletins summarizing northern research under the GEM program (2008-2020):

- Within papers, the reader is able to click on hyperlinked text and have the related geological elements dynamically display on the map or be redirected to other websites.
- Provides user with the ability to explore regions of interest, visualize

A new way for users to discover and engage with our science through an interactive format.

Query 1: Bravo Lake Formation - Central Baffin

CANADA-3D

Thrust contact at base of Bravo Lake formation
Existing Au high concentration structural deposit **(Au, Ag, Pb, Bi)**

Units from Query: Bravo Lake formation

Open all | Close all | Print Page

Bravo Lake formation

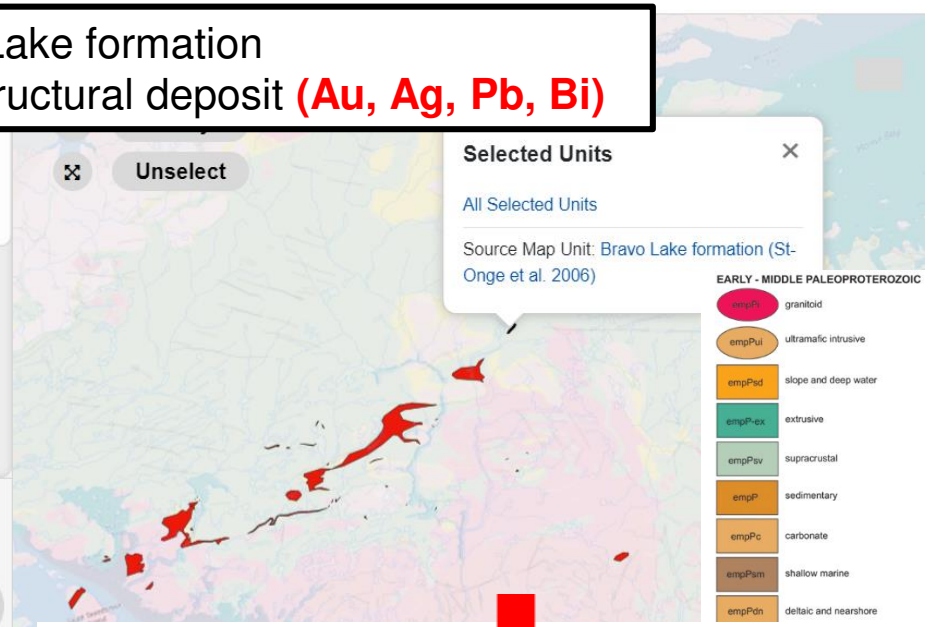
- **Unit details:** Click Here
- **Global Domain:** North American continent
- **Morphology:** wedge
- **Colour:** medium green
- **Metamorphic facies:** amphibolite
- **Metamorphic temperature:** medium temperature
- **Metamorphic pressure:** low pressure
- **Description:** basalt, amphibolite, pyribolite; volcaniclastic sedimentary beds; minor quartzite, semipelite, silicate-facies iron-formation; gabbro; peridotite; layered peridotite-gabbro sills
- **Comment:** sulphides, gold
- **Source map:** [GSC OF4931; 2006; St-Onge, M. R., Jackson, G. D., and Henderson, I.; Geology, Baffin Island (south of 70°N and east of 80°W), Nunavut; http://dx.doi.org/10.4095/222520]

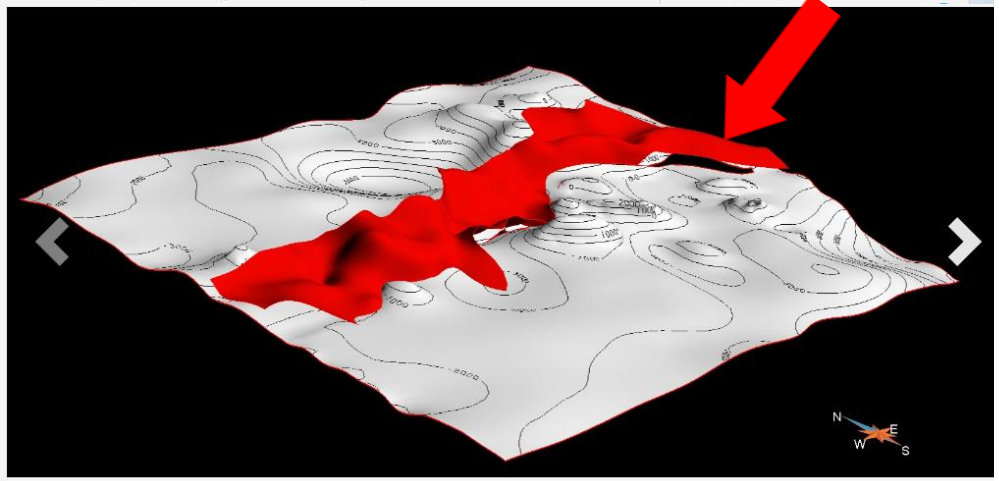
National Maps

- Faults (North of 60°)
- Geology of the North (live)
- Geology

Queries

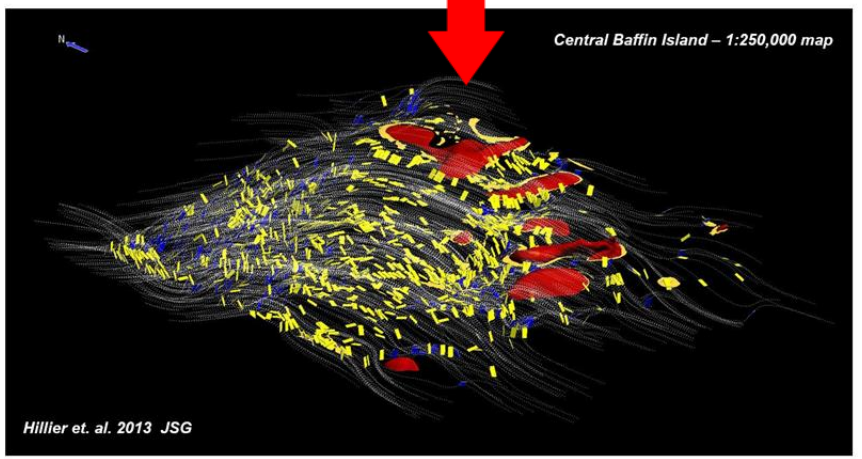
- Bravo Lake formation





3D structural model of Central Baffin Island

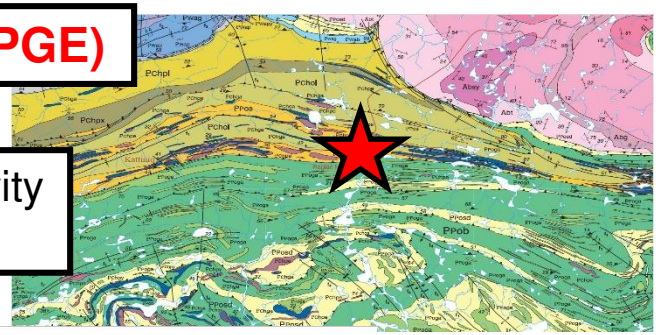
Structural Field Interpolation (SFI)



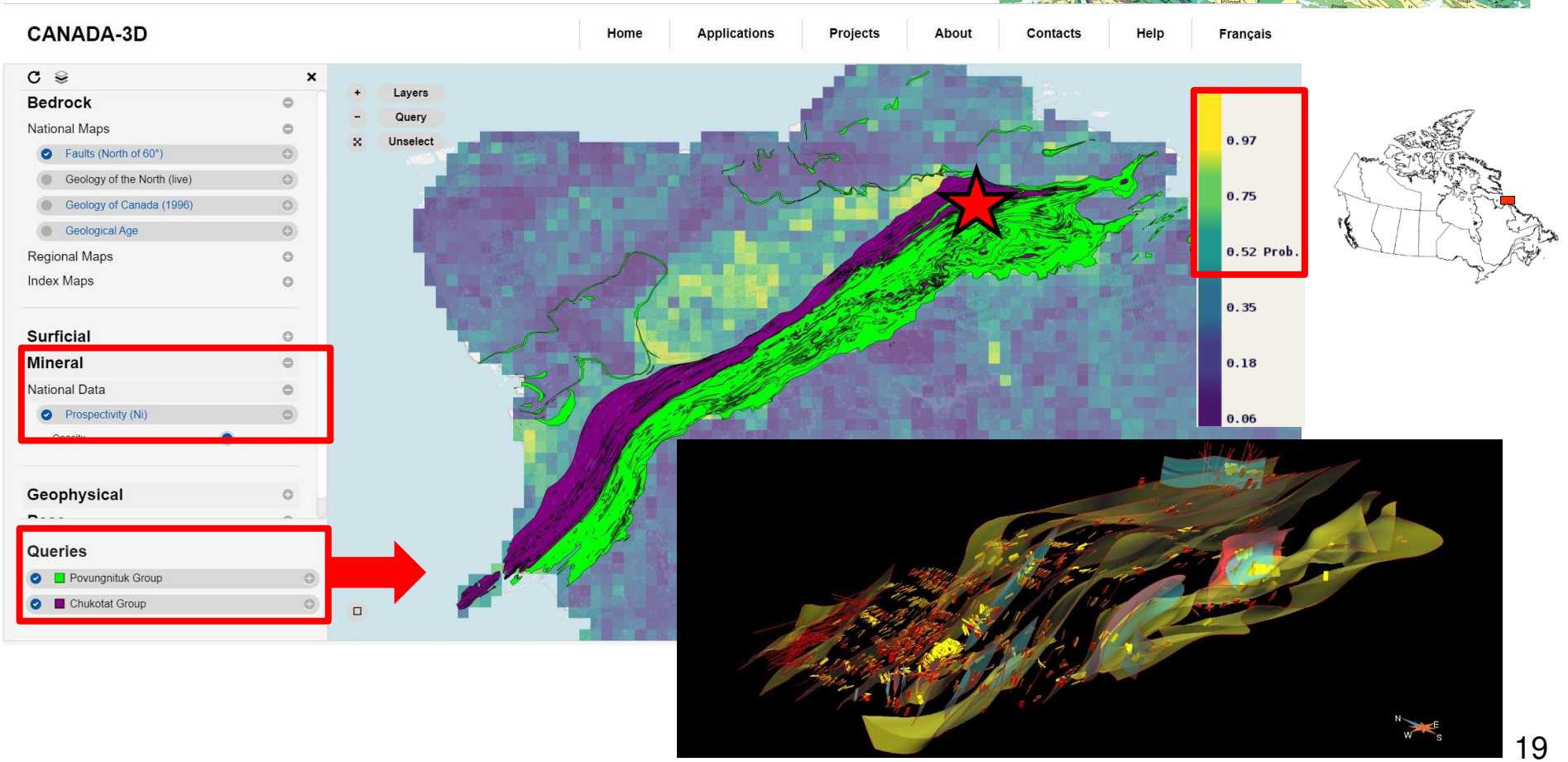
SFI + Cross-Section + parse

Query 2: Cape Smith – Raglan Mine

Interface of the Povungnituk and Chukotat groups **(Ni, PGE)**



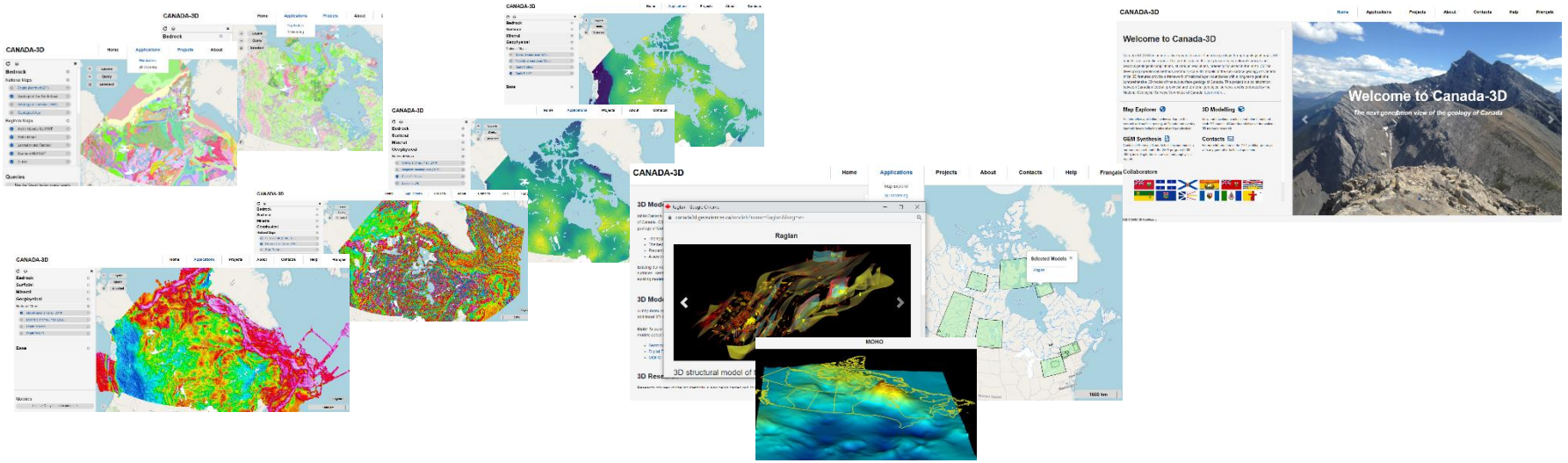
2D Bedrock geology + structural field data + metal prospectivity + 3D structural stratigraphic model = **Geological Context**



Canada-3D: Accomplishments

Most importantly provides a new framework to integrate variable scale data to query & view relationships between 2D map features/themes and specific 3D model elements.

2D Bedrock geology + structural field data + mineral prospectivity + 3D structural stratigraphic model = **Geological Context**



Future:

- The inclusion of additional 3D models and methods is ongoing, with enhanced visualization capability in future
- 2D compilations evolve & include the south, offshore collaboration – UNCLOS; additional geophysics and mineral layers
- Canada is a large landmass – volume of data and complexity – will take time
- Level of attribute detail, interpretations vary based on source and scale - query results may not include all rock units that meet the query criteria – more work required
- Scientific review of the data and queries is essential for accuracy - especially by PT and GSC researchers who know the geology

Acknowledgements

Bedrock Compilation:
Marc St-Onge
Chris Harrison
Data:
Dianne Paul

2D-Surficial Compilation:
Dan Kerr
Data:
Azadeh Ashoori Pareshkoohi
Dianne Paul

Geophysics:
Doug Oneschuk
Mathieu Ouellet
Minerals:
Chris Lawley

Data Model/Architecture
Boyan Brodaric

DB Maintenance/ Infrastructure:
Gabriel Huot-Vezina
Roman Mitura

C3D Portal:
Dianne Paul
Gabriel Huot-Vezina
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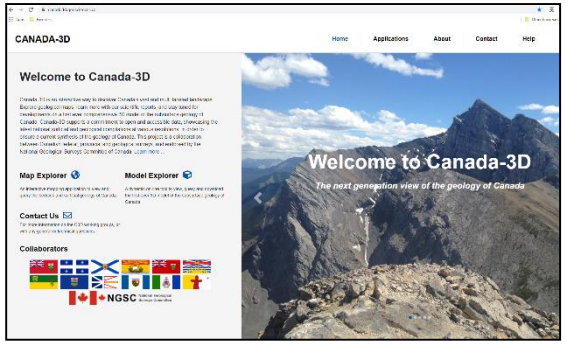
Patty Zhao
Heryk Julien
Eric Boisvert
Subhas Tella

Review – preliminary release June 2021

YGS: Maurice Colpron NWT: Doug Irwin, Kelly Pierce
GSC: Karen Fallas, Keith Dewing, Chris Lawley, Lynn Dafoe, Isabelle McMartin, Alain Plouffe, Ross Knight, Daniel Lebel

Canada-3D: Conclusion

Science + Technology = C3D Portal



A modern national scale geoscience framework, requires both to achieve:

- Consolidated and integrated knowledge of the geology of Canada through enhanced access to information.
- New ways to engage users to discover our science through innovative & interactive dissemination formats.
- Collaboration across provincial, territorial and federal geological surveys to enable current state of knowledge, scientific review and user feedback.

Thank you…

3D Geoscience Models: Activities and Use Cases in BC

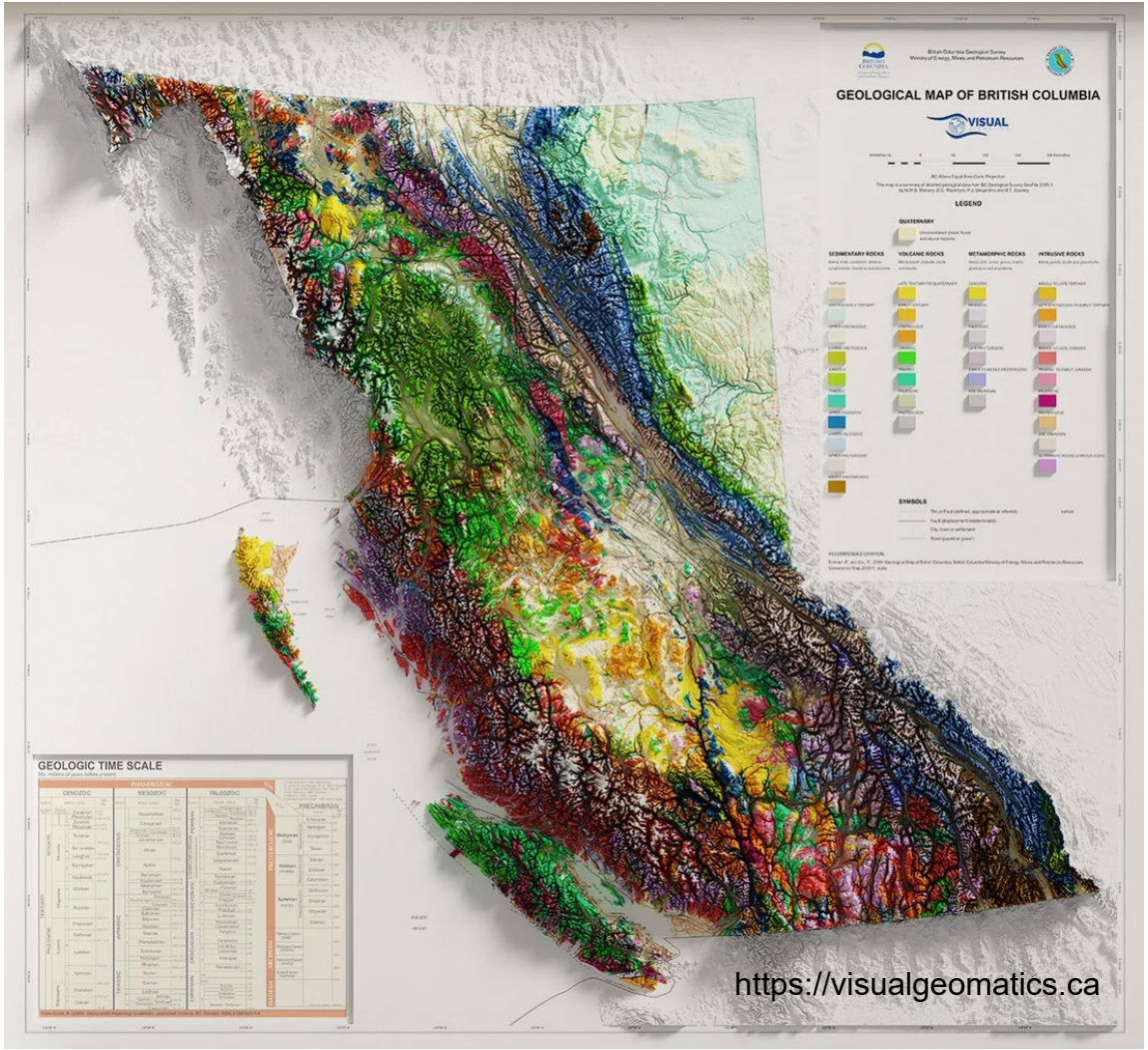
Yao Cui
Director of Resource Information

June 6, 2022

Topics

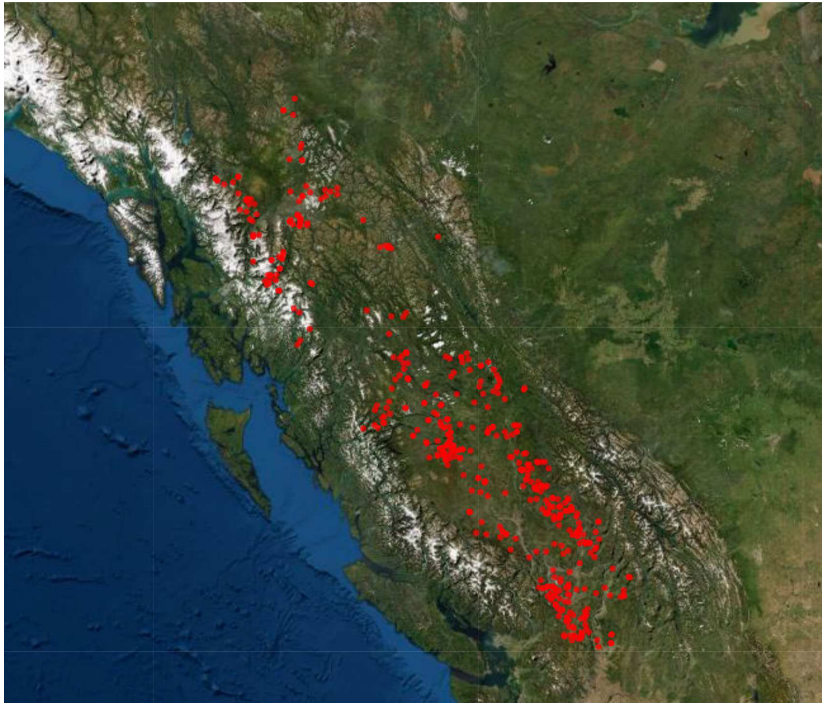
- Work in progress in digitization of data relevant to 3D models
- Use cases of 3D models at BCGS
- 3D model technologies from BC

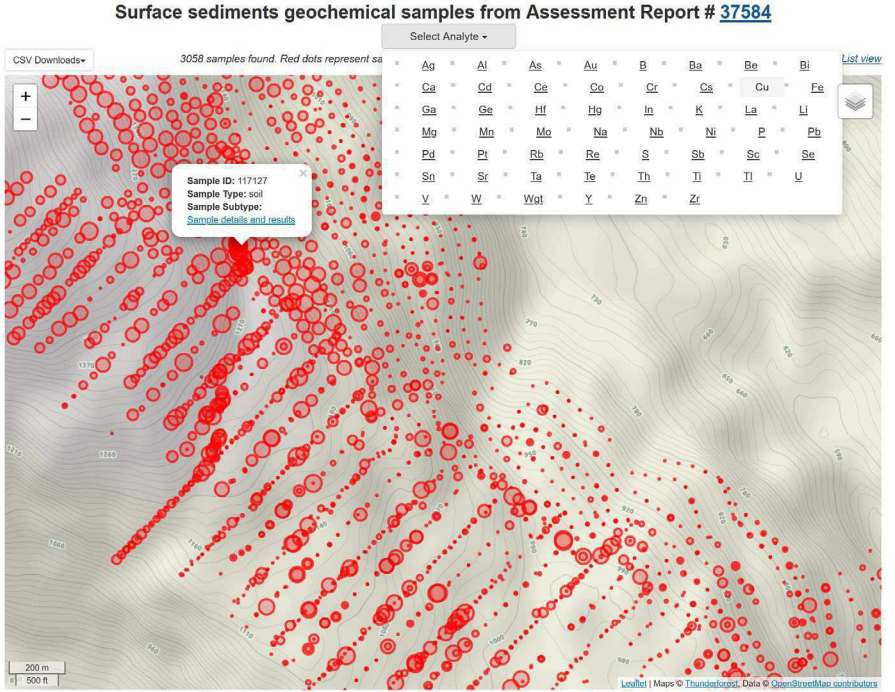
Geological map in 2.5D



Digital data capturing from mineral assessment reports

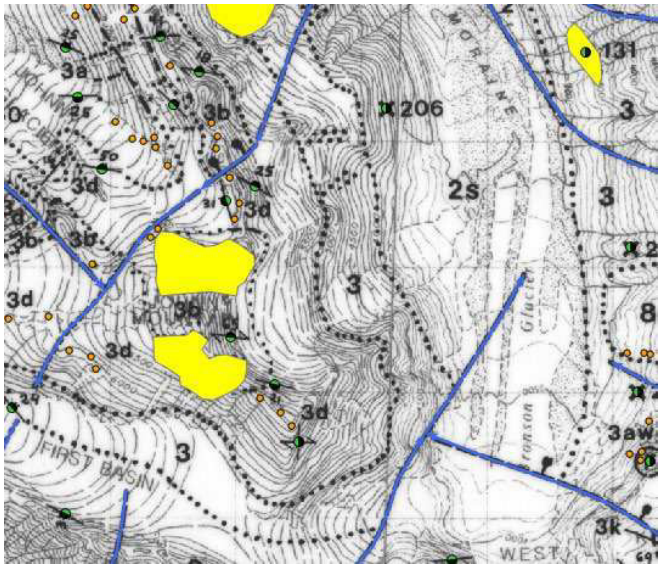
- Geochemical data from surface sediment samples
- Drill-hole locations and assays in progress: data extraction and standard

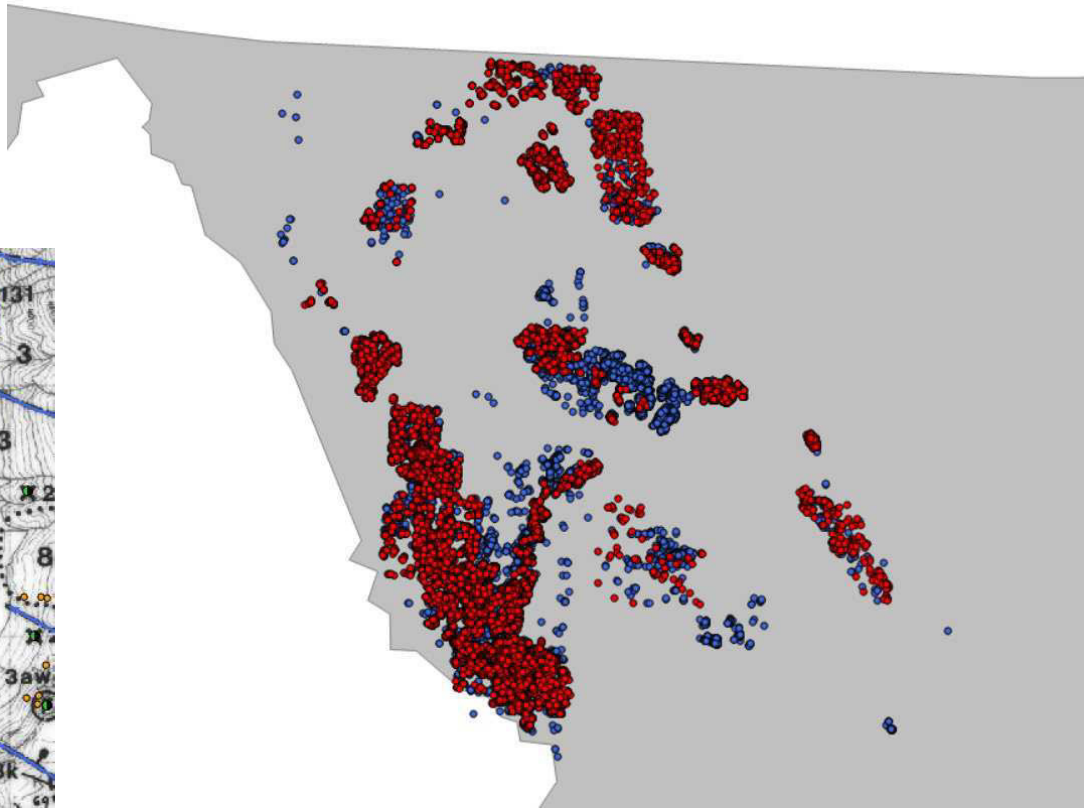




Observations

- **Field data**: observations, structural measurements, alteration
- **Laboratory analyses**: lithogeochem, drill-hole data, petrographic, isotopic data

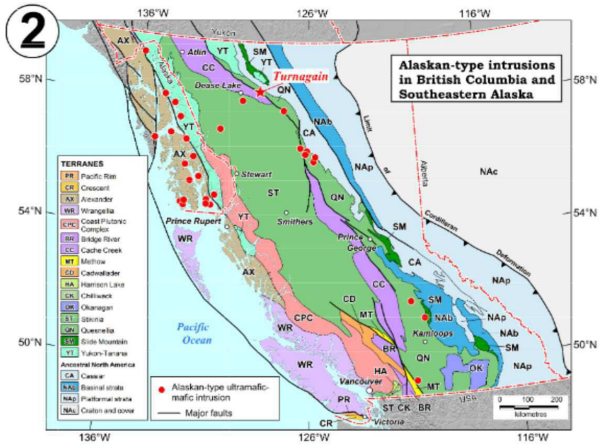


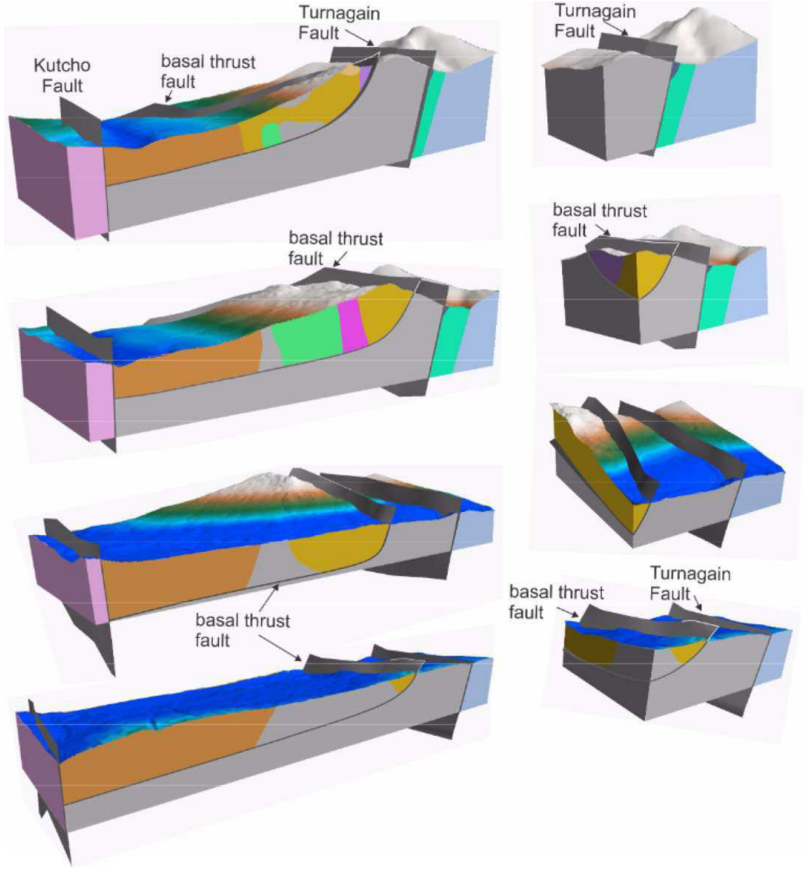


3D model of ultramafic intrusion

Turnagain ultramafic-mafic intrusion, early Jurassic Alaskan-type, the world's 9th largest deposits containing Ni metal

Nixon, Scheel, Friedman, Wall, Gabites, Miller, and Scoates; *BCGS Geoscience Map 2017-1*





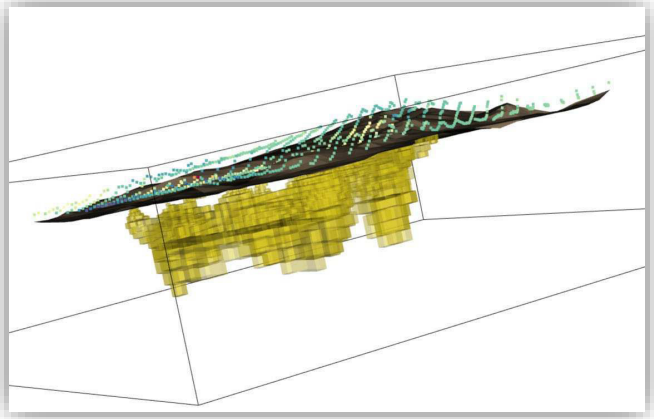
Anatomy of the Turnagain Intrusion

Intrusive Phase
- Phase 4
- Phase 3
- Phase 2
- Phase 1
- eJE
- uPvs
- MPvs
- Ms
- OSR
- COK
- CAm
- Fault

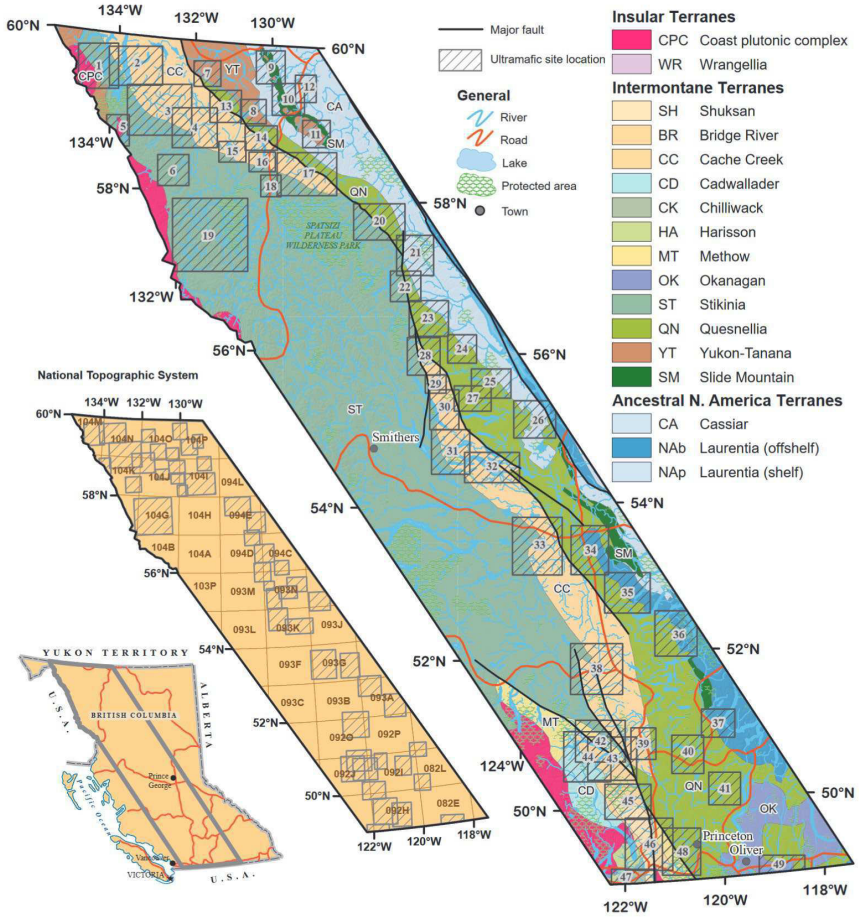
0 2.5 5
km

Carbon mineralization potential of ultramafic rocks in British Columbia

Mitchinson, Cutts, Fournier, Naylor, Dipple, Hart, Turvey, Rahimi, and Milidragovic, 2020



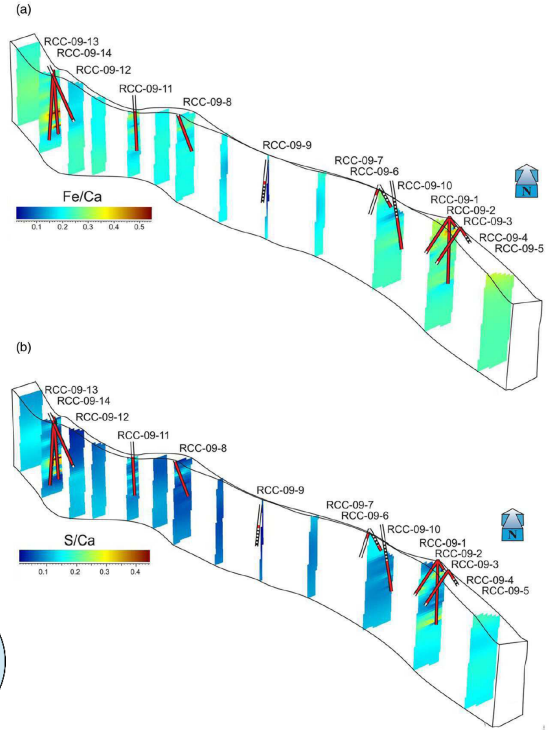
https://cmscontent.nrs.gov.bc.ca/geoscience/camp/SceneExplorer.html?fileURL=Inversion_42.1.vtkjs.zip



3D models showing extrapolated deposit scale variations

Rock Canyon Creek REE-F-Ba deposits, BC

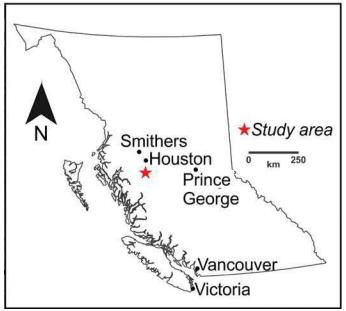
Simandl, et al.; GEEA *geochem2020-010*

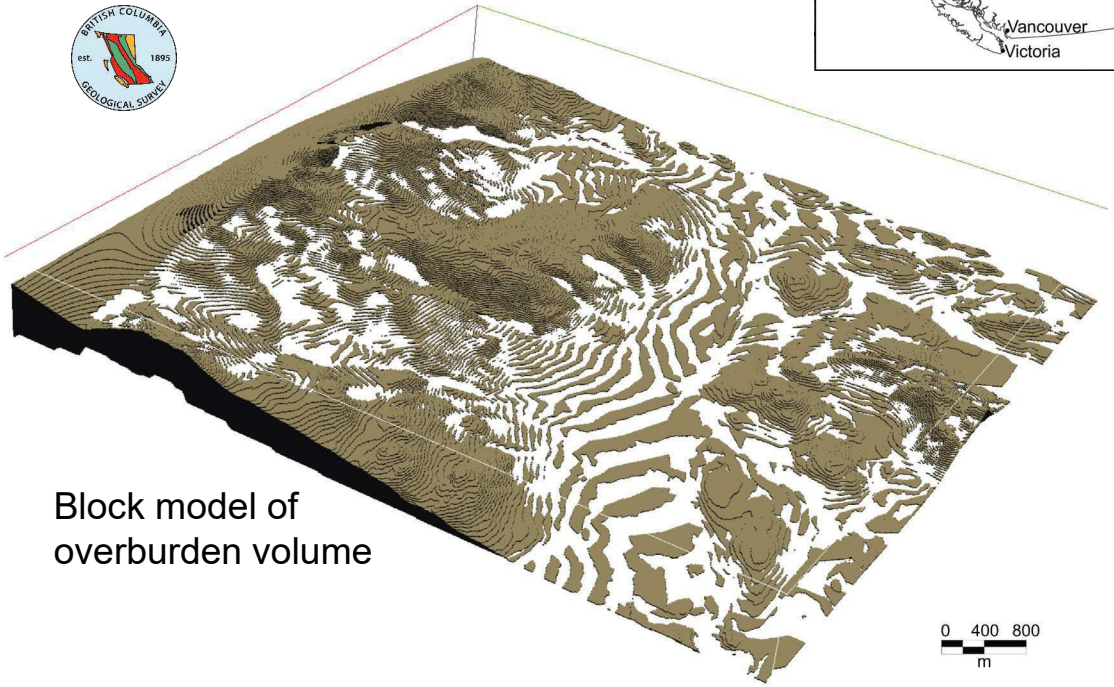


3D model of depth-to-bedrock (thickness of overburden)

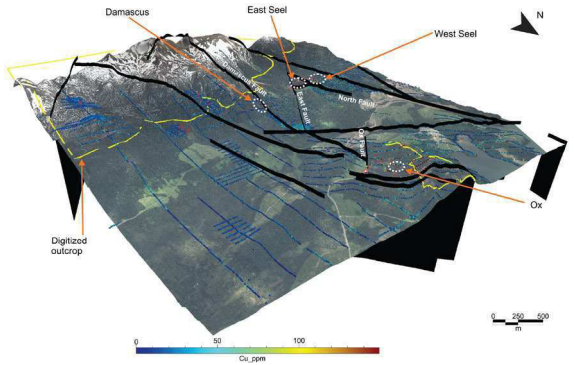
Ootsa Lake porphyry Cu-Mo-Au in BC

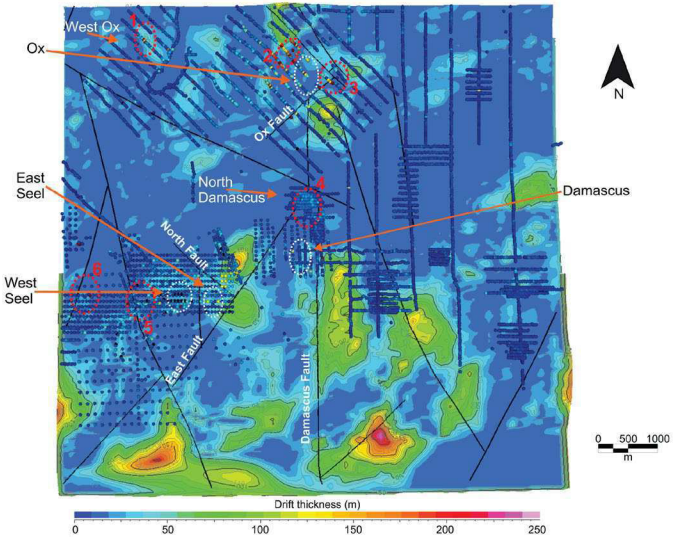
Rowins, Miller, and Cui; *BCGS Paper 2018-1*





Block model of overburden volume

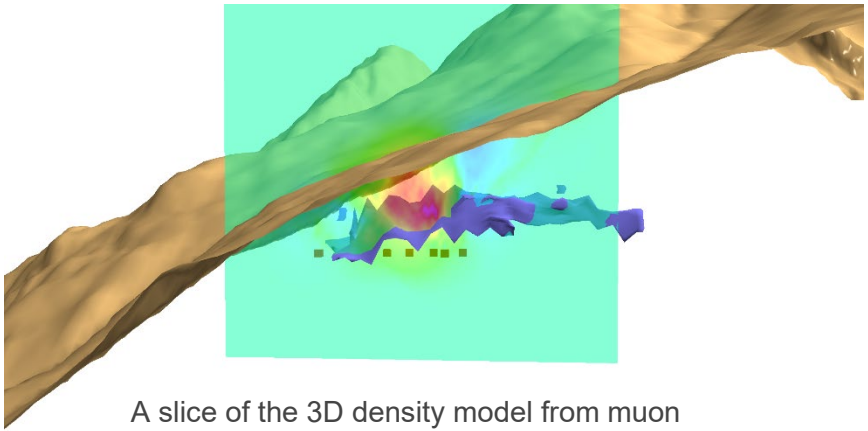




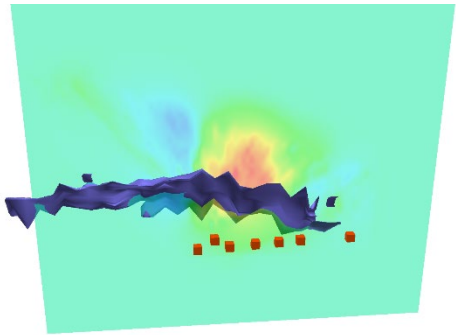
3D depth-to-bedrock model with potential exploration targets (red circles labelled 1 to 6)

Muon geotomography

- 3D model from ‘CAT scans’ of orebody by cosmic ray muons
- Developed by Douglas Bryman, UBC TRIUMF (Canada’s particle accelerator centre)
- Tested at the Myra Falls mine in BC (VMS deposits containing Zn, Cu, Pb, Au, Ag)

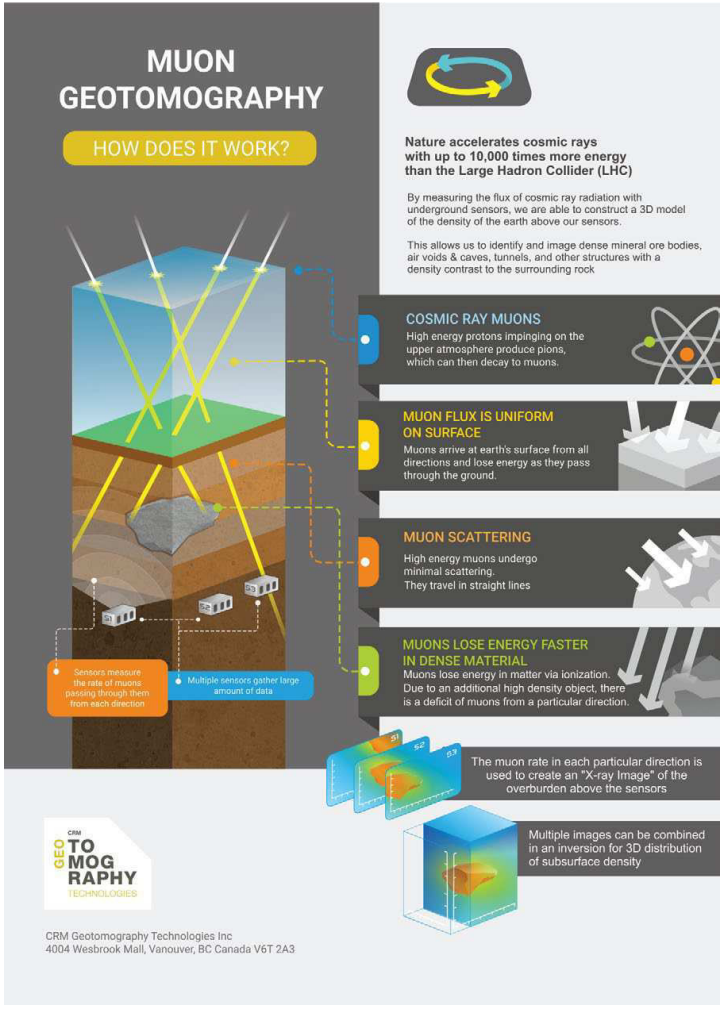


A slice of the 3D density model from muon geotomography; detectors are shown as cubes.

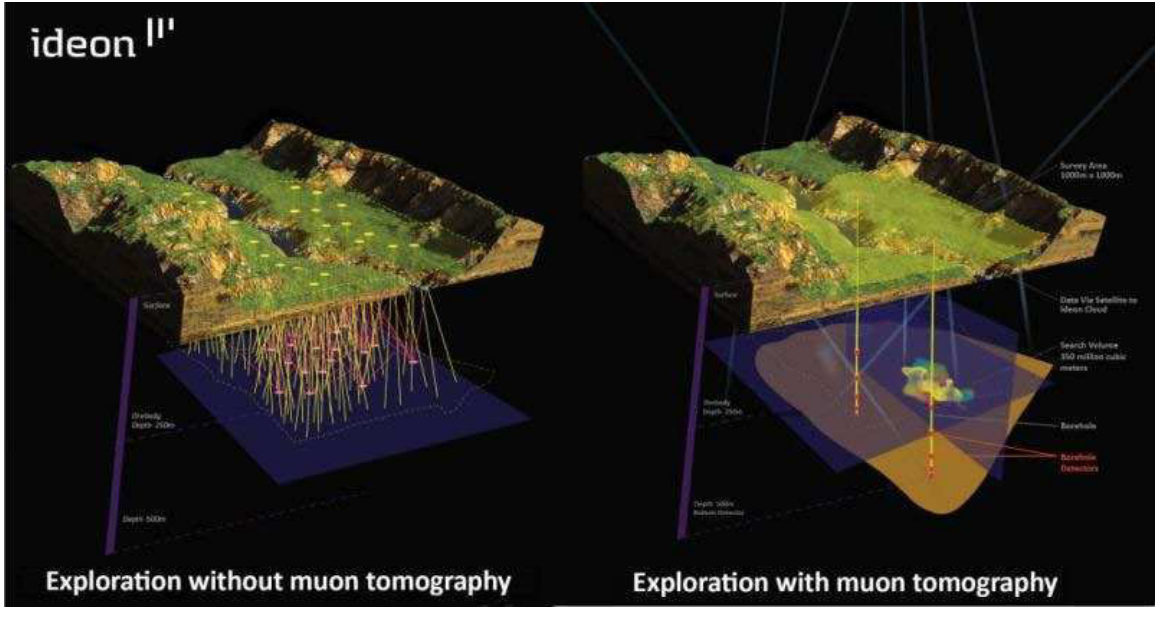


Closeup of ore shell model with section of density profile from muon data. Detectors are shown as cubes.

D. Bryman, J. Bueno, K. Davis, V. Kaminski, Z. Liu, D. Oldenburg, M. Pilkington, and R. Sawyer. 2014. Muon Geotomography - Bringing new physics to ore-body imaging. SEG 2014



- Spin-off from the UBC TRIUMF project
- CRM Geotomography, now **Ideon**



3D and Virtual Reality

VRIFY projects integrate ultra-high definition, 360-degree aerial, ground and underground photography; VRIFY Technology Inc.

Augmented reality, virtual reality, and holograph; **Finger Food** Advanced Technology Group (acquired by Unity)

Alberta Energy Regulator

C3D – Alberta Update

June 2022

AGS
ALBERTA GEOLOGICAL SURVEY

www.aer.ca
www.ags.aer.ca

C3D NGSC Summary by:

Kelsey MacCormack – *Director Geology and Resources,*
Geological Survey of Alberta / Alberta Energy Regulator

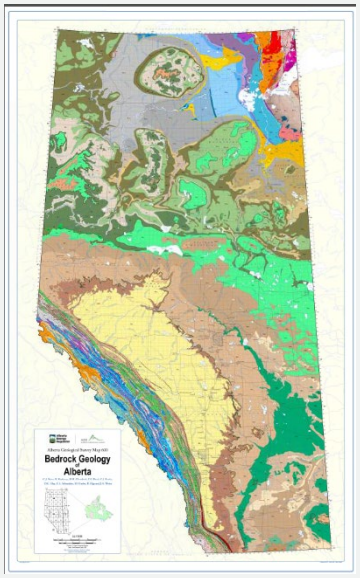
https://gfa-v3-ags-aer.hub.arcgis.com/

Kelsey MacCormack – *Director Geology and Resources, Geological Survey of Alberta / Alberta Energy Regulator*

I'll just give a summary of what's happening in Alberta, as an overview of where we're at with our 3D program. Just recently, in the last year released our version 3 of our provincial scale geologic model. It is available in ArcGIS on-line. We call it our 3D geologic framework of Alberta Portal. It's a phenomenal application that just came out in the new year, so it's relatively new. Basically, it allows people to access a bunch of information about our 3D modelling methodologies, the approach we've taken to modelling the province at 500 x 500 m resolution. It provides access to all 91 geological units that are currently contained within our provincial model. What is also interesting is that it allows users to access the components of the model that they are potentially most interested in, grids, thickness grids, extents, point data files and then to visualize them. You can pull these elements up online in an arc environment, and even add your own data to it. So, it's really pushing our data and model to being accessible and interactive with our user groups. This is something we have made accessible internally to the Alberta Energy Regulator, as well as fully externally accessible as well. We are already getting lots of great feedback from stakeholders in terms of things they like, things they would like us to add in subsequent versions. Everyone is encouraged to check this out, the link to the portal is right on the AGS web site. https://gfa-v3-ags-aer.hub.arcgis.com/pages/about. We have also provided people with a training manual with videos so they can go in and learn how to access this information as well. So, we are really trying to increase peoples access that that information and data.

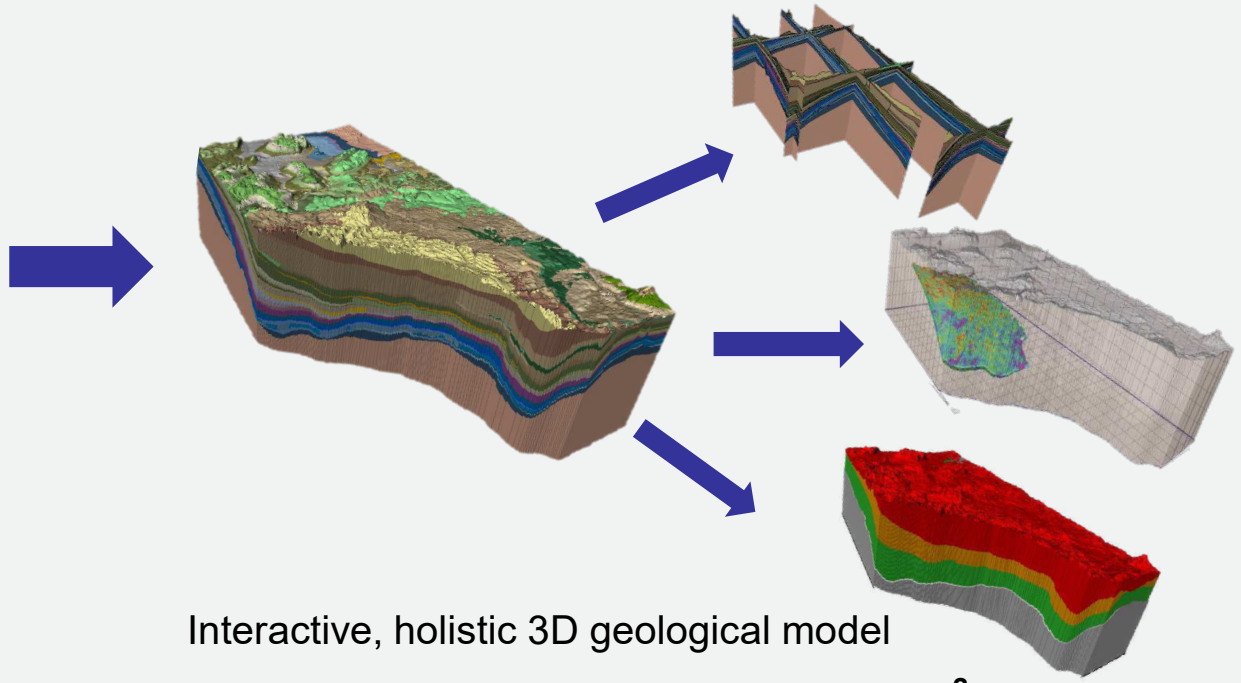
Geological Framework of Alberta:
From 2D Maps to 3D Models

2D Bedrock Geology



Traditional map products

3D Geological Framework

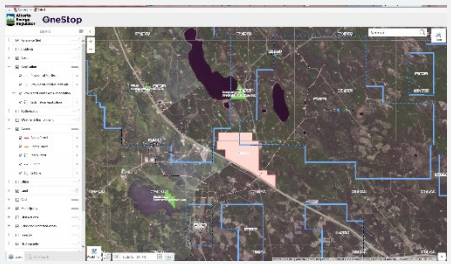


Interactive, holistic 3D geological model

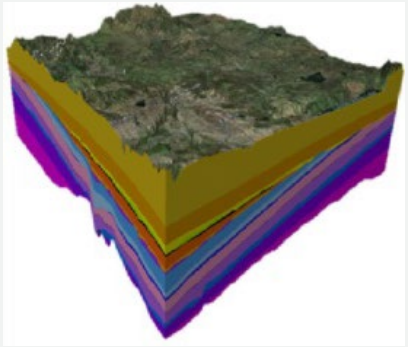
Kelsey MacCormack – *Director Geology and Resources, Geological Survey of Alberta / Alberta Energy Regulator*

In this coming year we will be kicking off another version of the provincial framework model that is now in the planning stages and will likely be ready by end of fiscal year (March 2023). As always, we have lots of sub-models that we are working on that are application specific or application dependent. One of the big initiatives that we have had, within the province of late, has been on mineral exploration investigation. As many of you are aware Alberta hasn't always had the historic investment into mineral exploration that we have seen in other parts of the country. So that's been a huge initiative that is underway in Alberta. We are collecting some additional data on minerals. That's one area were our 3D models have been absolutely critical because as we're collecting this information and data, we are geolocating them at surface or importantly at depth so they can tie to the subsurface and with good geological context such as at a specific formation location. We don't get into looking into the economics of it yet, but as we're learning this approach is something that many of our external stakeholders find incredibly valuable, to see and access that information and data in a 3D context, which helps them understand or look at what other exploration they would be interested in doing in that area and understand the economic viability and resource potential at these locations. That's one area that we are actively working on and will continue to develop in the coming year or two years.

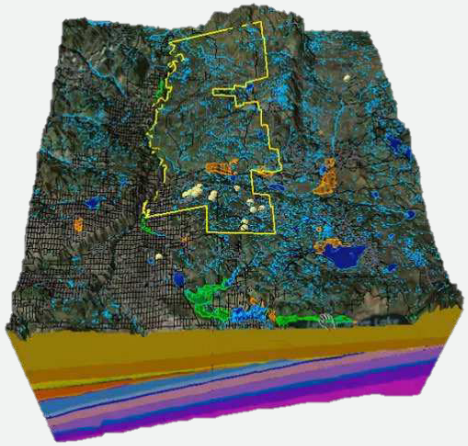
Ability to integrate Surface & Subsurface Information to Support Decision Making



Surface Data



Subsurface Model



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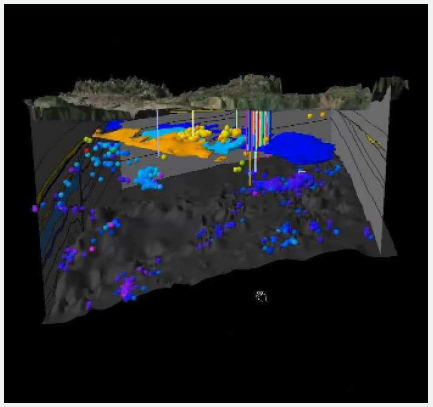
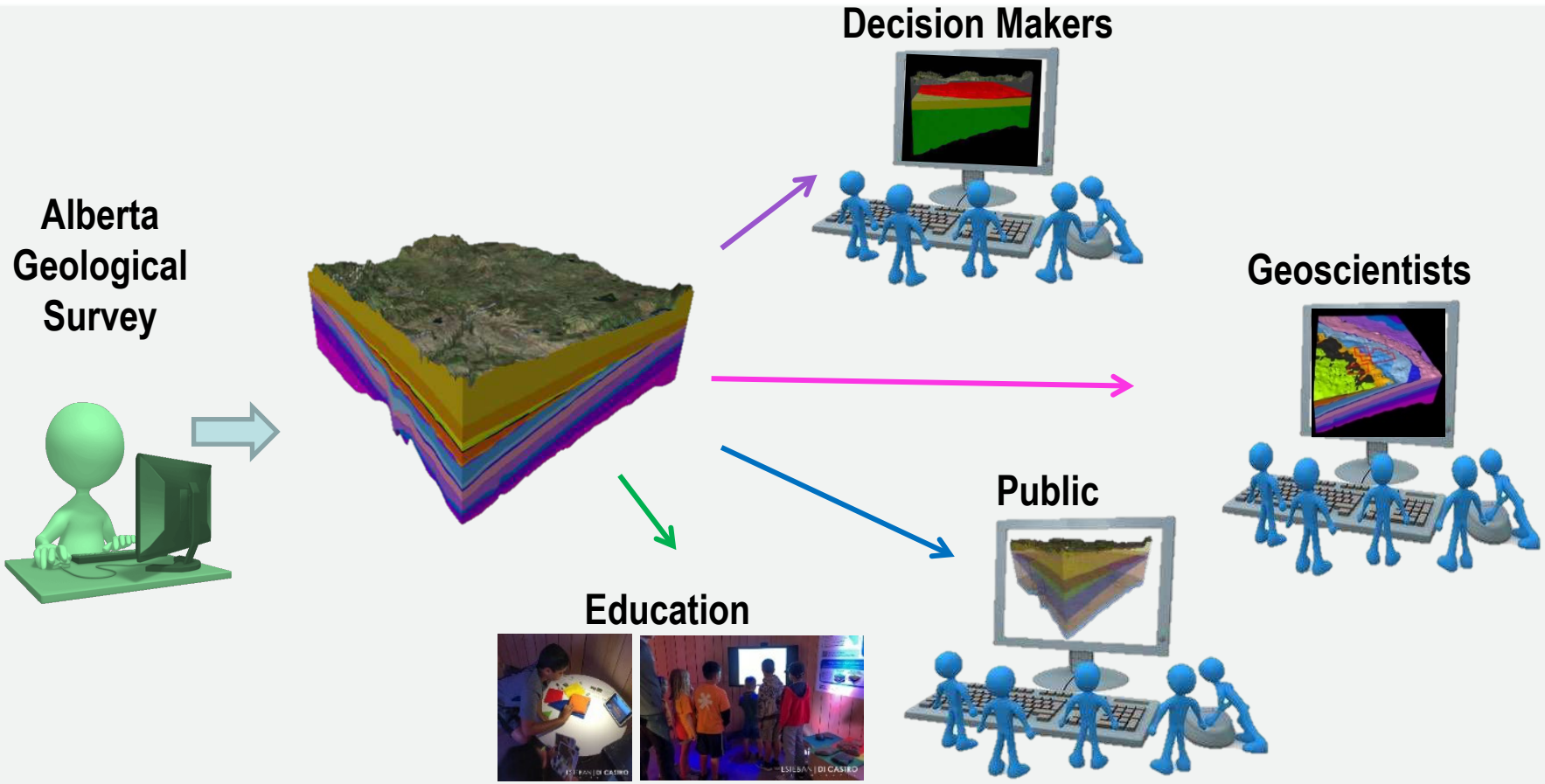


Ability to integrate surface information and subsurface geospatial data in a consistent and validated 3D geospatial environment

Supporting Integrated Resource Management

Goal: Single Source of Geological Truth



Build 1 multi-scale model to meet the needs of a variety of stakeholders for a variety of applications

Kelsey MacCormack – *Director Geology and Resources, Geological Survey of Alberta / Alberta Energy Regulator*

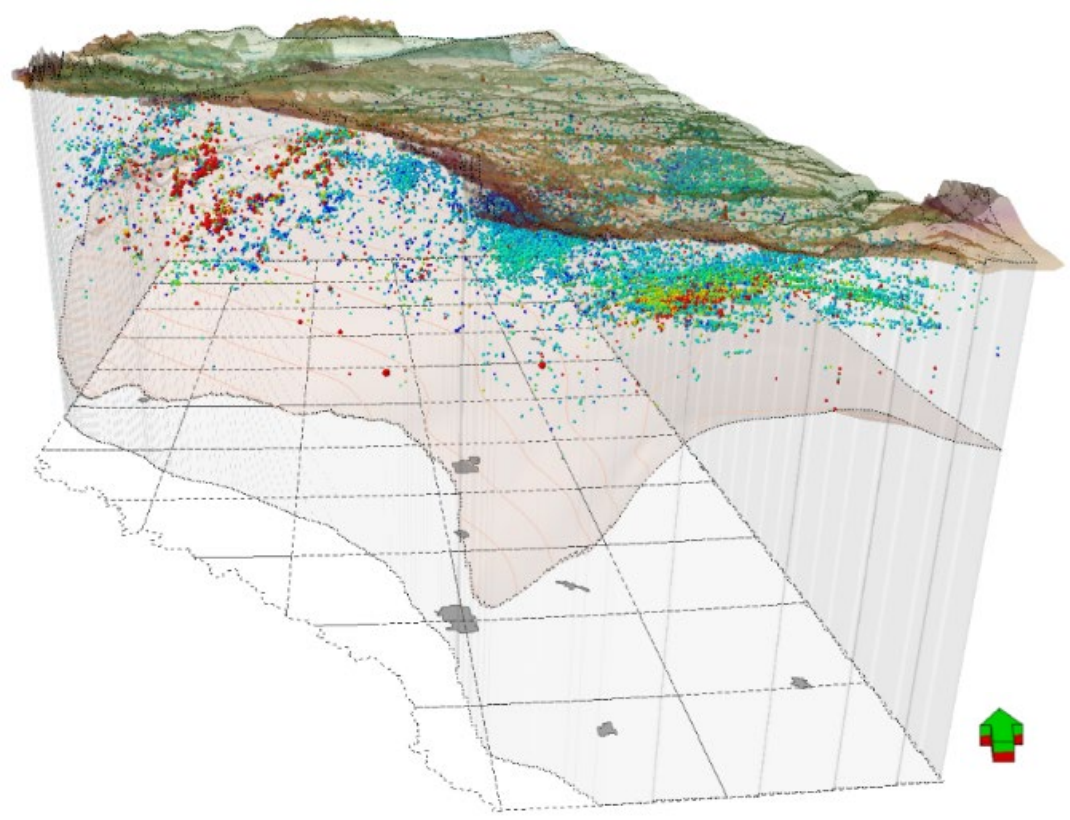
Another area has been with our 3D aquifer framework project which has been wrapping up so it will be integrating those resources within our geologic framework, so that we can not only support, in this case the individual projects but really finding a way to support decision makers from an integrated resources context. Recent conversations we have had with some high-level officials indicated that they have increasing concerns about resource decision making, and that we need to be doing that in a holistic and geospatial environment. So that if we are making a decision for one resource, we are not then impacting negatively other resources. Those are some of the big drivers right now for us with our 3D program, to help move it along in the level of detail we need to support that level of integrated resource decision making and to support the continued development of resources exploration in the province.

Atlas 2027

https://atlas2027.ca/

Integrating Resources in 3D - Helium

- Able to integrate resources within a consistent and reliable 3D geospatial environment
- Provides a more accurate depiction of the location and depth of the resource value/concentration
- For more information, please see AER/AGS INF 153 and the data can be found in DIG 2020-0033



'Land rush' on in Alberta as demand for lighter-than-air helium takes flight

Amanda Stephenson • Calgary Herald
May 24, 2021 • May 24, 2021 • 4 minute read • Join the conversation

Helium industry begins to take off

BY COLLIN GALLANT ON JUNE 22, 2021.

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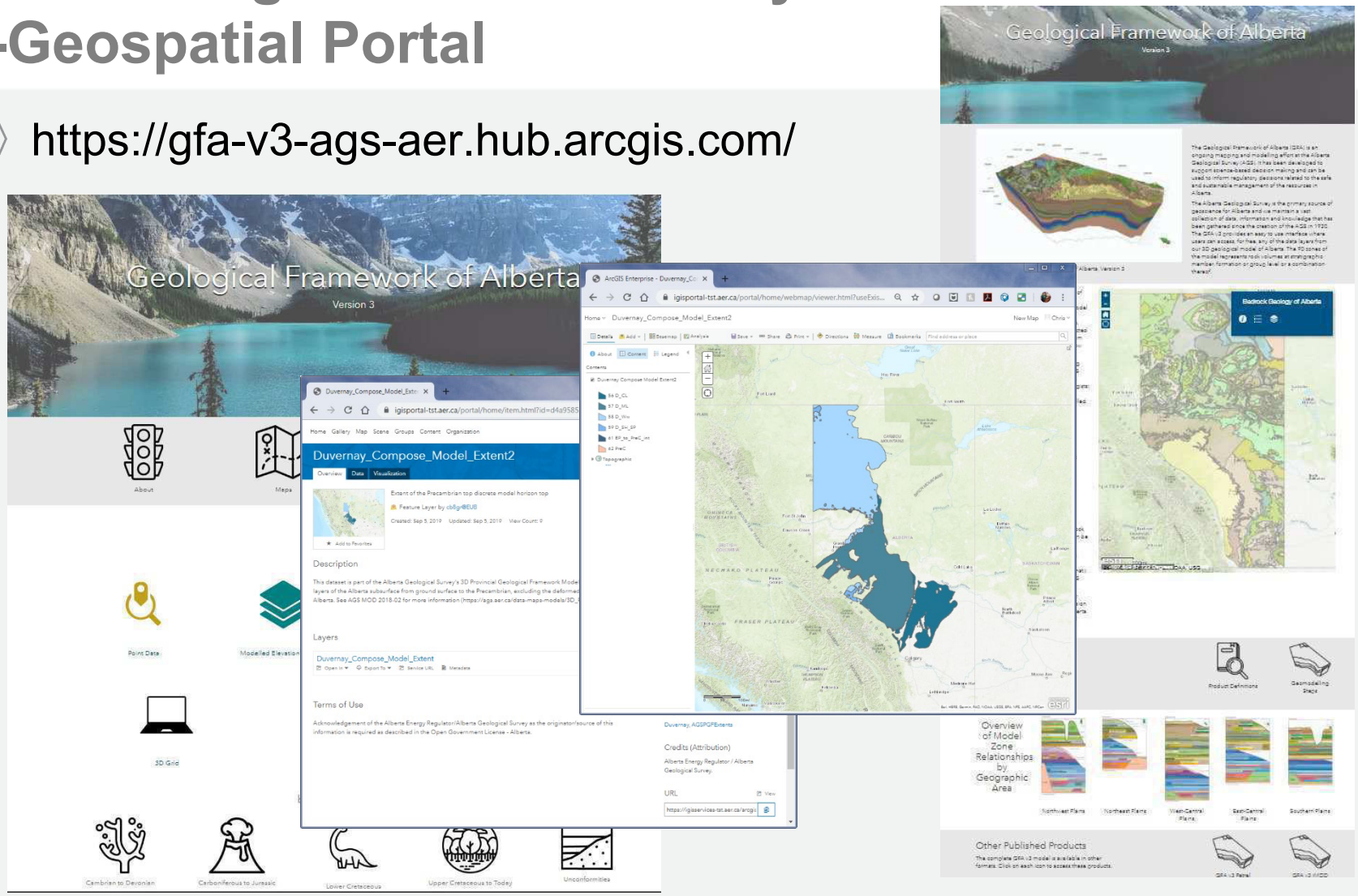
Alberta's new helium royalties could see rise of extraction industry

Exploration and drilling underway in province's southeast

Enhancing Data Accessibility -Geospatial Portal

- https://gfa-v3-ags-aer.hub.arcgis.com/



C3D – Saskatchewan Update

Sean Bosman – Research Geologist, Saskatchewan Geological Survey
NGSC Working Group, Virtual Meeting – June 6, 2022

Sean.Bosman@gov.sk.ca

saskatchewan.ca

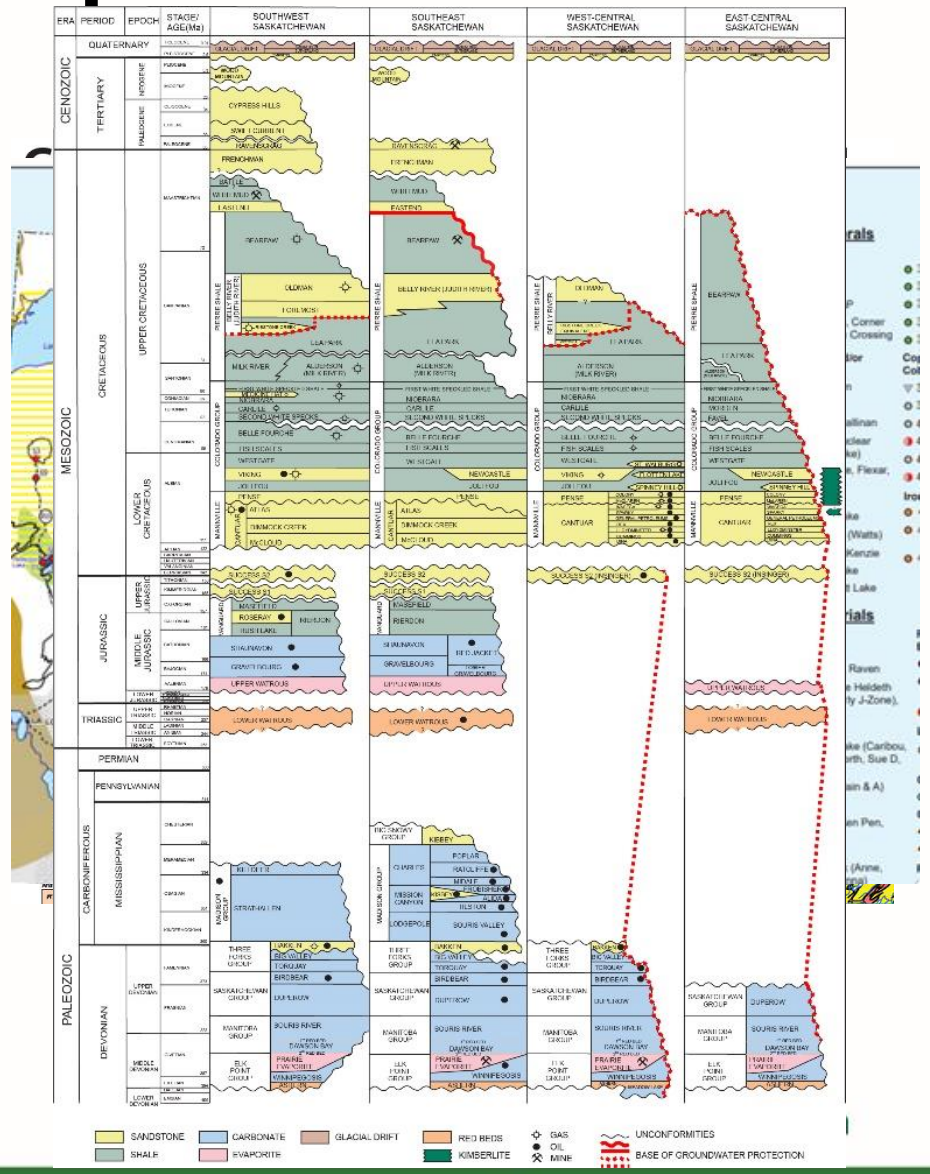
Government of Saskatchewan

Data Management

- SGS is undertaking a major, multi-year IT initiative to modernize its geoscience data management system
  - High-level objectives
    - simplify data workflows
    - decrease manual effort through automation and standardization
    - reduce data errors
    - make more data available to the public.
  - Project is anticipated to commence this fall and take 2-3 years to implement
- NGSC – IDM working group
  - Pilot project on a national mineral occurrence database
- Lithodemic Paper
  - Classify rocks of the Canadian Shield

Synthesis Map Compilation

- 1 Million Scale Provincial Bedrock Map
  - Replaces 1999 version
  - Comprehensive synthesis of the geology undertaken over the past 20 years
  - Considerable revisions in Rae Province, depiction of the Athabasca Supergroup and delineation of Late Cretaceous formations
- Provincial Resource Map
  - Updated map showing metallic minerals, energy materials, industrial materials and refining and processing facilities
- Base of Groundwater Protection project
  - Map the stratigraphic horizon that separates fresh groundwater aquifers from saline groundwater aquifers



Mapping – Machine Learning

- Mineral potential mapping
  - In the QA/QC process; determining best workflows and which datasets are most appropriate to use
- Quaternary Thickness/Depth to Bedrock map
  - 2 projects; partnership with GSC
    - Northern Saskatchewan – pilot study
    - Southern Saskatchewan – support for ground water protection project

Reindeer Zone

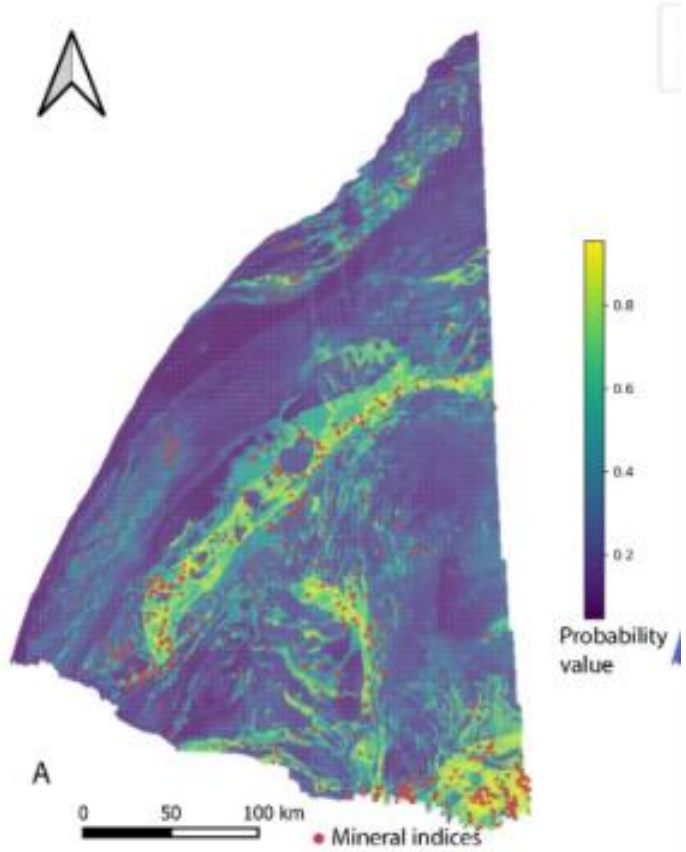
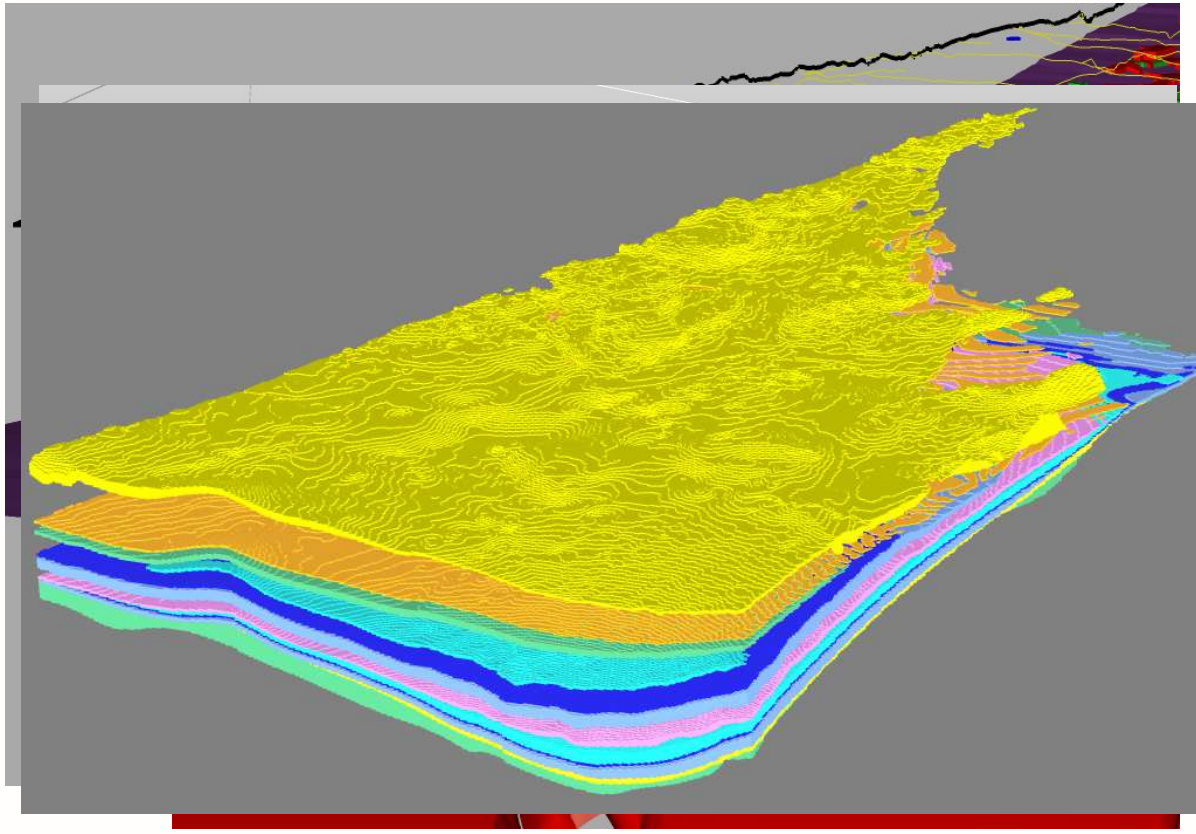


Figure 10 – A) *Map representing the average of probability values prec of base metal potential. Cold colours correspond to lower probability ar* ***B)*** *Binary map showing the area identified as the target with high base shown by dots on both maps.*

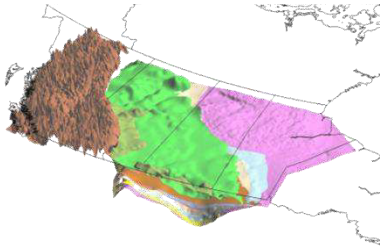
3D Modelling

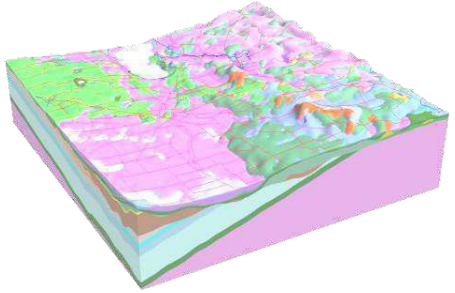
- New regional models
  - Archean-cored cratons (model available for download)
  - Provincial Resources
  - Phanerozoic surfaces (SKUA)
    - Partnership with GSC
  - Updated surfaces for Athabasca Supergroup (SKUA)
    - Mira Geoscience



Data Dissemination

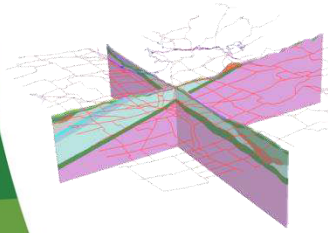
- SGS GeoHub
  - Launched in 2019 and provides a portal to all SGS geospatial data and applications
  - Contains ‘Story Maps’ that provide information to the public on various SGS activities and initiatives
- GeoAtlas





3D Geological Mapping in Manitoba
C3D

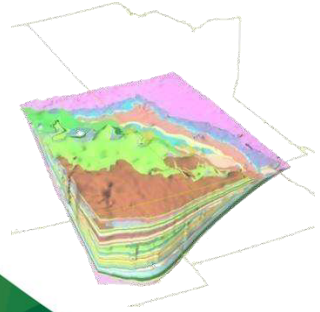
Modifed from GSA 2013



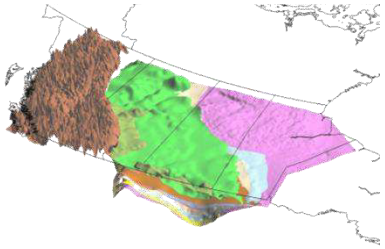
Greg Keller

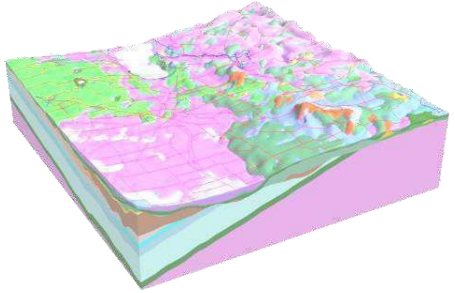
(greg.keller@gov.mb.ca)

Manager
Geoscience Data Management
Mantioba Geological Survey
Natural Resources and Northern Development

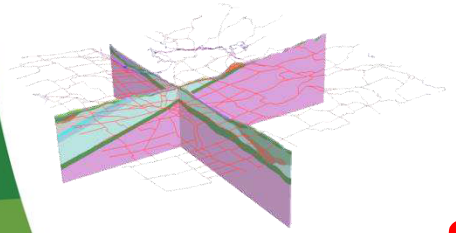


Manitoba



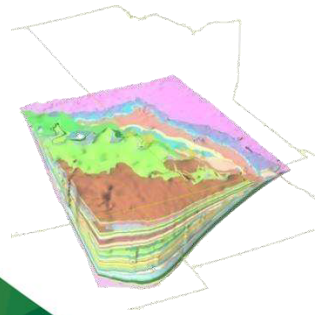


3D Geological Mapping in Manitoba
C3D

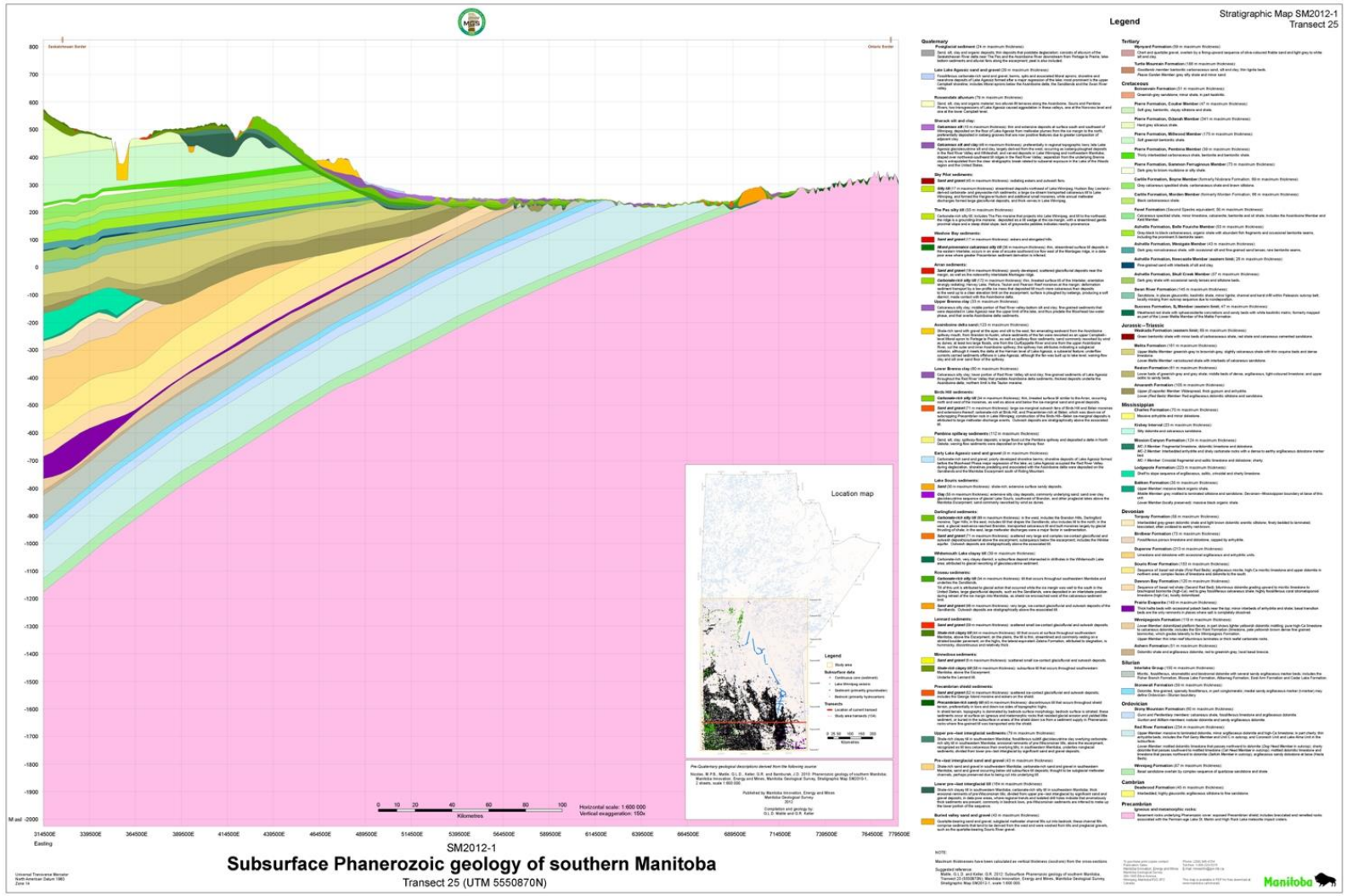


Acknowledgements:

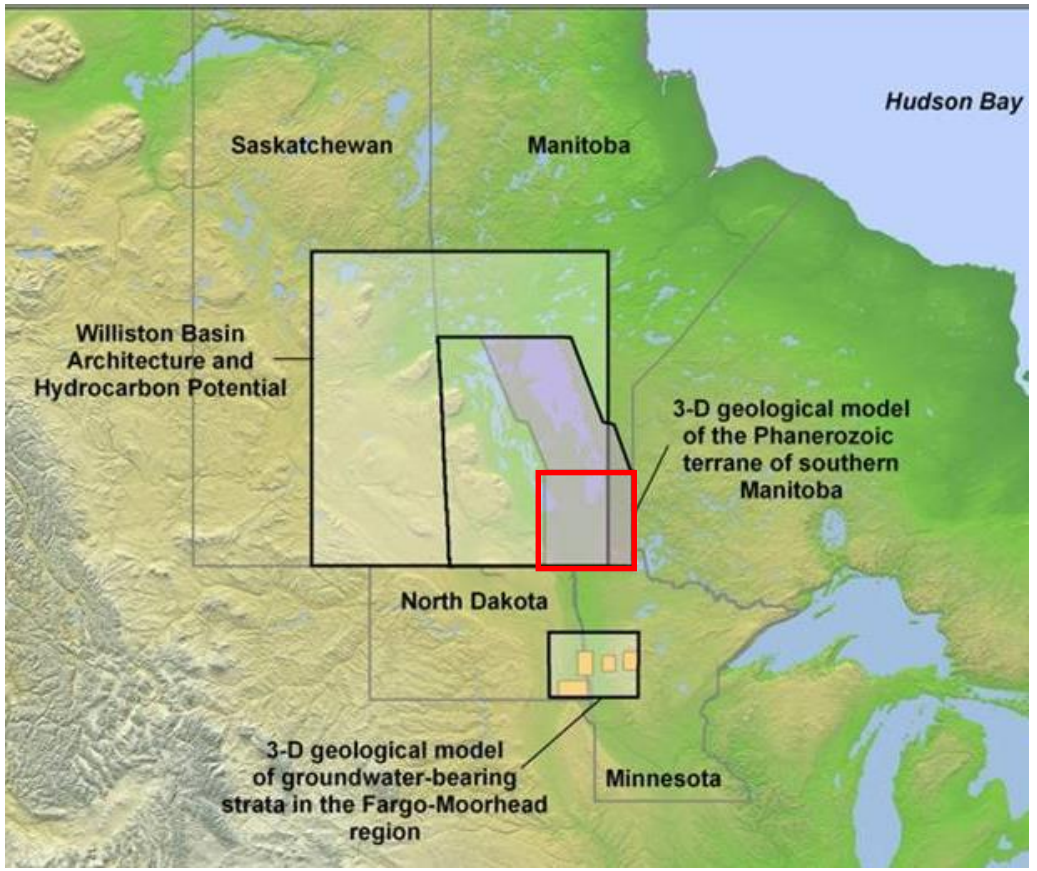
- Gaywood Matile (Ret. MGS)
-Harvey Thorleifson
(Minnesota Geological Survey)



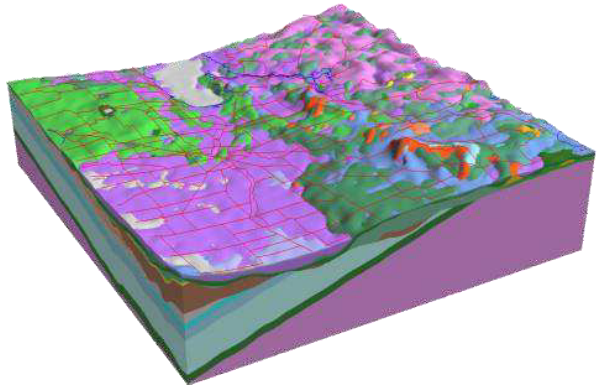
Manitoba


Stratigraphic Map SM2012-1
Transect 25
Legend
Location map
Horizontal scale: 1 600 000
Vertical exaggeration: 150x
Easting
Kilometres
SM2012-1
Subsurface Phanerozoic geology of southern Manitoba
Transect 25 (UTM 5550870N)

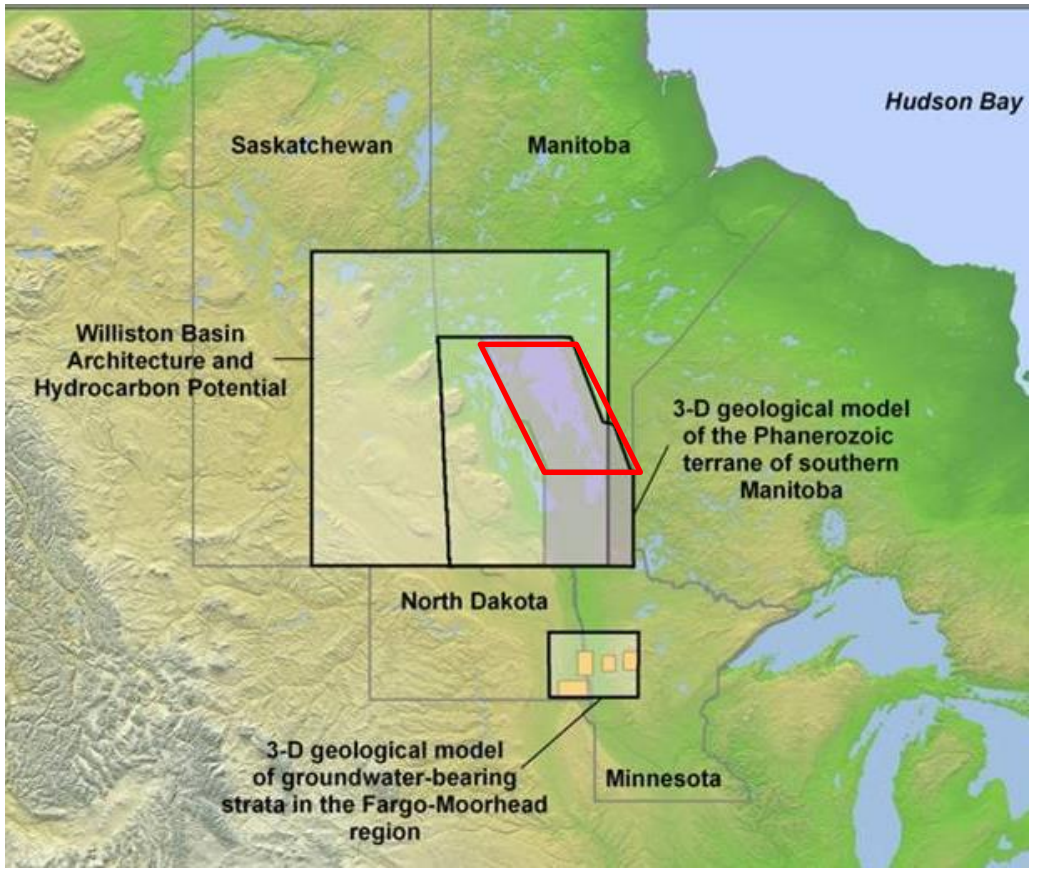
3D Geological Mapping in Manitoba



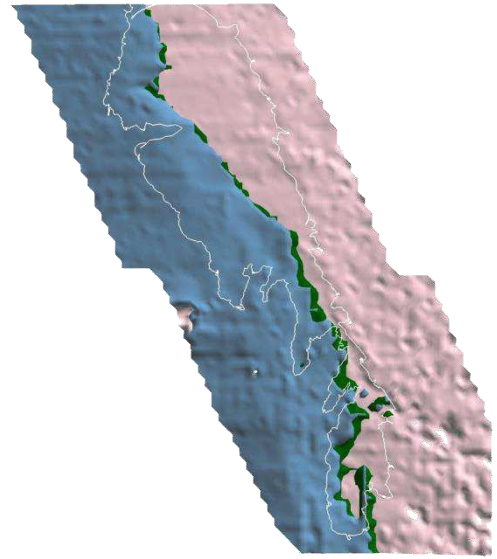
1) Southeast Manitoba (complete)



3D Geological Mapping in Manitoba



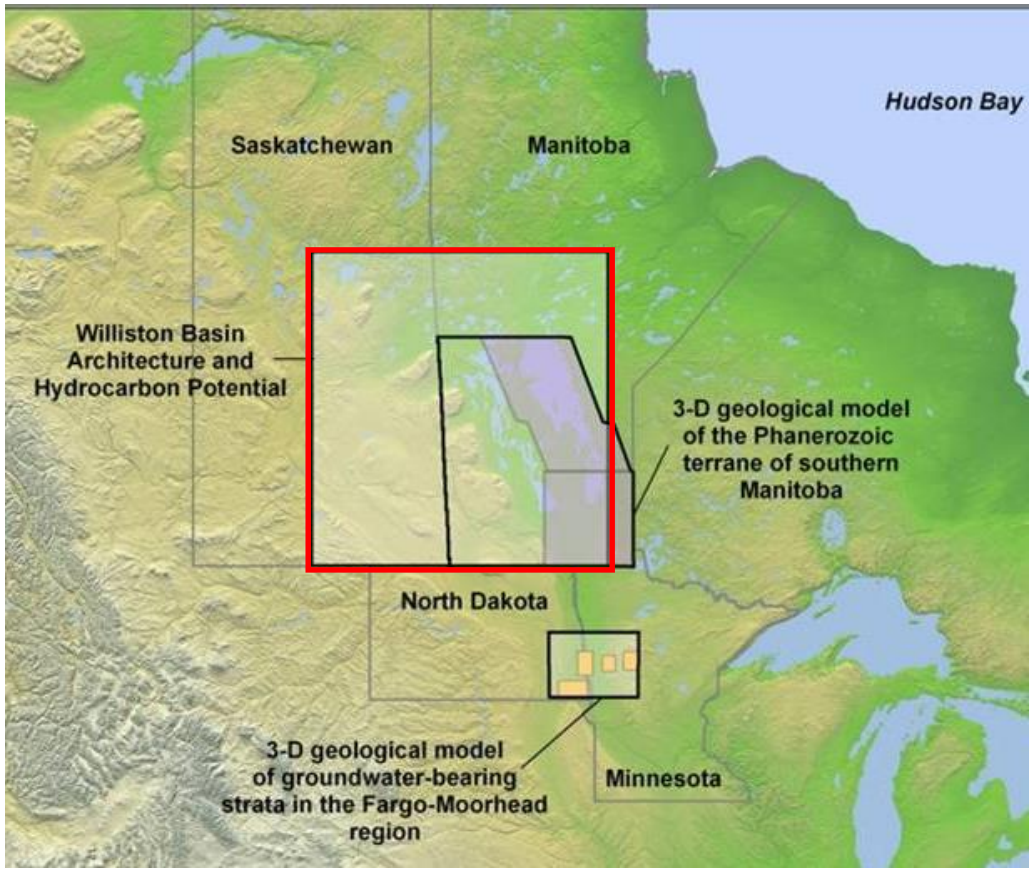
2) Lake Winnipeg region (complete)



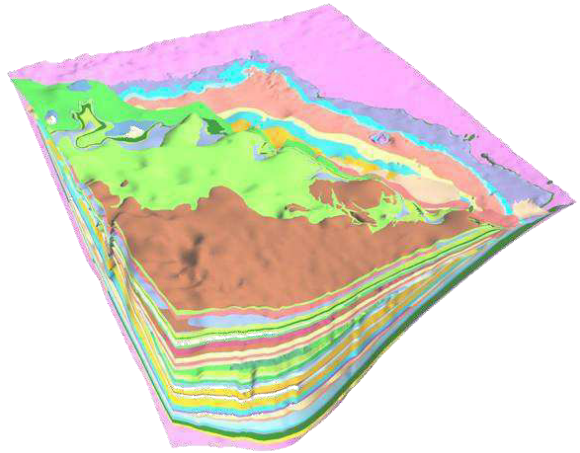
MANITOBA GEOLOGICAL SURVEY MGS 1928

Manitoba

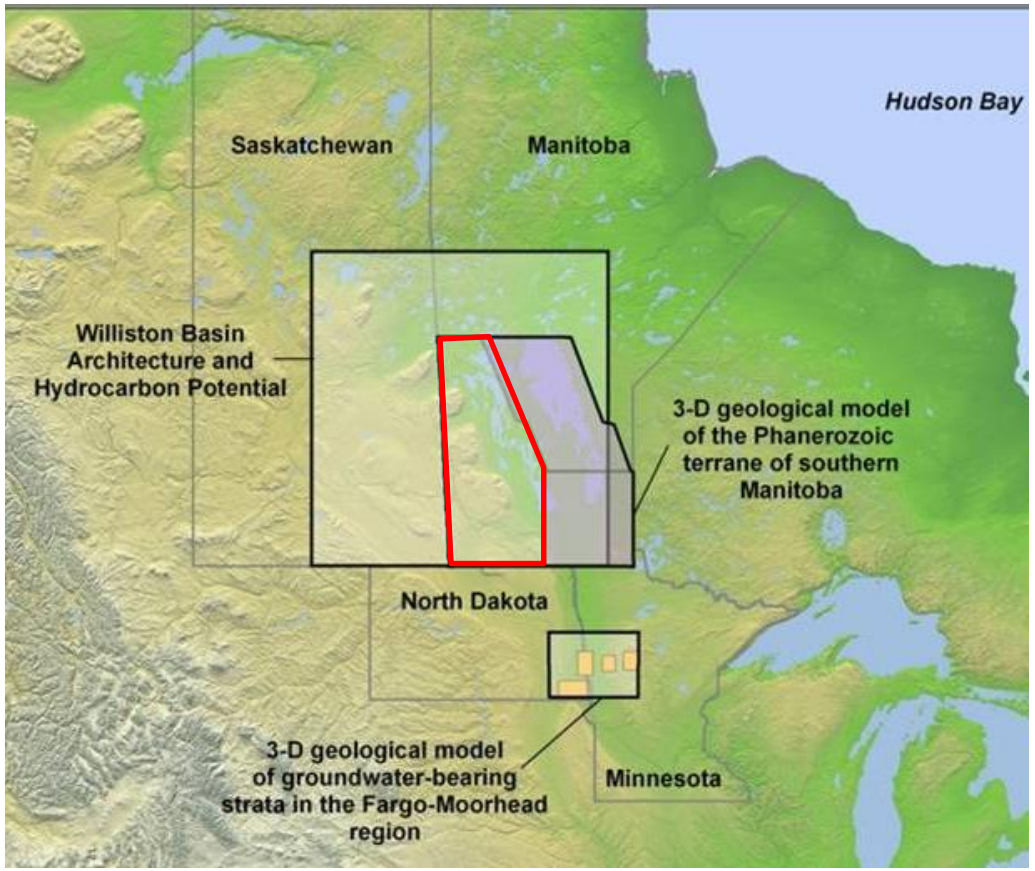
3D Geological Mapping in Manitoba



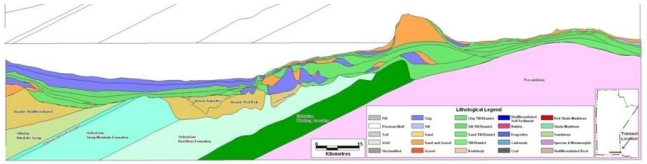
3) TGI Williston Basin (Complete)



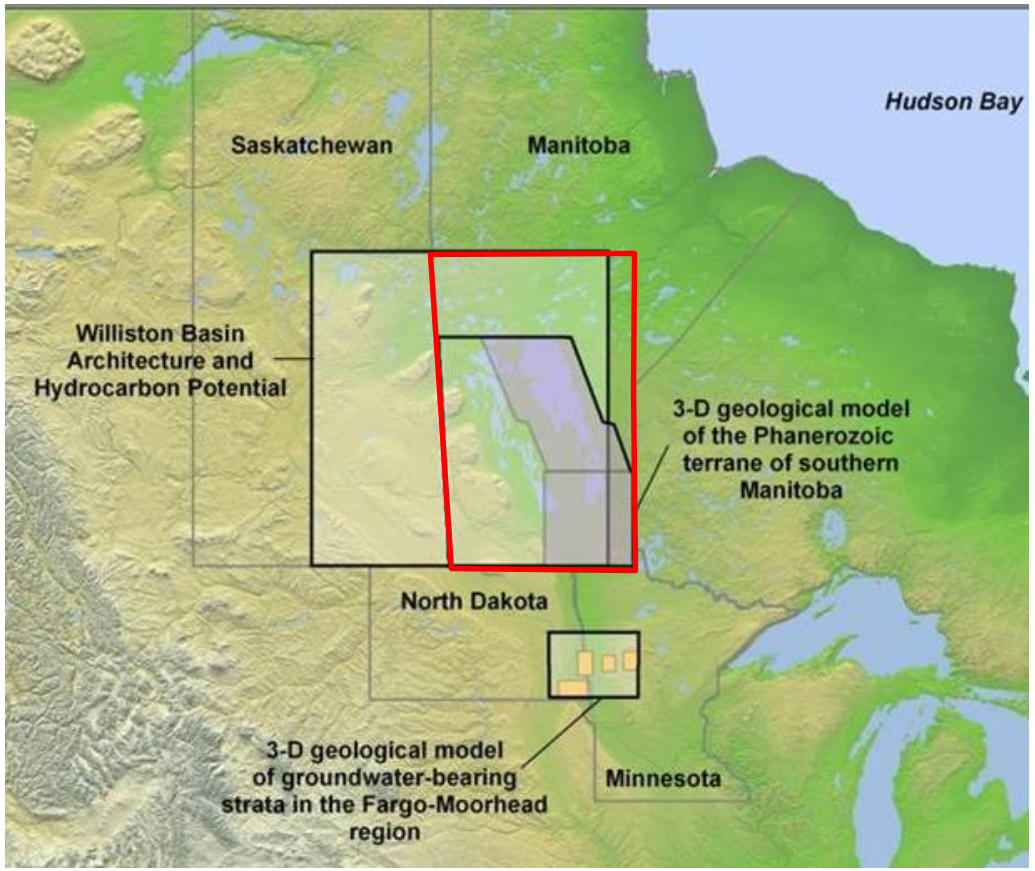
3D Geological Mapping in Manitoba

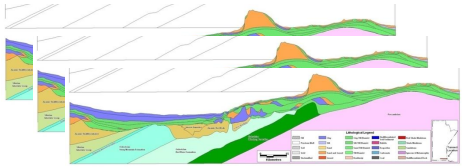


4) Southwest/Southern Manitoba
(Cross-sections complete)



3D Geological Mapping in Manitoba

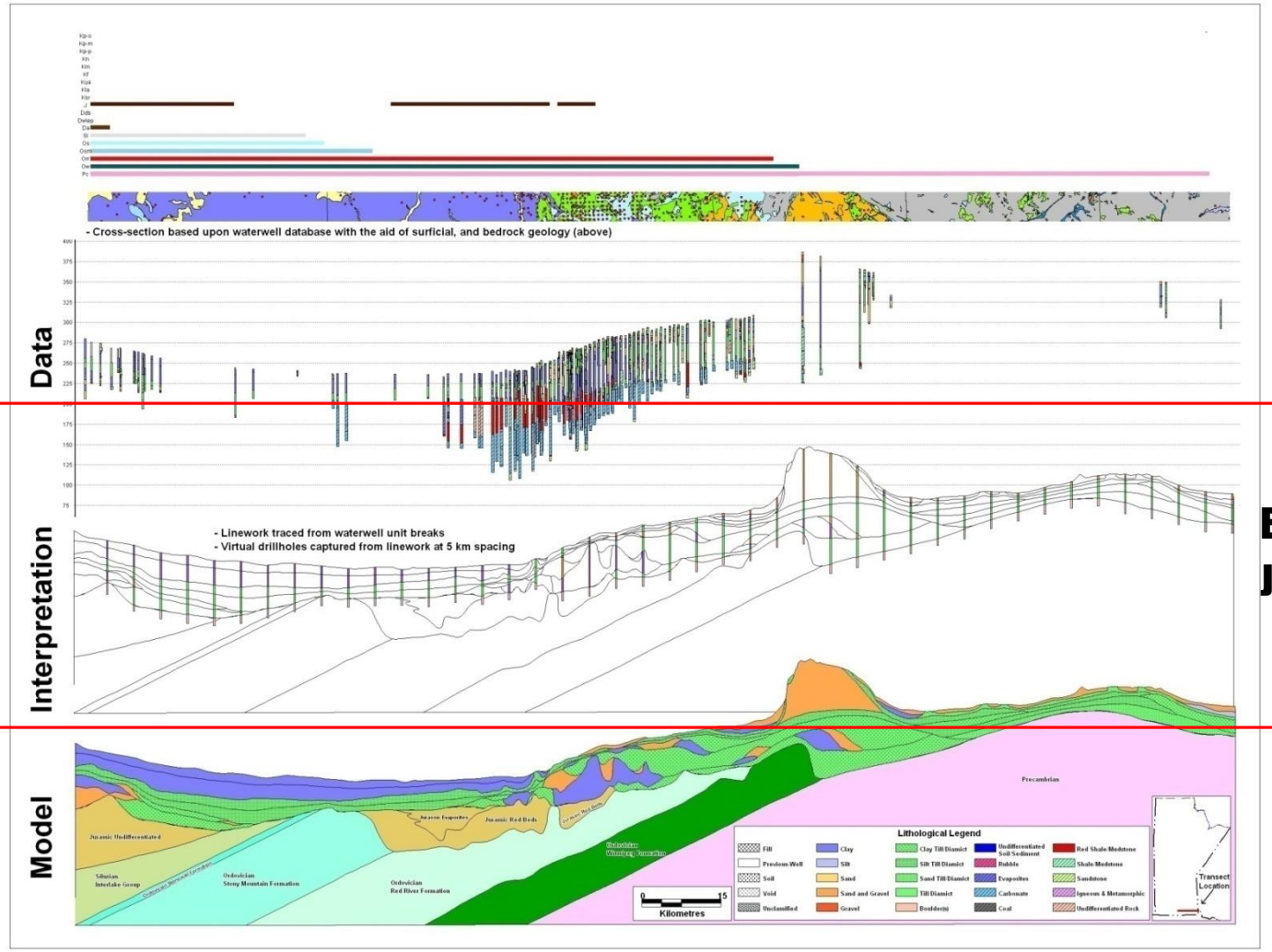


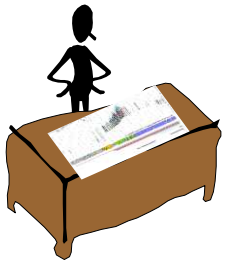


5) Southern Manitoba
(Concatenated sections complete)
(Modelling in-progress)

Manitoba

Cross-Section Construction





Experience

Judgement

Canada 3D

- Supports many project types
    - Petroleum, groundwater, drillhole targeting, education, etc
    - True impact won't be realized until the model is complete
- Mitigates data 'siloing'
- National project gives credence to the work and helps get our models completed
    - Modelling ceased ~2013 due staffing/budgets
    - C3D reinvigorated the need and brought attention to the project

Thanks!

All MGS content is available at:
http://www.manitoba.ca/minerals

More information about Manitoba's 3D Modeling is available at:
http://www.gov.mb.ca/itm/mrd/geo/3dmodel/index.html

Manitoba

ONTARIO GEOLOGICAL SURVEY ACTIVITIES 2020-2022

Canada in 3-D Meeting
June 6, 2022

Overview

- despite COVID, progress in several areas, including
  - acquisition of new geophysical data which will aid in mapping between March 2020 and March 2022 despite COVID
  - geochemical and geochronology data continued to be obtained between March 2020 and March 2022 despite COVID
  - continued updating of Paleozoic 3D model of southern Ontario
  - government released Critical Minerals Strategy in March 2022
    - ➢ OGS released related publications in April 2022
  - field program for 2022 has started!
  - *GeologyOntario*, our on-line portal has been updated and there is a new url https://www.geologyontario.mndm.gov.on.ca/index.html

New geophysical surveys acquired by OGS released

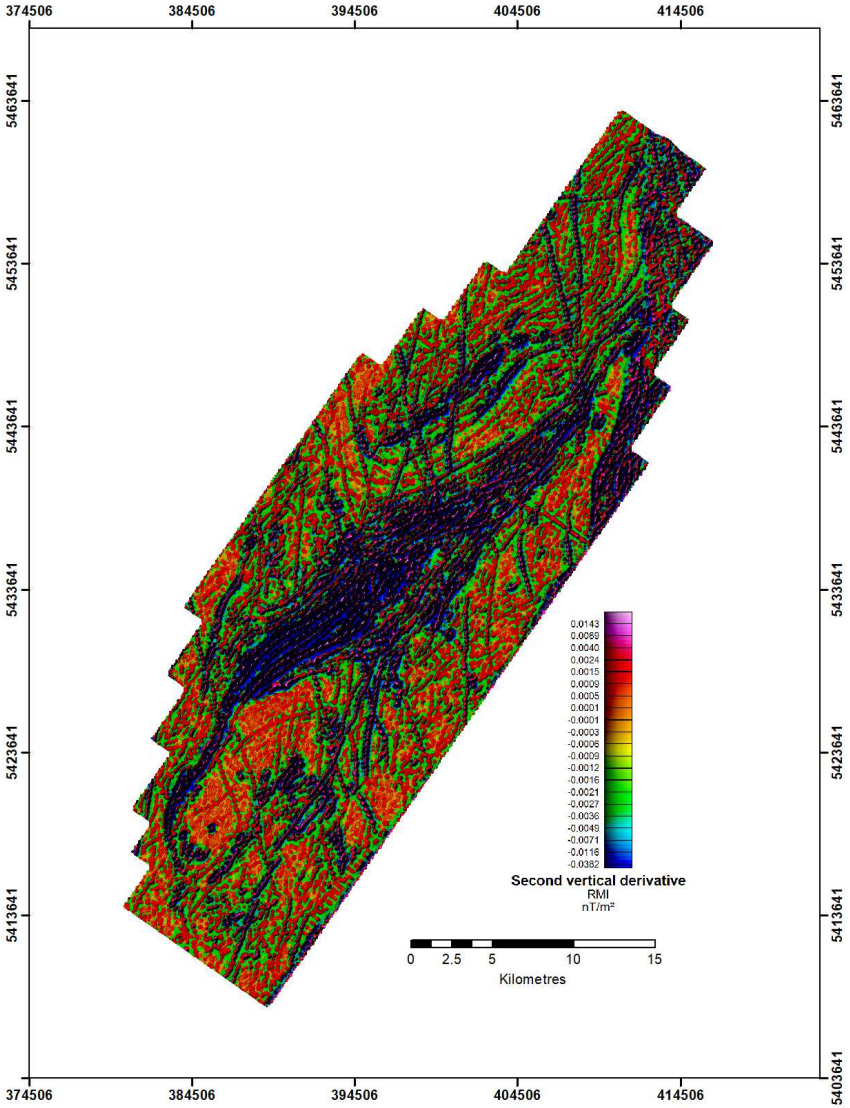
- Ramsey-Algoma area radiometrics and magnetics (2020)
  - *(see* SFW Article 5, 2019 and Article 5, 2020)
- Sturgeon River area magnetics (2020)
  - *(see* SFW Article 6, 2020)
- Biscotasing area magnetics (TDEM) (2020)
- Saganash area magnetics (TDEM) (2021)
  - *(see* SFW Article 6, 2021)
- flown by NWMO, published by OGS (2021)

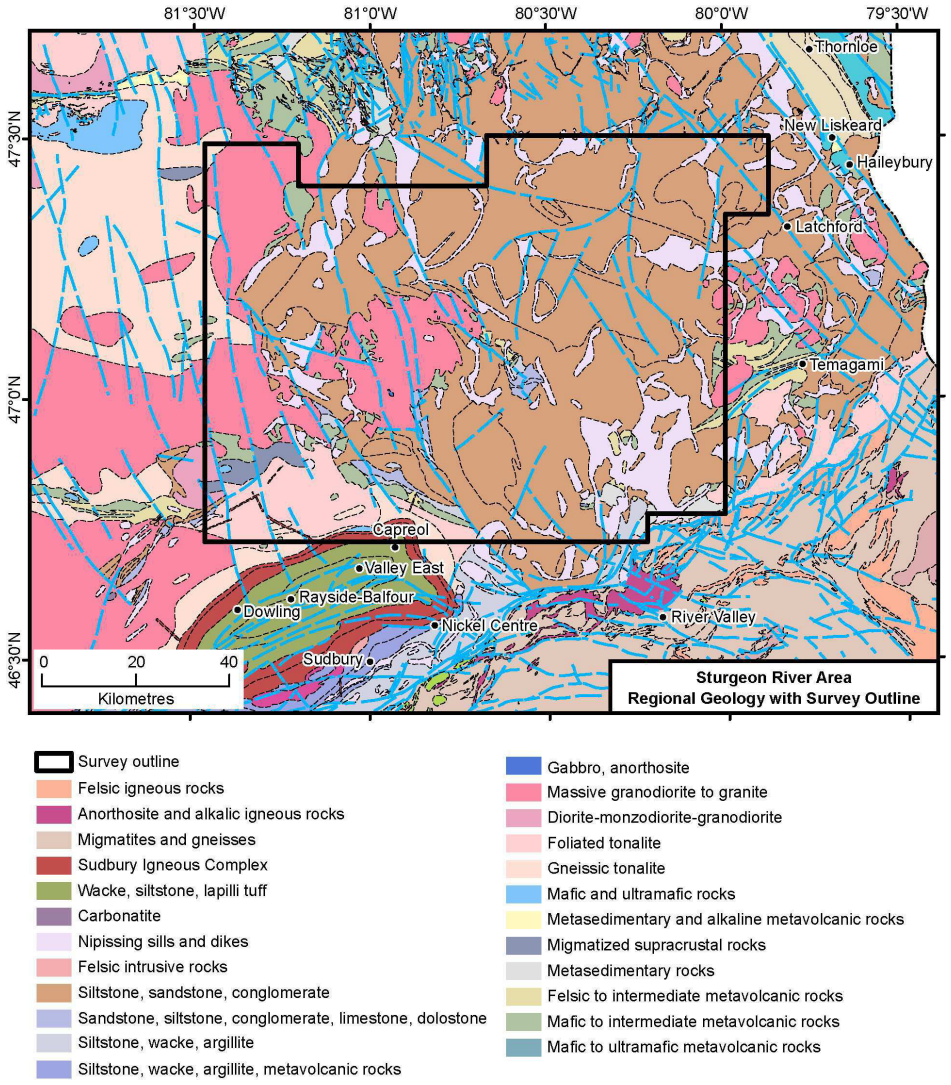
  – airborne gravity and magnetics
  - Mozhabong Lake (NE of Elliot Lake, maps 60516 to 60535)
  - Nameigos Lake (east of White River, maps 60484 to 60515)

Examples - Geophysical Surveys

Left – 2VD image, Saganash survey area

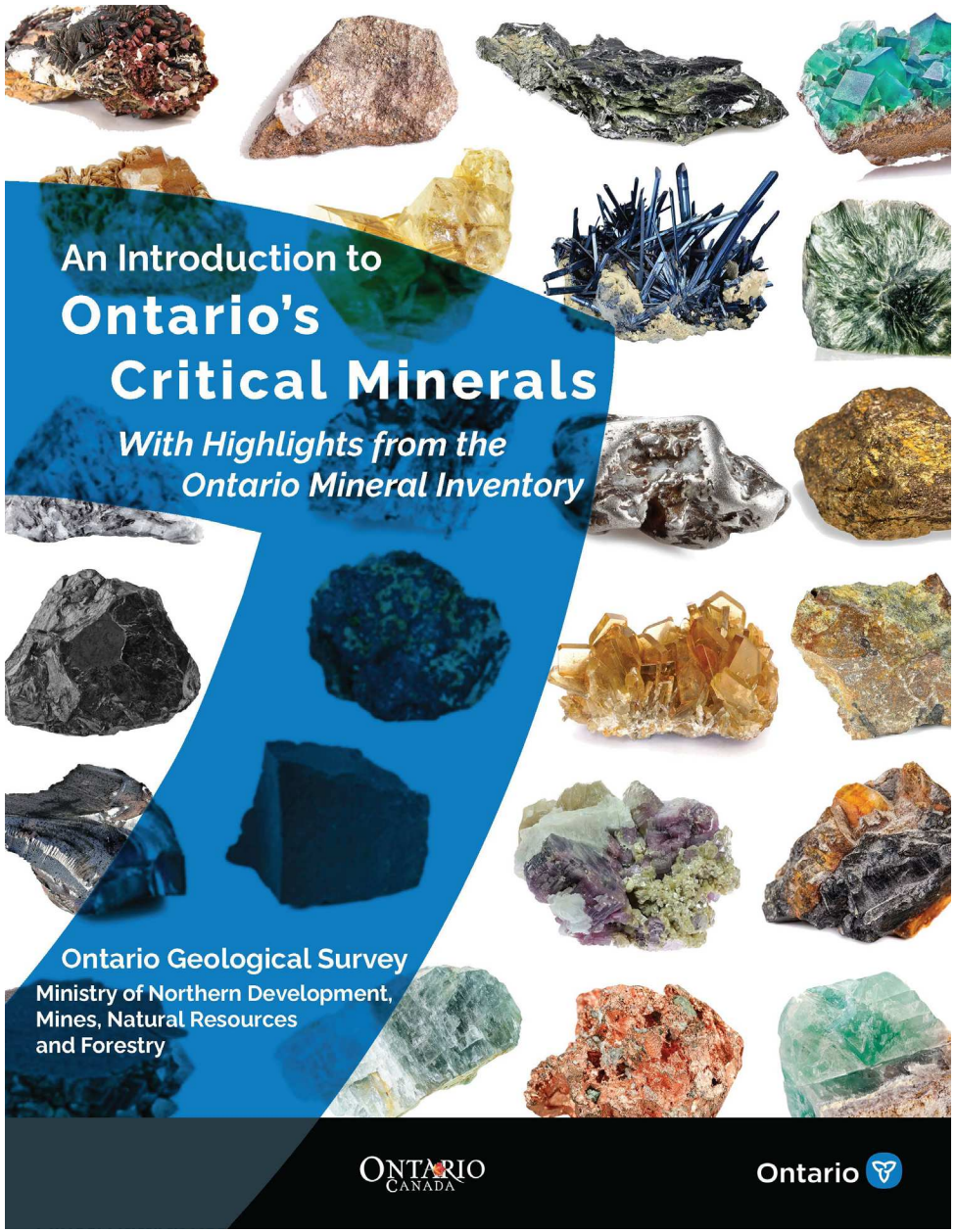
Right – area covered by the Sturgeon River area survey – enhanced understanding of thickness of Huronian Sgp in area





Ontario's Critical Minerals

- Consultation on *Ontario's Critical Minerals Strategy* begun in March 2021
- Strategy released in March 2022
- *Critical Minerals booklet* highlighting all 33 Ontario minerals-elements released mid-April 2022
- Compendium of *Recommendations for Exploration* regarding Critical Minerals from 2000-2022 was released at the end of April 2022

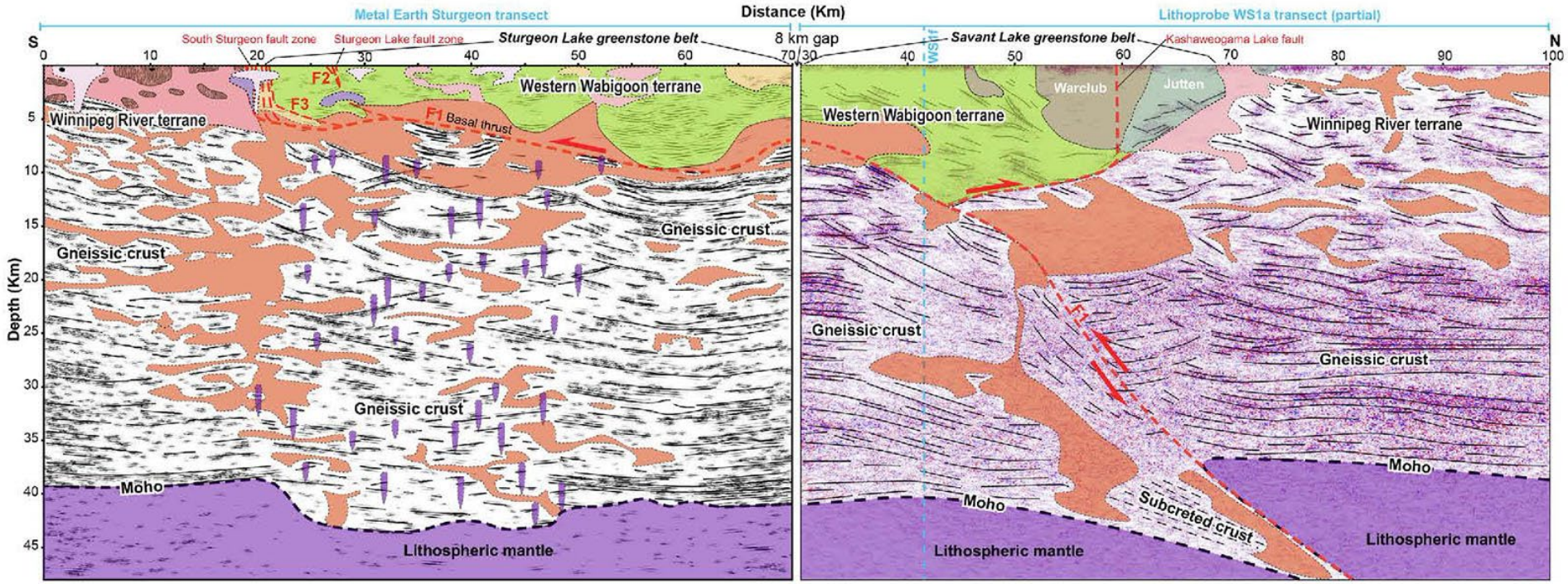


OTHER ACTIVITIES

- Geochronology Inventory released in October 2019
  - update in progress (~80 ages from OGS 2019-2022) plus literature
- project started in 2022 to revise and standardize Paleozoic stratigraphic nomenclature across southern Ontario
  - currently different schemes for subsurface, southwest, central and eastern Ontario
- in conjunction with Quebec, working on producing an updated map for the whole Abitibi subprovince
- NWMO work on Revell batholith is providing important data on the 3D structure of a typical Archean pluton

RELATED ACTIVITIES

- Metal Earth program at Laurentian University has resulted in the acquisition of several new seismic, AMT, and ground gravity transects throughout Ontario - will enhance 3D framework of Shield
  - (western Wabigoon transect interpretation below, Ma 2021 *Precambrian Research*)



Modélisation 3D à Géologie Québec

Patrice Roy

6 juin 2022

C3D Working Group Meeting

Votre gouvernement

Québec

Bref historique

- Les projets de géologie 3D ont débuté au début des années 2000
  - Partenariat avec l'URSTM-UQAT (Francine Fallara, Olivier Rabeau, Li Zhen Cheng)
  - Modèles 3D géo-intégrés avec GoCAD produits jusqu'en 2009.
  - Réalisation d'études thématiques en partenariat avec différentes universités du Québec de façon discontinue en fonction des besoins (UQAT, LAVAL, UQAM)
  - Travaux des compagnies minières

11 Modèles 3D géo-intégrés

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2. FALLARA, F., LEGAULT, M., 2004. MODELE 3D GEO-INTEGRE DE JOUTEL, SYNTHESE METALLOGENIQUE (PHASE 2/2). URSTM-UQAT, MRNFP; 3D 2004-03, 3D 2004-03 Disponible à *https://gq.mines.gouv.qc.ca/documents/EXAMINE/3D200403*.

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6. WILLIAMSON, K., PILOTE, P., RABEAU, O., 2013. MODELISATION REGIONAL DU CAMP MINIER DE MATAGAMI. MRN; MB 2013-05, MB 2013-05, 13 pages. Disponible à *https://gq.mines.gouv.qc.ca/documents/EXAMINE/MB201305*.

7. RONGIER, G., ALLARD, G., RABEAU, O., 2014. EVALUATION DU RECOUVREMENT QUATERNAIRE ET TOPOGRAPHIE DU ROC DE LA CEINTURE DE ROCHES VERTES DE L'ABITIBI : IMPLICATIONS POUR L'EXPLORATION MINERALE. ENSG, MERN; MB 2014-35, MB 2014-35, 61 pages, 1 plan. Disponible à *https://gq.mines.gouv.qc.ca/documents/EXAMINE/MB201435*.

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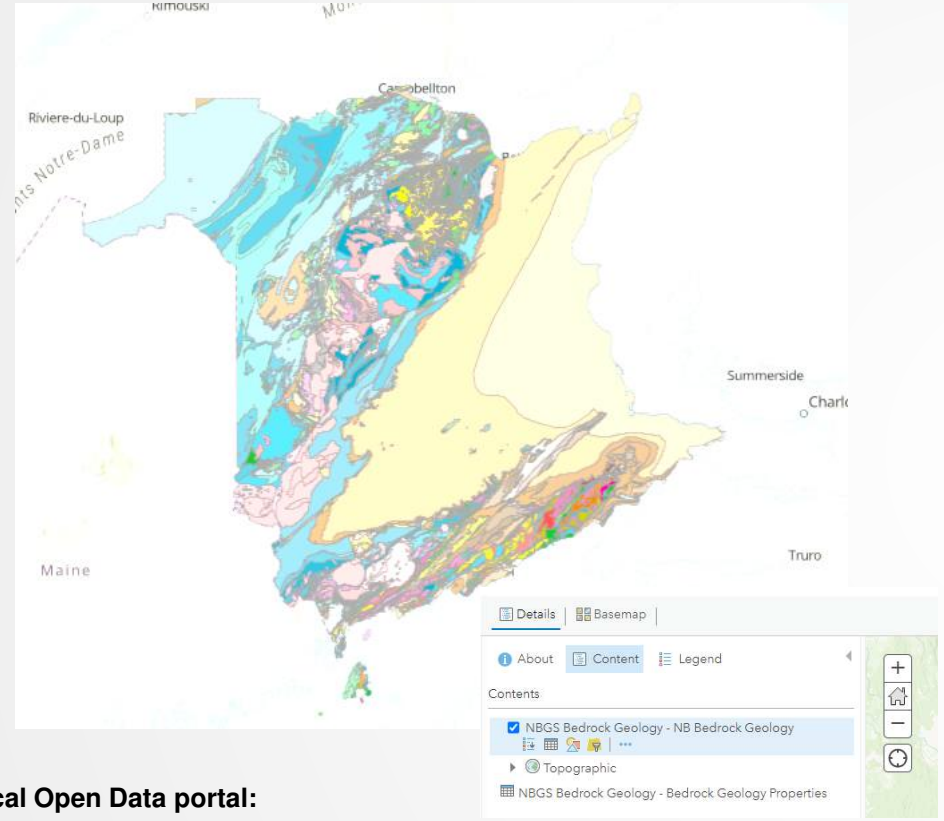
Rapports de l’industrie – principalement de la géophysique

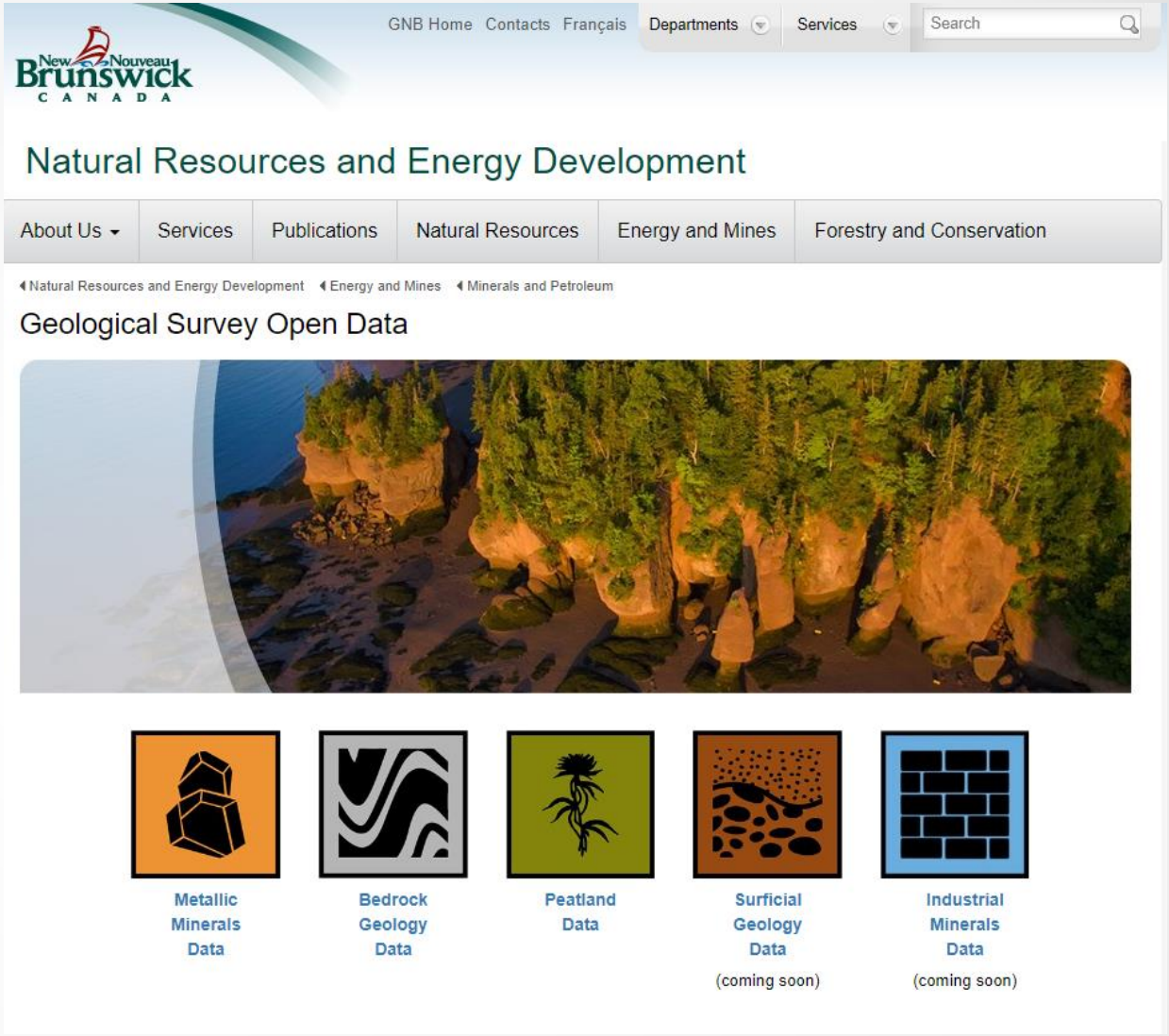
- OreVision 3D
- IPower3D
- Inversions magnétiques
- Hole-to-hole 3D
- 3D Infinitem
- Pulse EM 3D
- 3D Geo-Electric

Travaux à venir

- Consultation de l’industrie
  - Pertinence de la modélisation 3D publique pour l’exploration
  - Besoins de la clientèle d’exploration en données pour la modélisation 3D
    - Base de données de forages
    - Données géophysiques et diagraphies
- Expertise
  - Partenariat

C3D NGSC Summary by Serge Allard and Dustin Dahn



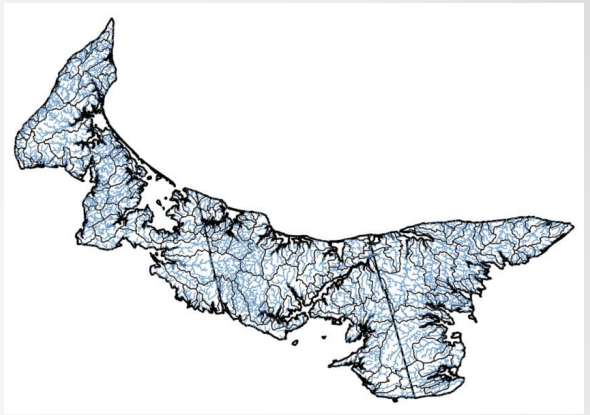


NB Geological Open Data portal:

https://www2.gnb.ca/content/gnb/en/departments/erd/energy/content/minerals/content/geo-survey-open-data.html

ArcGIS Online Mineral Exploration Map:

https://nbdnr.maps.arcgis.com/apps/webappviewer/index.html?id=9222d8a1ccf54f4a9655c9d7026112a3&locale=en



Geology in 3 Dimension in Prince Edward Island

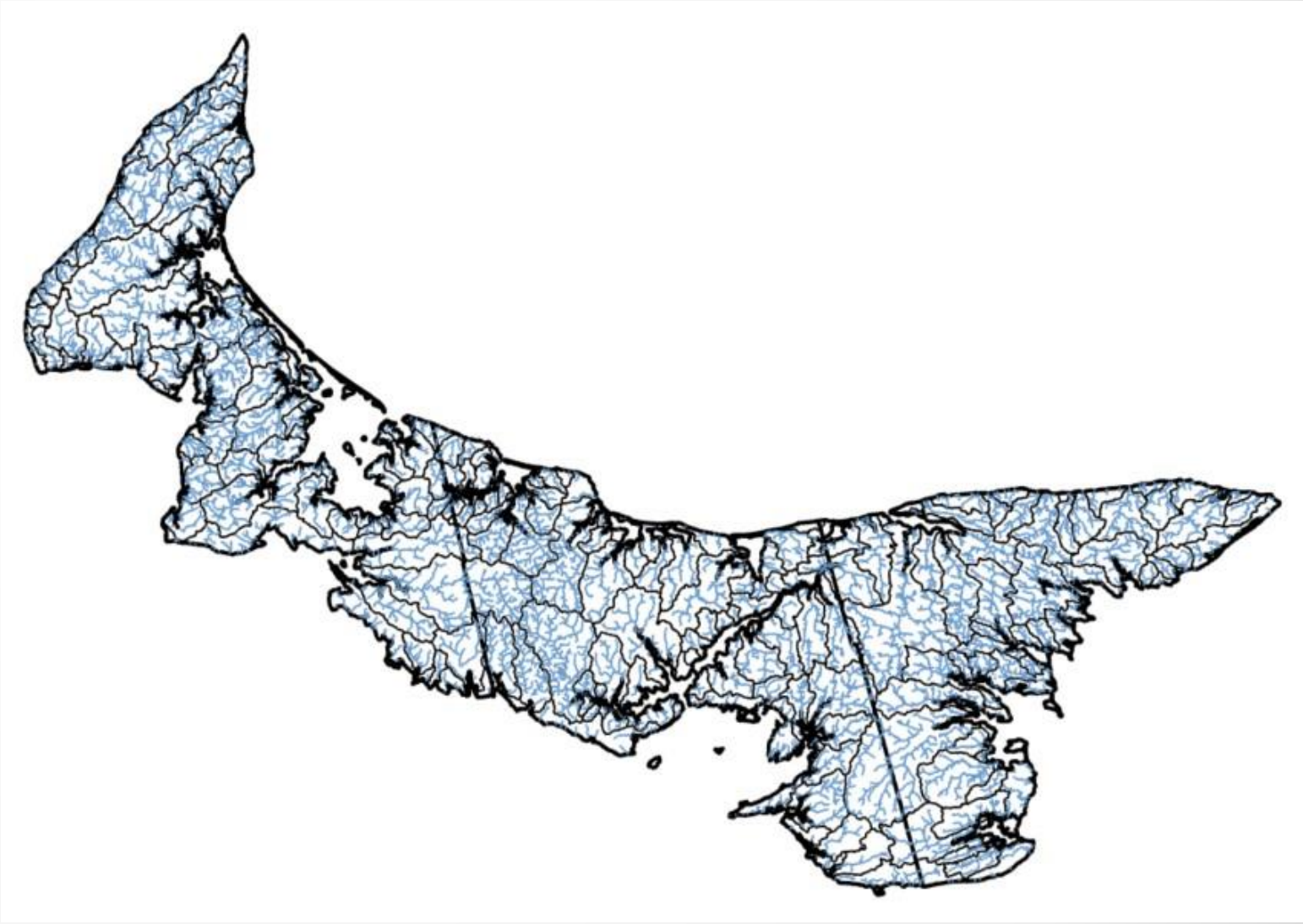
Presentation by Qing Li
Department of Environment, Energy and Climate Action

Geology and Hydrogeology in PEI

- The PEI Island is approximately 230 kilometers long, 6.5 – 50 kilometer wide and has a maximum elevation of 127 meters. Geologically, it is formed by a northeastward tilted low-angle (5-6 degrees) cuesta of red beds with Upper Pennsylvanian to Middle Permian in age.
- Geologically it belongs to Carboniferous Magdalen Basin (Atkinson et al., 2020) – a part of larger Upper Paleozoic Maritimes Basin (Gibling et al., 2008). The shallowest bedrock units underlying the PEI ("red-beds") consist of alternating continental sandstone, and mudstones and siltstones (Chi et al., 2003) and form a transmissive aquifer (Rivard et al., 2008).
- The lack of lithological continuity of mudstone units even at 100 m scale means that on a watershed scale the aquifer behaves as a single unconfined body (Francis, 1989). At the same time, aquifer compartmentalisation by mudstone beds can play important role on a local scale.
- Generally thin overburden with ranges from 0.5 to 5 m in thickness with a maximum of about 20 m limits importance of the surficial sediments for groundwater flow.

Watersheds in PEI

- Around 260 watersheds in small scale
- Groundwater model usually cover one or multiple watersheds
- 3D geological and hydrogeological model provide a conceptual model for a numerical model in stratigraphy and parameters.
- The fractures in the bedrock represent the primary water flow paths, while the bulk of the water is stored in the pores of the rock matrix. But modelling assumes the hydrogeological layers are pore media equivalent normally.
- Groundwater flow boundaries are same as watershed boundaries due to uniform geology and hydrogeology.



Geology from Outcrops and Deep Boreholes

- Bedrock stratigraphy variants derived primarily from outcrops (Van De Poll, 1989) and from deep borehole logs (Giles & Utting, 1999).
- Besides using different formation names and boundaries, borehole-based analysis did not find any evidence of the fining-upward megacyclic sequences identified in the outcrops.

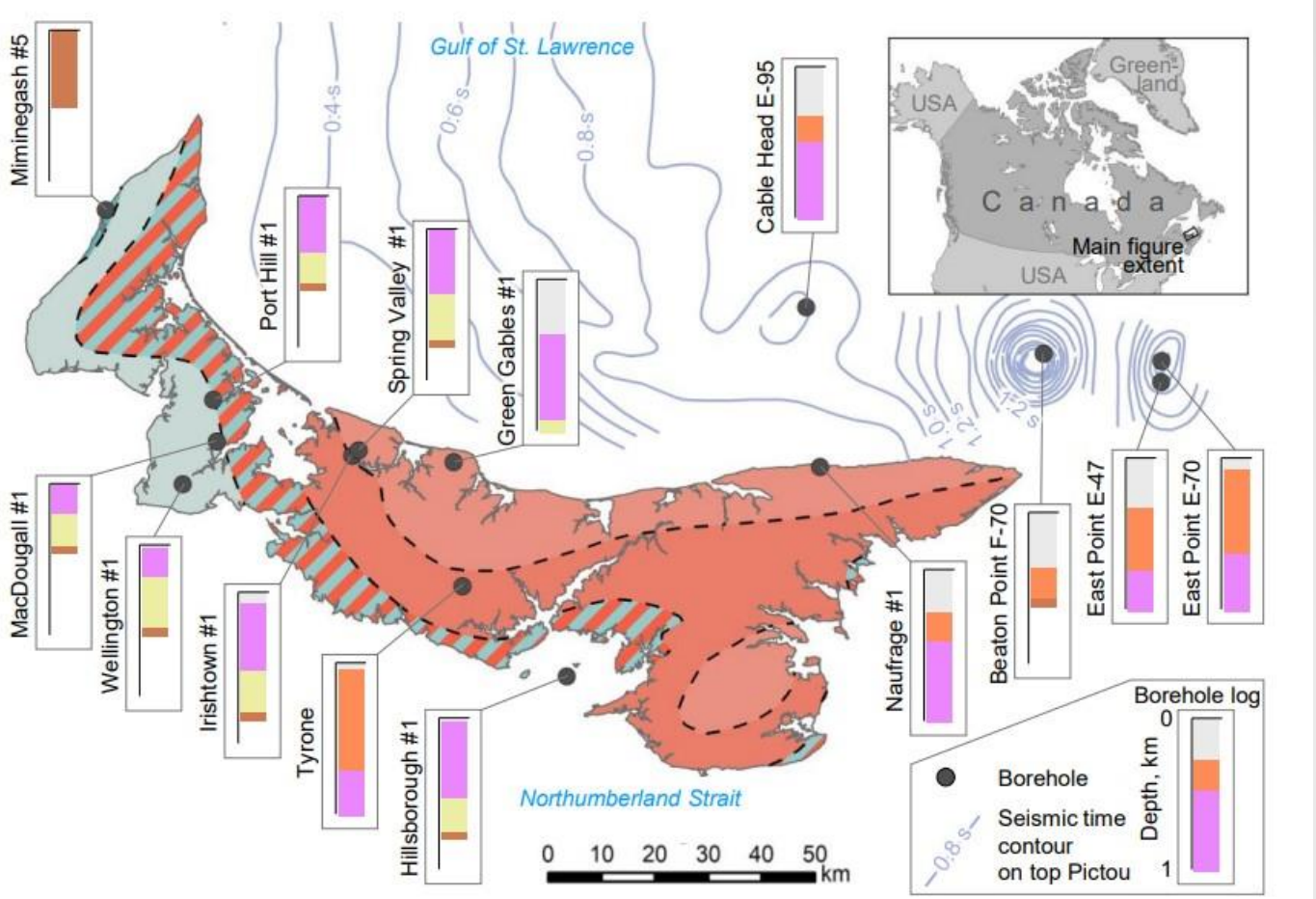
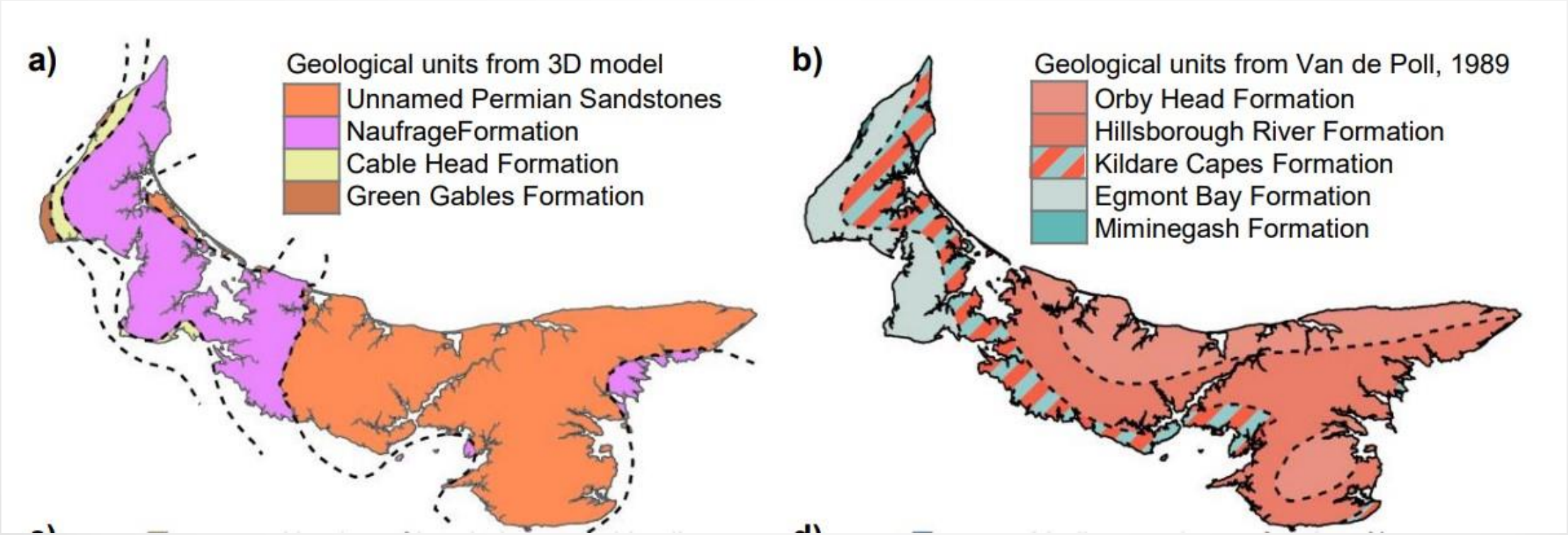


Fig. 1 Comparison between mapped units (Van de Poll, 1989) and interpreted borehole logs (Giles and Utting, 1999).
Only upper part of borehole logs shown. Seismic contours digitized from Chevron Standard Limited, 1981. Contour labels depict two-way travel time.

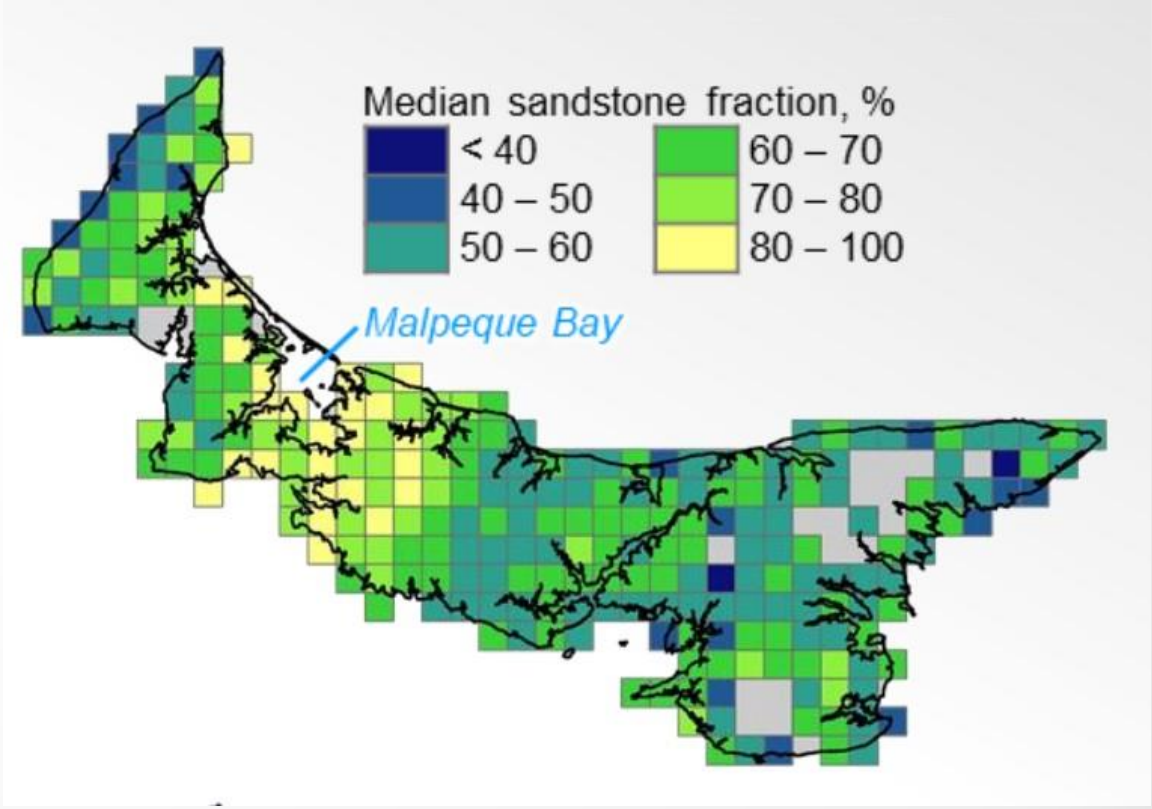
3 D Geological Model Vs. Outcrop Geology

The geological map based on 3D geological model (Fig. a) highlights lack of the direct equivalency between borehole-based (Giles & Utting, 1999) and outcrop-based (Van De Poll, 1989) (Fig. b) stratigraphy variants.



Water well data to analyze distribution of sandstone fraction in shallow layers

- the observed differences in sandstone fraction highlight variation of hydrogeological conditions across the island.
- 29160 borehole logs for groundwater wells was utilized in the model development, and the database spans a period from 1962 to July 2021 and has highly variable log quality.
- Coupled with uncertainty about borehole locations (in many cases coordinates were originally picked from the map or are based on legal land description), this limits the usefulness of individual logs. At the same time, the sheer size of the database supports possibility of extracting useful information by aggregating data from multiple wells.



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NOVA SCOTIA CANADA

Department of Natural Resources and Renewables

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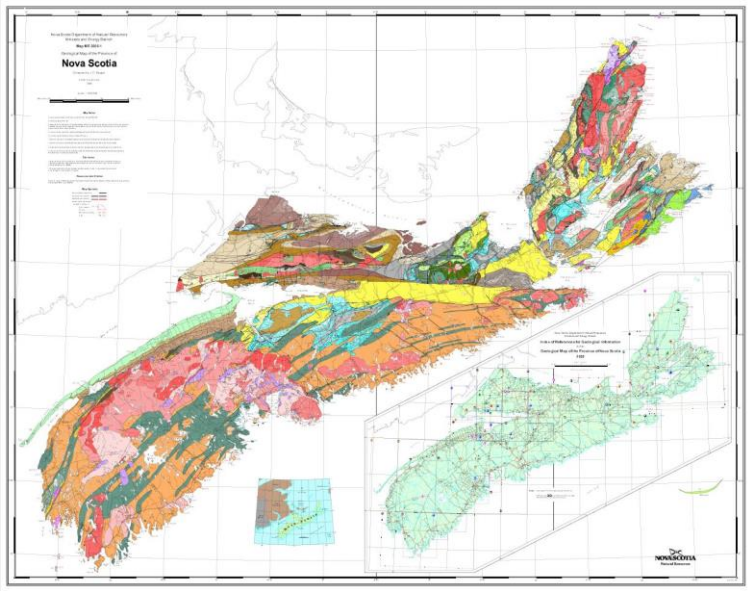
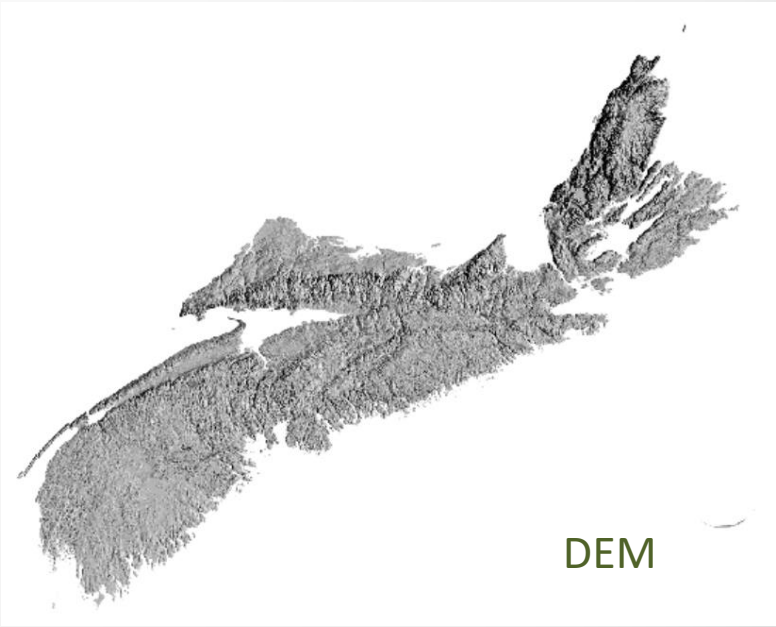


Nova Scotia Geological On-line data and map information:

https://novascotia.ca/natr/meb/download/gis-data.asp

Environmental Geology and Land Use

Rotational Slump, Lunenburg, Nova Scotia



DEM

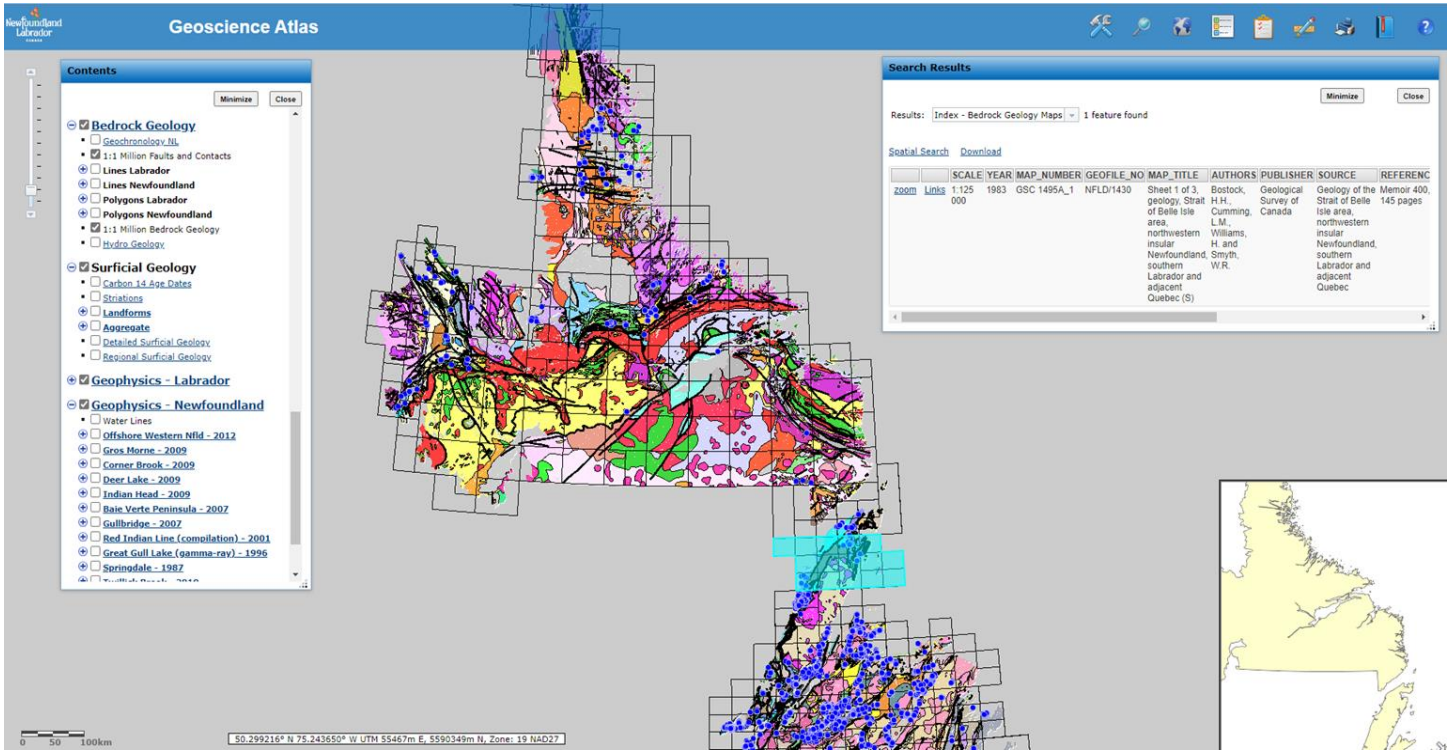
Current Progress:

for future 3D & advanced geological investigations

- Continued annual updates to our **Airborne Geophysical Program**: acquisition of new surveys, and development of regional compilations with GSC (2 new in 2021!)
- Continued **fundamental geological investigations** with increased focus on both projects in Labrador and critical minerals investigations.
- Adoption of the **GSC field application for bedrock investigations** — encourages more efficient incorporation of new data into GSC-managed regional and national compilations with **standardized nomenclature and ontologies.**
- Leadership role in two Priority Areas of the **Pan-Canadian Geoscience Strategy**: information management & data standards, and predictive mapping components.
- Short-term contract project to review our data preparedness for **applications of advanced analytics and predictive modelling**, focusing largely on data accessibility, interoperability, standardization.
- Water well and drillhole data compilation for drift thickness model (feasibility stage)

2D Resources

https://geoatlas.gov.nl.ca

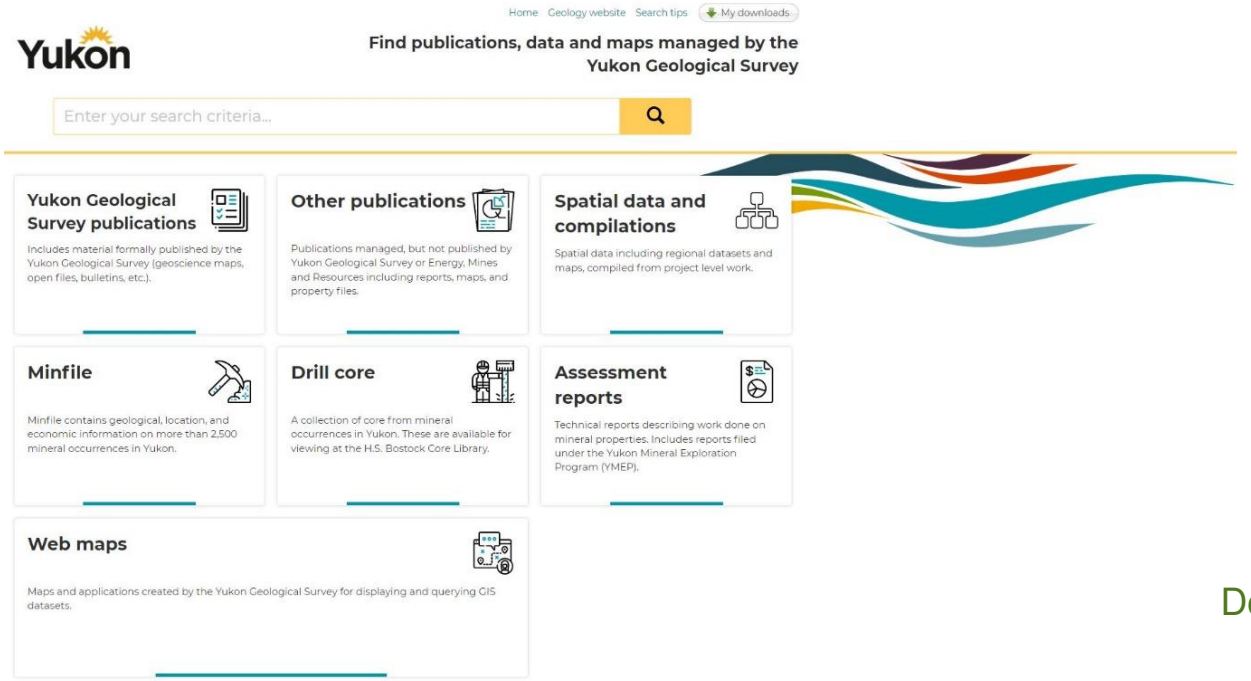


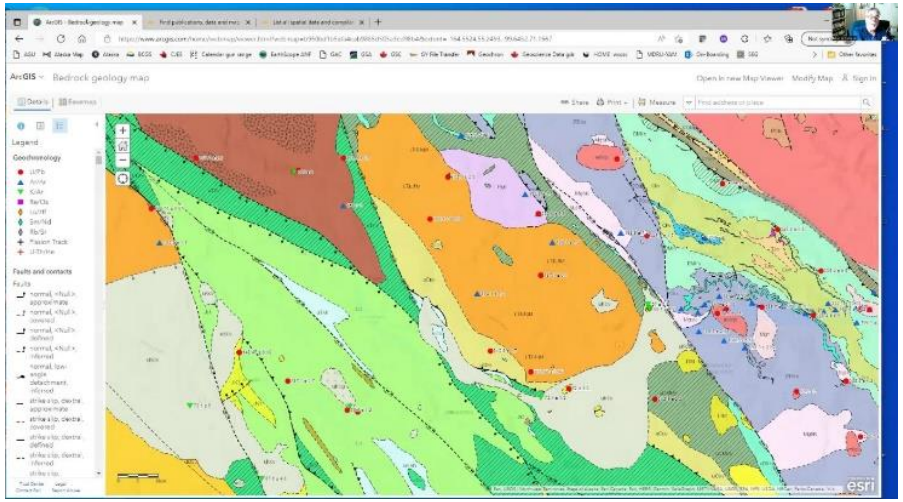
Current Challenges:

- At our current staffing levels **~150 years** to complete 1:50K mapping for province
- Augmenting our current **seamless geologic maps**, including building legends and reconciling outcrop-scale observations with multi-scale 2- & 3-D geological frameworks
- IT/Technological challenges — improvements in our platforms to store, manage, access and manipulate ever-expanding digital datasets
- Data **discoverability** — NGSC IDM committee is working to change that with a pilot project on cross-jurisdiction data interoperability and discoverability
- Data pipeline bottlenecks & **data silos** - groundwater management, hydrocarbon development, assessment reports from mineral exploration
- Sparse and unevenly distributed subsurface data (water wells and drill holes)

Maurice Colpron, Ph.D., *Head bedrock geology, Yukon Geological Survey*

We are primarily focused on 2D, we still have a lot of work. We currently have only four bedrock mapping geologists that are active, but we have many years to go to cover the territory at detailed scale. Our biggest thing is just to have an integrated and regularly updated GIS data set that's available through our website that can be viewed. The data is readily downloadable. We aim to have any new geological maps integrated into the geological compilation usually within about a year. On about a yearly basis we will release a new version of the map. There are several other compilation projects that are underway, our aim as we build these compilations, is to build them in a way to have an easy and regular updateable method.





Detailed bedrock geology snap-shot of part of Central Yukon.

Con't…

An example of the list of compilations that we have. Including geochronology, geochemistry etc.. We are building additional ones for isotopic analysis and now we are up to around 1200 samples. We have a mineral occurrence data base on-line for quite a few years, that is seeing continuous improvement. We are trying to get in rock properties which is under development. We are trying to disseminate all structural information that we collect during mapping.

List all spatial data and compilations

Spatial data and compilations including regional datasets and maps, compiled from project level work.

Clear filters Show 10 entries Search:

Name	Description	Feature Type	Abstract
Filter Name	Filter Description	Filter Feature Type	Filter Abstract
Assessment Report Footprints	Minerals Geology	Polygon	This data set represents the geographical extents of the work performed in annual Yukon mining assessment reports. The assessment reports are submitted by the owners of mining claims and are a technical report ...
Bedrock Geology dataset	Bedrock Geology	Dataset	This update of the Yukon bedrock geology map builds upon the previous compilation by Gordey and Makepeace (1999, 2001). The data set includes the bedrock geology, faults and contacts, geochronology and map ind...
Bedrock Geology Map Index	Bedrock Geology	Polygon	A Yukon-wide compilation of map footprints and associated citation data for 191 published bedrock geology maps that were incorporated into the Yukon bedrock geology compilation. The maps were originally produce...
Bedrock Terrane	Bedrock Geology	Dataset	A geological compilation map showing the tectonostratigraphic terranes of Yukon, British Columbia, and Alaska. Intended for use by the exploration community, prospectors, and geologists....
Drill core Locations	Minerals Geology	Point	The H.S. Bostock Core Library is a repository for drill core and rock samples from various Yukon mineral properties and YGS mapping programs. This data set shows the collar coordinates that the core was collect...
Geochronology	Bedrock Geology	Point	Geochronology is a discipline of geoscience which measures the age of earth materials and provides the temporal framework in which other geoscience data can be interpreted in the context of Earth history. This ...
Georeferenced Bedrock Geology 250k maps	Bedrock Geology	Map	These georeferenced pdf maps contain the most current bedrock geology information in Yukon. They are intended for use in software such as Avenza PDF Maps. The geological data used to create these maps can be d...
Glacial Limits	Surficial Geology	Polygon	The nature and extent of past glaciations are depicted on the glacial limits map of Yukon....
Lithogeochemistry	Bedrock Geology	Point	This product contains whole rock chemical analyses from Yukon samples....
Mineral Occurrences	Minerals Geology	Point	Minfile contains geological, location, and economic information on more than 2,500 metallic, industrial mineral and coal mines, deposits and occurrences in Yukon. This GIS data set is a daily extract of our...

Showing 1 to 10 of 17 entries Previous 1 2 Next

Con't…

We also have another project that is to relate to our geothermal research program in which we are compiling in an on-line map all information relevant for geothermal exploration in the Yukon. Another component that is not so much my field, my surficial geology colleagues are working on an integrated Yukon wide compilation. Up to now they have a web page, on-line maps where you can easily search for the individual map, the NTS sheet, publication number etc. They are working toward integrating this into a broader data base. I don't know what the timeline is as far as when that is going to be released.
On the 3D level we don't do a whole lot. Most of the 3D stuff we do, it's a question of capacity, it's not capacity we've lost, it's capacity we've never had. Most of the 3D work we do is in collaboration, I see Vicki Tschirhart (GSC) is on the call, she is working in collaboration with Jim Craven (GSC) and others to specifically to focus on our geothermal research program, so we are developing 3D models, but they are very focused and on small areas in various parts of the Yukon. This is an integration of geophysics and geology, everything we can bring together, usually magnetics, gravity in many cases we have electromagnetic surveys in the areas. Vicki and Jim are particularly focused on the Magneto-Telluric data. That is basically the extent of what we are doing currently.

Victor Terlaky, Ph.D., *- Manager, Energy Geosciences Group, North West Territories Geological Survey*

Government of
Northwest Territories

We also don't have a dedicated 3D program up here in the Territories unfortunately. I am the manager of the Energy Geosciences Group and within our work we have been working at a really small scale a 3D model of the Horne River Group in the Central McKenzie Valley. just for oil and gas exploration purposes and to map and model thermal maturity and potential migration pathways. This study is just restricted to one portion of the stratigraphy (Horne River – Devonian) and one small area in the territory. That's all we are doing in 3D work but we are very committed to providing public data for anyone who is willing to take these things on. For example I have been in contact with Hazen before and provided tops files for our overarching project. That is on-going and I am also involved with the Atlas 2027 project and the 3D chapter with Kelsey. We have talked about what will happen with C3D under the umbrella of the Pan-Canadian Geoscience Strategy and it will be probably taken on as a side project by our information and GIS groups. Previously these were two working groups now they are integrated into one geological information, GIS and Geomatics work group.

Horne River Group 3 modelling in the Central McKenzie Valley

(See utube video by Jonathan Richeleau NWT GS; Jan. 24, 2022 https://www.youtube.com/watch?v=OfXxCIwFUYA&t=909s)

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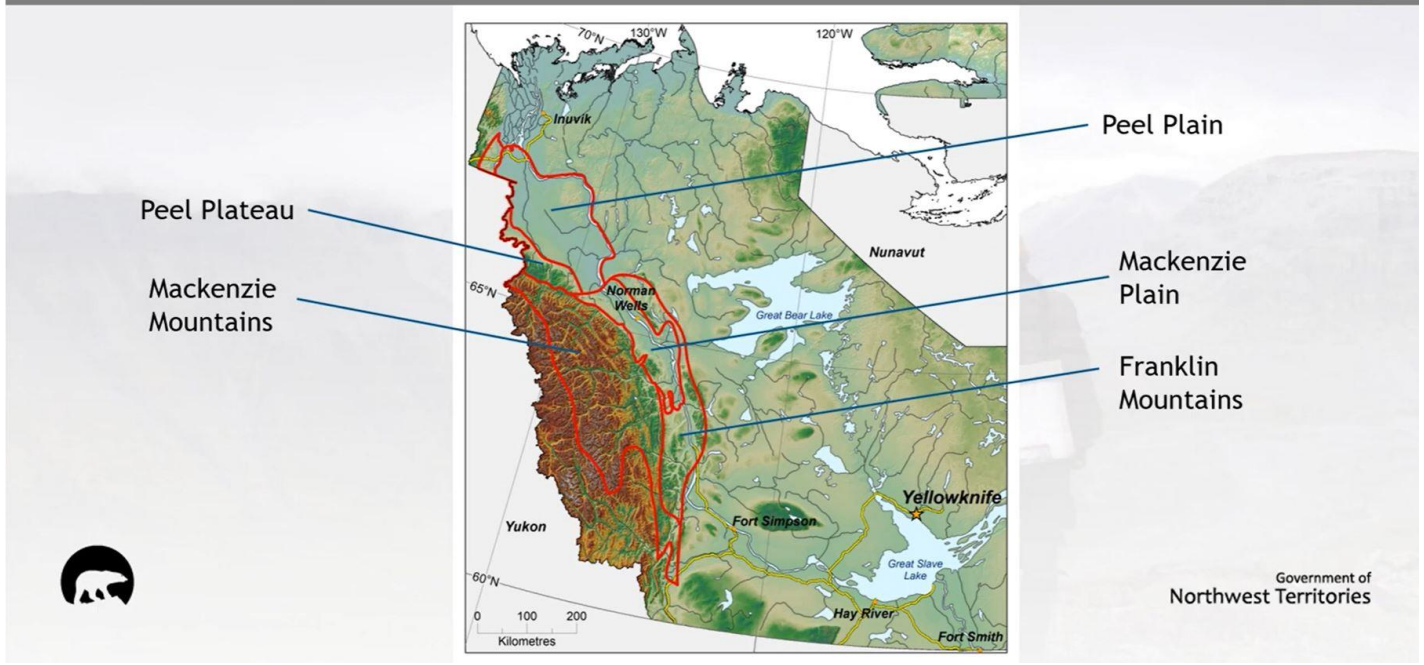
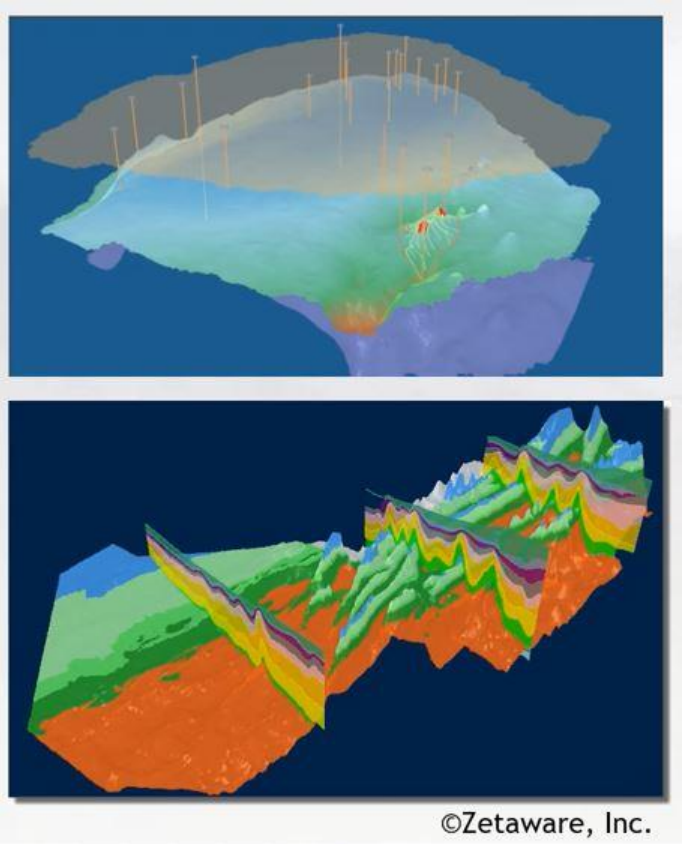
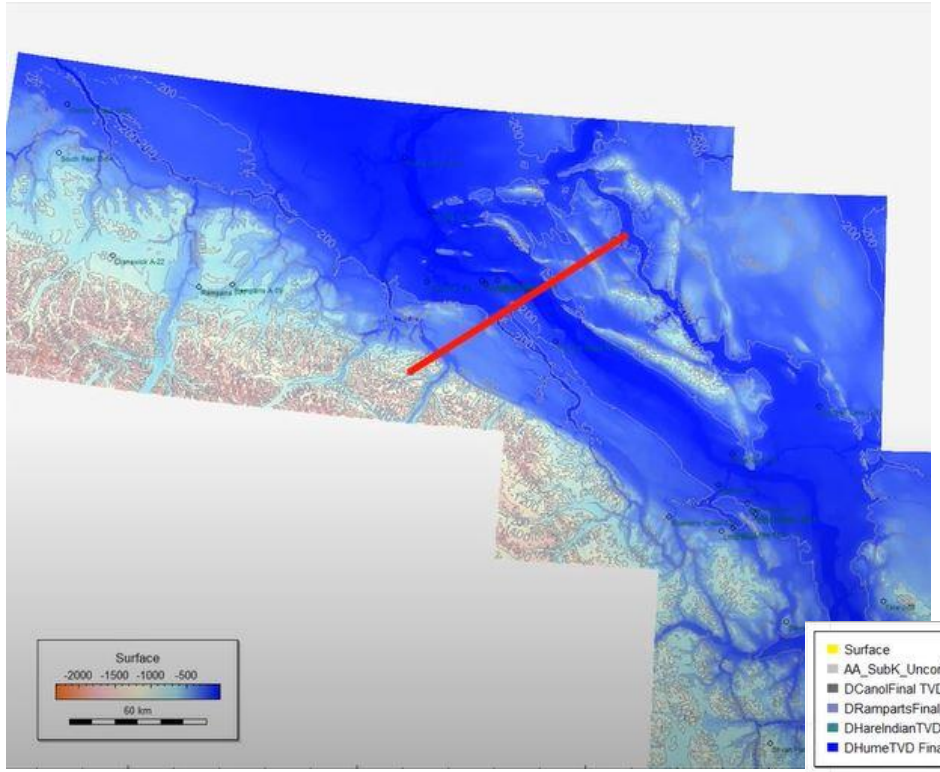
Study Area





Atlas 2027



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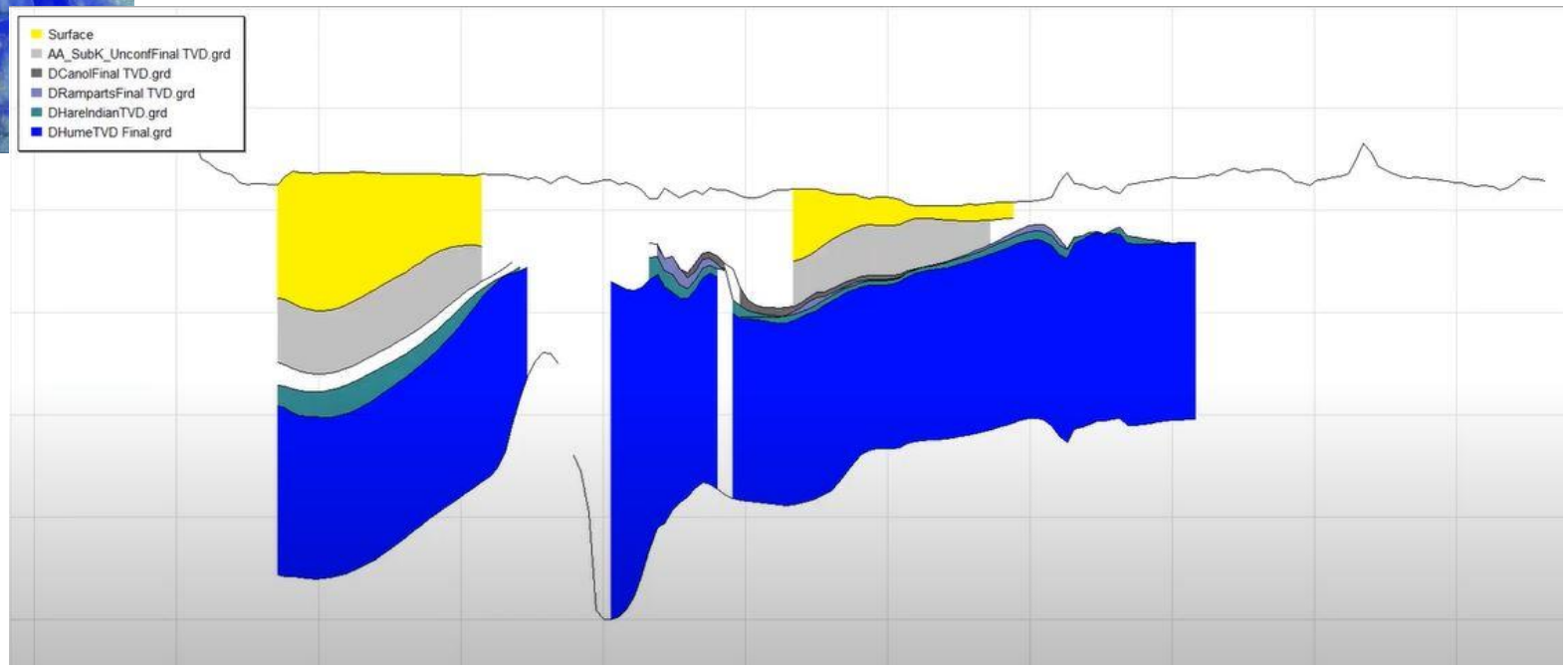
Horne River Group 3 modelling in the Central McKenzie Valley



Atlas 2027

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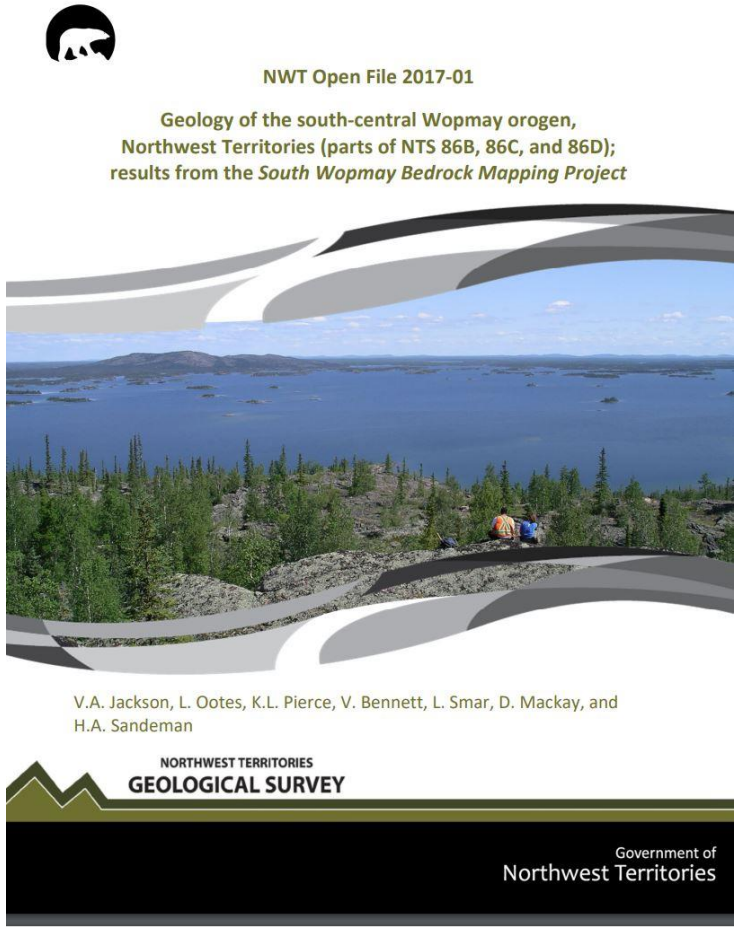
Kelley Pierce, B.Sc., *- Geomatics Specialist, North West Territories Geological Survey*

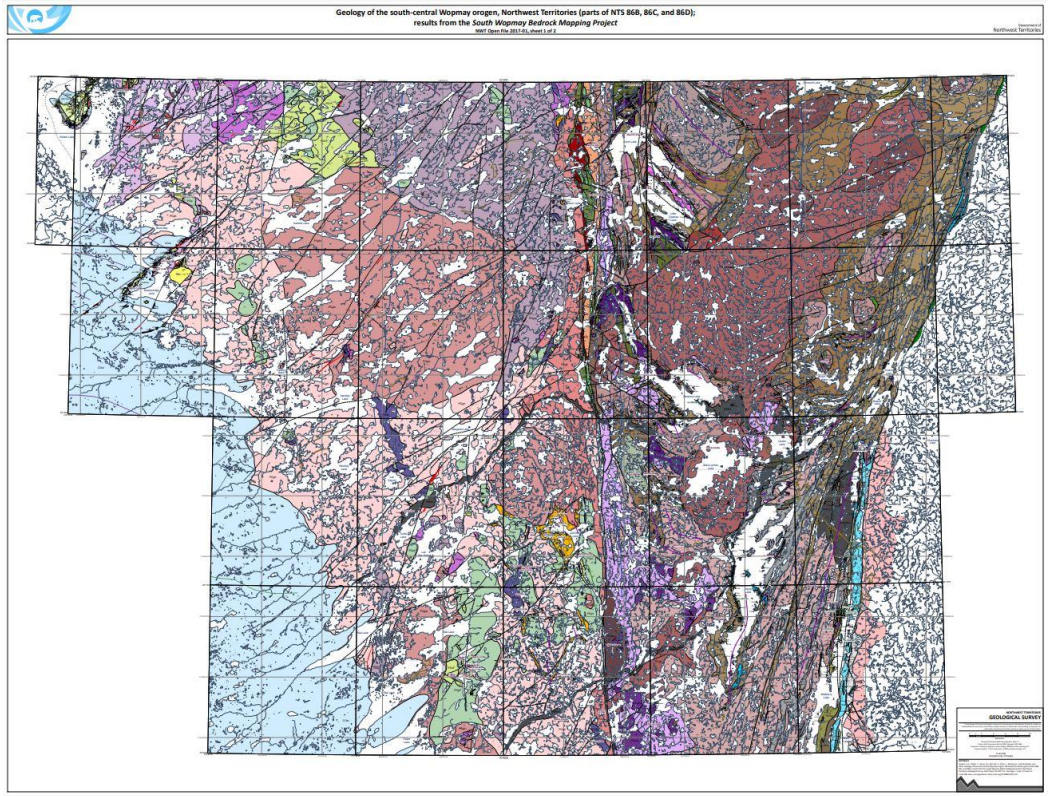
My previous manger I had been working with was Doug Irwin, who retired last summer and is not being replaced. He worked on several compilations and before he left, he completed another compilation that filled in a gap that completes the Wopmay orogen. That was just published a couple of months ago now. That should be forwarded on to be put into the 3D portal.

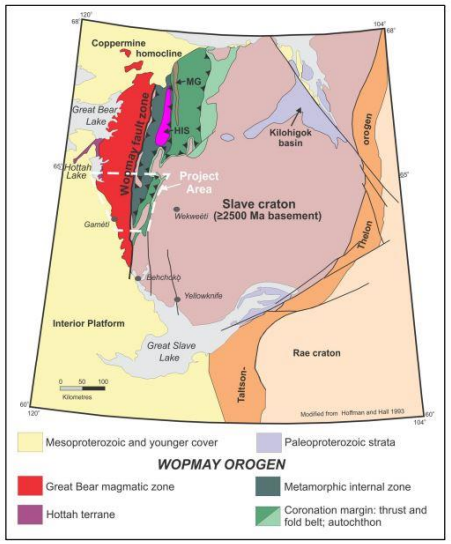
https://doi.org/10.46887/2017-01

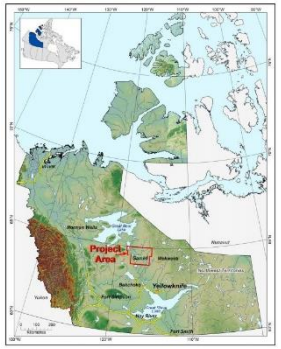


Major product release 2022 : Wopmay Orogen

Publication Date: 2022-03-23







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Potential update to C3D - 3D Portal

Geology of the south-central Wopmay orogen, Northwest Territories (parts of NTS 86B, 86C, and 86D); results from the South Wopmay Bedrock Mapping Project

https://doi.org/10.46887/2017-01

Reference Number: 2017-01
Publisher: Northwest Territories Geological Survey (formerly Northwest Territories Geoscience Office and CS Lord Northern Geoscience Centre)
Authors: VA Jackson; L Ootes; KL Pierce; V Bennett; L Smar; D Mackay; HA Sandeman

Con't…

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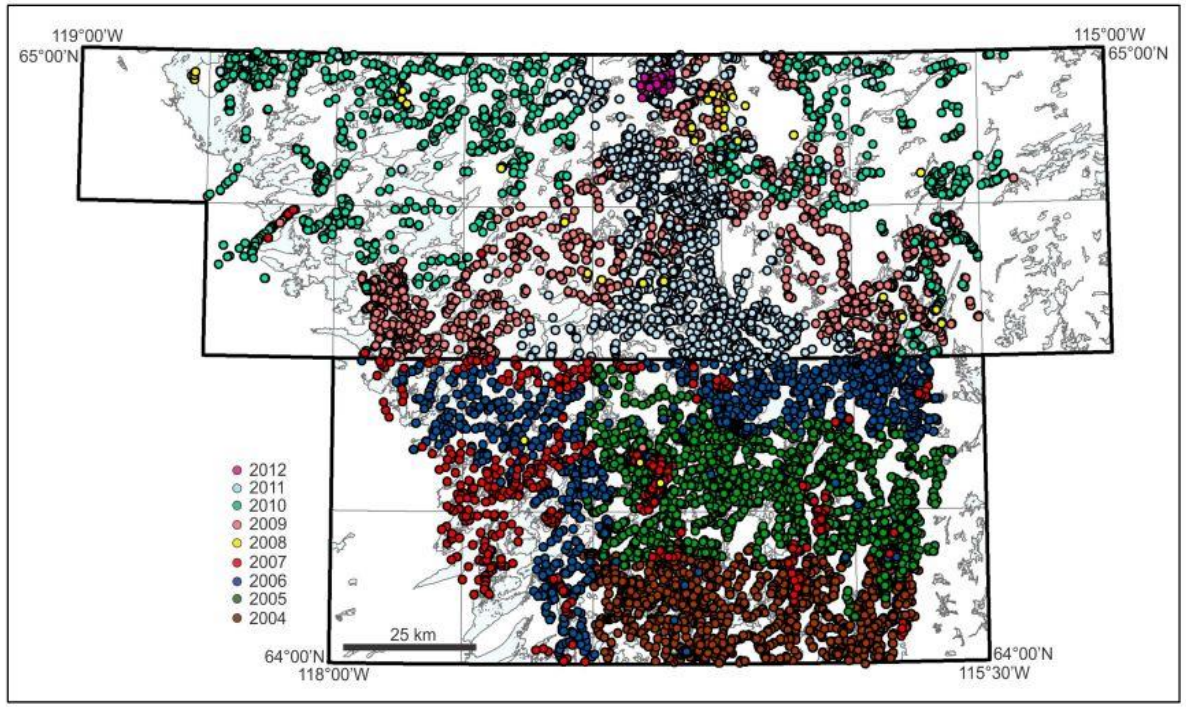
At this time there are no plans to do a nice seamless NWT wide geology although that would be lovely, but we are limited in capacity, and we will look into getting that done down the road. We do have various web aps for searching our data bases. They are currently in the process of being overhauled and updated and as part of that we have an open data hub, so our bedrock compilations, bedrock project maps, geophysical compilations, and our mineral showings data base, are all downloadable as shape files. However, our latest compilations of bedrock maps are not yet downloadable. We'll be working on getting these downloadable over the summer.



Geological field station coverage
South Wopmay

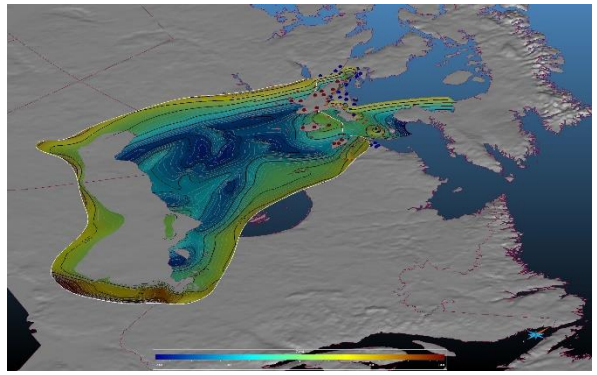
NWT Open File 2017-01

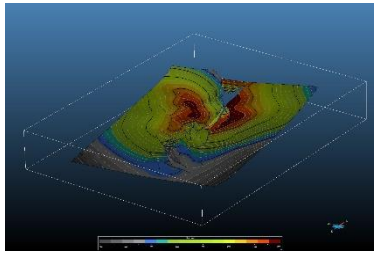
Celine Gilbert, B.Sc., *- GIS Specialist, Canada Nunuvut Geoscience Office*

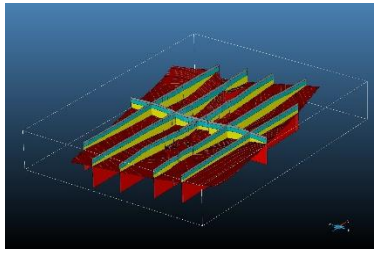
CANADA-NUNAVUT GEOSCIENCE OFFICE
BUREAU GÉOSCIENTIFIQUE CANADA-NUNAVUT
KANATAMI-NUNAVUMI GEOSCIENCE TITIGAKVIIT

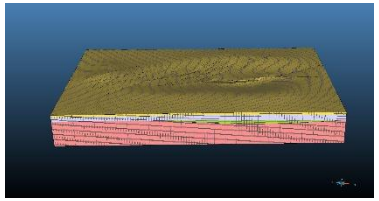
Representative for CNGO NGSC – 3D working group meeting June 6th, 2022

Celine had to leave the meeting early. The link to the summary of activities is here: https://cngo.ca/summary-of-activities/2021/
We highlight the potential contribution to C3D from the regional Paleozoic basin analysis.

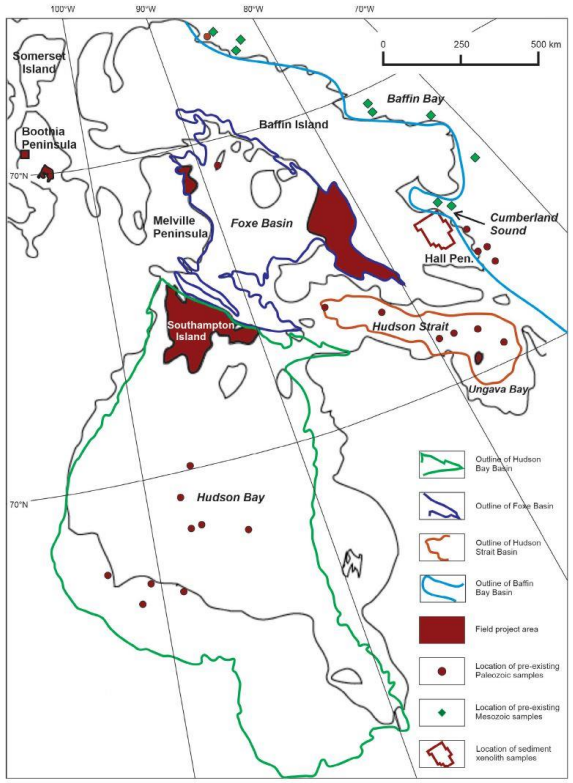


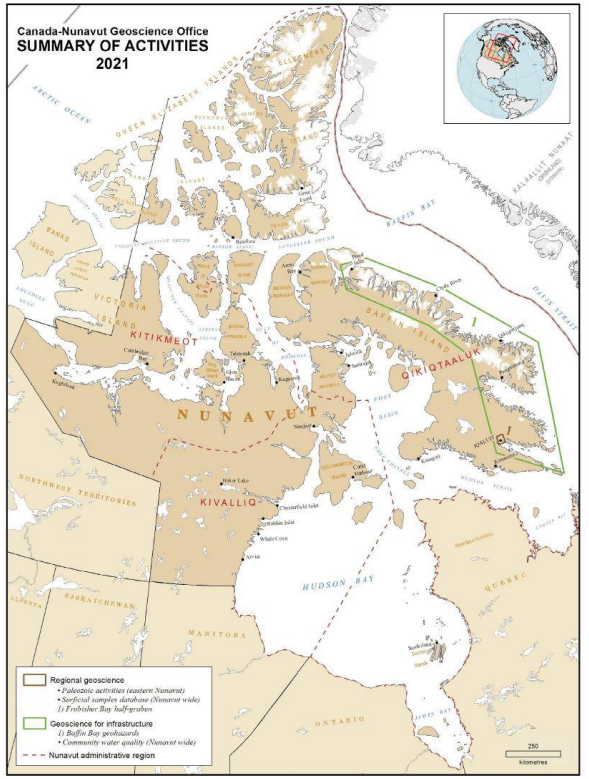






CNGO 2021 summary of activities map of recent sampling within Paleozoic stratigraphy.





Eric de Kemp noted potential for C3D collaboration in Paleozoic stratigraphic and structural modelling. Extending work of Shunxin Zhang CNGO and Pinet et al. 2013. See 3D models depicted herein. Also, several regional unpublished models from Central Baffin could be more developed.

3D Model developed from data in Nicolas Pinet, Denis Lavoie, Jim Dietrich, Kezhen Hu, Pierre Keating, 2013, Architecture and subsidence history of the intracratonic Hudson Bay Basin, northern Canada, Earth-Science Reviews,125, 1-23. https://doi.org/10.1016/j.earscirev.2013.05.010

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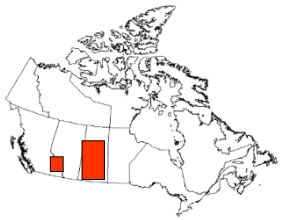
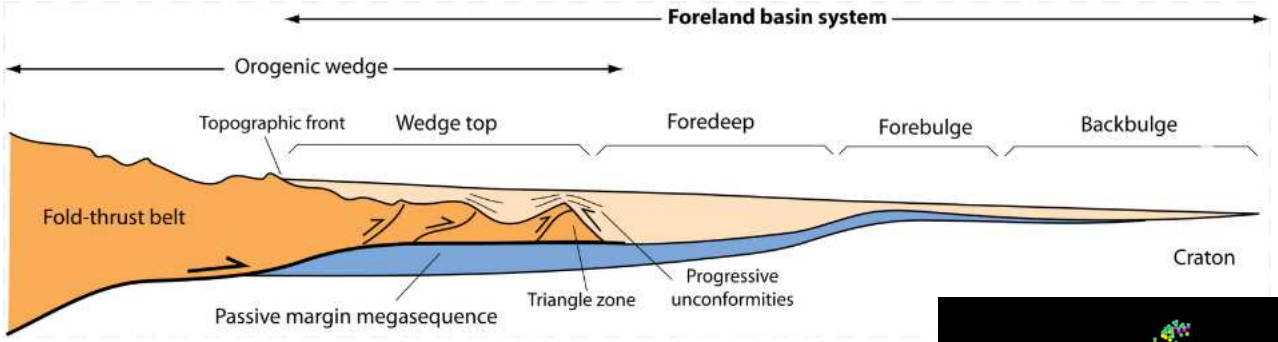
Collaborative Model Development
Développement de modèles en collaboration

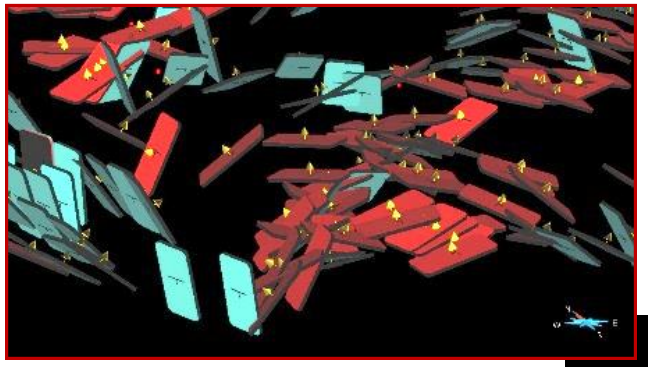
Canada

Various expertises and modelling methods

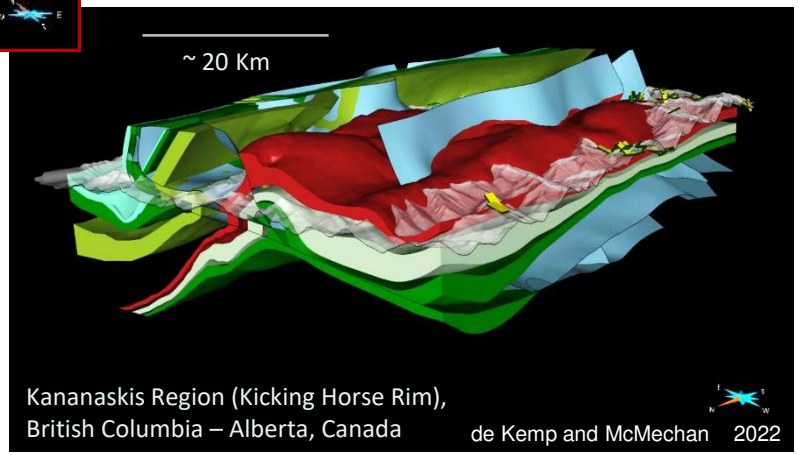


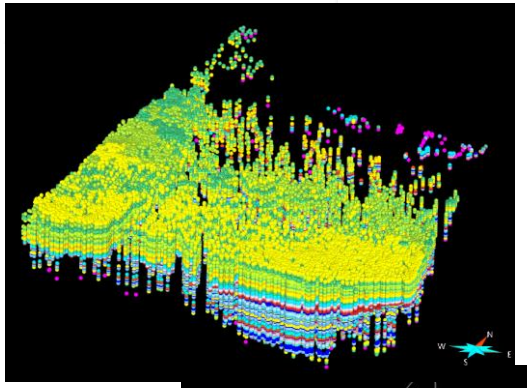


Saskatchewan sedimentary basin 3D model - Stratigraphic column

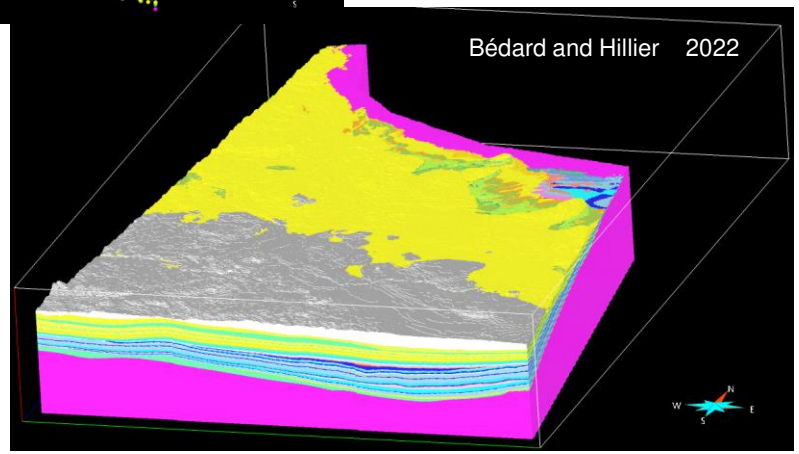


Kananaskis





Saskatchewan



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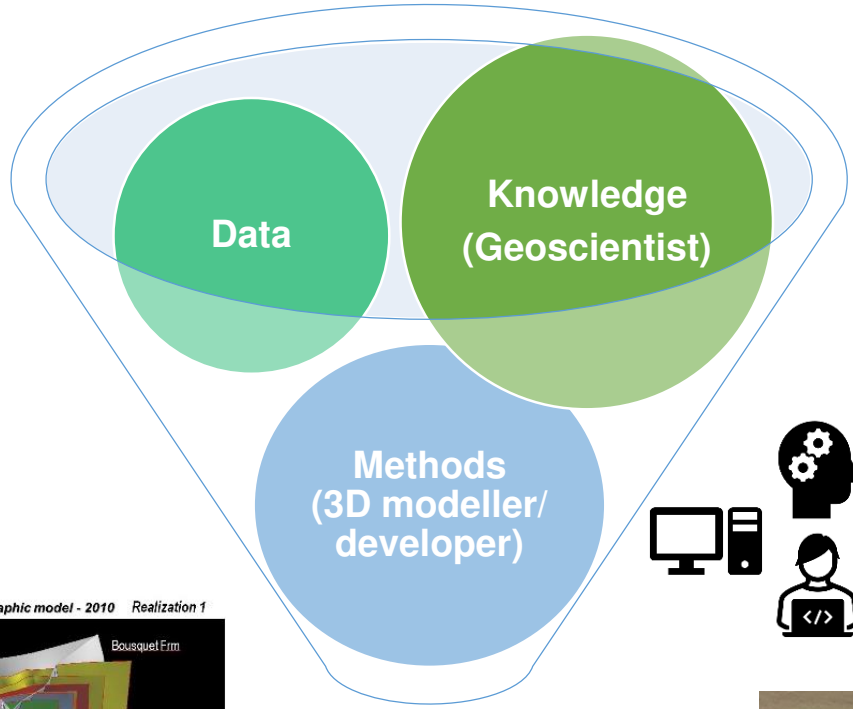
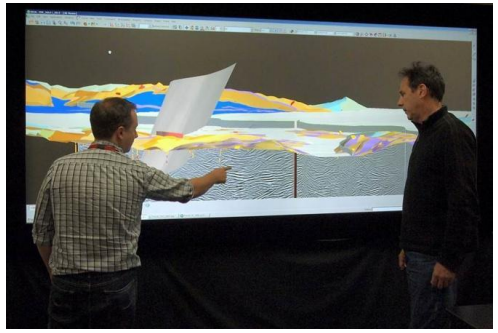
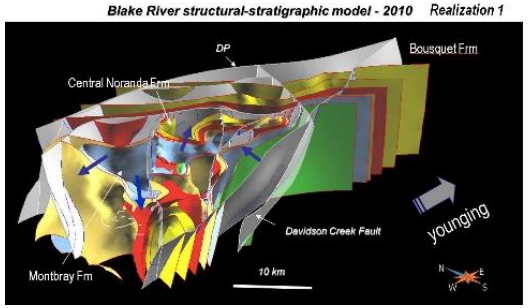
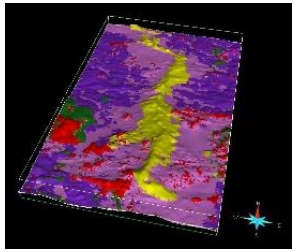
However… collaboration is essential !

- We all have data
- Geologists/geoscientists have the geological knowledge
- Modellers can translate that knowledge into 3D models

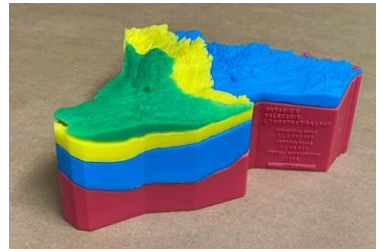


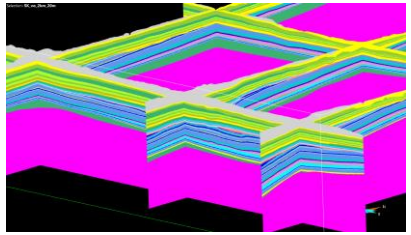






3D geological model





Examples of recent and future collaborations with GSC

Southern Ontario (2014-2019)

- Ontario Geological Survey
- Oil, Gas and Salt Resources Library
- Nuclear Waste Management Organization

Ontario

nwmo

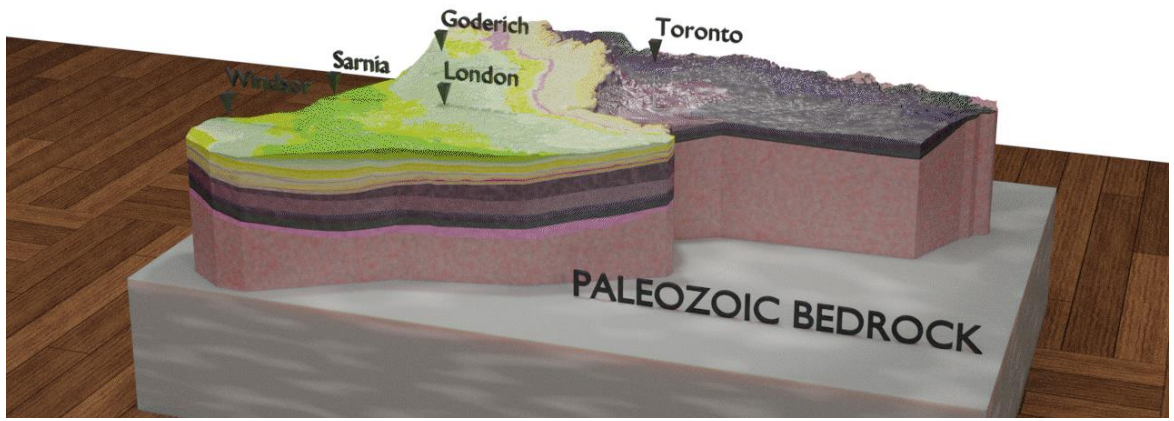
54 Layers Lithostratigraphic Model

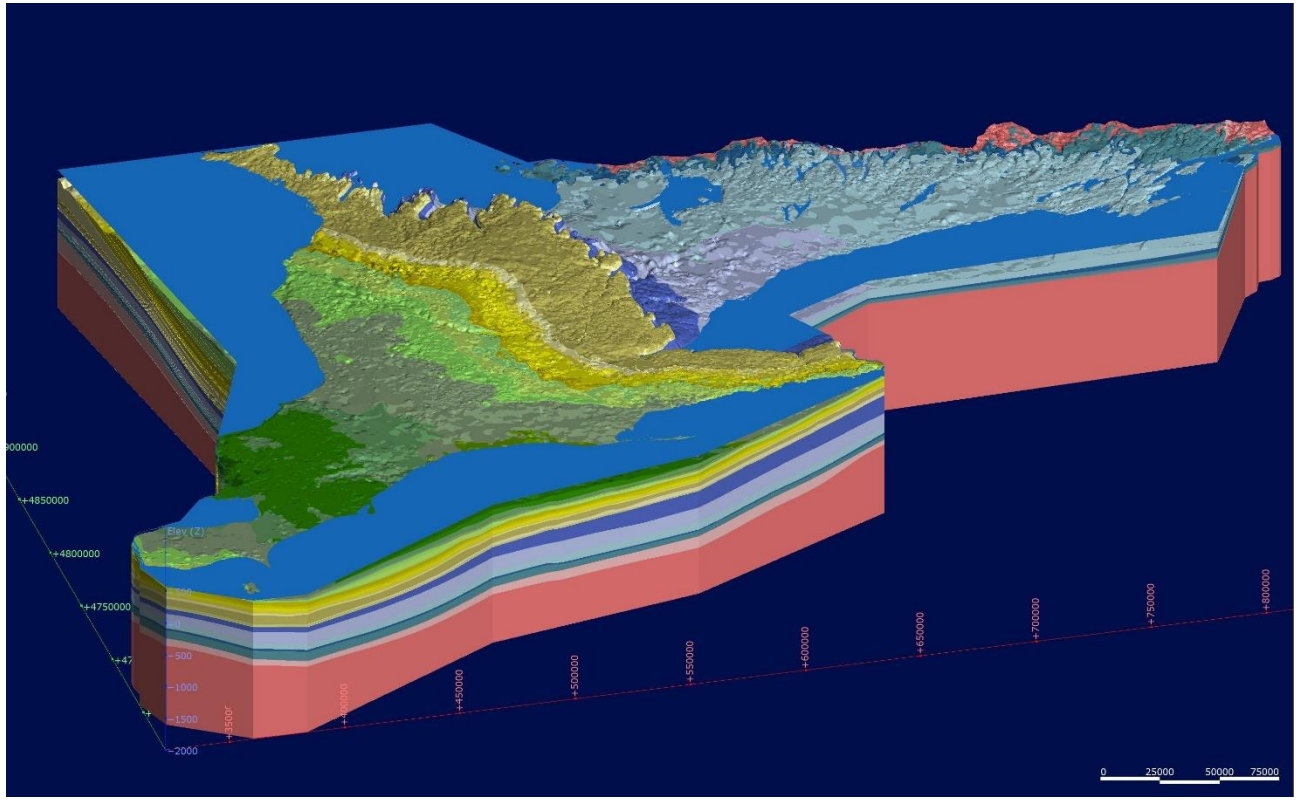
Unconformities, Faults, Pinnacle Reefs, Salt Solution

~27,000 wells → ~300,000 markers

leapfrog
FAST, DYNAMIC GEOLOGICAL MODELLING

OGSR Library





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Examples of recent and future collaborations with GSC

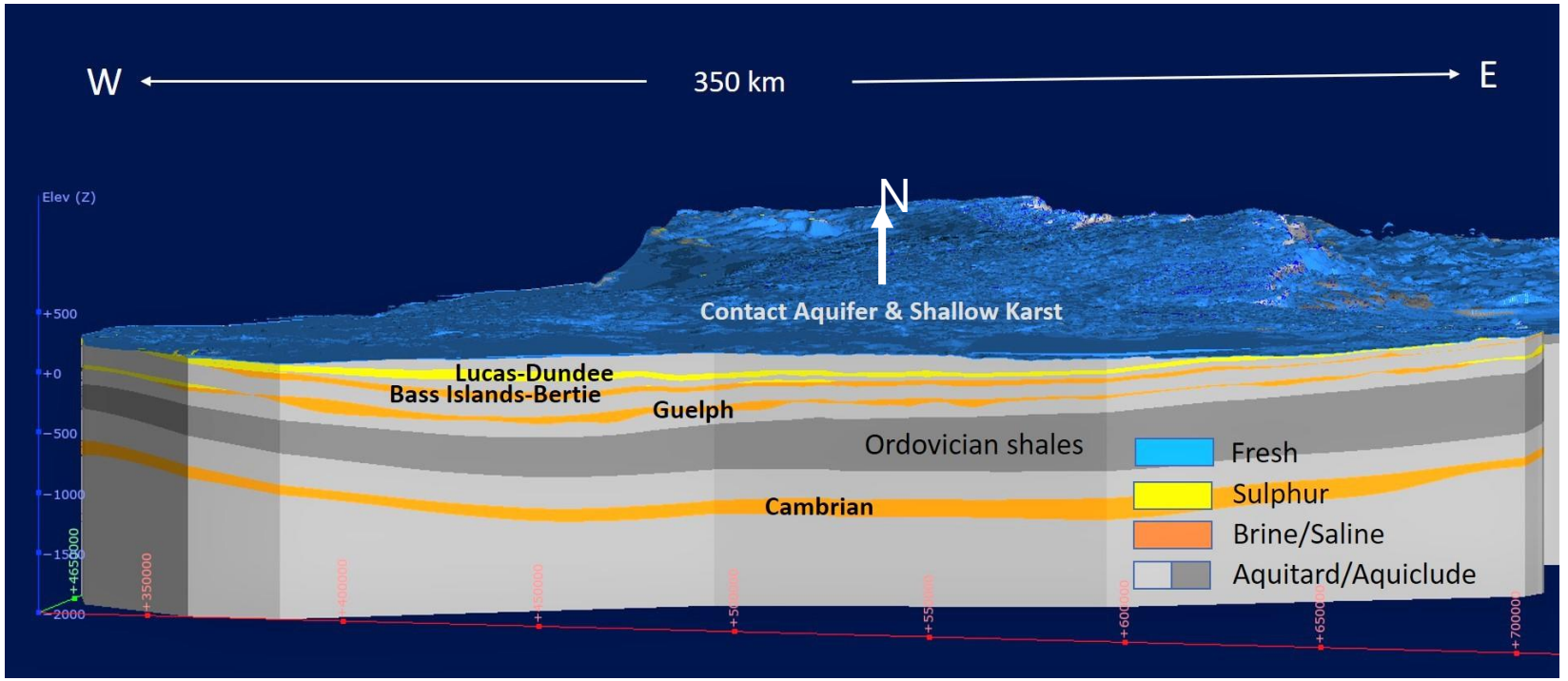
Southern Ontario (2014-2019)

- Ontario Geological Survey
- Oil, Gas and Salt Resources Library
- Nuclear Waste Management Organization

15 Layers Hydrostratigraphic Model

Aquifers and Aquitards, Contact aquifer and shallow karst, Hydrochemical zonation, Petroleum réservoirs, Static levels

leapfrog
FAST, DYNAMIC GEOLOGICAL MODELLING



Examples of recent and future collaborations with GSC

Southern Ontario (2014-2019)

- Ontario Geological Survey
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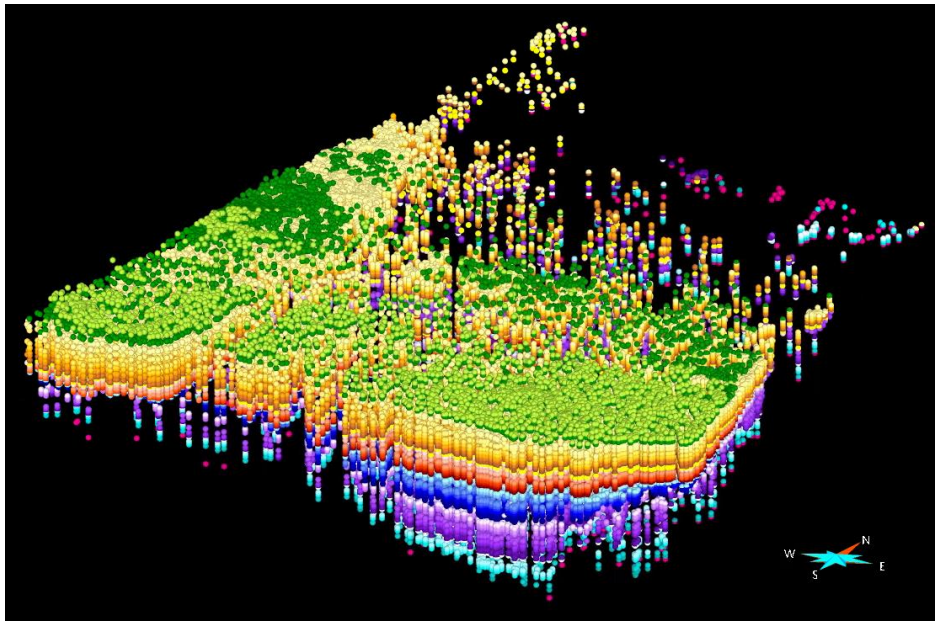
- Nuclear Waste Management Organization

Saskatchewan 3D model (2021-2022)

- Saskatchewan Geological Survey

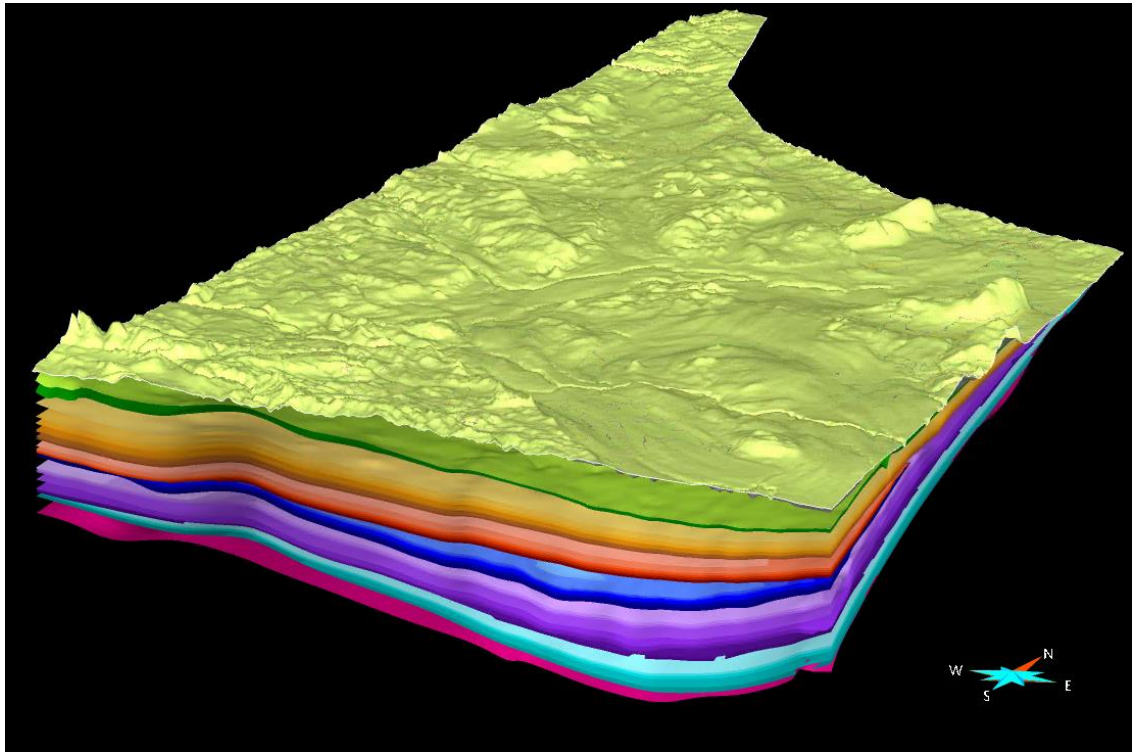


51 Layers Lithostratigraphic Model

~14,000 wells → ~167,000 markers

0 to 4353 m depth

SKUA-GOCAD™



Examples of recent and future collaborations with GSC

Southern Ontario (2014-2019)

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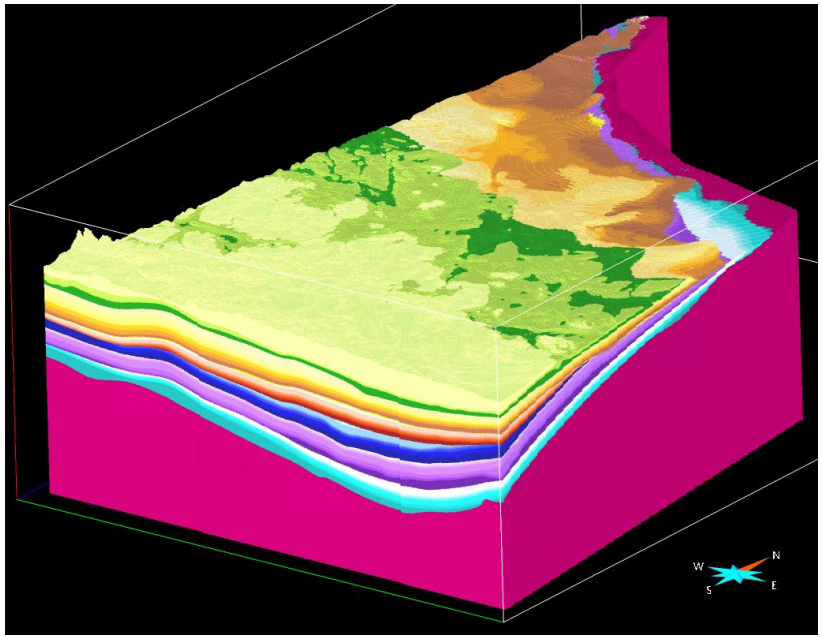
- Oil, Gas and Salt Resources Library
- Nuclear Waste Management Organization

Saskatchewan 3D model (2021-2022)

- Saskatchewan Geological Survey



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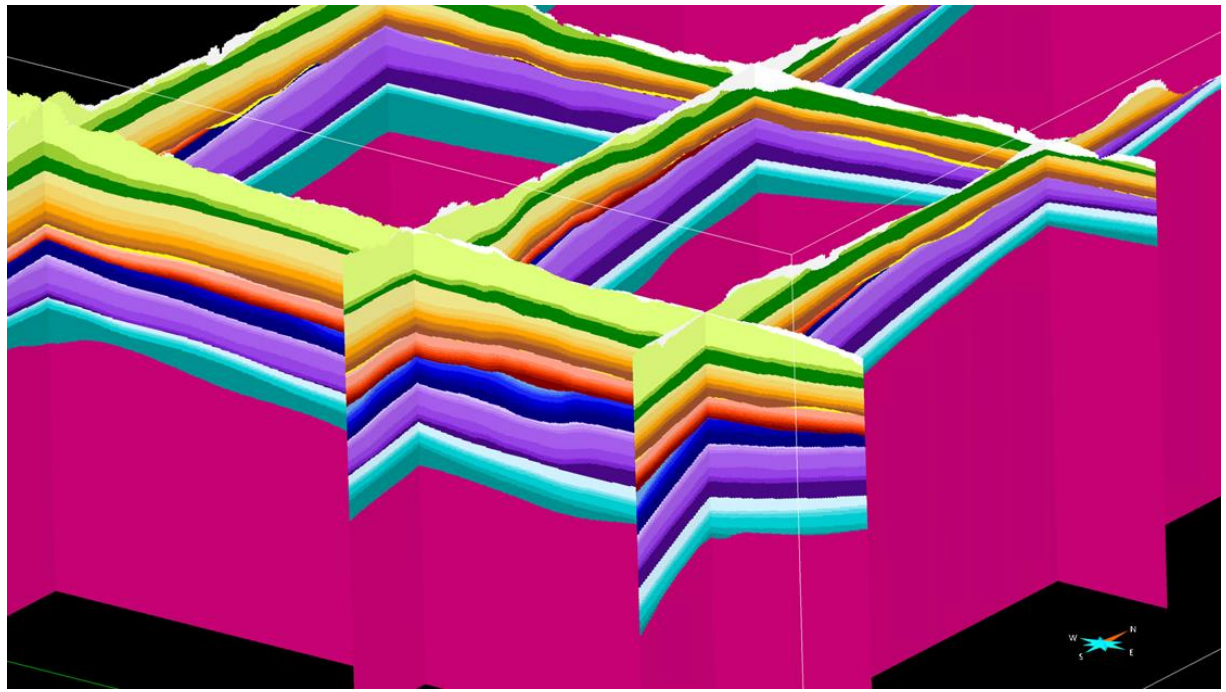
0 to 4353 m depth

SKUA-GOCAD™



Examples of recent and future collaborations with GSC

Southern Ontario (2014-2019)

- Ontario Geological Survey
- Oil, Gas and Salt Resources Library
- Nuclear Waste Management Organization

Saskatchewan 3D model (2021-2022)

- Saskatchewan Geological Survey

Manitoba 3D model (2022-….)

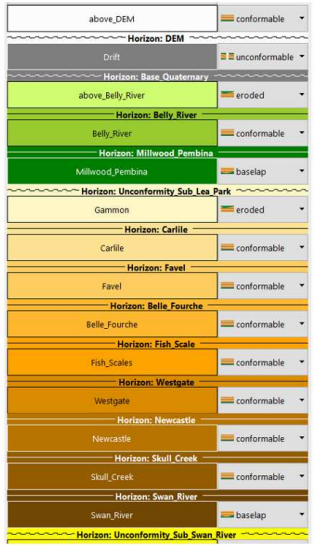
- Manitoba Geological Survey

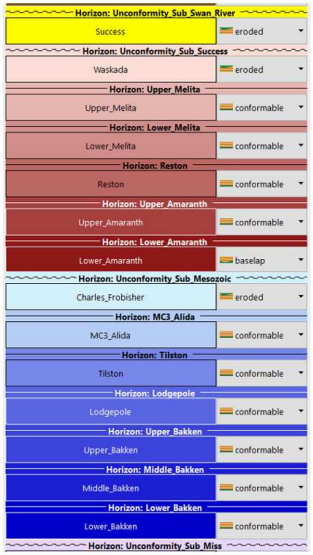
~44 units + 8 unconformities

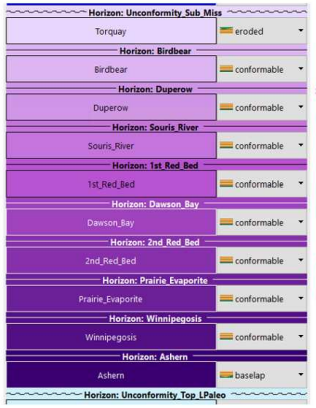
~2700 wells → ?? Markers

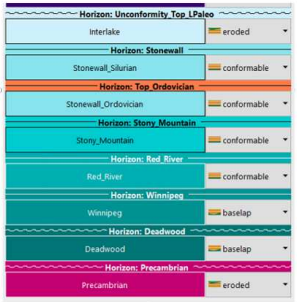
Cross-sections ?

0 to 2110 m depth









Examples of recent and future collaborations with GSC

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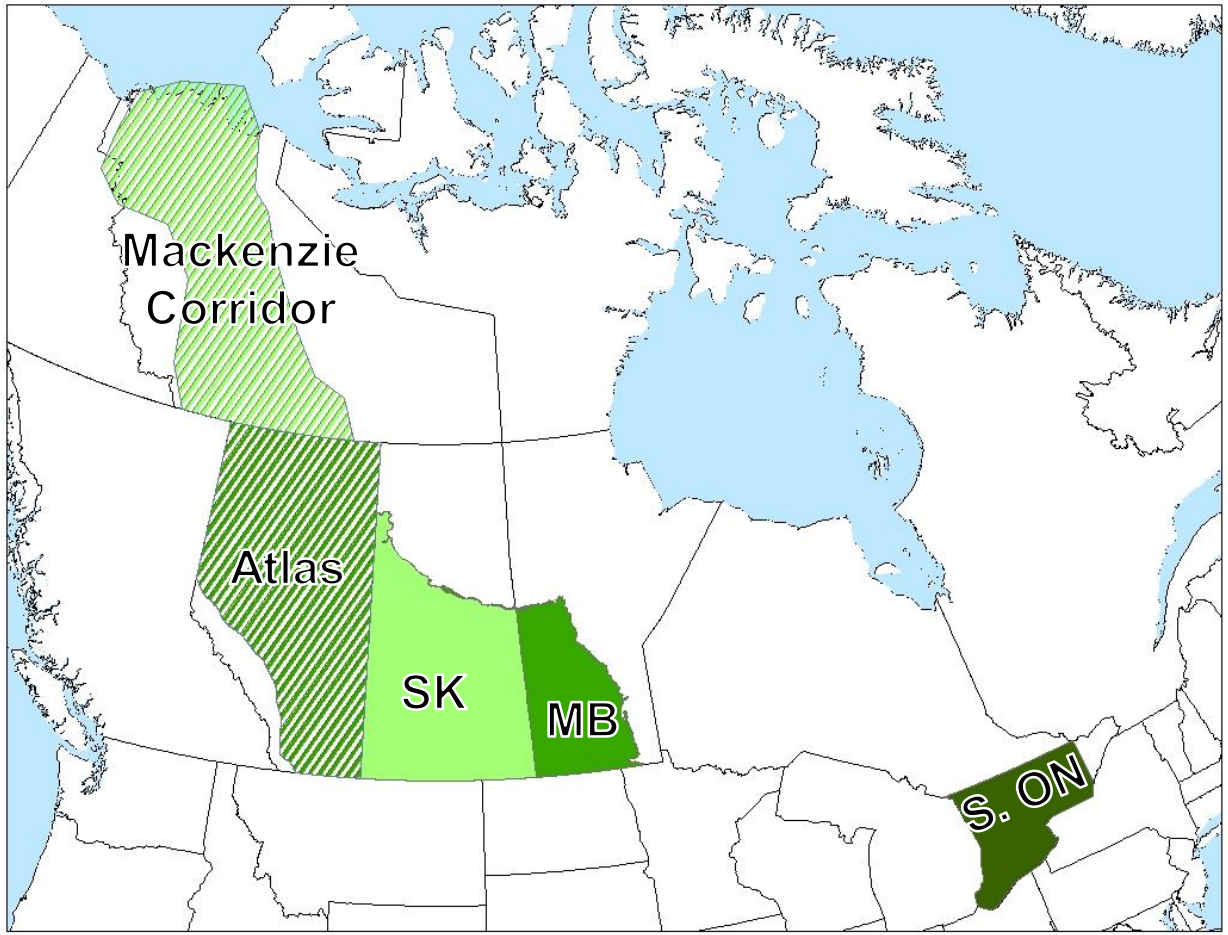
Manitoba 3D model (2022-….)

- Manitoba Geological Survey

Future collaboration with Atlas 2027

Atlas 2027

Future collaboration for Mackenzie Corridor - TBD



Ressources naturelles Canada
Natural Resources Canada

Data exchange and standards

Canada3D

Éric Boisvert and Boyan Brodaric, Geological Survey of Canada

June 6th, 2022, 6 juin 2022

Canada

Data exchange – *Échange de données*

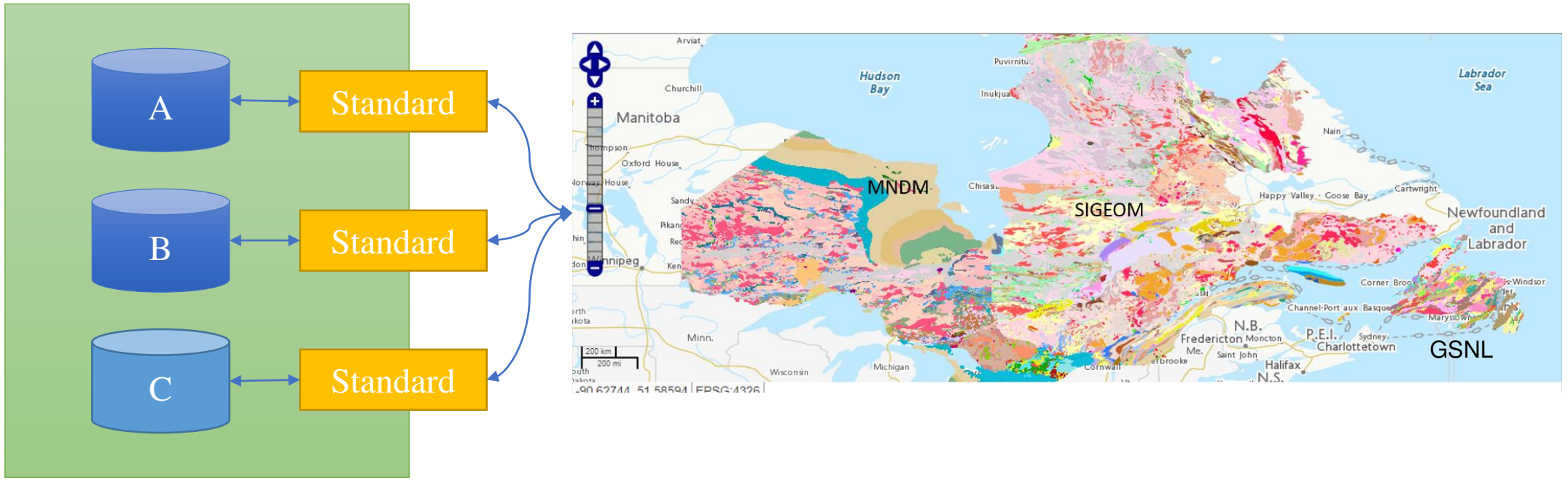
- Data exchange is surprisingly hard
  - A lot of work goes into finding, accessing, decode, interpret and use data
  - 3D model are built on top of basic geological data

- *L'échange de données est suprenamment difficile*
  - *Beaucoup de travail va dans la découverte, l'accès, le décodage, l'interpretation et l'utilisation des données*
  - *Les modèles 3D sont bâtis du des données géologiques de base*

Multiples sources of heterogeneities
Sources multiples d'hétérogénéités

- Geometries / *Géometries*
  - Models (vector/raster, voxets, surfaces, tetahedrons, TIN, Point clouds,etc)
  - Encoding (WKT, GeoJSON, GML, software specific)
- Dictionaries (terms, science languages)
  - Code list (the same term might mean different things in different contexts)
- Formats
  - GeoJON, CSV, SHP, GoCAD, etc.. (GDAL has 150 raster formats and 80 vector)
- Data Models
  - Ah Hoc, GeoSciML, CityGML, etc..
- Pragmatic

Goals of Spatial Data Infrastructure
Buts des Infrastructures de données spatiales

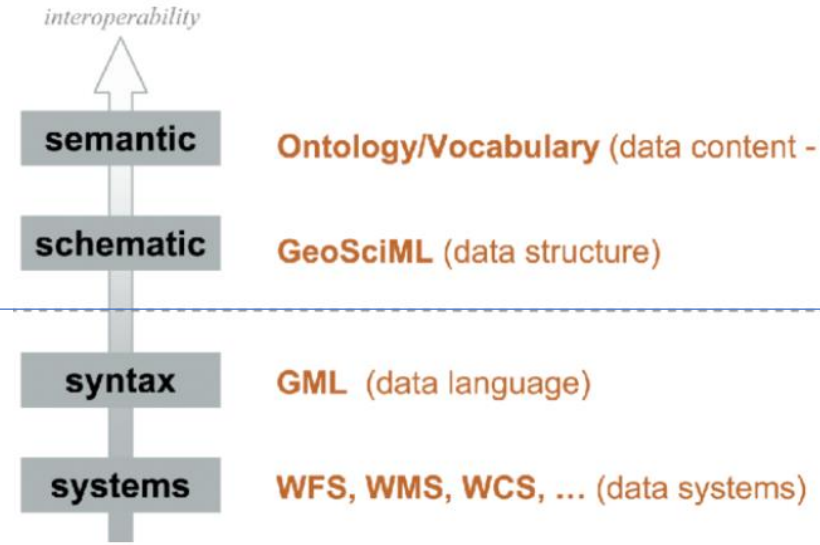


An SDI is a coordinated series of agreements **on technology standards**, institutional arrangements, and policies that enable the discovery and use of geospatial information by users and for purposes other than those it was created for (Kuhn, 2005)

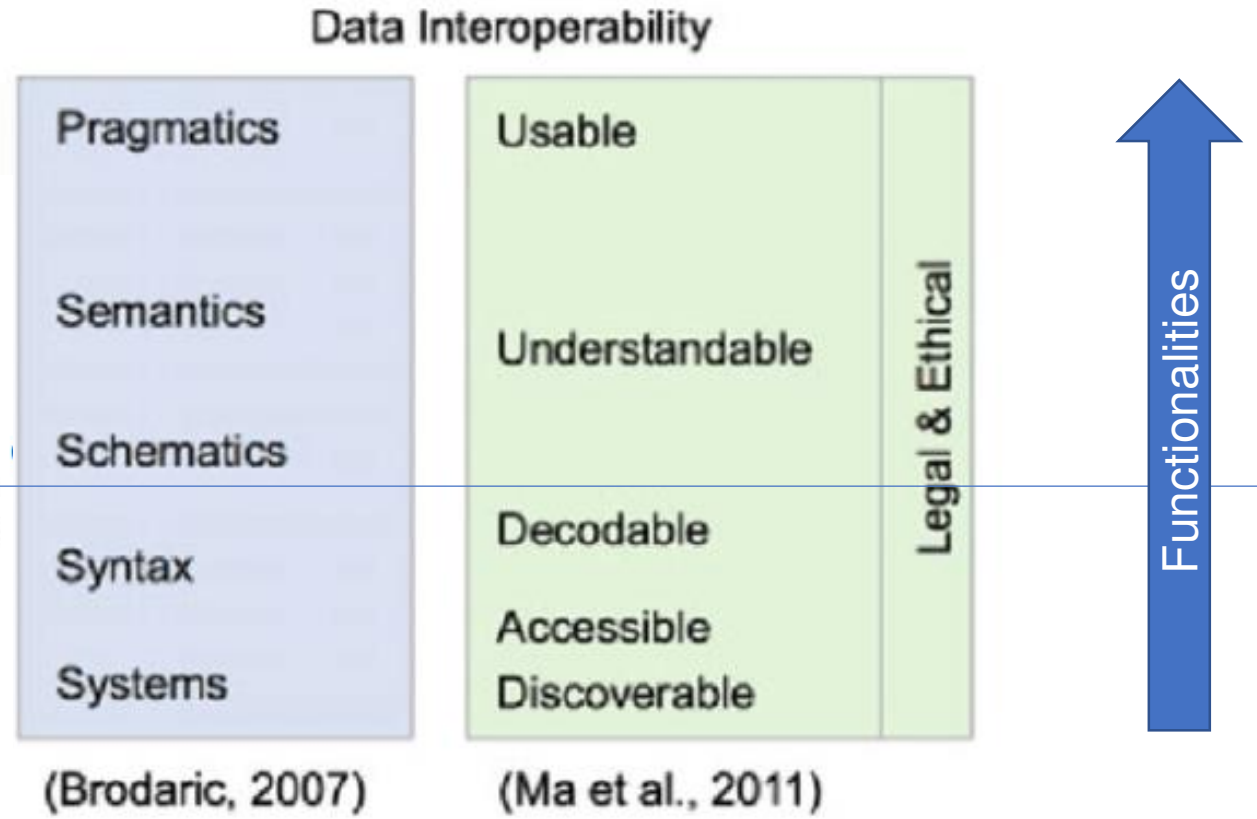
Une IDS est un ensemble coordonné d'ententes sur des standards technologiques, des arrangements institutionnels, et des politiques pour la découverte and l'utilisation de données spatiales par les usagers pour des applications autres que celles pour lesquelles elles ont été créées. (Kuhn, 2005)

Levels of interoperability
Niveaux d'intéropérabilité

Different standards for different purposes
Des standards différents pour des but différents



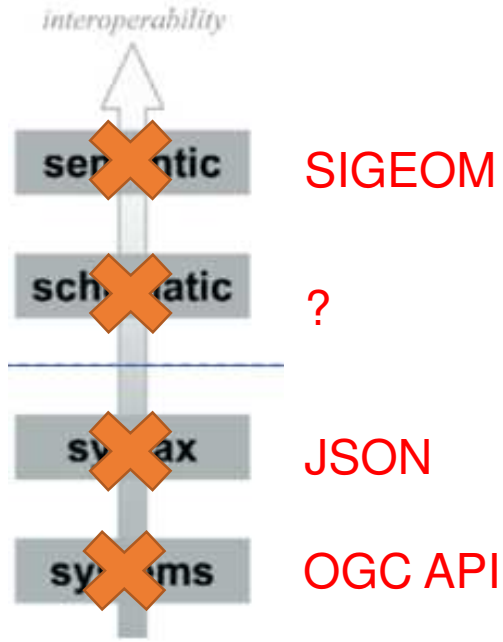
Multiple levels of interoperability (Brodaric and Gahegan, 2006).



Sample	X	Y	Zone	Material
98-ABC-00012	654839	52116541	18	Basalt
98-ABC-00013	624221	52355621	18	Granit

These two representations contains the same information

Ces deux représentations contiennent les même informations



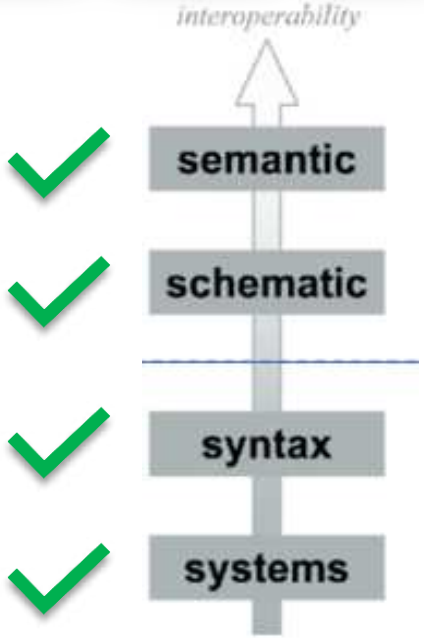

```
{
 "type": "FeatureCollection",
 "features": [
{
  "type": "Feature",
  "geometry": {
   "type": "Point",
   "coordinates": [-100.7579617,70.8962837]
  },
  "properties": {
   "nom": "98-ABC-00012",
   "lithologie": "V3B"
  }
},
{
  "type": "Feature",
  "geometry": {
   "type": "Point",
   "coordinates": [-101.9246038,68.7730817]
  },
  "properties": {
 "nom": "98-ABC-00012",
  "lithologie": "I3A"
  }
}]
}
```


Standards are agreements – *Les standards sont des ententes*

Existing systems that tackled those issues
Systèmes existants qui ont travaillé sur ces enjeux

- GIN / RIES (Groundwater Information Network, Réseau d'information sur les eaux souterraines)
- OneGeology
- AuScope
- USGIN,AusGIN
- EPOS (European Plate Observation System)
- Arctic SDI

NGSC PGS pilot – *Pilote SGP CNCG*

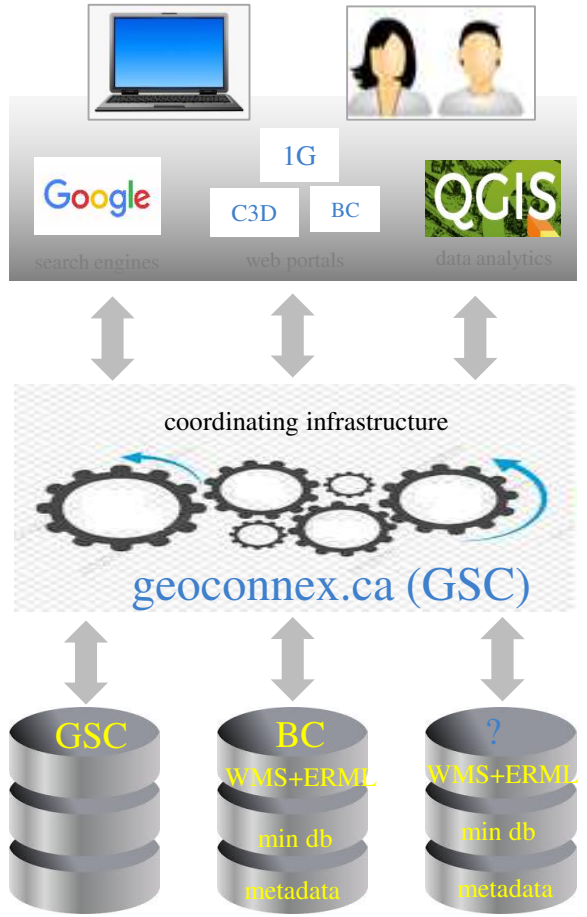


ERML vocabulary **(Standard)**

EarthResourceML **(Standard)**

GML XML **(Standard)**

OGC WFS 2.0 API **(Standard)**

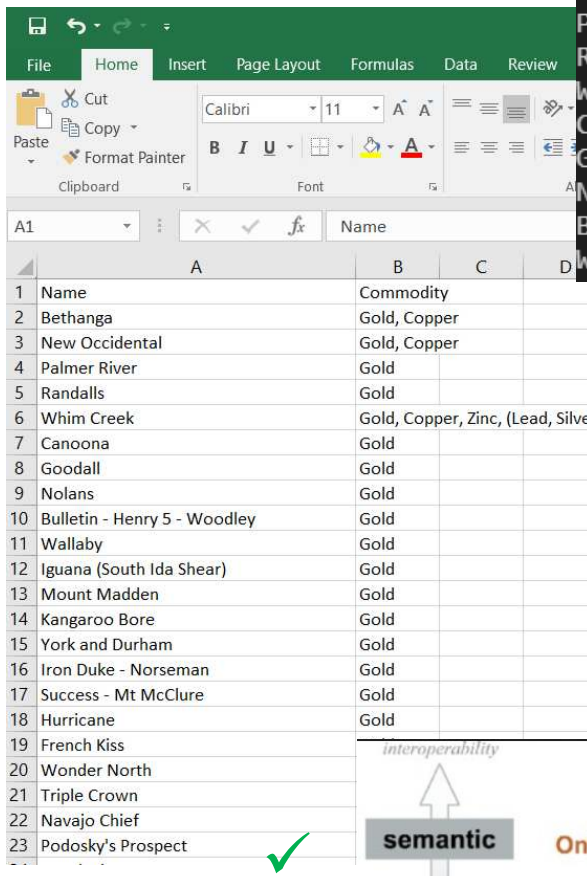


Recent initiative to implement SDI in Canada

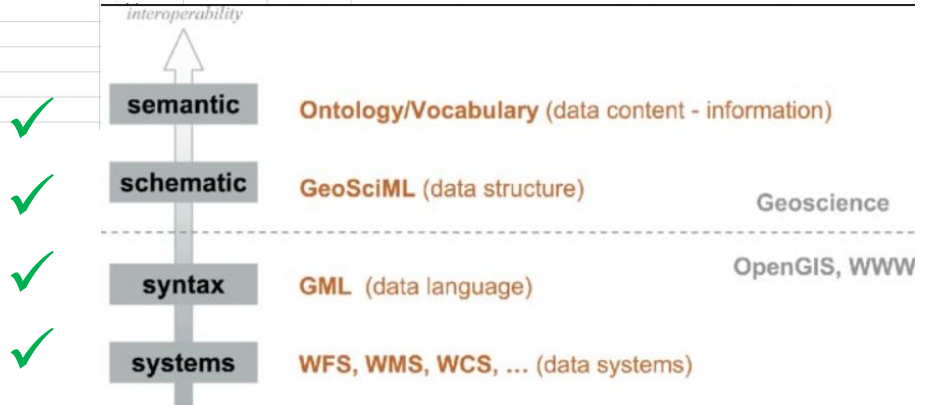
Exemple récent de mettre en place une IDS au Canada

```
Bethanga,Gold, Copper
New Occidental,Gold, Copper
Palmer River,Gold
Randalls,Gold
Whim Creek,Gold, Copper, Zinc, (Lead, Silver)
Canoona,Gold
Goodall,Gold
Nolans,Gold
Bulletin - Henry 5 - Woodley,Gold
Wallaby,Gold
```

```python
from owslib.wfs import WebFeatureService
import xml.etree.ElementTree as ET
from lxml import etree

erl='{http://xmlns.earthresourceml.org/earthresourceml-lite/1.0}'

print("Getting gold from Geoscience Australia")
wfs20 = WebFeatureService(url='http://services.ga.gov.au/earthresour

gold= """<fes:Filter  xmlns:fes="http://www.opengis.net/fes/2.0" xml
      <fes:PropertyIsEqualTo>
        <fes:ValueReference>erl:representativeCommodity_uri</fes:Val
        <fes:Literal>http://resource.geosciml.org/classifier/cgi/com
      </fes:PropertyIsEqualTo>
    </fes:Filter>
"""
# Get some mineral occurrences
response = wfs20.getfeature(typename='erl:MineralOccurrenceView',
    maxfeatures=10,
    method="{http://www.opengis.net/wfs}Post",
    filter=etree.fromstring(gold))

featureCollection = ET.fromstring(response.read().decode('utf-8'))
for member in featureCollection:
    name = member[0].find(erl+'name')
    commodity=member[0].find(erl+'commodity')
    print(name.text + ',' + commodity.text)
```



	A	B	C	D
1	Name	Commodity		
2	Bethanga	Gold, Copper		
3	New Occidental	Gold, Copper		
4	Palmer River	Gold		
5	Randalls	Gold		
6	Whim Creek	Gold, Copper, Zinc, (Lead, Silver)		
7	Canoona	Gold		
8	Goodall	Gold		
9	Nolans	Gold		
10	Bulletin - Henry 5 - Woodley	Gold		
11	Wallaby	Gold		
12	Iguana (South Ida Shear)	Gold		
13	Mount Madden	Gold		
14	Kangaroo Bore	Gold		
15	York and Durham	Gold		
16	Iron Duke - Norseman	Gold		
17	Success - Mt McClure	Gold		
18	Hurricane	Gold		
19	French Kiss			
20	Wonder North			
21	Triple Crown			
22	Navajo Chief			
23	Podosky's Prospect			



Pros and Cons

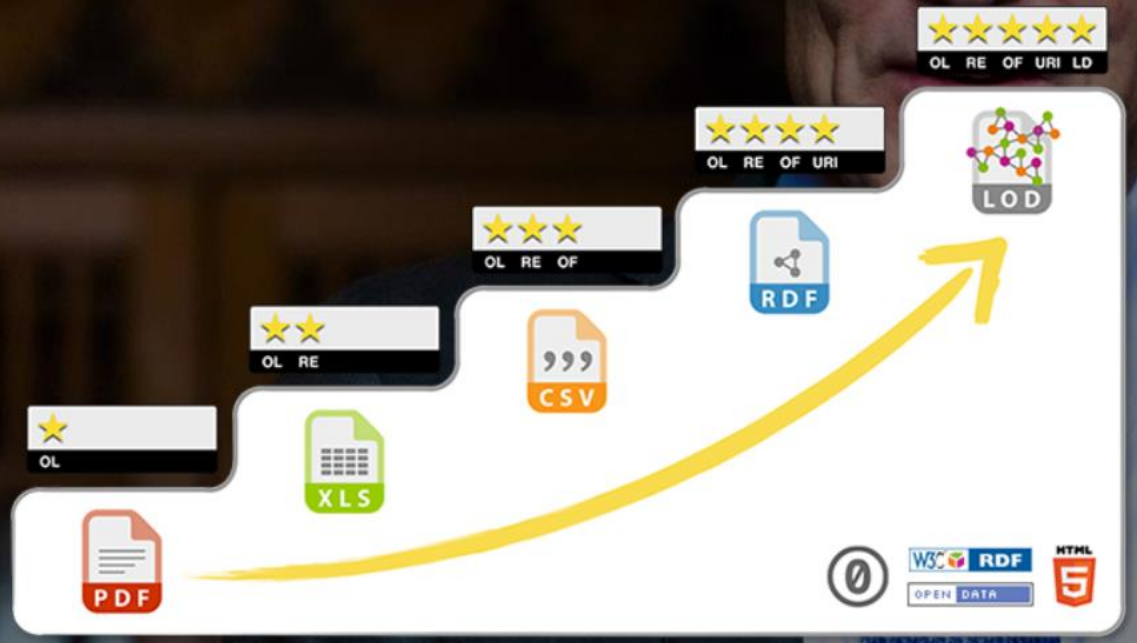
- Data managed at the source
  - « single point on truth »
- Tasks can be automated
- New kinds of analysis, applications can be done
- Distributed systems and governance are harder to maintain
- The more layers of interoperability you achieve, the trickier it gets
  - « Highler levels » are harder to implement
  - Better allow « progressive compliance »
- Once the system is running, it’s like fixing a plane while flying it
- There is no silver bullet

5 ★ OPEN DATA BY EXAMPLE COSTS & BENEFITS SEE ALSO

5 ★ OPEN DATA

Tim Berners-Lee, the inventor of the Web and Linked Data initiator, suggested a 5-star deployment scheme for Open Data. Here, we give examples for each step of the stars and explain costs and benefits that come along with it.

Merci !



Ressources naturelles Canada
Natural Resources Canada

Canada

Natural Resources Canada | Ressources naturelles Canada

Method Development: 3D Structural Geological Modelling

Michael J. Hillier[1], Florian Wellmann[2], Boyan Brodaric[1], Eric A. de Kemp[1], Ernst M. Schetselaar[1] ,

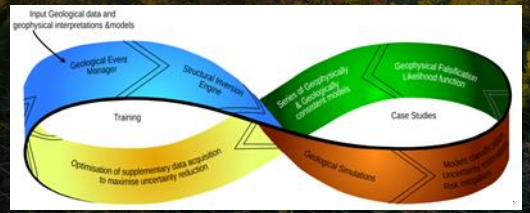
Karine Bédard[3] , Hazen A.J. Russell[1]

Geological Survey of Canada (Ottawa[1], Québec City[3])

Computational Geoscience and Reservoir Engineering (CGRE) RWTH Aachen University[2]

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

AICES Aachen Institute for Advanced Study in Computational Engineering Science | RWTH AACHEN UNIVERSITY

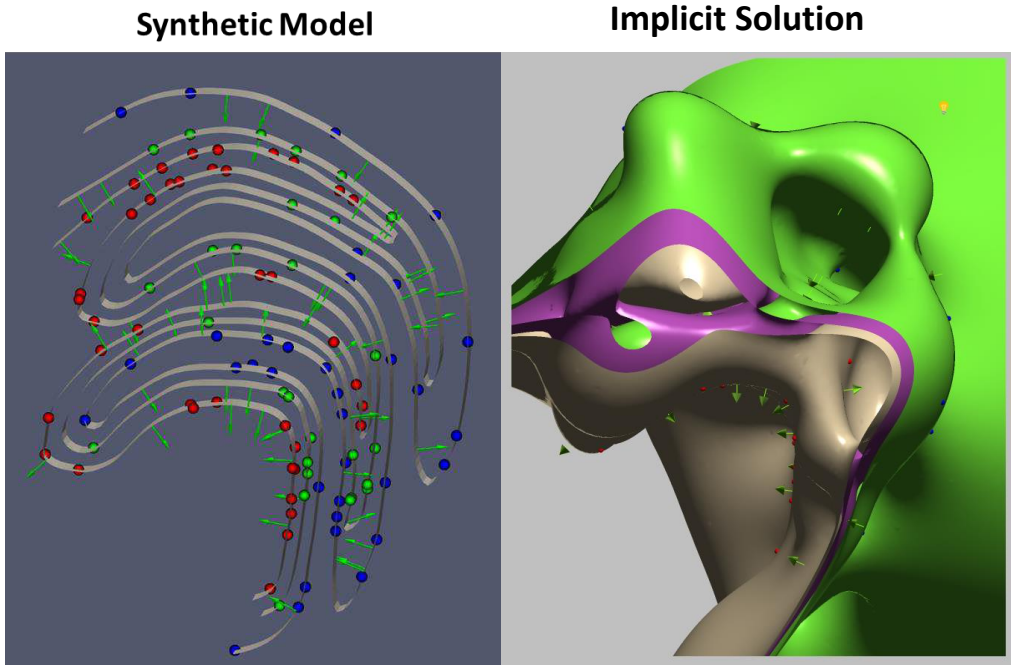


Canada

Method Development for 3D Structural Geological Modelling

- Limitations of existing methodologies
  - Challenges in producing geological reasonable models in complex settings
  - Can not utilize all the available geological knowledge in the modelling process
  - Do not scale well with big data; updatable models and uncertainty analysis difficult
  - Multivariate remains challenging (geophysics – geology – geochemistry)

Complex settings

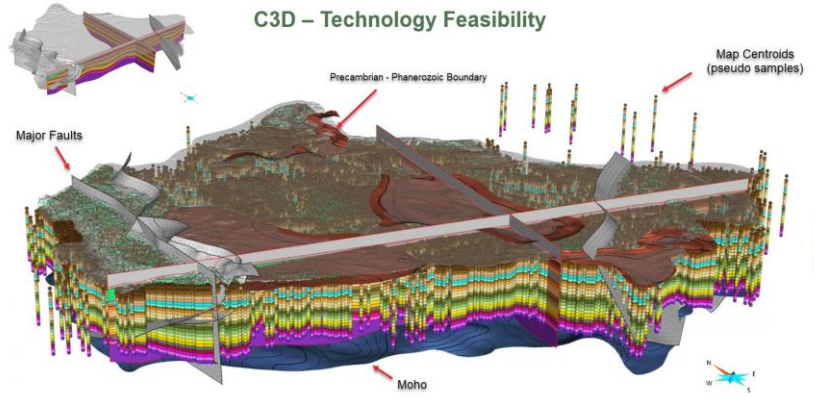


Apriori Knowledge

- Thickness constraints
- Zero edges
- Geological Ontology
- Spatial relations

Big Data

- National Scale Volumetric Models
- WCSB (> 7M formation tops) Atlas 2027



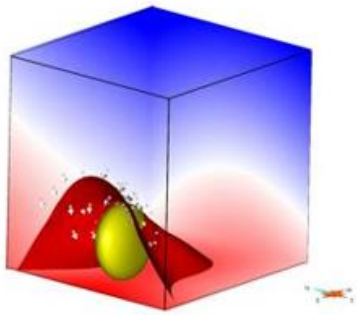
Simulation Capacity Test Model

Atlas 2027

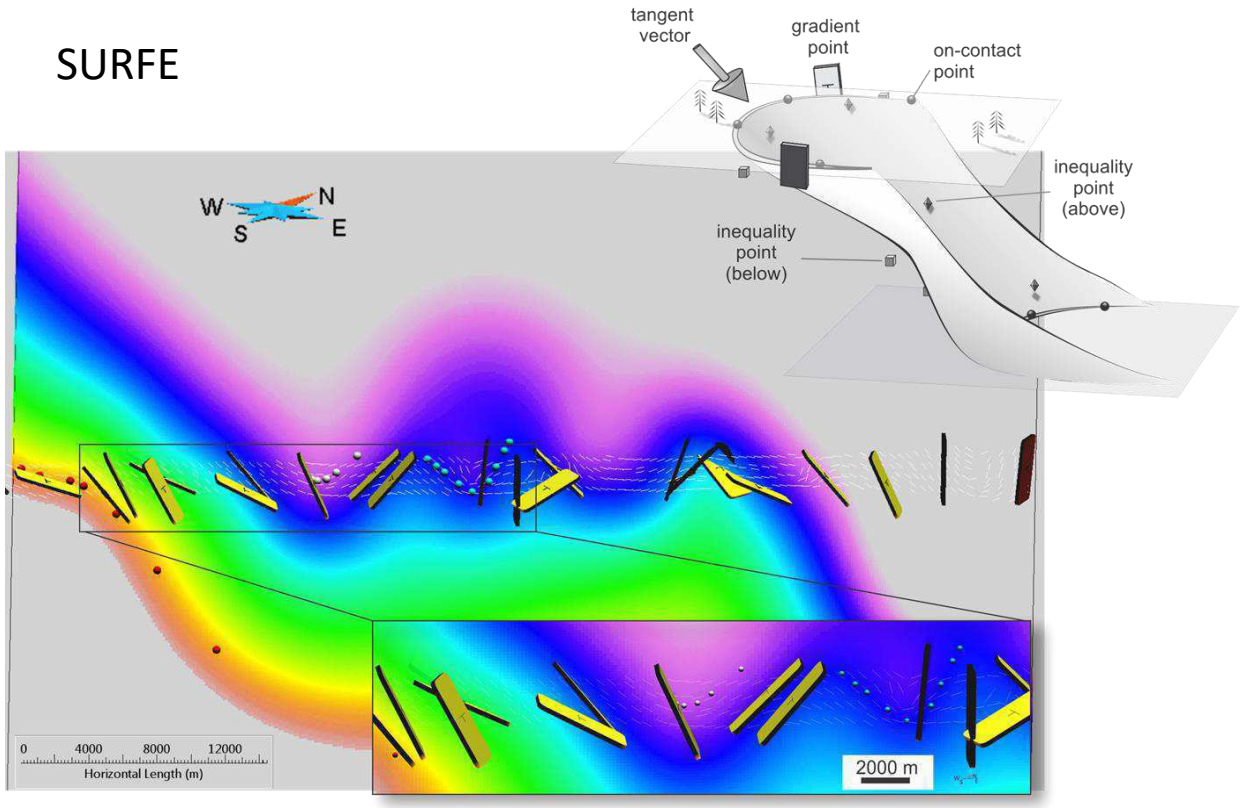
https://atlas2027.ca/

Method Development for 3D Structural Geological Modelling

- Developed new mathematical constraints to include rock unit observations and structural anisotropy derived from field observations (SURFE)
- Developing agent-based approach (AI) using geological rules to build 3D models

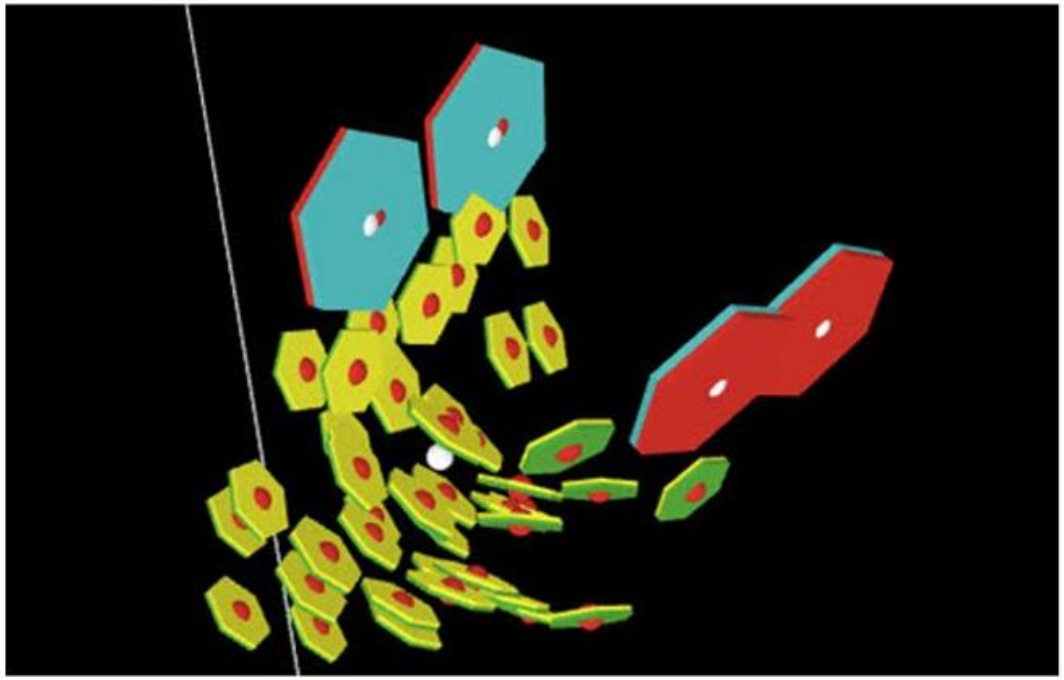


SURFE



Hillier MJ, Schetselaar EM, de Kemp EA, Perron G (2014) Three-dimensional modelling of geological
surfaces using generalized interpolation with radial basis functions. Math Geosci 46(8):931–953

STRUCTURAL AGENTS

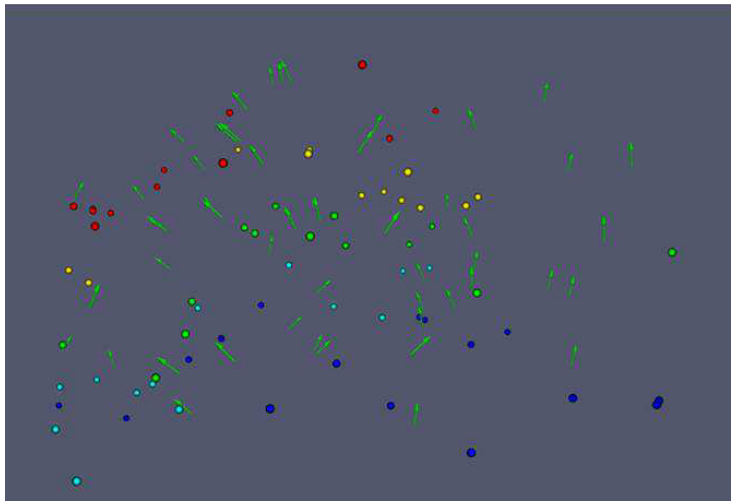


de Kemp, E. A.,(2021), Spatial agents for geological surface modelling, *Geosci. Model Dev.*, **14**, 6661–6680, https://doi.org/10.5194/gmd-14-6661-2021, **(Open Access)**.

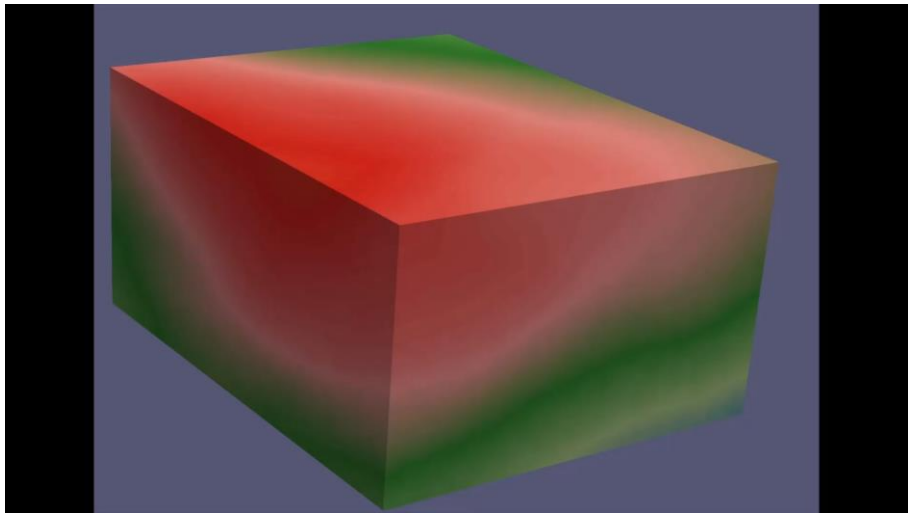
Method Development for 3D Structural Geological Modelling

- New method uses a deep learning approach to parameterize implicit functions that model 3D geological structures from point data.
- Based off a learning by training paradigm
  - Iterative scheme where modelling errors are computed at every iteration and minimized.

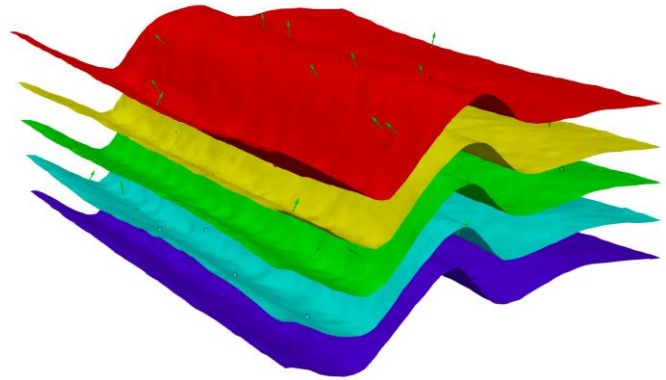
Training data



Model Evolution



Extracted Modelled Horizons

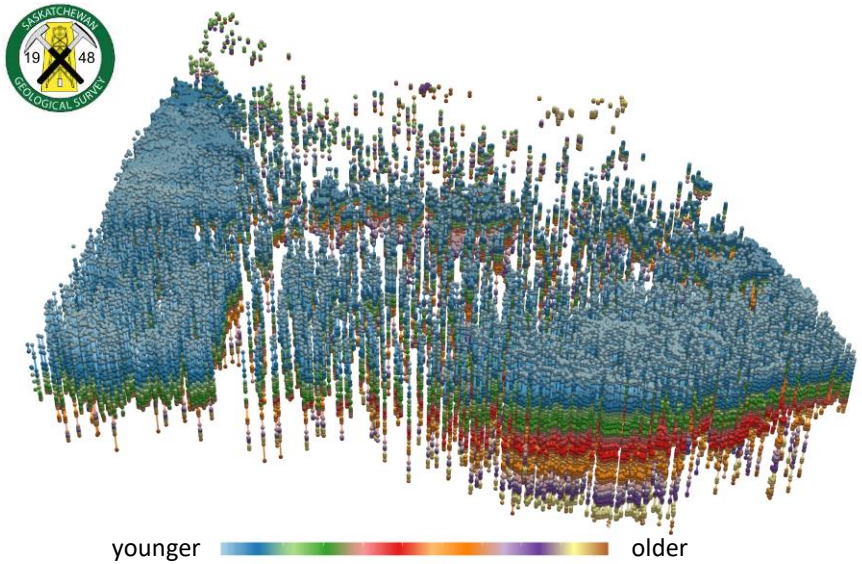


Hillier, M., Wellmann, F., Brodaric, B., de Kemp, E., Schetselaar, E., (2021), Three-Dimensional Structural Geological Modeling Using Graph Neural Networks, *Math Geosci* , **53**, 1725–1749. https://doi.org/10.1007/s11004-021-09945-x, **(Open Access)**.

Method Development for 3D Structural Geological Modelling

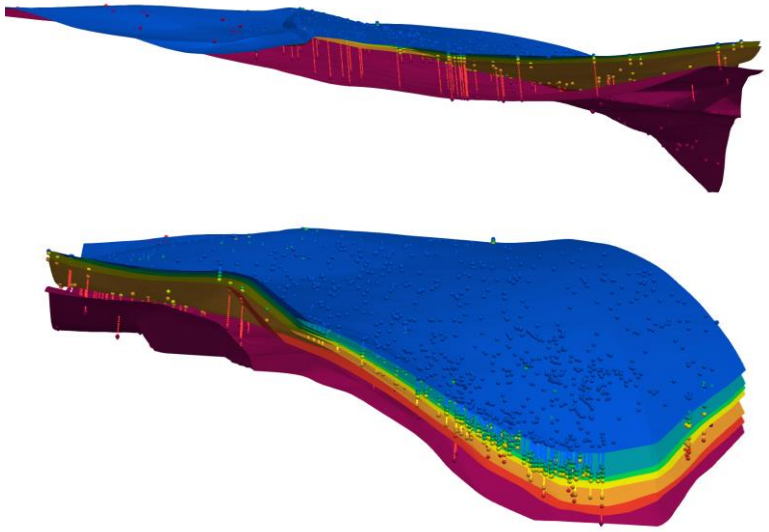
- Developing new approach using emerging deep learning methods
  - Considerable flexibility on types of geological constraints included in the modelling process
  - Scalable for massive datasets leveraging cloud computing infrastructure
  - Suitable foundation for incorporating relational-based knowledge constraints using graph data structures.

WCSB dataset in Saskatchewan



Massive datasets and efficient modelling

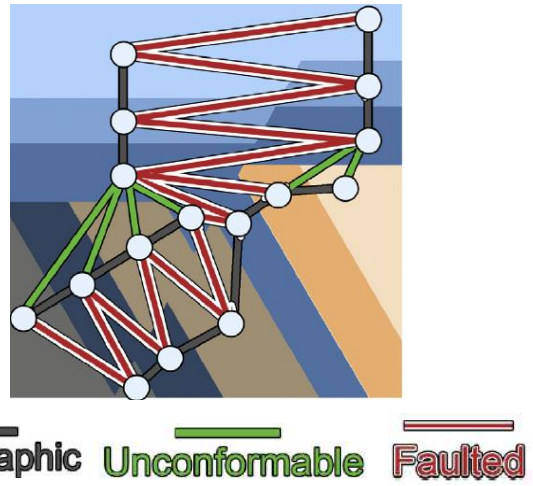
- 513, 211 total point constraints
- 2 minutes to build model
- Support national scale modelling initiatives



Incorporation of unconformities and intraformational observations

Manuscript in prep.

Thiele et al. 2016



Future framework for graph-based geological knowledge constraints

Discussion

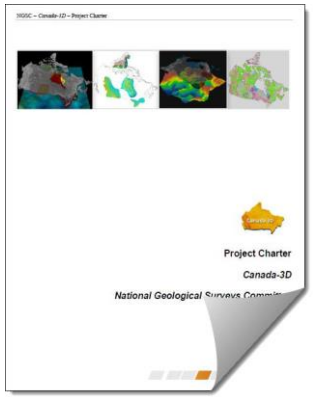
C3D Governance

C3D Vision statement

C3D is an NGSC project with a steering committee (Geneviève Marquis as chair).

Has a Charter (see https://canada3d.geosciences.ca/).

C3D-NGSC Charter 2020



C3D Transformation

GSC Internal updates (CMGD, Open Geoscience)

C3D – Vision

“The Canada-3D project is a national collaboration involving the provincial and territorial geological surveys and the Geological Survey of Canada (GSC), operating under the auspices of the National Geological Surveys Committee (NGSC).”

Main Goal:

To develop the next-generation representation of the geology of Canada (previous compilation ~ 25 years old) .

Outputs:

National 3D geological model for the geology of Canada
National-scale 2D geology maps for Canada (aka a new "Geological Map of Canada").

Expected beneficiaries:

International and national Users of geoscience information and knowledge, including industry, other federal and provincial government departments, educational institutions, NGOs and the general public.

C3D Transformation

- Realignment and reprioritization at GSC following Critical Minerals Funding (CMGD).
- Primary Mission of Critical Minerals – "*The goal is to accelerate access to top 14 critical minerals, for the production of batteries and magnets that are much needed for the transition to a low carbon economy and to fight climate change*."
- Transformation of our 3D spatial infrastructure (Open Geoscience).
- C3D will contribute to 3D National Geological framework for mineral systems.
- Develop linkages to other program activities (GSC & PT) to support 3D modelling activities.

  i.e. ATLAS 2027 (NGSC coordination of surveys and C3D P&T collaboration), SASK and Manitoba 3D models, Alberta Foothills and Rocky Mountains.

Atlas 2027

Comments from Participants:

Kelsey MacCormack, Ph.D. – *Director Geology and Resources, Geological Survey of Alberta / Alberta Energy Regulator*

I think it's a really critical time, for C3D. There have been a lot of initiatives under way, I think the various presentations today from provinces and territories, highlight the fact that momentum is gaining in this space. Lots of support is still required, but when you look at it from an applications perspective, the range of applications is still quite diverse. 3D models, the utility of them I think, is growing exponentially. Decision makers are requesting information in 3D space as well in terms of supporting exploration and development, and the sustainability of our resources. It's almost becoming a necessity to move from that 2D to 3D space. Just to focus on our resources, from a resources perspective. Our natural resources are in fact 3D and require a 3D approach, we need to understand them in 3D. I think more and more often, we are having to think and rationalize cross-jurisdictional resource characterization and decision support, and I really feel from a geological survey perspective its critical for us to be developing our geology and our resources in 3D, but also having that support to connect that information across, jurisdictionally. There are some great projects and great applications that are highlighted, obviously we are excited about Atlas 2027, but we also recognize that it is going to be a huge amount of work. So, myself I think, that the time is really coming and critical for many jurisdictions to have support and learn from each other, leverage that communication, integrate into what we've done, what we're doing, what's worked, and what doesn't work or hasn't. Michael (Hillier) great slides, and great presentation on methods, which we can all really benefit from your work, and having that kind of support right now.

Geneviève Marquis, Ph.D. – *Director Central Canada Division, Geological Survey of Canada*

Thank you for all those very nice presentations today. But they were not all equal in terms of accomplishment in Canada 3D, so I noticed that in some jurisdictions, it became really a side project. In other jurisdictions it became central to the data management. So, Canada in 3D is not being deployed equally, Canada in 3D is not even a program right, it's a project. So, we have to figure out just as you mentioned (EdK) what is going to be the future of Canada 3D. To make sure there is a making sense, that there is a real contribution, to some key geoscience questions. Namely for instance de-risking mineral exploration as an example but could be other geoscience questions but right now the big focus in geosciences is about critical minerals. So, this is a really important crossroad. I don't know what will happen with Canada 3D, what will happen with the charter, maybe it would be a good opportunity to clean up the charter making sure that it's still up to date, and now what will happen next for Canada 3D. I don't have the answer for what will happen next, but I am certainly interested to listen to you about that.

Sean Bosman, M.Sc. **-** *Geologist – Saskatchewan Geological Survey*

I have been part of this for a while now and what I have seen from Canada 3D and the collaboration with the GSC, I have worked with Kelsey and less so with Manitoba, but I am excited to work with them as well. It's a really neat project to work with and I am looking forward to it continuing. I would be disappointed to see it not continue, would be my comment there. I am just going to leave it at that, it would be a real shame if Canada 3D wasn't continuing on that charter. It may need to be revamped a little bit but, yes on ward and forward! Let's create a national 3D model.

Hazen Russell, Ph.D., *– Research Scientist Geological Survey of Canada*

There were a lot of really good presentations here today, and some really interesting developments from provinces and maybe we should just encourage people to just pose some questions even if they are a bit more technical. So, for the BC presentation I was interested in the geophysical approach and collaboration with BCGS and UBC to give us geoscience insight. I would be interested to hear about that.

Yao Cui, M.Sc. P.Geo *– Sr. Geomatics Geoscientist British Columbia Geological Survey*

So, that project was a collaboration between BCGS and Geoscience BC, which is a funding agency in BC, and UBC's Mineral Deposit Research Unit (MDRU). The leading scientist is Dianne Mitchinson at MDRU. This project is pretty well done right now (using MUON particles to delineate large ore bodies), but something similar is going on leading to identifying some carbon capturing material, with Greg Dipple (UBC), many things are happening and it's a big topic that we are following. I am happy to give more information to those interested.

Eric de Kemp, Ph.D. *- Research Scientist Geological Survey of Canada*

Question for Mike Easton of OGS, I am wondering if the work at Laurentian with Metal Earth and OGS will result in a synthesis, and if 3D modelling at a big regional scale may be part of, or one of the things they are trying to aim at, and a third point is whether C3D could play a role in that?

Mike Easton, Ph.D. *- Senior Geoscientist in the Earth Resources and Geoscience Mapping Section, Ontario Geological Survey*

They have something called Metal Earth Hub where a lot of their material is available from some of the stuff they have collected. They are in different stages along various transects, so some transects they've well completed and done the interpretation, and other transects they're still working on them. For instance, western Wabigoon is largely completed but they're still working on the modelling for Sudbury. So far everything is working on the individual transect basis. They were looking for a 2 year 'data modelling, interpretation, extension to the project. The project is supposed to end in 2024. But they are looking at not getting any extra (data acquisition) money but continuing to 2026 to do more modelling and interpretation. But of course, the big problem with Laurentian these days, has ben that they have been in bankruptcy protection for 1 ½ years now, that's going to continue until September 2022, and so that's really hindered them in terms of getting some things done and retaining people. Again Dave Snyder's tunned into that group and will be able to help determine what can and can't be

done. OGS is sort of on the periphery, monitoring what they are doing. They are using our aerial magnetic data for instance in modelling of their transects, they're looking at all the geophysical data sets. The only thing they collected new was the MT and the gravity data, but there are some MT transects where they don't have seismic data, for instance in the Red Lake area.

Sean Bosman, M.Sc. **-** *Geologist – Saskatchewan Geological Survey*

The other Eric (Éric Boisvert) is gone but I didn't fully understand his presentation with the different levels (of interoperability) and the different programing languages, is there something that can be sent to the different jurisdictions, that might help guide what the various jurisdictions do in the future. I am just thinking we have a big data management project coming up. Is that something to think about, as we're developing these new data bases and new warehouses. I'm not the guy to deal with that but I am wondering if there is information from the GSC that can assist with that.

Sara Jenkins, M.Sc., - *Terrain Sciences and Geoscience Data Section Manager, Geological Survey of Newfoundland and Labrador*

We are one of the NGSC sub-committees for the IDM group and is focusing on not necessarily picking a standard, but on starting the discussions how we would pick a standard Canada wide and how that could be potentially incorporated for each jurisdiction. Also, visa-versa how each jurisdiction can adapt their data with this standard. I think there are a couple of other folks here who are also familiar with what is happening.

Yao Cui, M.Sc. P.Geo *– Sr. Geomatics Geoscientist British Columbia Geological Survey*

This sub-committee is tasked with managing this pilot project is focusing on the mineral occurrences. So it could be minerals occurrences but also mineral resources, so I think the NGSC idea to run a pilot project and do some testing. There are about 7 or 8 jurisdictions that will be participating. The idea is that we are going to start with 4 or 5 and up to 8 jurisdictions, essentially as Sara mentioned will decide the standard, either GEOSCIENCE Markup language, and the extension, Earth Resource Markup language or a light version thereof. So, we need to decide how light it must be. Also, there will be some use cases, which Eric Boisvert has been working on but again will be discussed by this technical working group. Nothing will happen before the end of this summer because, Geneviève will know more, we are still in the process of getting some resources together including hiring a contractor, a casual employee to work with us. So much in the background and in the discussion, hopefully by this fall we will start some real work. Then we can talk to some jurisdictions and decide how to go from there. So, this might take about 10 months to a year before we have some kind of demo to show what we are going to come up with, both in terms of standards and what kind of services, what else we can do and expanding to the rest of the country.

Geneviève Marquis, Ph.D. *– Director Central Canada Division, Geological Survey of Canada*

To complement on this explanation, it super important that we all feel the urgency to share our data and extract intelligence to create one powerful national, not silos of jurisdictions. This is the concept that I want to place Canada in the world as a strong nation for our data sharing amongst us. So just to give you some context, with this IDM project. This is not the first project, but the second project. Last year we completed a data readiness assessment and we put a contract in place with Minerva Intelligence, so Minerva came up with a report on what was the difference with jurisdictions and how

the data is being managed. You can have access to the results of this analysis, that was paid for by TGI, Targeted Geoscience Initiative. Then next we picked a theme to work it out, with a standard and to define what are the main challenges. It's really like an experimentation to see what the main challenges will be, we don't expect that to be easy, we expect that to be difficult, we expect to have a theme of mineral occurrences within critical minerals and will again be paid by the Targeted Geoscience Initiative for the second time. We developed a statement of work with Miren Lorente working with Yao to find the final clauses of statement of work. We hope to put this contract in place in September 2022. In particular because in the summertime it is very slow with procurement. We understand it's going to be slow to put that in place. We hope to find some recommendation on how to improve our data sharing. That's the ultimate goal. How can we improve that? It's outside of Canada 3D.

Mark Deptuck, Ph.D. *– Geology Senior Advisor, Canada Nova-Scotia Offshore Petroleum Board*

As an observer to this group, one of the things that strikes me is that this is a huge aspirational project, that is very worthwhile. I sit in an off-shore silo with CNSOPB, but a lot of our data sets would lend themselves to contributing to a 3D model, but in the off-shore. One of the things that is a bit daunting to me is to think about how the sort of data sets that we work with could possibly get integrated with some of the bedrock geology data sets that were used to build models with, and what that might look like. Perhaps some of the hesitation in speaking, for some of us, who may be new to this (3D geological modelling) is that it can be quite daunting when we think of the magnitude of this kind of a project. For me if I were to parse out, for example the off-shore piece, where our data sets are principally well control from oil and gas, and seismic we build 3D models, the distribution of salt, different stratigraphic surfaces, in the off-shore in the subsurface, and we grid those in 3D. We use different software to build and view these models. I have a sense what something like that at the national scale might look like. If we saw some of the work the BC government is doing. Stepping into the BC offshore I could see what that might look like. This could tie in with something we might do in the offshore of Eastern Canada where we have huge, huge data rich regions in terms of reflection seismic and well control but are data poor in terms of bedrock geology. In terms of critical minerals, it may not be at the same priority, but it might also be low hanging fruit for C3D. We have already developed 3D stratigraphic horizons in many regions so it is easier to envision how we could extract and develop a national scale offshore 3D geological model.

Eric de Kemp, Ph.D. *- Research Scientist Geological Survey of Canada*

Yes, for sure Mark, I have always felt that development of a National 3D geological model should include the offshore. It is part of Canada's jurisdiction and is rich in data and has a long history of methods development from the petroleum sector, along with expertise that is available to produce this important component.

Mark Deptuck, Ph.D. *– Geology Senior Advisor, Canada Nova-Scotia Offshore Petroleum Board*

For example, it would not be hard to produce a 3D horizon of the K-T boundary for the entire Canadian offshore with the data that is already in hand and organized. In fact, we have just produced a 3D seismic atlas half the size of Nova Scotia covering horizons from the Moho up to surface. It includes top basement map, primary salt layer, top allochthonous salt layers, all mapped in 3D all the way up to the sea floor. We have a big off-shore and NL has an even bigger off-shore so could be making a big impact for sharing geology knowledge of Canada.

Hazen Russell, Ph.D. – *Geoscientist, Geological Survey of Canada*

I though Geneviève made a very good point, at the end of her statement whereby the data standards committee in NGSC is not part of Canada 3D. I am sure that is completely accurate, but it highlights the fact that C3D is really a vision to operate on top of data standards. It will never be able to achieve the success that is envisioned for it without data standards, and the commensurate data repositories, that are able to be accessed. So, they're intimately related.

Eric de Kemp, Ph.D. - *Research Scientist Geological Survey of Canada*

We will be sending out an email with this report and some thoughts on next steps for C3D. This concludes this NGSC C3D project meeting. Thanks to all for participating and sharing your experiences with us. Until we meet again!

Canada 3D

Thank you !

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THE UNIVERSITY OF WESTERN AUSTRALIA

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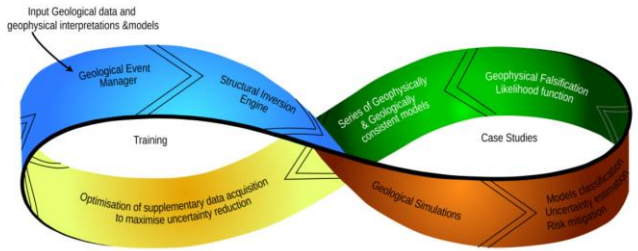

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