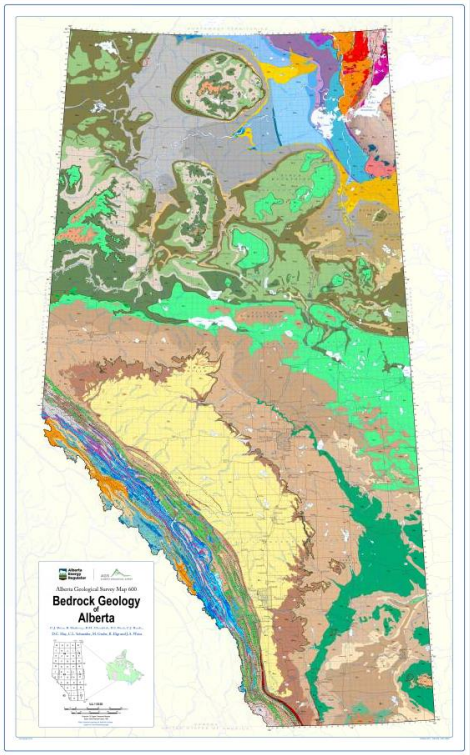
Geological Framework of Alberta; An update on the Alberta Geological Survey's 3D Modelling Program

Kelsey MacCormack, Ph.D.

June 17th, 2020

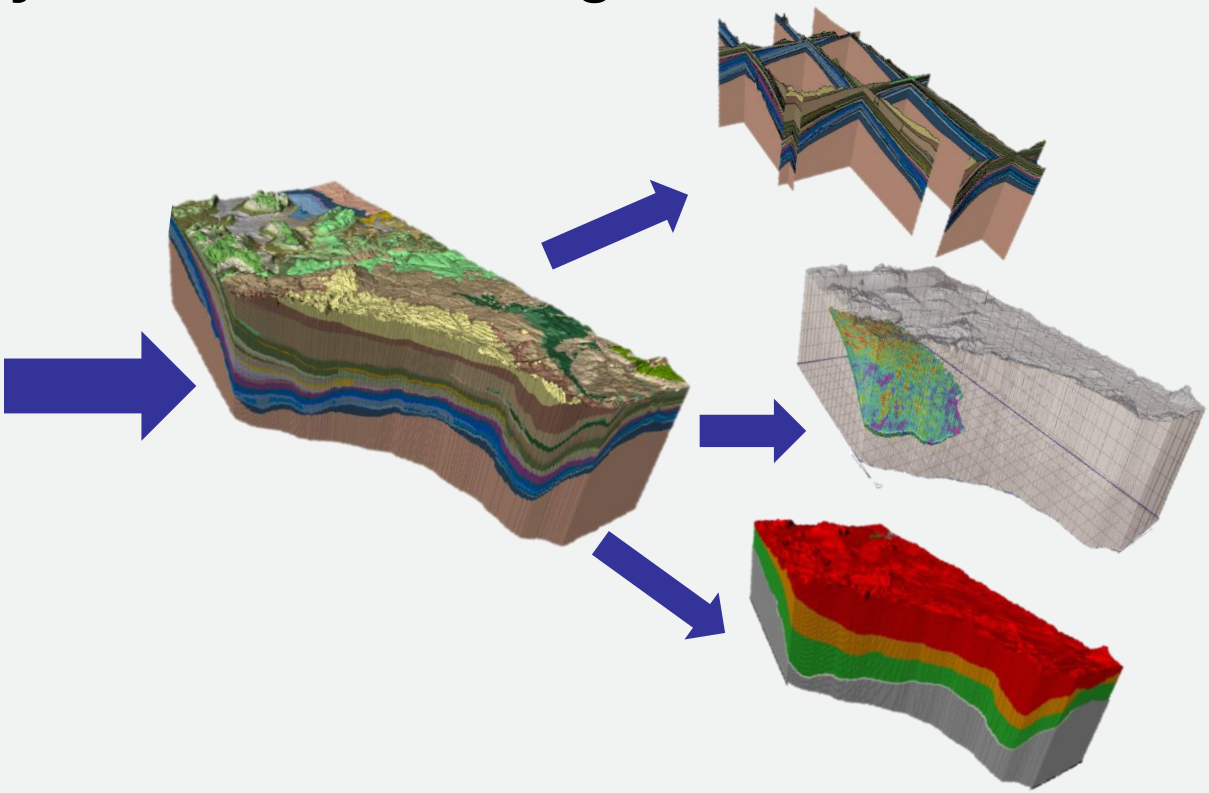
From 2D Maps to 3D Models

2D Bedrock Geology



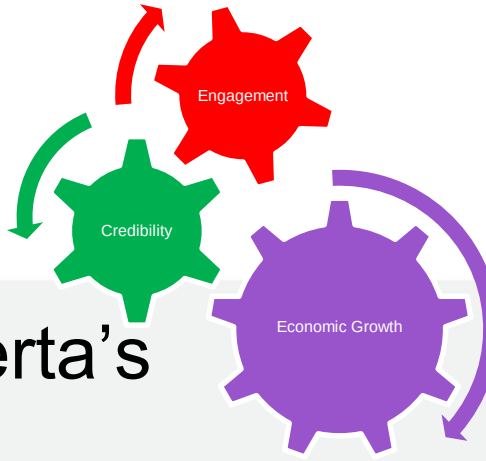
Traditional map products

3D Geological Framework

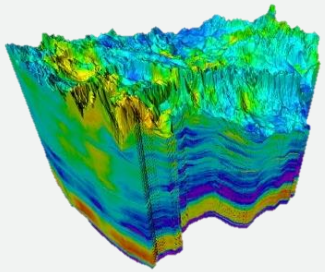


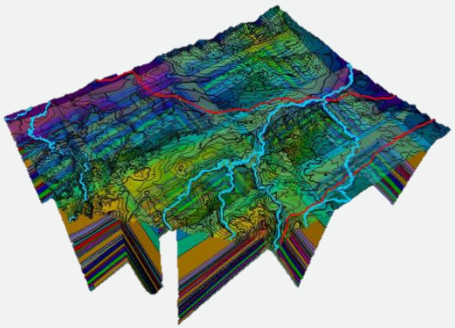
Interactive, holistic 3D geological model

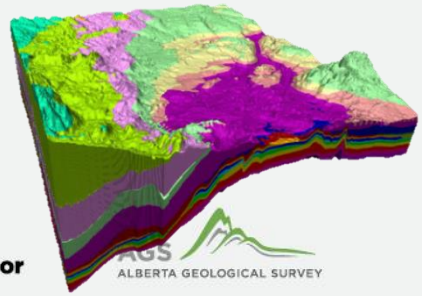
Why are we building it?



- To communicate information about Alberta's surface and subsurface for;
  - Support **safe** and **sustainable** resource development and protection
  - **Science-based** decision making
  - Deliver **interactive and engaging** geoscience information
  - **Efficient** and **effective** evaluation and use of geospatial data







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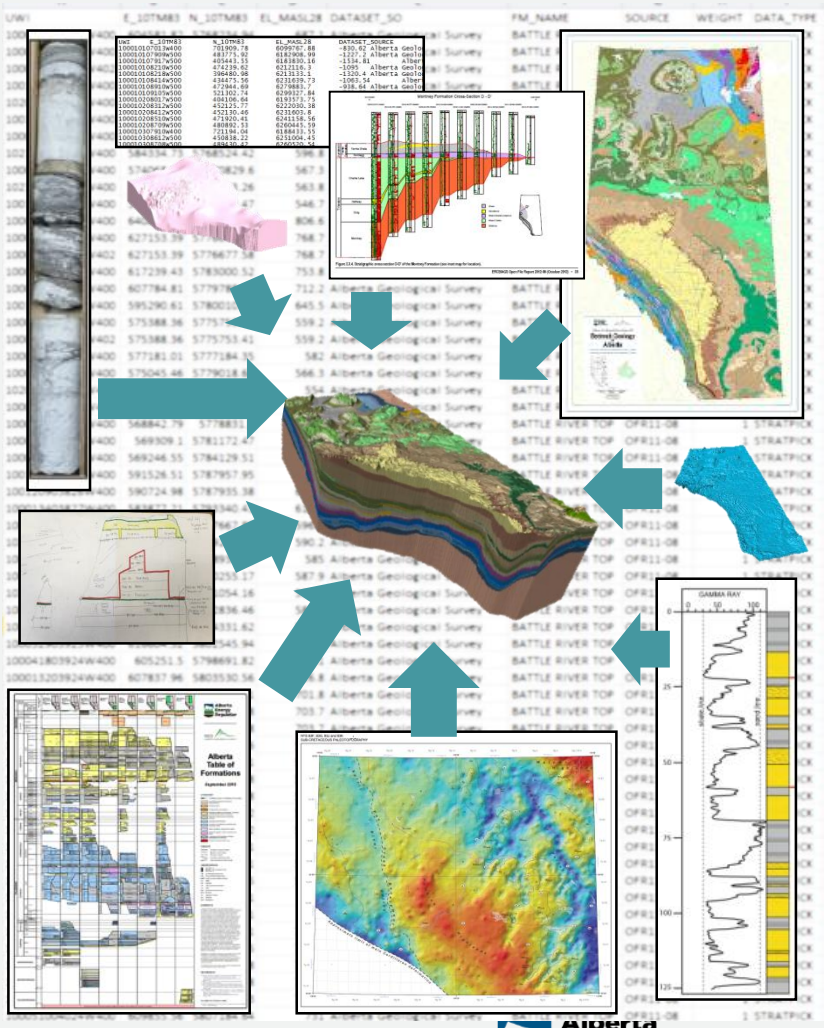
AGS ALBERTA GEOLOGICAL SURVEY

Optimizing Data Integration

Integrating data from a variety of sources;

- Stratigraphic data
- Reports
- Maps
- Cross-sections
- Conceptual models
- Seismic data
- Lineament



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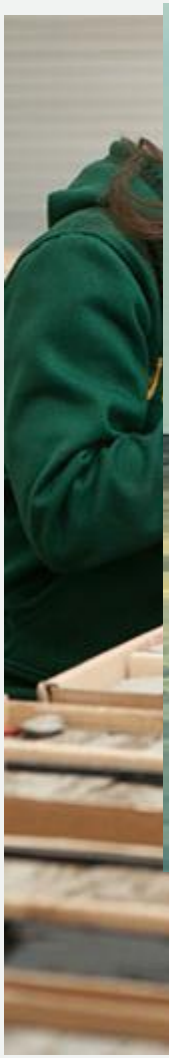
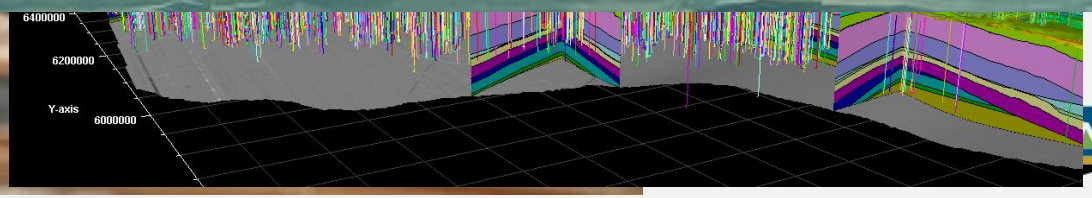
Managing and Optimizing our Data





3.5 x

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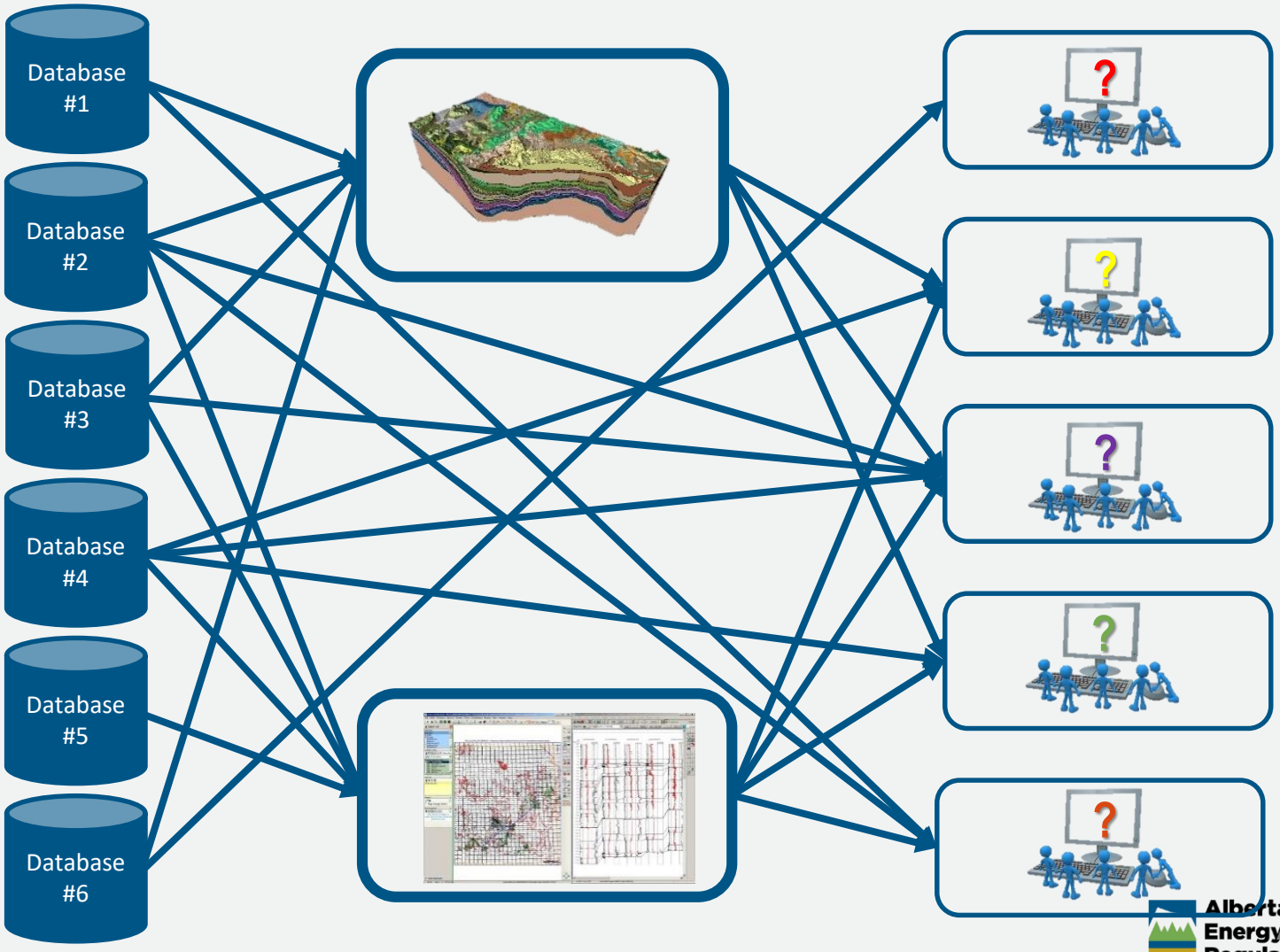
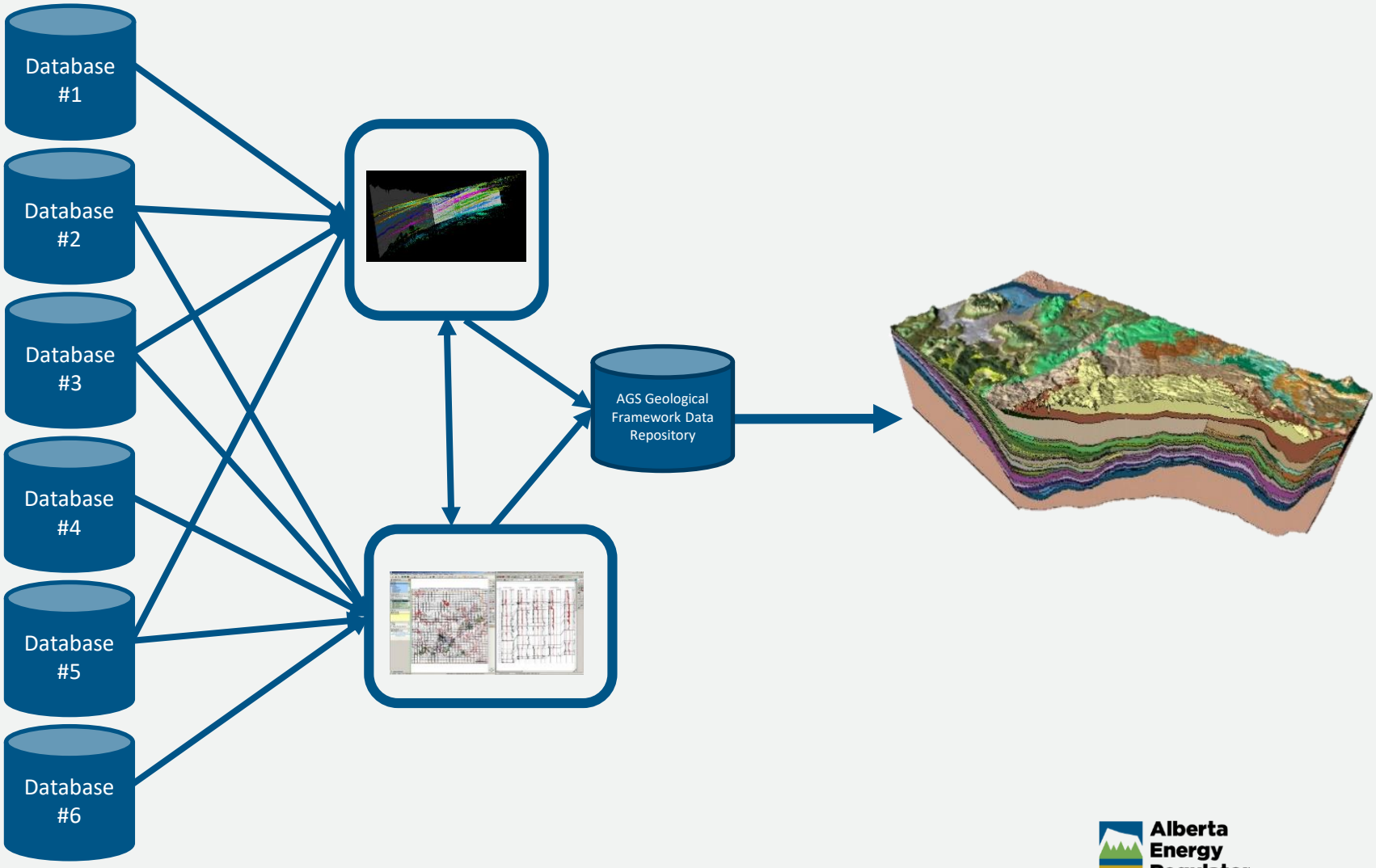
Importance of Data Management



Importance of Data Management



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Efficiently Share 3D Models

Duplication of efforts

Potential for inconsistencies

Efficient use of staff resources

Promotes consistency and credibility

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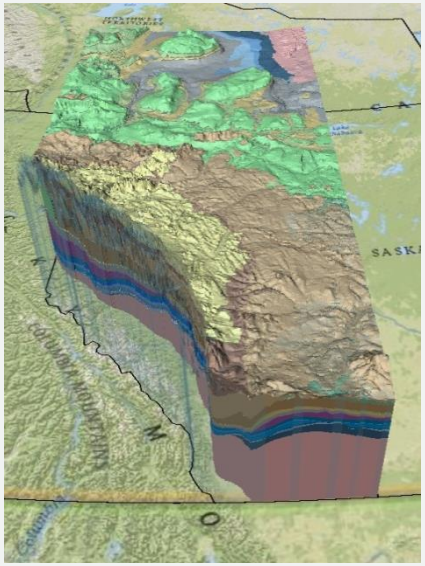
3D Geological Framework of Alberta

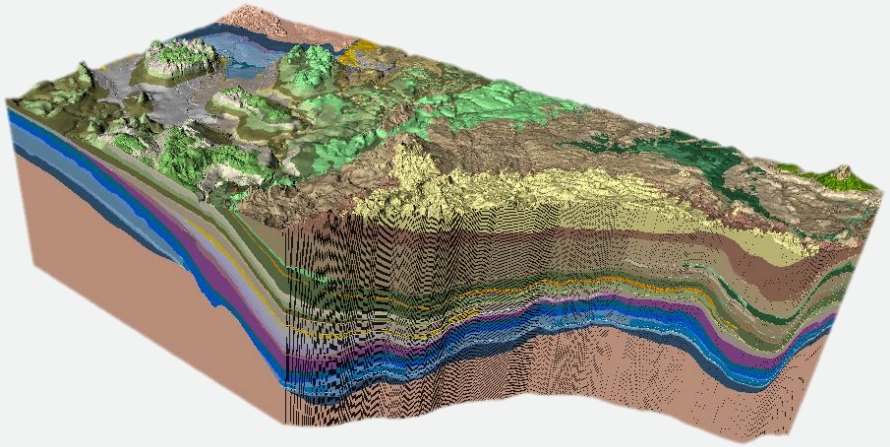
Version 1

- 32 model zones (layers)
- 620,812 data points
- 500x500m resolution



Version 2

- 62 model zones (layers)
- 1,235,761 data points
- 500x500m resolution



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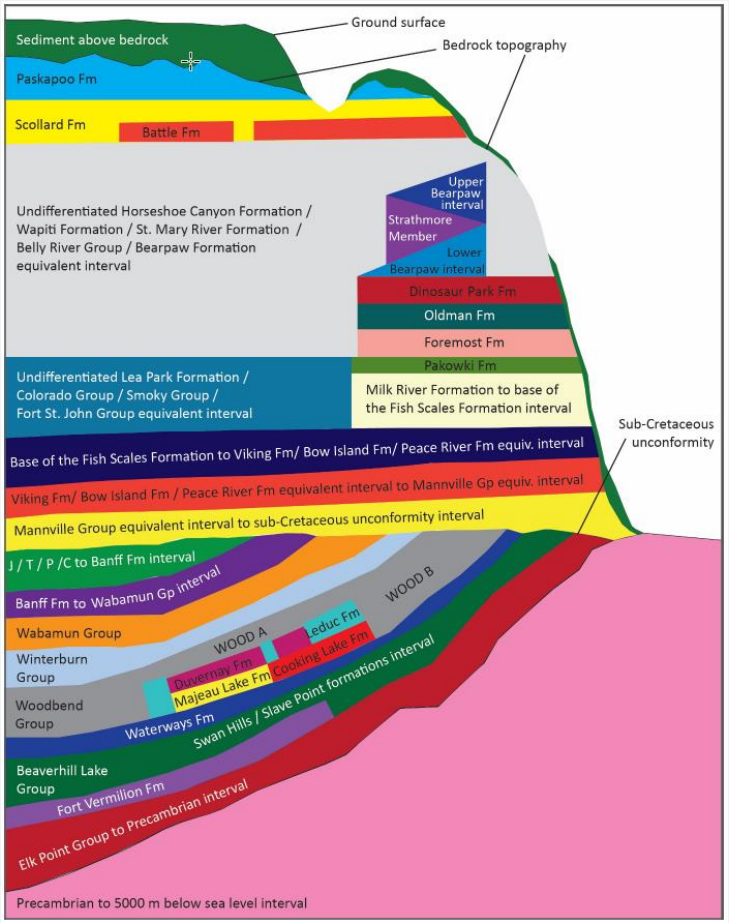
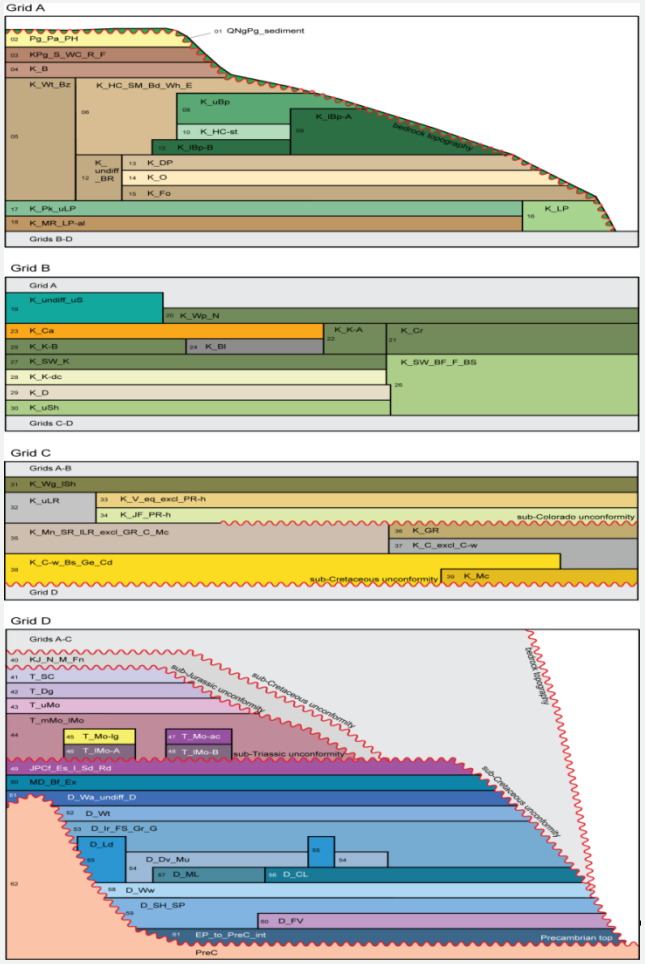
Schematic Cross-sections

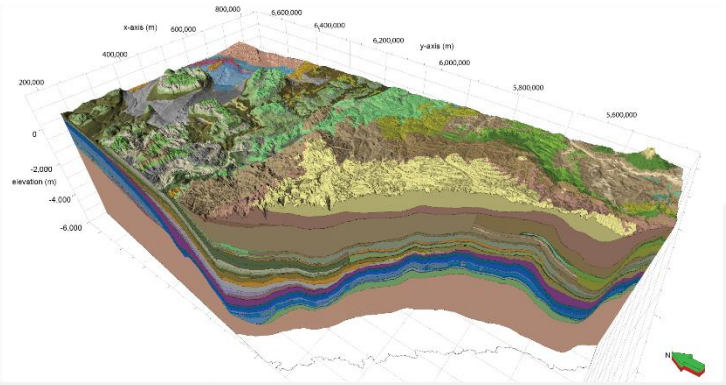
Version 1

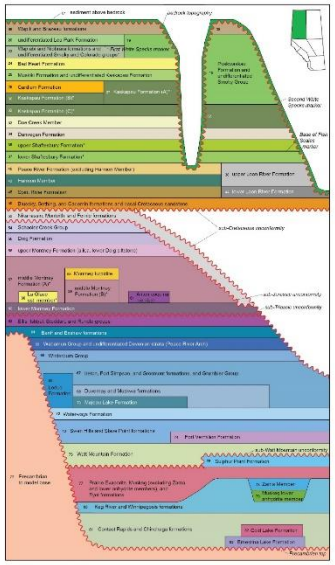


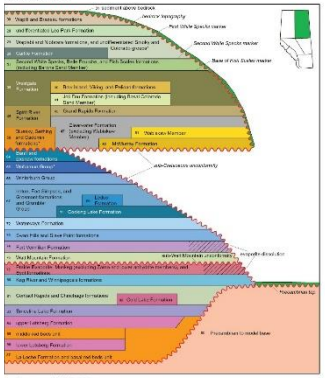
Version 2

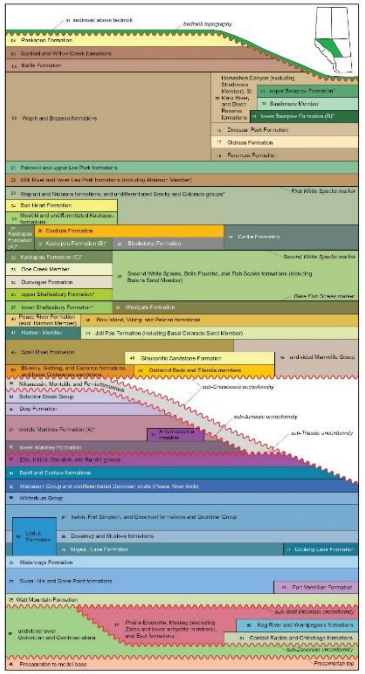


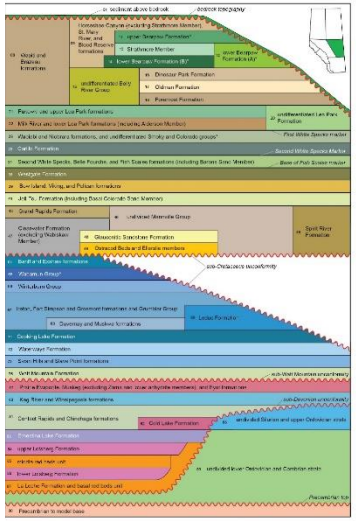
Version 3 – 90 layers!!

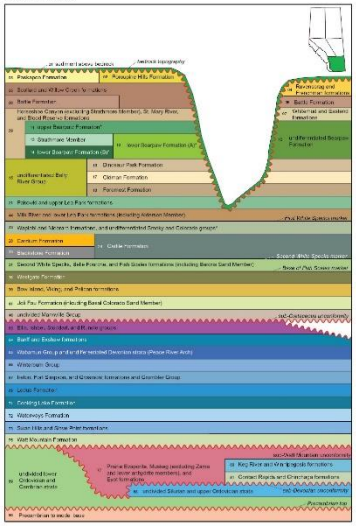












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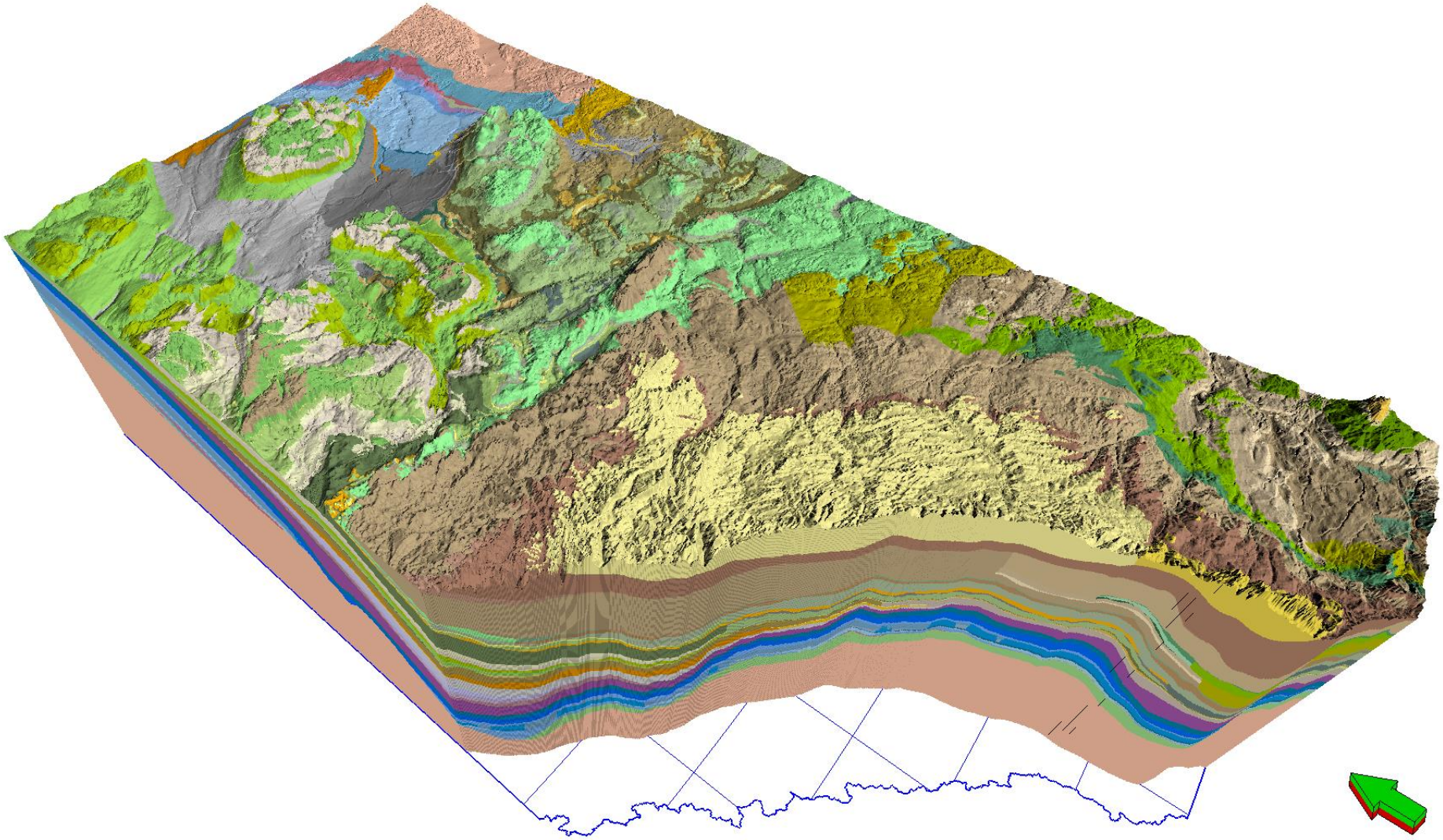
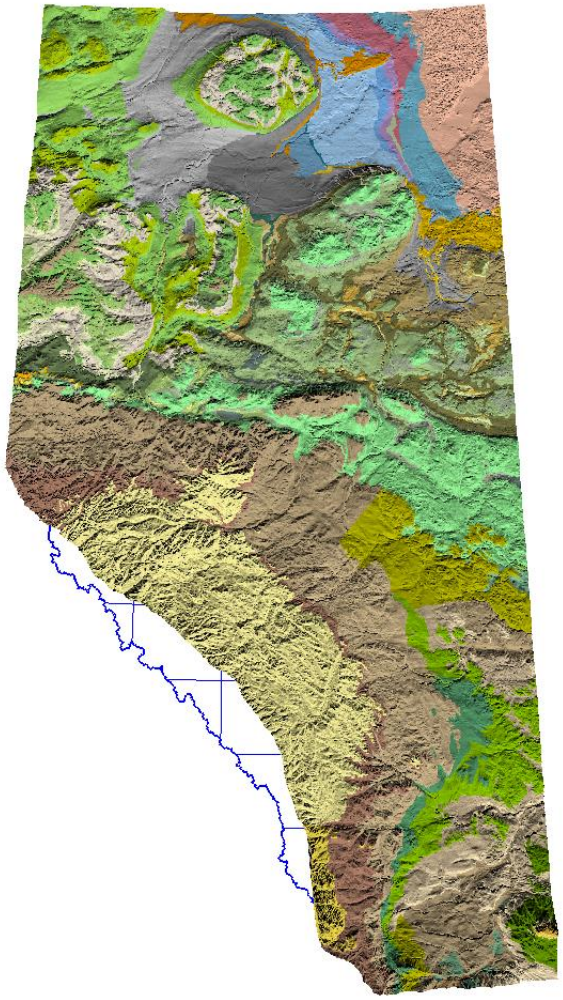




What is the Impact?

Conceptual Model

Science and Evidence-based Model

Modern

Efficient

Credible

Decision-support

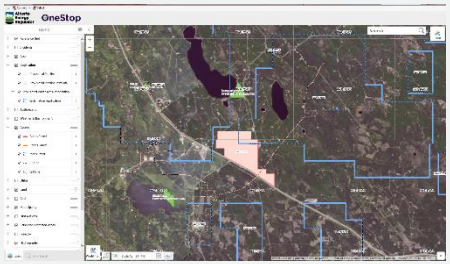
Transparent

Single-Source of Truth

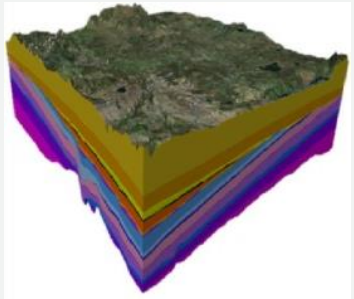
Stakeholder Communication

Alberta Energy Regulator

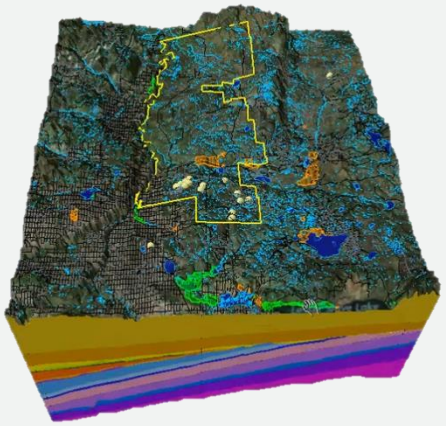
Ability to integrate Surface & Subsurface Information to Support Decision Making



Surface Data



Subsurface Model



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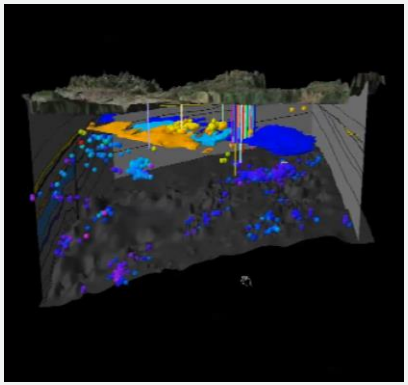

Ability to integrate surface information and subsurface geospatial data in a consistent and validated 3D geospatial environment

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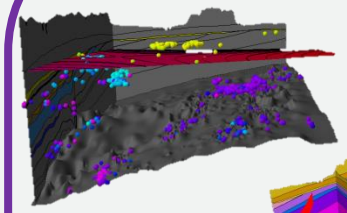
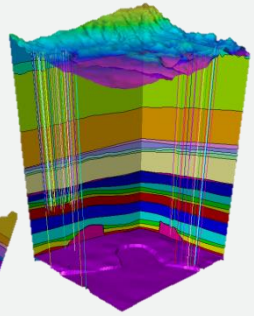
Feedback: Decision Makers and Stakeholders

Data Integration

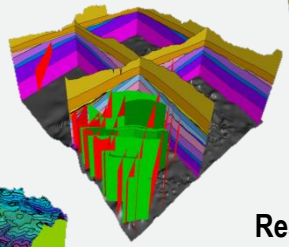
Geochemical Data



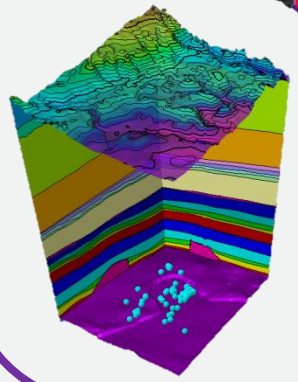
Well Data



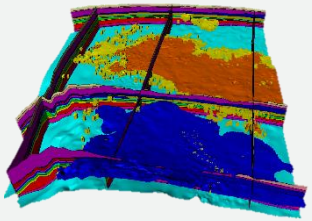
Faults



Event Data

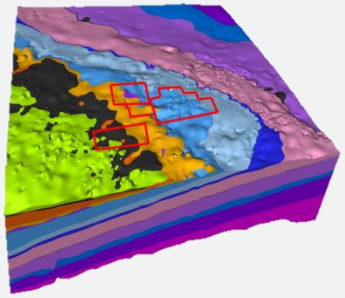


Resource Volumes

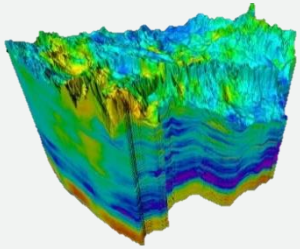


Geospatial Context

Formation Extents

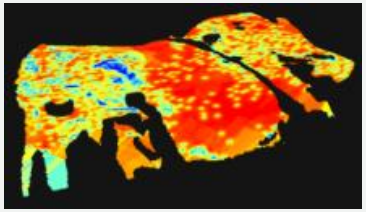


Internal Characterization

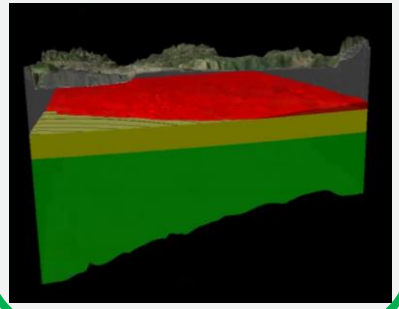


Decision Support

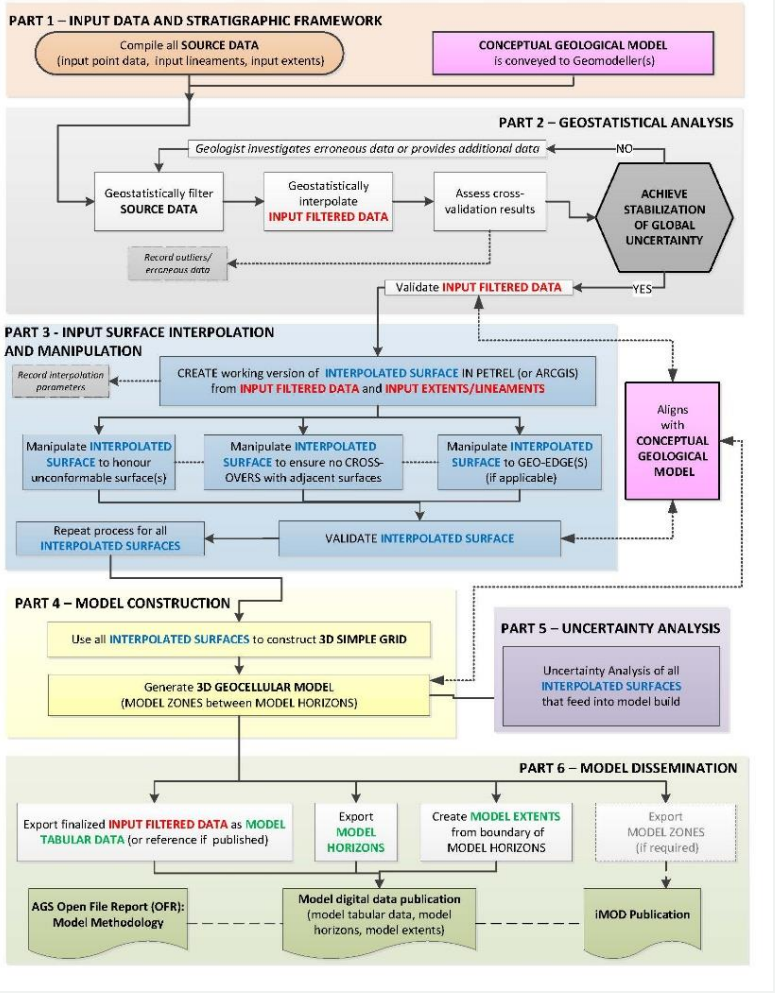
Uncertainty Analysis



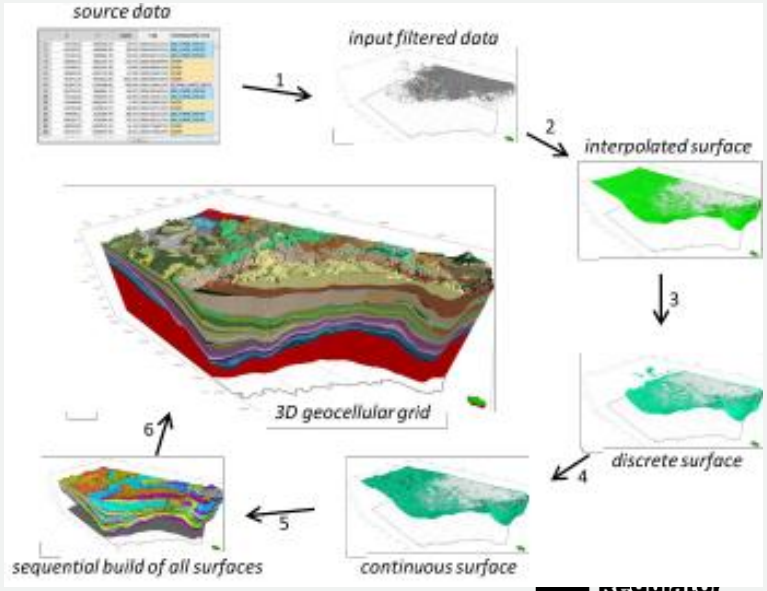
Risk Analysis



Modelling Approach

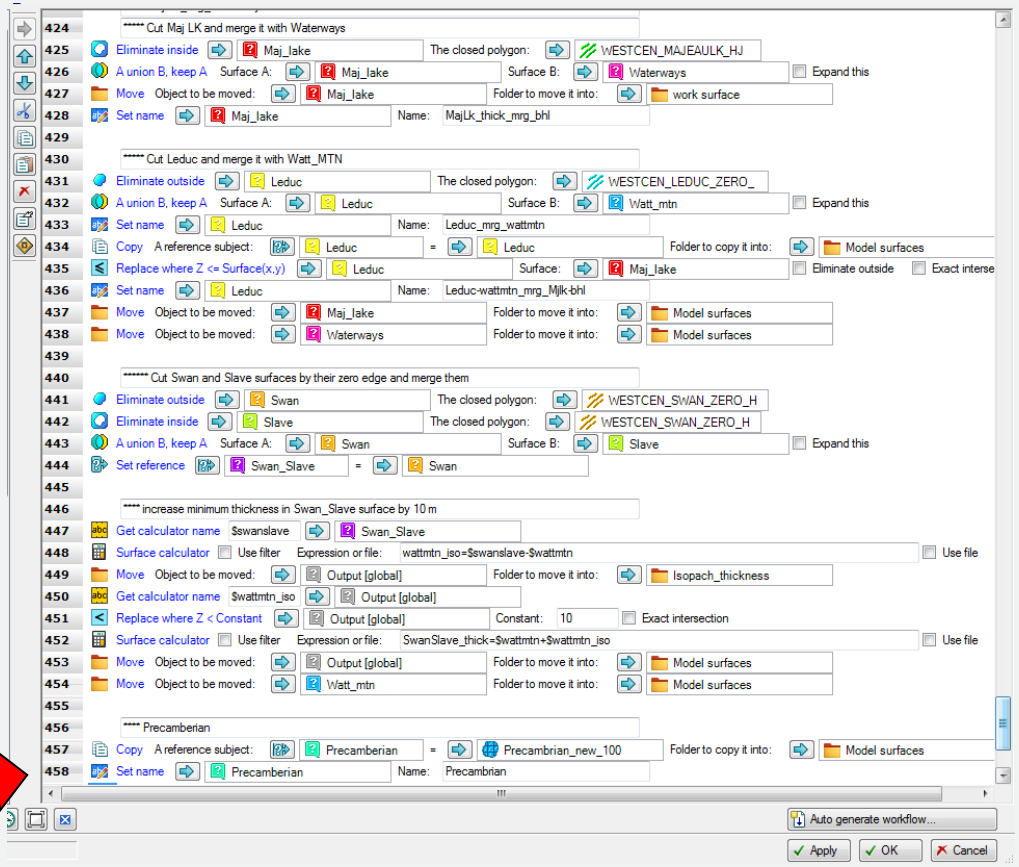


- Data QC/QA occurs throughout the modelling process
- Process identifies data requiring further evaluation by geologists

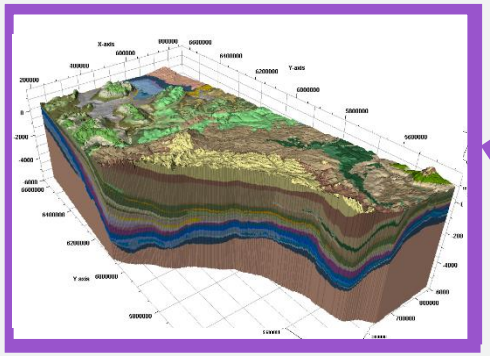


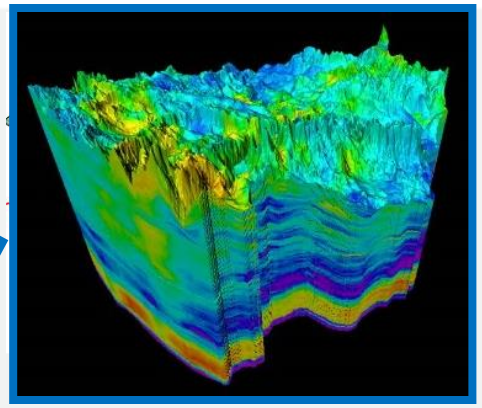
Innovation: Automated Workflows

- Decrease Model build time from **2 days** to less than **2 hours**
- Increased efficiency (**87.5%**)
- Reduce chance of user error



Development and Innovation





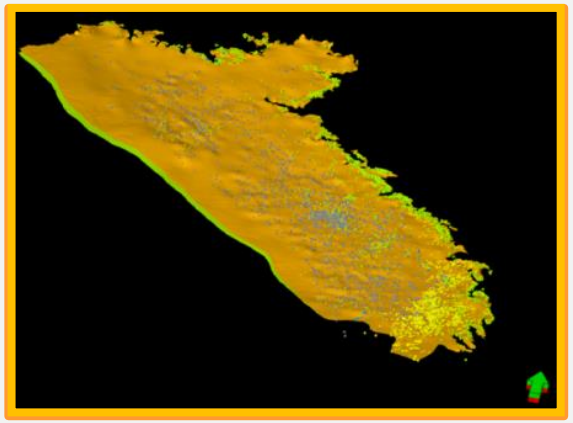
3D PROVINCIAL MODEL

PROPERTY MODELLING

INTEGRATED RESOURCES

Virtual and Augmented Reality

MINECRAFT OUTREACH



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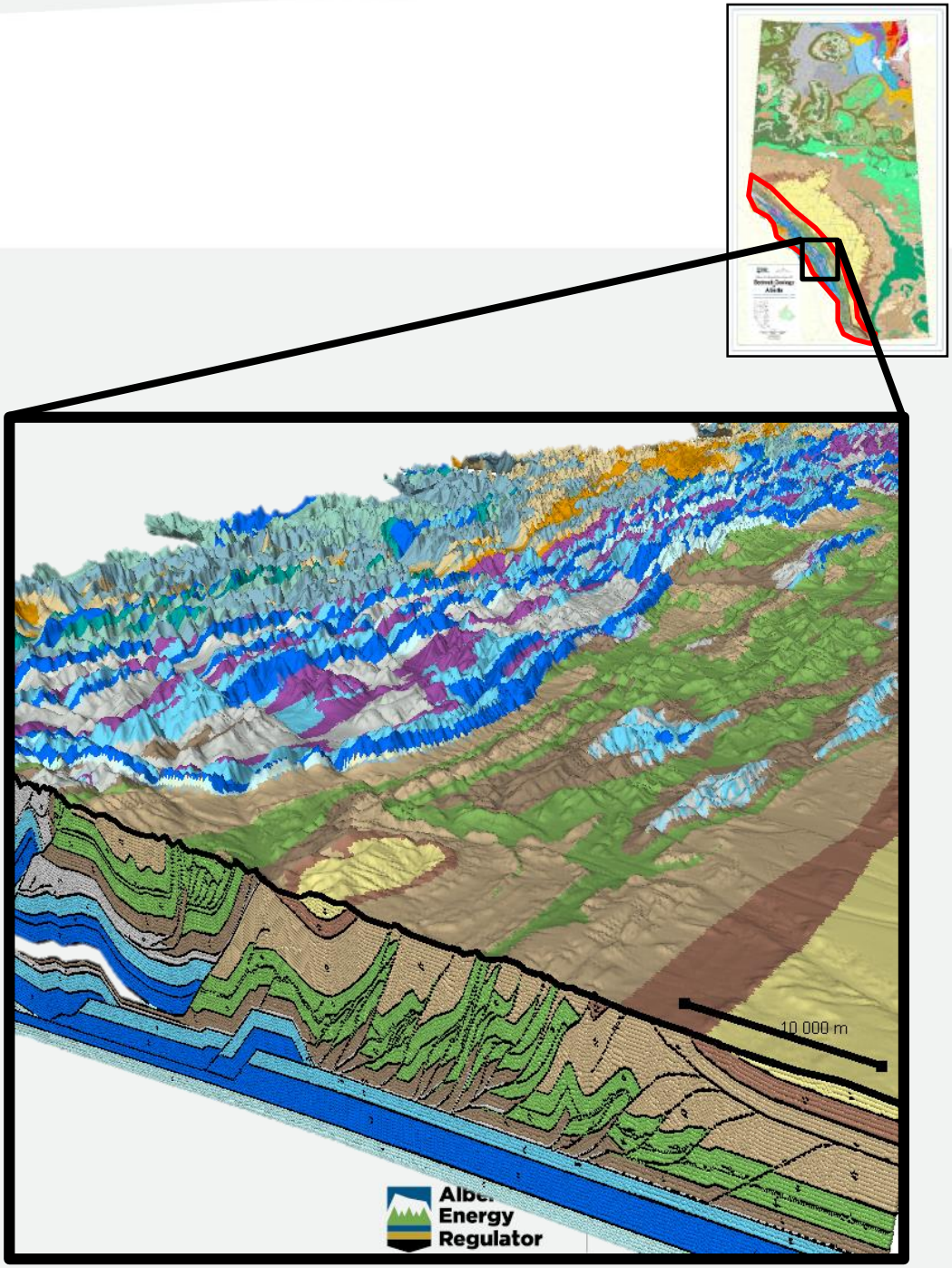
Challenges

Modelling the highly deformed region of the Rocky Mountains

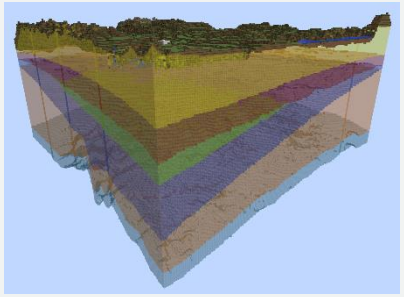
Computing Requirements

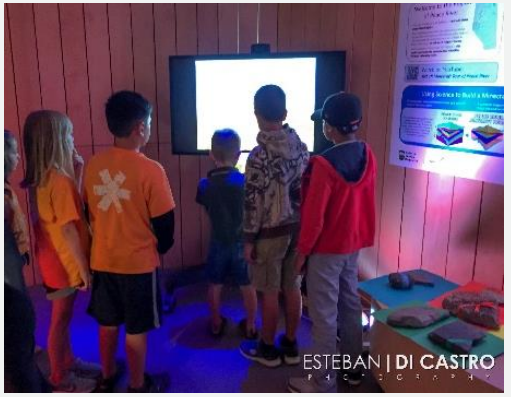
Availability of subject matter experts



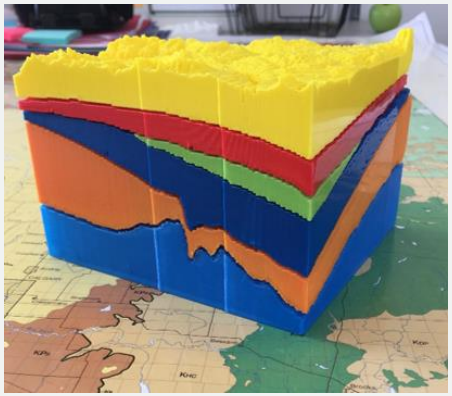
Engaging and Sharing Information with Our Stakeholders

- Minecraft





- 3D Prints



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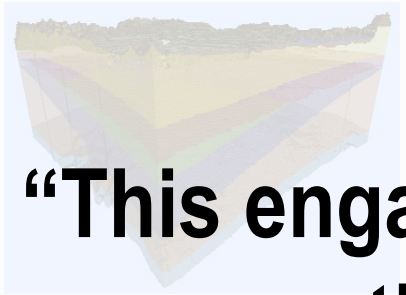
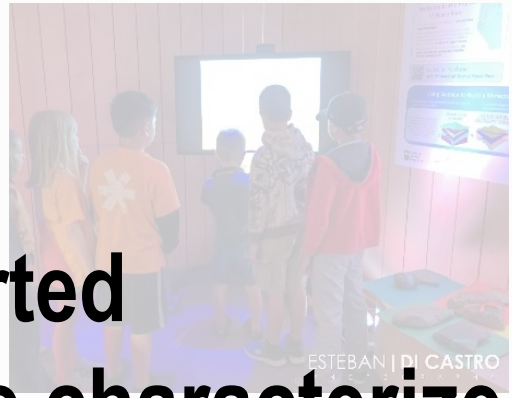
Engaging and Sharing Information with Our Stakeholders

- Minecraft



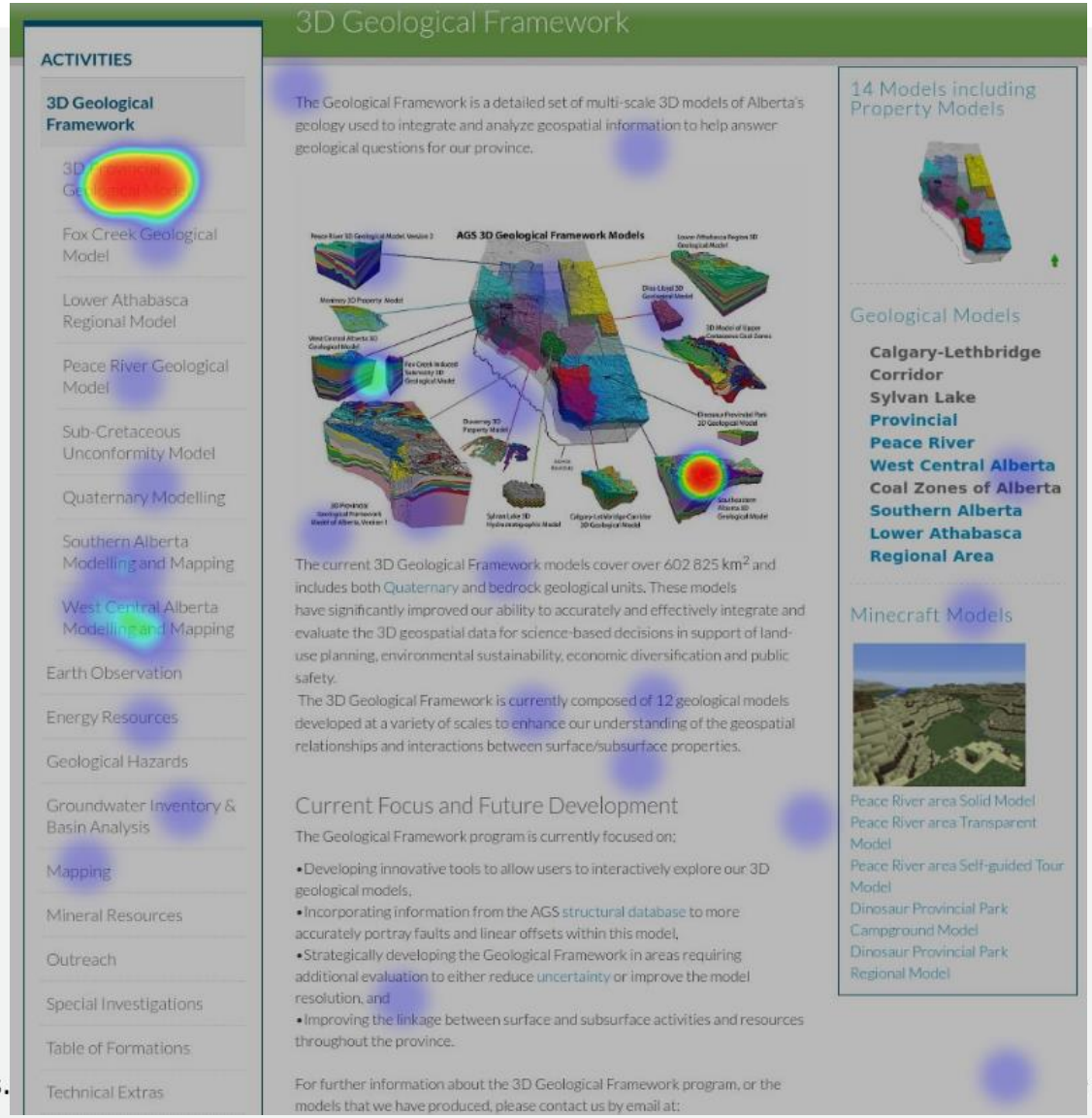


- 3D Prints

"This engaging material started conversations about *how* we characterize the subsurface, and *why* we do it"

Elwyn Galloway - Young Global Petroleum Show (June 13, 2018)

Website: What are people looking for



3D Geological Framework

ACTIVITIES

- 3D Geological Framework
- Fox Creek Geological Model
- Lower Athabasca Regional Model
- Peace River Geological Model
- Sub-Cretaceous Unconformity Model
- Quaternary Modelling
- Southern Alberta Modelling and Mapping
- West Central Alberta Modelling and Mapping
- Earth Observation
- Energy Resources
- Geological Hazards
- Groundwater Inventory & Basin Analysis
- Mapping
- Mineral Resources
- Outreach
- Special Investigations
- Table of Formations
- Technical Extras

The Geological Framework is a detailed set of multi-scale 3D models of Alberta's geology used to integrate and analyze geospatial information to help answer geological questions for our province.

AGS 3D Geological Framework Models

The current 3D Geological Framework models cover over 602 825 km^2 and includes both Quaternary and bedrock geological units. These models have significantly improved our ability to accurately and effectively integrate and evaluate the 3D geospatial data for science-based decisions in support of land-use planning, environmental sustainability, economic diversification and public safety.

The 3D Geological Framework is currently composed of 12 geological models developed at a variety of scales to enhance our understanding of the geospatial relationships and interactions between surface/subsurface properties.

Current Focus and Future Development

The Geological Framework program is currently focused on:

- Developing innovative tools to allow users to interactively explore our 3D geological models.
- Incorporating information from the AGS structural database to more accurately portray faults and linear offsets within this model.
- Strategically developing the Geological Framework in areas requiring additional evaluation to either reduce uncertainty or improve the model resolution, and
- Improving the linkage between surface and subsurface activities and resources throughout the province.

For further information about the 3D Geological Framework program, or the models that we have produced, please contact us by email at:

14 Models including Property Models

Geological Models

Calgary-Lethbridge Corridor
Sylvan Lake
Provincial
Peace River
West Central Alberta
Coal Zones of Alberta
Southern Alberta
Lower Athabasca Regional Area

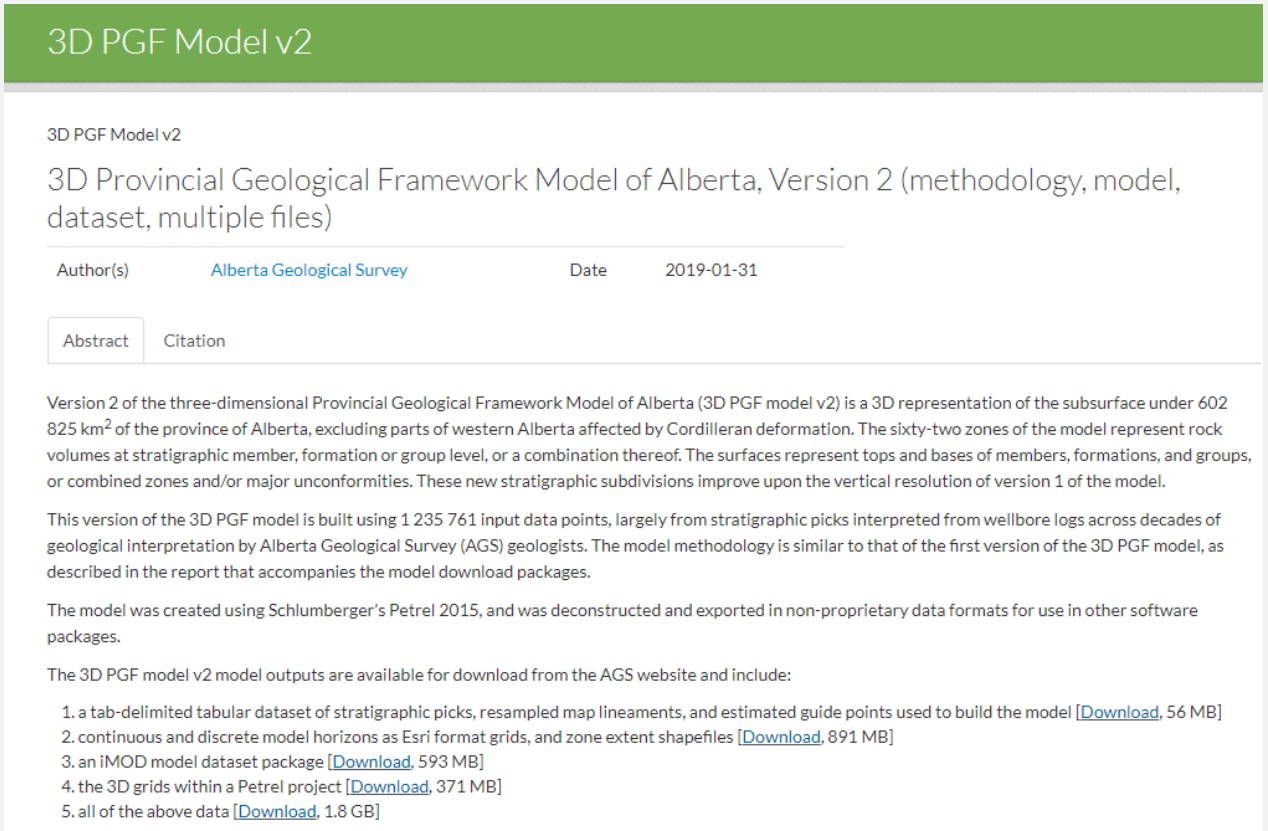
Minecraft Models

Peace River area Solid Model
Peace River area Transparent Model
Peace River area Self-guided Tour Model
Dinosaur Provincial Park Campground Model
Dinosaur Provincial Park Regional Model

How is it shared?

Current State (v1 & v2)

- .zip files accessible through the AGS website:
  - https://ags.aer.ca/data-maps-models/MOD_2018_02.html



3D PGF Model v2

3D PGF Model v2

3D Provincial Geological Framework Model of Alberta, Version 2 (methodology, model, dataset, multiple files)

Author(s) Alberta Geological Survey Date 2019-01-31

Abstract Citation

Version 2 of the three-dimensional Provincial Geological Framework Model of Alberta (3D PGF model v2) is a 3D representation of the subsurface under 602 825 km^2 of the province of Alberta, excluding parts of western Alberta affected by Cordilleran deformation. The sixty-two zones of the model represent rock volumes at stratigraphic member, formation or group level, or a combination thereof. The surfaces represent tops and bases of members, formations, and groups, or combined zones and/or major unconformities. These new stratigraphic subdivisions improve upon the vertical resolution of version 1 of the model.

This version of the 3D PGF model is built using 1 235 761 input data points, largely from stratigraphic picks interpreted from wellbore logs across decades of geological interpretation by Alberta Geological Survey (AGS) geologists. The model methodology is similar to that of the first version of the 3D PGF model, as described in the report that accompanies the model download packages.

The model was created using Schlumberger's Petrel 2015, and was deconstructed and exported in non-proprietary data formats for use in other software packages.

The 3D PGF model v2 model outputs are available for download from the AGS website and include:

1. a tab-delimited tabular dataset of stratigraphic picks, resampled map lineaments, and estimated guide points used to build the model [Download, 56 MB]
2. continuous and discrete model horizons as Esri format grids, and zone extent shapefiles [Download, 891 MB]
3. an iMOD model dataset package [Download, 593 MB]
4. the 3D grids within a Petrel project [Download, 371 MB]
5. all of the above data [Download, 1.8 GB]

How is it shared?

Current State (v1 & v2)

Alberta Energy Regulator

3D Provincial Geological Framework Model of Alberta, Version 2 – Metadata and Methodology

AGS

- Within each download file:

Discrete Model Zone					Model Horizon Top (Zone Top)			Model Horizon Base (Zone Base)
Zone #	Abbreviation	Geological Components	Geological Component Types	Geological Age	Input: Top Continuous Surface #	Input: Continuous Surface	Output: Continuous Model Horizon	Output: Base Model Horizon
1	QNgPg_sediment	sediment above bedrock (surficial deposits)	an unconsolidated sedimentary layer	Eocene to Recent	1	ground surface	cmh_01_QNgPg_sediment_top	cmh_02b_Pg_Pa_PH_top
2	Pg_Pa_PH	Paskapoo and Porcupine Hills formations	volume lesser than a Group but greater than a Formation	Paleocene to Eocene	2	bedrock topography surface	cmh_02b_Pg_Pa_PH_top	cmh_03_KPg_S_WC_R_F_top
3	KPg_S_WC_R_F	Scollard, Willow Creek, Ravenscrag, and Frenchman formations	volume lesser than a Group but greater than a Formation	Upper Cretaceous (Maastrichtian) to Paleocene	3	Scollard - Willow Creek - Ravenscrag formations top	cmh_03_KPg_S_WC_R_F_top	cmh_04_K_B_top
4	K_B	Battle Formation	entire Formation	Upper Cretaceous (Maastrichtian)	4	Battle Formation top	cmh_04_K_B_top	cmh_05_K_Wi_Bz_top
5	K_Wi_Bz	Wapiti and Brazeau formations	volume lesser than a Group but greater than a Formation	Upper Cretaceous (Campanian to Maastrichtian)	5	Horseshoe Canyon - Whitemud - St. Mary River - Wapiti formations top	cmh_05_K_Wi_Bz_top	cmh_06_K_HC_SM_Bd_Wh_E_top
6	K_HC_SM_Bd_Wh_E	Horseshoe Canyon (excluding Strathmore Member), St. Mary River, Blood Reserve, Whitemud, and Eastend formations	volume lesser than a Group but greater than a Formation	Upper Cretaceous (Campanian to Maastrichtian)	6	Horseshoe Canyon - Whitemud - St. Mary River formations top	cmh_06_K_HC_SM_Bd_Wh_E_top	cmh_07_K_undiff_Bp_top
7	K_undiff_Bp	undifferentiated Bearpaw Formation	portion of a Formation that is not a Member	Upper Cretaceous (Campanian to Maastrichtian)	7	Bearpaw Formation top	cmh_07_K_undiff_Bp_top	cmh_08_K_uBp_top
8	K_uBp	upper Bearpaw Formation	portion of a Formation that is not a Member	Upper Cretaceous (Campanian to Maastrichtian)	8	Upper Bearpaw interval top	cmh_08_K_uBp_top	cmh_09_K_lBp-A_top
9	K_lBp-A	lower Bearpaw Formation (A - outside of Strathmore Member and below Bearpaw maximum flooding surface)	portion of a Formation that is not a Member	Upper Cretaceous (Campanian)	9	Eastern part of maximum flooding surface within Bearpaw Formation	cmh_09_K_lBp-A_top	cmh_10_K_HC-st_top
10	K_HC-st	Strathmore Member	entire Member	Upper Cretaceous (Campanian)	10	Strathmore Member top	cmh_10_K_HC-st_top	cmh_11_K_lBp-B_top
11	K_lBp-B	lower Bearpaw Formation (B - below Strathmore Member)	portion of a Formation that is not a Member	Upper Cretaceous (Campanian)	11	Lower Bearpaw interval top (below Strathmore Member)	cmh_11_K_lBp-B_top	cmh_12_K_undiff_BR_top
12	K_undiff_BR	undifferentiated Belly River Group (excluding Dinosaur Park, Oldman, and Foremost formations)	volume lesser than a Group but greater than a Formation	Upper Cretaceous (Campanian)	12	Belly River Group top	cmh_12_K_undiff_BR_top	cmh_13_K_DP_top
13	K_DP	Dinosaur Park Formation	entire Formation	Upper Cretaceous (Campanian)	13	Dinosaur Park Formation top	cmh_13_K_DP_top	cmh_14_K_O_top
14	K_O	Oldman Formation	entire Formation	Upper Cretaceous (Campanian)	14	Oldman Formation top	cmh_14_K_O_top	cmh_15_K_Fo_top
15	K_Fo	Foremost Formation	entire Formation	Upper Cretaceous (Campanian)	15	Foremost Formation top	cmh_15_K_Fo_top	cmh_16_K_LP_top
16	K_LP	Lea Park Formation	portion of a Formation that is not a Member	Upper Cretaceous (Campanian)	16	Lea Park - Pakowki formations top	cmh_16_K_LP_top	cmh_17_K_Pk_uLP_top

Stratigraphic Picks Name	Continuous Surface		Filtered Input Data					Interpolated Surface		Discrete Surface Parameters		Continuous Surface Parameters	Continuous Model Horizon
	Name	Surface Number	Total # of Data Points	Dataset Type	Count	Source	Data Weight	Parameters: Algorithm and special steps / conformable inputs	Uncertainty Analysis: RMSE (m)	Geo-Edge Notes	Surface Manipulations (assume starting point is the interpolated surface)	Surface Manipulations (assume starting point is the discrete surface)	
sub-Jurassic Unconformity	sub-Jurassic Unconformity	41	4,609	stratigraphic picks	4,609	Recent AGS interpretation	1	convergent interpolation	1.93	subcrop edge (erosion by subK_unc surface)	clip to subcrop edge	replace where is lower than discrete (47 and 48) surfaces. Merge with subK_unc surface and replace with subK_unc surface where is higher than subK_unc surface.	ero_41a_subJ_unc
													cmh_41b_T_SC_top
Doig non-eroded Formation top	Doig Formation top	42	399	stratigraphic picks	399	Recent AGS interpretation	1	convergent interpolation	2.08	subcrop edge (erosion by sub-Jurassic)	clip to subcrop edge	merge with subJurassic surface (41), replace with (41) surface where is higher than (41) surface	cmh_42_T_Dg_top
Montney non-eroded Formation top	Montney Formation top	43	2,908	stratigraphic picks	2,908	Recent AGS interpretation	1	convergent interpolation	2.72	subcrop edge (erosion by sub-Jurassic and subK_unc surface)	clip to geo-edge	merge with subK_unc surface (between subK_unc surface subcrop and zero edge) and merge with sub-Jurassic surface (41), replace with (41) surface where is higher than (41) surface	cmh_43_T_uMo_top
middle Montney Formation top	middle Montney Formation top	44	1,914	stratigraphic picks	1,914	Recent AGS interpretation	1	convergent interpolation	2.80	zero edge of upper Montney Formation	clip to the zero edge	merge with adjacent continuous surface (43)	cmh_44_T_mMo_Mo_top
La Glace sandstone member top	La Glace sandstone member top	45	887	stratigraphic picks	887	Recent AGS interpretation	1	convergent interpolation	2.92	zero edge of La Glace sandstone member	clip to the zero edge	merge with adjacent continuous surface (45)	cmh_45_T_Mo-lg_top
La Glace sandstone member base	La Glace sandstone member base	46	556	stratigraphic picks	556	Recent AGS interpretation	1	convergent interpolation	3.16	zero edge of La Glace sandstone member (edited for razor edges)	clip to the zero edge	merge with adjacent continuous surface (47)	cmh_46_T_Mo-A_top
Antern coquina member top	Antern coquina member top	47	753	stratigraphic picks	753	Recent AGS interpretation	1	conformal gridding (conform to sub-Jurassic and sub-Triassic continuous surfaces)	2.41	zero edge of Antern coquina member	clip to the zero edge	thickness of 1 meter added to Antern Coquina top discrete surface where is lower than Antern Coquina base discrete surface, merge with adjacent continuous surface (48)	cmh_47_T_Mo-an_top
Antern coquina member base	Antern coquina member base	48	756	stratigraphic picks	756	Recent AGS interpretation	1	conformal gridding (conform to sub-Jurassic and sub-Triassic continuous surfaces)	2.54	zero edge of Antern coquina member (edited for razor edges)	clip to the zero edge	merge with adjacent continuous surface (49)	cmh_48_T_Mo-B_top
sub-Triassic Unconformity	sub-Triassic Unconformity	49	5,669	stratigraphic picks stratigraphic picks	3,918 1,979	Recent AGS interpretation AGS-AER interpretation	1 0.8	convergent interpolation	2.35	subcrop edge (erosion by sub-Jurassic)	clip to subcrop edge	merge with sub-Jurassic surface (41), replace with (41) surface where is higher than (41) surface	ero_49a_subT_unc cmh_49b_UPOI_Es_l_Sd_Rd_top

Wabamun Group top

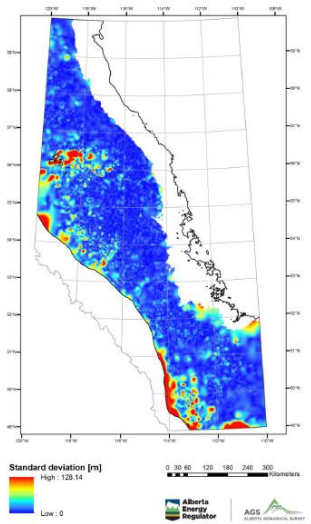
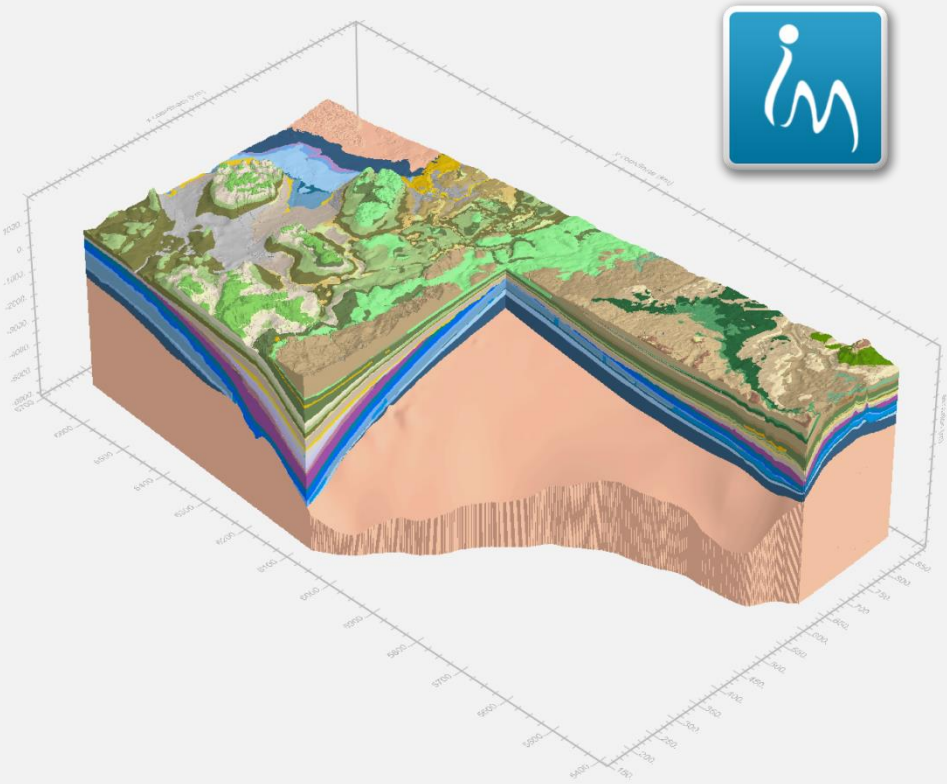


Figure96. Standard deviation uncertainty map of the non-eroded Wabamun Group top surface.

How is it shared?

Current State (v1 & v2)

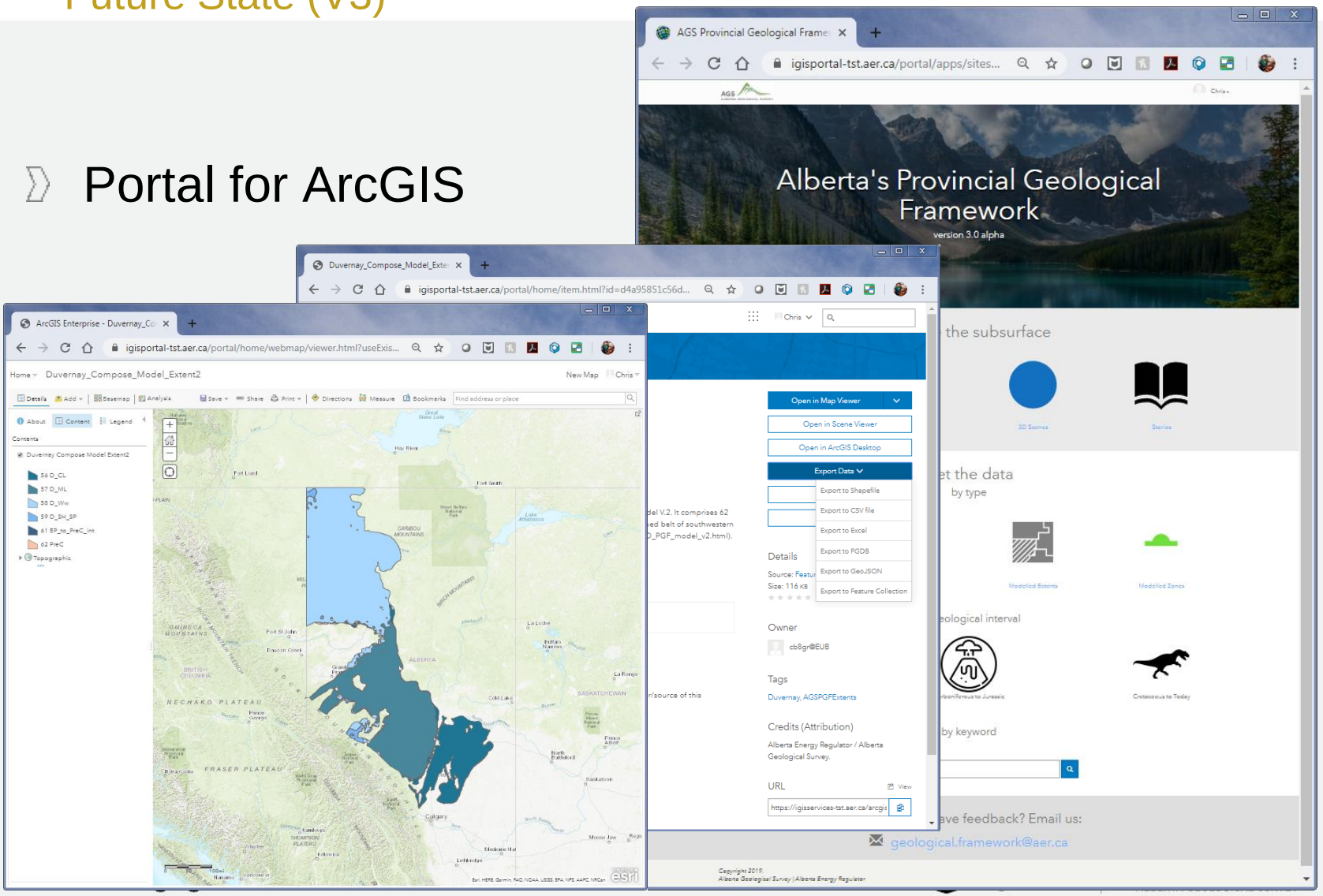
- iMOD collaboration with Deltares
- Petrel project file



How is it shared?

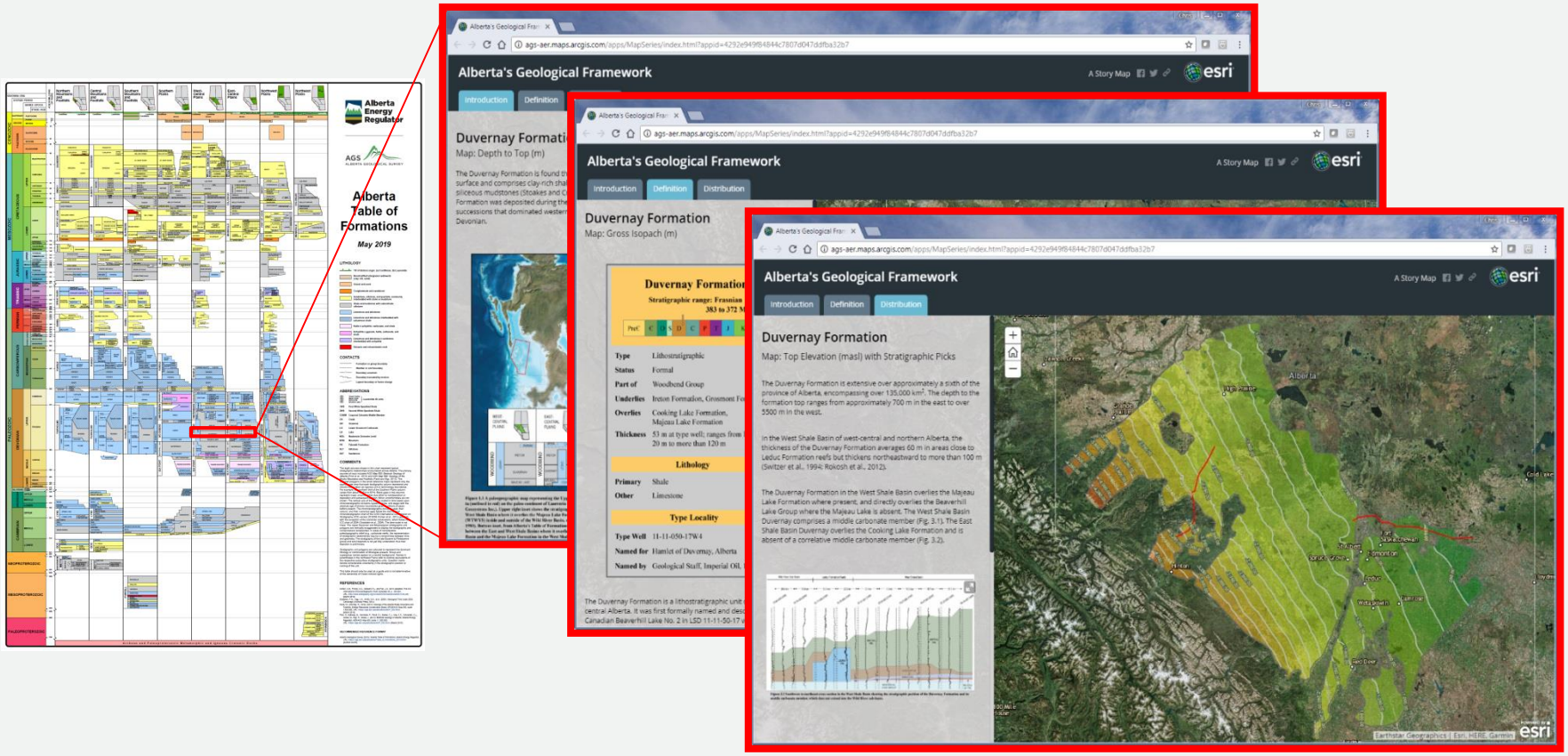
Future State (V3)

- Portal for ArcGIS

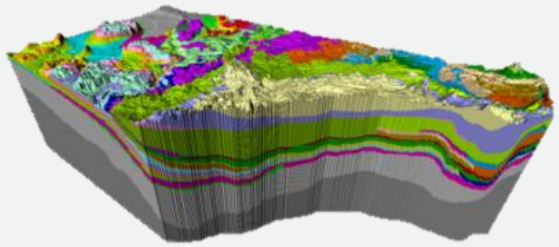


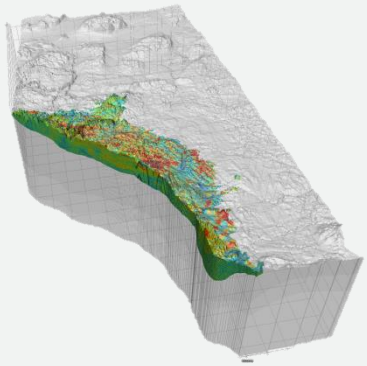
How is it shared?

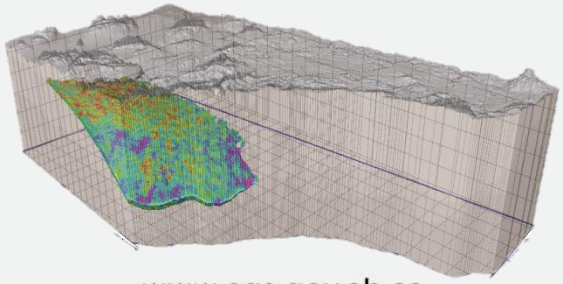
Future State (v3)



Next Steps….

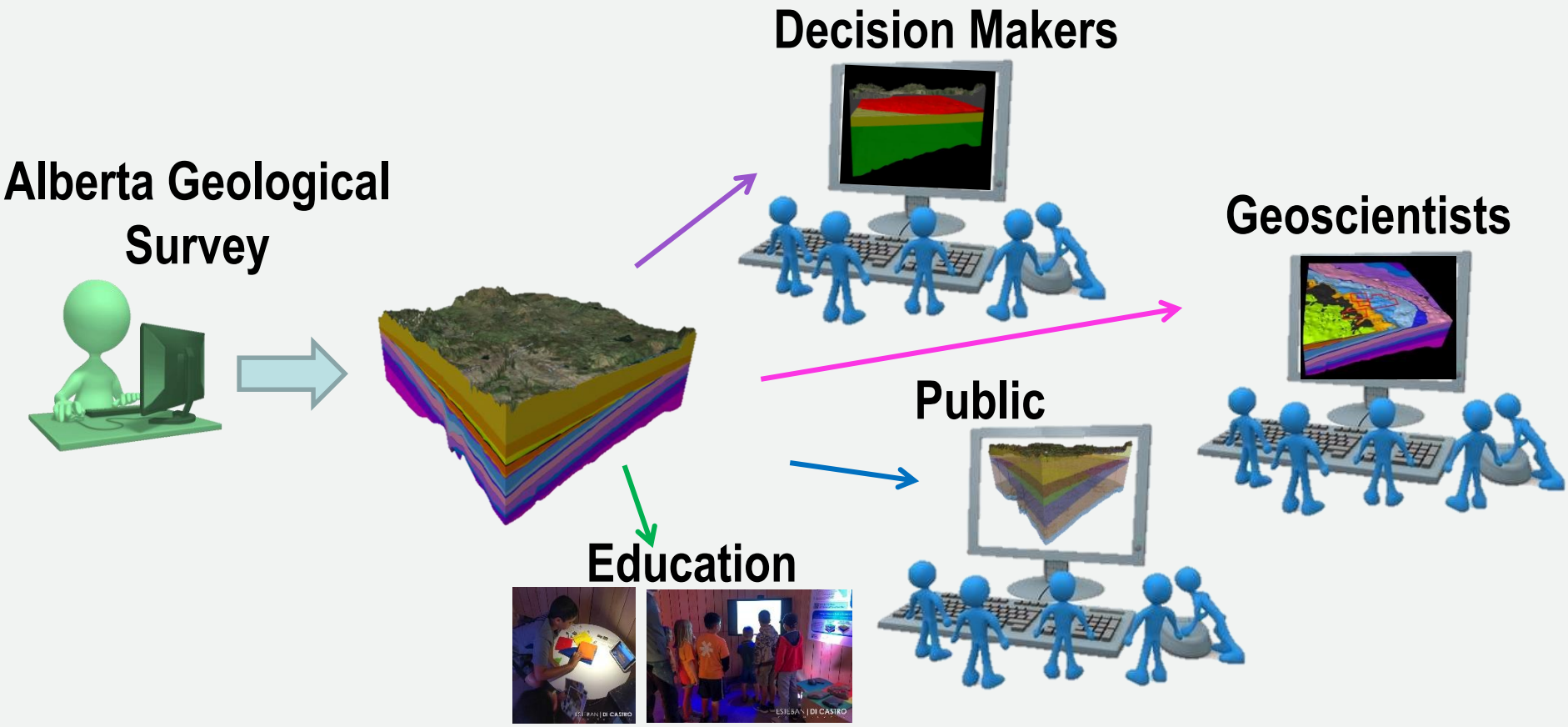






- Optimize data by leveraging machine and deep learning applications.
- Optimize our staff resources by allocating them to the areas where they can have the greatest impact.
- Support holistic science-based decision-making within Alberta (3D aquifer framework, multi-resource analysis)
- And finally……

Single Source of Geological Truth



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

Take Home: Geological Framework

- Provide **transparent** and **effective** communication of complex geological and environmental information to stakeholders using **tangible graphics and visualizations**, which are easy to understand and based on **scientific evidence**

- **Improve access** to geological information meeting the needs of our diverse stakeholder groups

Questions

Thank You

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