Characterizing Alberta’s subsurface in 3D – exploring innovative solutions to enhance communication of geoscience information to stakeholders and provide decision support

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Introduction

The Alberta Geological Survey (AGS) is developing a 3-dimensional (3D) geological framework for the province of Alberta (661,848 km²). Our goal is to develop ‘The Framework’ as a sophisticated platform, capable of integrating a variety of data types from multiple sources enabling the development of multi-scale, interdisciplinary models with built-in feedback mechanisms, allowing the individual components of the model to adapt and evolve over time as our knowledge and understanding of the subsurface develops. The Framework will be delivered as a multi-scale geocellular model based on the properties of each stratigraphic unit within the regional modelling domain (Figure 1). The success of this model is contingent on well documented and transparent processes to generate reproducible and scientifically credible predictions that can be used to communicate complex geology and subsurface geoscience information to users with various levels of background knowledge.

Figure 1. A) Birds eye view of the Geological Framework of Alberta. B) Oblique angle view of the Geological Framework. C) Cross-sections through the provincial scale model.

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Geological Framework Objectives

The Geological Framework of Alberta will provide the 3D geospatial context within which all geospatially referenced information either on the ground surface or within the subsurface can be integrated (Figure 2). Thus the Geological Framework will provide a mechanism to support data integration, and will also be used as a data repository to identify and visualize subsurface data. The Geological Framework has been used to support subsurface investigations by integrating a variety of subsurface data to more accurately and efficiently evaluate the relationship of subsurface properties and interactions, ultimately allowing for improved geologic risk characterization. The Geological Framework has been effectively used to provide a consistent and reliable subsurface geological context, ensuring efficient communication between subject matter experts, decision makers, stakeholders, and the general public. Ensuring that we can provide open access to our geoscience information in a way that all stakeholders can easily understand is a key component of regulatory excellence.

The Geological Framework has been built to:

1) The AGS has access to vast amounts of subsurface data (+465,865 wells), however not all of this information is considered to be high quality. Therefore, our modelling workflows must be able to account for data quality to ensure that the model results are more heavily influenced by the high quality data, while the impact of lower quality data is constrained to areas of sparse data coverage.

2) Have well documented workflows to ensure transparency and credibility in our modelling results.

3) Integrate models provided at a various scales throughout the province. The Geological Framework is designed to be multi-scalar ensuring that any modelling work done within the province, regardless of the level of detail required, can be incorporated back into the Geological Framework. This allows us to optimize and incorporate all modelling efforts within the province and preserve the highest level of resolution, detail, and accuracy possible.

4) Able to characterize geological complexity such as faults and unconformities, where present. These features can have a significant impact on subsurface investigations and should be accounted for when estimating subsurface complexity and uncertainty.

5) Be able to integrate multi-disciplinary datasets. The Geological Framework needed to be adaptable, in order to integrate all subsurface information with geospatial coordinates (X,Y,Z). Information without accurate Z coordinates can still be integrated into the Geological Framework by assigning the data to the most representative surface. This allows the Geological Framework to be used as both an individual and integrated resource management tool (Figure 3). Provide graphical representations of geological uncertainty to facilitate communication with stakeholders. The concepts of uncertainty can be difficult to communicate, especially in geographic areas where they vary significantly. The
Geological Framework provides geospatial estimates of uncertainty to provide stakeholders and decision makers with additional information about the models.

6) Support semi-automated systematic workflows to allow for **timely and efficient model updates** when new information becomes available. This allows us to produce multi-scalar models where necessary to address specific questions and ensure that this higher resolution information is integrated back into the Geological Framework. The system is also triggered to identify areas requiring further investigation or update when information integrated into the Geological Framework conflicts with current predictions. This feedback mechanism ensures that our models remain as accurate as possible.

**Current Development**

The Framework has been built using a fully documented geostatistical approach. The Grid Metadata system catalogues all the details necessary to reconstruct the model surfaces if required, as well as all the pertinent information derived from every model cross-validation run. Retaining this information allows us to plot the statistics and compare improvements to model with each successive cross-validation run to determine the point at which we have most effectively characterized the currently available data, beyond which additional runs would become superfluous. The benefits of analyzing the cross-validation results are two fold; 1) it allows us to improve the efficiency of our modelling efforts by identifying when the drop in model RMSE has stabilized, and 2) by identifying the number and location of potential outliers, we can alert the geologist to potentially unidentified issues within a dataset, or that there may be unexplained variability that requires additional characterization. This system allows us to measure model performance and document improvements.

Another positive attribute of the Framework is that the workflow has an adaptable design, which allows individual surfaces, or specific areas to be updated. The need to update and remodel these surfaces can be initiated by either internal or external triggers such as; 1) a significant amount of new data becomes available for a particular stratigraphic unit, 2) the results of an external project conflict with a current surface, or 3) a unit has not been updated for a long period of time and requires reassessment (Figure 4). This allows us to develop the Framework on an ‘as needed’ basis, by integrating units of varying quality and refinement, thereby allowing modelling tasks to be triaged and focused on those units that have the greatest strategic priority, or in specific regions identified as areas of high risk or concern.

![Figure 3. A) Cross-section through a 88,786 km² model in southern Alberta. B) Integration of groundwater and hydrocarbon resources within the model.](image)
Future Development

We are working to enhance the Geological Framework capabilities in a few key areas: 1) easy, open, and interactive access to our subsurface information, 2) Improve efficiencies in model building and updating, 3) enhanced predictive modelling capabilities.

It is important that we are providing open access to our subsurface information in a manner that is accessible and comprehensible to both industry, and the public. We are constantly looking for innovative ways to communicate and disseminate our 3D Geological Framework models, allowing users to interactively navigate our 3D subsurface geological models and geospatially referenced subsurface data. We need to put our subsurface geoscience information in the hands of our stakeholders and then let them explore. This will likely require multiple solutions to fully engage with our diverse stakeholder groups. For example, offering our subsurface geology in Minecraft format (#1 downloaded game with over 100 million downloads, as of February 2014) can be targeted at people between the ages of 5 and +100, and would allow generalized exploration of Albertas subsurface geology and resources.

Ensuring reproducibility of our modelling results is a key component of scientific credibility. However, in areas of high geological complexity, there are often many modelling steps that are taken in order to achieve the final model surface. Therefore we are in the process of developing semi-automated model
construction workflows to ensure model updates are more efficient and less susceptible to user error, and also serve as a method for documenting modelling procedures.

We are also working to enhance the predictive capabilities of our subsurface models by evaluating subsurface properties and interactions to characterize geologic risks. Once subsurface characteristics in known high-risk areas have been identified, we will query the Geological Framework to predict additional locations of potential risk based on similarities in subsurface characteristics.

**Summary**

The Alberta Geological Survey has made significant progress on the Geological Framework this year. Development has been focused in producing strategically located high-resolution sub-models, containing multi-disciplinary datasets to enhance communication of geoscience information to stakeholders and provide decision support. We are well underway to achieving our goal of developing the Geological Framework as a sophisticated platform capable of integrating multi-disciplinary data within a strategically developed, multi-scalar, geological context. The development of semi-automated workflows with built-in feedback mechanisms, will allow individual components of the model to adapt and evolve over time as our knowledge and understanding of the subsurface develops. The success of this model is contingent on well documented and transparent processes to generate reproducible and scientifically credible predictions that can be used to communicate complex geology and subsurface geoscience information to users with various levels of background knowledge.

**Take Home Message**

Our goal is to produce a 3-dimensional, multi-scalar, geostatistically optimized, probabilistically parameterized, geocellular model of Alberta to effectively communicate and disseminate geological information meeting the needs of a diverse stakeholder group to ultimately develop a tool for integrating information and communicating geoscience information with anyone.