Laurence Jayawardane
Mahshid Babakhani

Alberta Geological Survey
402, Twin Atria Building
4999-98 Avenue
Edmonton, AB
aer.ags.ca

The Three-Dimensional Provincial Geological Framework Model, Version 2: Updating a province-wide 3D geocellular model to incorporate 30 new model zones

Introduction

1. The Geological Framework Program

The Geological Framework Program is an ongoing modelling and data integration effort at the AER. Multiple AGS projects are associated with it, including this version of the three-dimensional (3D) Provincial Geological Framework (PGF) model: version 2 (v2). Table 1 lists its contributors.

Table 1: List of PGF Program contributors (to date).

Role	Contributors
Project Director	K.E. MacCormack[1]
Project Leaders	K. Haug[1] (v3-in progress), P. Branscombe[1] (v2-geological modelling) and T.E. Hauck[1] (v2-subsurface geology) and K.E. MacCormack (v2)
Subsurface Geology	B. Hathway[1], T.E. Hauck[1], T.L. Playter[1], J.T. Peterson[1], H.J. Corlett[1], D. Chen[1], C. Parsa[1], C. Fiweger[1], S.D.A. Anderson[1], F.J. Hein[1], M. Grobe[1], C.D. Rokosh[1], L.D. Andreashek[1], D.J. Lilling[1], G. Hartman[1], E.R. Tremere[1], S. Bolterfft[1], and previous Alberta Geological Survey / Alberta Energy Regulator staff
Geological Modelling	M. Babakhani[1] (v2, v3), L. Jayawardane[1] (v2, v3), M. Berhane[1] (petrophysical analysis), S. Lyster[1] (Morrisey property model), S. Mei[1] (Cardium and Paskapoo property models), E. Galloway[1] (v3-structure), L. Anderson[1] (v3-bedrock), S. Pawley[1] (v3-bedrock), F. Marshall[1] (Duvernay property model), P. Branscombe[1] (v1) and K.E. MacCormack[1] (v2)
Publication Process	S.D.A. Anderson[1], B.J. Fildes[1], J.E. Warren[1], E.J. Walters[1], M. Grobe[1], K. McKay[1], J. Lacroix[1] and K. Nanten[1]
Project Support	J.E. Warren[1], R. Elgr[1] and S. Glas[1]

[1]Alberta Energy Regulator, Alberta Geological Survey
[2]Formerly of the Alberta Energy Regulator / Alberta Geological Survey

2. The 3D Model: Version 2

The 3D PGF v2 model is comprised of 210 million cells (Table 2), for a total of 62 model zones. It incorporates many updates, including:
- changes to modelling methodology,
- incorporation of vast amounts of new stratigraphic wellbore picks used as input (increase by 614,949 points), and
- further subdivision of the model to refine its vertical resolution (net change: 30 additional zones added).

Table 2: Statistics of the 3D PGF v2 model.

Item	3D PGF v2 model
Input Data	1,235,701 input points; interpolated polylines - stratigraphic picks: 99.8% of point dataset - remaining 0.2%: outcrop, mine, incorporated map information, guide points
Areal extent	602,825 km²
Depth	6 km below sea level
Horizontal resolution	500 x 500 m (aligned N-S)
Vertical resolution	62 single-layer model zones
Cell count	210,706,112 cells (as 4 separate 3D grids)
Model type	Deterministic; stratigraphic; no calculated properties

The 3D PGF v2 Model: Modelling Workflow

The 3D PGF v2 model (Figure 1) is an evolution of its predecessors. The modelling workflow for v2 includes these major changes to methodology:

1. Creation of "continuous surfaces" to serve as bounding elements of all zones (Figure 2), spanning the areal extent of the entire model, regardless of areal extent of zone modelled. The 2D surfaces used as input to the 3D model were built sequentially (Figure 2).

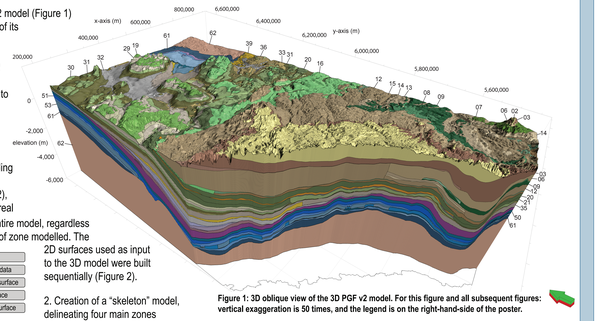

Figure 1: 3D oblique view of the 3D PGF v2 model. For this figure and all subsequent figures: vertical exaggeration is 50 times, and the legend is on the right-hand-side of the poster.

Figure 2: Data cleanup and input surface creation workflow for all surfaces used as input to the 3D PGF v2 model.

2. Creation of a "skeleton" model, delineating four main zones associated with major geological elements (Figure 3A):
- crystalline Precambrian basement,
- cratonic platformal succession of the Western Canada Sedimentary Basin (WCSB),
- foreland basin succession of the WCSB,
- Neogene-Quaternary surficial deposits.

3. Splitting of entire modelling process between two geomodellers. The surfaces of the platformal succession (Figure 2B) were built in parallel to those of the foreland basin succession (Figure 2C).

4. Introduction of automated workflows to aid in faster updates during 2D and 3D modelling.

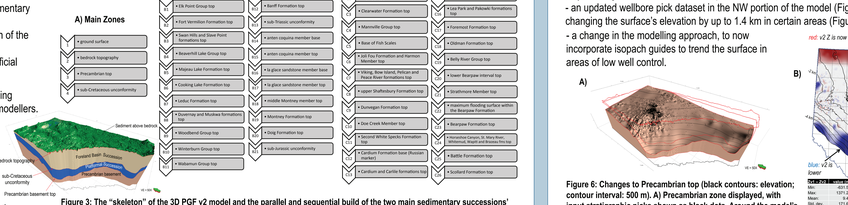

Figure 3: The "skeleton" of the 3D PGF v2 model and the parallel and sequential build of the two main sedimentary successions' input surfaces. A) Top: Sequential build order of the main "skeleton" surfaces. Bottom: The model's main zones. B) Sequential build order of the surfaces present within the platformal succession main zone. C) Sequential build order of the surfaces present within the foreland basin succession main zone.

Unconformities: Elevation Surfaces

1. Bedrock Topography

Many new zones subcrop at bedrock (Figure 4A). Main changes include:
- use of Map 602 elevation grid as input to bedrock topography (effects in Peace River valley, Caribou and Birch Mountains, Figure 4B), and
- local update in the McMurray Formation subcrop area (Figure 4B).

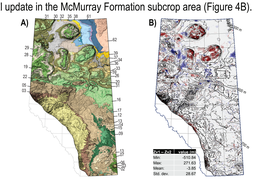

Figure 4: Updates to bedrock topography. A) Subcrop map at bedrock topography, showing zones of the PGF v2 model. B) Difference map between elevation grids for bedrock topography for v1 to v2 (red: the surface was raised, blue: surface was lowered). Contours: current bedrock topography elevation grid (100 m contour interval). Inset table: statistics of the Zv1-Zv2 calculation.

2. sub-Cretaceous Unconformity

Main changes to this surface include a 23% increase in the dataset (24,508 new points used as input), resulting in:
- an increase the detail of the structural grid (Figure 5A), and
- a localization of the standard deviation uncertainty around areas of low well control and of high structural relief (Figure 5B).

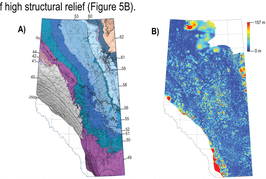

Figure 5: Updated sub-Cretaceous unconformity. A) Subcrop map at the unconformity, showing zones of the PGF v2 model. Contours show the elevation of the unconformity (contour interval: 250m). B) Standard deviation uncertainty map.

3. Precambrian Top

Major changes to the Precambrian top are noted, due to:
- an updated wellbore pick dataset in the NW portion of the model (Figure 6A), changing the surface's elevation by up to 1.4 km in certain areas (Figure 6B), and
- a change in the modelling approach, to now incorporate isopach guides to trend the surface in areas of low well control.

Figure 6: Changes to Precambrian top (black contours: elevation; contour interval: 500 m). A) Precambrian zone displayed, with input stratigraphic picks shown as black dots. Around the model's edges, the major unconformities used to delineate the main zones are shown in red. B) Difference map between the structural surfaces for v1 and v2, highlighting in red where the surface was raised, and in blue where it was lowered. Inset table: statistics of this calculation.

Foreland Basin Succession: Highlights

1. Edmonton Group & Equivalents

New zones were added (Figure 7):
- the Wapiti and Brazeau formations (zone 5) were split from Horseshoe Canyon Formation and equivalents (zone 6),
- a new dataset was used for Bearpaw top (zones 7 and 8), and
- the MFS dataset re-assigned to zone 9 top.

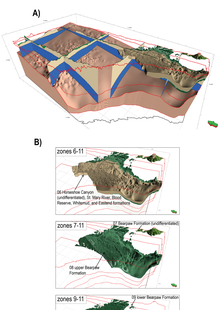

Figure 7: Some of the 3D PGF v2 zones within the Edmonton Group (zones 6-11).

2. Belly River Group

A new zone was added (zone 12), incorporating the undifferentiated portion of the Belly River Group (Figure 8).

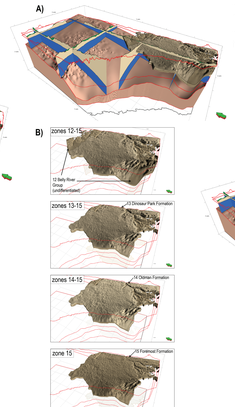

Figure 8: All 3D PGF v2 zones within the Belly River Group (zones 12-15).

3. Colorado Group & Equivalents

The Colorado Group and its correlative equivalents were defined in v2. Three v1 zones were subdivided into 18 zones in v2 (zones 16-34). Highlights include:
- new zones around the Cardium Formation (Figure 9),
- new zones from Doe Creek Member top to the base of Fish Scales marker (Figure 10), and
- new zones in Lower Cretaceous between the base of Fish Scales and the Mannville top.

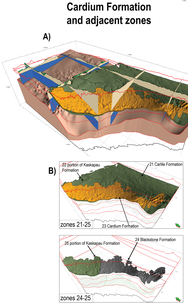

Figure 9: Some of the 3D PGF v2 zones within the Colorado Group and its correlative equivalents associated with the Cardium Formation (zones 21-24).

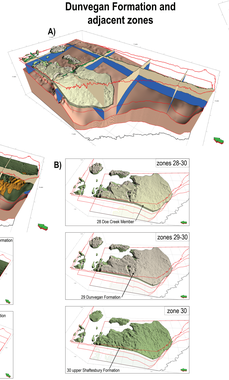

Figure 10: Some of the 3D PGF v2 zones within the Colorado Group and its correlative equivalents associated with the Dunvegan Formation (zones 28-30).

4. Mannville Group & Equivalents

The Mannville Group and its correlative equivalents, which was comprised of one zone in v1, is subdivided into 5 zones in v2 (zones 35-39).

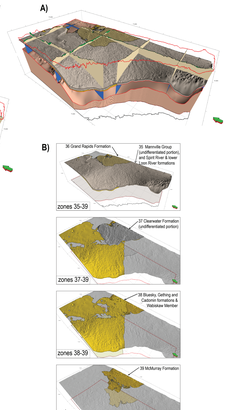

Figure 11: All 3D PGF v2 zones within the Mannville Group and its correlative equivalents (zones 35-39).

Figure 7-13: A) Zones displayed within the context of the 3D PGF v2 model's main zones. B) Zoomed in oblique 3D view of the zones, displayed sequentially for visual context of their vertical relationships.

Platformal Succession: Highlights

1. Diaber Group

Updates to the Diaber Group include new subdivisions in v2 from sub-Cretaceous unconformity to Banff top (zones 40-49), of which 7 new zones lie within the Diaber Group (Figure 12).

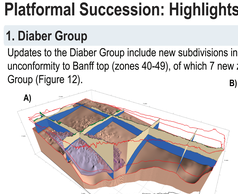

Figure 12: All 3D PGF v2 zones within the Diaber Group (zones 42-48).

2. Woodbend Group

Updates to the Woodbend Group include:
- onlap relationships refined around the Peace River Arch (Figure 13A),
- Cooking Lake and Leduc formations extended northward (Figure 13B),
- Muskwa Formation added to zone 54, and
- Woodbend Group (undifferentiated portion) grouped into a single zone.

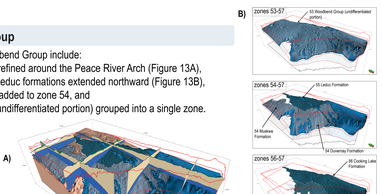

Figure 13: All 3D PGF v2 zones within the Woodbend Group (zones 53-57).

Summary

The Geological Framework Program is an ongoing effort at the AER, to support science-based decision making. The PGF v2 is an update of the associated 3D model, incorporating new data and new zones to this regional-scale geomodel (Figure 14). The model thus is more detailed at the zones' tops and bases, as well as vertically.

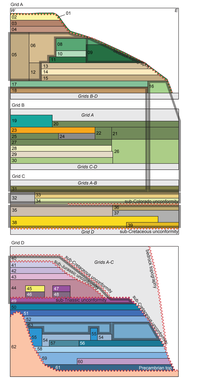

Figure 14: Schematic, generalized representation of the main zonal relationships for all PGF v2 zones (not to scale). These were split between the four 3D grids created for this model. The thick black outlines represent zones from the v1 model, when different from the v2 ones.

Way Forward

The ongoing PGF Program includes property modelling of individual formations and proof-of-concept projects related to incorporating new data types into the model (structural elements, mineral resources). Construction of the 3D PGF v3 model is already underway, and will feature additional zones and input data.

Legend for Figures

Getting in Touch

The 3D PGF v2 model is available online at *ags.aer.ca*. Email us at *geological.framework@aer.ca*.

References

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