



Three-Dimensional Property Modelling of the Duvernay Formation in Alberta

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Abstract

The Upper Devonian Duvernay Formation is present in the subsurface of most of central Alberta except where the stratigraphically equivalent Leduc Formation carbonate platforms and reefs are located, defining two distinct regional areas of Duvernay Formation deposition: the West Shale Basin (WSB) and the East Shale Basin (ESB). The organic-rich shales and carbonate and silicious mudstones of the Duvernay Formation have long been considered an important source rock for hydrocarbon accumulations in Alberta and, more recently, have become a major target for unconventional oil and gas exploration and development.

Two three-dimensional (3D) property models of the Duvernay Formation were created. The WSB and ESB were modelled separately due to the differences in depositional and petrophysical properties of each basin. The modelling was focused on the Duvernay Formation and excluded the Leduc Formation platforms and reefs.

The WSB and ESB Duvernay 3D property models cover an area of approximately 86 532 km² and 34 984 km² respectively, and include the entire thickness of the Duvernay Formation. The skeleton of the two 3D property models builds on the 3D Provincial Geological Framework Model of Alberta, Version 1, and was supplemented with more detailed internal architecture and modelled properties for the Duvernay Formation including total porosity (PHIT), total organic carbon (TOC) and carbonate fraction from petrophysical analysis of oil and gas well data; as well as temperature and pressure gradients, condensate-gas ratio (CGR), and gas-oil ratio (GOR) from production data.

The models were created in Schlumberger's Petrel 2015 (Petrel) and exported in non-proprietary formats for use in other software. The 3D property models are available for download in the following formats:

- Petrel model files,
- a deconstructed model dataset composed of discrete and continuous model horizons as Esri format grids, and zone model extent shapefiles,
- populated model properties as point data in ASCII format, and
- an iMOD model dataset package.

All of the standard format digital datasets can be viewed in iMOD, an open source software, and Petrel, enabling users to visualize rotate, slice, explode, and toggle data on and off in 3D. The iMOD software provides users with an interactive geospatial environment where end users can manipulate 3D geological models and import their own geospatially referenced subsurface and surface data into it.

1 Introduction

The organic-rich shales and carbonate and silicious mudstones of the Duvernay Formation are an Upper Devonian hydrocarbon source rock in the subsurface of much of central Alberta except where the stratigraphically equivalent Leduc Formation carbonate platforms and reefs are present. The Duvernay Formation is the source rock for many conventional plays in the Western Canada Sedimentary Basin and, in recent years (15+), has been a target of unconventional shale gas, natural gas liquids, and oil development. The aerial extent of the Duvernay Formation can be divided into two main areas: the West Shale Basin (WSB) in west-central Alberta and the East Shale Basin (ESB) in east-central Alberta ([Figure 1](#)).

Two 3D property models of the Duvernay Formation provide an updated regional view of the Duvernay Formation in Alberta. Because of differences in depositional architecture and petrophysical characteristics of the Duvernay Formation between the WSB and ESB, two separate 3D property models were created. The Duvernay 3D property models do not include the Leduc carbonate platforms and reefs that border the basins. The Leduc reefs within the WSB and ESB were modelled as a separate facies and not populated with properties for this study ([Figure 1](#)). The WSB and ESB Duvernay 3D property models cover approximately 86 532 km² and 34 984 km² respectively and were generated from the base of the Duvernay Formation to its top. For reference, [Figure 2](#) shows an isometric view of the WSB and ESB Duvernay 3D property models within the 3D PGF model v1 (Branscombe et al., 2018a, b).

This modelling effort is a compilation of a substantial amount of previous AGS work. The 3D property models are a continuation of previous work done by Lyster et al. (2017) and build on work from the 3D Provincial Geological Framework Model of Alberta, Version 1 (3D PGF model v1) (Branscombe et al., 2018a, b). The 3D property models were built using Petrel 2015 by assembling legacy AGS data, corporate data holdings from the AER, and new interpretations provided by AER/AGS geologists. These datasets were compiled and used to build the 3D property models using an iterative approach with the assistance of an AGS geologist providing input at each stage to improve model results and ensure the models provided a realistic representation reflecting our current understanding and knowledge.

1.1 Objectives

This report documents the methodology used to construct the 3D geocellular models of the properties of the Duvernay Formation in Alberta and provides information about the spatial distribution of input data and modelled properties. This report outlines the modelling workflow and provides the parameters used during structural and property modelling. This allows critical evaluation of the modelling, aids reproducibility, and increases efficiency in future property modelling projects.

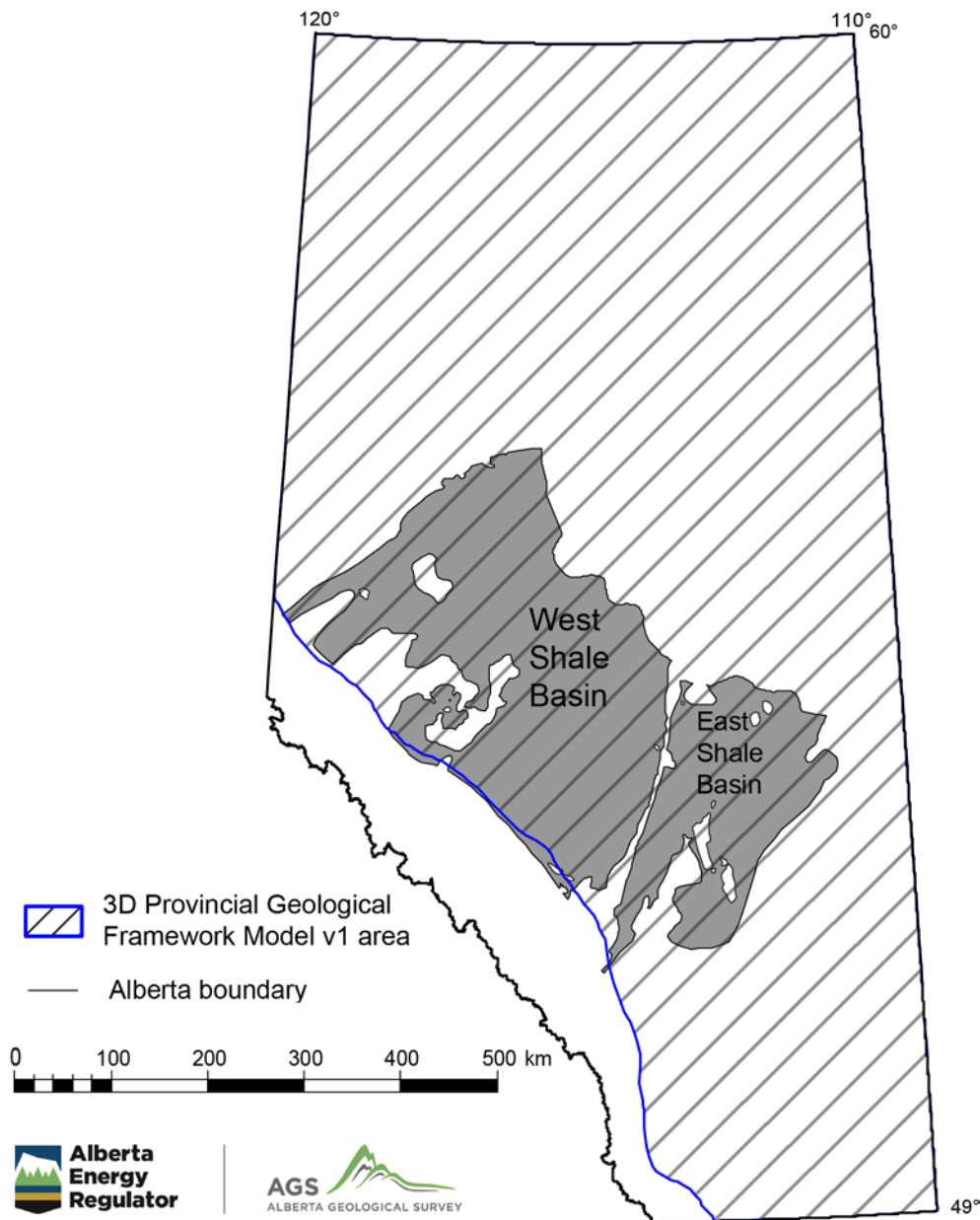


Figure 1. Map showing the location and extent of the Duvernay Formation (dark grey) in Alberta. The Duvernay Formation is divided in two basins, the West Shale Basin (WSB) and the East Shale Basin (ESB).

2 Stratigraphic Framework

The Duvernay Formation is part of the Upper Devonian Woodbend Group in Alberta, ([Figure 3](#)) and was deposited as basin-filling fine-grained sediments (organic-rich, argillaceous, calcareous and siliceous muds) in areas between the stratigraphically equivalent Leduc Formation carbonate platforms and reefs (Switzer et al., 1994). In the ESB, the Duvernay Formation overlies the platform carbonates of the Cooking Lake Formation. In the WSB, the Duvernay overlies the basinal Majeau Lake Formation in all areas except in the northwestern portion of the WSB, referred to as the Wild River area, where it was

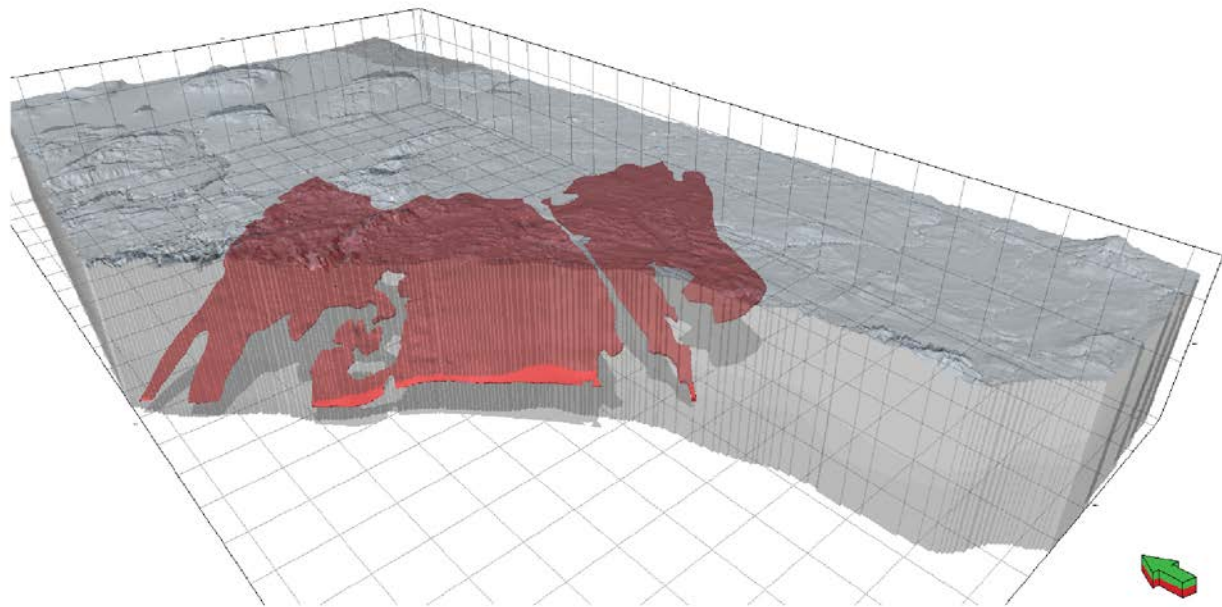


Figure 2: An isometric view of the WSB and ESB Duvernay 3D property models (red solids) within the 3D PGF model v1 (grey transparency) (data from Branscombe et al., 2018b). Vertical exaggeration is 25 times.

deposited directly on Beaverhill Lake Group strata (Wendte et al, 1998). In both the ESB and WSB, the Duvernay Formation is overlain by calcareous shales and argillaceous limestones of the Ireton Formation. Throughout most of the WSB, a middle carbonate layer has been recognized in the Duvernay Formation separating it into upper and lower shale units (Munson, 2015; Walter et al., 2016). In the ESB, the Duvernay Formation has an overall higher carbonate content than in the WSB, which is likely due to shedding of carbonate material from the Leduc reefs and platform margins that completely surround the ESB, making it impossible to discern a distinct middle carbonate layer.. The upper and lower Duvernay shales in the WSB are rich in clay and silica, and in general, contain higher levels of total organic carbon (TOC) than the middle carbonate layer. The ESB shales are comprised of carbonate and clay with variable TOC content throughout.

3 Model Definitions

This section provides a common terminology and defines model inputs and outputs as in Branscombe et al. (2018a). The authors use a standardized terminology to ensure the methodology used to generate, store, and visualize the 3D geological models created at the AGS is the same. The terminology used for the modelling process is outlined below:

Common Terminology

- **3D simple grid:** A simplified process/step when creating 3D grids with no faults in Petrel.
- **3D pillar grid:** A process/step when creating 3D grids that may or may not have faults in Petrel and more closely follows the model boundaries. More robust than the 3D simple grid process.
- **3D geocellular grid:** A 3D geological model divided into cells/voxels resulting from the 3D simple

grid or 3D pillar grid process.

- **discrete surface:** An interpolated surface that does not span the entire model extent (see interpolated surface) (see [Figure 4](#)).
- **property:** A value that represents a physical or reservoir characteristic of a defined volume of rock.

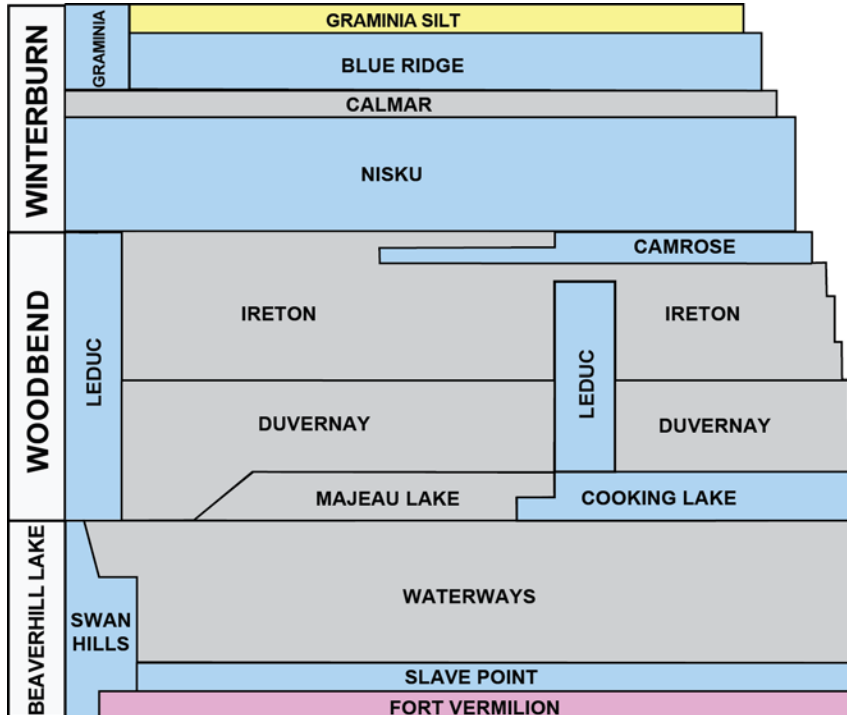


Figure 3. A simplified stratigraphic column for the Devonian in central Alberta.

Model Inputs

- **source data:** A set of unfiltered, original, multisource point data defining the stratigraphic pick of a zone top or base. These data include geospatial coordinates (x, y) and elevation (z) information. Most of the data are from well boreholes and have a unique well identifier (UWI); however, a UWI is not provided for outcrop or lineament sampled data.
- **input filtered data:** A set of geostatistically filtered, multi-source point data defining the stratigraphic pick of a zone top or base. These data include UWI, geospatial coordinates (x, y), and elevation (z) information. This dataset excludes outliers and erroneous data captured in the *source data*. The outliers and erroneous data were eliminated in a series of successive culls to reduce global uncertainty.
- **input extent / lineament(s):** A set of discrete polygons or polylines delineating a zone top or base zero-edge, subcrop edge, or other GIS information outlining a zone top or base and attributed with elevation (z) values.
- **interpolated surface:** A discrete gridded surface interpolated in modelling software over the geospatial extent of a zone top or base from *input filtered data* and *input extents / lineaments* (if applicable). Defines the elevation (z) of a zone top or base and is manipulated where necessary to eliminate cross-overs with adjacent *interpolated surfaces* and/or to honour unconformities.

Interpolated surfaces are considered primary input data for the construction of a model and are used to constrain the top and base of a model as well as discretizing the model within. Each *interpolated surface* is defined as a particular type to define the geological relationship to other contacts (e.g., erosional, conformable, etc.), which ensures the geospatial and temporal relationships of all zone tops and bases are honoured.

- **geo-edge:** A set of polygons or polylines used to constrain (or clip) an *interpolated surface* to areas where the zone is present, as defined by a zero-edge and/or a subcrop-edge. *Geo-edges* are primarily defined by the geologist or geomodeller based on the distribution of zone stratigraphic picks and/or from external supporting data such as previously published literature.
- **continuous surface:** A gridded surface generated from discrete *interpolated surfaces* and modelled to span the entire model extent. Although a formation may only exist in part of the province, the surface must be modelled to cover the entire province to ensure the zone is completely sealed for continuous style model construction. To do this, we merge the discrete surface with the nearest surface or unconformity if the discrete surface is subcropping or outcropping (see [Figure 4](#)).

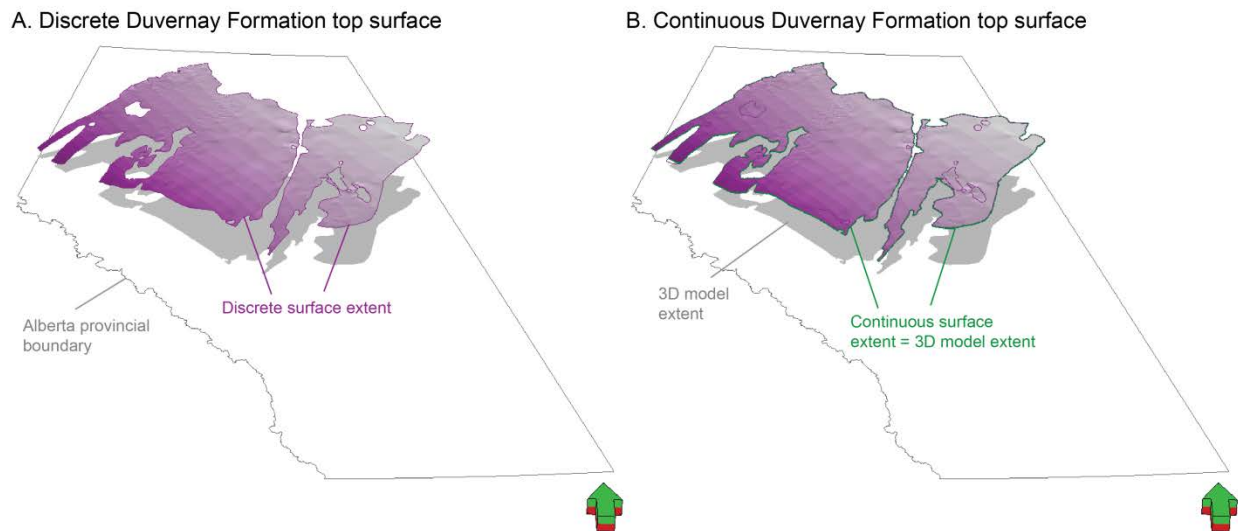


Figure 4. Illustration of the difference between discrete and continuous surfaces using the Duvernay Formation top surfaces as an example (vertical exaggeration is 25 times). The continuous surface of the Duvernay Formation top (B) is a resampled surface of the discrete Duvernay Formation top surface to cover the extended boundary and the internal Leduc reefs (A).

Model Outputs (illustrated in)

- **model tabular data:** The set of finalized stratigraphic data selected from the *input filtered data* with lowest global uncertainty; published with UWI, geospatial coordinates (x, y), elevation (z) and dataset source for zone top and bases as a point dataset.
- **model extent:** A polygon that defines the boundary of a zone top or base *model horizon* and is attributed with elevation (z) values.
- **model horizon:** A grid that represents the 3D distribution and elevation of a zone top or base. It captures the geospatial extent and elevation (z) values of discrete *interpolated surfaces*; however, where sufficient minimum vertical 3D geocellular grid cell sizes are not achieved, the horizon does

not exist. The collection of all model horizons partitions the 3D geocellular grid into a series of *model zones*.

- **model zone:** Defines the vertical resolution of the 3D simple grid between *model horizons*.
- **model:** The combination and construction of all model zones in correct stratigraphic sequence.
- **property model:** The populated geocellular grid with defined property values for all cells/voxels with nonzero volumes.

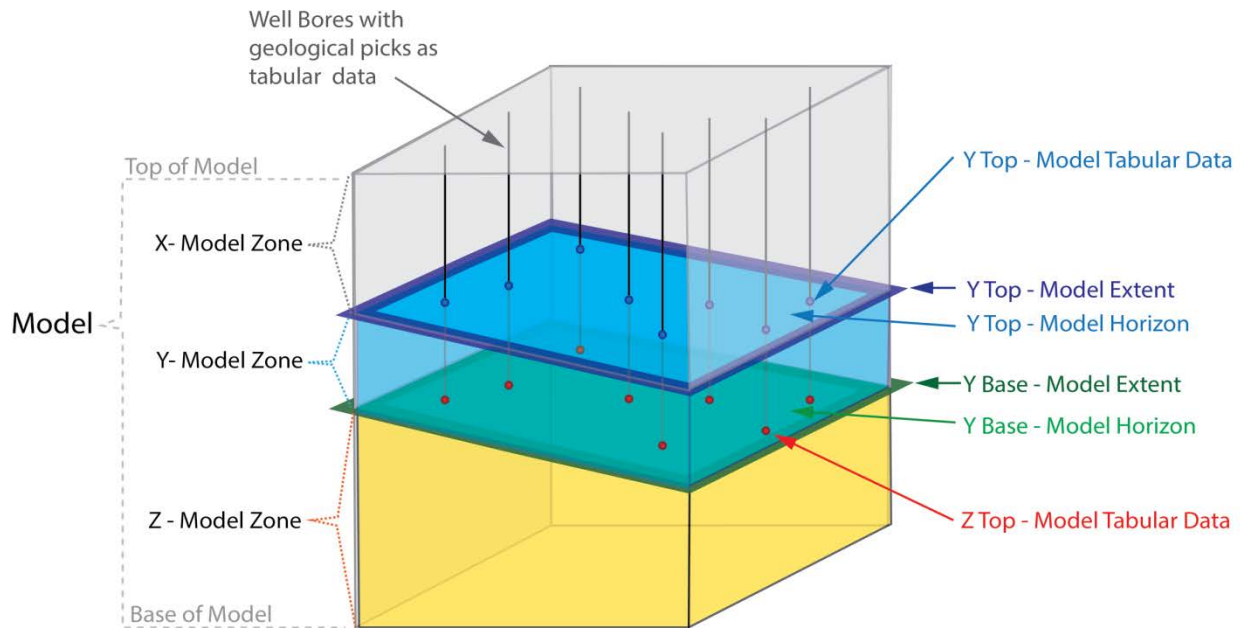


Figure 5. Illustration of model outputs showing the relationship between the model, model tabular data, model extents, model horizons, and model zones (Branscombe et al., 2018a).

4 Modelling Workflow

This section outlines the AGS Property Modelling Workflow that is an extension of the current AGS Geomodelling Workflow (Branscombe et al., 2018a). The AGS Property Modelling Workflow focuses on populating properties within a 3D geocellular grid with properties after the framework model construction is complete, and expands on Part 5, Model Construction.

The current AGS Geomodelling Workflow is grouped into six main steps described below:

- a) **Part 1: Input Data and Stratigraphic Framework (Section 5.1)**
 - a. compile all source data (input points, lineaments and extents)
 - b. combine multisource input data defining the top and base of each zone
 - c. establish conceptual geological model(s) and convey to geomodeller(s)
 - d. completed by geologists and geomodellers
- b) **Part 2: Geostatistical Analysis**
 - a. geostatistically filter source data
 - b. achieve stabilization of global uncertainty
 - c. completed by geomodellers
- c) **Part 3: Input Surface Interpolation and Manipulation (Section 5.2 and 5.3)**

- a. create interpolated surfaces for tops and bases of zones
 - b. manipulate interpolated surfaces to honour unconformable surfaces
 - c. manipulate interpolated surfaces to ensure no crossovers with adjacent surfaces
 - d. manipulate interpolated surfaces to geo-edges (if applicable)
 - e. assess alignment with conceptual model(s)
 - f. completed by geomodellers
- d) **Part 4: Uncertainty Analysis (Section 5.4)**
- a. provide uncertainty analysis for interpolated surfaces
 - b. completed by geomodellers
- e) **Part 5: Model Construction (Section 6)**
- a. generate a 3D geological model of all zones from specified input parameters
 - b. *populate properties (Section 6.2, 6.3, & 6.4)*
 - i. *facies model (Section 6.2)*
 - ii. *3D property model (Section 6.3)*
 - iii. *2D property model (Section 6.4)*
 - c. completed by geomodellers
- f) **Part 6: Model Dissemination (Section 7)**
- a. disseminate deconstructed 3D property model outputs
 - b. disseminate iMOD package for 3D visualization of model
 - c. completed by geomodellers

The AGS Geomodelling workflow has three main phases, pre-construction phase (parts 1 to 4), the construction phase (part 5), and the dissemination phase (part 6). This report focusses on model construction in Part 5.

5 Model Input Data

The 3D property modelling methodology relies on a series of model input data which were created following Parts 1 and 2 of the workflow outlined in the previous section. Input data include geostatistically filtered data from subsurface data sources and interpolated surfaces generated from these datasets in Petrel. The following sections provide information about the input data, surface interpolation, and surface manipulations.

5.1 Input Source Data

Part 1 of the AGS Geomodelling Workflow includes compiling all available source data required for constructing the 3D property models. Three types of data were used: stratigraphic data, 3D property data, and 2D property data.

5.1.1 Stratigraphic Data

Stratigraphic data include previously created discrete surfaces, stratigraphic picks, input extents, and geo-edges, which were used to build the structural framework of the model.

Previously created discrete surfaces from the 3D PGF model v1 (Branscombe et al., 2018b) were imported to define the top and base of the Duvernay Formation, which in turn represent the top and base of the 3D property models in the WSB and ESB. The discrete surfaces from the 3D PGF model v1 were considered discrete due to the presence of gaps over the Leduc reefs within the basins (Figure 6).

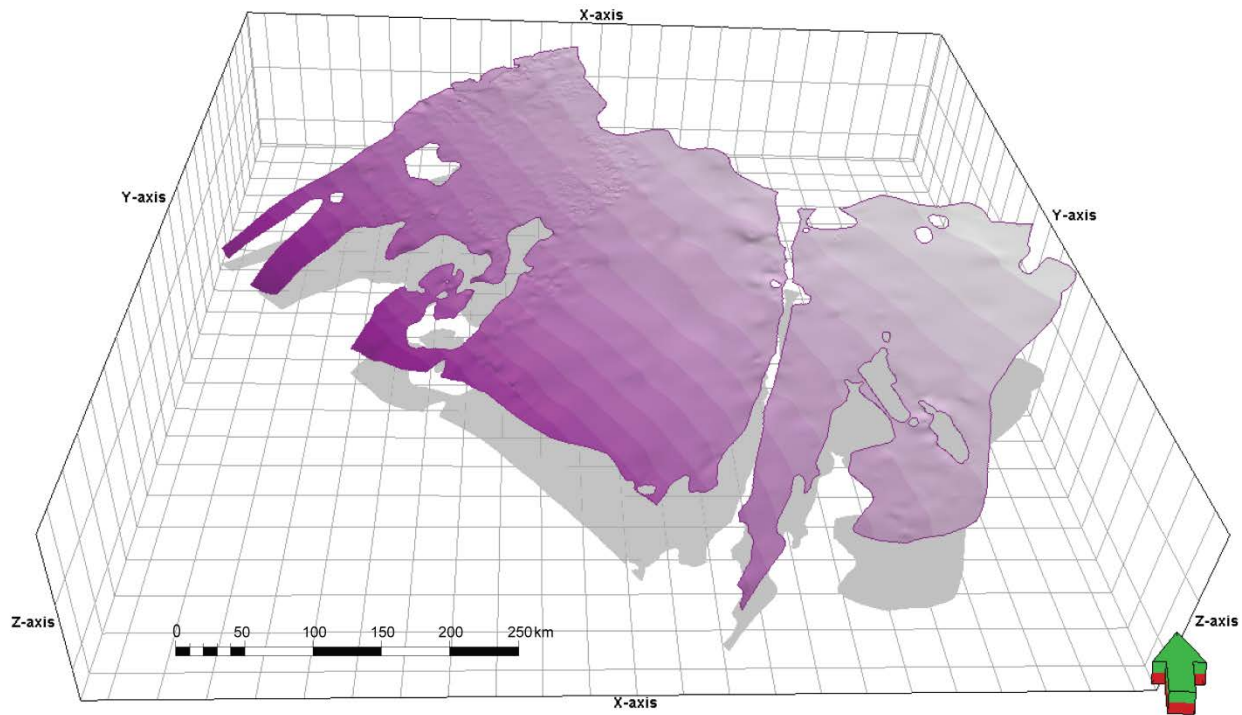


Figure 6. Example of discrete surface, Duvernay Formation top surface showing gaps representing the Leduc reefs within WSB and ESB. Data from Branscombe et al. (2018b). Vertical exaggeration is 25 times.

A total of 4309 stratigraphic picks (picks) were provided by AER/AGS geologists to describe the internal architecture of the Duvernay Formation, which were interpreted from down-hole well logs from oil and gas wells. The picks define the top and base of the WSB Duvernay 3D property model carbonate zone. The ESB Duvernay 3D property model does not have a differentiated carbonate zone. The initial data set consisted of 2202 carbonate zone top picks and 2204 carbonate zone base picks. Picks were visualized in 3D to look for and remove outliers. After culling, the final dataset contained 2152 carbonate zone top picks, and 2157 carbonate zone base picks. The picks were compiled and exported as x, y and z (elevation) from Petra software and imported into Petrel as a point dataset. [Figure 7](#) shows a map of the carbonate zone top picks and [Figure 8](#) shows a map of the carbonate zone base picks.

Input extents/geo-edges for the 3D property models include polygon lines defining the zero-edge of the carbonate zone and aerial extent of the Leduc reefs that are present within the WSB and ESB as interpreted by AGS geologists. The extents polygons were compiled and exported from Petra software and imported into Petrel.

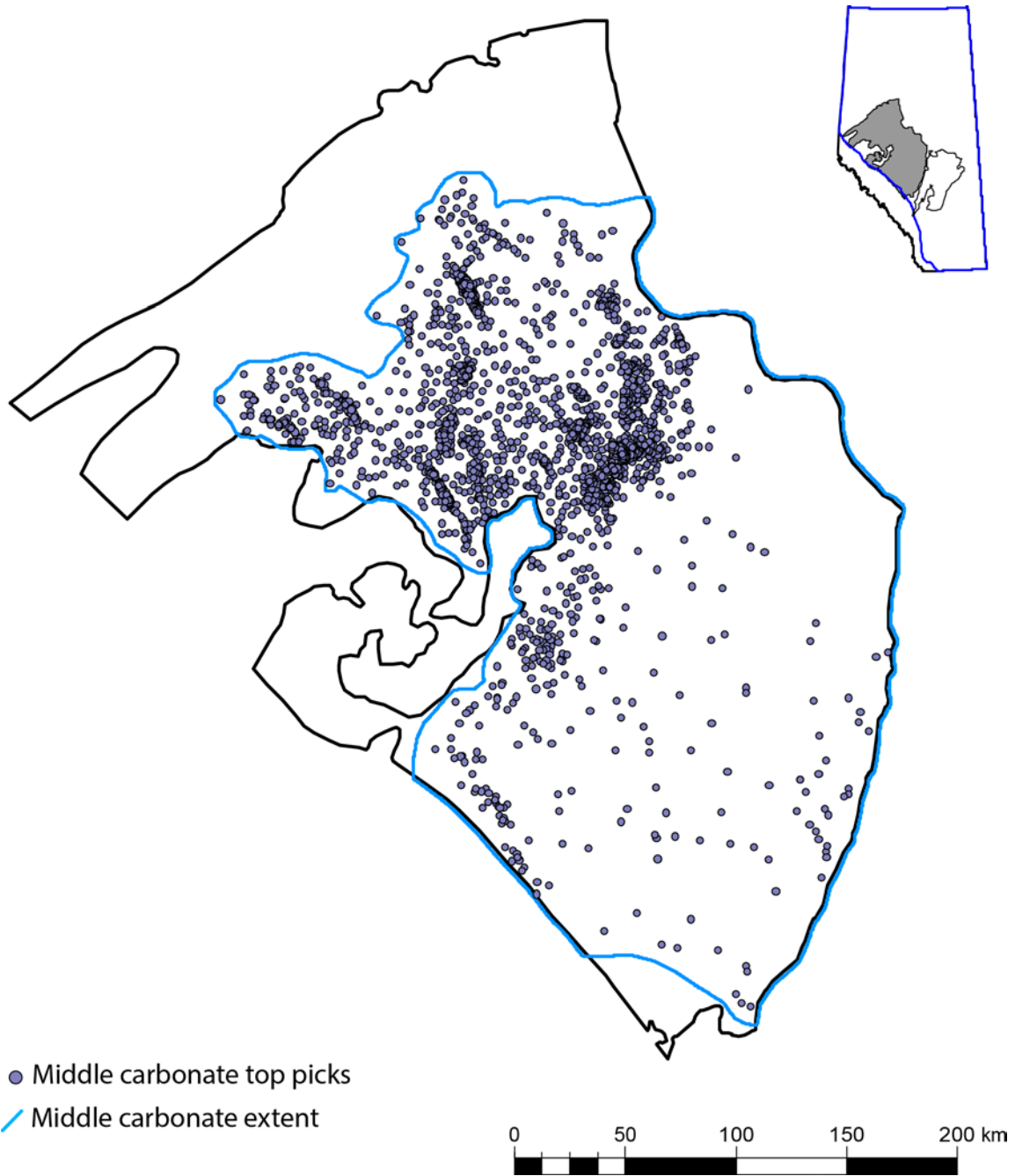


Figure 7: Location map of the 2152 carbonate zone top picks used for modelling.

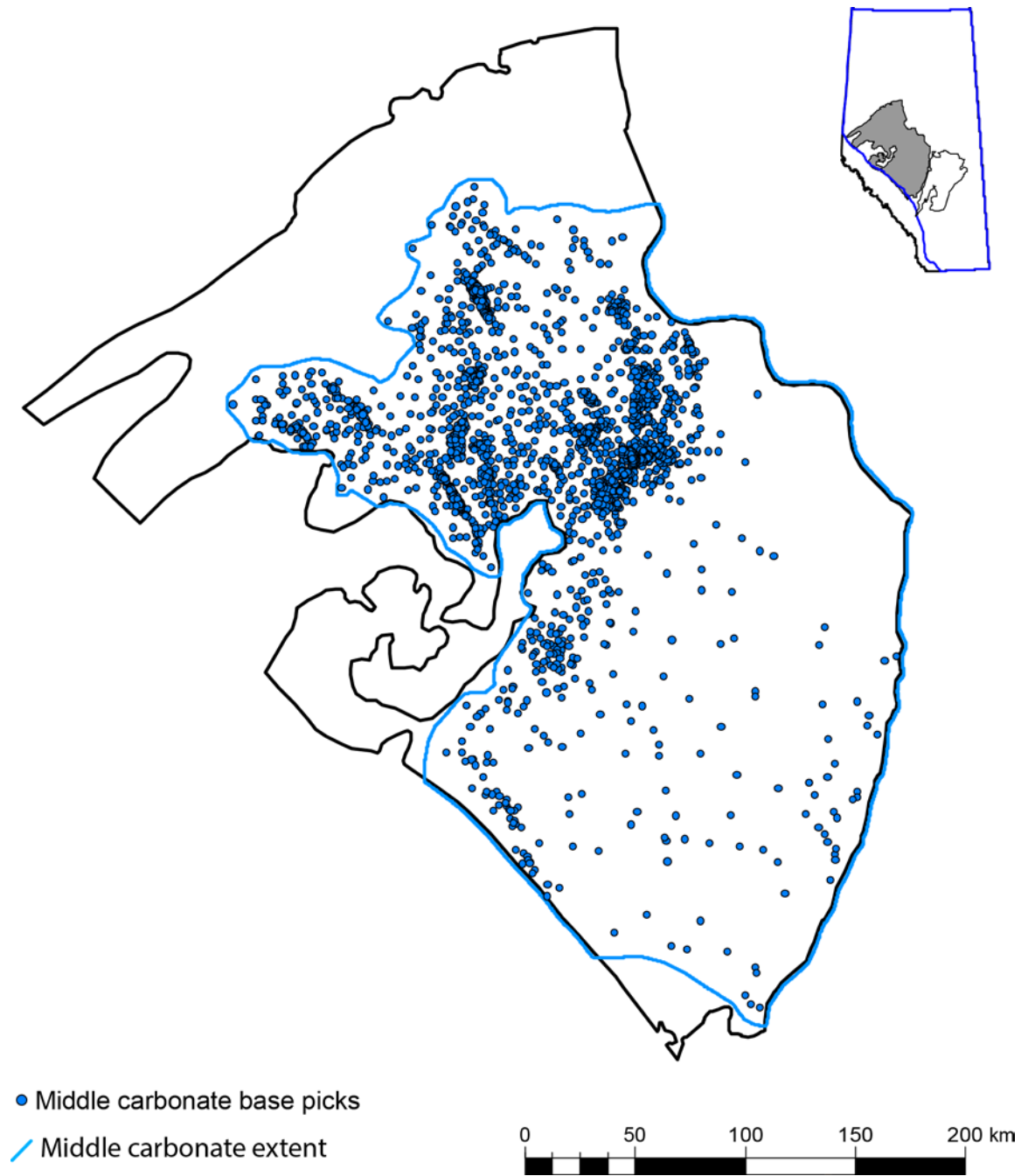


Figure 8: Location map of the 2157 carbonate zone base picks used for modelling.

5.1.2 3D Property Data

The 3D property models were built using data from petrophysical logs calculated from vertically continuous oil and gas well logs within the Duvernay Formation. The decision on which properties to model was determined through an assessment of which properties are required to understand the reservoir and calculate resources. Three petrophysical logs were used to calculate the following properties in 3D: total porosity (PHIT), total organic carbon (TOC) and carbonate fraction (CARB).

The well logs used for petrophysical analysis are gamma ray (GR), density (RHOB), deep resistivity (RESD), neutron porosity (PHIN), sonic (DT) and when available, spectral GR and elemental curves. The well logs were normalized in Prizm (GeoGraphix software) and the results were calibrated by measured lab data where possible.

Total organic carbon (TOC) was calculated using DT and RESD using Passey's method (Passey et al., 1990). [Figure 9](#) shows the locations of the TOC logs used for modelling.

To calculate total porosity (PHIT), a consistent grain density must be determined, and TOC must be converted to kerogen and used as a mineral component. This is done by using mineralogical data from X-ray diffraction reconciled with X-ray fluorescence data for each sample and converted mineral weight per cent to volume. TOC was converted to kerogen using a conversion factor of 1.2 to account for the portion of kerogen that is not carbon. Then a kerogen incorporated matrix density was calculated for each sample with the density of kerogen assumed to be 1.35 g/cm³. PHIT was then calculated from RHOB and kerogen incorporated matrix density where TOC was greater than 1.5%. No kerogen was incorporated where TOC was less than 1.5%. [Figure 10](#) shows the locations of the PHIT logs used for modelling.

Carbonate fraction is estimated by calculating a calcium curve using a spectral GR well log. Everett's method (Everett et al., 2014) was used to calculate a calcium curve which was cross-checked with measured calcium in wells that included elemental curves. The resulting carbonate fraction was compared against AGS geologists' stratigraphic picks for the carbonate zone in the WSB Duvernay Formation and was deemed a good fit where carbonate fraction is greater than 50%. [Figure 11](#) shows the locations of the carbonate-fraction logs used for modelling.

5.1.3 2D Property Data

2D property data refers to data from oil and gas wells that are not available as a vertically continuous dataset, or dependent on depth. These data include tests done at the well head of producing wells or tests done down-hole over a large interval. There is usually only one to a very few data points available per well, which does not allow assignment to a specific depth value. These data are therefore modelled in 2D and populated in the x, y directions without a vertical (z) value. The 2D properties modelled include temperature and pressure gradients and hydrocarbon ratios (gas-oil ratio [GOR] and condensate-gas ratio [CGR]). The datasets used to model these properties were compiled from wells that were reported to produce from the Duvernay Formation.

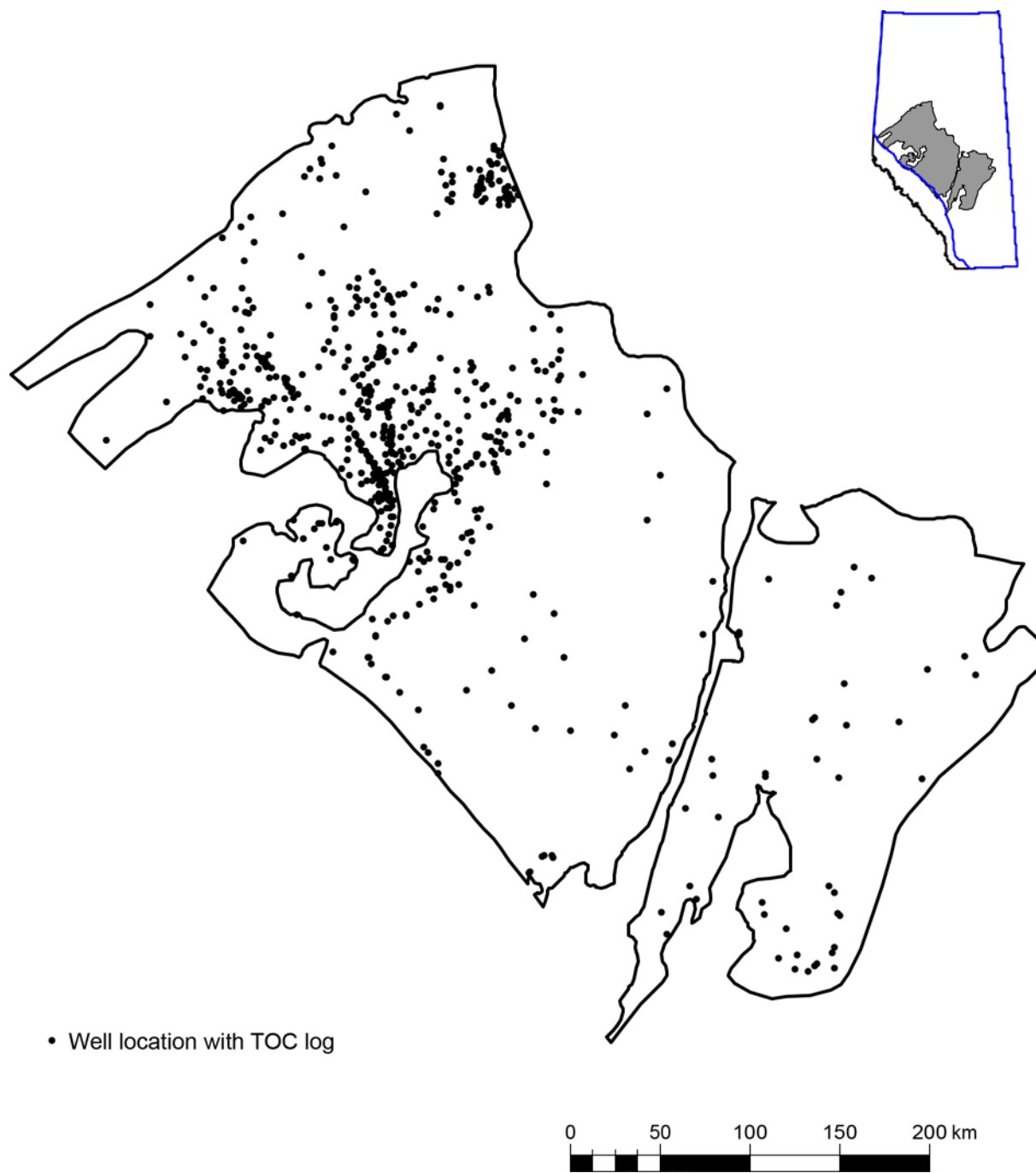


Figure 9: Location map of the TOC logs used for modelling.

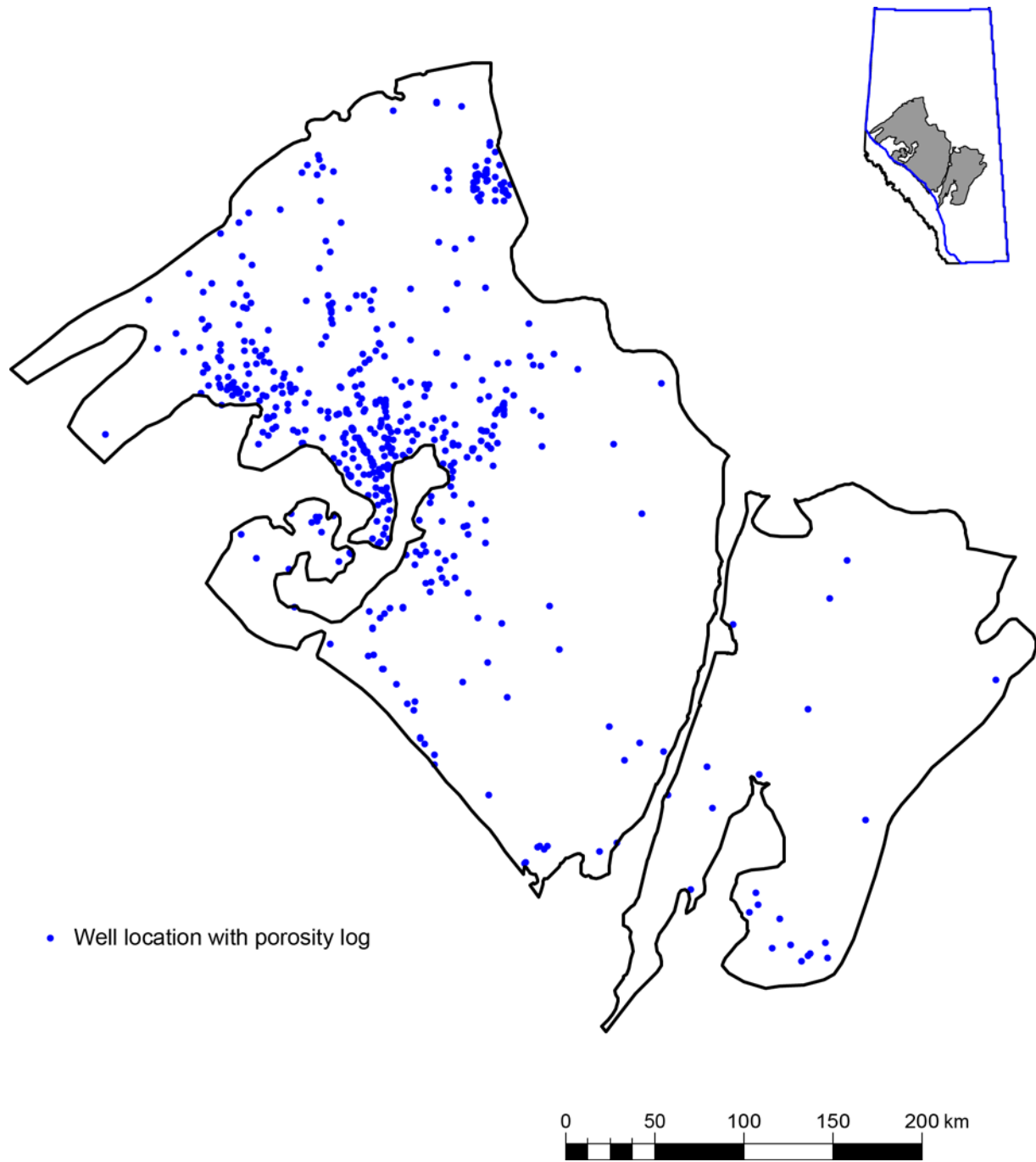


Figure 10: Location map of the total porosity logs used for modelling.

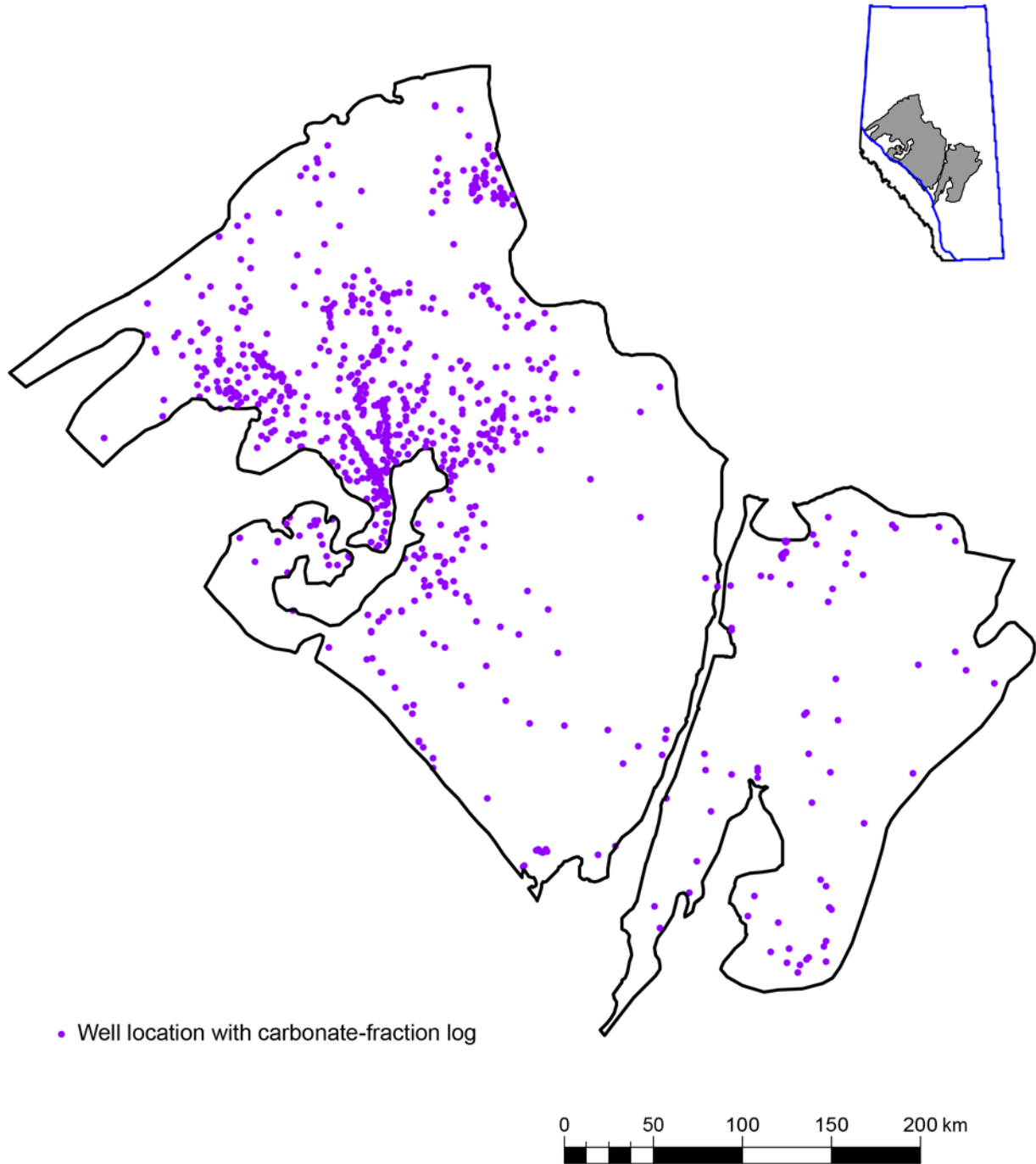


Figure 11: Location map of the carbonate-fraction logs used for modelling.

Temperature and pressure have an impact on gas compressibility and, therefore, hydrocarbon quantities in the reservoir. As pressure increases, more gas is compressed into solution in the reservoir, increasing the amount of gas stored in the reservoir. If the temperature increases in the reservoir, less gas is able to be stored because gas expands as it is heated. The gradients of temperature and pressure are modelled. There are 102 wells in the WSB and 12 wells in the ESB with temperature and pressure gradient data points.

Figure 12 shows a map of the temperature gradient data points, and Figure 13 shows a map of the pressure gradient data points.

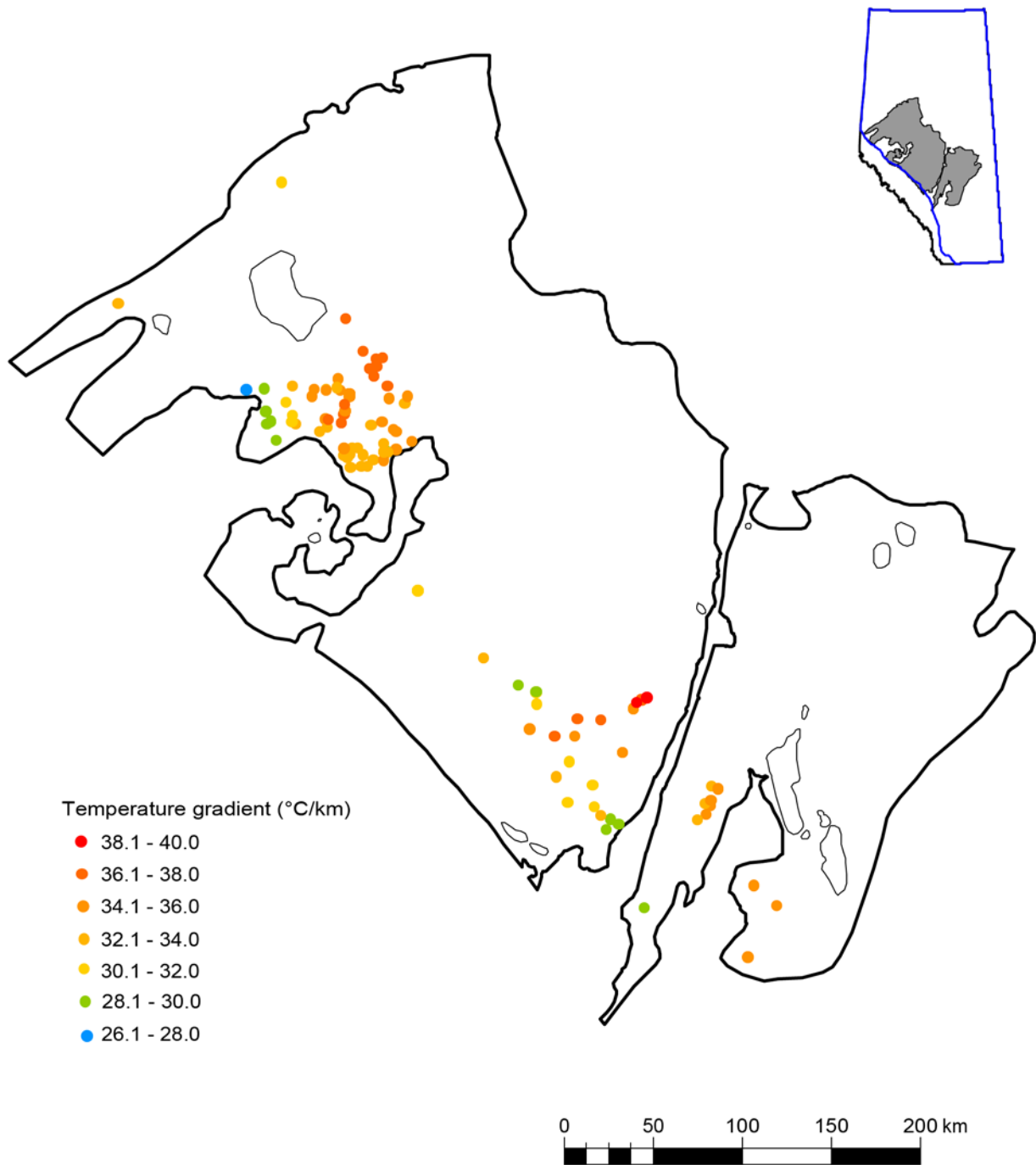


Figure 12: Map of the 114 temperature gradient data points used for modelling.

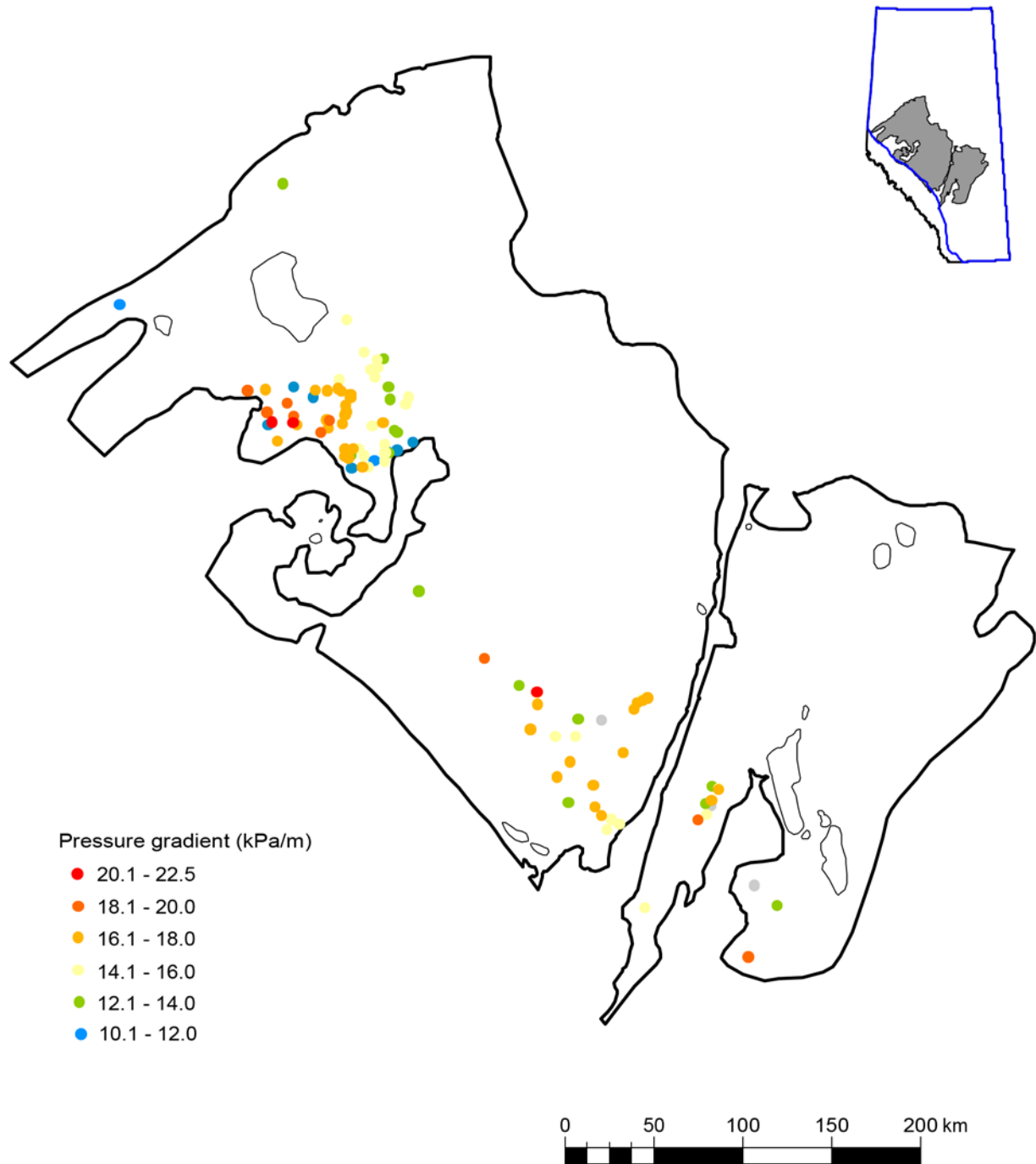


Figure 13: Map of the 114 pressure gradient data points used for modelling.

This study used well production data to estimate hydrocarbon ratios including gas-oil ratio (GOR) and condensate to gas ratio (CGR). Duvernay Formation production data were filtered to include only data labelled as being from 2160 hours (90 days) of production time. All liquid hydrocarbons produced were treated as oil whether it was as oil (from an oil well) or field condensate (from a gas well) similar to the methodology by Lyster et al. (2017). In the WSB, 401 CGR data points and 440 GOR data points were

modelled. In the ESB, 11 data points for CGR and 24 data points for GOR were modelled. [Figure 14](#) shows a map of the GOR data points, and [Figure 15](#) shows a map of the CGR data points.

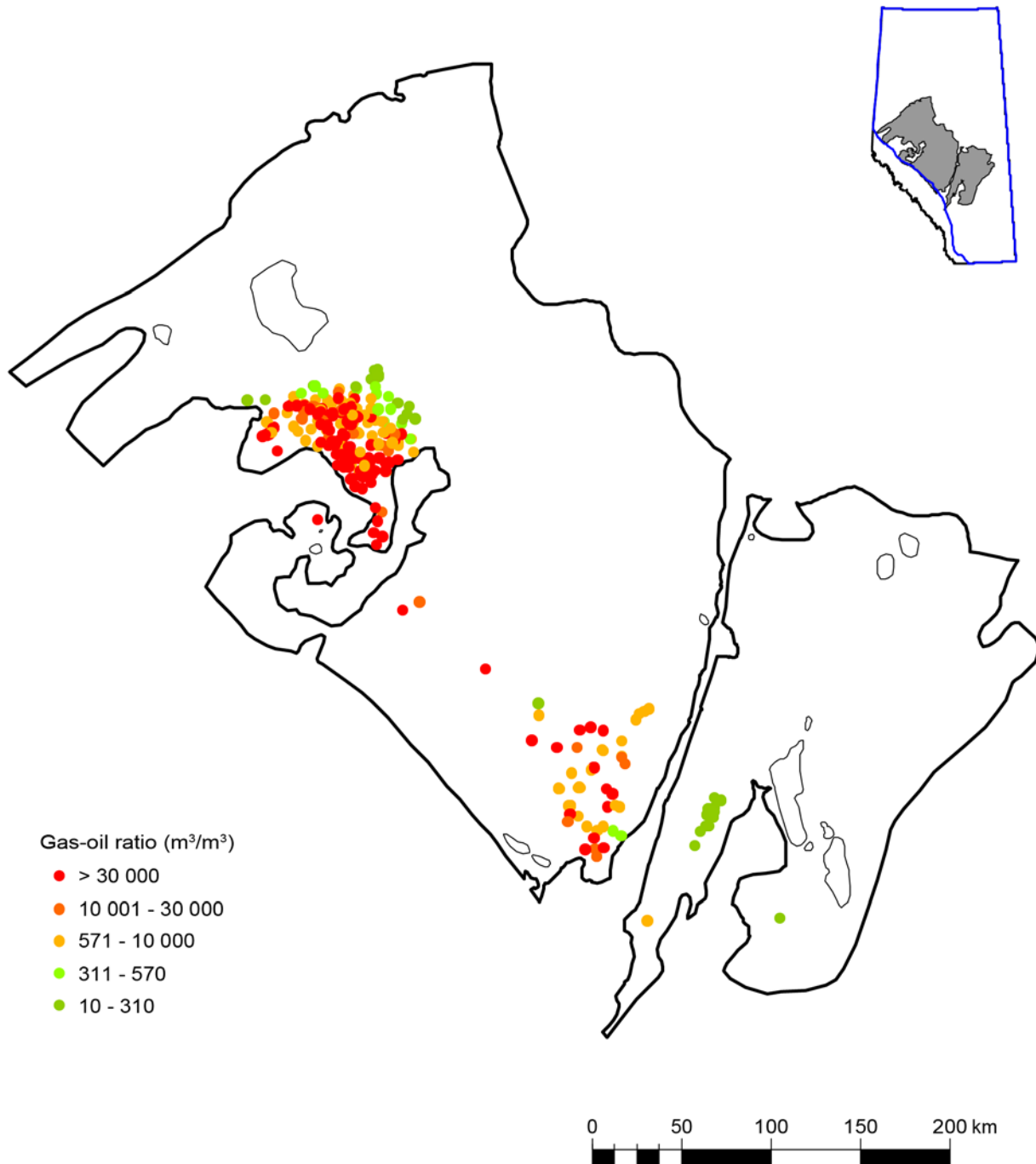


Figure 14: Map of the 464 gas-oil ratio data points used for modelling.

5.2 Input Surface Interpolation

Input surface interpolation is the process of creating surfaces from stratigraphic picks. Stratigraphic picks of the carbonate zone top and base were used to create two interpolated surfaces defining the internal

architecture of the Duvernay Formation in the WSB. The conformal gridding algorithm in Petrel was used to interpolate the data and ensure the surfaces did not cross the adjacent boundaries, and reduce crossovers in data poor areas. To ensure the zero-edge of the carbonate zone was accounted for, a geo-edge polygon was used as additional data. The carbonate zone base surface was generated using the conformal gridding algorithm, conforming to the Duvernay Formation base and using the zero-edge boundary polygon as additional input data. The carbonate zone top surface was generated using the conformal gridding algorithm, conforming to the carbonate zone base surface below and the Duvernay Formation top surface above, and was constrained to the zero-edge as well. The resulting interpolated surfaces were visualized in 3D with all input source data to quality check the results and to make sure the surfaces correspond with the geologist's current understanding of the stratigraphic architecture.

5.3 Input Surface Manipulation

A series of surface manipulations were applied to ensure that proper model zone minimum thicknesses as defined by the geologist were maintained and the interpolated surfaces could be used as input into the 3D property models.

The Duvernay Formation top and base discrete surfaces from the 3D PGF model v1 (Branscombe et al., 2018b) were used. The first manipulation was to extend the surfaces across the WSB and ESB Duvernay 3D property models so that they coincide with the model boundary from Lyster et al. (2017). This resulted in a continuous surface across the entire 3D property model extent. The second manipulation was to ensure a minimum thickness of 5 m was achieved across the Duvernay Formation extent. This was accomplished by creating an isochore from the top and base continuous surfaces of the Duvernay Formation and setting the isochore minimum to 5 m. The adjusted isochore was added to the Duvernay Formation base surface to re-create the Duvernay top surface, thus ensuring a minimum thickness of 5 m across the Duvernay Formation extent.

For the interior zones of the WSB, a minimum thickness of 1.5 m was also applied for the carbonate zone and underlying lower shale zone following the same process as previously discussed in this section.

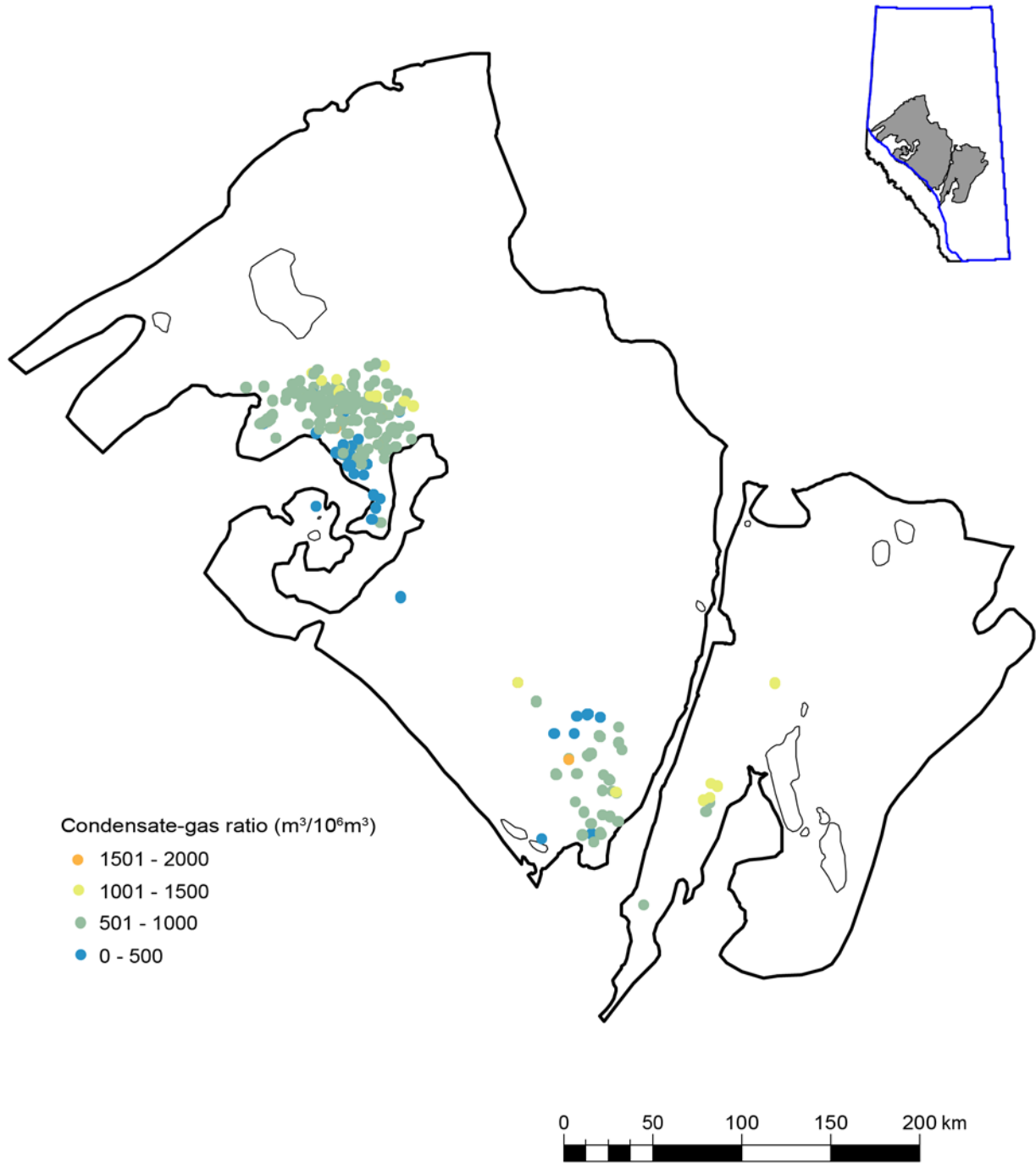


Figure 15: Map of the 412 condensate-gas ratio data points used for modelling.

5.4 Input Surface Uncertainty

Global uncertainty was evaluated using root-mean-square error (RMSE) values and local uncertainty was characterized using standard deviation maps. The global uncertainty represents the regional uncertainty across the Duvernay Formation and the standard deviation represents the local uncertainty. The two analyses provide insight into the magnitude of errors present within the carbonate zone top and base continuous surfaces. For the uncertainty analysis on the Duvernay Formation top and base discrete surfaces, see 3D PGF model v1 (Branscombe et al., 2018a).

The RMSE was computed for the carbonate zone top and base continuous surfaces in the WSB Duvernay 3D property model by comparing the input stratigraphic picks to the values of the interpolated surfaces. The RMSE value for the carbonate zone top continuous surface is 3.03 and 2.84 for the carbonate zone base continuous surface. The RMSE is analogous to standard deviation. As standard deviation increases, the uncertainty increases; as the RMSE number increases, the uncertainty increases as well.

Standard deviation maps were created using the methodology of Babakhani (2016). Standard deviation maps were created for the carbonate zone top and base surfaces by randomly selecting 80% of the input reference data for each surface (ten realizations). These ten subsets were interpolated using the convergent interpolator algorithm with identical gridding parameters. The ten surfaces were converted to points and the standard deviation was calculated at the same grid node location for all realizations (Babakhani, 2016). This methodology provides a graphical representation of variations in uncertainty across the interpolated surface ([Figure 16](#) and [Figure 17](#)). Areas with lower standard deviation values represent areas of lower uncertainty.

The uncertainty analysis results confirm that areas of sparse data and/or close proximity to the deformation belt have the highest uncertainty and could benefit from additional data (Branscombe et al., 2018a). The uncertainty results for the carbonate zone top and base continuous surfaces were deemed acceptable for defining the internal architecture of the Duvernay Formation and therefore satisfactory inputs for model construction.

6 Model Construction

The Duvernay 3D property models were built in Petrel 2015 using the pillar gridding process. Two separate 3D property models were built because of the differences in Duvernay Formation depositional architecture and petrophysical properties between the WSB and ESB. [Figure 18](#) shows generalized model columns of the WSB and ESB 3D property models.

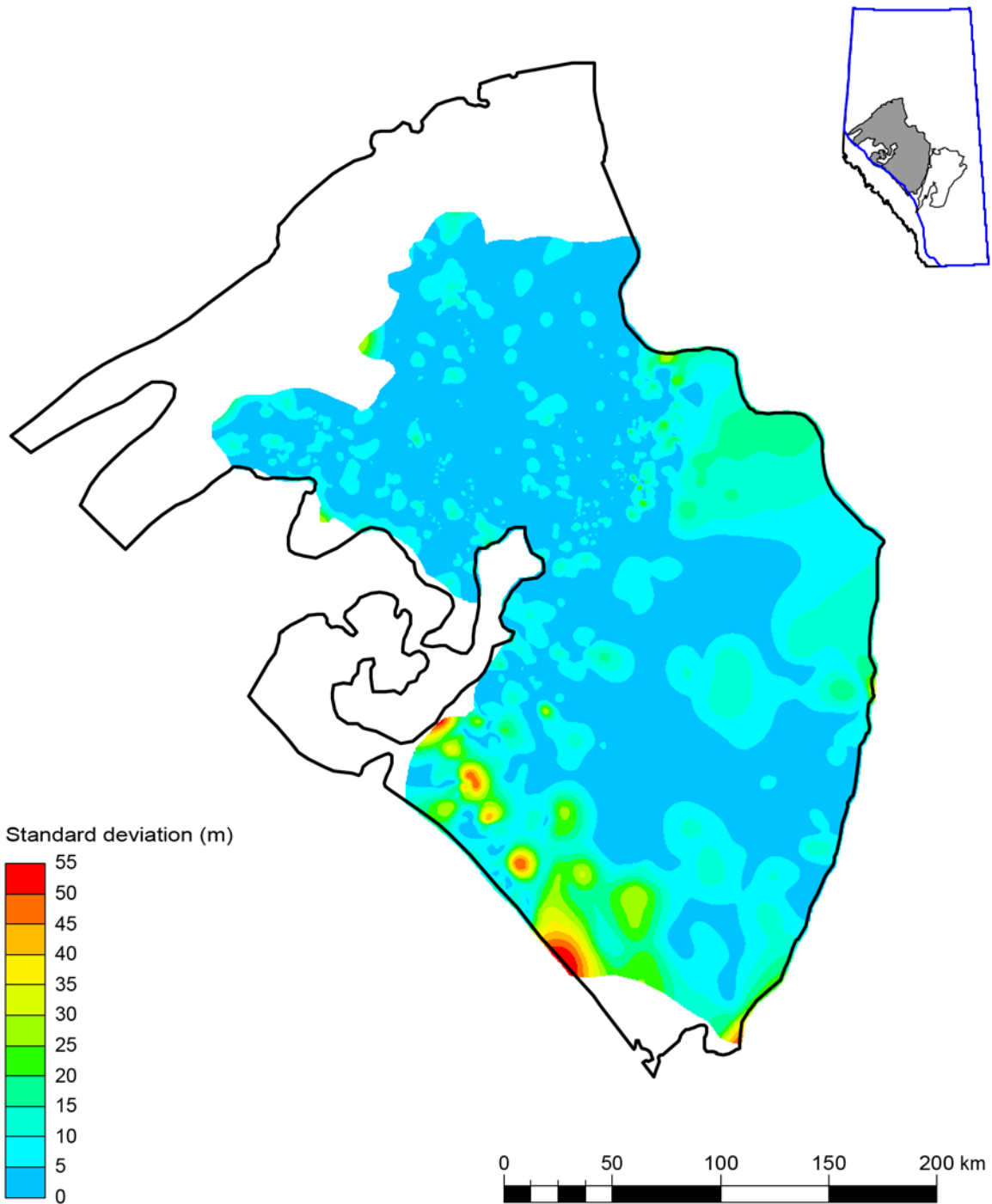


Figure 16. Carbonate zone top standard deviation map.

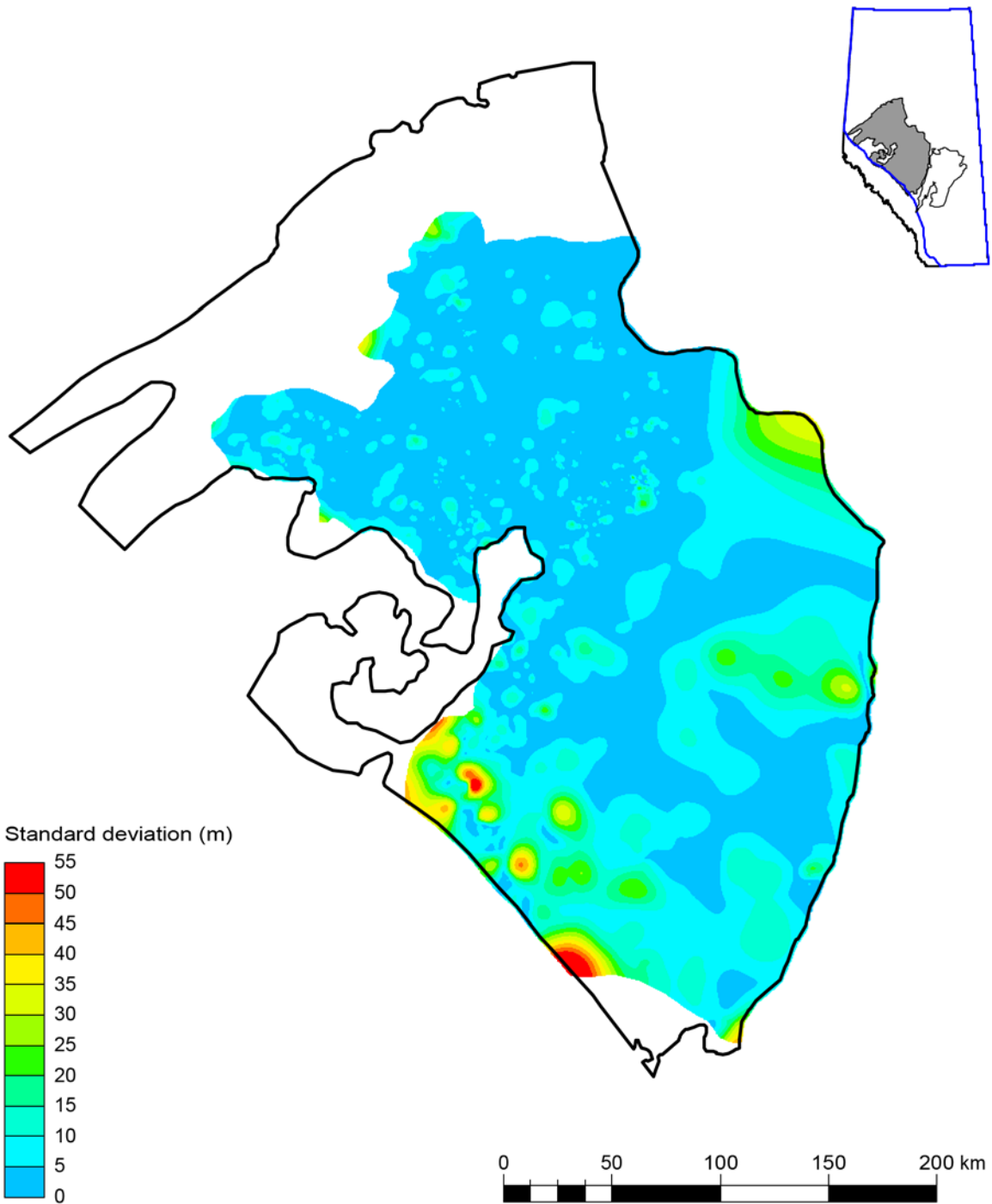


Figure 17. Carbonate zone base standard deviation map.

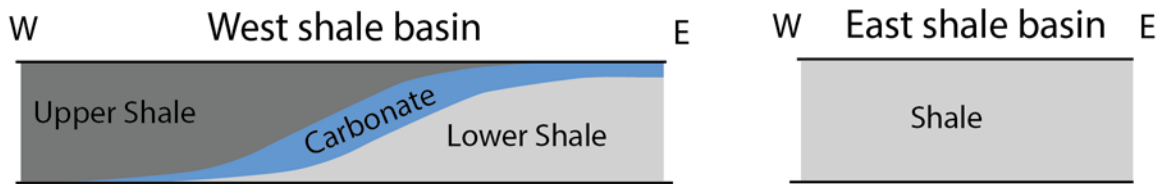


Figure 18. Generalized model columns of the WSB and ESB Duvernay 3D property models.

6.1 Structural Framework

The WSB Duvernay 3D property model structural framework was built in three steps using the pillar gridding workflow (Figure 19). The first step involved building the top and base horizons of the 3D property model using the Duvernay Formation top and base continuous surfaces discussed in Section 5. Figure 20 shows a map of the elevation of the Duvernay Formation top horizon and Figure 21 shows a map of the elevation of the Duvernay Formation base horizon in both the WSB and ESB. The cell size used was 500 x 500 m. The second step added the internal architecture of the Duvernay Formation in the WSB defining three zones using isochores created in Section 5.3. The three zones are: 1) lower shale zone, 2) carbonate zone and 3) upper shale zone. Figure 22 shows a map of the elevation of the top of the carbonate zone in the WSB. Figure 23 shows a map of the thickness of the Duvernay Formation in the WSB and ESB. Figure 24, Figure 25, and Figure 26 show thickness maps of the of the lower shale zone, carbonate zone, and upper shale zone, respectively, in the WSB. The lower shale and carbonate zones pinch out to northwest and southwest in keeping with the depositional model as determined by AER/AGS geologists (Figure 18). The third step added further refining to the internal architecture of the individual zones by adding layers at 1.5 m thickness following the base horizon of each zone. The final cell size was 500 x 500 x 1.5 m resulting in a total of 187 295 056 3D cells and 248 layers.

The ESB Duvernay 3D property model framework was built in two steps following the pillar gridding process and skipped over step 2, which created internal zones within the 3D property model for the WSB. The internal zones are not necessary for the modelling of the ESB Duvernay because a distinct carbonate zone cannot be distinguished (Figure 18). The first step built the top and base horizons of the 3D property model using the Duvernay Formation top and base continuous surfaces discussed in Section 5. Figure 20 and Figure 21 show the elevation of the Duvernay Formation top and base horizons, respectively, in the WSB and ESB. Figure 23 shows a map of the thickness of the Duvernay Formation in the WSB and ESB. The cell size used was 500 x 500 m. The second step was skipped over, and the third step refined the internal architecture of the 3D property model by adding 1.5 m layers following the Duvernay Formation base continuous surface. The final cell size was 500 x 500 x 1.5 m resulting in a total of 29 808 504 cells and 99 layers.

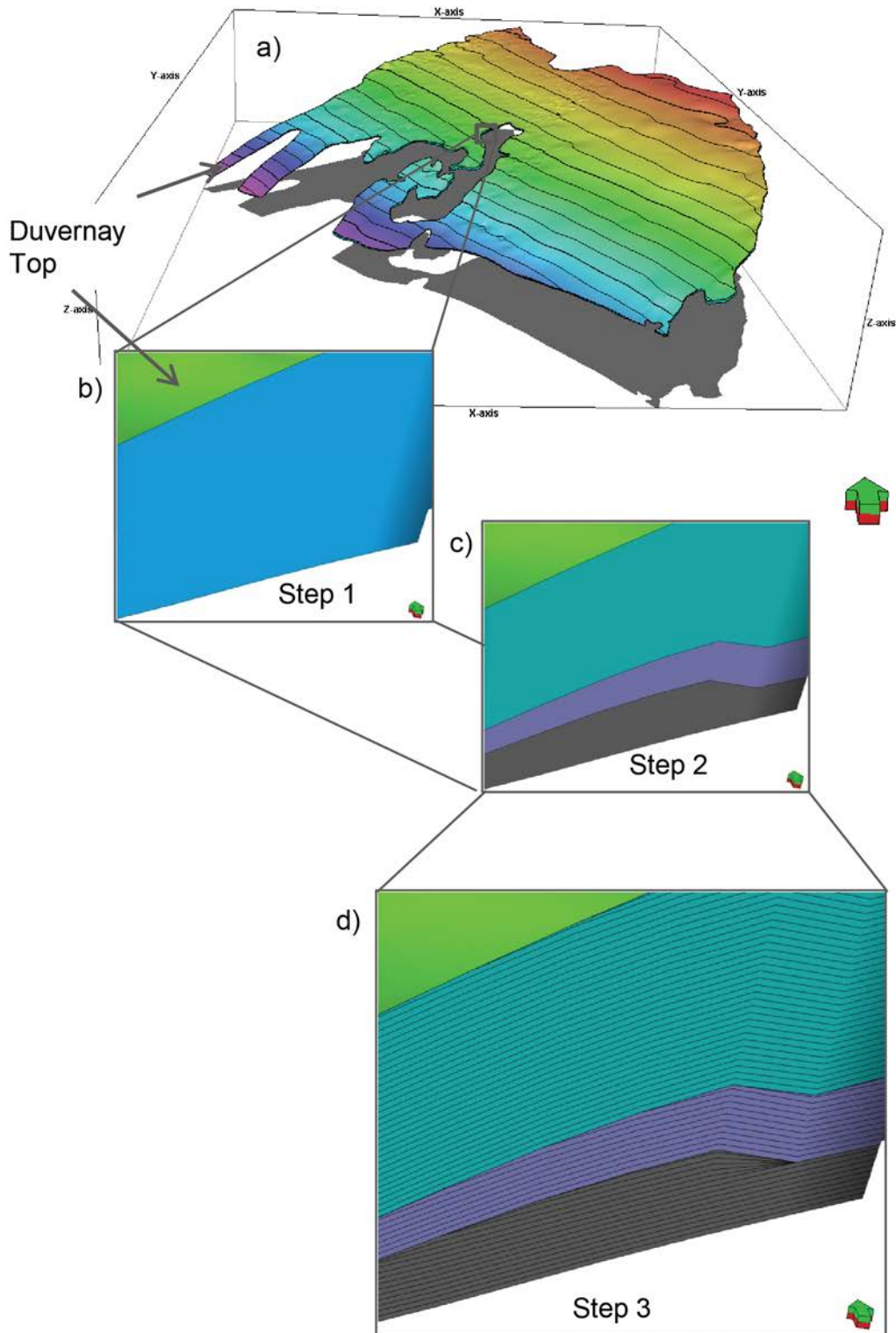


Figure 19. Steps used during the pillar gridding process for the WSB Duvernay 3D property model. Step 1 builds the structural framework (a and b). Step 2 added zones using isopachs (c). Step 3 shows further internal refinement of layers at 1.5 m thickness (d).

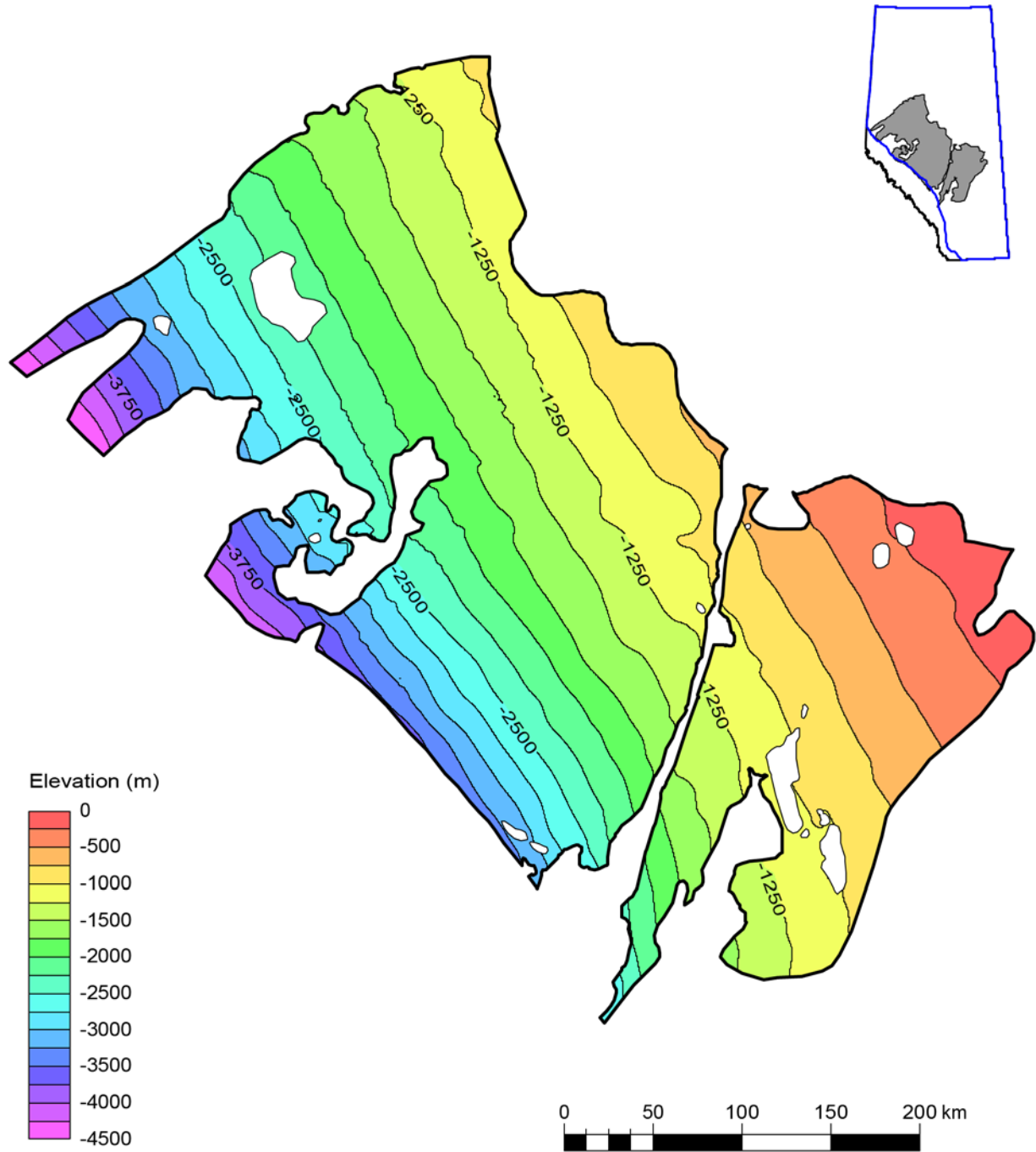


Figure 20: Elevation of the Duvernay Formation top horizon in the WSB and ESB Duvernay 3D property models.

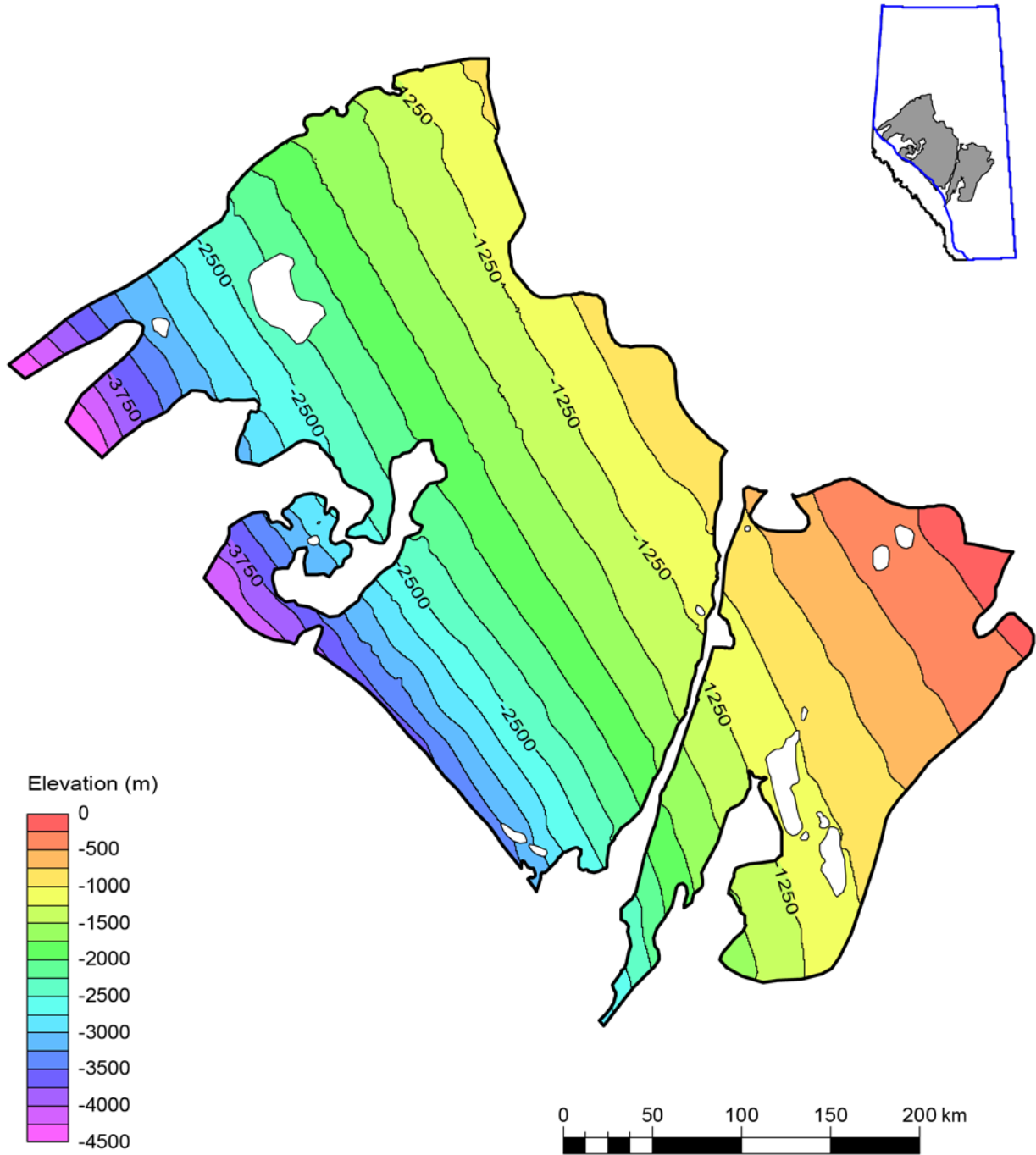


Figure 21: Elevation of the Duvernay Formation base horizon in the WSB and ESB Duvernay 3D property models.

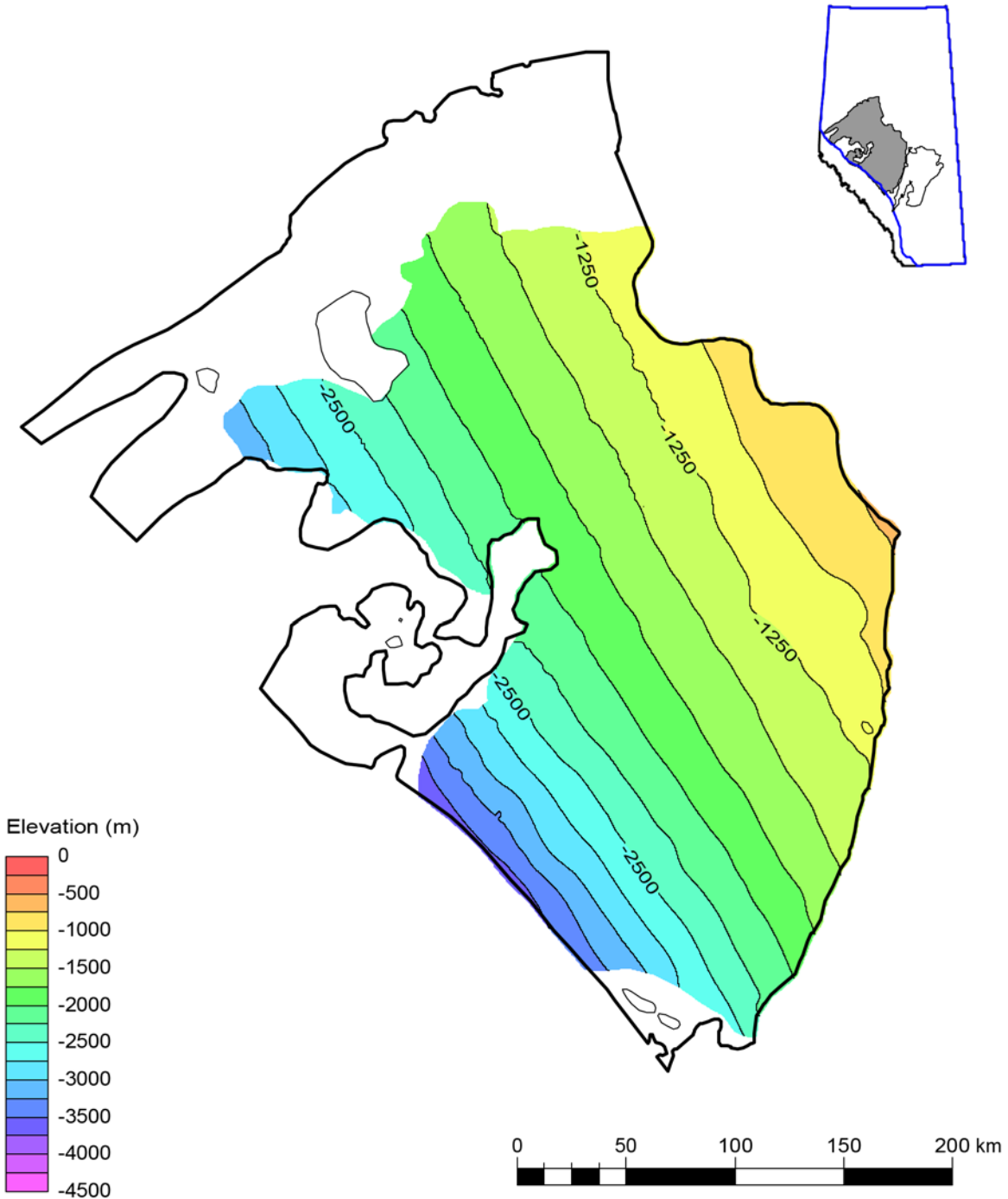


Figure 22: Elevation of the top of the carbonate zone in the WSB Duvernay 3D property model.

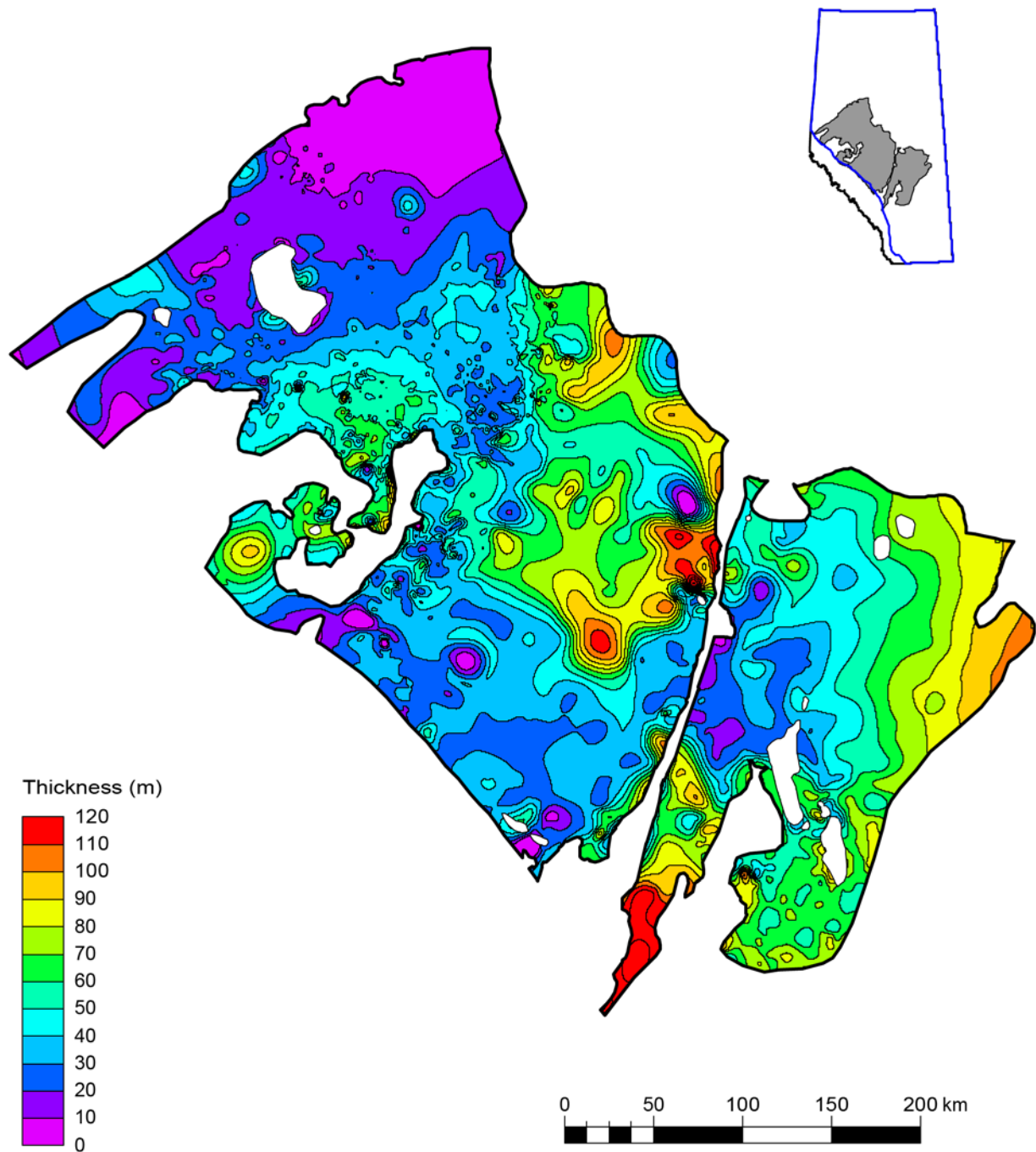


Figure 23: Map of the Duvernay Formation thickness in the WSB and ESB Duvernay 3D property models.

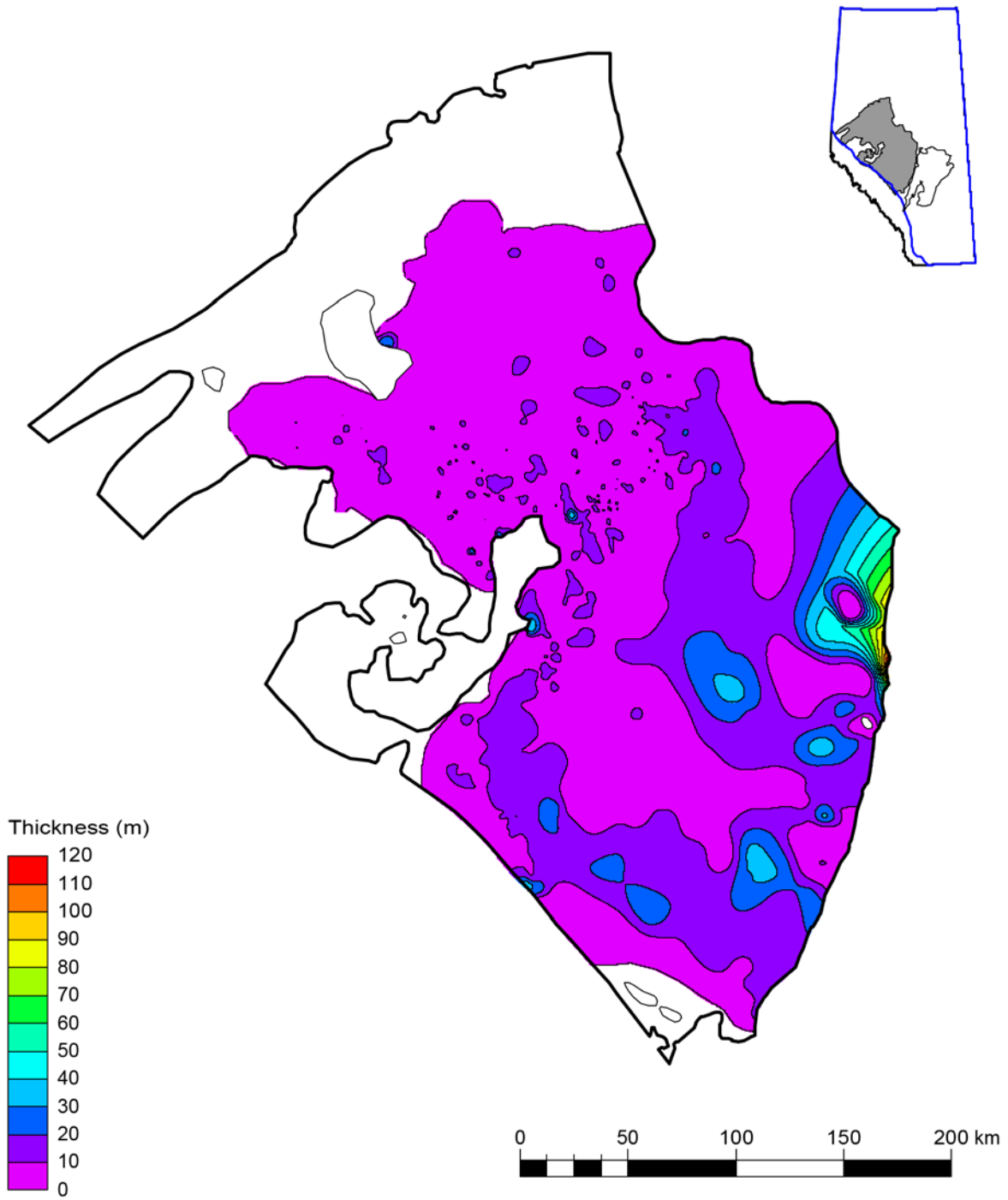


Figure 24: Thickness of the lower shale zone in the WSB Duvernay 3D property model.

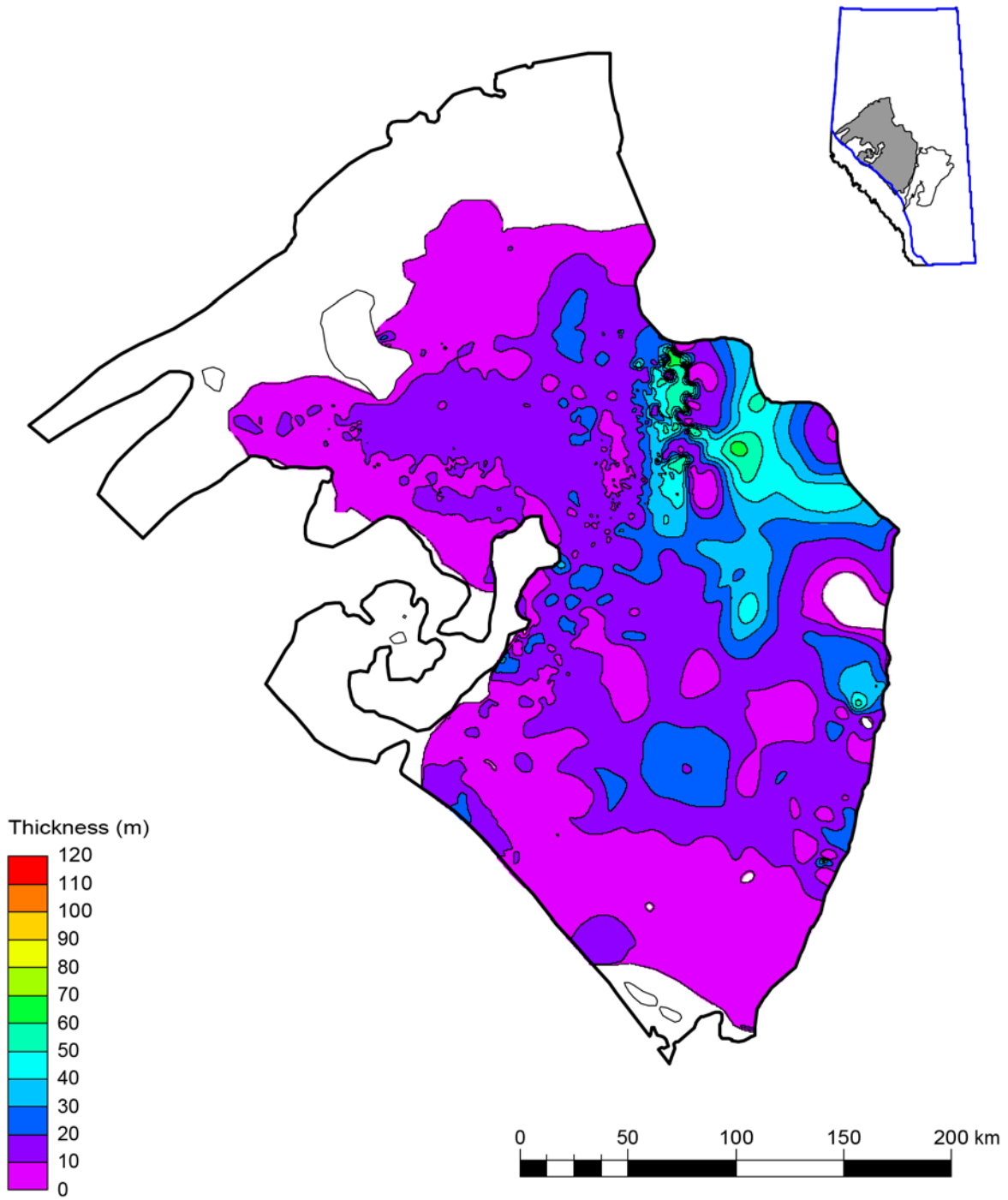


Figure 25: Thickness of the carbonate zone in the WSB Duvernay 3D property model.

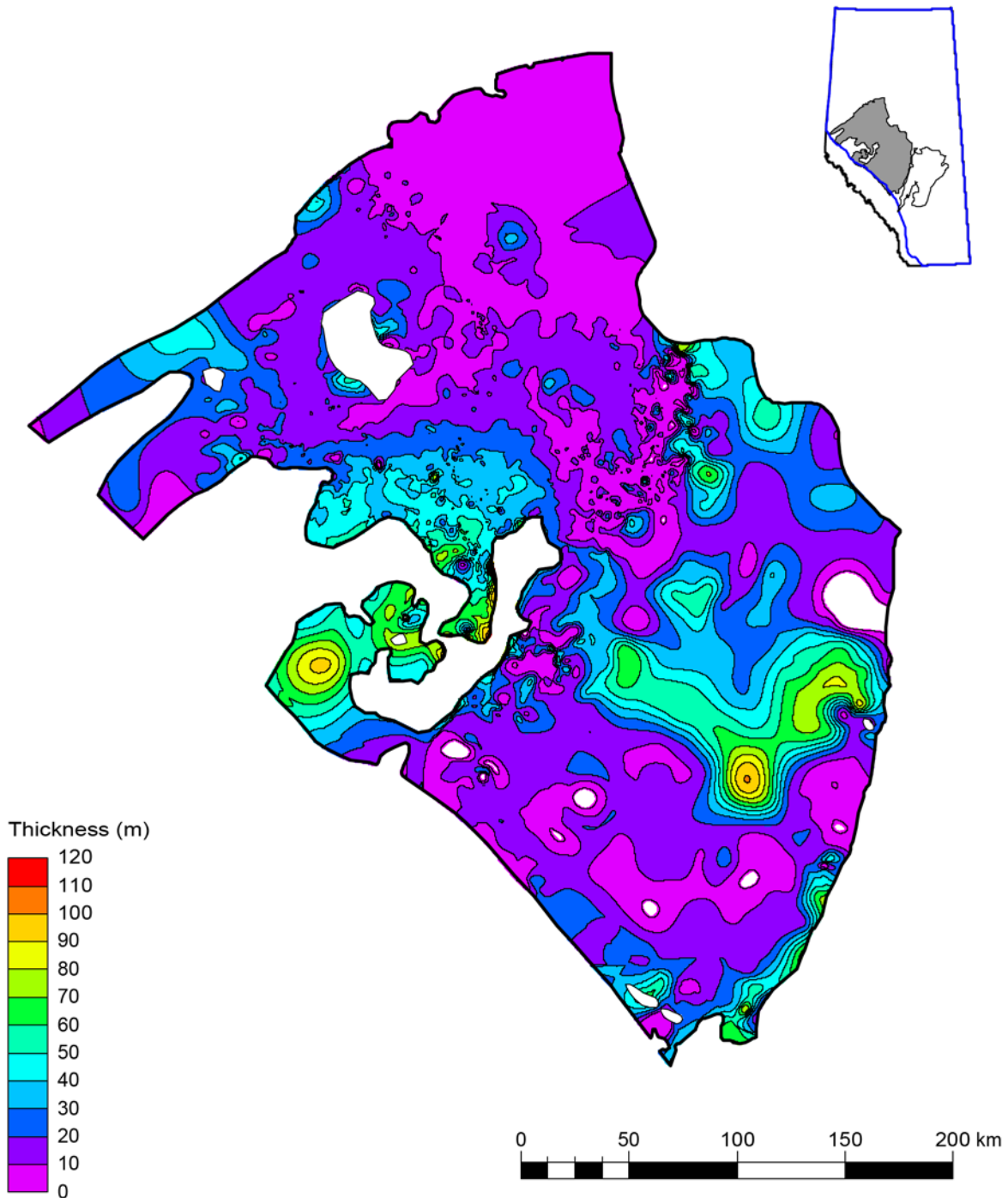


Figure 26: Thickness of the upper shale zone in the WSB Duvernay 3D property model.

6.2 Facies Model

With the structural framework built, a simple facies model was created to define the Leduc reefs that fall within the areal extent of the Duvernay Formation. The facies model was constructed as a discrete

property giving a single integer value to a particular facies for each cell. The WSB Duvernay 3D property model has 4 facies; WSB lower shale, WSB carbonate, WSB upper shale and WSB Leduc reefs. The ESB has 2 facies; ESB shale and ESB Leduc reefs ([Figure 27](#)).

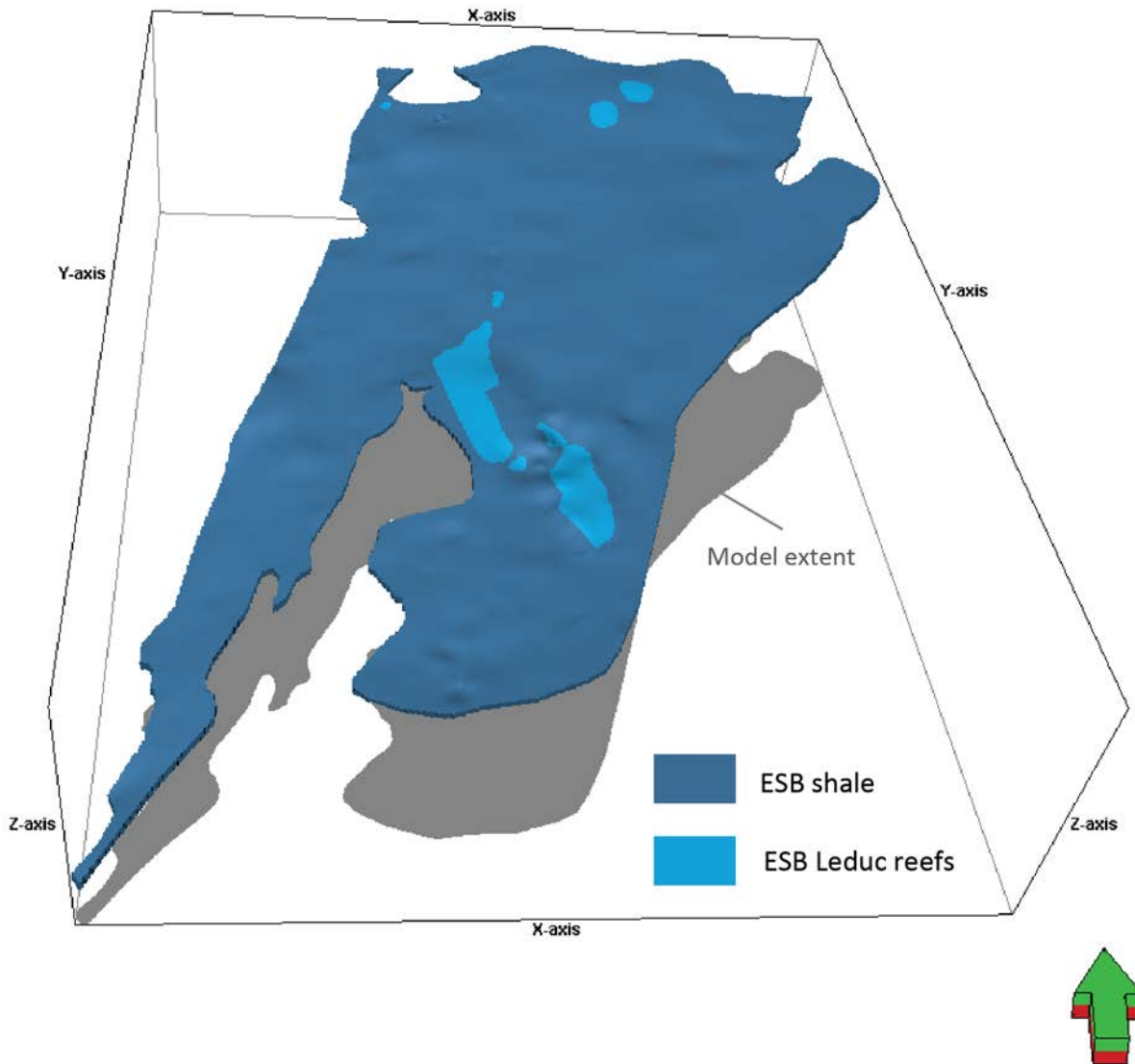


Figure 27. 3D view of the ESB facies model showing the ESB shale and ESB Leduc reefs facies. Vertical exaggeration is 25 times.

6.3 3D Property Model

The 3D property modelling follows the petrophysical modelling workflow in Petrel 2015 and created models using vertically continuous data, from petrophysical logs. The workflow has 3 main steps which will be described in greater detail: 1) upscale well-log data ([Section 6.3.1](#)); 2) geostatistical analysis ([Section 6.3.2](#)); and 3) populate 3D geocellular grid cells with property values ([Section 6.3.3](#)).

6.3.1 Upscale Well-Log Data

In order to model the properties in 3D, the data must be upscaled from the well-log scale (0.2 m) to the 3D property model scale (1.5 m). This is done through the process of well-log upscaling. Well-log upscaling is used to ensure that each of the 3D grid cells which are penetrated by a well bore is assigned a single value. Upscaling takes all the log values that fall within the 3D grid cell and averages them to produce one representative value per cell ([Figure 28](#)).

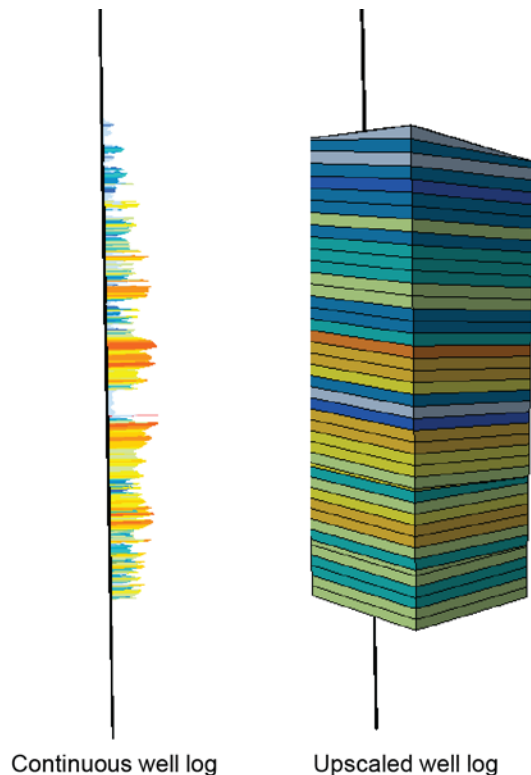


Figure 28. Example of a continuous well log (left) and the resulting upscaled well log in the 3D property model (right).

6.3.2 Geostatistical Analysis

Geostatistical methods were used to simulate the 3D properties (PHIT, CARB, and TOC) in the 3D property model (see Pycrz and Deutsch, 2014 for more details on geostatistics). In Petrel 2015, geostatistical analysis was done using the data analysis process which allows for transformations and variograms to be applied to the 3D property data used for populating the 3D property model ([Section 6.3.3](#)). Variograms are a geostatistical tool that allows the user to define the size, shape, and orientation of the properties being modelled (i.e., useful for optimization for fluvial channel or sand bodies). Variograms were used to quantify the spatial structure of each 3D property dataset and transformations were used as required by algorithms for populating the property data in the 3D property models (Pycrz and Deutsch, 2014).

Geostatistical analysis of the WSB Duvernay property data was conditioned to zones (i.e., upper shale,

carbonate zone, lower shale) and facies (i.e., upper shale). The result is a geostatistical analysis specific to each zone and facies within each zone, except for the Leduc reefs facies, which were left as a null value and not modelled for this project. ESB Duvernay 3D properties were not conditioned to facies because there was only one zone and therefore this step was not required. Similarly to the WSB, the ESB Leduc reefs facies were left as null and not modelled as part of this project. The following subsections will first discuss the geostatistical analysis of the WSB Duvernay property data, using the lower shale zone as an example, followed by a discussion of the geostatistical analysis of the ESB Duvernay property data.

6.3.2.1 Total Porosity (PHIT)

The range of data values for the WSB Duvernay total porosity after the upscale well log process ([Section 6.3.1](#)) are shown in [Table 1](#). Using the WSB lower shale zone values as an example, the values and results are discussed throughout the geostatistical analysis process. The total porosity data for the WSB lower shale zone shows a right skewed distribution with values ranging from 0 to 0.243 with a mean of 0.052. A normal score transformation was applied because the simulation algorithms ([Section 6.3.3](#)) require normal score data prior to modelling.

Once populating the 3D property models was complete, the data were back transformed to their original distribution. Cell declustering was applied to the data due to areas of high and low density which can affect the mean of the data causing it to provide a biased result. If not properly declustered, the mean would be artificially higher than it actually is due to the preferential drilling of wells in prospective locations. The declustered mean of the data is 0.049 ([Table 1](#)).

Variograms were modelled which may include up to two structures for the major and minor directions. Structure 1 represents short or local trends of the data and structure 2 represents the regional trends of the data. The vertical variogram was set to infinity, nulling the second variogram so it was not used in the modelling. The orientation of the variograms takes into account the direction of deposition based on AGS geologists' depositional model of the Duvernay Formation. See [Table 2](#) for the variograms settings for all three zones in the WSB Duvernay 3D property model and [Figure 29](#) for example variograms.

The ESB Duvernay total porosity shows a right skewed distribution with values ranging from 0 to 0.151 and a mean of 0.044. A normal score transformation was applied as well as declustering. The declustered mean of the data is 0.043. Variogram models were calculated ([Table 2](#)) and included 2 structures per variogram to account for local and regional trends in the data.

Table 1. Table of total porosity data distribution for the Duvernay Formation model zones in the WSB.

WSB Zone	Distribution	Minimum Value	Maximum Value	Mean	Declustered mean
Upper shale	Right skewed	0	0.300	0.055	0.049
Carbonate zone	Right skewed	0	0.254	0.029	0.027
Lower shale	Right skewed	0	0.243	0.052	0.049

Table 2. Total porosity variogram model settings for the Duvernay Formation model zones in the WSB and ESB.

Basin	Zone	Major Azimuth (degrees)	Structure	Sill	Major Range (m)	Minor Range (m)	Vertical Range (m)
WSB	Upper shale	215.9	1	0.2683	9 370.52	8279.67	7.58
			2	0.7024	87 293.48	75 570.83	infinity
WSB	Carbonate zone	218.3	1	0.5416	8 780.49	8 032.18	5.96
			2	0.4229	50 709.74	46 576.00	infinity
WSB	Lower shale	205.8	1	0.4727	10 193.39	7 430.44	4.62
			2	0.4514	86 691.62	79 306.75	infinity
ESB	Shale	203.3	1	0.332	9 325.36	8 166.63	7.17
			2	0.5731	53 225.89	45 230.20	infinity

6.3.2.2 Carbonate Fraction

The carbonate fraction in the WSB lower shale zone shows a normal distribution with values ranging from -0.112 to 0.825 (Table 3). The negative values are an artifact from the petrophysical log calculation and were set to 0 using the input truncation transformation. The resulting values ranged from 0 to 0.825 with a mean of 0.446. A normal score and cell declustering transformation was applied resulting in a new mean of 0.433. See Table 3 for the WSB carbonate zone and WSB upper shale zone data values.

Variograms were modelled for each zone and the settings can be reviewed in Table 4.

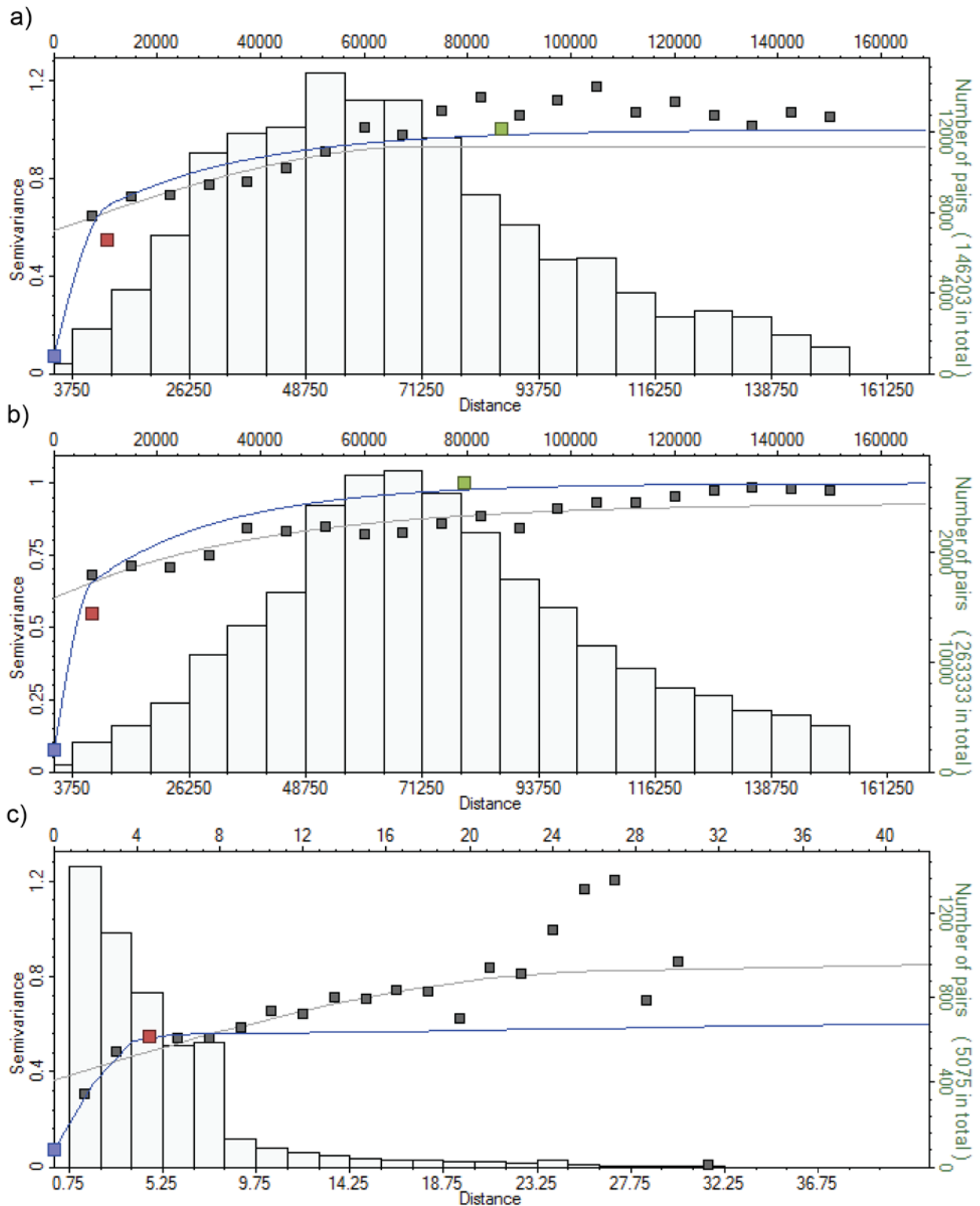


Figure 29. Variograms for total porosity in the WSB lower shale zone. a) Major horizontal direction. b) Minor horizontal direction. c) Vertical direction. Blue lines: modelled variogram functions; grey squares: experimental variograms; grey bars: number of pairs at each experimental lag; red/green/purple squares: individual variogram function ranges and sills.

The ESB shale zone carbonate fraction shows a right-skewed distribution with values ranging from 0.105 to 0.995 with a mean of 0.650. Normal score and cell declustering transformations were applied resulting in a new mean of 0.617. Variograms were modelled for the zone and the settings can be viewed in [Table 4](#).

Table 3. Carbonate fraction data value ranges per zone in the WSB.

WSB Zone	Distribution	Minimum Value	Maximum Value	Mean	Declustered Mean
Upper shale	Slightly right skewed	0	0.826	0.395	0.403
Carbonate zone	Right skewed	0	0.874	0.603	0.603
Lower shale	Normal	0	0.825	0.446	0.433

Table 4. Carbonate fraction variogram model settings for the WSB and ESB.

Basin	Zone	Major Azimuth (degrees)	Structure	Sill	Major Range (m)	Minor Range (m)	Vertical Range (m)
WSB	Upper shale	223.2	1	0.3044	9 023.26	7 771.26	7.30
			2	0.6255	48 612.65	47 902.57	infinity
WSB	Carbonate zone	219.6	1	0.5049	9 368.25	7 797.65	7.75
			2	0.4434	46 345.24	44 812.12	infinity
WSB	Lower shale	208.8	1	0.6009	11 102.14	10 507.00	7.32
			2	0.3066	73 201.02	72 173.00	infinity
ESB	shale	220.9	1	0.2692	7 657.83	6 137.59	7.45
			2	0.7680	34 106.10	32405.94	infinity

6.3.2.3 Total Organic Carbon (TOC)

The TOC dataset for the WSB lower shale zone shows a slightly left-skewed distribution with values ranging from 0 to 7.044 with a mean of 2.479 ([Table 5](#)). A normal score and cell declustering transformation was applied resulting in a new mean of 2.357. Variograms were calculated for each zone. See [Table 6](#) for variogram model settings.

The TOC dataset for the ESB shale zone shows a left-skewed distribution with values ranging from 0 to 7.573 with a mean of 1.582. A normal score and cell declustering transformation was applied resulting in a new mean of 1.572. See [Table 6](#) for variogram model settings.

Table 5. Table of TOC data value ranges per zone in the WSB.

WSB Zone	Distribution	Minimum Value	Maximum Value	Mean	Declustered Mean
Upper shale	Left skewed	0	10	2.686	1.997
Carbonate zone	Left skewed	0	8.656	1.181	1.128
Lower shale	Left skewed	0	7.044	2.479	2.357

Table 6. Variogram model settings for TOC in the WSB and ESB.

Basin	Zone	Major Azimuth (degrees)	Structure	Sill	Major Range (m)	Minor Range (m)	Vertical Range (m)
WSB	Upper shale	213.2	1	0.7213	9 123.27	8 256.95	34.25
			2	0.2045	82 485.32	78 963.28	Infinity
WSB	Carbonate zone	239.4	1	0.4703	5 097.89	4 916.66	13.87
			2	0.4774	66 282.19	65 849.19	Infinity
WSB	Lower shale	208.7	1	0.5774	11 229.25	8 931.68	7.67
			2	0.3334	68 031.97	6 635.38	Infinity
ESB	shale	220.9	1	0.653	12 249.11	11 897.26	9.17

6.3.3 Populate 3D Geocellular Grid

Each 3D property for the WSB and ESB Duvernay 3D property models was simulated using a Gaussian simulation algorithm. One hundred representations (realizations) were run to fully quantify the spatial uncertainty of each 3D property model. A random starting point (seed) is used for each realization which results in different realizations with similar data distributions ([Figure 30](#)).

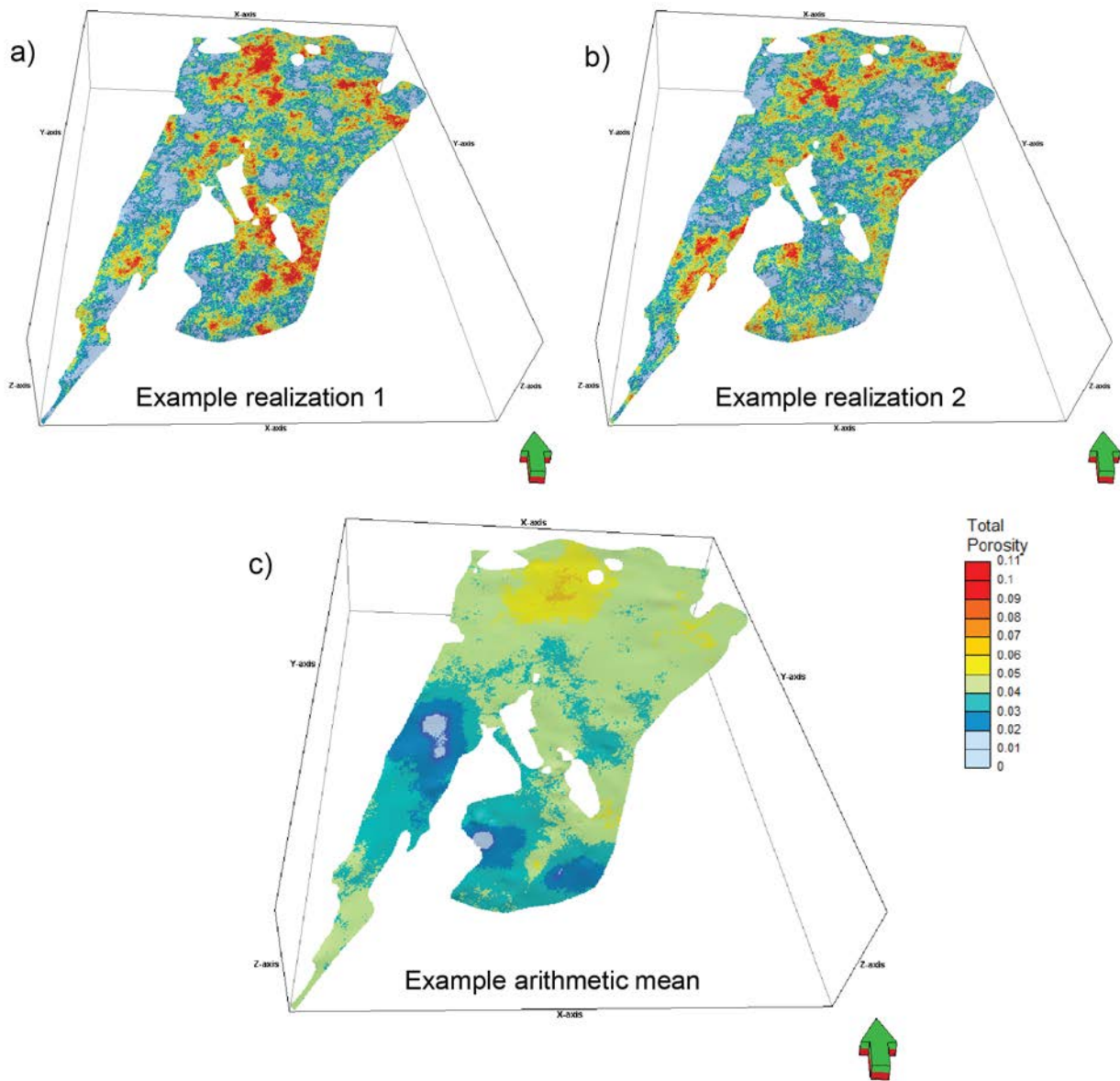


Figure 30. Example of a 3D property model. Vertical exaggeration is 25 times. Images show the distribution of total porosity in the basal 1.5 m grid cell layer of the ESB Duvernay 3D property model. a) and b) represent two different realizations; c) represents the arithmetic mean of 100 realizations.

6.4 2D Property Model

The 2D properties do not always have an associated z (depth) value. As a result, the 3D property model structural framework was recreated to only have one zone/layer, stopping after step 1 of the structural framework workflow (Section 6.1; Figure 19). The modelled facies for the WSB were simplified to two facies, either WSB Duvernay shale or WSB Leduc reefs. As with the 3D properties, the WSB Leduc reefs facies grid cells were not populated by properties and left as null. By reducing the internal architecture of the 3D property models to one zone/layer, the 2D properties are able to be modelled in 3D. The result is a modelled property in the x, y direction with the same value in the z direction (Figure 31). The ESB facies

model already includes only ESB shale and Leduc reefs; the Leduc reefs were not populated by properties.

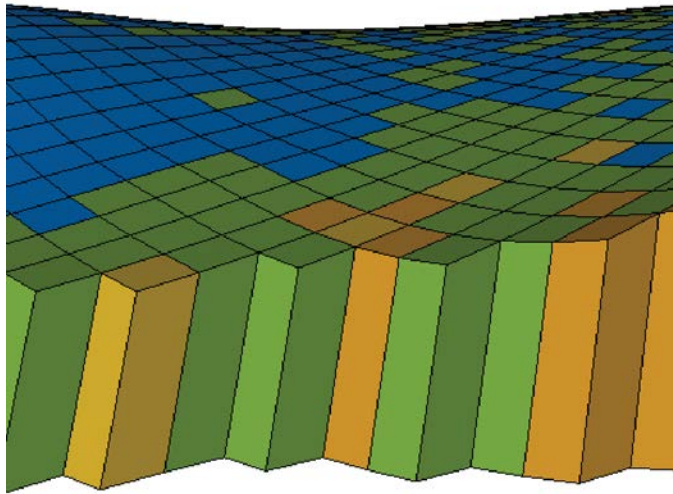


Figure 31. 3D view of the one zone/layer model in the WSB. The example property varies in the x and y direction, and is constant in the z (depth) direction. Vertical exaggeration 25x

The 2D property modelling follows the petrophysical modeling workflow in Petrel similar to the 3D property modelling; 1) upscale 2D property data ([Section 6.4.1](#)), 2) geostatistical analysis ([Section 6.4.2](#)), and 3) populate geocellular grid cells with 2D property values ([Section 6.4.3](#)).

6.4.1 Upscale 2D Property Data

2D properties are sets of points rather than continuous data, as discussed in [Section 6.3.1](#). The upscaling process follows the same workflow as discussed for the 3D properties in [Section 6.3.1](#). Four 2D properties were upscaled to the one layer model for both the WSB and ESB and include temperature gradient, pressure gradient, and gas-oil ratio (GOR) and condensate-gas ratio (CGR).

6.4.2 Geostatistical Analysis

As discussed in [Section 6.3.2](#), the data analysis process was used to simulate the 2D properties in the one zone/layer 3D property models in the WSB and ESB. Conditioning to zone is not required for one zone/layer 3D property models. Both basins are conditioned to facies, either Duvernay shale or Leduc reefs facies with the Leduc reefs facies being nulled. The modelled 2D properties are discussed in the following paragraphs.

Temperature gradient values in the WSB Duvernay range from 27.18 to 39.72 °C/km with a mean of 33.86 °C /km. The ESB values range from 28.11 to 35.65 °C /km with a mean of 33.83 °C /km. A normal score transformation was applied and major and minor variograms were calculated. The vertical variogram was set to infinity because the model only has one zone/layer and the vertical variogram does not apply. Cell declustering is not used for the 2D properties because of the sparsity of the data. For variogram model settings see [Table 7](#).

Pressure gradient test values in the WSB Duvernay range from 4.11 to 21.32 kPa/m with a mean of

15.7 kPa/m. Values below 10 kPa/m were interpreted to be poor quality data points and were not used in the modelling process. The ESB Duvernay pressure gradient values range from 7.33 to 18.87 kPa/m with a mean of 15.05 kPa/m. Data coverage in the ESB is low resulting in high uncertainty in areas of no/sparse data. The background pressure gradient in both basins was assumed to be close to the hydrostatic pressure in high uncertainty areas and was set to 10.1, which is close to the minimum data value and so does not cause errors in the data transformation. This assumption avoids extrapolating high pressure gradients across the basins without data support. Variograms were modelled in the major and minor directions. For variogram model settings see [Table 7](#).

Gas-oil ratio (GOR) in the Duvernay Formation shows a trend with depth. The shallow portions of the Duvernay to the northeast are less mature having more gas and less oil, the deeper portions to the southwest are more mature containing dry gas and less oil. The liquids-rich fairway is in between the shallow and deeper portions. The trend in the data is taken into account by using a directional data trend transformation with an azimuth of 55 degrees. Other transformations applied include logarithmic, due to the data being on a logarithmic scale, and a normal score. Variograms were calculated in the major and minor directions. For variogram model settings see [Table 7](#).

The condensate-gas ratio (CGR) trends with depth and inversely trends with GOR. A directional trend of 45 degrees was applied to account for the trend with depth and normal score transformation. Variograms were calculated for the major and minor directions. For variogram model settings see [Table 7](#).

Table 7: 2D property variogram model settings.

Basin	2D Property	Major Azimuth (degrees)	Structure	Sill	Major Range (m)	Minor Range (m)	Vertical Range (m)
WSB	Temperature gradient	189.9	1	0.8916	48 820.41	42 832.47	Infinity
WSB	Pressure gradient	138.6	1	0.7	29 337.89	20 229.31	Infinity
WSB	GOR	128.6	1	0.2953	31 170.57	19 737.83	Infinity
			2	0.2953	54 085.40	51 076.67	Infinity
WSB	CGR	287.2	1	0.6069	41 985.12	35 864.39	Infinity
ESB	Temperature gradient	42.9	1	0.8617	22 721.56	21 610.49	Infinity
ESB	Pressure gradient	47.1	1	0.7608	29 320.70	28 364.50	Infinity
ESB	GOR	31.8	1	0.502	18 443.43	16 979.76	Infinity
ESB	CGR	0.8801	1	0.8801	17 116.44	15 722.29	infinity

6.4.3 Populate 2D Geocellular Grid

Each 2D property was simulated using a Gaussian simulation algorithm. One hundred multiple

realizations were run to fully quantify the spatial uncertainty of each 2D property. A random starting point (seed) is used for each realization resulting in different results with similar data distributions (Figure 32).

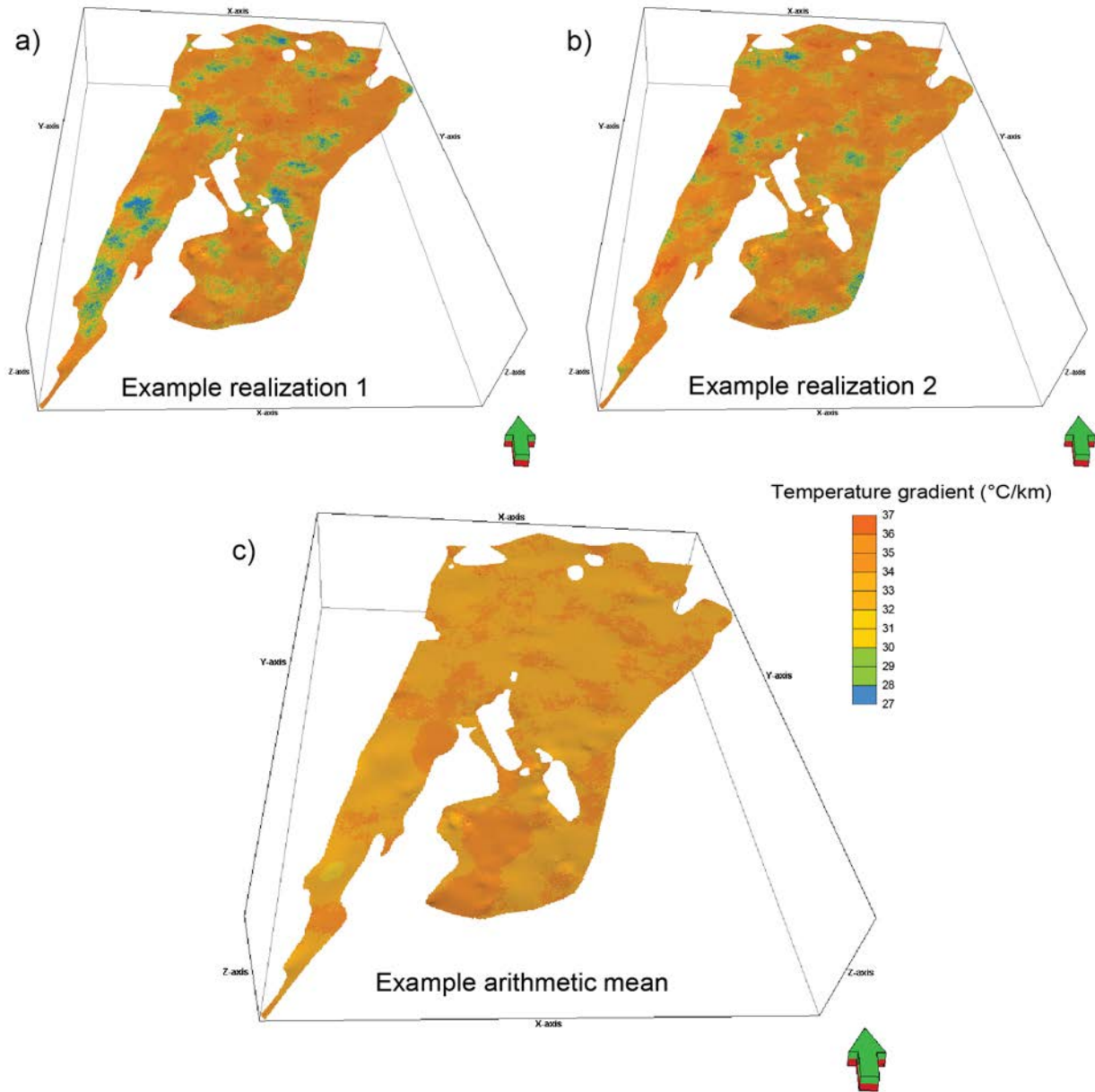


Figure 32. Example of a 3D property model populated with 2D properties in the ESB (Vertical exaggeration is 25 times). Image shows the simulated temperature gradient. a) and b) represent two different realizations; c) shows the arithmetic mean of 100 realizations.

6.4.4 Upscaling to the 3D Grid

The 2D properties must be upscaled to a 3D property model. In Petrel the process is called grid upscaling which allows the properties of a 3D property model with different vertical resolution to be added to another 3D property model with a different vertical resolution. The upscaling assigns the single 2D value at each (x,y) location to all of the 1.5 m layers in the 3D grid (Figure 33).

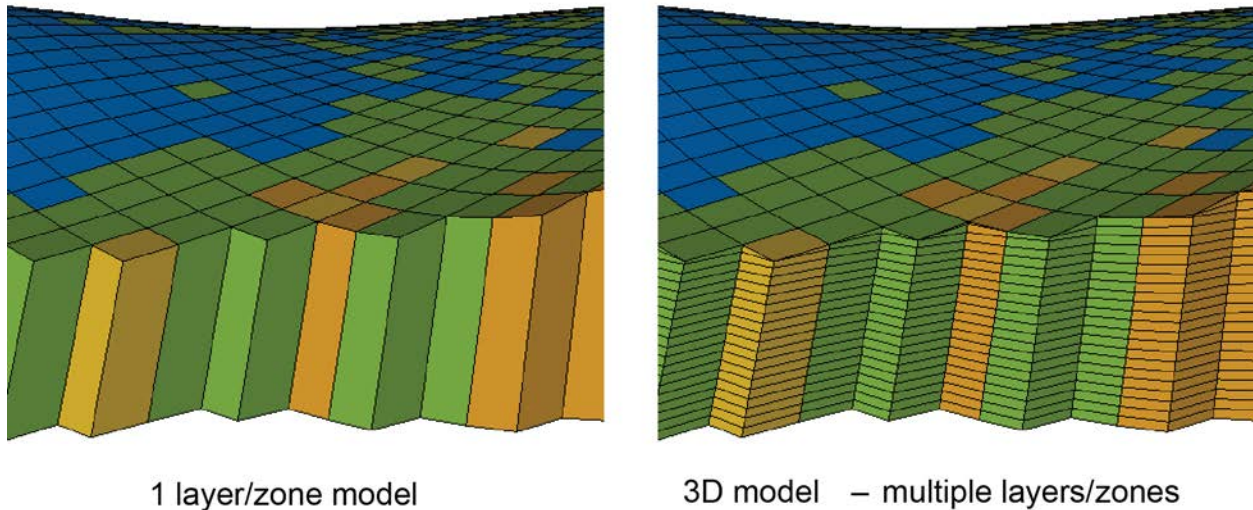


Figure 33. The left image shows an example of a 2D property in a one layer/zone model. The right image shows the result of upscaling a property from a one layer/zone model to a 3D property model. The values of the 2D model are same in the 3D property model after upscaling.

7 Model Outputs

This section describes the post-construction part of the geomodelling workflow (Part 6) after model construction was finalized. The WSB and ESB Duvernay 3D property models (and components of the 3D property models) are disseminated to the end user without the need for Petrel software. Digital data outputs generated from the 3D property models include model tabular point data, model extents, discrete and continuous model horizons, and model surfaces in iMOD format (see [Section 3](#) for definitions).

7.1 Digital Data

The WSB and ESB Duvernay 3D property models were deconstructed to provide digital data in a standard format to the stakeholder. This allows the end user to download the information they are interested in, or to re-construct the models in accordance with the methodology outlined in this report.

There are four digital data deconstructed model outputs from the WSB and ESB Duvernay 3D property models, available in standard formats:

- **Model extents:** zone model extents published as GIS data polygon features
- **Model horizons (discrete):** discrete model horizons published as gridded data in ASCII format
- **Model horizons (continuous):** continuous model horizons published as gridded data in ASCII format for use with iMOD 3D visualization (see [Section 7.2](#))

- **Model properties:** populated model property of facies, and/or 3D or 2D properties (mean of 100 realizations and standard deviation) as point data in ASCII format and in Petrel format.

7.2 iMOD 3D Visualization

Visualization of the 3D property models can be done in iMOD, an open source 3D digital data viewing software available for download from Deltares (<http://oss.deltares.nl/web/imod/>). All deconstructed model digital data can be viewed in 2D and 3D (model tabular point data, extents, and horizons). In this software, 3D property models can be rotated, toggled on and off, or exploded for viewing. Additional functionality of iMOD includes the ability to create cross-sections and clip the model using an intersection plane. The user can import any data into the model domain and visualize how they relate to the zones within the 3D property model.

8 Model Quality

The 3D property models of the Duvernay Formation in the WSB and ESB are a visual representation of the current geological interpretation by AER/AGS geologists at the time the 3D property models were built. The uncertainty of the 3D property models is dependent on the uncertainty of the distribution of the input data. This section discusses the qualitative assessment of the input surfaces and 3D and 2D populated properties.

The qualitative assessment provides a confidence level (low to high) for each model zone and property based on three quality categories (Branscombe et al., 2018a): 1) data quality, 2) data quantity, and 3) trueness to geological complexity (for zones) or trueness to reality (for properties). All categories are scored between 1 and 3 (1 = low; 2 = medium; and 3 = high). For each model zone or property the categories are added to a maximum of 9. Confidence levels are determined based on the total score range with: 3–4 = low; 5–7 = medium; and 8–9 = high. Lower confidence levels were influenced by lack of data in certain areas of the WSB and ESB and higher confidence levels were influenced by abundant data quantity and if the model zone provided an accurate representation of its geologic complexity. The quality of the model zones of the WSB and ESB Duvernay 3D property model is considered to be high ([Table 8](#)); the quality of the 3D and 2D properties is considered to be medium ([Table 9](#)).

A limitation of the Duvernay 3D property models structural framework is the ability to accurately characterize the Duvernay Formation near the Grosmont Platform to the northeast and the Peace River Arch to the northwest. The stratigraphy in these areas is complex and requires further subsurface correlation and interpretation from available drill core. The area to the northeast requires delineation of Grosmont Platform growth stages to determine where the Duvernay Formation is present and not present. The Duvernay Formation becomes more carbonate-rich in the northwestern portion of the WSB, complicating correlation using well logs. Extensional faulting of the Precambrian basement in the area surrounding the Peace River Arch resulted in structural highs and lows that controlled deposition and subsequently, the present-day distribution of Devonian strata. In addition to the complexity associated with the geological features in the northern portion of the WSB, well control in these areas is relatively poor.

The 2D property data have a noticeable limitation to accurately represent the true distribution of properties in the Duvernay Formation compared to the 3D property data due to the lack of data across

both the WSB and ESB. Generally, the northeastern edge of both the WSB and ESB Duvernay 3D property models has few to no data available for the 2D properties while the 3D properties have sparse data in that area. In areas of poor/no data coverage, geostatistical analysis was used to help populate both the WSB and ESB Duvernay 3D property models with property values.

Table 8. Confidence level of all model zones. All three categories are scored from 1 to 3 (1 = poor, 2 = average, 3 = good). The category values are then summed for each zone (minimum of 3 and maximum of 9). The model zone confidence level is based on this total value with: low = 3–4, medium = 5–7, high = 8–9.

3D property model Zone	Data Quality	Data Quantity	Trueness to Geological Complexity	Model Zone Confidence Level	
WSB upper shale zone	3	3	3	9	High
WSB carbonate zone	3	3	3	9	High
WSB lower shale zone	3	3	3	9	High
ESB shale zone	3	2	3	8	High

Table 9. Confidence level of all modelled properties. All three categories are scored from 1 to 3 (1 = poor, 2 = average, 3 = good). The category values are then summed for each property (minimum of 3 and maximum of 9). The modelled property confidence level is based on this total value with: low = 3–4, medium = 5–7, high = 8–9.

Basin	Model Property	Data Quality	Data Quantity	Trueness to Reality	Modelled Property Confidence Level	
WSB	Total porosity	2	3	2	7	Medium
WSB	Carbonate fraction	2	3	2	7	Medium
WSB	Total organic carbon	2	3	2	7	Medium
WSB	Temperature gradient	2	2	2	6	Medium
WSB	Pressure gradient	2	2	2	6	Medium
WSB	Gas-oil ratio	2	2	2	6	Medium
WSB	Condensate-gas ratio	2	2	2	6	Medium
ESB	Total porosity	2	2	2	6	Medium
ESB	Carbonate fraction	2	2	2	6	Medium
ESB	Total organic carbon	2	2	2	6	Medium
ESB	Temperature gradient	2	2	2	6	Medium

ESB	Pressure gradient	2	2	2	6	Medium
ESB	Gas-oil Ratio	2	2	2	6	Medium
ESB	Condensate-gas ratio	2	2	2	6	Medium

9 Summary

The Duvernay 3D property models are contained within a regional model constructed over the area the Duvernay Formation exists in the subsurface of Alberta. Due to the difference in Duvernay Formation depositional architecture and petrophysical properties between the WSB and the ESB, two models were built; one for each basin. The models represent the conceptual model of the Duvernay Formation as described by AER/AGS geologists. This report describes the methodology used for the geomodelling workflow and all model parameters. The WSB and ESB Duvernay 3D property models were deconstructed and all components are available in digital data format.

The WSB Duvernay 3D property model covers approximately 86 532 km² and is defined by the Duvernay Formation top and base interpolated surfaces from the 3D PGF model v1 (Branscombe et al., 2018a, b). The WSB Duvernay 3D property model was divided into three zones using stratigraphic picks and extents/lineaments generated by AER/AGS geologists. The three zones are the WSB upper shale zone, the WSB carbonate zone, and the WSB lower shale zone. Definition of Leduc reefs within the WSB was completed through facies assignment, where a discrete value was given to each zone defining the zone facies (i.e., WSB upper shale, carbonate, and lower shale facies) and the WSB Leduc reefs facies.

The ESB Duvernay 3D property model covers approximately 34 984 km² and is similarly defined by the Duvernay Formation top and base interpolated surfaces from the 3DPGF model v1 (Branscombe et al., 2018 a, b). Based on the geological interpretation, the Duvernay Formation in the ESB was modelled as a single zone, called the ESB shale zone. Leduc reefs that fall within the ESB were defined through facies assignment similarly to the WSB with the ESB facies being called ESB shale and the ESB Leduc reefs facies.

Both the WSB and ESB Duvernay 3D property models were populated with 3D and 2D properties. The spatial uncertainty of the 3D and 2D properties was simulated using a Gaussian simulation algorithm that runs multiple realizations of a property with a similar data distribution. In total, each 3D and 2D property had 100 simulated realizations.

An iterative multi-disciplinary approach was taken to building the WSB and ESB Duvernay 3D property models. Collaboration between geoscientists, geostatisticians, and geomodellers was essential for creating 3D property models of the WSB and ESB that represent the conceptual model of the Duvernay Formation at the AGS. These models are not intended for local-scale or site-specific investigations. They could, however, support science based decision making and act as a geological framework to inform regulatory decisions related to the management of the subsurface (Branscombe et al., 2018a).

10 References

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