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Three-Dimensional Property Modelling of Scollard and Paskapoo Formations and Their Equivalent Bedrock Units in Southwest Alberta

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Summary

A three-dimensional (3D) property model of sandiness/shaliness and porosity was developed for the uppermost Cretaceous–Paleogene bedrock deposits in southwest Alberta. The bedrock units are the Scollard Formation and its equivalent Willow Creek Formation, and the younger Paskapoo Formation and its equivalent Porcupine Hills Formation. These units represent a shale/mudstone-siltstone-sandstone sequence of high energy alluvial and fluvial floodplain sedimentation. The percentage of shale is inversely related to the sandstone abundance in the sequence and was calculated from a combination of GR logs from 29 429 oil/gas wells and lithological descriptions from 86 184 water wells. The porosity was calculated from bulk density logs from 13 611 oil/gas wells. The 3D property model covers an area over 65 000 km^2 and represents an eastward-thinning wedge, with a present-day maximum thickness of over 1000 m close to the Foothills of the Canadian Rocky Mountains, that pinches out towards the plains (Figure 1).

Theory / Method / Workflow

Through casing gamma-ray logs, and outlier gamma-ray and density logs (identified using geostatistical method) were corrected by log normalization. The normalized gamma-ray logs were then merged and pooled with other normal, openhole logs. Then, shale percentage logs were calculated using the linear estimation method for shale volume using 30 API as the sand element and 120 API as the shale element in the equation. Total porosity logs were calculated directly from the bulk density logs using a matrix density of 2.77 g/cm^3 obtained from the neutron-density cross plot. Water-well drillers' descriptions of geological material were grouped into three categories: sandstone, siltstone and shale; Shale percentage logs from water wells were then derived by assigning 0 (0% shale) for the sandstone category, a value of 0.5 (50% shale) for the siltstone category and and a value of 1 (100% shale) for the shale category. Figure 2 shows the subsuface distribution of the derived shale percentage logs and porosity logs.

The shale percentage logs and the porosity logs were imported into Schlumberger's Petrel 2015 and the 3D model of shale percentage and porosity were created using Gaussian Random Function Simulation (GRFS) (Daly et al, 2010) with each voxel being 500 m x 500 m horizontally and 5 m vertically. In creating the shale percentage model, GRFS with collocated simple cokriging method was employed using the gamma ray log derived shale percentage as the primary varible and the water well derived shale percentage as the secondary variable.

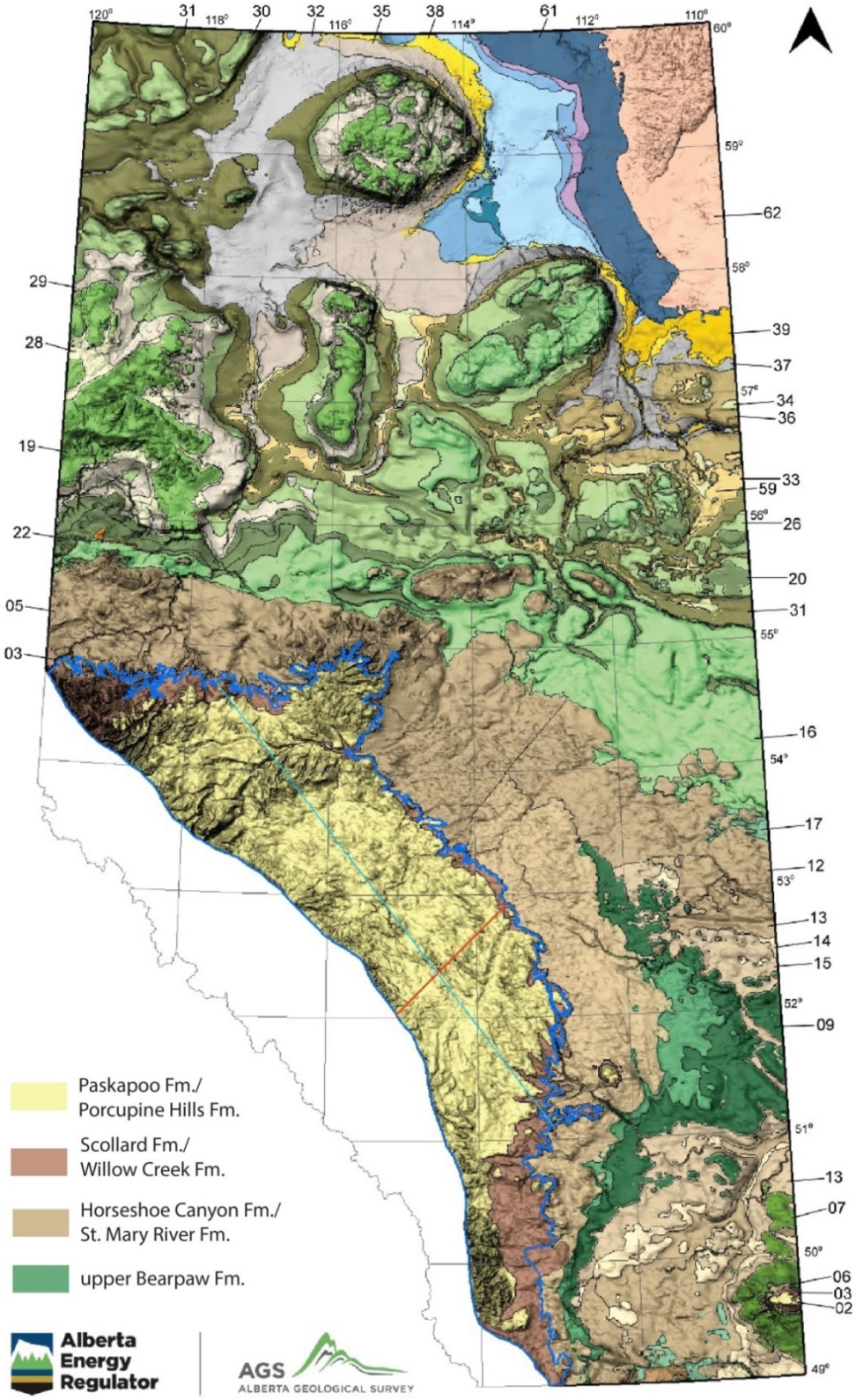

Figure 1. Location of the study area and bedrock geology map (modified from Alberta Geological Survey, 2019). The Battle Fm. is located between Scollard Fm. and Horseshoe Canyon Fm. and too thin to be shown on the map. The boundary of the 3D model is marked as blue and based on the extent of Scollard Fm./Willow Creek Fm. and the red and cyan lines indicate the location of SW and SE trending cross sections, respectively.

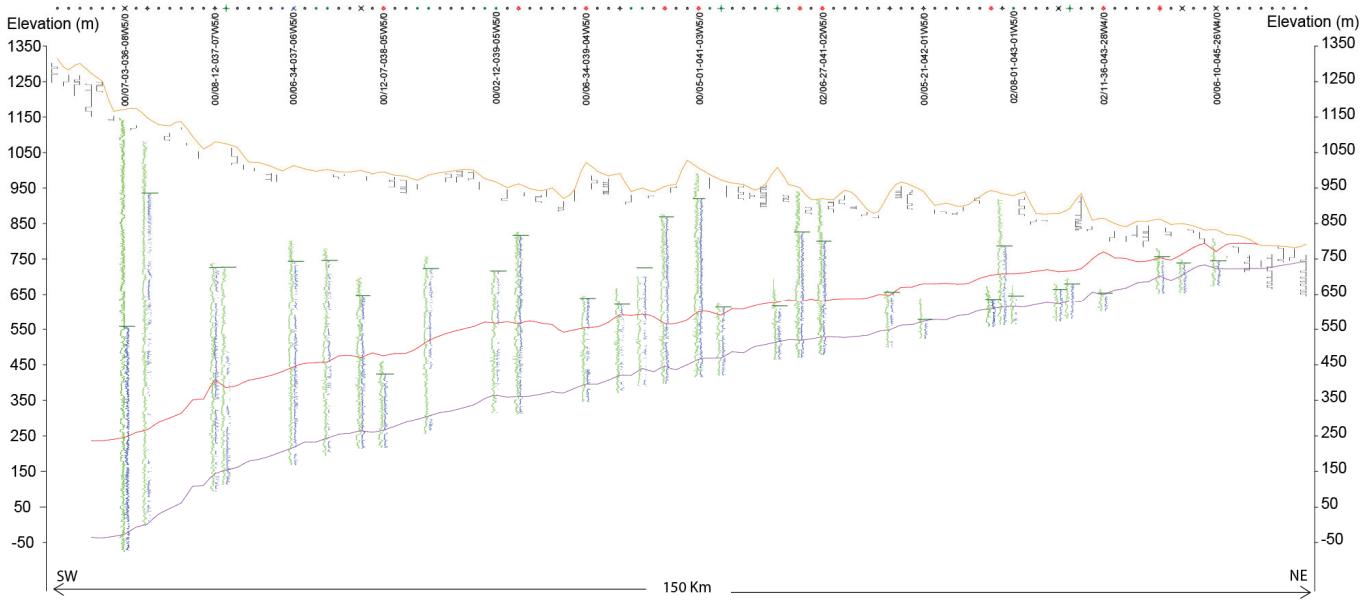

Figure 2. Well log cross-section along the red line indicated in Figure 1. Logs: black is the coded shale percentage log from water wells; green is the shale percentage log from oil/gas wells; blue is the density porosity log. Horizons: orange is KB; red is the base of the Paskapoo Formation; purple is the base of the Scollard Formation. Dark green bars indicate the base of surface casing. Top row are oil/gas well and water well symbols, and only selected oil/gas wells are labelled.

Results, Observations, Conclusions

Several trends emerge from the 3D modelling, including:

- A basal sandstone unit within the Paskapoo Fm. is well developed in the central part of the study area; it becomes discontinuous and absent in the northern and southern parts of the study area. Above the basal sandstone unit is a mudstone dominated interval in the middle part of the Paskapoo Fm.; it grades into an interval of higher sandstone abundance towards the central west. The mudstone interval grades into an interval of higher sandstone abundance in the upper portion of the Paskapoo Fm (Figure 3).
- The equivalent Porcupine Hills Fm. in the southwest of the study area does not show a three-layer structure but is characterized by a sandier interval in the lower part and a mudstone and siltstone interval for the middle and upper part of the formation.
- The density porosity generally increases up-dip from west to east for both Scollard Fm. and Paskapoo/Porcupine Hills formations and is generally greater in the northern part than in the southern part of the study area (Figure 4).

Novel/Additive Information

The 3D property model developed for this study illustrates at a higher resolution compared to previous studies (Grasby et al., 2008; Parks and Andriashek, 2009; Lyster and Andriashek, 2012; Quartero et al., 2015) the degree of heterogeneity of shale percentage and porosity in the near-surface bedrock of southwest Alberta. The model is appropriate only for regional-scale use (1:100 000) and not intended for use in place of site-specific investigations.

Acknowledgements

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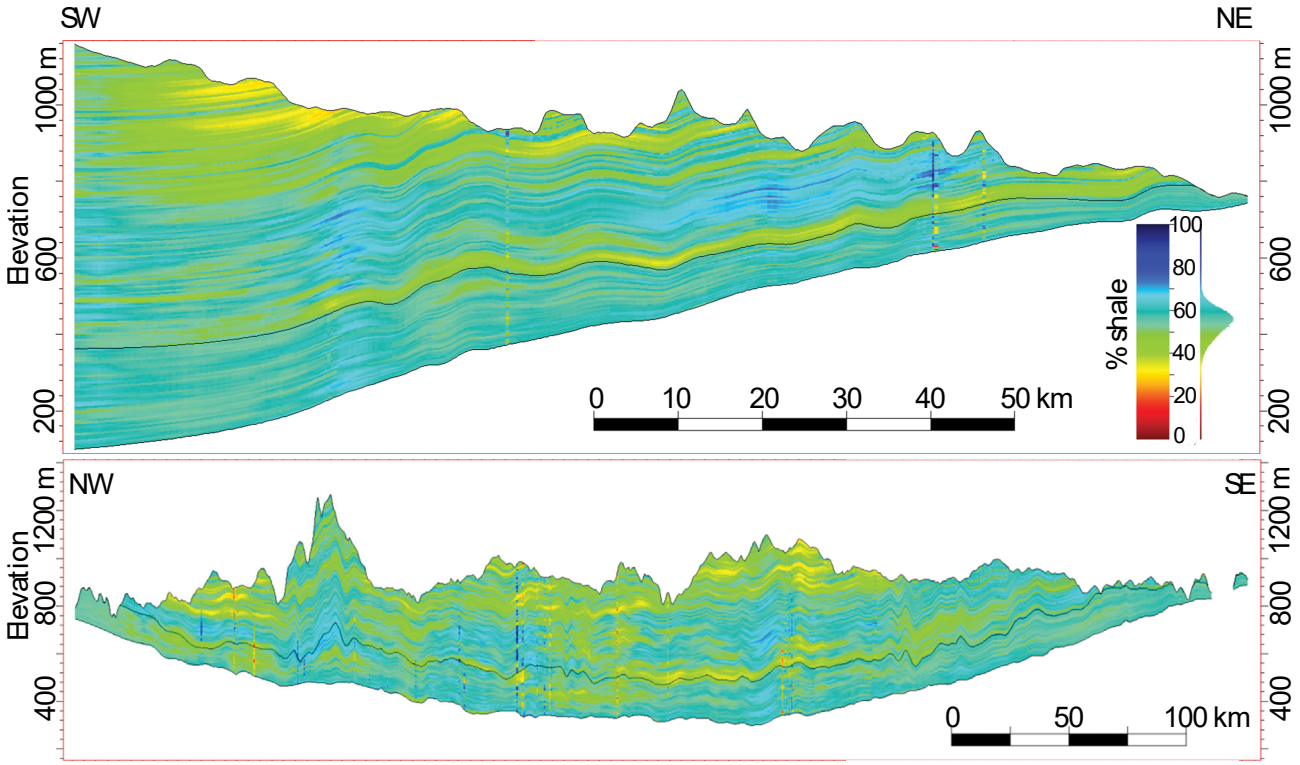

Figure 3. Cross-sections of the shale percentage model. The black line indicates the boundary between Paskapoo Fm. and Scollard Fm. Location of the two cross sections are indicated by the red and cyan lines, respectively, in Figure 1. Vertical exaggeration is 45 times (upper) and 100 times (lower).

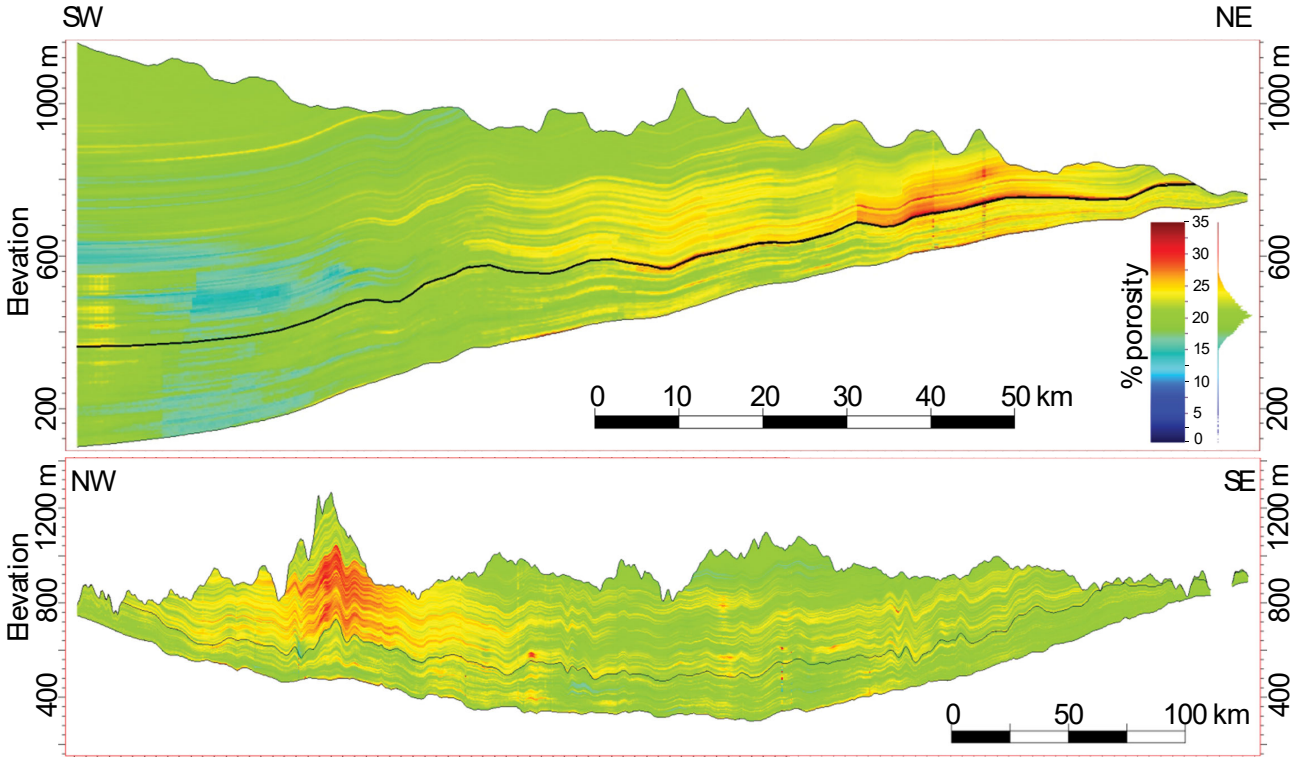

Figure 4. Cross-sections of the density porosity model. The black line indicates the boundary between Paskapoo Fm. and Scollard Fm. Location of the two cross sections are indicated by the red and cyan lines, respectively, in Figure 1. Vertical exaggeration is 45 times (upper) and 100 times (lower).

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