

Alberta Geological Survey Map 603 Explanatory Notes

Sediment Thickness of Alberta

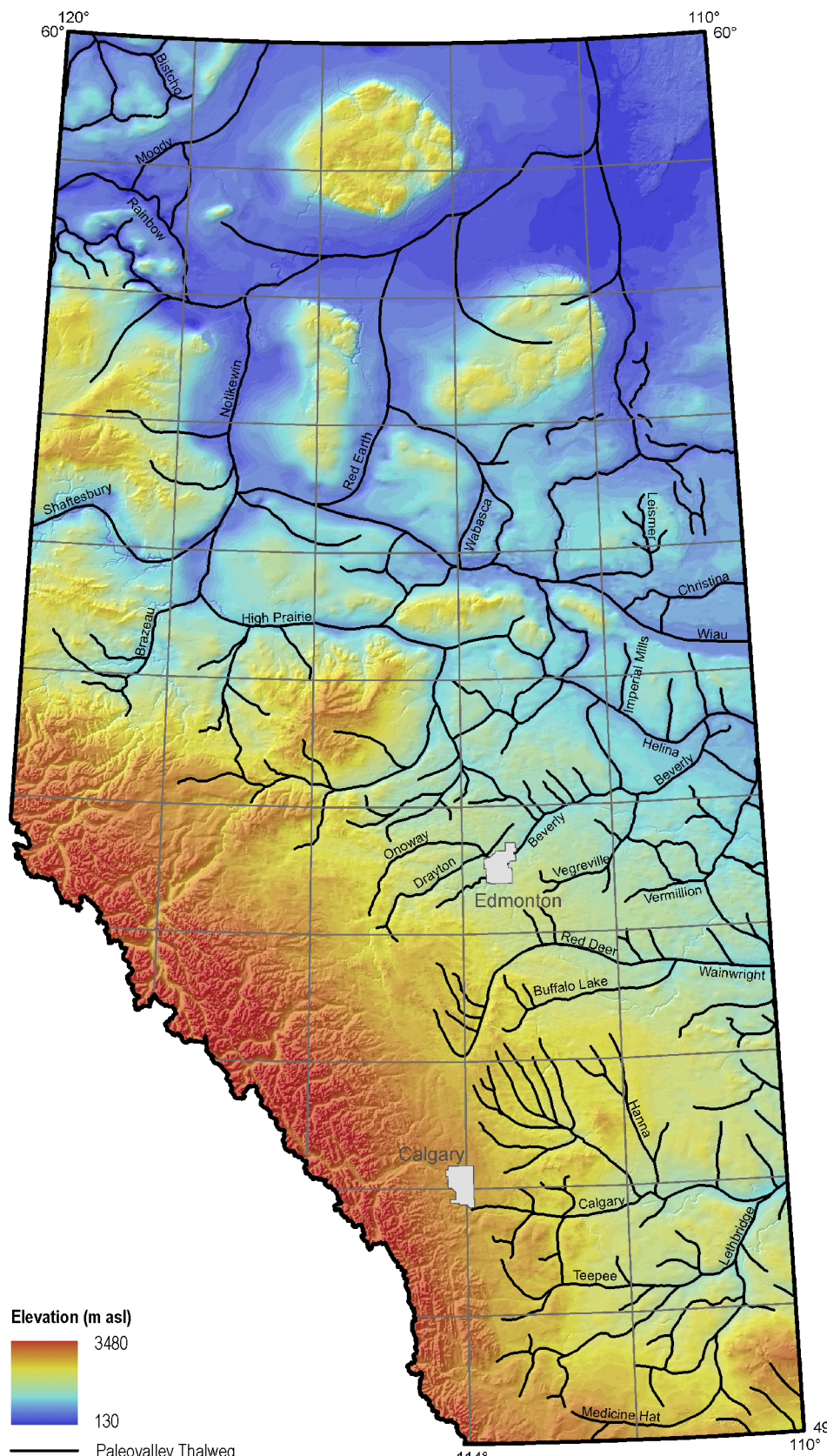


Figure 1. Bedrock paleovalley systems and thalwegs across the Alberta Plains.

Introduction

This map is a rendering of a geostatistical model of the thickness and distribution of sediment overlying bedrock in Alberta using a newly revised bedrock topography model of the province (MacCormack et al., 2015) and provides detailed details on an earlier reconstruction of the sediment isopach map of the province (Atkinson and Lyster, 2010). Alberta occupies the Interior Plains of western Canada, with small components of the Canadian Shield and Western Cordillera in the northeast and southwest parts of the province respectively, and covers an area of approximately 662 000 km². To the south, Alberta is bounded by the 49° parallel, which separates it from the U.S. state of Montana, and to the north, it borders the Northwest Territories along the 60° parallel. To the east, Alberta is separated from Saskatchewan along the 110° meridian, and to the west, its border with British Columbia follows the 120° meridian until the Continental Divide, which it follows to the Montana border.

Interpretation

The thickness and distribution of sediments overlying the bedrock surface in Alberta is highly varied, ranging from less than 1 m to as much as 400 m. These sediments include Neogene fluvial deposits, glacial materials deposited during Quaternary glaciation as well as postglacial sediments. Sediment thickness is greatest in the eastern and northern parts of the province, progressively thinning toward the Rocky Mountains in the southwest. The areas of thickest sediment occur along the axes of large, regionally integrated paleovalley systems which are incised into the bedrock surface (Figure 1). These paleovalleys are filled with 30 to 400 m thick deposits of stratified and non-stratified sediment including clay, silt, sand, gravel, and diamict (Andriashchuk, 2000; Andriashchuk and Atkinson, 2006; Slattery et al., 2010). The largest of these infilled paleovalley systems spans north-central Alberta, and comprises two northwest-southeast trending trunk paleovalleys (the Wau and High Prairie-Helina) with subsidiary paleovalleys (the Red Earth and Wabasca) extending to the north. Additional subsidiary paleovalleys within this regional system extend subparallel to the Wau paleovalley, and include the Leismer, Christina and Imperial Mills. Sediment thickness along the thalwegs of these paleovalleys ranges from approximately 100 to 240 m. In

northwest Alberta, the thickest sediments range from 100 m to as much as 350 m and are found above the thalwegs of deeply incised paleovalleys (the Rainbow, Moody, Biatcho) and across the Cameron Hills (H1), Birch Mountains (H5), and Firebag Hills (D2) uplands (Figures 1 and 2). In central Alberta, the thickest sequences of sediment range from 70 to 180 m and occur above the thalwegs of the Wainwright paleovalley system. In southern Alberta, the thickest sediments occur along the deepest parts of the Lethbridge and Calgary paleovalleys, which are filled with 30 to 150 m of sediment. Elsewhere in Alberta, there is a spatial relationship between sediment thickness and the physiography of the underlying bedrock. Areas of thin sediment (less than 5 m) generally occur where the bedrock surface is near to, or forms the modern land surface. These areas include the Rocky Mountains, foothills, benchlands, and uplands physiographic regions (Pettapiece, 1986; Figure 2). Areas of thicker sediment (greater than 5 m) typically occur across the plains and lowlands physiographic regions (Figure 2). Exceptions to this relationship between physiography and sediment thickness occur in the Cameron Hills (H1), Birch Mountains (H5), and Firebag Hills (D2) uplands and along the northern Rainy Hills (F14) and southern Cooking Lake (F16) uplands, where thicker accumulations of sediment account for the elevated topography of the modern landscape. In the Cameron Hills (H1), Birch Mountains (H5), and Firebag Hills (D2) uplands, sediment ranges from 5 to 350 m thick, with the thickest sediment typically occurring on the southwestern flanks of these uplands, as well as along the thalwegs of adjacent infilled paleovalleys. In contrast, sediment thickness on the Sullivan Lake (P6) and Olds (G2) plains is generally less than 5 m, particularly along two prominent low-relief corridors that extend between Edmonton and Calgary, to the east and west of Red Deer (c.f. Shetson, 1984, 1987). Despite relatively thin sediment cover across these plains, the intervening Rainy Hills and Cooking Lake uplands are covered by up to 70 m of sediment, marking the position of the Sufield and McGregor moraines respectively (Evans et al., 2014). The sediment isopach exhibits prominent thickening at the southern limit of the central and western corridors of thin sediment along a broad arc extending from Strathmore to Medicine Hat. This comprises sediment ranging from 30 to 90 m thick, and coincides with the position of the Lethbridge moraine (Stalker, 1977).

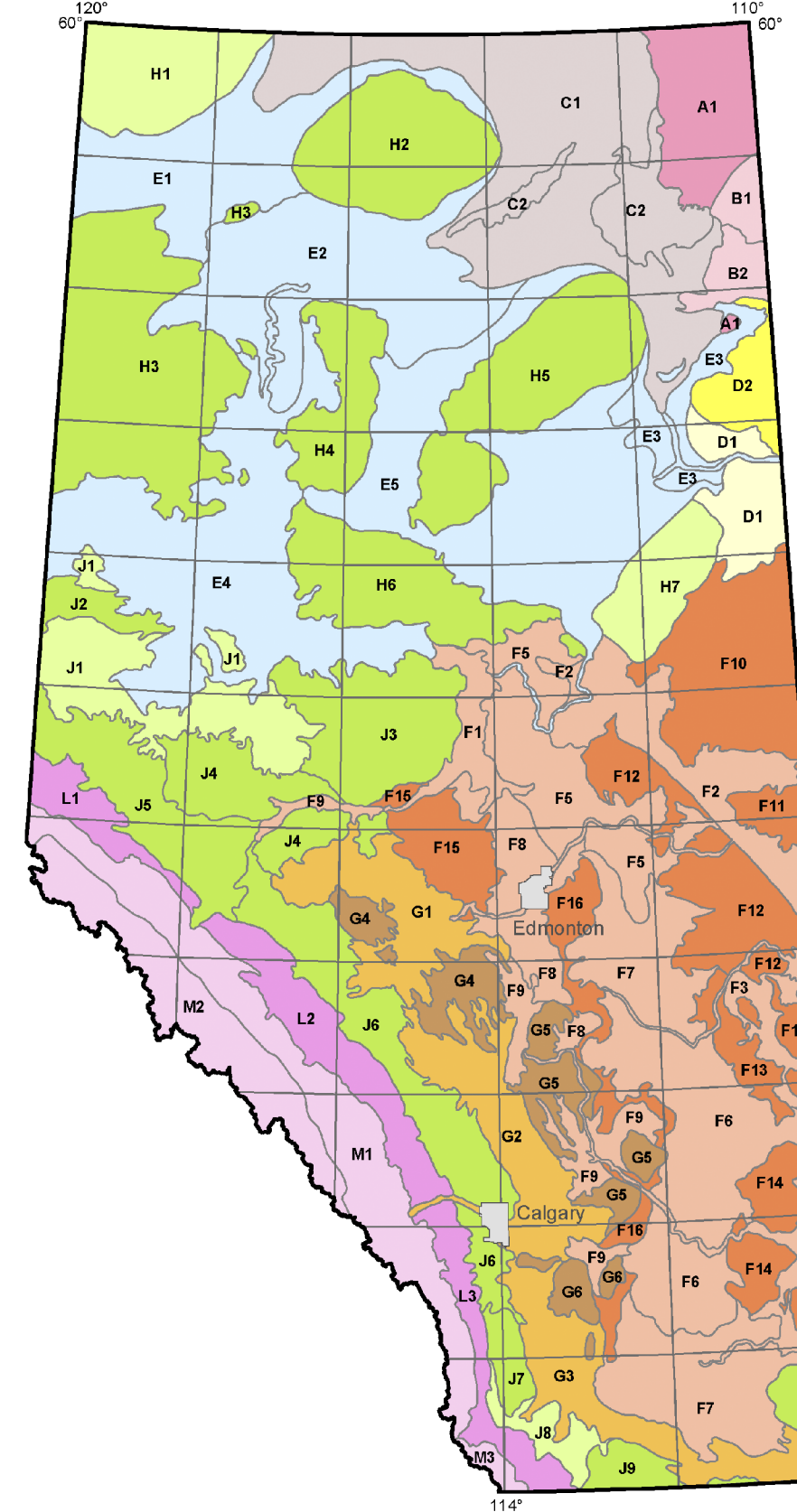


Figure 2. Physiographic regions of Alberta (modified from Pettapiece, 1986).

Creating the Sediment Thickness Map

The sediment thickness map (Figure 3) was derived by subtracting the computer-generated geostatistical model of the bedrock topography of Alberta (MacCormack et al., 2015; Figure 4) from the 25 m grid-spaced Alberta Sustainable Resource Development (SRD) Digital Elevation Model (DEM; Figure 5) of the modern land surface.

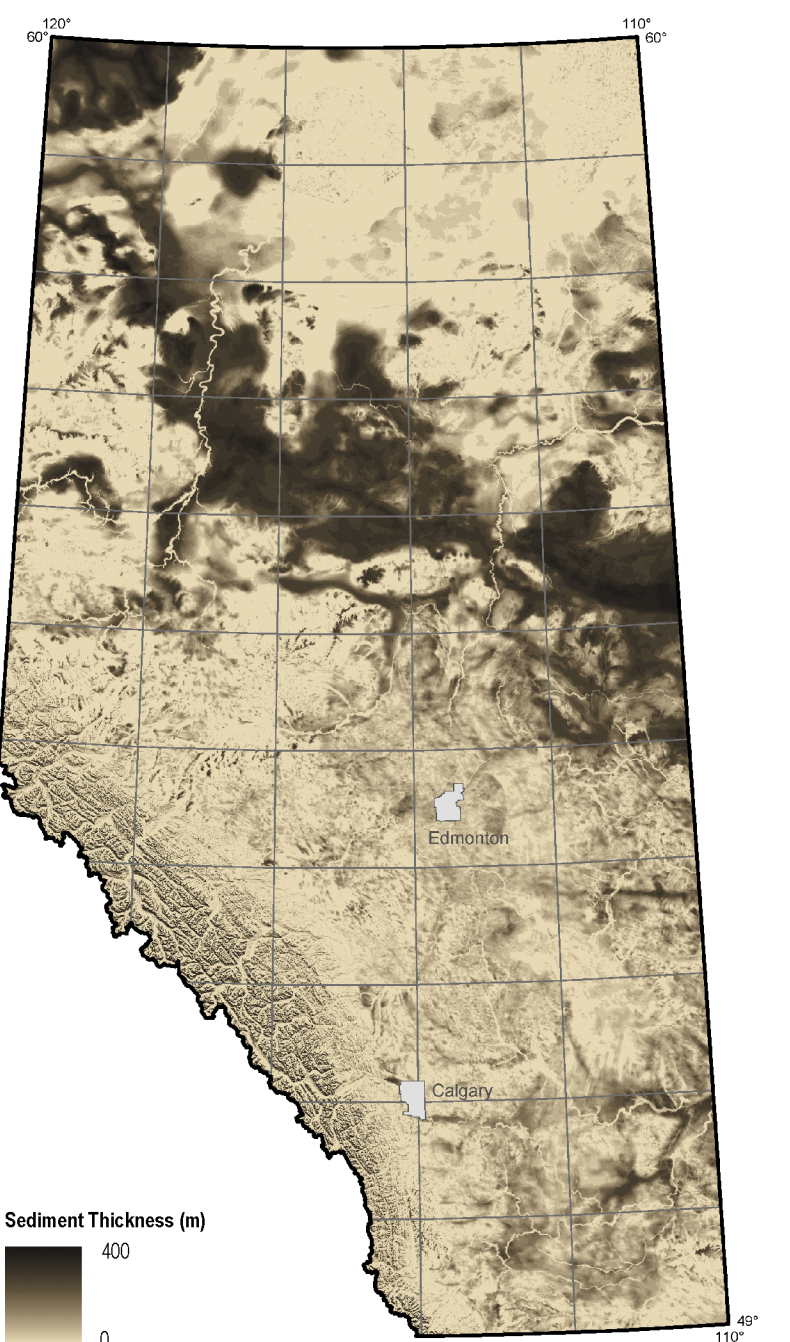


Figure 3. Sediment thickness mapped at a 500 m resolution.

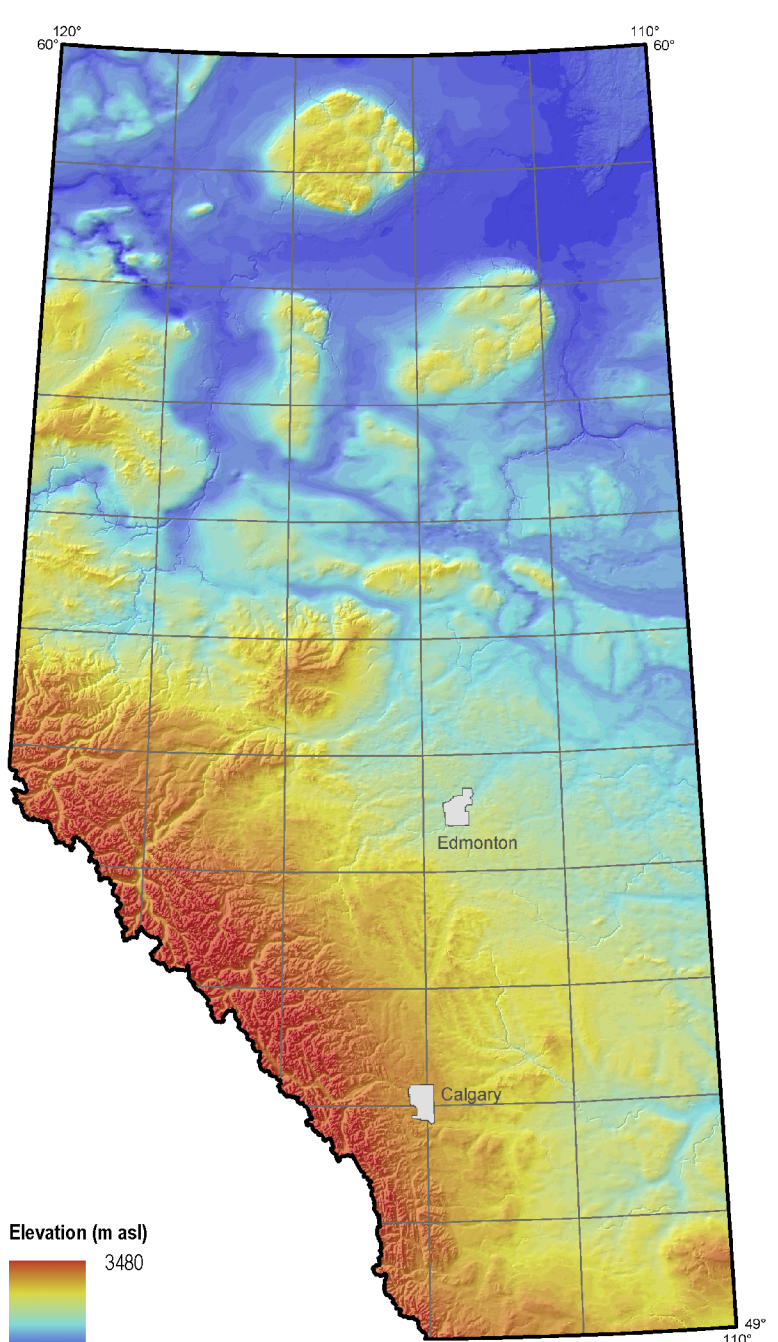


Figure 4. Bedrock topography mapped at a 500 m resolution (MacCormack et al., 2015).

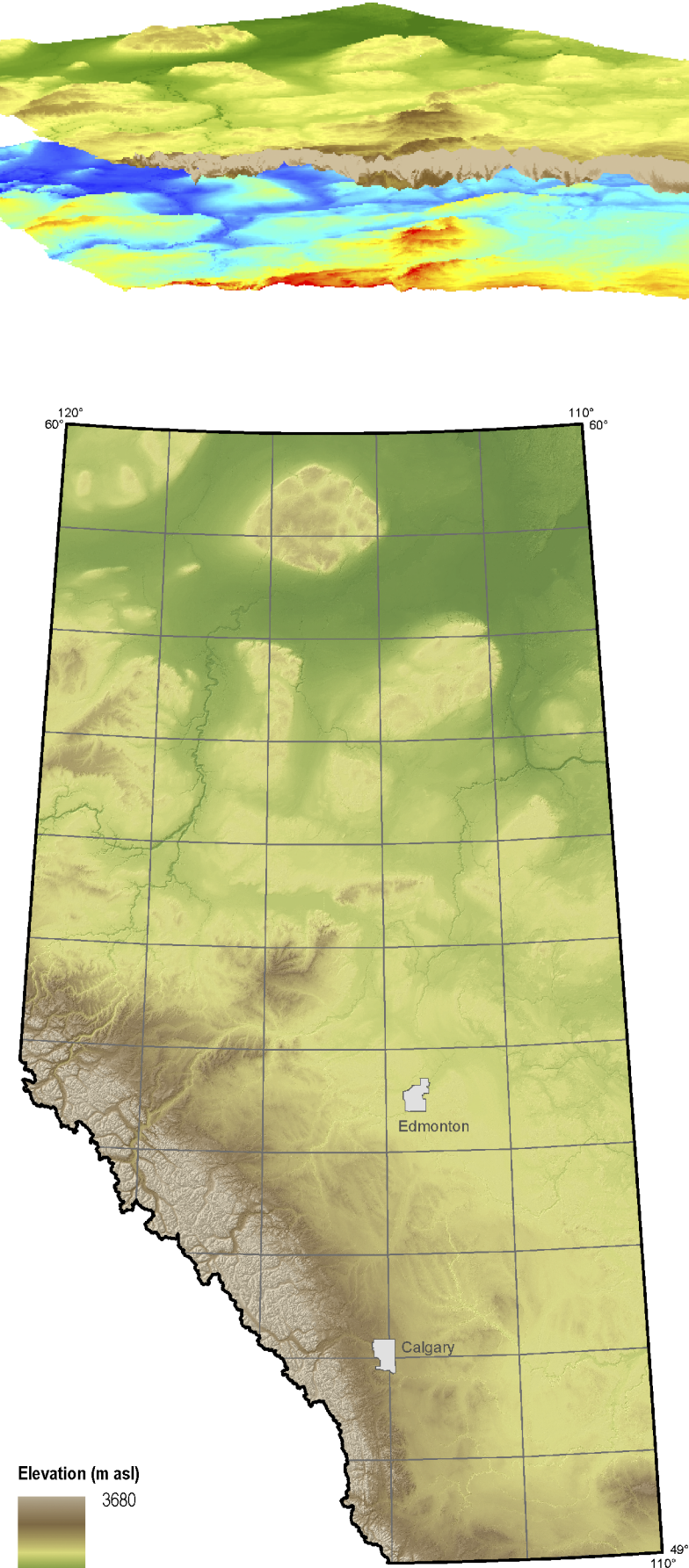


Figure 5. SRD digital elevation model mapped at a 25 m resolution.

Figure 6. Three-dimensional view of the DEM (top) and bedrock topography (bottom) surfaces used to calculate the sediment thickness. Surfaces are shown with a vertical exaggeration of 20x and separated by 100 m in the z-dimension.

Because the sediment thickness map is derived from two other surface models, it is important to make sure that they are both as accurate as possible. The sections on "Modelling the Bedrock Topography" and "Choosing the Most Appropriate Digital Elevation Model" provide an overview of how the bedrock topography was modelled (Figure 4) and how two different DEMs were evaluated in order to select the most appropriate DEM for this task.

Choosing the Most Appropriate Digital Elevation Model

Sediment thickness is calculated by subtracting the elevations of the bedrock topography (MacCormack et al., 2015) from the DEM surface. Therefore, choosing the most appropriate DEM is important as it has a considerable amount of influence on the calculated sediment thicknesses. Two DEMs were evaluated: the Shuttle Radar Topography Mission (SRTM), and the Alberta Sustainable Resource Development (SRD) digital elevation model (DEM; Figure 5) of the modern land surface. The DEMs' values were compared to measurements obtained by LiDAR, which has an approximate vertical accuracy of 1 m. Unfortunately, LiDAR coverage is not available across the entire province, and combining the LiDAR

coverage with the other DEMs would likely introduce artifacts. Therefore, we used the increased accuracy and resolution of the available LiDAR data to test the provincial DEMs. This was done in two areas of the province with varying topography (Figure 9). NTS map sheet 84D was selected because it has considerable topographic variability (Figure 10), while NTS sheet 83A is located on the Alberta Plains and has a much more consistent topography (Figure 11).

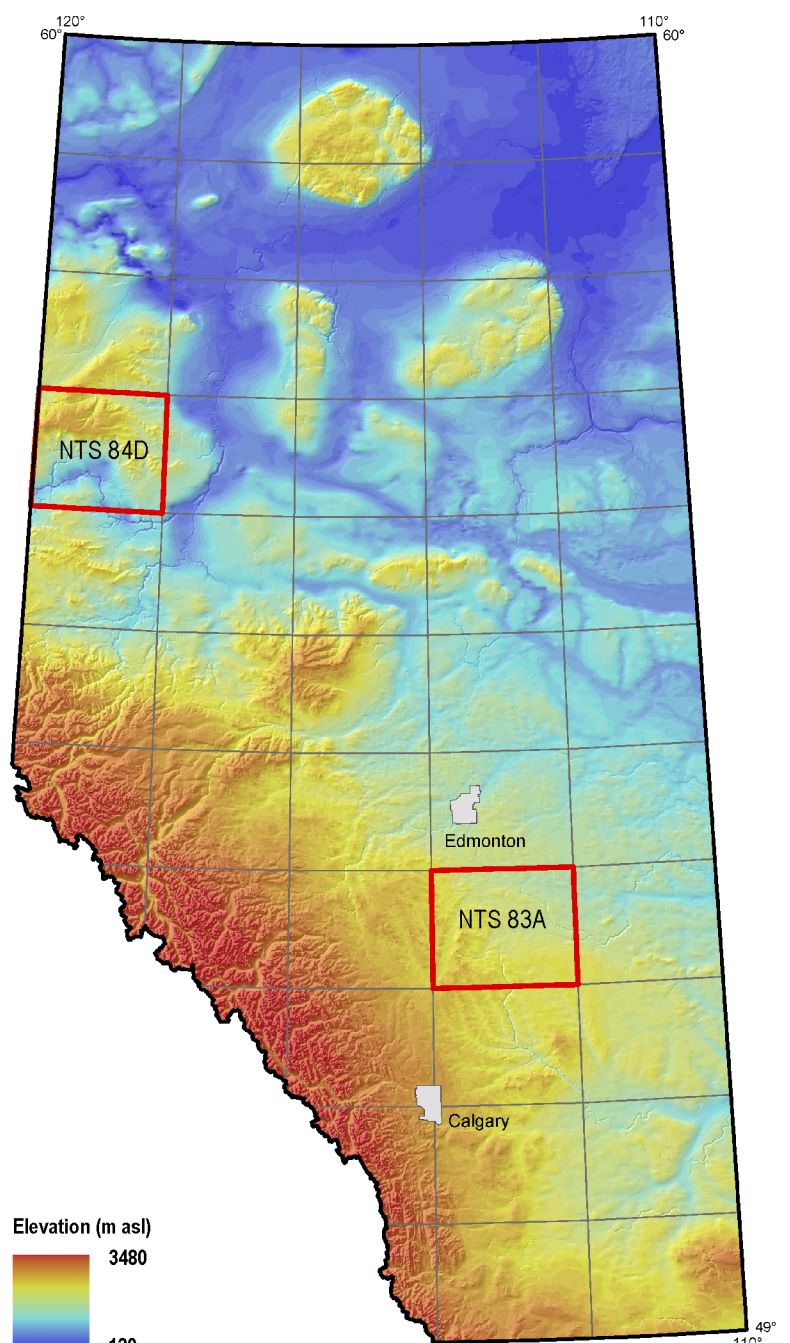


Figure 9. Bedrock topography of Alberta (MacCormack et al., 2015).

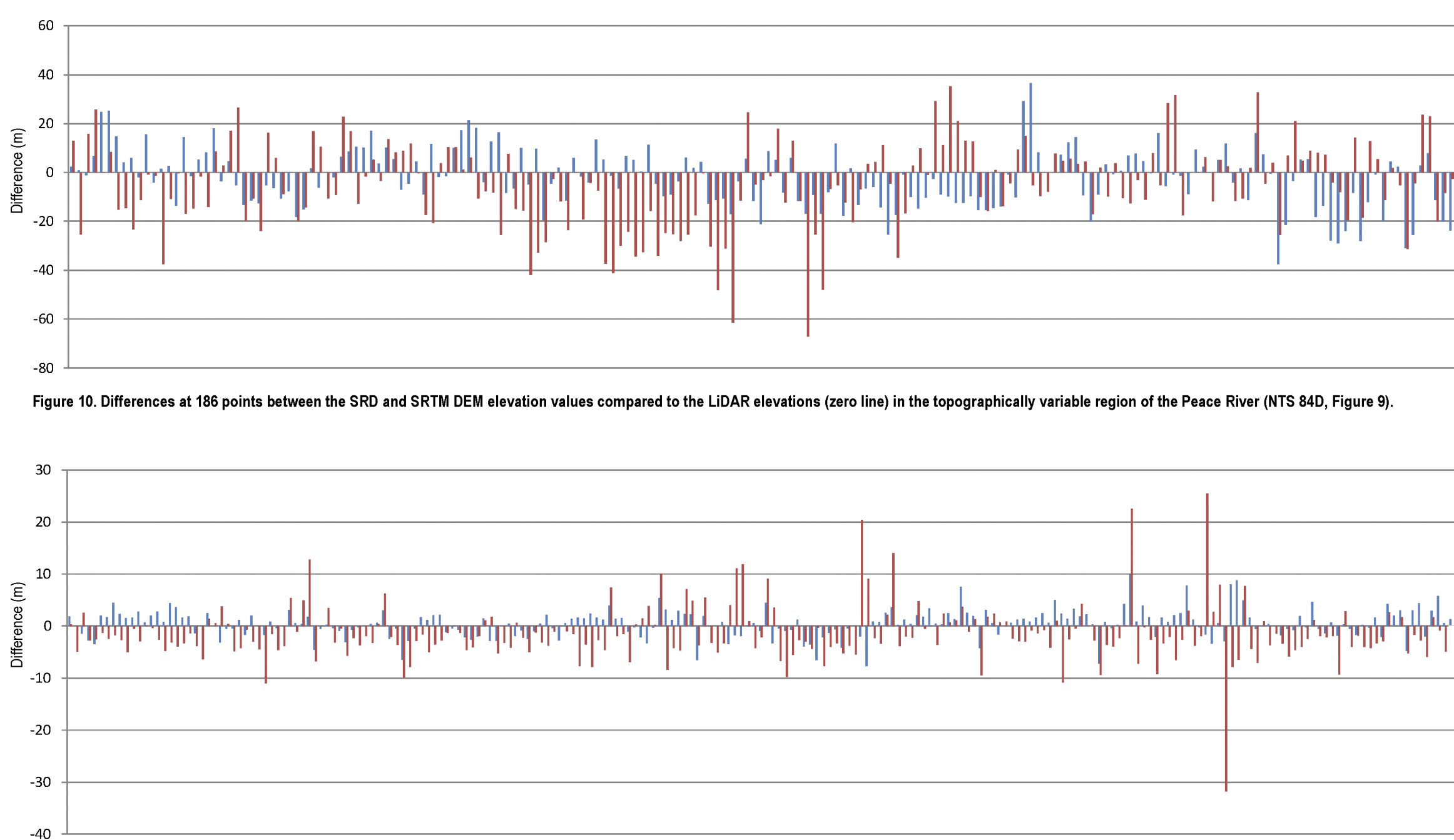


Figure 10. Differences at 186 points between the SRD and SRTM DEM elevation values compared to the LiDAR elevations (zero line) in the topographically variable region of the Peace River (NTS 84D, Figure 9).

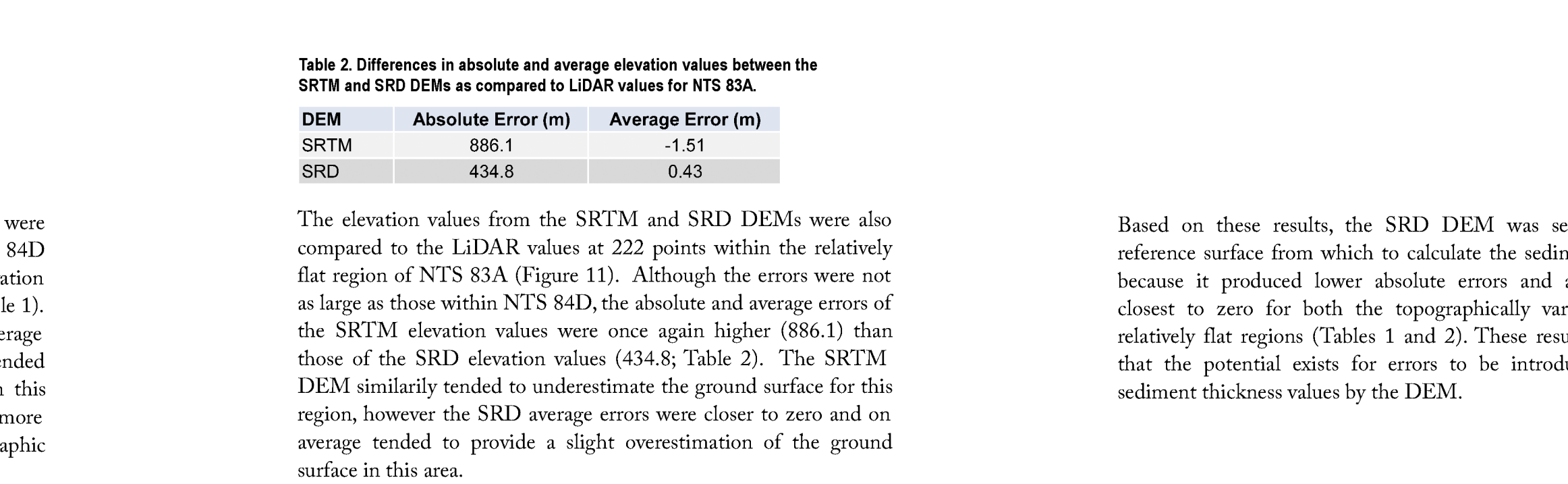


Figure 11. Differences at 222 points between the SRD and SRTM DEM elevation values compared to the LiDAR elevations (zero line) in the relatively flat Alberta Plains (NTS 83A, Figure 9).

DEM	Absolute Error (m)	Average Error (m)
SRTM	2621.9	-5.33
SRD	1803.6	-2.28

The elevation values from the SRTM and SRD DEMs were compared to the LiDAR values at 186 points within NTS 84D (Figure 10). The absolute and average errors of the SRTM elevation values were higher than those of the SRD elevation values (Table 1). Interestingly, both the SRTM and SRD values were on average lower than the values reported by the LiDAR data and thus tended to provide underestimates of the ground surface elevation in this area. These results indicate that the SRD DEM provides a more accurate representation of the ground surface in this topographic region.

DEM	Absolute Error (m)	Average Error (m)
SRTM	885.1	1.51
SRD	434.8	0.43

The elevation values from the SRTM and SRD DEMs were also compared to the LiDAR values at 222 points within the relatively flat region of NTS 83A (Figure 11). Although the errors were not as large as those within NTS 84D, the absolute and average errors of the SRTM elevation values were once again higher (886.1) than those of the SRD elevation values (434.8; Table 2). The SRTM DEM similarly tended to underestimate the ground surface for this region, however the SRD average errors were closer to zero and on average tended to provide a slight overestimation of the ground surface in this area.

Based on these results, the SRD DEM was selected as the reference surface from which to calculate the sediment thickness because it produced lower absolute errors and average errors closest to zero for both the topographically variable and the relatively flat regions (Tables 1 and 2). These results also show that the potential exists for errors to be introduced into the sediment thickness values by the DEM.

Modelling the Bedrock Topography

The bedrock topography of Alberta (MacCormack et al., 2015) was modelled using 178 466 data points identifying the top of bedrock throughout Alberta. Of these data points, 72 131 were from high-quality data sources, 32 720 from medium-quality sources, and 67 989 from low-quality data sources (Figure 7). The data points were quality filtered to ensure that the bedrock topography model was based primarily on the highest quality data available. This was accomplished by plotting all high-quality data and then removing any medium-quality data points that were within 1000 m of any high-quality data. This reduced the number of medium-quality points used for interpolation from 119 005 to 32 720. The remaining medium-quality data points were merged with the high-quality data points and then used to filter the low-quality dataset to remove any data points that were within 2500 m of any high- or medium-quality data points. This reduced the number of low-quality data points used for interpolation from 253 824 to 67 989. The filtered low-quality data points were then combined with the high- and medium-quality data. The final quality filter was applied to a dataset containing data points collected from a previous 1:2 million (2M) scale bedrock topography map (Pawlowicz and Fenton, 1995) for which much of the map area represents a collection of geologists' conceptual interpretations about the bedrock surface. Although the 2M data points are not hard data, they do represent expert geological knowledge through the rendering of concepts. Therefore, in the absence of any other bedrock data, these points were used sparingly to help constrain the bedrock surface. The 2M points were filtered to remove any data that were within 10 km of any high-, medium-, or low-quality data point. The data composition for the final model consisted of 41.7% data from high quality sources, 18.9% from medium quality sources, 39.3% from low quality sources, and 0.1% from the 2M dataset (Figure 7).

Regardless of the effort taken to ensure that the high-quality data has as much influence over the bedrock topography model as possible, there is still uncertainty associated with the model results. Areas of higher uncertainty (orange and red areas) in the northern parts of the province are largely associated with areas of sparse data coverage (Figure 8).

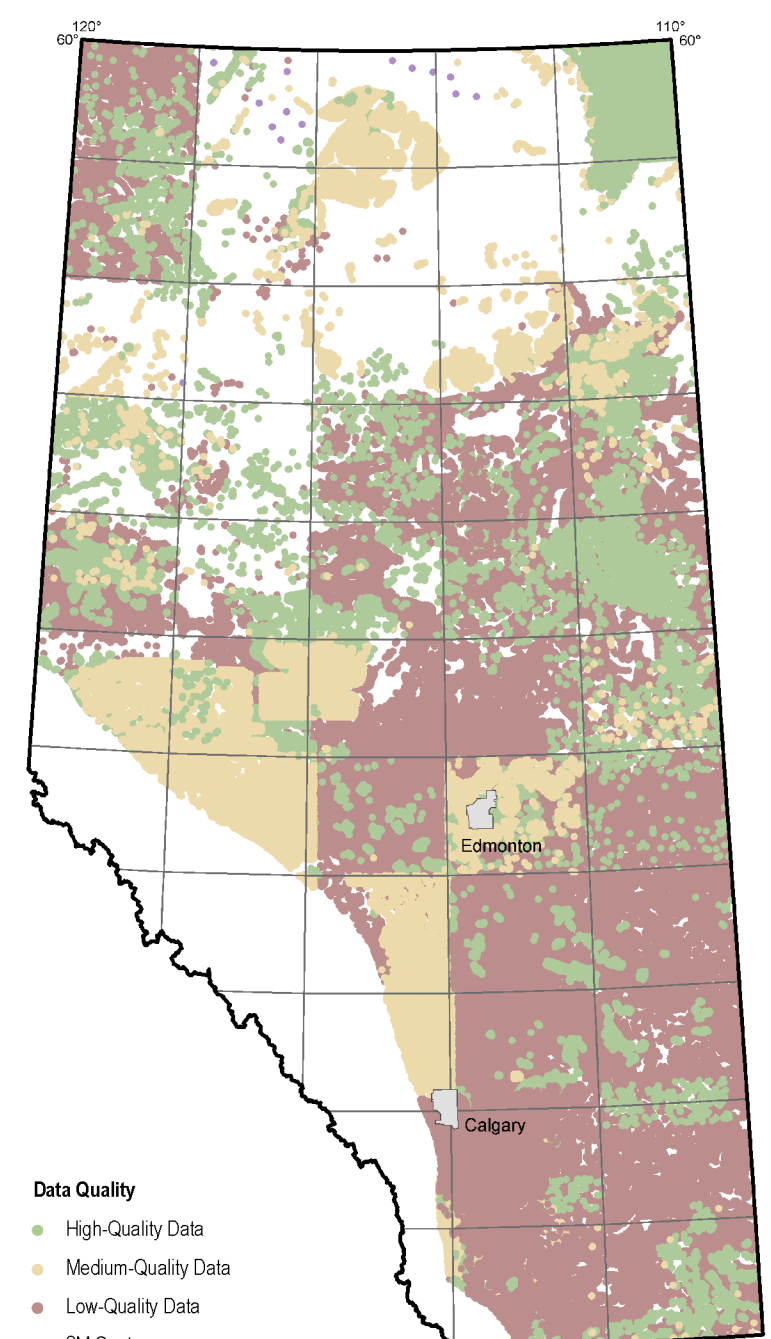


Figure 7. Distribution of high-, medium-, and low-quality, and 2M data used to model the bedrock surface elevation in Alberta (MacCormack et al., 2015).

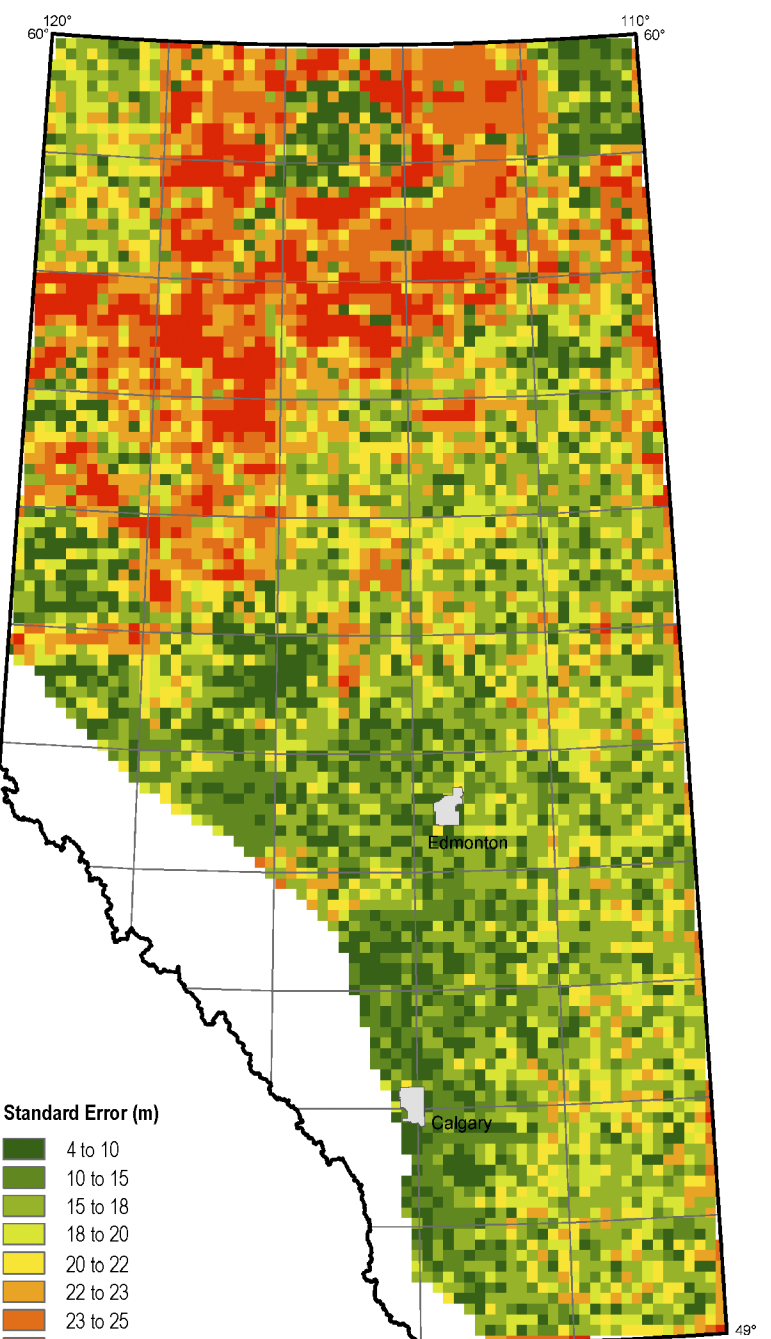


Figure 8. Uncertainty associated with the bedrock topography map (MacCormack et al., 2015).

Difference Between the Previous Sediment Thickness Map of Alberta (AGS Map 551) and the Current Version (AGS Map 603)

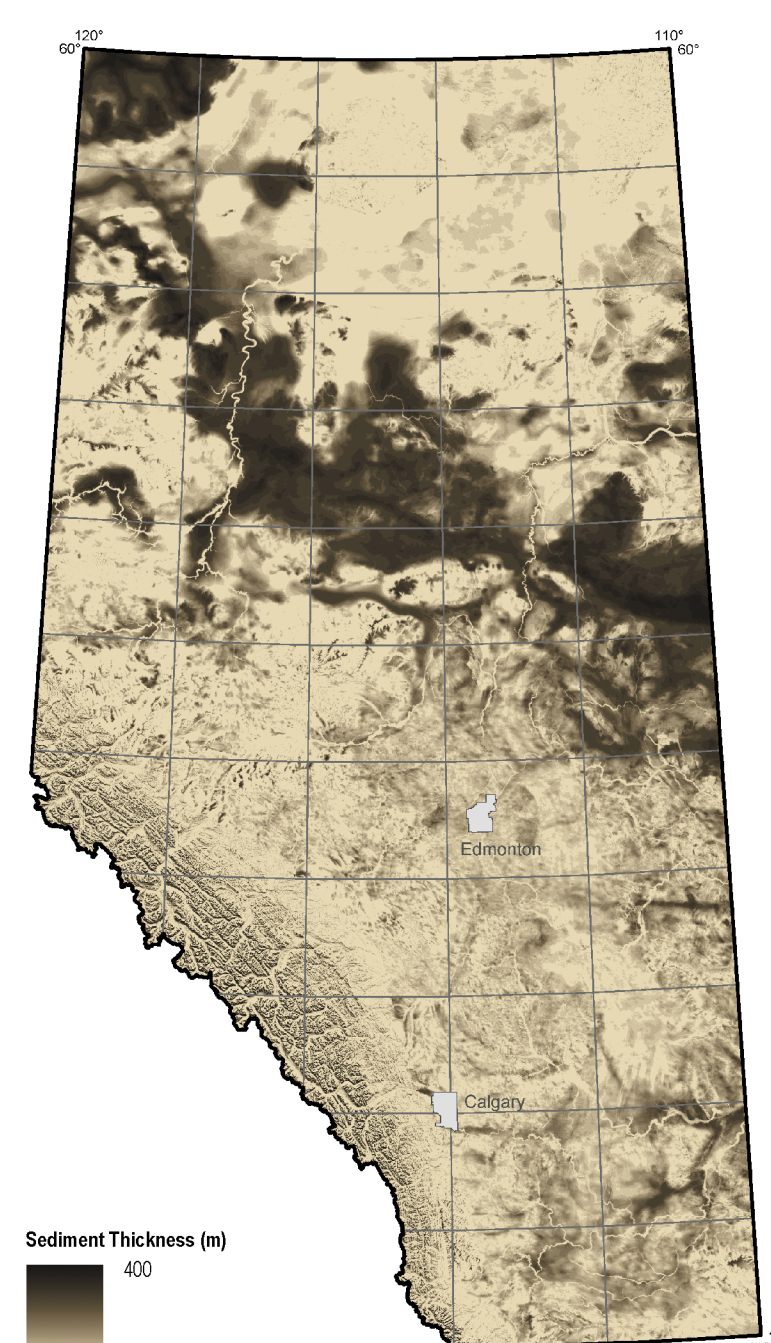


Figure 12. AGS Map 603 sediment thickness.

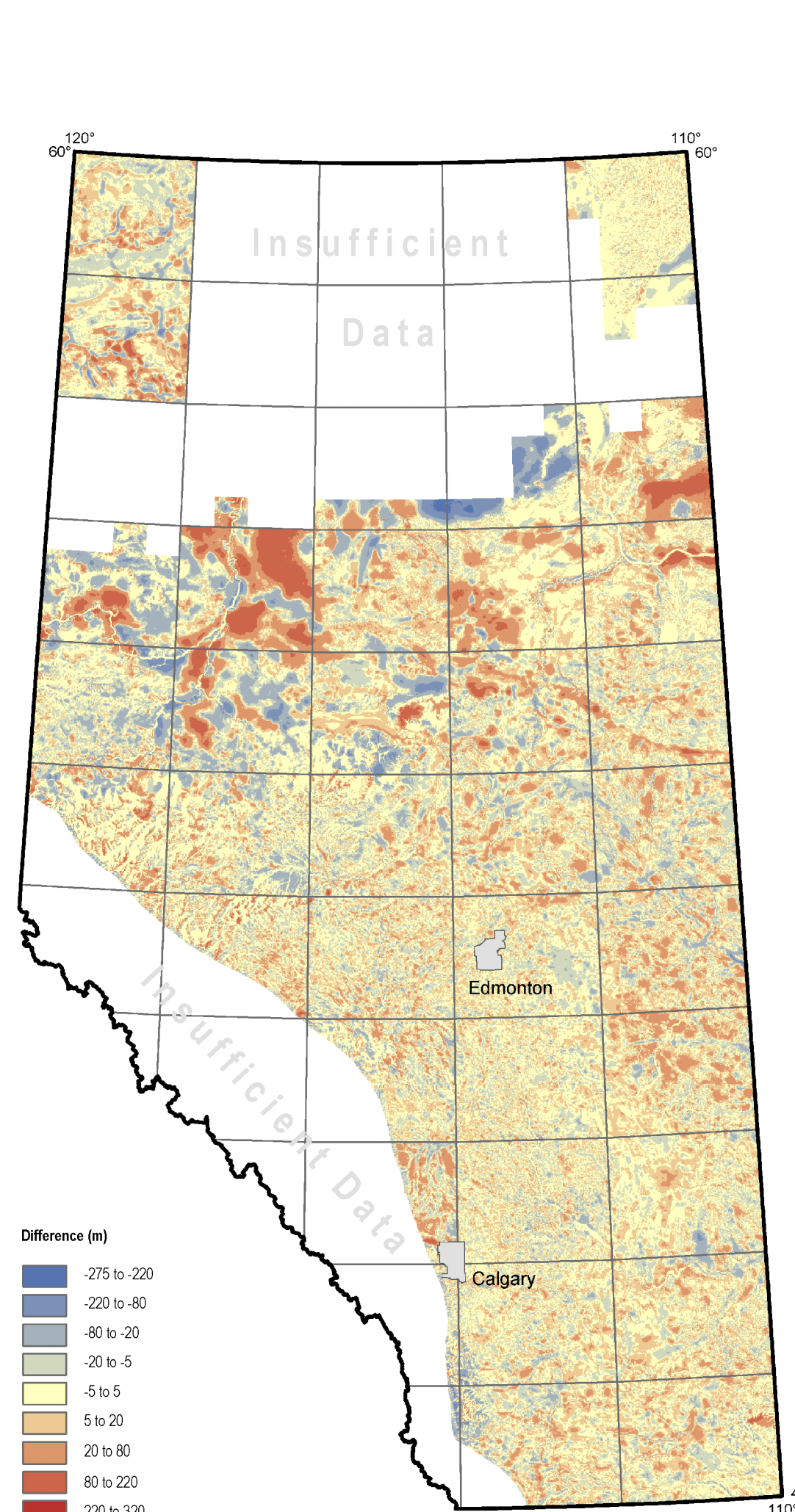


Figure 14. Differences between the previous (AGS Map 551) and current (AGS Map 603) sediment thickness maps of Alberta.

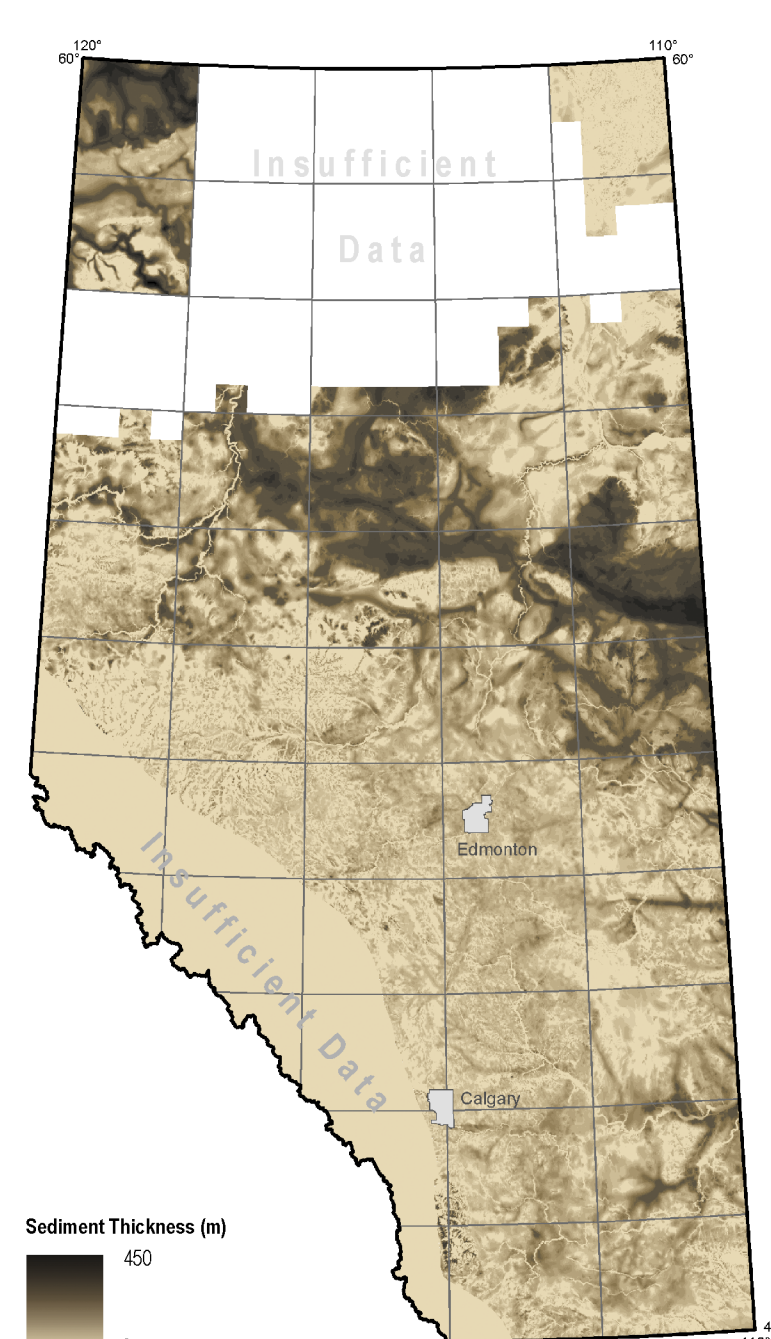


Figure 13. AGS Map 551 sediment thickness (Atkinson and Lyster, 2010).

Sediment thicknesses for AGS Map 603 were calculated using the SRD DEM (compared with AGS Map 551 which used the SRTM DEM) and the updated bedrock topography map, resulting in differences between AGS Map 603 (Figure 12) and AGS Map 551 (Figure 13). Figure 14 highlights the difference between the previous (AGS Map 551) and current (AGS Map 603) sediment thickness maps of Alberta. The pale yellow color indicates regions where there is little difference (less than 5 m) between the two maps (Figure 14). The blue regions show where AGS Map 603 has been updated to reflect shallower bedrock topography, while the red portions indicate that the new bedrock surface is topographically lower than its previous version (Figure 14). The white portions of the map are areas where a comparison was not possible because AGS Map 551 did not include sediment thickness values for the Alberta Rocky Mountains and Foothills and the northern portion of the province due to insufficient data.

Spatial Distribution of Sediment Thickness

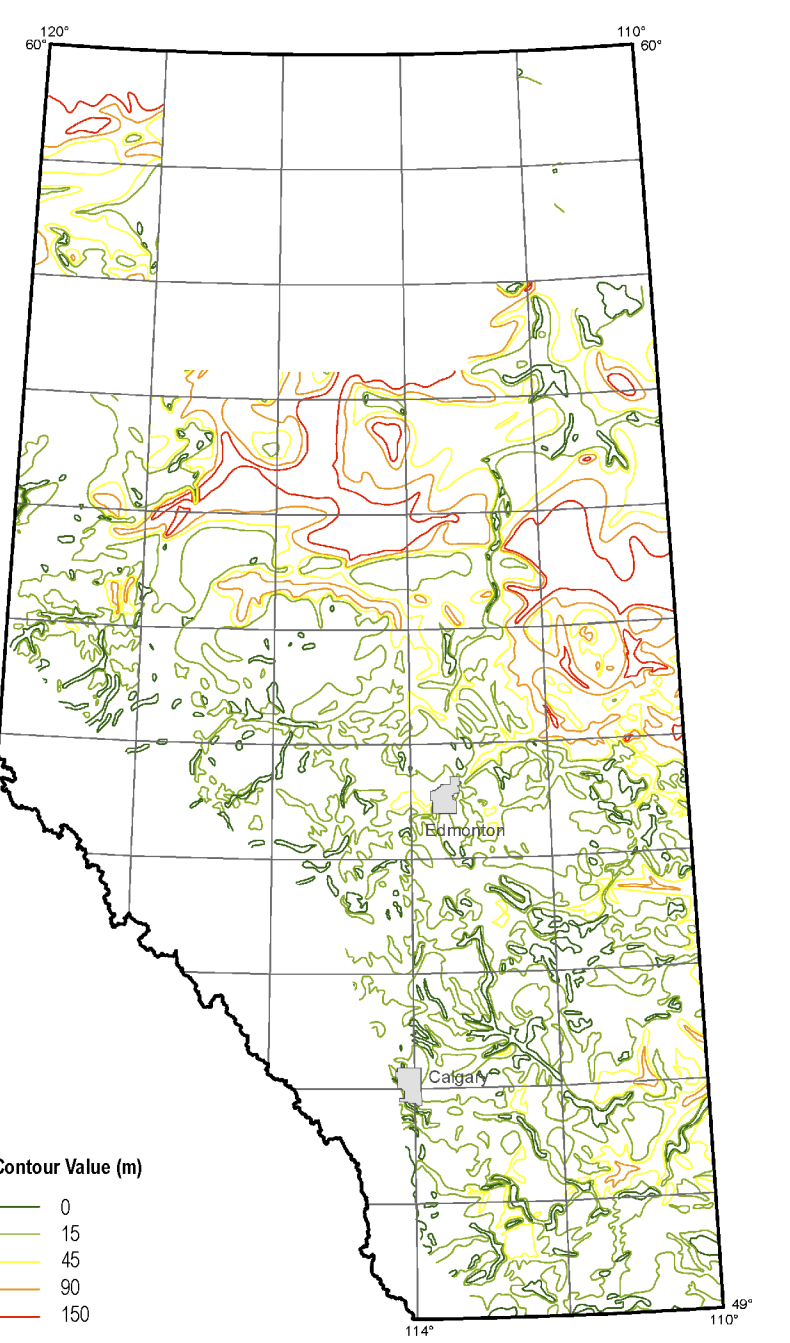


Figure 15. AGS Map 551 sediment thickness contours (Atkinson and Lyster, 2010).

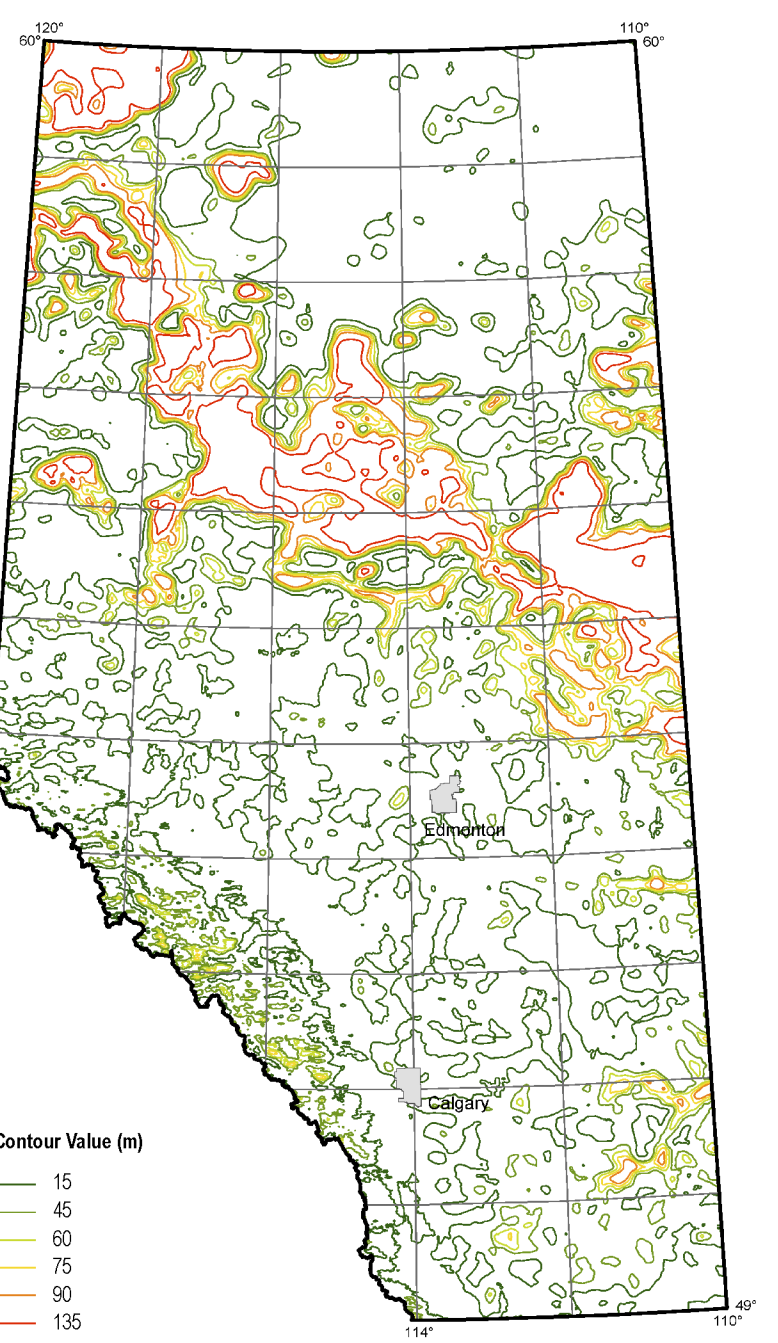


Figure 16. AGS Map 603 sediment thickness contours.

Contour maps were used to highlight the spatial distribution of particular sediment thickness ranges (Figures 15 and 16). The contours created from the previous sediment thickness map (Figure 15) as well as those for the current sediment thickness map (Figure 16) show that the thickest packages of sediments are constrained to a southeast-trending corridor through the northern portion of the province (Figures 15 and 16). Thicker successions of sediments (yellow, orange and red contours) are also found in streamlined/linear features throughout the province, which are often associated with buried valleys. Areas of thinner sediments (less than 30 m) have green contours and are typically found in the northeastern and central southwestern portions of the province.

Sediment Thickness (m)	Area of Alberta Plains Covered (%)
0 to 2	24.0
2 to 5	4.2
5 to 10	7.8
10 to 20	14.1
20 to 40	18.6
40 to 60	9.6
60 to 80	5.4
80 to 100	3.8
100 to 150	6.4
150 +	6.1

Sediment Thickness (m)	Area of Alberta Rocky Mountains and Foothills Region Covered (%)
0 to 2	47.7
2 to 5	3.9
5 to 10	5.4
10 to 20	8.1
20 to 40	10.2
40 to 60	6.3
60 to 80	4.4
80 to 100	3.3
100 to 150	5.3
150 +	5.3

The Alberta Rocky Mountains and Foothills are predominantly covered by a thin layer of sediments, with 48% of the region covered by less than 2 m (Table 4; Figure 17). The percentage of the Alberta Rocky Mountains and Foothills covered by thicker sediments generally decreases, with only 18% of the region covered by more than 60 m of sediment (Table 4). Some of these thick deposits evidently relate to infilling along valley floors; however, it is also possible that these are anomalous artifacts caused by the DEM and bedrock topography models not being able to accurately accommodate the extreme elevation variations of the Rocky Mountains at such a regional scale.

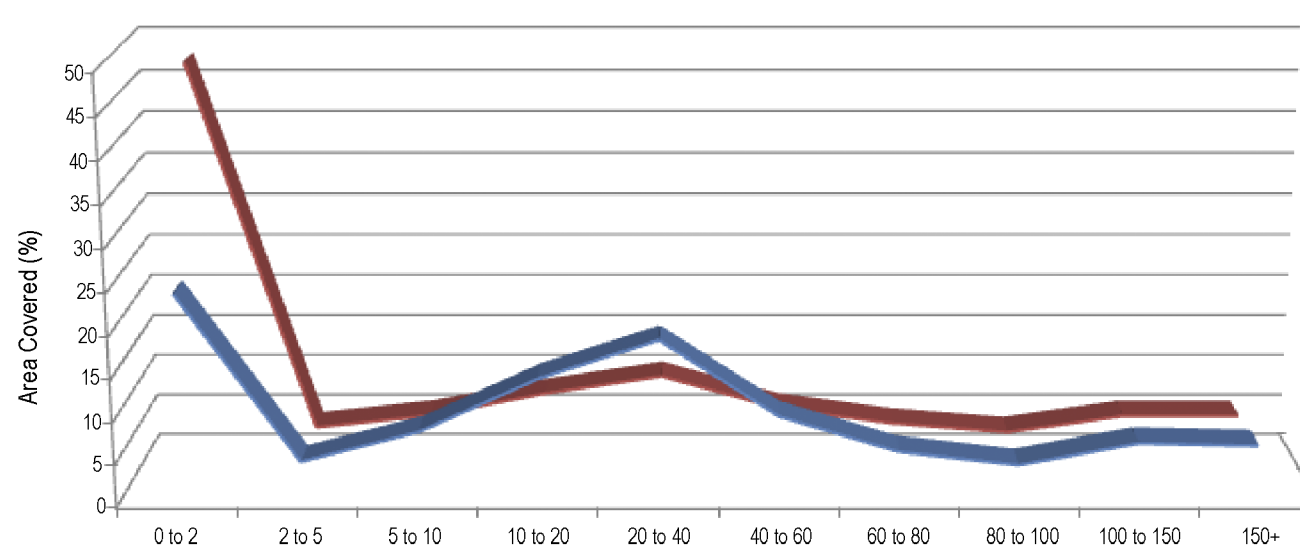


Figure 17. Percentage of the Alberta Plains and Alberta Rocky Mountains and Foothills covered by varying ranges of sediment thickness.

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Acknowledgements

K. McKay completed the digital cartography and GIS. Base data were modified from the Atlas of Canada (Natural Resources Canada, 2012) and the National Atlas of the United States of America[®] (United States Department of the Interior, 2003).

Recommended Reference Format

MacCormack, K.E., Atkinson, N. and Lyster, S. (2015). Sediment thickness of Alberta, Canada, Alberta Energy Regulator, AERAGS Map 603, scale 1:1 000 000.

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