Preparing for experimental CO_2 injection: Seismic data analysis

J. Helen Isaac and Don C. Lawton

ABSTRACT

We processed and interpreted a small new 3D seismic survey in the study area in Southern Alberta. This area is of interest for planned experimental CO_2 injection into sandstones in three formations; the Basal Belly River at about 285 m, the Medicine Hat at 475 m and the Second White Speckled Shale, at 710 m.

The processing included noise attenuation, Gabor deconvolution and post-stack time migration. We also filtered the data after NMO to remove strongly dipping noise events.

We interpreted the data and made time and depth structure maps. We also mapped the formation tops from wells. In general there is gentle geological dip to the northwest. In the immediate area of interest (section 22, R017 T18W4M) the surface elevations vary by only about 7 m.

INTRODUCTION

The Containment and Monitoring Institute (CaMI), which has been established by Carbon Management Canada, is developing a Field Research Station (FRS#1) to refine and calibrate monitoring systems and technologies for CO_2 injection. The program at FRS#1 will be designed to inject small amounts (up to 1000 tonnes per year) of CO_2 into the subsurface at depths of approximately 285 m, 475 m and 710 m. The primary injection target is water-filled sandstones within Upper Cretaceous clastic Basal Belly River Formation, with secondary targets in the Medicine Hat and Second White Speckled Shale formations (http://www.cmcghg.com/cami-3/field-research-station-1/).

The location is within the Countess Field, near Brooks in Southern Alberta, about 150 km southeast of Calgary, in section 22 T17 R16W4M. Figure 1 shows the location of the 3D survey and the locations of important wells referred to in the companion geology paper (Isaac and Lawton, 2014). There are many wells in the area. We reprocessed the seismic data, tied them to well formations using synthetic seismograms, and interpreted and mapped key horizons.

SEISMIC DATA PROCESSING

We acquired a new small baseline 3D seismic survey in section 22 (Figure 1). The source was the University of Calgary's Envirovibe at a source interval of 5 m and 10 m along 20 lines spaced 50 m and 100 m apart. Receivers were also spaced at 5 m and 10, along lines spaced 50 m and 100 m apart. Figure 2 shows the layout of the shots and receivers in the 3D survey. Further details are provided by Lawton et al. (2014).

The data were processed using a fairly standard processing flow which included both refraction and residual statics. The final datum was 800 m with a replacement velocity of 2600 m/s.

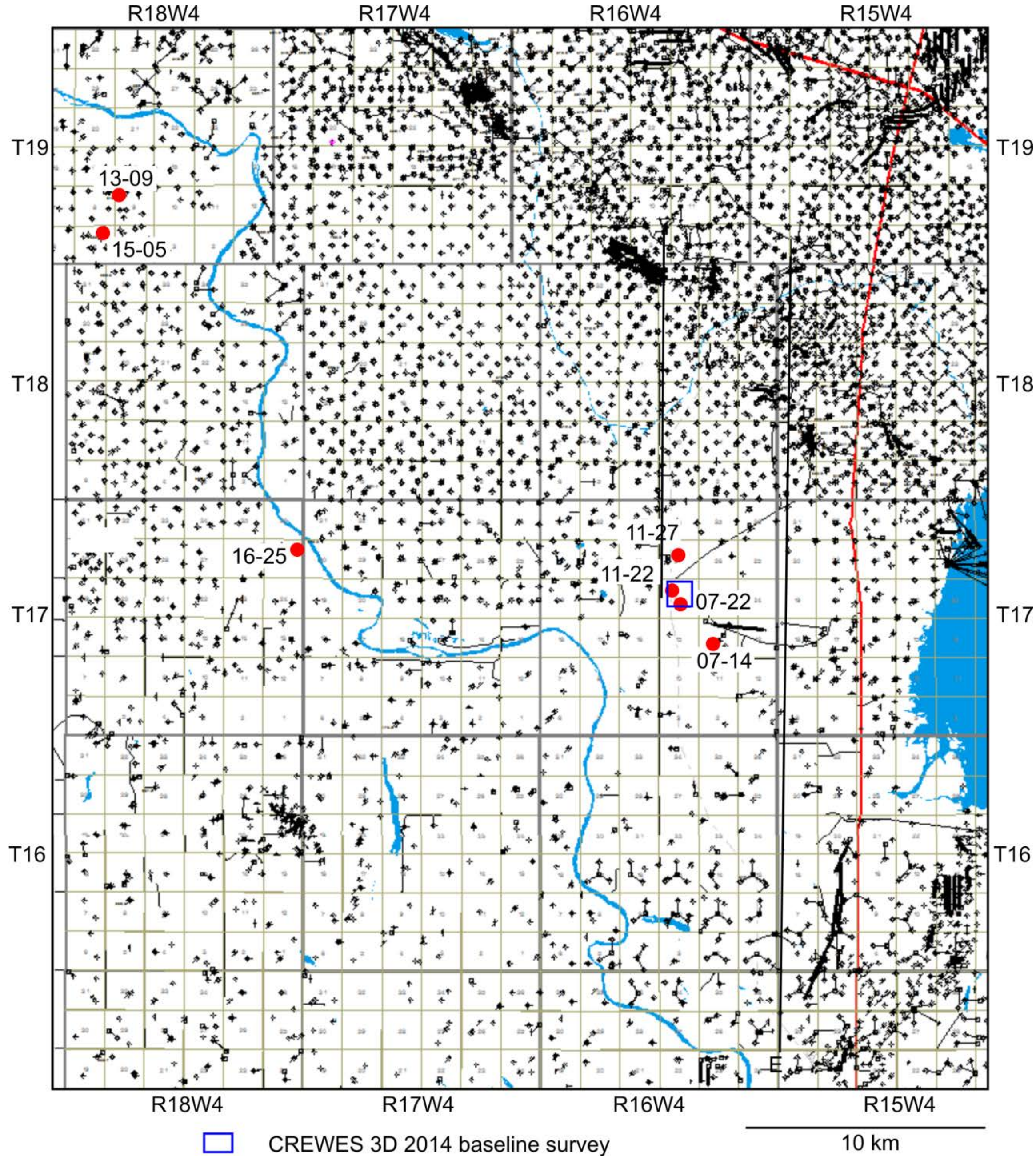

FIG 1: The location of the 3D seismic data processed and interpreted for this study. Also annotated are the wells referred to in the companion geology paper (Isaac and Lawton, 2014).

We applied air blast attenuation, spike and noise edits, and predictive deconvolution to attenuate noise and multiples. We also applied Gabor deconvolution (Margrave and Lamoureux, 2002) and a spatial filter applied after NMO in the shot domain to help bring out the signal in the shallow section of interest. Figure 3 shows part of a shot gather from the 3D survey. Note how the processing reveals reflections between 0.2 and 0.3 s. After stack another Gabor deconvolution was applied prior to post-stack finite difference migration.

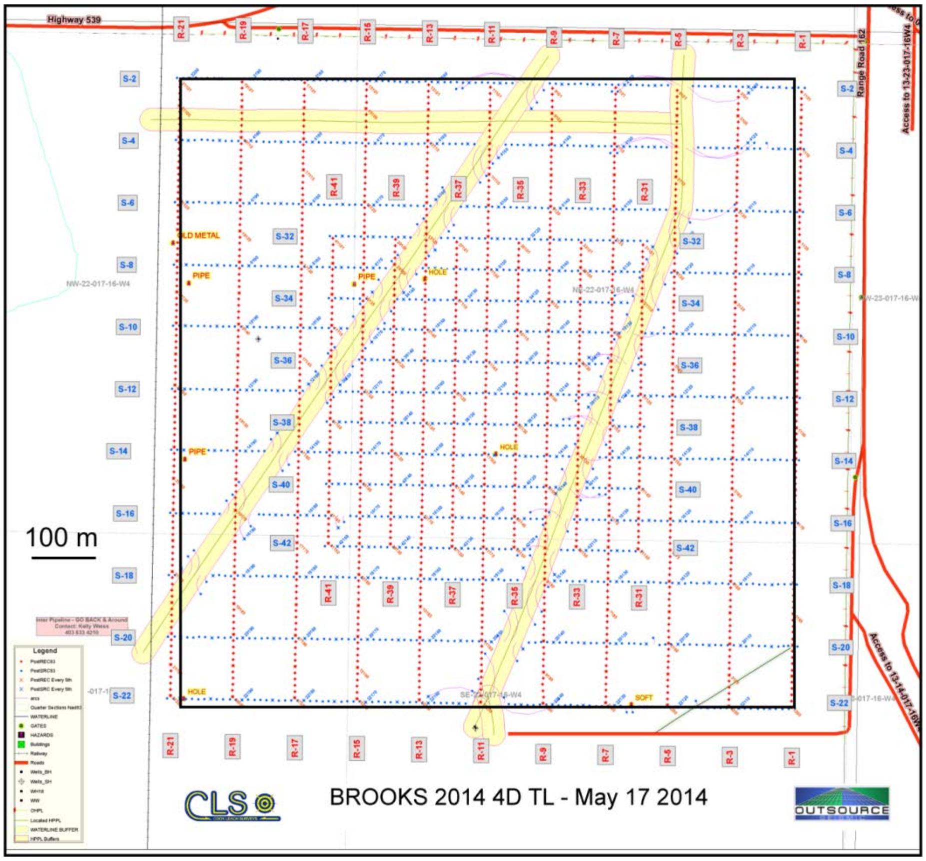

FIG. 2: Layout of the 3D survey.

Seismic data interpretation

The seismic, well and culture data were loaded into Kingdom Suite. Synthetic seismograms were created and tied to the seismic data. We also used Geosyn to create synthetic seismograms to tie to the data. The tie between well 11-22-017-016W4M and 3D crossline 117 is shown in Figure 4. Figure 5 shows the same crossline 117 with interpreted horizons.

We also created a synthetic seismogram cross-section using local wells (Figure 6). The gas sands are usually too thin to be identified by seismic signatures but there may be subtle changes in the character of events when gas is present.

We interpreted reflections representing the top of the Foremost, Basal Belly River sandstone, Pakowki, Medicine Hat, Second White Speckled Shale, Base Fish Scales, Mannville and Banff formations. The seismic horizon picks were gridded and converted into depth using laterally constant interval velocities. The well depths of significant formation tops were also gridded. Figure 7 shows the gridded well depths for the top of the Pakowki Formation, which is essentially at the base of the Belly River Formation. It has very gentle regional dip toward the northwest.

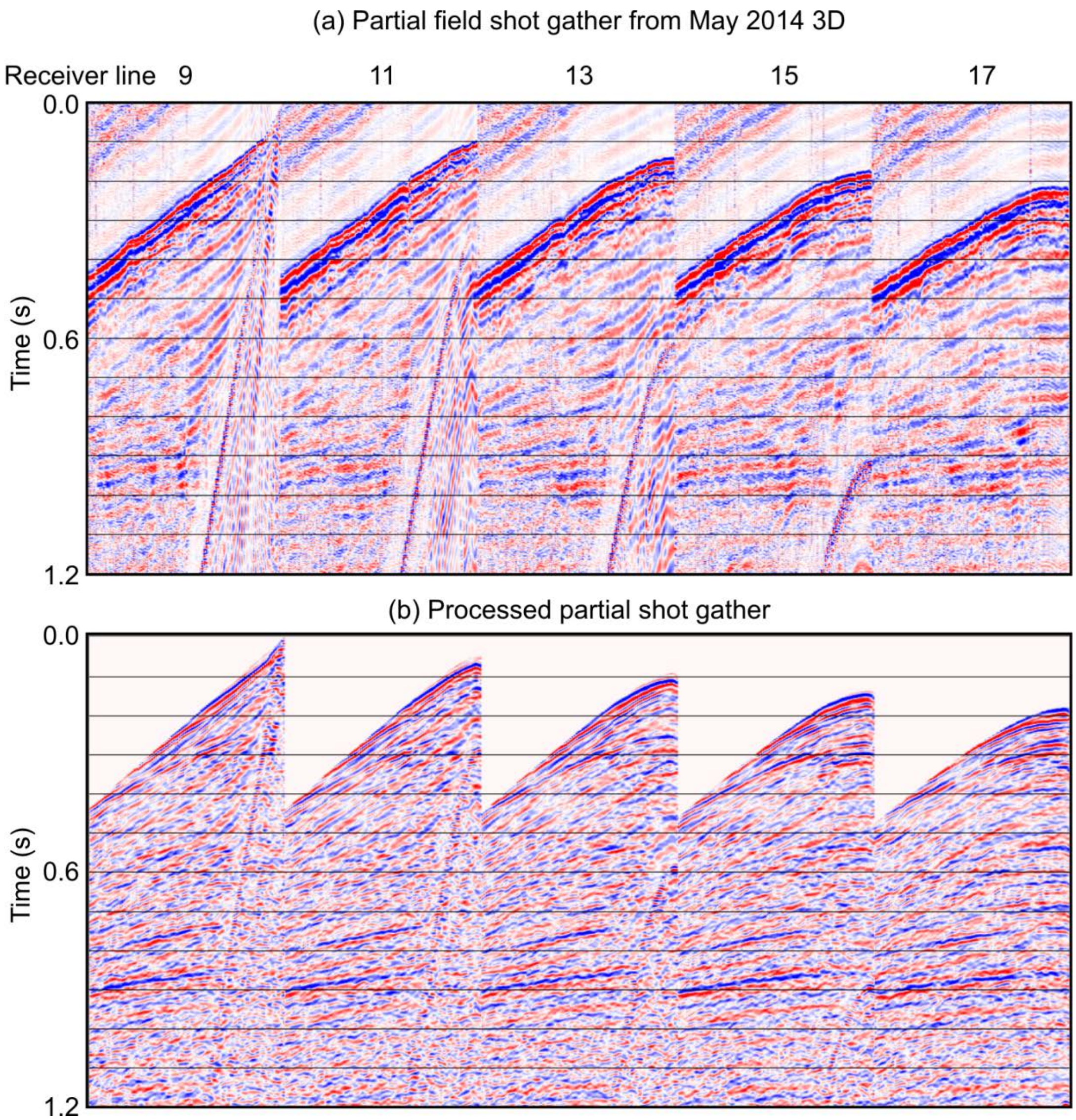

FIG 3: Field and processed partial shot gathers from the new 3D survey.

In Figure 8 we display the gridded well depths for the top of the Basal Belly River Formation and the gridded, converted seismic depths for the top of the Basal Belly River Formation over Section 22. The depth of the Basal Belly River Formation at the location of the proposed new well is 492 m above sea level, or 285 m below ground level.

The gridded well depths for the top of the Medicine Hat Formation and the gridded, converted seismic depths for the top of the Medicine Hat Formation over Section 22 are shown in Figure 9. The pick for the top of the Medicine Hat Formation was not very consistent and was fairly weak. The depth of the top of the Medicine Hat Formation at the location of the proposed new well is 302 m above sea level, or 475 m below ground level. We also expect to encounter a thin sand at 284 m above sea level (493 m below ground level).

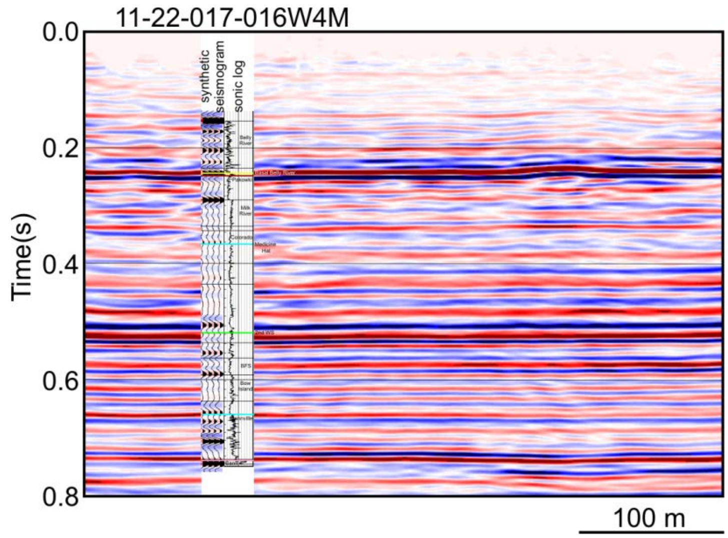

FIG. 4: Tie between synthetic seismogram for well 11-22-017-16W4M and a crossline from the 3D survey.

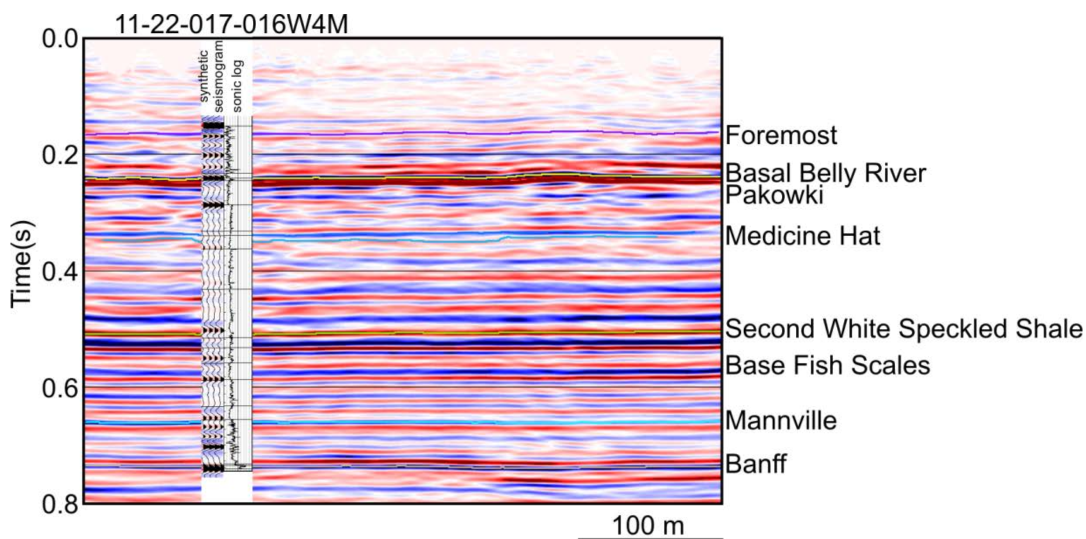

FIG 5: Synthetic seismogram for well 11-22-017-16W4M and the crossline with interpreted horizons.

Figure 10 shows the gridded well depths for the top of the Second White Speckled Shale Formation (a) and the gridded, converted seismic depths (b) for the top of the Second White Speckled Shale Formation over Section 22. The depth of the target thin sand within the Second White Speckled Shale Formation at the location of the proposed new well is about 68 m above sea level, or 710 m below ground level.

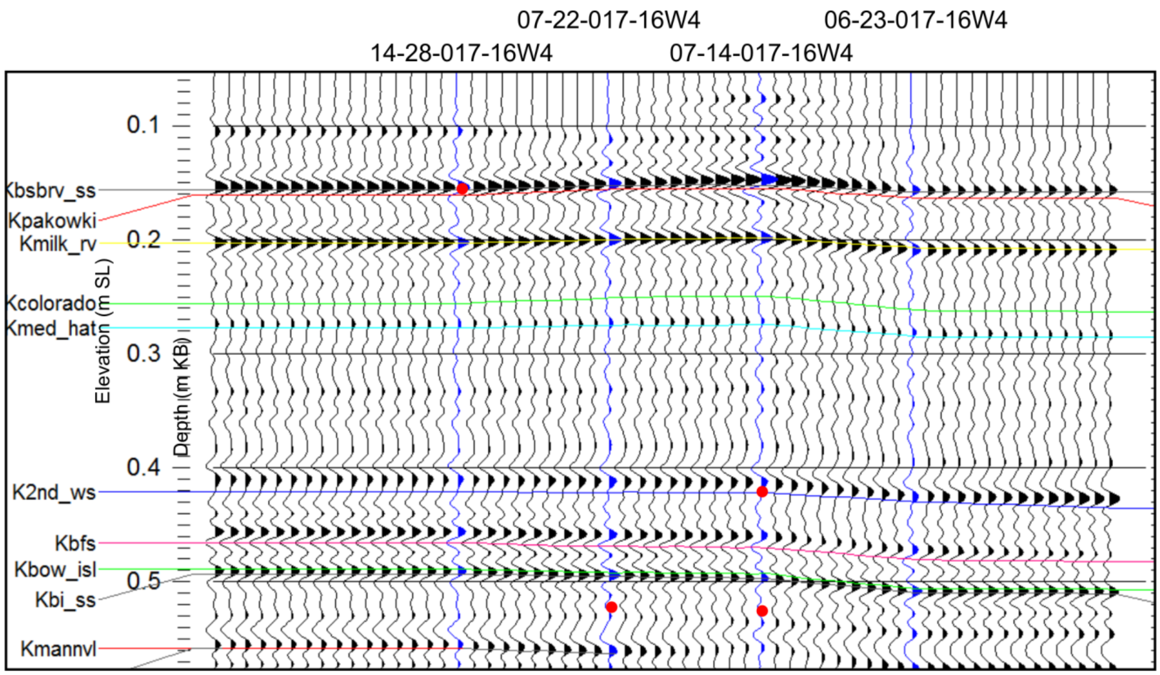

FIG. 6: Synthetic seismogram cross-section using local wells. The reservoir sands are usually too thin to be identified by seismic signature but there are subtle changes in the character of events when gas is present (red dots).

SUMMARY

We processed and interpreted new 3D seismic data in an area of Southern Alberta targeted for a planned CO_2 injection experiment. The data processing included noise attenuation, Gabor deconvolution and post-stack time migration. The imaging quality of the new 2014 3D data was encouraging.

We interpreted the data and made time and depth structure maps. We also mapped the formation tops from wells. In general there is very gentle geological dip to the northwest and almost no dip in the immediate area of interest (section 22, R17 T18W4M).

ACKNOWLEDGEMENTS

We thank Carbon Management Canada and the CREWES sponsors for their financial support. We also gratefully acknowledge support from NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 379744-08. We also appreciate the generous contribution by Landmark of processing software, and we acknowledge IHS for Geosyn and Kingdom Suite.

REFERENCES

Isaac, J. H., and D. C. Lawton, 2014, Preparing for experimental CO_2 injection: Geology: CREWES Research Report, Vol. 2: Introduction and demonstration, CREWES Research Report, Vol. 11, ch. 36.

Lawton, D. C., M. B. Bertram, K. L. Bertram, K. W. Hall and J. H. Isaac, 2014, A 3C-3D seismic survey at a field research station near Brooks, Alberta, this volume.

Margrave, G. F. and M. P. Lamoureux, 2002, Gabor deconvolution: CSEG Annual Convention Expanded Abstracts.

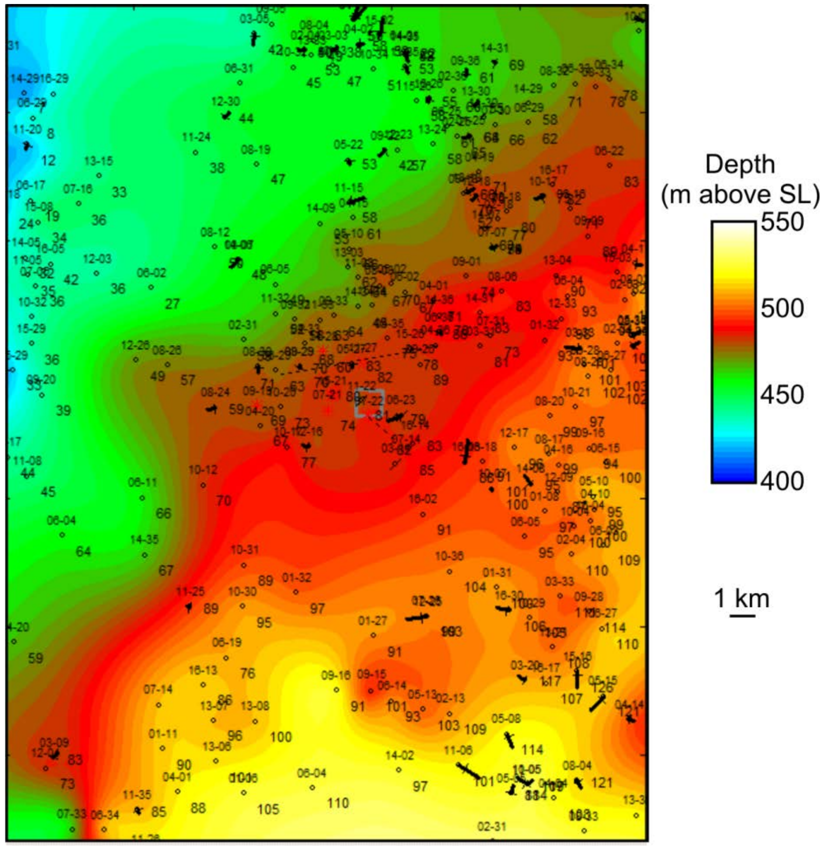

FIG. 7: Regional top Pakowki Formation depth map, showing very gentle regional dip to the northwest.

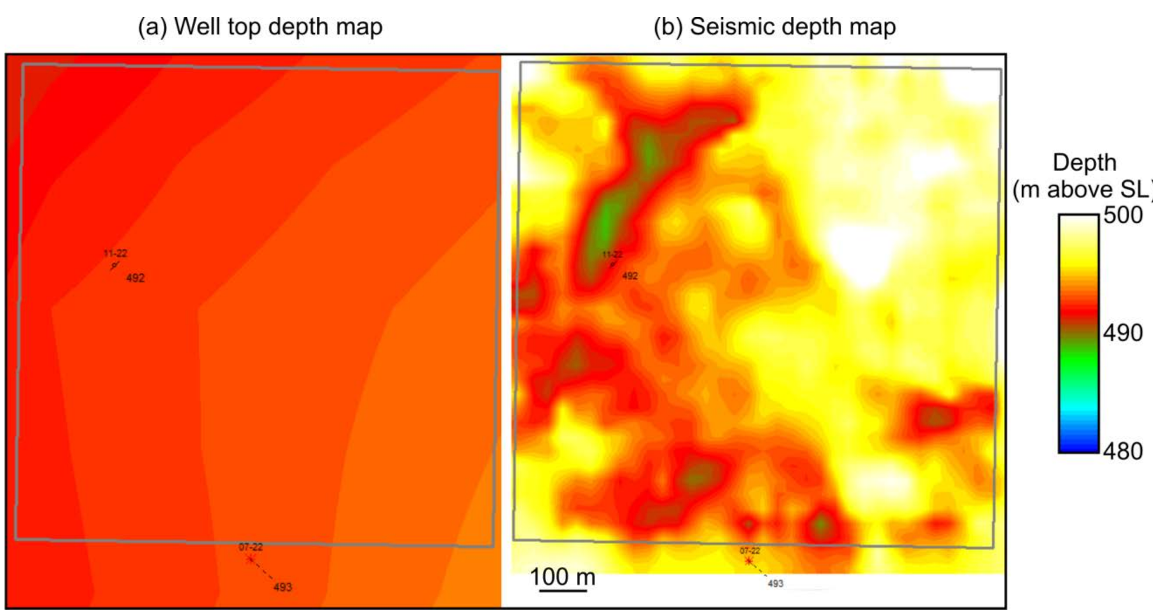

FIG. 8: Depth maps of the (a) gridded well top and (b) gridded seismic horizon from the 3D seismic survey for the top Basal Belly River Formation over Section 22.

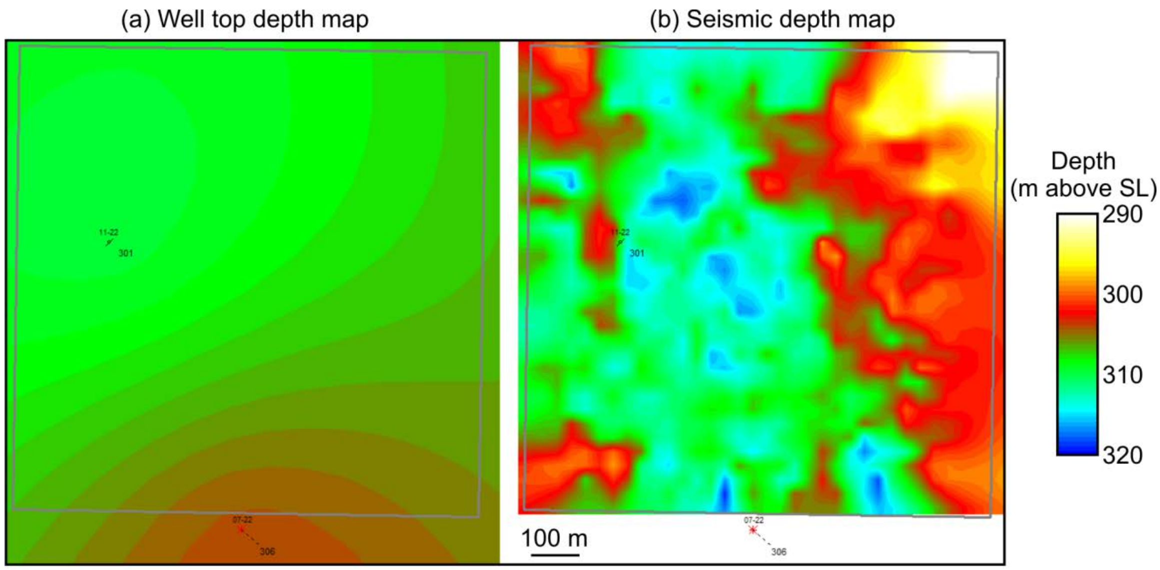

FIG. 9: Depth maps of the (a) gridded well top and (b) gridded seismic horizon from the 3D seismic survey for the top Medicine Hat Formation over Section 22.

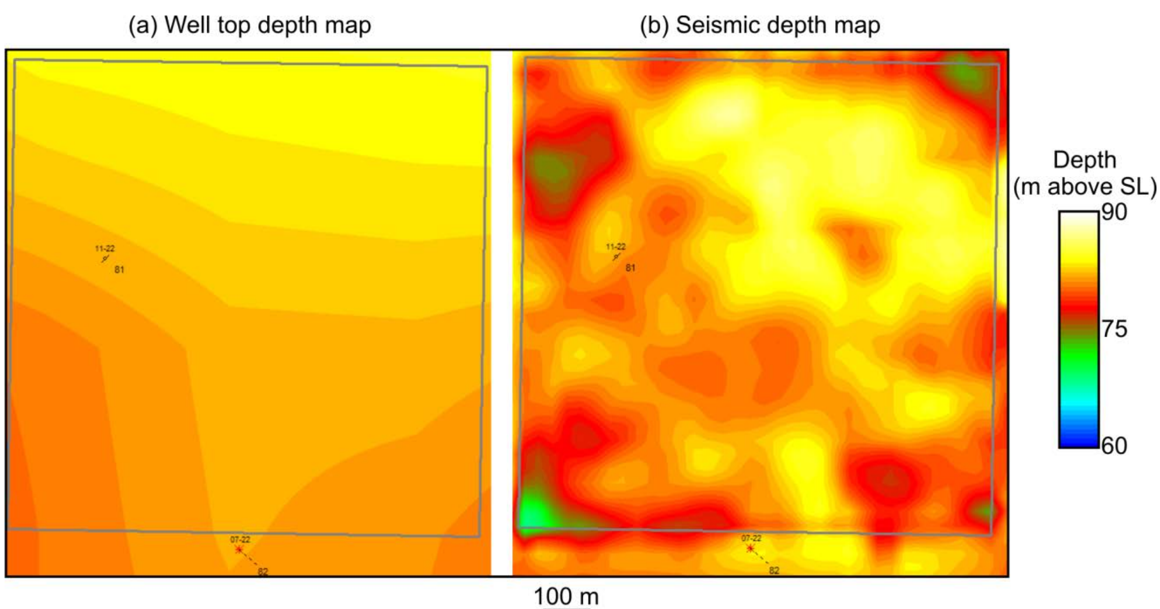

FIG. 10: Depth maps of the (a) gridded well top and (b) gridded seismic horizon from the 2014 3D seismic survey for the top second white Speckled Shale Formation over Section 22.