Seismic studies of the near-surface at the CaMI Field Research Station, Newell County, Alberta

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ABSTRACT

We reassessed the processing and analysis of the two S-wave seismic surveys that were acquired at the CaMI Field Research Station (FRS) in the summer of 2018. We refined the S-wave depth/velocity model derived from refraction statics analysis of the S-wave fixed array data by limiting the offsets in the analysis. The new model shows a 19-26 m thick near-surface layer with velocities ranging from 222 to 288 m/s. Below this layer is bedrock having S-wave velocities between 885 and 930 m/s. The depths to bedrock compare well with the actual bedrock depth at the injection well location. The profile of the near-surface S-wave velocity corresponds well with the refractor depth profiles obtained through refraction analysis of 2D P-wave data.

We also improved the imaging of the S-wave streamer data by reprocessing the data. We rebinned the CDPs and applied updated stacking velocities. We also applied pre-stack trace mixing and post-stack f-x deconvolution because of the very short receiver spacing of 1 m and low fold. The resulting reflector is more continuous and better focussed. However, we found that the observed time structure is highly sensitive to the stacking velocities, as they are so low.

INTRODUCTION

The Containment and Monitoring Institute (CaMI), established by CMC Research Institutes Inc, has a Field Research Station (FRS) in Newell County, near Brooks, Alberta, where technologies for the measurement, monitoring and containment of subsurface fluids, including carbon dioxide, are being developed, refined and calibrated. A well was drilled in 2015 to a depth of 550 m for the injection of CO_2 into the Upper Cretaceous Basal Belly River Formation, which is a water-wet sandstone capped by shales, coals, silts and silty sands of the Belly River Formation.

Two S-wave seismic surveys were acquired at the FRS in the summer of 2018 close to line 13 from previous P-wave surveys. They were both around 1.1 km long and ran SW-NE past the injection well. For the first survey, receivers were placed every 10 m in a fixed array and the source interval was 20 m. The second survey consisted of a 72-m streamer array towed behind the truck. The source interval was 2 m and the receiver interval was 1 m. We had derived a near-surface depth/velocity model from refraction statics analysis of the fixed array data, and we obtained an image of the near-surface on the streamer data (Lawton et al, 2018).

ANALYSIS

Since last year we have refined the near-surface S-wave velocity model obtained from the fixed array data and improved the imaging on the streamer data.

The first near-surface velocity model derived from refraction statics analysis of the fixed array data showed a lateral increase in velocity in the shallowest layer with a corresponding lateral decrease in the layer beneath. This seemed to be too much of a coincidence, so we reran the refraction statics analysis with restricted input offset ranges in the analysis. The final model was stable and used an offset range of 70-500 m, reduced from 60-1000 m in the original computation, in the calculations. The original and new models are shown in Figures 1 and 2, respectively. The velocities increase from west to east in the shallow layer and are between 222-288 m/s. Bedrock velocities are 885-930 m/s below the bedrock depth of 19-26.4 m.

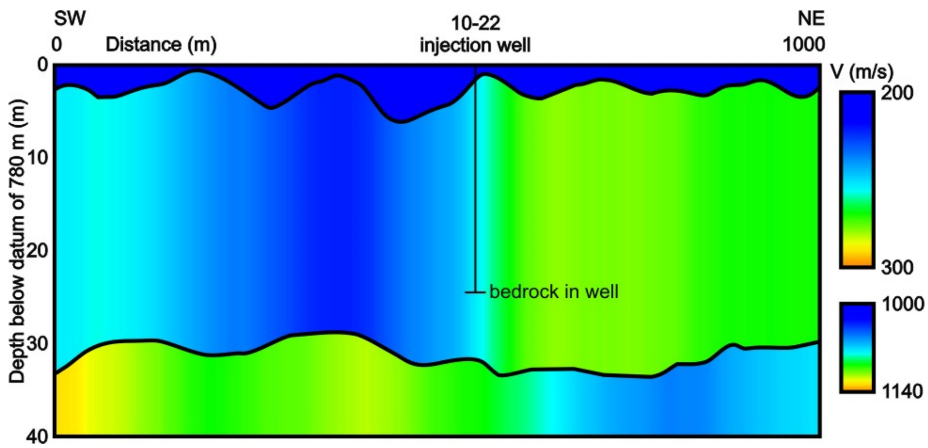

FIG. 1. The first depth/velocity model derived from refraction analysis. Near-surface velocities are 222-280 m/s and bedrock velocities are 1040-1110 m/s. Bedrock depth varies from 28.5-34.5 m. The actual depth of bedrock at the well location is 25 m below the datum of 780 m.

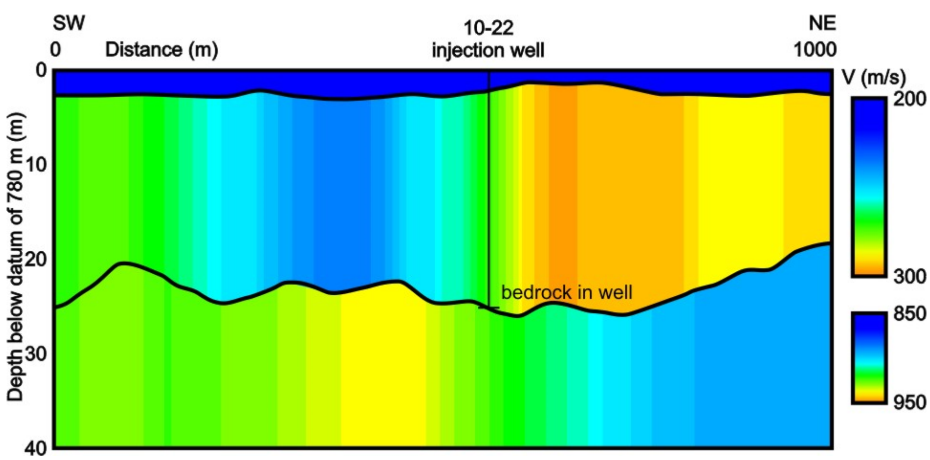

FIG. 2. The revised depth/velocity model. Near-surface velocities are 222-288 m/s and bedrock velocities are 885-930 m/s. Bedrock depth varies from 19-26.4 m.

We also compared the near-surface refractor structure derived from the S-wave data to that derived from the analysis of P-wave data acquired in 2017 and 2018 along almost the same surface line as the shear-wave data. The two P-wave models (Figure 3) are similar and both show a significant increase in depth of the refractor around the centre of the model. We do not see such a change on the S-wave model but this model is, however, sensitive to changes in the very low velocity.

When we overlay the near-surface S-wave velocity on the plot of P-wave refractor depths, we see a similarity between the P-wave refractor depth and the S-wave velocity profile (Figure 4). This is in agreement with the observed relationship between S-wave speed and topographical slope made by researchers studying the near-surface in connection with earthquake studies around the world (e.g., Wald and Allen, 2007; Park and Ishii, 2018).

We also compared the average of the two 2D P-wave refractor depths with the depth obtained from the 3D3C acquired in 2014 (Figure 5). The refractor depth varies from 20 - 32 m with a SW-NE trending high appearing to run through the middle of the area. It is possible that we are seeing the presence of channels or boulders in the bedrock. We do not see such structure on the S-wave reflection seismic data; however, these data are highly sensitive to changes in stacking velocity.

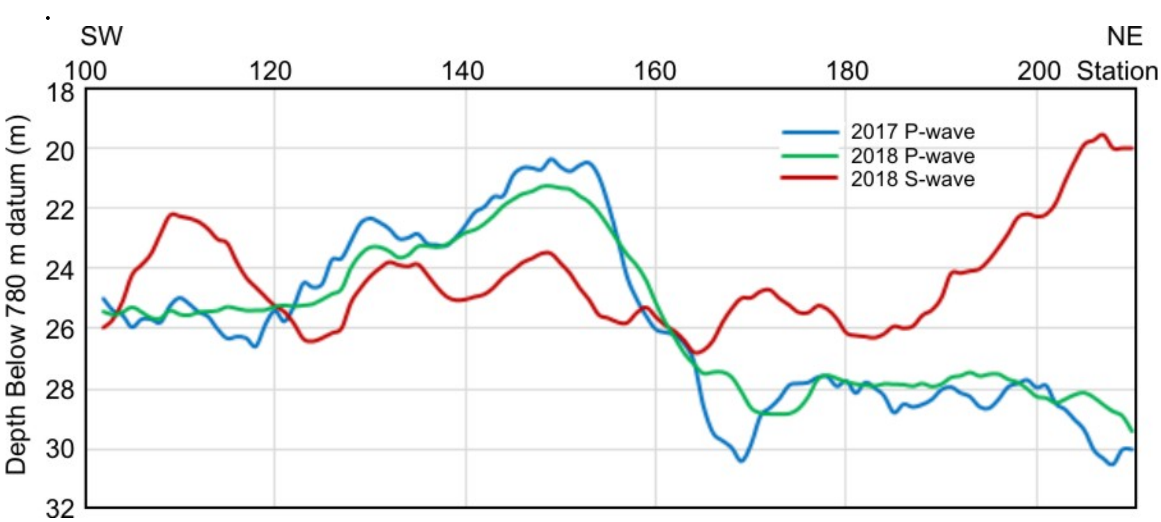

FIG. 3. The refractor depth models derived from analysis of the 2017 and 2018 P-wave data and the 2018 S-wave fixed array data.

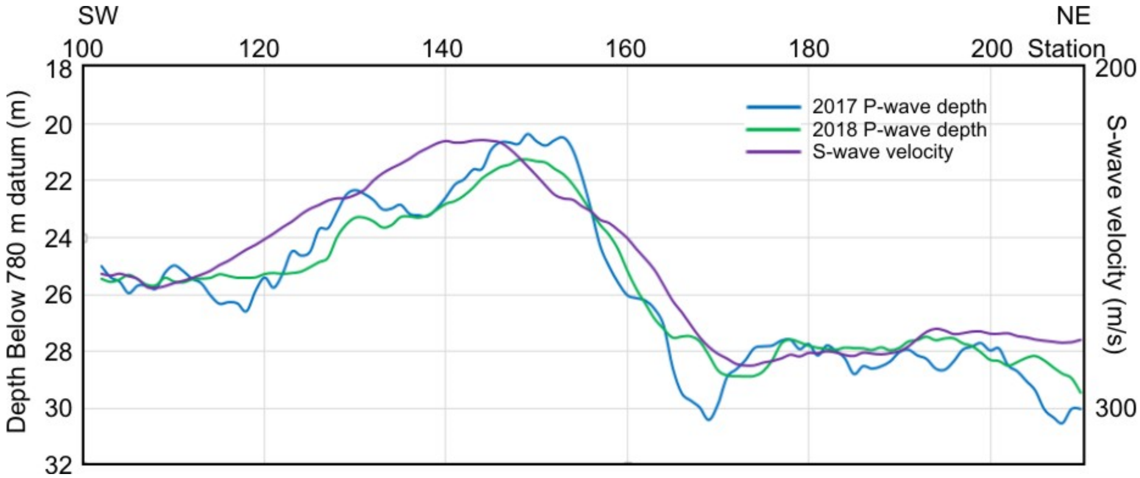

FIG. 4. The refractor depth models derived from analysis of the 2017 and 2018 P-wave data with the S-wave near-surface velocity overlain.

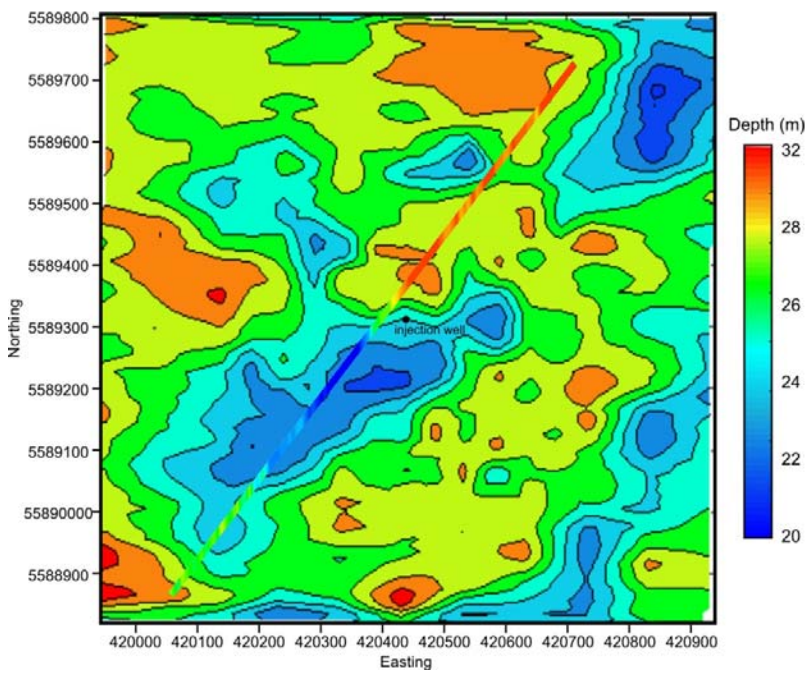

FIG. 5. The refractor depth derived from the 2014 3D data with the average of the 2017 and 2018 2D data overlain.

We redatumed the streamer data to 780 m, which is a datum very close to surface, to eliminate any statics effects resulting from a shift to the regular datum of 800 m which had been used in all the P-wave data processing. We also rebinned the data to achieve a higher CDP fold. After applying the new static solutions to the shear fixed array data we repicked the stacking velocities and used an average of these velocities as an initial model for the streamer data. We found that the observed structure on the time stack of the streamer data was very sensitive to the stacking velocities, which are very low. We also applied pre-stack trace mixing and post-stack f-x deconvolution to improve the continuity of the reflector. The original and remigrated depth-converted stacks are shown in Figure 6. The event at 25 m on the new section is more continuous and is better imaged, particularly in the northern part of the line. We tried applying the statics obtained through refraction analysis of the fixed array survey but this did not improve the image. This reprocessed section does not show the structure predicted by the refraction analysis. However, since the stack is so sensitive to the stacking velocities, a change in these velocities could easily introduce structure across the section. We did not attempt to bias the velocity picks.

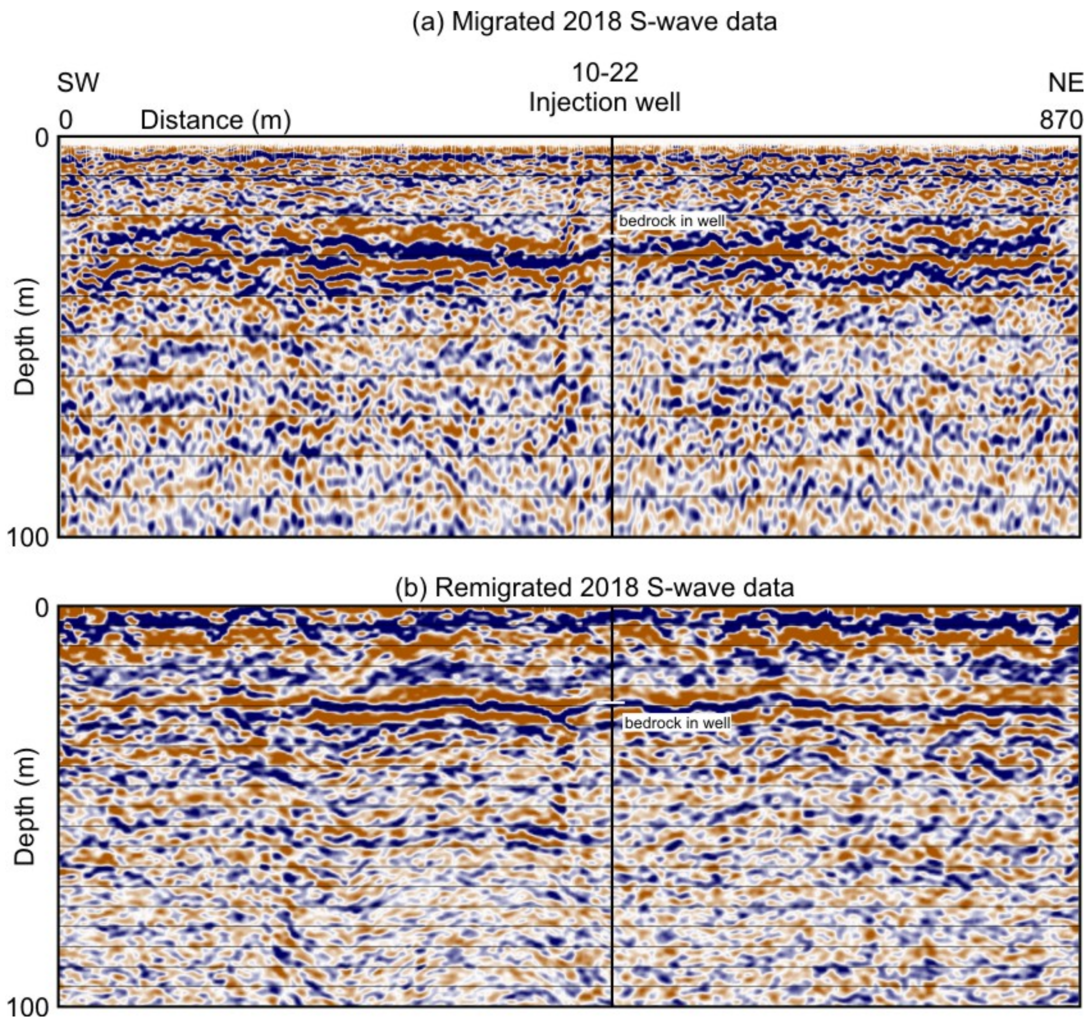

FIG. 6. The original (a) and remigrated (b) S-wave streamer data from 2018.

CONCLUSIONS

We reassessed the processing and analysis of the two S-wave seismic surveys that were acquired at the FRS in the summer of 2018. We refined the S-wave depth/velocity model derived from refraction statics analysis of the fixed array data by limiting the offsets in the analysis. The new model shows the near-surface S-wave low velocity layer to be 19-26.4 m thick with velocities ranging from 222 to 288 m/s. S-wave bedrock velocities range between 885-930 m/s. The depths to bedrock compare well with the actual bedrock depth at the injection well location.

We compared the S-wave refractor depth model to the models obtained from two 2D P-wave surveys acquired along the same surface line in 2017 and 2018. Refraction analysis of these two P-wave surveys gave similar results and showed similar trends as the model obtained by analysis of the 3D P-wave data acquired in 2014. The P-wave and S-wave refractor depth profiles do not match but the S-wave depth profile is, however, very sensitive to changes in velocity. The profile of the near-surface S-wave velocity corresponds well with the 2D P-wave refractor depth profiles.

We also improved the imaging of the S-wave streamer data by reprocessing the data. We rebinned the CDPs and applied updated stacking velocities. We also applied pre-stack trace mixing and post-stack f-x deconvolution because of the very short receiver spacing of 1 m and low fold. The resulting reflector is more continuous and better focussed. However, we found that the observed time structure is highly sensitive to changes in the very low stacking velocities.

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REFERENCES

Lawton, D. C., J. H Isaac and M. B. Bertram, 2018, Shear-wave studies of the near-surface at the CaMI Field Research Station in Newell County, Alberta, CREWES Research Report, Vol. 30.

Park, S. and M. Ishii, 2018, Near-surface compressional and shear wave speeds constrained by body-wave polarization analysis, Geophysical Journal International, Vol. 213, Issue 3, 1559-1571.

Wald, D. J. and T. I. Allen, 2007, Topographic slope as a proxy for seismic site conditions and amplification, Bulletin of the Seismological Society of America, Vol. 97 (5), 3379-1395.