Seismic modelling and monitoring of carbon storage in a shallow sandstone formation

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Summary

Sallow sandstones of the Lower Paskapoo Formation were considered as a possible target for storage of CO_2 for a test facility. In order to evaluate the monitoring viability, Gassmann Fluid Substitution and 3D seismic modeling were undertaken. Synthetic seismograms were generated to assess changes given the injection of CO_2 in Lower Paskapoo sandstone. Results show that time-lapse seismic surveys are capable of tracking the CO_2 plume in this formation, but the time-lapse differences are subtle.

Introduction

Carbon Management Canada in association with CREWES have invested in a research project that investigates the feasibility of injecting and monitoring reduced amounts of CO_2 in a sandstone aquifer in Alberta. The main goal was to generate a 3D geological model and subsequent seismic model in order to estimate the seismic response before and after CO_2 injection. The study area is in the University of Calgary land, next to the Rothney Astrophysical Observatory (RAO) located in the eastern flank of the Rocky Mountains, southwest of Calgary (Figure 1). The model attempts to characterize shallow geology, being based on the 2010 2D seismic line. The 3D survey covers the expected injection zone to give a reasonable simulation of the seismic response after CO_2 injection. In order to select a suitable geological formation to storage CO_2, the main condition that has to be covered is the presence of a permeable geological section overlain by an impermeable section (Havorka, 2008) such as clean sandstone in a shale trap. Based on these conditions, the Basal Paskapoo Fm. was selected as the injection target. In this project, the well used as reference in order to define the target properties is 12-33-21-2W5.

Method

A 3D geological model was generated reproducing a detailed scenario of the injection zone. This model is based on the interpretation of the seismic data acquired during 2010 by the University of Calgary geophysics field school. The formations of interest are Lower Paskapoo (LP), Edmonton (E) and a selected layer called Seal (Figure 2 (a)). Using Norsar3D, a seismic survey was designed in order to image the Paskapoo Formation and the plume. In addition to the modelling, the CO_2 plume was estimated, calculating size and shape by using a volumetric method and cylindrical approximation. The reservoir was considered to have 50% CO_2 saturation and a transition zone of 2% saturation. This plume was incorporated into the geological model, representing the post-injection scenario. The velocity and density values were obtained after applying Gassmann fluid substitution (Figure 2 (b)). Finally, Norsar3D common shot wavefront ray-tracing was undertaken and data were processed and stacked, generating a baseline and monitor seismic volumes.

Results

- The presence of the CO_2 plume causes a decrease in density and P-wave velocity, producing: a reduction of the reflectivity values across the injection area and a time delay of the reservoir basal reflectors and horizons underneath it.
- Times for LP and E are approximated 380 ms and 392 ms respectively for the baseline, with a time delay after injection of 1ms (Figure 3). Figure 4 (a) shows detail of the injection zone of the baseline (0% CO_2 saturation) in comparison with 50% CO_2 saturation volume (Figure 4 (b)), presenting an evident reduction of the amplitude.
- There is a difference in amplitude and time recognizable in seismic by subtracting the post-injection volume to the baseline. Figure 5 (a) is the difference between the monitor and baseline volumes from an inline and crossline perspective and Figure 5 (b) shows the 3D perspective of the CO_2 plume

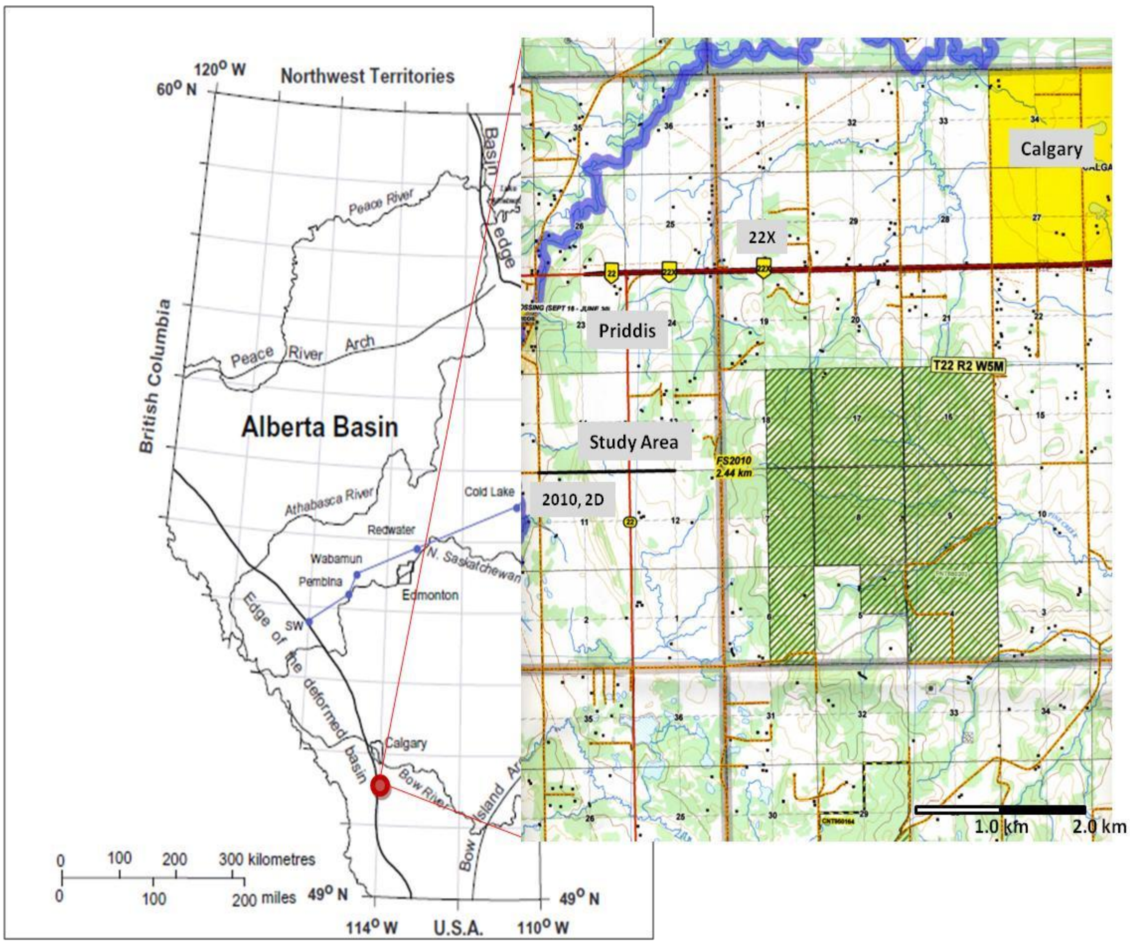


Figure 1: Study area location. Location in Alberta (from Bachu et al., 2000) and detail view (Modified from Priddis 2010-1 2D preliminary plan, courtesy of OutSource Seismic).

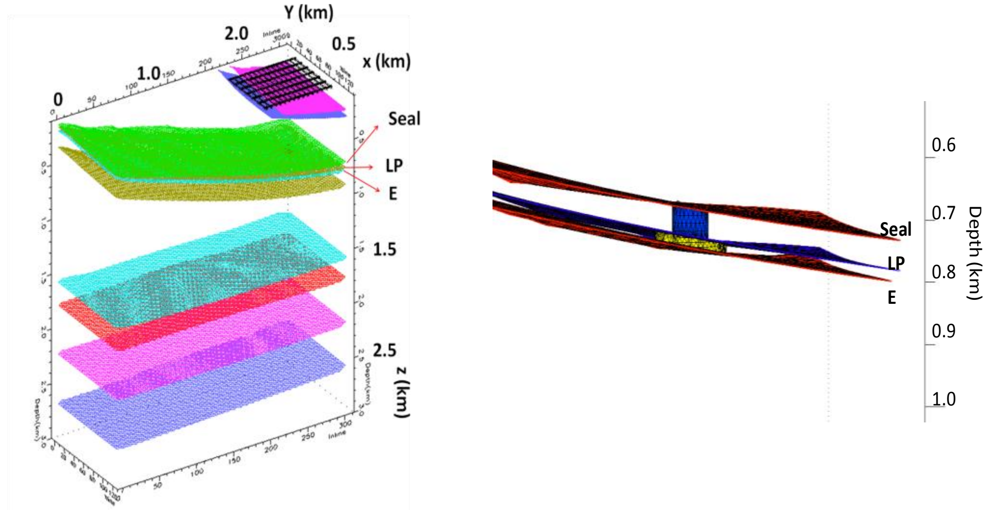


Figure 2: a) Geological model with the survey location and the position of the Seal, LP and E. b) 3D view of the plume. The first cylinder is between LP and E and the second between Seal and LP.

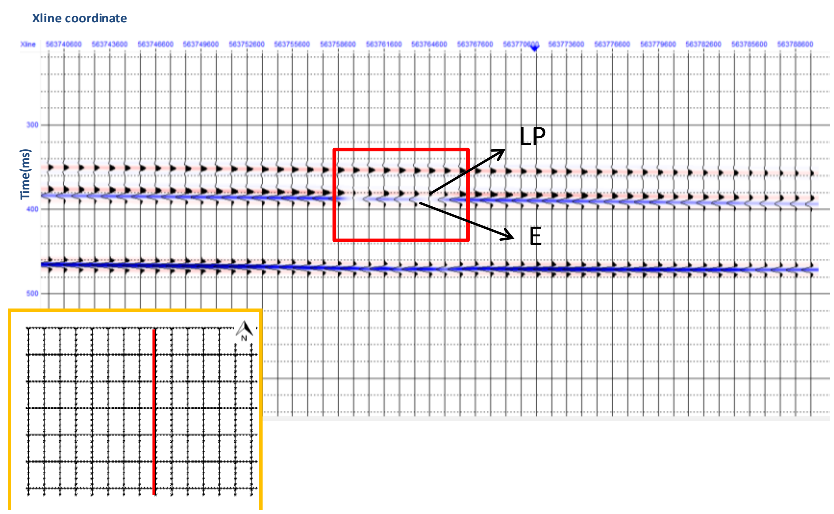
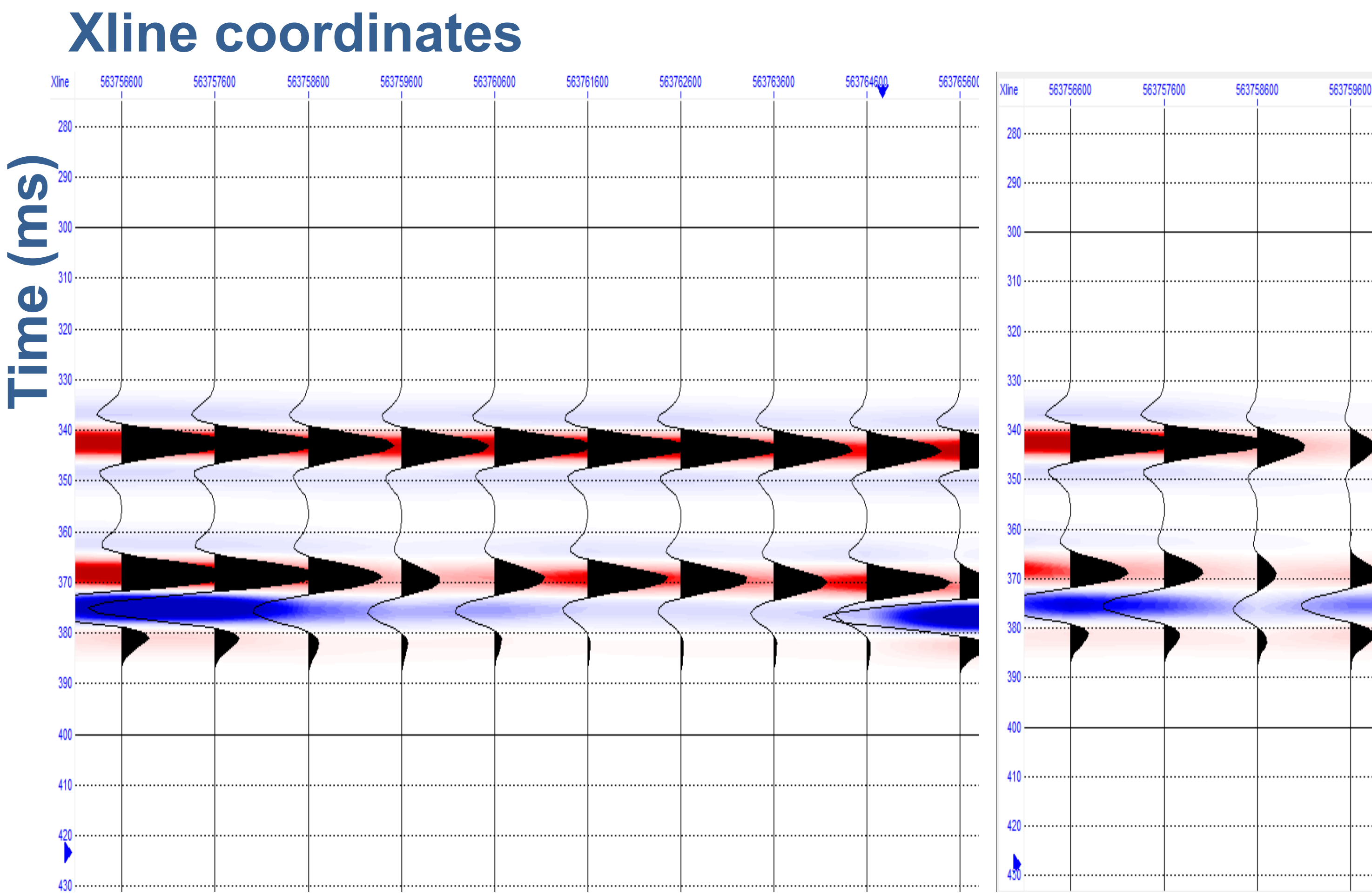


Figure 3: Crossline 140 showing the injection area in a red square, LP and E tops.



a) b)

Figure 4: Detail of the injection zone a) 0% CO_2 saturation and b) 50% CO_2 saturation

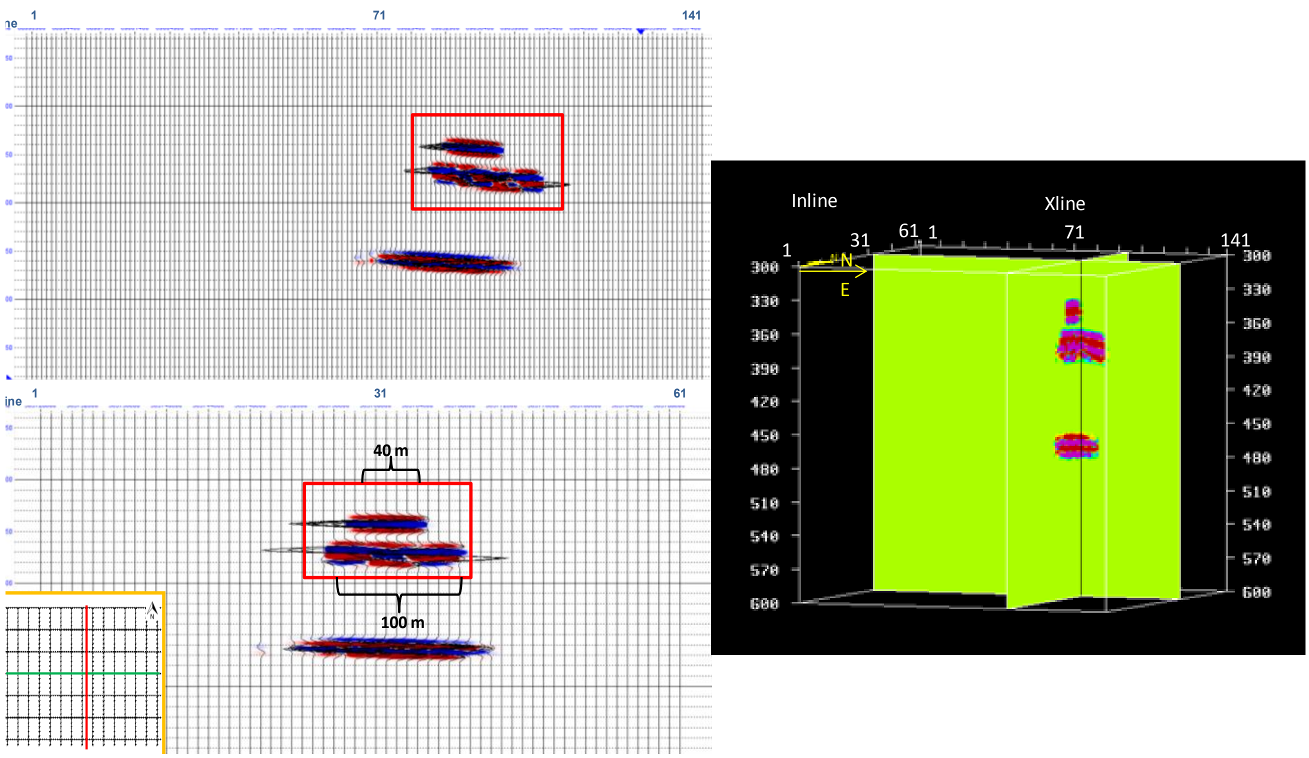


Figure 5: a) Inline (top) and crossline (bottom) view of the volume resulting from the difference between the original model and the CO_2 saturated. The area of injection is marked in a red square. b) 3D view of the difference volume. The anomaly is evident in the area of injection.

Conclusions

- The presence of the CO_2 plume was detected in the seismic volume: measured time delay of approximated 1ms and an amplitude reduction of approximated 30 %.
- Even these subtle changes caused considerable variations in the seismic response, and it is observable on the difference between the monitor and baseline volumes.
- Lower Paskapoo Fm has suitable properties for a CO_2 storage site. The feasibility of monitoring small amounts of CO_2, under small saturation changes, it has been proven by using fluid substitution and seismic modelling,

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