True scattering attenuation for monitoring injected CO_2 at CMC Newell County Facility, Alberta

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Summary

The concept of scattering Q is often used in studies of seismic attenuation, particularly for estimating the intrinsic Q of the medium. Negative values of scattering Q are often reported, which are interpreted as nonphysical results and generally ignored. Nevertheless, these results are significant, and the scattering Q should be defined more carefully. In practical measurements, the conventional scattering Q is dominated by spatial variations of layering, which lead to positive and negative variations of scattering Q with depth. The true scattering Q characterizes the layering (reflectivity) of sub-wavelength scale. Such true scattering Q can be obtained from log data with longer-scale layering removed by filtering. We evaluate the true scattering Q from the log data from the CMC Newell County Facility (NCF) CO_2 injection project in Alberta, Canada.

NCF CO_2 injection project

The NCF is in Newell County, southern Alberta (Figure 1a). At the NCF CO_2 injection project, we focus on the development of subsurface and surface measurement, monitoring and verification technologies for the carbon capture and storage. There is one injection well and two observation wells (OBS1 and OBS2, Figure 1b). Different instruments are installed at the NCF, such as DAS using straight and helical fibre optic cables with a continuous loop of about 5 km in a horizontal trench and two observation wells (Wang and Lawton, 2022). There were accumulative ~34 tonnes of CO_2 injected at the NCF prior to the VSP acquisition date of March 1st, 2021 (Figure 1b). The Basal Belly River Sandstone (BBRS) at ~300 m depth is the target formation for CO_2 injection.

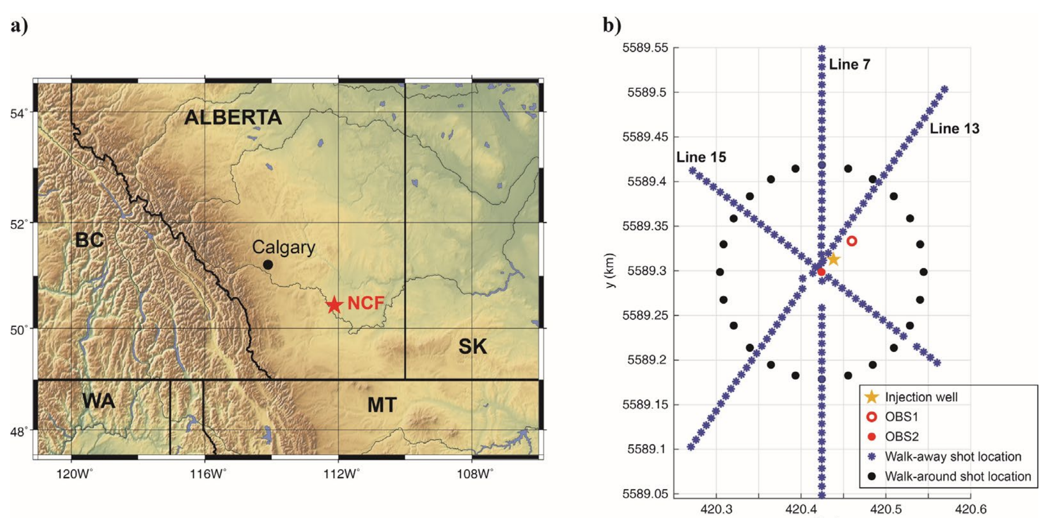

Figure 1: a) Location map of the CMC NCF in southern Alberta, Canada and b) VSP layout map of the survey acquired in March 2021.

Scattering attenuation measurement

We can measure parameter Q^{-1} from well-log reflectivity series by using the approach as noted by Wang and Lawton (2022). Such Q^{-1} from reflectivity series is conventionally associated with the scattering Q^{-1} (e.g., Aki, 1969), which is also called the apparent Q^{-1} by Matsushima (2006). However, the true scattering Q^{-1} assumes a homogeneous medium with subwavelength-scale random intrusions, and consequently the measured Q^{-1} must also be spatially uniform. For example, in earthquake coda studies, a single coda Q is attributed to the whole ~100-km area enclosing both the source and receiver (Aki, 1969). Nevertheless, the Q^{-1} from reflectivity series also contains a contribution from deterministic layering within the subsurface, which is called the fluctuation Q^{-1} by Morozov and Baharvand Ahmadi (2015). We thus measure the true scattering Q^{-1} from the well-log reflectivity series at the CMC NCF by using the procedures as below:

1) Evaluate the Q^{-1} from well-log reflectivity series by using the approach as noted by Wang and Lawton (2022). Such Q^{-1} would show negative and positive fluctuations.
2) Automatic-gain-control (AGC) filter the well-log reflectivity series, which should lead to reflectivity series with the same short-scale statistics but without layering.
3) Perform step 1) with the AGC filtered reflectivity. The measured Q^{-1} should be constant and positive but of much lower magnitude. This would be the true scattering Q^{-1}.
4) The difference of the Q^{-1} from steps 1) and 3) would the fluctuation Q^{-1} (Figure 2).

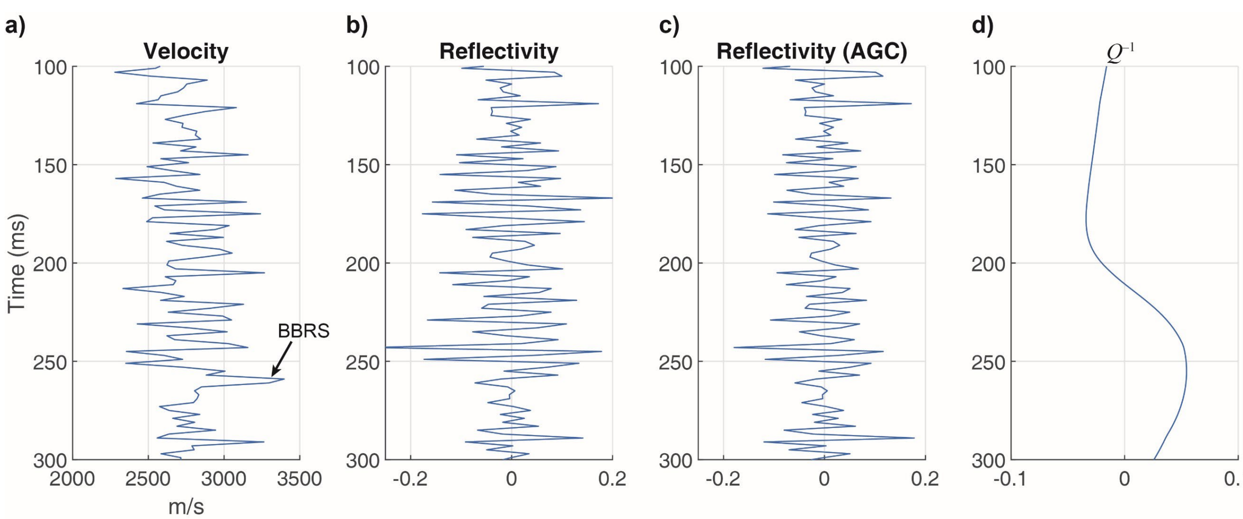

Figure 2: Q^{-1} from well-log reflectivity series at the CMC NCF: a) P-wave velocity log, b) well-log reflectivity series, c) reflectivity series after AGC, and d) fluctuation Q^{-1}.

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