Spectral ratios for the Pembina Cardium formation computed with virtual sources

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ABSTRACT

Spectral ratios across the Pembina-Cardium formation are computed from surface source lines and down-hole receiver gathers by applying virtual source principles. It is found necessary to apply first-arrival wave package windowing to reduce ringing of these spectral ratios. There is an increase of attenuation across the reservoir layer for all three source line experiments following CO_2 injection. This attenuation increase is confirmed by spherical wave modelling employing a multi-interface Sommerfeld integral algorithm and using monitor well-logs as well as fluid substitution derived perturbations of reservoir parameters. Spherical wave modelling also shows far-offset tuning across the reservoir when offsets are retained rather than applying virtual source methods. Alternate measures of CO_2 injection effects are demonstrated by displaying time domain maximum amplitude differences as function of offset as well as plotting frequency domain magnitude spectral differences as function of frequency and offset.

MOTIVATION

- Does CO_2 injection change attenuation sufficiently to be visible on spectral ratios?
- Can field observations be confirmed by model computations?
- Are there other seismic measures to indicate the presence of CO_2?

CONCLUSIONS

- Following one year of CO_2 injection the spectral ratios of all three source lines are modified.
- Assuming 90% CO_2 saturation the observed spectral ratio changes are confirmed by model computations.
- CO_2 injection can also be monitored by *spectral magnitude differences* as function of frequency and offset.

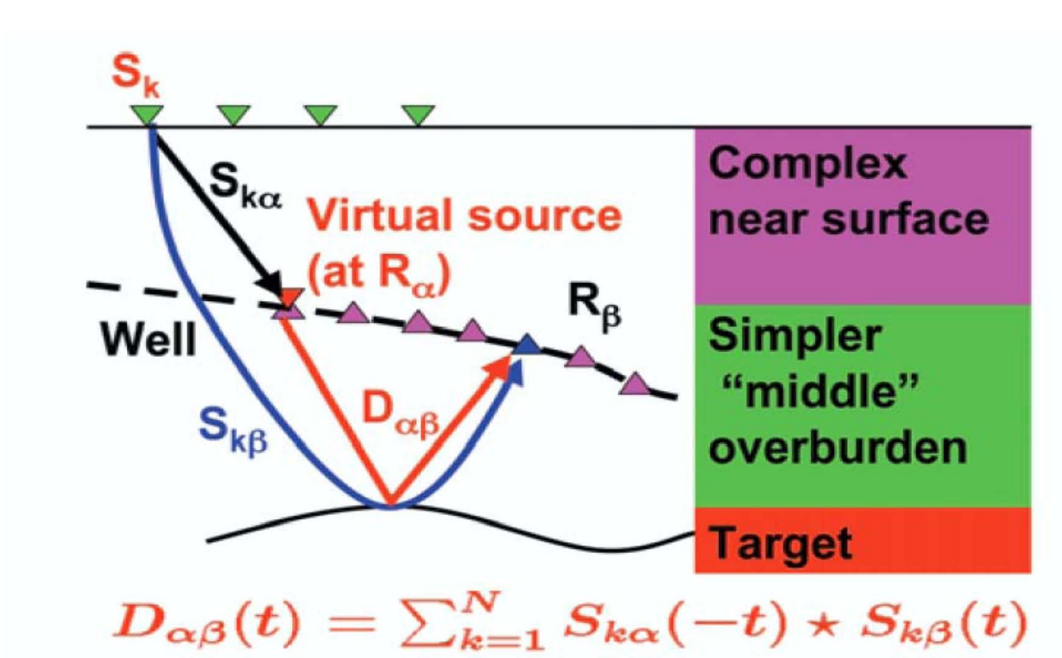

FIG. 1. Schematic of virtual source method (Bakulin et al., June 2007, The Leading Edge).

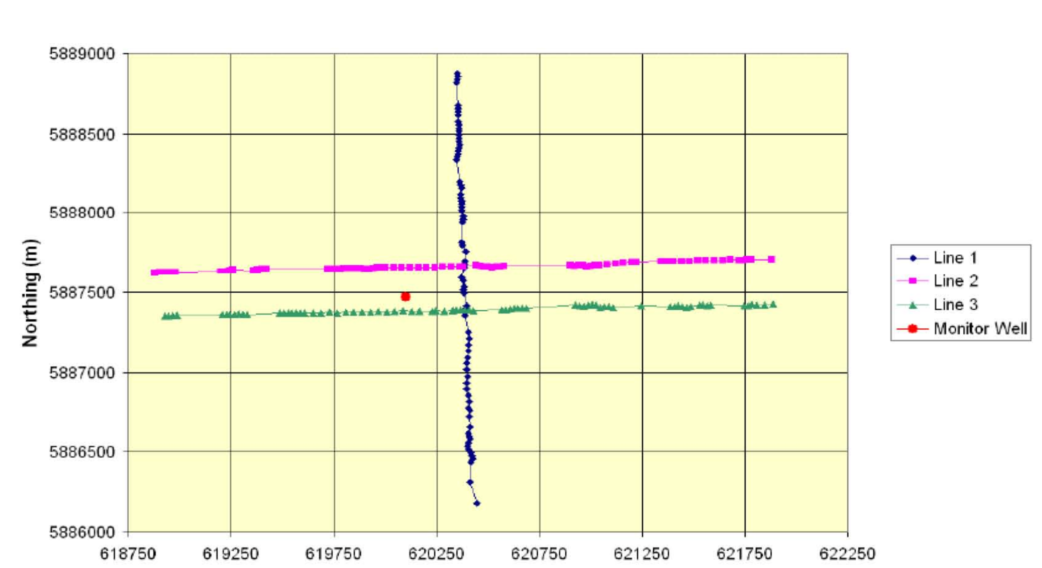

FIG. 2. Shot locations for the baseline survey (Coueslan, 2007, Fig. 1.7).

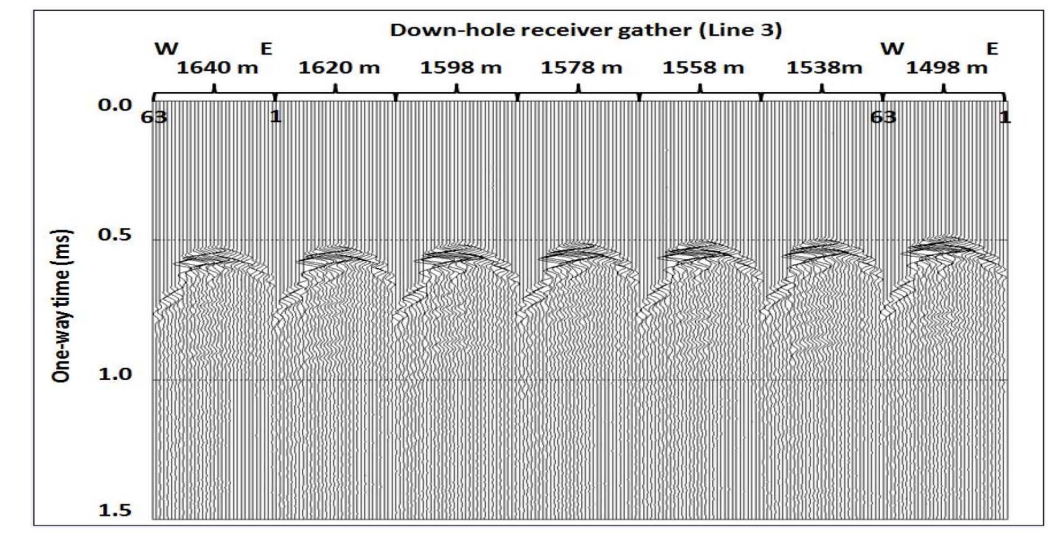

FIG. 3. Down-hole receiver gathers for line 3 (vertical components).

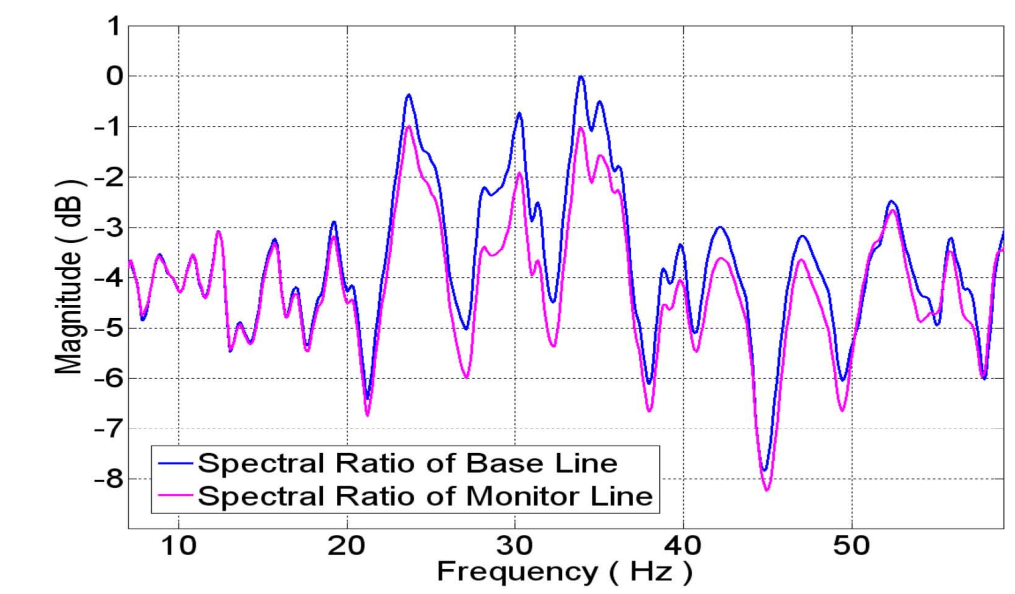

FIG. 6. VSP-trace interferometry spectral ratios.

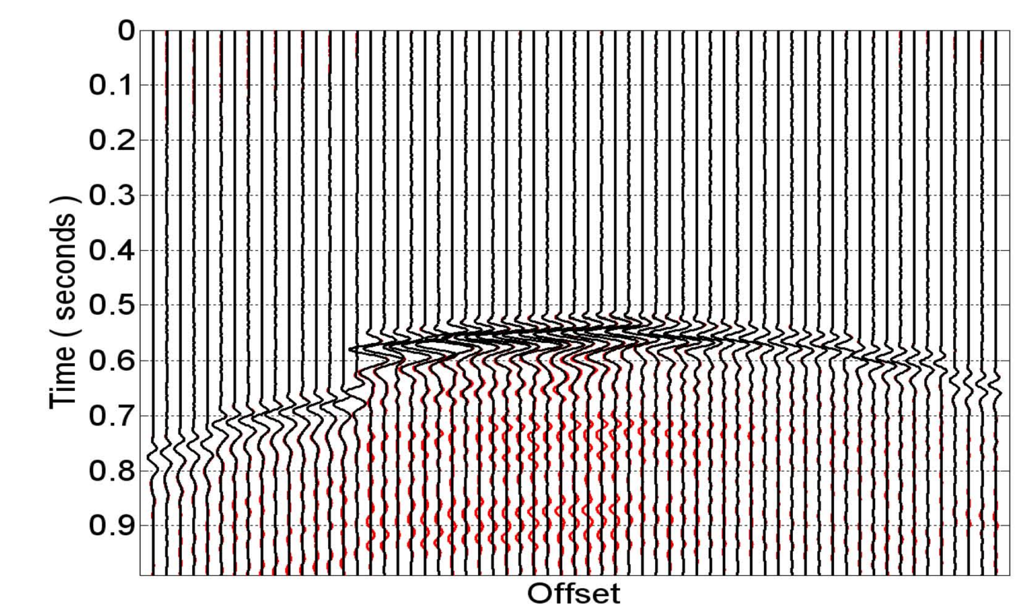

FIG. 7. VSP-traces before (red) and following (black) Gaussian windowing of first arrival.

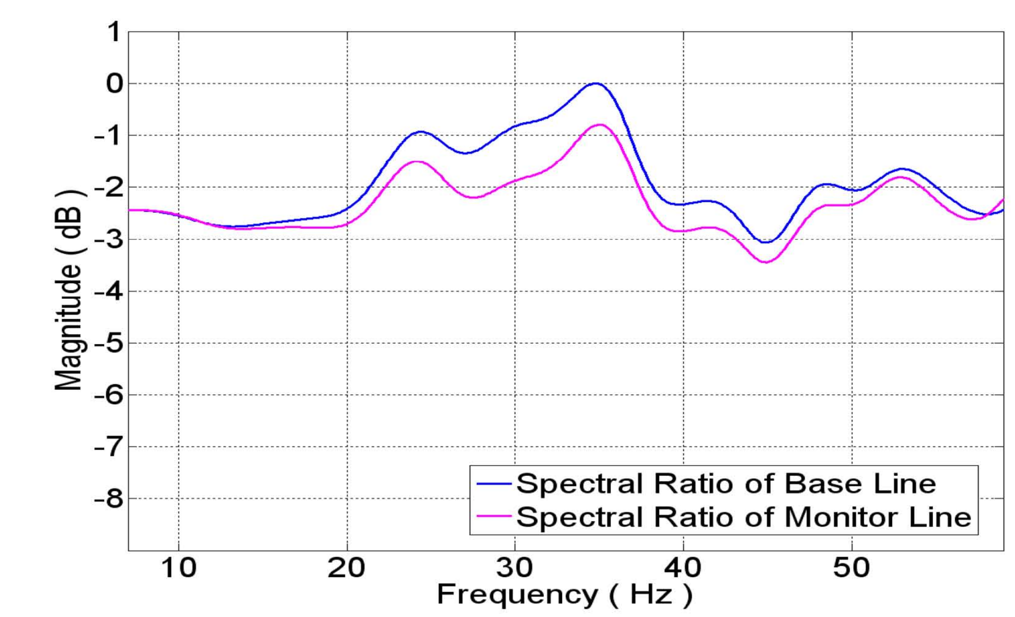

FIG. 10. VSP-trace interferometry spectral ratios of line 3 (Gaussian window applied).

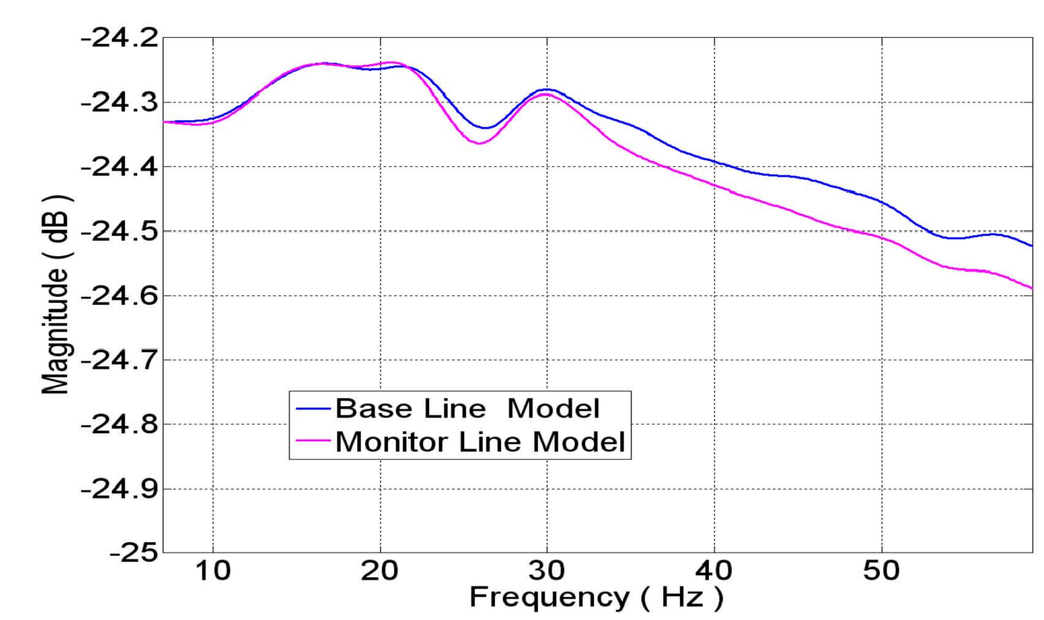

FIG. 16. VSP-model interferometry spectral ratios.

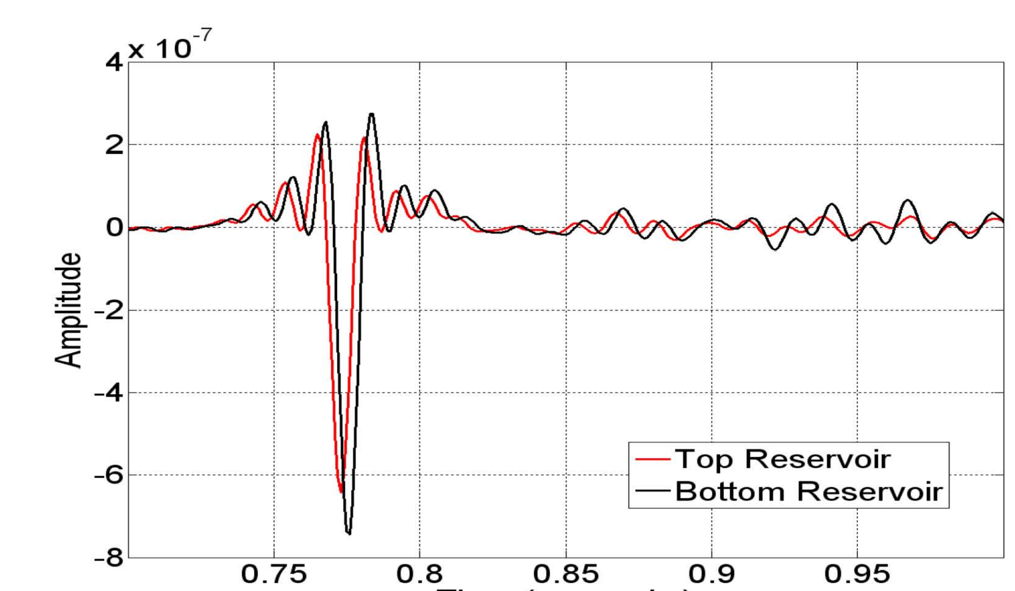

FIG 18. Model transmitted wave vertical components at far offset.

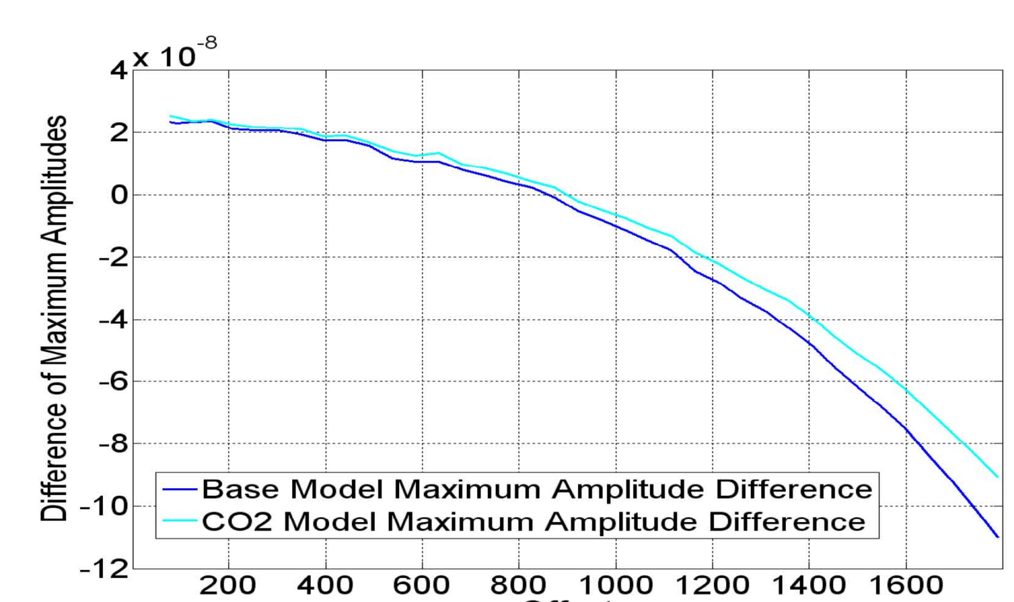

FIG. 20. Smoothed maximum amplitude differences of both models.

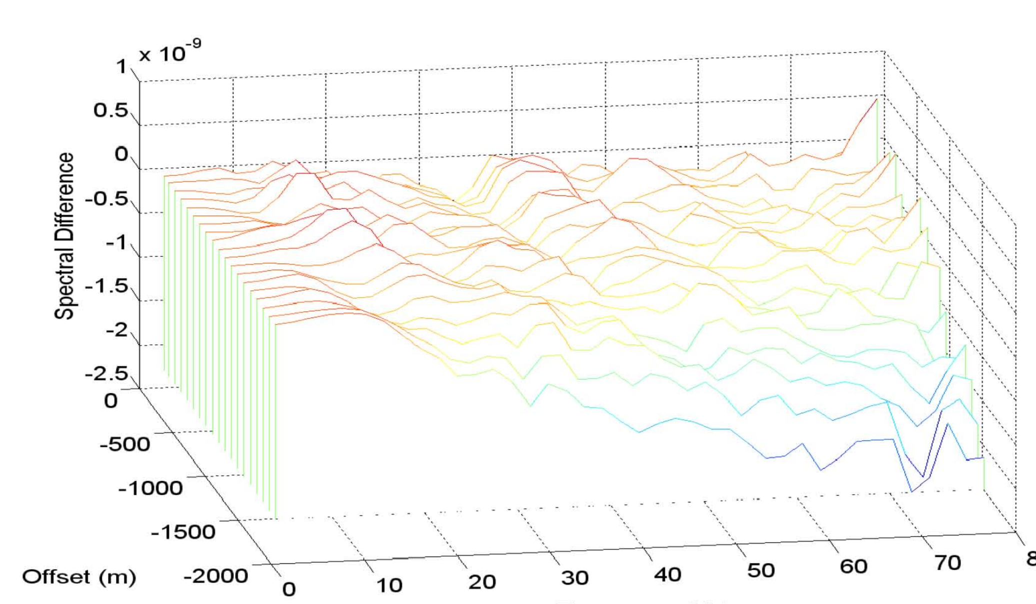

FIG. 21. Baseline-model to CO_2-model differences as function of offset and frequency.