Prestack depth migration of bi-static georadar data

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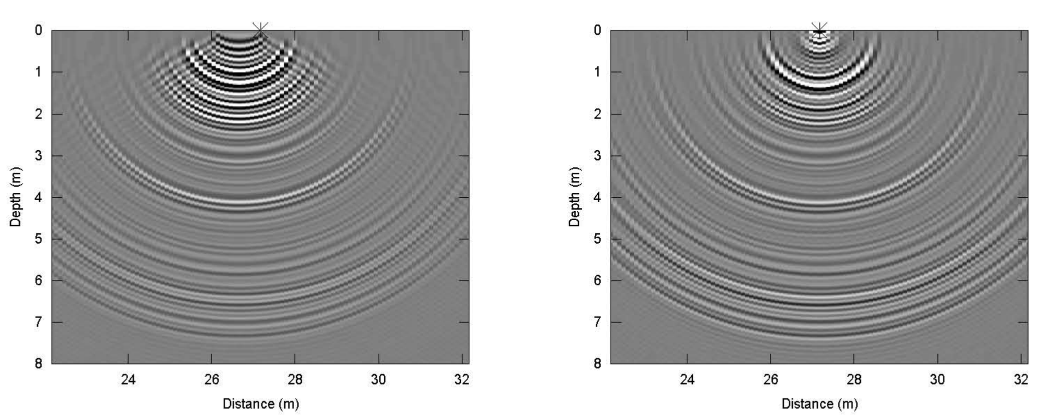
Summary

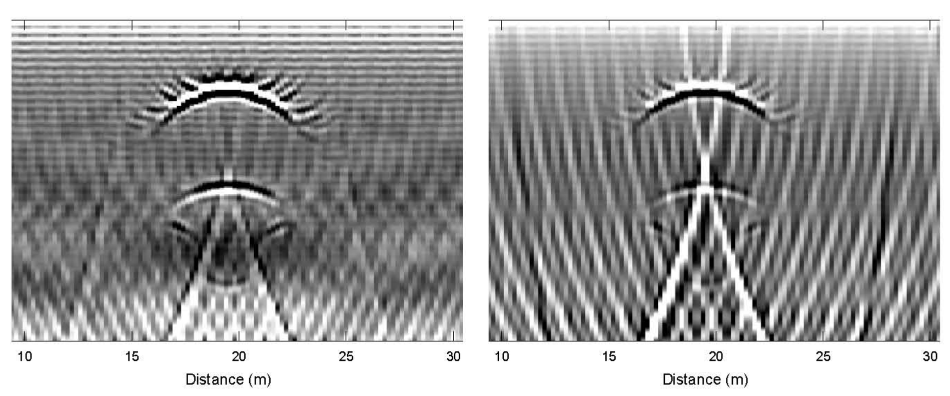
- Improved image quality justifies the cost of Gabor nonstationary deconvolution and prestack Depth Migration (PSDM) for georadar data.
- In the examples presented, PSDM velocity analysis indicates a slower imaging velocity than anticipated.
- Sparse survey of trace elevation, northing, and easting reduces resolution.
- Reflection events continue beyond end-of-record. Imaging deeper in this region is possible.

Theory

Theory and experimental evidence suggests that PSDM has desirable noise cancellation properties.



(a) PSDM impulse response (b) ZOM impulse response



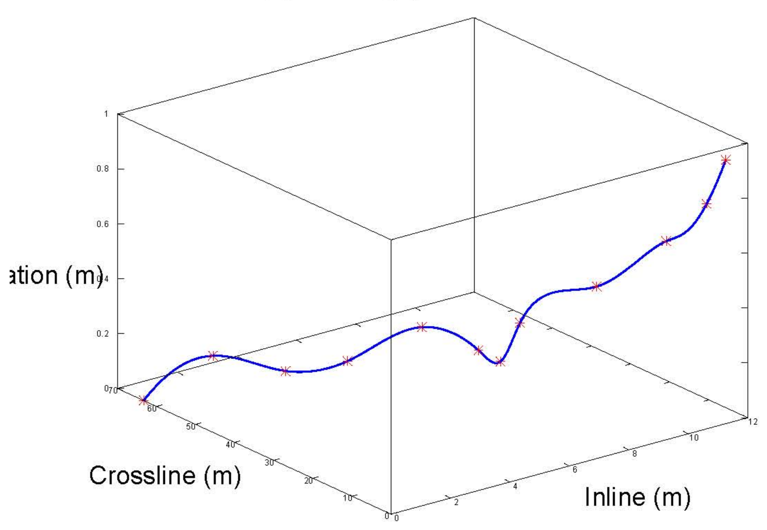
(c) Synthetic PSDM (d) Synthetic ZOM

Figure 1: A comparison of migration impulse responses and a synthetic example. (a) PSDM is elliptical in the near surface with the source and receiver locations at the foci. (b) ZOM is circular for all depths. ZOM and PSDM converge beyond 5 m depth. (c) PSDM of synthetic data shows some migration noise, while (d) ZOM migration has significantly more noise.

Acquisition

Parameter	Value
Number of traces	629
Δx	$\sim$ 10 cm
Source - receiver offset	1 m
Expected velocity	0.053 m/ns (5.3 $\times 10^7$ m/s)
f_{dom}	100 MHz
λ_{dom}	0.53 m
Δz_{Ricker}	0.11 m

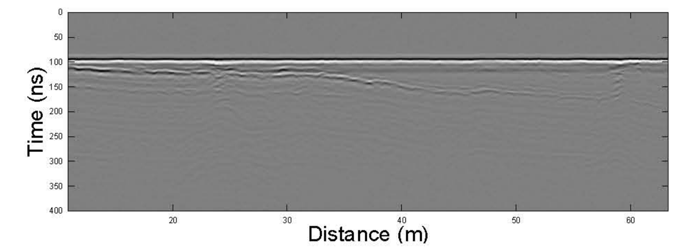
(a) Survey parameters.



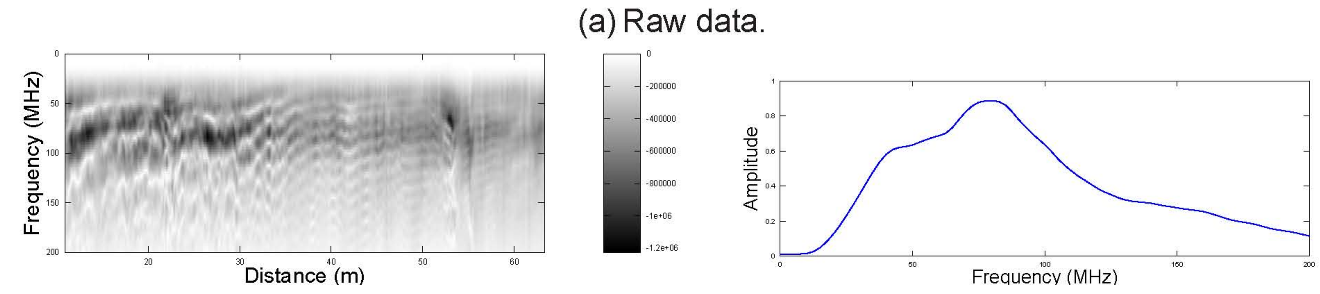
(b) Interpolated survey.

Figure 2: (a) The nominal trace spacing of 10 cm is interpolated from the actual survey shown in (b). (b) Red asterisks indicate the survey locations. The solid line is the interpolated (by splines) survey.

Signal analysis



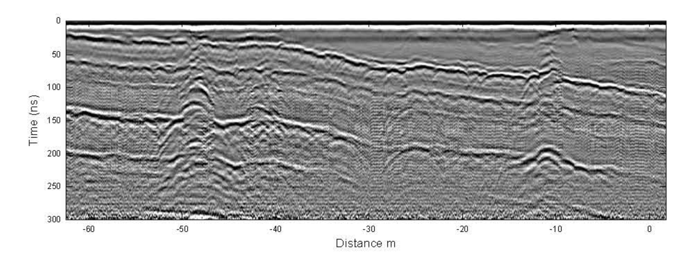
(a) Raw data.



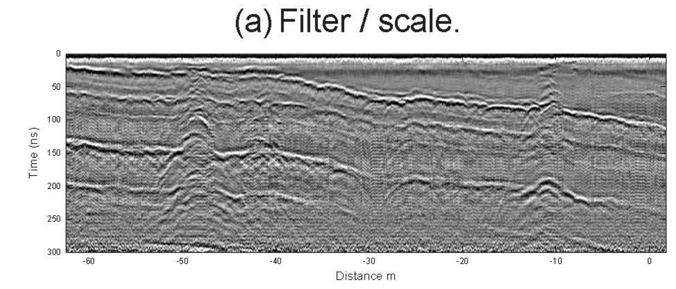
(b) Spectrum. (c) Average spectrum.

Figure 3: Quarry data. (a) Raw data showing first break delay. (b) Fourier spectrum of the raw data. The dominant frequency is somewhat less than the antenna frequency. (c) The average spectrum of the raw data.

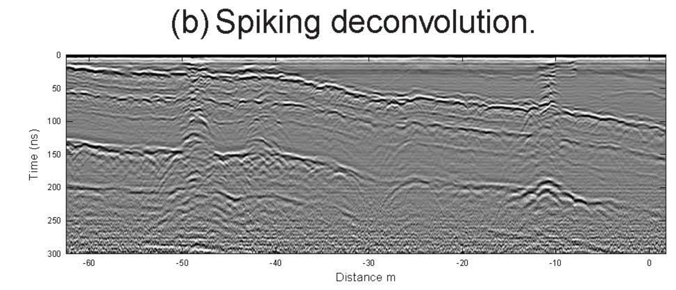
Pre-processing: filter and scale vs. spiking decon vs. Gabor decon



(a) Filter / scale.



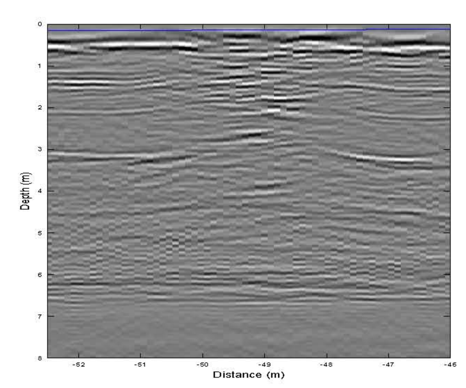
(b) Spiking deconvolution.



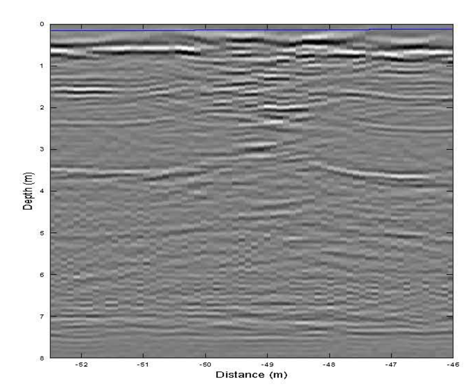
(c) Gabor nonstationary deconvolution (Margrave et al, 2005).

Figure 4: (a) Relative to the raw data of Figure 3(a), reflections are now apparent to 300 ns. (b) Reflections are sharpened, "ringiness" is reduced, but high-frequency noise is introduced. (c) "Ringiness" is reduced significantly, and very little high-frequency noise is added.

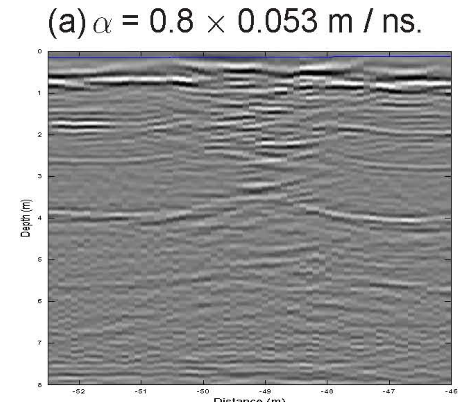
Velocity analysis



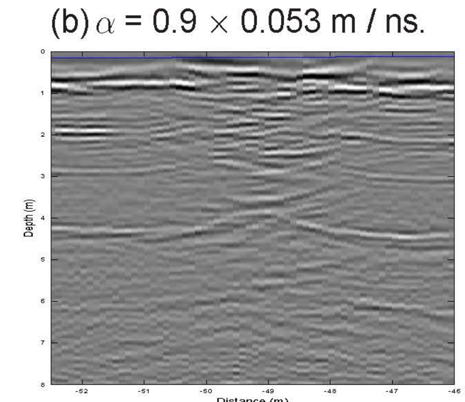
(a) α = 0.8 $\times$ 0.053 m / ns.



(b) α = 0.9 $\times$ 0.053 m / ns.



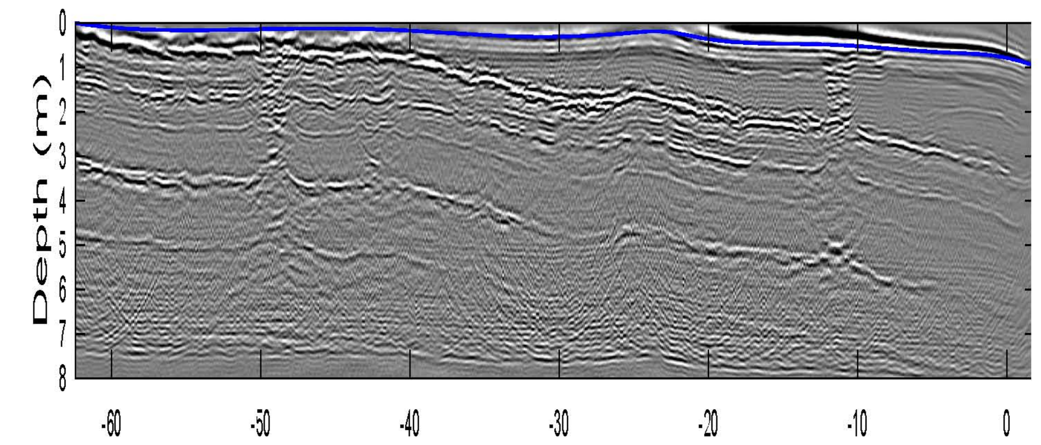
(c) α = 0.053 m / ns.



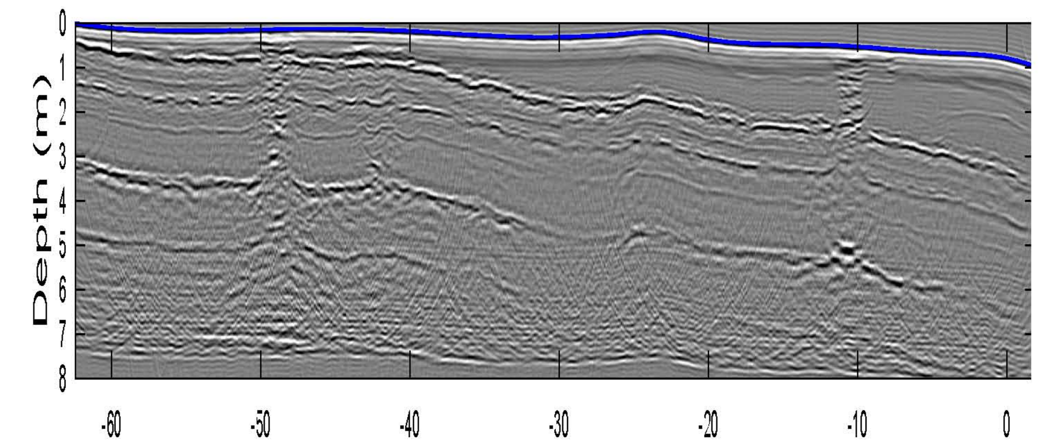
(d) α = 1.1 $\times$ 0.053 m / ns.

Figure 5: PSDM velocity analysis for a diffraction on the left side of the line near 3 m depth.

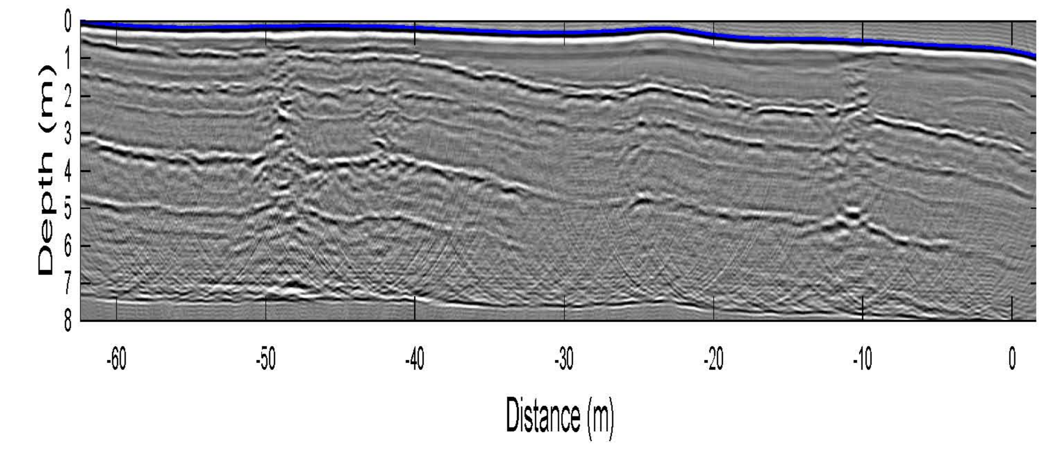
Imaging



(a) Gabor deconvolution, trace EQ, and PSDM.



(b) Gabor deconvolution, trace EQ, and ZOM.



(c) AEC and ZOM

Figure 6: Final images using 0.9 $\times$ 0.053 m / ns. (a) Gabor deconvolution followed by PSDM. (b) Gabor deconvolution followed by ZOM. When compared to PSDM in (a), this image has less sharpness of events above 5 m, and there is slightly more migration noise throughout. (c) AEC followed by ZOM. Though this image is interpretable, it low frequency and contains significant reverberation noise.

Conclusions

- Gabor deconvolution and PSDM improve the radar image.
- f_{dom} in the data is lower ($\sim$ 80 Hz) than the antenna frequency (100 Hz).
- PSDM velocity analysis indicates %10 slower velocity.
- The interpolated survey locations probably limit resolution.
- Data is present at later times in the recording - longer recordings will capture deeper reflections.

Acknowledgements

The authors wish to thank the sponsors, faculty, and staff of the Consortium for Research in Elastic Wave Exploration Seismology (CREWES), and the Natural Sciences and Engineering Research Council of Canada (NSERC, CRDPJ 379744-08) for their support of this work.

References

G. F. Margrave G. F., P. C. Gibson, J. P. Grossman, D. C. Henley, V. Iliescu, and M. Lamoureax, 2005, The Gabor transform, pseudodifferential operators and seismic deconvolution: Integrated computer-aided engineering, 12, pages43 - 55.