Shot record depth migration of georadar

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Summary

We modify common shot record migration from seismic imaging into a single trace prestack depth migration (PSDM) specifically for georadar. Implemented using a combination of Linux, Pearl, and Octave programming languages, our georadar PSDM runs in parallel on the CREWES cluster Gilgamesh. This PSDM migrates the radar data from topography, and when compared to conventional migration derived from normal-incidence topography correction followed by zero-offset migration (ZOM), we find that our PSDM returns significantly improved migrated images. As part of pre-image processing, we find that nonstationary deconvolution implemented in the Gabor domain significantly enhances the sharpness of reflection and diffraction events, and it significantly enhances reflection and diffraction arrivals at later times when compared to conventional spiking deconvolution.

Introduction

At Craters of the Moon, Idaho, USA, a large basalt flood contains a plumbing system of volcanic conduits. Some conduits are so well known that they are open to tourists, while others are unknown and unexplored. To understand the origins and extent of the basalt flow, there is great interest in complete characterization of this conduit system, and an initial interpretation is provided in a companion paper (Rowel et al.) in this volume of the CREWES Report. The target conduits are metres in height and circumference, so georadar soundings must be acquired with sub-decimetre bin spacings. Such small targets require processing and imaging far beyond what is the common practice, so we adapt our advanced seismic processing and imaging for 2D georadar imaging.

Data preparation

During acquisition, the acquisition unit is set to acquire traces continuously at a fixed acquisition time interval, so trace spacing varies with the velocity of acquisition. Also, when acquisition progress is halted, redundant traces are acquired for the corresponding spatial location. Data preparation prior to processing and imaging consists of (see Table 1):

Process	Parameters
Rotate survey	Linear fit
Delete redundant traces	
Interpolate elevations	Linear interpolation ($\Delta x \sim 14$ cm)
Align $t = 0$ for traces	Delete top pad
Interpolate traces	Linear interpolation ($\Delta x \sim 14$ cm)

Table 1: Data preparation parameters.

Survey rotation was done to simplify the survey for later processing steps. Survey data were read in from the headers, the survey origin was shifted to $(0, 0)$, and a rotation operator was determined to minimize variation in the Northerly direction. The original irregular elevation survey is interpolated from the true survey locations onto a regular grid, and the irregular traces are mapped onto a regular grid (Figure 1)— both interpolations are done using linear interpolation.

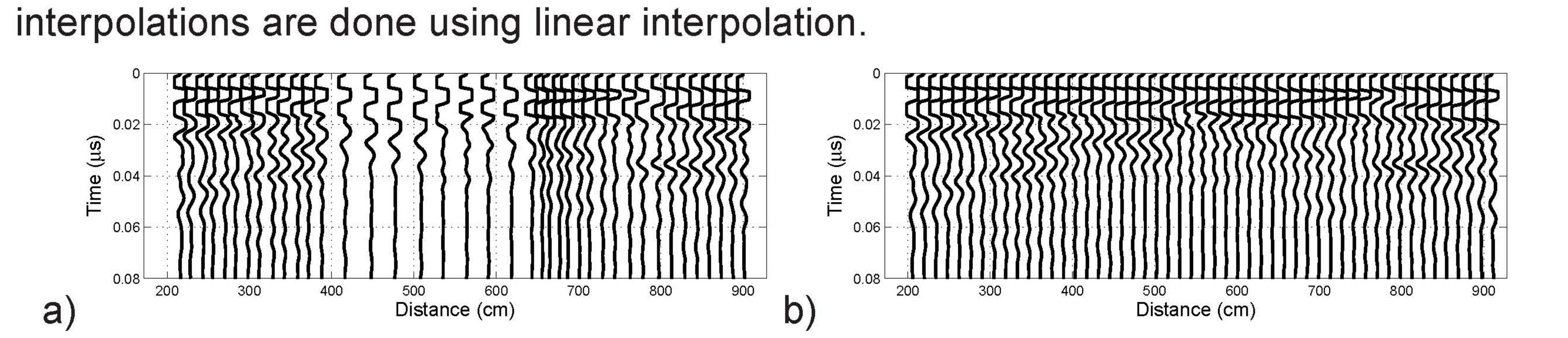

Figure 1: Data regularization. a) Data from the original survey have irregular trace spacing. b) Data from (a) interpolated onto a regular grid.

Data processing

Data processing consists of deconvolution, and we present here a direct comparison of conventional spiking deconvolution and Gabor deconvolution. For later PSDM / ZOM comparison, terrain statics corrections are applied to a copy of the deconvolved output.

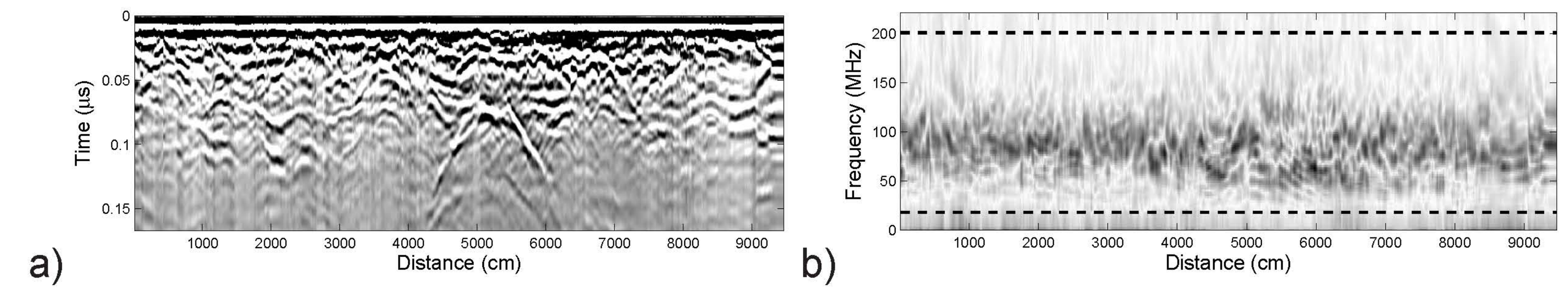

Figure 2: The raw data. a) The regularized raw data. b) The spectrum of the raw data. Note the dominant frequency at 100 MHz.

Parameter	Value
Design trace	Design on trace
# points in f boxcar	17
Stabilization factor	0.0001
Output phase	Zero

Table 2: Spiking deconvolution[a] parameters.

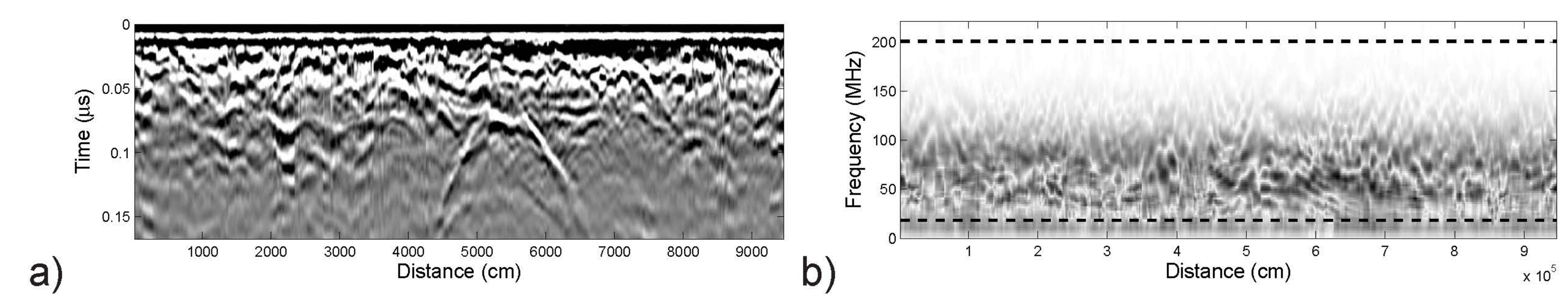

Figure 3: Spiking deconvolution of the raw data. a) The deconvolved output. b) The spectrum of the deconvolved output. Spiking deconvolution has recovered some low-frequency, with minimal gain of higher frequency.

Parameter	Value
Gaussinan window width	0.12 μs
Window increment	0.0024 μs
Width of t smoother	0.016 μs
Width of f smoother	110 MHz
Smoothing	Hyperbolic
Order of Burg spec.	10
Stability factor	0
Phase of output	0
Synthesis window	Unity

Table 3: Gabor deconvolution parameters[b].

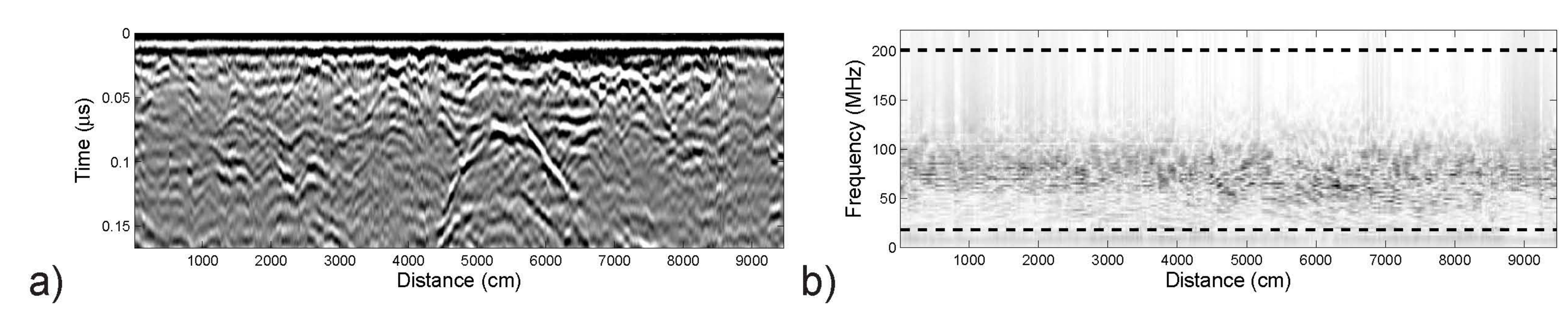

Figure 4: Gabor deconvolution of the raw data. a) The deconvolved output. b) The spectrum of the deconvolved output. Gabor deconvolution has recovered low-frequency, and events appear sharper than spiking deconvolution (Figure 3).

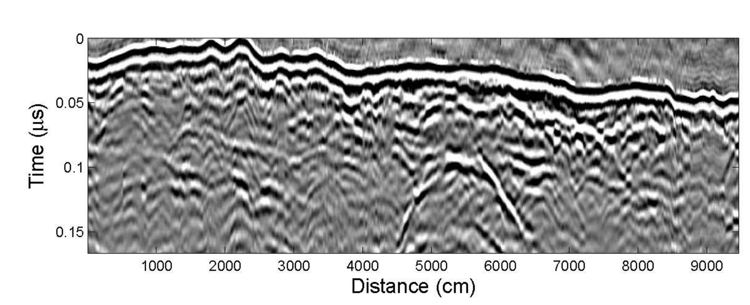

Figure 5: Input data for ZOM. These data have Gabor deconvolution and statics applied.

[a]See `deconf` in the CREWES matlab toolbox.
[b]See `gabordeconb` in the CREWES Matlab toolbox.

Imaging

We compare our new PSDM to conventional post stack migration. Our PSDM is implemented using a set of script files `mssh_psdm`, `run_psdm_radar`, and `psdm_radar` and `gaz_mig` from the CREWES Matlab Toolbox. Rather than use Matlab, however, and have to cope with the parallel implementation of Matlab, we chose instead to modify the Matlab routines slightly to run in Octave. Octave is a free Matlab-like system that we have installed on all 19 *Gilgamesh* nodes.

Our PSDM migrates each trace in a shot-record migration. Each migrated trace is then stacked according to it's elevation an lateral location. The comparison ZOM is applied to the terrain corrected data of Figure 5.

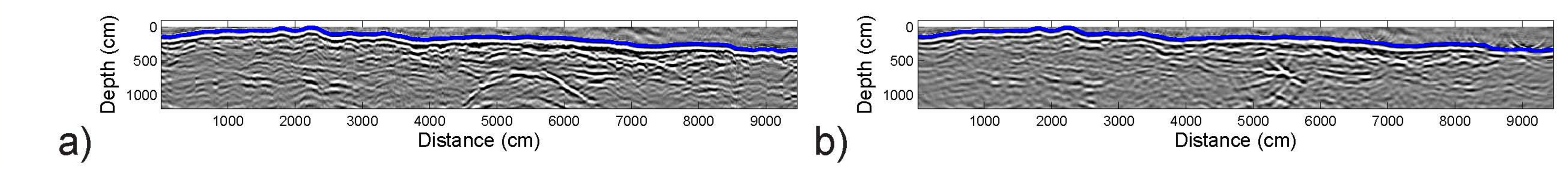

Figure 6: ZOM. a) The input data (Figure 5) are stretched to depth for comparison. b) ZOM output. The elevation profile is overlain as a solid line.

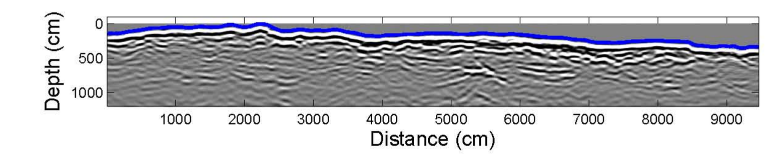

Figure 7: Stack of all PSDM migrated traces.

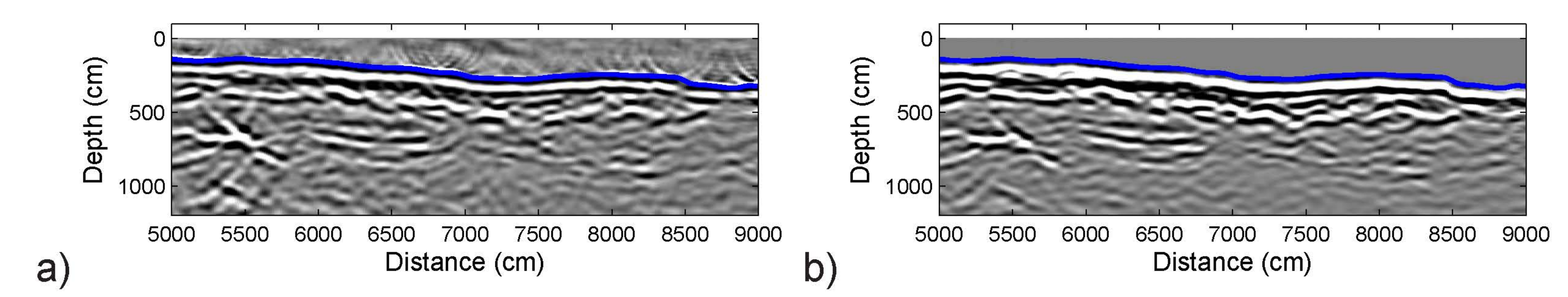

Figure 8: Migration comparison of 5000-9000 cm. a) ZOM. b) Stacked PSDM migration. PSDM is less noisy, and energy is more coherent.

Conclusions

We find that application of our Gabor deconvolution and PSDM to georadar enhances significantly the final image. In particular, we find that nonstationary deconvolution whitens the spectrum and draws out deeper reflection energy than conventional spiking deconvolution. We find also that PSDM, implemented as single trace shot migration, significantly improves upon the combination of terrain correction followed by ZOM.

We implement our georadar imaging algorithm in parallel on our multi-core, multi-node computer cluster, and we use Octave as the central processing language with Linux and Pearl used to effect parallelism. We find that this combination is relatively easy to use, and it is very cost effective in that it uses only freely available software.

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