Shot record depth migration of georadar data

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Similar to electromagnetic propagation in ice, the low dielectric permittivity of basalt causes strong electromagnetic reflections from interfaces, and because the low conductivity of basalt allows a great depth of penetration, georadar is well suited to image structures within basalt. 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. 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 in this paper, we adapt our advanced seismic processing, imaging, and inversion for 2D georadar imaging.

Though our acquisition approach allowed us to acquire a large amount of data in a short time, it did result in irregular spacing of georadar soundings. As a remedy, we develop a sequence of data preparation steps where the survey geometry is simplified, and then we interpolate the elevation and georadar data onto a regular grid. We then 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. 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, 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.

Our images of Indian Tunnel and Beauty Cave at Craters of the Moon show that georadar is able to resolve lava tubes. The main sections of the smaller tube, Beauty Cave, measure between 5 and 10 meters across. These sections are imaged to depths of at least 10 meters, and we have example images with coherent reflections at 25 meters. The small crawl space in Beauty Cave, at about 1 meter across and 10 meters deep, is beyond the current resolution of our processing procedure, but we anticipate improvement through more detailed velocity analysis. Our nonstationary deconvolution and PSDM produce georadar sections that more closely resembled the actual geometry of the subsurface; We now have greater ability to resolve lava tubes and interpret their geometries than would otherwise have been possible.

We also demonstrate that good quality data can be collected in this area with the antennas elevated above the surface. The exceptionally rough terrain and need for fast acquisition necessitate carrying the antennas above the surface. While this undoubtedly results in some loss of signal quality, the overall resolution and depth of signal penetration for these surveys are very good.