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Diffraction imaging of surface reflection GPR data

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In ground-penetrating radar (GPR) reflection studies it is common practice to use diffractions caused e.g. by faults, fractures, and small-scale heterogeneity to constrain the sub-surface velocity distribution. However, interference between reflections and diffractions may cause difficulties in the identification of diffractions and thereby limit the number of diffractions going into the velocity analysis. In order to improve the identification of diffractions and improve velocity estimation, we adopt a diffraction imaging approach, which was originally developed for seismic imaging, to GPR reflection data (Fomel et al., 2007). Using this approach, which we tailor to fit GPR data, we are able to separate the reflections and diffractions and thereby increase the number of diffractions that can go into the velocity analysis. Moreover, we pick the migration velocity through focusing analysis of the local attributes. Finally, we migrate the data using the so-called velocity continuation method, which allows changing the migration velocities through differential steps. In synthetic tests, we observe that the applied method, which picks the migration velocities from separated diffractions, can better reflect the subsurface velocity variations and, thereby, provide better imaging results. Further, we compare the migration velocities so obtained from real surface reflection GPR data with velocity images found from coincident cross-hole experiments. These comparisons based on real data also show that the diffraction imaging approach applied to surface-based reflection GPR data actually has the potential to resolve detailed velocity structures of the subsurface, including zones of low velocity. Our findings suggest that, depending on the depth penetration of the surface-based GPR reflection data, porosity and water saturation variability may be estimated from surface-based GPR reflection studies.

[1] Sergey F., Evgeny L., M. Turhan T. 2007, Post-stack velocity analysis by separation and imaging of seismic diffractions, Geophysics, 72, U89-U94.