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Full waveform forward seismic modeling of geologically complex environment: Comparison of simulated and field seismic data

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Reflection seismic data acquired in hard-rock terrains are often difficult to interpret due to complex geological architecture of the target areas. Even fairly simple geological structures, such as folds, can be difficult to identify from the seismic profiles because the reflection method is only able to image the sub-horizontal fold hinges, and no reflections arise from the steep fold limbs. Furthermore, typically acquisition lines in the hard-rock areas are crooked, and the data can rarely be acquired perpendicular to the strikes of the structures, if the strikes are even known. These further complicate the interpretation, because conventional processing techniques fail to compensate for the associated distortions in the ray paths.

Full waveform seismic forward modeling can be used to facilitate the interpretations, to help to find optimal processing algorithms for specific structures, and also to guide the planning of a seismic survey. Recent increases in computational power and development of softwares make full wavefield forward modeling possible also for more complex, realistic geological models. In this study, we use Sofi3D-software for seismic forward modeling of 2D reflection seismic data acquired along a crooked acquisition line over a 3D fold structure. The model presents the structures previously interpreted in the Pyhäsalmi VHMS deposit, central Finland. Density, P and S-wave velocities required for the modeling are derived from in-situ drill hole logging data from the Pyhäsalmi mining camp, and Paradigm GoCad is used to build the geological 3D models.

Meaningful modeling results require a sufficiently dense modeling grid, however, increasing the grid density comes at the cost of increased running time of the Sofi3D. Thus, careful parameter selection needs to be done before running the forward modeling. The results of the forward modeling aim to facilitate the interpretation of the 2D reflection seismic data available from Pyhäsalmi mining camp. The main cause of reflectivity in the area is contact between felsic and mafic volcanic rocks. The forward modeling approach used in this study provides a basis for simulating the expected response of these folded structures, for a number of realistic 3D models of the structures and acquisition geometries across them. The comparison between the simulated and observed reflectivity can be used to validate the geological models.