Seismic signature of shear zones: insights from 2-D convolution forward modelling

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Shear zones play an important role in localizing crustal deformation during rifting, continental break up and passive margin formation. Because shear zones change physical rock properties relative to the surrounding undeformed rocks, we can image them in seismic reflection data. The exact seismic signature of shear zones is however still largely unknown, making it difficult to identify and differentiate them from large-scale structures, such as magmatic sill complex or dike swarms. This study therefore aims to explore the seismic signature of shear zones using 2-D seismic forward modelling. Our workflow includes these steps: (1) extraction of shear zone geometries from three outcrop examples (Holsnøy, Cap de Creus, Pernambuco), (2) collection of physical properties of these shear zones and their host rock, (3) construction of acoustic impedance models, (4) generation of seismic images by 2-D convolution of the models with point-spread function, (5) geophysical sensitivity analysis (frequency, illumination) of seismic images and (6) comparison of seismic images to observational studies. In general, we find that the relationship between shear zones and their seismic signatures is non-trivial, as the intricate structure of shear zones produces complex seismic signatures. Nevertheless, our models show several features previously used to identify shear zones in seismic data, including subparallel, inclined and converging seismic reflections. On the other side, we also observe features, such as cross-cutting reflections, which have previously been associated with magmatic intrusions rather than shear zones. These observations emphasizes the importance of seismic forward modelling as method that can bridge the gap between field and seismic studies of crustal shear zones.