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How seismic diffraction improves the imaging of the crust

Benjamin Schwarz (1), Alexander Bauer (2), Dirk Gajewski (2), Karin Sigloch (1), and Tarje Nissen-Meyer (1)
(1) Department of Earth Sciences, University of Oxford, Oxford, United Kingdom (benjamin.schwarz@earth.ox.ac.uk), (2) Institute of Geophysics, University of Hamburg, Hamburg, Germany

Due to their faint signatures, diffracted wave fields are still largely neglected in attempts to image the earth's crust with active or passive seismic sources. This contrasts with applications in optics, where diffraction represents a key phenomenon. Aside from encoding sub-wavelength information on the scattering geometry or indicating small-scale structural complexity, diffraction provides superior crustal illumination compared to reflected or transmitted waves. Seismic diffraction occurs in essentially all realistically complex media. In particular, it can be observed in the context of crustal faults and in regions with discontinuous changes in elastic properties, such as salt environments close to the surface or the deeper crystalline basement of the crust. Since diffraction can rarely be observed on individual seismograms, we suggest to identify, extract and amplify its low-amplitude wave fields with robust coherence techniques adapted from and motivated by geometrical optics, and promote their use in active and passive-source seismic imaging and inversion.

From a wavefront perspective, diffractive structures behave exactly like passive (secondary) sources buried in the ground, because they have the same non-directional radiation characteristics. Following this approach, we identify propagation symmetries and local passive source equivalent attributes, which can be measured in the data by means of coherence analysis. While in conventional beamforming only the local slopes of the emerging wavefronts are estimated, we in addition make use of local wavefront curvature measurements. This can yield a successful discrimination of different wave field components even when only single-channel or near-offset data are available, as is the case in most active-source academic surveys. Closing the gap to earthquake seismology, we suggest that the wave fields of earthquakes diffracted at discontinuities in the crust and mantle could significantly increase illumination, with the potential to naturally complement receiver functions where seismological arrays are sufficiently dense.