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Imaging of demultipled data: a new approach based on seismic interferometry and Marchenko autofocusing

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Standard seismic processing steps such as velocity analysis and reverse time migration are based on the single-scattering Born approximation, and assume that all reflections are primaries; multiples represent a source of coherent noise and must be suppressed to avoid artefacts. Surface related multiples particularly impact on seismic images resulting from marine data, and much effort has been
devoted to their removal. Internal multiples strongly affect land data, and relatively fewer techniques exist to predict and remove them from reflection data.

We present a novel internal-multiples prediction method based on the combined use of seismic interferometry and Marchenko autofocusing. Seismic interferometry techniques synthesise Green's functions between real source or receiver locations by integrating cross-correlations or convolutions of wavefields recorded by receivers or emanating from sources located elsewhere. Marchenko autofocusing estimates up- and down-going components of Green's functions between virtual source locations inside a medium and real receivers at the surface. In contrast to interferometry, autofocusing requires an estimate of the direct wave from the virtual source, illumination only from one side of the medium, and no physical receivers inside the medium. We first illustrate how primary and internal multiple reflections are reconstructed in convolutional interferometry by combining up- and down- going Green's functions from virtual sources in the subsurface. These Green's functions can usually be neither directly measured nor modelled accurately. However, autofocusing estimates all such Green's functions and their up- and down-going components.

We then discuss how primaries and internal multiples intrinsically differ in terms of the constitutive components involved in the interferometric process. Specifically, we show that primary reflections reconstructed through convolutional interferometry necessarily involve direct and reflected Green's functions, whereas internal multiples can theoretically be reconstructed by combining purely reflected wavefields; we propose an internal multiple prediction algorithm based on this discrimination
criterion.

First, we generate the relevant up- and down-going wavefields at virtual sources along discrete subsurface boundaries using autofocusing. Then, we convolve purely scattered components of up- and down-going Green's functions to reconstruct only the internal multiple field which is adaptively subtracted from the measured data. Crucially, this is all possible without detailed modelled information about the Earth's subsurface. The method only requires surface reflection data and estimates of direct (non-reflected) arrivals between subsurface sources and the acquisition surface.

The method is demonstrated on synthetic models and is shown to be particularly robust against errors in the velocity model used in the autofocusing step. Subsurface images are much improved using the resulting data without internal multiples.