Motivation

Complex subsurface structures, such as sub-basalt and sub-salt structures, generate strong scattering which makes them challenging to image with conventional techniques.

Reverse-time-migration (RTM) techniques accurately handle the propagation of such complex scattered waves, and produces a band-limited high-frequency representation of the subsurface structure that is assumed to be linear in the contrasts in the model parameters. Because of this linear single-scattering assumption, most RTM methods do not satisfy energy conservation and do not optimally use illumination and sensitivity of multiply scattered waves.

Migrating multiply scattered waves requires preserving the nonlinear relation between image and model parameters: first, by modifying the extrapolation of source and receiver wavefields to more accurately reconstruct multiply scattered waves, and second, by extending the concept of imaging condition in order to map into the subsurface structurally coherent seismic events which correspond to the interaction of both singly and multiply scattered and to analyze separated contributions to the final nonlinear image.

The result is an imaging process referred to as nonlinear reverse-time migration (NLRTM). NLRTM provides a tool suitable for both interpretation and velocity analysis with multiply scattered seismic waves.

Nonlinear reverse-time migration

Figure 1: Comparison of the (a) RTM and (b) NLRTM source- and receiver-side wavefield extrapolations and imaging conditions (e.g., crosscorrelation or deconvolution).
Targeted sub-salt imaging

Figure 2: Conventional Sigbsee RTM: (a) the shot-profile data are depth-migrated with (b) the velocity model to obtain (c) the seismic image.

Figure 3: Sigbsee NLRTM in the poorly illuminated targeted sub-salt area: (a) NLRTM sub-images and (b) estimate of the contrast model

Conclusions

The strategy for NLRTM imaging outlines the potentials of utilizing energy, illumination, and sensitivity of multiply scattered waves in seismic imaging.

NLRTM applies to targeted imaging in complex scattering subsurface environment. In the sub-salt imaging example, the method leads to refined interpretation of the subsurface geological structures by analysis of the consistency of each NLRTM sub-image and the consistency between NLRTM sub-images.

These two consistency criteria are interpretable as an extension of what is commonly referred to as semblance principle and are applicable to the design of new migration velocity analysis algorithms.

References