CLAIMS

1. A method for removing internal multiple reflections from seismic data, or performing local inversion or local imaging of seismic data, comprising defining a conceptual subsurface box having sources and receivers located on its edges or faces and estimating Green's functions by estimating direct arrival times from source locations to receiver locations, then updating the Green's functions by iterative optimization that minimizes error in source field reconstruction, or by another numerical solution technique, then using the optimized Green's functions to determine simulated internal multiple reflections within the box and subtracting them from the seismic data, or using the optimized Green's functions to do local imaging of the seismic data within the box or build a local velocity model for the box, or for any other seismic data processing purpose requiring redatuming the seismic data to a different subsurface location, wherein at least said iterative optimization is performed using a computer.

2. The method of claim 1, wherein the seismic data were measured using surface source and receiver locations, the box is defined to have a top face located on the surface, and data measured at the surface receiver locations are used in the iterative optimization or other solution technique, wherein the source and receiver locations in or on the box that are located below the surface are conceptual rather than actual.

3. The method of claim 2, wherein said simulation uses a seismic wavelet determined by deconvolving the seismic data, and wherein the seismic data are processed to remove surface-related multiple reflections before using in the iterative optimization or other solution technique.

4. The method of claim 1, wherein the source field reconstruction comprises multi-dimensional auto-correlation of the estimated or updated Green's functions.

5. The method of claim 1, further comprising defining, below the box, hereinafter called the first box, a second conceptual box and repeating the obtaining of optimized Green's functions for the second conceptual box.

6. The method of claim 5, wherein the second conceptual box has a top face that coincides, at least partly, with a bottom face of the first box.

7. The method of claim 6, wherein further conceptual boxes are defined and the method of claim 1 is repeated for each of them, until an entire subsurface region has been processed.

8. The method of claim 1, wherein another solution technique is used, it being one of a group consisting of a series expansion and iterative wavefield extrapolation.

9. The method of claim 1, wherein the determining simulated internal multiple reflections uses a forward model that is expressed as, or is mathematically equivalent to:

$$\mathbf{X}_0 = \mathbf{G} + \mathbf{GYG},$$

and

$$\mathbf{G}^*\mathbf{G} = \mathbf{I}.$$

where

$\mathbf{X}_0$ is an outgoing impulse response, representing a seismic wavefield that starts in the box and moves out of the box;

$\mathbf{Y}$ is an incoming impulse response, representing a seismic wavefield that starts outside the box and moves into the box;

$\mathbf{G}$ is a Green's function representing a seismic wavefield that starts in the box and ends at an edge or face of the box, never leaving the box; and

$\mathbf{I}$ is a reconstructed seismic source.

10. The method of claim 9, further comprising using the reconstructed seismic source to reconstruct missing surface seismic data for further processing of the seismic data that requires source and receiver locations on a regular grid.

CLAIMS

1. A method comprising:

defining, with a computer, a virtual subsurface box having sources and receivers located on its edges or faces, wherein the virtual subsurface box represents a selected part of Earth's subsurface;

estimating, with a computer, Green's functions by estimating direct arrival times from locations of the sources to locations of the receivers;

updating, with a computer, the Green's functions by one of iterative optimization that minimizes error in source field reconstruction, a series expansion, or iterative wavefield extrapolation; and

running a simulation, with a computer, wherein the simulation simulates seismic waves generated by the sources being reflected off of at least two subsurface reflectors, which causes simulated internal multiple reflections within the box from the optimized Green's functions, and subtracting the simulated internal multiples from seismic data collected by actual receivers, wherein the seismic data includes internal multiple reflections, and the subtracting reduces the internal multiple reflections in the seismic data;

generating, with a computer, a subsurface image from the seismic data with the simulated internal multiples subtracted therefrom.

2. The method of claim 1, wherein the seismic data were measured using surface source and receiver locations, the box is defined to have a top face located on the surface, and data measured at the surface receiver locations are used in the iterative optimization, series expansion, or iterative wavefield extrapolation, wherein the source and receiver locations in or on the box that are located below the surface are virtual rather than actual.

3. The method of claim 2, wherein said simulation uses a seismic wavelet determined by deconvolving the seismic data.

4. The method of claim 1, wherein the source field reconstruction comprises multi-dimensional auto-correlation of the estimated or updated Green's functions.

5. The method of claim 1, further comprising defining, below the box, hereinafter called the first box, a second virtual box and repeating the obtaining of optimized Green's functions for the second virtual box.

6. The method of claim 5, wherein the second virtual box has a top face that coincides, at least partly, with a bottom face of the first box.

7. The method of claim 6, wherein further virtual boxes are defined and the method of claim 1 is repeated for each of them, until an entire subsurface region has been processed.

8. The method of claim 1, wherein running the simulation includes using a forward model that is expressed as, or is mathematically equivalent to:

$$\mathbf{X}_0 = \mathbf{G} + \mathbf{GYG},$$

and

$$\mathbf{G}^*\mathbf{G} = \mathbf{I}.$$

where

$\mathbf{X}_0$ is an outgoing impulse response, representing a seismic wavefield that starts in the box and moves out of the box;

$\mathbf{Y}$ is an incoming impulse response, representing a seismic wavefield that starts outside the box and moves into the box;

$\mathbf{G}$ is a Green's function representing a seismic wavefield that starts in the box and ends at an edge or face of the box, never leaving the box; and

$\mathbf{I}$ is a reconstructed seismic source.

9. The method of claim 8, further comprising using the reconstructed seismic source to reconstruct missing surface seismic data for further processing of the seismic data that requires source and receiver locations on a regular grid.

10. The method of claim 1, further comprising generating a velocity model for the box with a full waveform inversion process, wherein the subsurface image is generated using the velocity model.