Reverse time reflection imaging of active and passive seismic data with ocean-bottom seismographs

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Introduction

In most case of crustal seismic surveys or earthquake observations using ocean-bottom seismometers, however, because receiver spacing is generally large in the wide range survey/observation, technical improvements of imaging methods are required to interpolate the lack of subsurface imaging area. On the other hand, high-dense and continuous seismic (earthquake) observation using new and existing optic fiber cables have been advancing. Development of an efficient imaging method is also necessary to utilize the enormous data. Reverse time migration (RTM) in reflection seismic exploration is one of effective seismic imaging techniques for complex subsurface structures with reconstructing full wavefield. In this study, we developed reverse time reflection imaging method which is available in active seismic survey and passive seismic observation, and we conducted a field data application and a numerical feasibility study.

Method

A. basic RTM: source-to-receiver pairs

In case of active survey with artificial seismic sources or a passive observation with accurate source locating, basic imaging principle using primary reflections between the sources and receivers is available. In the basic reverse time reflection imaging, reflected waves are focused on subsurface imaging points by a temporal integration of product between forward-extrapolated wavefields from source and backward-extrapolated wavefields of the recorded seismic data from receiver points.

B. modified RTM: receiver-to-receiver (source-to-source) pairs

We propose a modified reverse time reflection imaging method in passive seismic survey without determining source information. Both forward and backward wavefield extrapolations are performed from all receiver locations with the recorded seismograms, and the surface-reflected multiple reflections are focused on the subsurface imaging points as pseudo-primary reflections. Based on source-receiver reciprocity, this method can be applied to source-to-source pairs to use multiple reflections in airgun-OBS surveys.

Case study

(1) Airgun-OBS survey data in the Nankai Trough

We applied the proposed method to a 2D wide-angle reflection survey data acquired along 170 km survey line (200 m spacing of airgun shots, and 1 - 10 km spacing of OBSs) in the Nankai Trough. In wavefield reconstruction in the imaging process, sources and receivers are exchanged based on source-receiver reciprocity. A final reflection profile can be obtained by stacking two results derived from the primary reflections from OBS to airgun locations with the basic RTM method and from the multiple reflections between different airgun locations with the modified RTM method. Deep structures including the subducting plate and its relationship with old and young accretionary prisms are imaged with long offset reflections. Shallow structures are also clearly shown including sea floor and topographic relief of the base surface of sedimentary basin without lack of imaging area.

(2) Numerical simulation of earthquake observation

We tested reflection imaging with the modified RTM method by using numerical simulation data of both on-land and ocean-bottom earthquake observation. There is a big difference on a boundary condition (i.e. presence of a water layer above receivers) between the ocean-bottom and on-land observation. Multiple reflections due to the water layer is significant in the ocean-bottom observation. We confirmed that reflection imaging is possible from passive observations both of the on-land and ocean-bottom seismometers with the modified RTM method. The multiple reflections are helpful to illuminate subsurface reflectors more effectively in the ocean-bottom observation in case of spars receiver deployment.

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