Crustal structure analysis by reverse time reflection imaging and automated waveform feature tracking

*Kazuya Shiraishi[1], Takao Nibe[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. JGI, Inc.

For reflection imaging of crustal structures from marine seismic survey with ocean-bottom seismographs (OBS), combination use of surface-related multiple reflections with primary reflections is effective way to obtain continuous image from shallow to deep. The surface-related multiple reflections can illuminate wide area where the primary reflections cannot image due to the spars deployment. Additionally, reverse time migration (RTM) is an effective method for resolving complex geological structures. On the other hand, structural interpretation of such reflection images is highly dependent on the image quality and the complexity of the geological structures. To reduce subjectivity and uncertainty of interpretation, we adopted an automated event tracking method based on waveform features.

In applying the RTM to OBS wide-angle seismic data, an effective method is a combination of two imaging approaches: a general shot-based RTM for the primary reflections, and a seismic interferometric RTM for the multiple reflections. The reflected waves are focused on subsurface imaging points by a temporal integration of the product between forward-extrapolated wavefields from source and backward-extrapolated wavefields of the recorded seismic data from receiver points. In the seismic interferometric RTM, the both wavefield extrapolation are performed from all air gun locations, and the surface-reflected multiple reflections are focused on the subsurface reflectors as pseudo-primary reflections.

Seismic skeletonization (e.g. Vasudevan et al 2006) is a useful technique to extract structural features on geophysical data. The reflection events can be tracked based waveform features, such as amplitude and duration, among neighboring traces with a pre-defined waveform. The extracted reflectors can be quantitatively evaluated with event attributes: coordinate, amplitude, dips, and spatial continuity. In addition to reflection images, the objectively tracked information is useful for interpretation of the geological structure, especially the complex structures in crustal-scale imaging.

We apply the RTM imaging and the automated waveform tracking to OBS wide-angle seismic data in the Nankai Trough. The combination of the primary and multiple reflections provides a merged RTM image without imaging gap in the shallow part, and the reflection image shows regional seismic evidence of the relationship between the subducting plate and the accretionary wedge and of the deformation structures in the inner accretionary sediments. The shape of the Kumano forearc basin is clearly imaged, and the deep reflections such as the subducting oceanic crust and the plate boundary décollement are readily visible. A trenchward dipping reflector, which may be a boundary between the old and young accreted sedimentary layers, is imaged as terminated at the landward subducting plate boundary décollement. Around the termination point, clear horizontal reflector with slight deformation is imaged and the plate boundary décollement seems to be stepping down. The relationship of the three reflectors might imply the reflection evidence of underplating of subducting sediments stripped by the old accreted sediments. Additionally, the automated waveform tracking provides not only long connectivity for the clear reflection events but also short connectivity for subtle reflection events. The extracted short connectivity events within the accretionary sediments could be meaningful for structure interpretation, in other words, the disconnectivity imply the distribution of multiple faults within the inner accretionary sediments.

Keywords: crustal structure analysis, reflection imaging, reverse time migration, automated waveform feature tracking

