Interferometric imaging from borehole seismic data with long-term observatory system and vertical seismometer array

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We applied interferometric seismic imaging with multiple reflections to borehole seismic survey data with airgun shooting. In the conventional primary reflection imaging such as a vertical seismic profile (VSP), we obtain the reflection image around boreholes in a deeper section than receiver locations, but do not obtain the reflection image in wide range including shallower part than receivers. In addition, boreholes are sparsely distributed. The multiple reflections are generally noise in the primary reflection imaging, but they contain much information in both the deeper part and the shallower part. One effective method to utilize them to obtain subsurface image is seismic interferometry. It is a technique to redatum the multiple reflections to all airgun shooting points them as pseudo-primary reflections by means of cross-correlation for each borehole seismic survey data. Then continuous subsurface image can be obtained along airgun shooting lines.
In this study, we use the borehole seismic data in Nankai Trough. One dataset is a walkaway VSP data acquired in 2009 at IODP C0009 site. The vertical seismometer array was temporally deployed by D/V Chikyu using a downhole wireline tool at 16 levels in the borehole, and a tuned airgun array of R/V Kairei was fired along 54 km shooting line. Other datasets were acquired in airgun surveys with the long-term borehole observatory systems installed at IODP C0002 site and at C0010 site. The airgun surveys were repeatedly conducted with tuned airgun array on R/V Kairei in 2013, 2015, and 2016, In this study, we used the dataset in 2016 along a 128-km-long shooting line, NS1. This line is almost crossing three holes: C0009, C0002, and C0010, and it is very close to the shooting line of the walkaway VSP survey at C0009. The distances from C0009 to C0002 and from C0002 to C0010 are about 20 km and 11 km, respectively. In this study, final reflection image was obtained after merging the post-stack migration sections from each borehole dataset. We achieved to obtain the continuous reflection image along the survey line in the shallow part, including the structures in Kumano forearc basin and faults in frontal thrust zone. Integration of the multiple reflection imaging with the primary reflection imaging will be useful to obtain the whole subsurface image from the shallow to the deep. The spatial resolution and artifacts due to the data sparseness should be investigated for further practical applications. Our result shows an important possibility of the reflection imaging from the sparse borehole seismic data for future monitoring surveys, for example, we might be able to image the location of timelapse change on the subsurface section with the long-term observatory system.

Keywords: borehole seismic survey, long-term borehole observatory system, vertical seismometer array, seismic interfetometry

