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Advanced use of refraction tomography using long-spread reflection seismic data for exploring deep crustal structure

Kazuya Shiraishi[1*], Susumu Abe[1], Hiroshi Sato[2], Takaya Iwasaki[2]

[1]JGI, Inc., [2]Eathquake Research Institute, the University of Tokyo

(1) Recent advances for reflection and refraction survey

We introduce recent advances of data acquisition and processing in the reflection seismic survey. Today's reflection survey exploring deep crustal structures use the long-spread survey line with dense receiver deployment by combining the stand-alone recording systems and the wired telemetry type recording systems. In addition, different kinds of seismic source are used in a survey such as vibrators with high mobility and dynamite explosion on land, and an airgun system in marine. These innovations enabled us to improve the efficiency of simultaneous acquisition of the reflection seismic data and the refraction seismic data. In data processing, there are some remarkable technologies to profile the deep structures with the long-spread seismic data. The deep reflections appeared in a long-offset range are effectively used on the reflection imaging. The advanced refraction tomography are carried out to estimate velocity structures with highly dense traveltime data using both the reflection survey data and refraction survey data. These advances have achieved to reveal the basin structures in a lot of areas in Japan.

(2) Standard specification of data acquisition aiming deep crustal structure

The standard specifications in the simultaneous reflection and refraction survey for deep seismic profiling are briefly reviewed. The thousands of receivers are deployed along a 50 km or longer survey line with 50 m geophone spacing on land and 25 m spacing of receivers on an ocean bottom cable in marine. For the reflection survey, four vibrators are used to generate sweep signal with from 150 to 250 m intervals on land, and the airguns are used with 25 m or 50 m intervals. For the refraction survey, we need high energy seismic source in order to record the high S/N data on the whole line. Three kinds of sources are used with about 5 km shot intervals, the dynamaites with 100 kg or more charge and vibrators with hundreds sweeping on land, and the airgun with 30 or more stacks in marine.

(3) Refraction tomography with dense traveltime data

The velocity distribution in the ground is estimated by the refraction tomography using the traveltime information of first arrival waves, which are picked manually on both the reflection and the refraction data. By updating the velocity model iteratively to minimize the traveltime difference between the observed and the calculated for each source-receiver pair, the reasonable velocity distribution is estimated.

(4) Uncertainty analysis by a initial model randomization

We adopt the Monte Carlo uncertainty analysis by initial model randomization to evaluate the tomography result, because the refraction tomography has a high non-linearity and the solution also has high dependence on initial model selection,. We assumed that the effect on the uncertainty by selection of the initial models is bigger than the effect by pick error of the traveltimes on both the dense reflection data and the high S/N refraction data. By averaging the tomographic results from hundreds of initial models, we obtain statistically optimum solution with the averaged velocity model and the uncertainty distribution by the standard deviation.

(5) Final model update by cascade tomography

The cascade tomography is a practical solution to retrieve fine velocity perturbation around velocity boundaries which are smoothed by averaging the hundreds of tomograms. The averaged model after uncertainty analysis is used as the best initial model for the final tomography, and the velocity model is update slightly in a few iterations. The parts of fine-scale update in the cascade process are well correspondent to the parts of high standard deviation in the uncertainty analysis.

Keywords: reflection seismic, refraction tomography, Mote Carlo uncertainty analysis, cascade tomography