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地下深部の地震学的タイムラプスイメジング
Seismic time-lapse imaging of subsurface

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1. Introduction

The imaging of the Earth has been carried out by the passive method using natural earthquakes. When we use natural earthquakes, it is difficult to select source positions and ray paths. Although seismic interferometry technique acts as virtual sources, it seems difficult due to less excitation on refracted and reflected waves. The control sources are complementary to the natural earthquakes.

The benefit to use control sources is that we can get detailed information on the source signatures. Knowing the precise source signature, we can estimate the temporal changes of transfer functions between source and receiver.

To determine the location causing temporal change it is necessary to know the 3D seismic structure in details. Once we identify the ray path and travel time of the seismic wave concerning the target area, continuous monitoring using only a few receivers might be possible. To monitor the wider area and know the spatial distribution of changing zone, the time-lapse imaging is demanded.

2. Time-lapse Imaging

If numbers of sources and receivers are not so dense, the resolution of subsurface imaging will be limited. To enhance the resolution we can increase number of sources or receivers. In the field of the most recent seismic exploration surveys the number of receivers reaches to 10,000 with receiver spacing of 25-50 m. We might be possible to increase the density of receivers.

In the time lapse study of the subsurface, it is likely to exploit the temporal changes of waveforms. By use of residual waveforms and the reciprocal relation between source and receiver, we can do back-propagation of the residual waveforms from the receivers to focus to the location of temporal change.

3. Effects of near surface, weather conditions and rain falls

Through our knowledge of the seismic time lapse studies, the travel time changes of first arrivals are not large compared to the coda parts. One of the reasons for this is that we tend to observe the fastest arrivals and it is difficult to identify arrivals through a slower region. By use of the waveform residuals we might reduce this effect.

The temporal change in near surface layer strongly affects to observed waveforms. Without the consideration of near surface effects the results might lead to wrong answer. We will show some examples obtained in Awaji Island and a quarry field. Rainfalls and change of moisture contents due to weather conditions could be the most significant. The experimental observation of the time lapse in a quarry filed showed changes the residual waveforms day by day. The frozen of ground soil changes the waveforms during a day. We think that in the volcanic area the moisture contents in lava might strongly affect to the estimation of volcanic activity.

The effects of ground coupling of source can be eliminated by use of heavy concrete basement as in the installation of ACROSS sources.

The heterogeneity and anisotropy of the near surface layer might also affect to the paths of seismic waves and electromagnetic waves. This has to be considered.

4. Discussion and conclusions

Use of active source for the structural imaging could improve the resolution of blind parts of Earth's interior and possibly provide the time-lapse image. However, there are important factors that we should consider. The 3D structure is needed to evaluate the correct location of the temporal change. The backpropagation of residual waveforms from dense receivers gives better image of temporal changes if we properly evaluate the effects of near surface, heterogeneity and anisotropy. One of the ways to minimize the effects of near surface and weather condition on the time lapse is to place source(s) and receiver(s) in the ground.

The EM time lapse has similarity as the seismic one.

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