Refraction study using ACROSS seismic source to interpret the time-lapse data in Al Wasse field, Saudi Arabia

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Introduction

To understand the physical change of subsurface by injection of CO2 or vapor into the ground, we are proposing the time-lapse method using the very stable ACROSS (Accurately and Routinely Operated Signal System) seismic source and an array of seismometers for our studies.

In 2011, we carried out the time lapse study in Awaji Island by the injection of air into the ground and showed the clear migration of air just after the air injection (Kasahara *et al.*, 2013). In 2012, we moved the whole system to the water pumping site in Al Wasse, Saudi Arabia. In the test site, there are no seismic structural surveys in past. By our study in this field, we observed very rapid and large temporal changes during several months (Kasahara *et al*., 2015). No structural data and sparse seismic stations in 500 m grids make difficult to explain the cause of temporal change seen in observed data. To solve this problem, we carried out refraction and reflection studies. In this paper, we report the first part.

Survey and processing:

Water is pumped up by more than 64 wells from aquifers at ~400m depth. The geological information is very poor. The surface of ground is partly covered by loose-sand and limestone pebbles.

The total length of survey line was 3 km. We used the ACROSS as the seismic source and placed 60 data loggers on the surface with 50 m spacing. The each sweep was 10 to 40 Hz during 200 seconds and an hour data contain 16 sweeps. The direction of rotation of ACROSS was switched every hour. One day data were recorded by data loggers with 200 Hz sampling and 24 bit A/D.

Recorded data were processed by similar way to the previous one (*e.g.*, Kasahara *et al*., 2013 and 2015). We compared observed and synthetic waveforms. The synthetic waveform was calculated by FDM. We used vertical single force with 20Hz Ricker wavelet as the source.

Results

The records show that the first arrival has approximately 3.5km/s and tend to disappear around 700 m in offset distance. Later phases of 3.5km/s phase show weak amplitudes, but they disappear for further distance than 1.7km. The strong later arrivals with 4.5 km/s appear and become dominant at further than 1.5km/s.

The comparison of observed and synthetics suggests the presence of low velocity layer just about of 3.5km/s layer. The 4.5km/s phase seems the refracted phase from the deeper basement layer with velocity of 4.5-5km/s. The layer between 3.5km/s and 4.5km/s is thought to be inter-bedding of sand stone and limestone with velocity lower than 2.5km/s. The negative gradient of inter-bedding layer could explain the decay of amplitudes of 3.5km/s phase with distance.

Discussion and conclusions

The observed data show very weak first arrivals even if the offset distance of 1km. As shown in our results in Kasahara *et al.* (2015), the temporal change of the first arrivals is as much as 1-1.5ms during two months at the largest case. On the other hand, the most of large amplitude later phase show slower arrivals and seems Rayleigh waves in the present study. The rapid change of waveforms with time suggests the rapid migration of water in aquifers due to the pumping. The continuous monitoring stations are located at the grids of 500m distance and it is still difficult to explain the magnitude of migration. The refracted arrivals from 4.5km/s layer is only identified a few grid stations and it is also difficult to find this phase.

Acknowledgements
This survey was supported by JCCP (Japan Cooperative Center for Petroleum) in Japan and KACST (King Abdulaziz City for Science and Technology) in Saudi Arabia. We express our great thanks to members of JCCP and KACST for their aggressive support of this project. We also express our great thanks to staffs in KACST for the hard works during the survey.

Keywords: Time-lapse, ACROSS, crustal structure, shadow zone, aquifer, water pumping

