Time-lapse observation and its interpretation in Al Wasse field in Saudi Arabia using ultra-stable seismic source

*Junzo Kasahara[1,2,4], Khaled Al Damegh[3], Ghunaim Al-Anezi[3], Kei Murase[4], Aya Kamimura[4], Osamu Fujimoto[4], Hiroshi Ohnuma[4], Yoko Hasada[5]

1.University of Shizuoka, Faculty of Earth Scieces, 2.Tokyo University of Marine Science and Technology, 3.KACST, 4.Kawasaki Geological Engineering Co. Ltd., 5.Daiwa Exploration and Consulting Co. Ltd.

1. Introduction

The Carbon Capture and Storage (CCS) is one of ways to reduce the CO2 radiation to the air. In CCS, CO2 is injected to the subsurface and is stored in the subsurface. Technologies of monitoring (time-lapse) of CO2 leakage from the storage zone have been studied in many institutions. We have used the ACROSS seismic source for the time-lapse and have tested the technology in Al Wasee field, Saudi Arabia after the air injection study in Japan (Kasahara *et al*., 2013). The same technology can be used in EOR (Enhanced Oil Recovery) and PRM (Permanent Reservoir Monitoring) cases.

2. Time-lapse observation in Saudi Arabia and data processing

The test site is a national water pumping field. Water is pumped up from aquifers around 400 m depth. The geology of this area comprises limestone, sandstone and unconsolidated sand. There is no seismic survey in this area before our study.

We used the ACROSS unit as an ultra-stable seismic source and 32 seismographs at 500 m spacing grids with distances between 500 m to 1.76 km. The source transmitted chirp signal from 10 to 40 Hz and the seismic waves were recorded by data-loggers. Because of so frequent power downs during the observation, the obtained data were intermittent. The transfer functions between the source and receivers were obtained by division of observed records by source signatures in spectral domain by the similar way as before (*e.g.*, Kasahara *et al*., 2013, 2015). By processing, we obtained the transfer functions corresponding to vertical and horizontal forces. As the interpretation of one-day stacked data, we used the refraction survey in 2015 (Kasahara *et al*., 2016; in this session).

3. Results

We obtained the transfer functions from April to December, 2015 for 30 stations, but the data are not continuous for whole period due to frequent power downs. The first arrivals disappear at the distance further than 1 km and large amplitude phase is dominant at the stations further than 1.5 km. The temporal variation in the arrivals later than 1.0 seconds is extremely large as same as that in April to June, 2015 (Kasahara *et al*, 2015). The first arrivals closer than 1 km do not give large temporal changes, which is similar to the previous results in April to June 2015

Using the refraction data obtained in 2015 we interpreted the phases. The first arrivals at the distance less than 1 km are refracted wave with 3.5 km/s travelling the upper limestone layer. The phase with large amplitude at the distance further than 1 km is estimated as refracted wave with 4.5 km/s travelling in the basement. This phase shows some temporal variation. The Raleigh wave could have large amplitude and this is dominated after refracted waves. The temporal changes in surface waves do not show coherent characteristics from one to another.

4. Discussion and conclusions

The presence of low velocity zone just below the 3.5 km/s layer makes difficult to interpret the temporal change. The first arrivals quickly decay at the distance further than 1 km by the low-velocity layer. At the distance further than 1 km, large amplitude phase refracted at the layer deeper than 800 m is dominant. The upper limestone layer does not show large temporal changes and the refracted arrivals show some temporal changes due to the migration of aquifer. The surface waves seem travel in the low velocity layer, and the temporal change of surface wave is so large and shows roughly week period. This may be caused by pumping of water from aquifer.

Acknowledgements

This survey was supported by JCCP (Japan Cooperative Center for Petroleum) in Japan and KACST in Saudi Arabia. We express our great thanks to members of JCCP and KACST for their aggressive support of this project.

Keywords: Time-lapse, ACROSS, shadow zone, refracted wave, low-velocity layer, aquifer

