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Processing and interpretation of shallow-water seismic data for CO_2 injection

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SUMMARY

2-D seismic data were acquired in Yeong-il Bay of Korea in search of proper prospects for CO_2 injection into an offshore basin. The unfavourable situation for operation and very shallow water prevented the operator from obtaining quality data. Small number of channels and short offsets incapacitated velocity analysis and migration. Main efforts have been thrown into finding out the best processes to attenuate linear noises and strong short-period multiples raised from the shallow water that masked the whole data. The processing methods ascertained to be useful for this purpose are DENOISE, DWD (deterministic water-layer demultiple), and τ-p deconvolution, which were applied by using Omega 2 processing system. The resultant images are successfully free from the strong noise and revealed the geological structures obscured by the noise.

The processed data were geologically interpreted to identify the prospective formations in the basin so as to inject carbon dioxide into them.

Key words: shallow-water seismic data, CO_2 injection

INTRODUCTION

KNOC (Korea National Oil Corporation) is participating in a CCS (Carbon Capture & Storage) project that injects CO_2 into an offshore basin in a pilot scale. A 2-D seismic survey was conducted to obtain subsurface image so that the prospective formations can be located. The target formation is saline aquifer in the depth of 800-1000 m below seabed, which can store the carbon dioxide in super-critical state. Since the survey area lies within an embayment, in which a lot of steady shipping is taken place at a port in the bay, the operator was unable to deploy sufficient amount of equipment in that confined site. Table 1 shows the main acquisition parameters used for the survey. Normally sufficient number of channels and long offsets are required in order to get quality data. This survey, however, could not help using a short streamer (75 m) with 24 channels due to the limited area of operation. A total of 62 L-km data were acquired along 14 lines (Figure 1). The water depth in the bay is very shallow and varies from approximately 15 to 20 m along the lines. As a result of deficient deployment of streamer and very shallow sea bottom as well as a number of vessels plying through the bay, the data are attended with very low signal-to-noise ratio.

Source type	Bolt air-gun
Shot point interval	6.25 m
Streamer length	75 m
Number of channels	24
Group interval	3.125 m
Near offset	25 m
Far offset	96.875 m
Record length	2 s
Sample rate	0.25 ms

Table 1. Main parameters of 2-D seismic survey in confined area of shallow water environment.

One of the main objectives of this study is to investigate proper processing techniques and flow that can be useful with small offsets and channels so as to attenuate the strong noise introduced by shallow water and eventually to enhance the signal-to-noise ratio of the data. There are some studies (e.g. Rana *et al.*, 2012) that processed the data of very shallow water but with long streamers and plenty of channels. Processing the seismic data of poor quality with restricted choice of methods was highly challenging. Six lines were selected to be processed and interpreted in order to identify formations that are feasible to inject CO_2 into the basin.

DATA PROCESSING

Multiples due to shallow water and other strong coherent noises are observed in the acquired data. The short period multiples in particular pose significant problems to the interpretation of geological structures as they appear at similar locations in time and space with many different orders. However, the conventional multiple attenuation methods such as SRME (surface-related multiple elimination) and Radon filtering could not handle the multiples in this data properly. SRME requires the recorded data to be extrapolated to zero offset, but in the shallow water situation the extrapolation becomes inaccurate and the predicted multiples are degraded when the ratio of the water depth to the recorded minimum offset is small (Moore and Bisley, 2006). In addition, the primary water bottom reflection, which is required by SRME, is indistinct in the data to make SRME have difficulties in attenuating the shallow-water multiples (Verschuur, 2006).

The limited number of channels used for the survey allowed very small coverage of folds (nominally 6). Velocity analysis

and migration became ineffective by lack of the CMP fold as well as short offsets. Under the condition that many of the conventional processing methods are not useful, we tried to find out the most adaptive methods to remove noises and reveal the obscured structures underneath. The methods that were eventually ascertained to be most effective among the processes applied are DENOISE, DWD (deterministic water-layer demultiple), and *τ-p* deconvolution. DENOISE is a module of Omega 2 processing system that attenuates interference noise and random noise. DENOISE uses the randomness of marine interference noise in the common-receiver domain and applies *f-x* prediction error filter to remove it (Gulunay and Pattberg, 2001a, b). The strong linear noise contaminating the data in the area ranging from 0.3 to 0.7 s and in deeper area is removed clearly. DWD is an algorithm for the prediction of both simple and peg-leg water-layer multiples, and subtracts the predicted multiples using an adaptive subtraction (Moore and Bisley, 2006). The result of DWD presents significant suppression of multiple energies. Deconvolution in *τ-p* domain has worked out the problems of multiples for a long time notwithstanding its limitations. For this data, deconvolution showed dramatic improvement of image quality by diminishing the remnant short-period multiples and reverberation. Figure 2 demonstrates the example results of DENOISE, DWD, and *τ-p* deconvolution.

DATA INTERPRETATION

Through the structural interpretation of the processed seismic sections, 6 horizons and 5 main sedimentary units were identified as a result (Figure 3). As there is no well drilled in Yeong-il Bay, vertical velocity function for the seismic data is not available. Therefore a velocity profile yielded from onshore wells that penetrate the same basin near the bay was used to convert the acoustic basement from time domain to depth domain, which is estimated to be ca. 1200 m below seafloor. The lowest Unit 1 that has poor continuity and chaotic characteristic tends to downlap to lower boundary. The Unit 2 gets thinner going from north-west toward south-east, and has strong reflection with distinct boundary defined by faults. The Unit 3, characterized by uniform thickness, has bright reflection with partial discontinuities and onlaps to upper boundary. The Unit 4 has very good continuity and has been exerted under less influence of fold than the Units 1, 2, and 3. The Unit 5 downlaps to lower boundary and characterized by strong reflection clearly bounded by faults. It is noticed from the isopach map (Figure 4) that the thickness of prospective anticline formation tends to be thicker in the areas of north-west and south-west, where the seismic data are not available.

CONCLUSIONS

In the situation that conventional multiple attenuation methods are not useful, and velocity analysis and migration are ineffective for the shallow water seismic data acquired with limited channels and offsets, it is revealed that a combination of DWD and *τ-p* deconvolution is very effective to enhance the signal-to-noise ratio by suppressing strong short-period multiples and reverberations. According to the interpretation of the data, the Unit 1 and acoustic basement that can preserve the carbon dioxide in super-critical state are considered to be feasible for geological storage of CO_2.

ACKNOWLEDGMENTS

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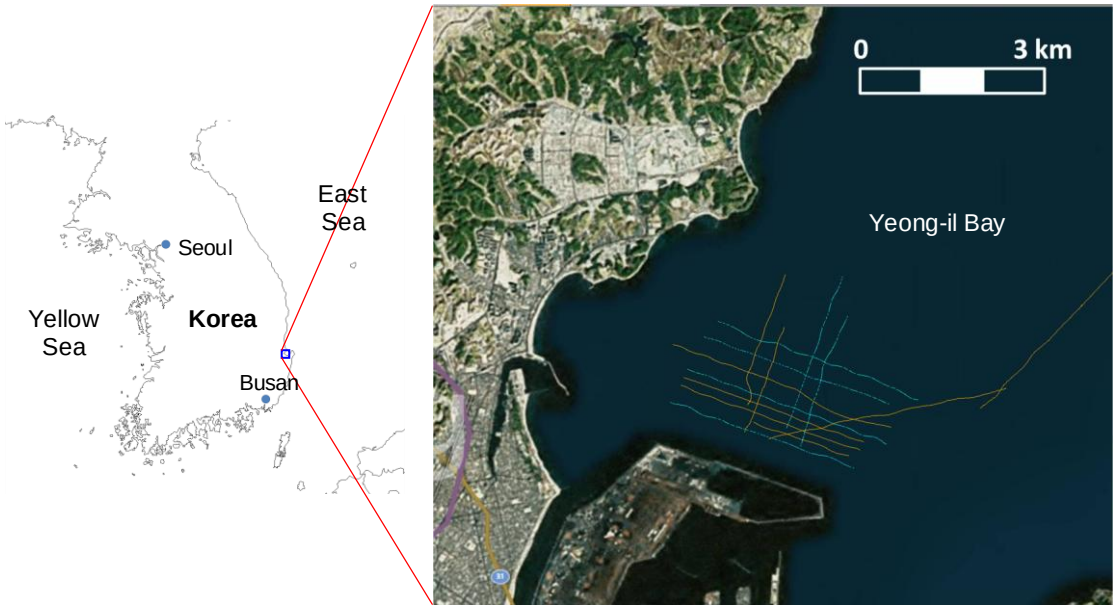

Figure 1. Base map of the seismic survey located in Yeong-il Bay in the east coast of Korea. The 6 lines selected to be processed and interpreted are indicated as blue.

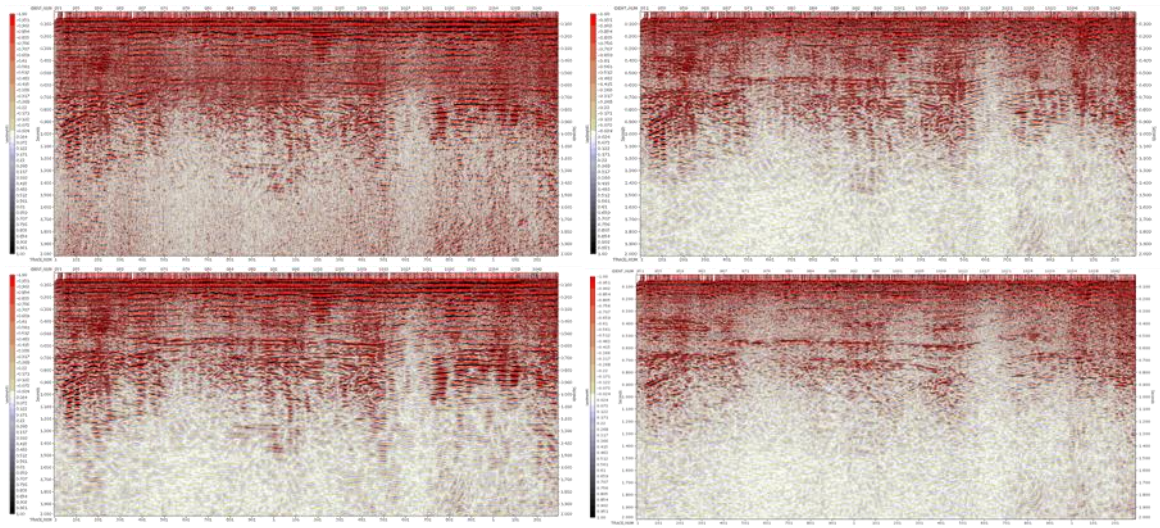

Figure 2. Stacks of input data (top left), DENOISE result (bottom left), DWD result (top right), and deconvolution result (bottom right) for line 11.

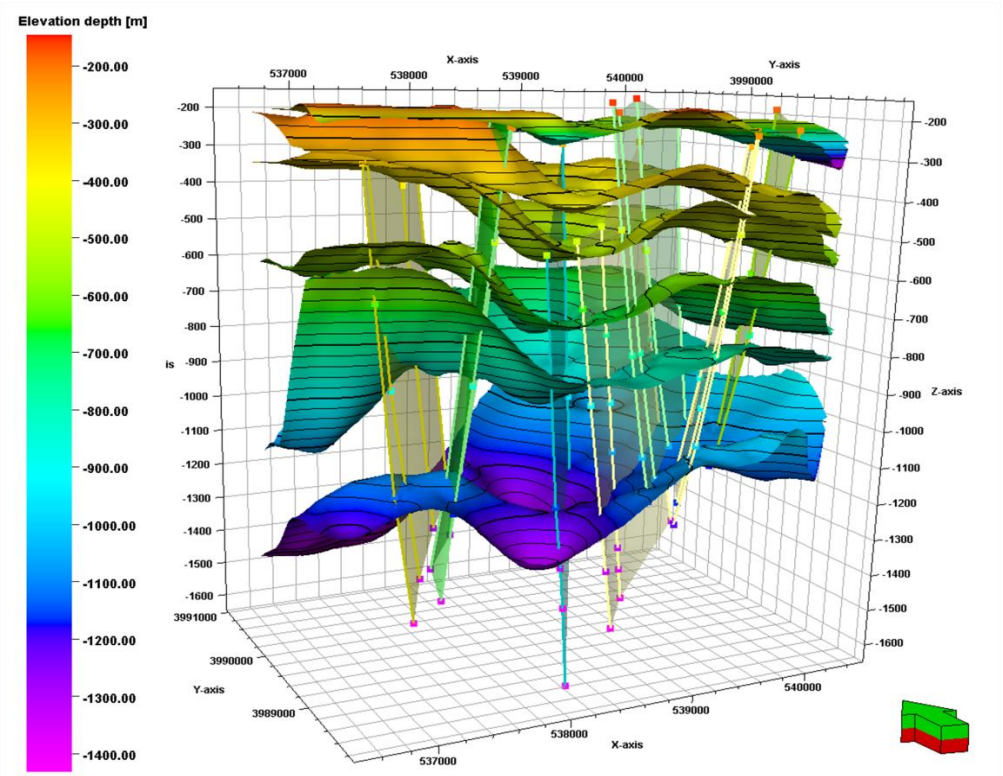

Figure 3. The interpreted 6 horizons and 5 sedimentary units displayed in 3-D. The acoustic basement is located at the base and the 5 units are named upward from the basement in ascending sequence (i.e. Unit 1 on top of acoustic basement, Unit 2 above Unit 1, etc.). Note that the strike of fault planes orients northward.

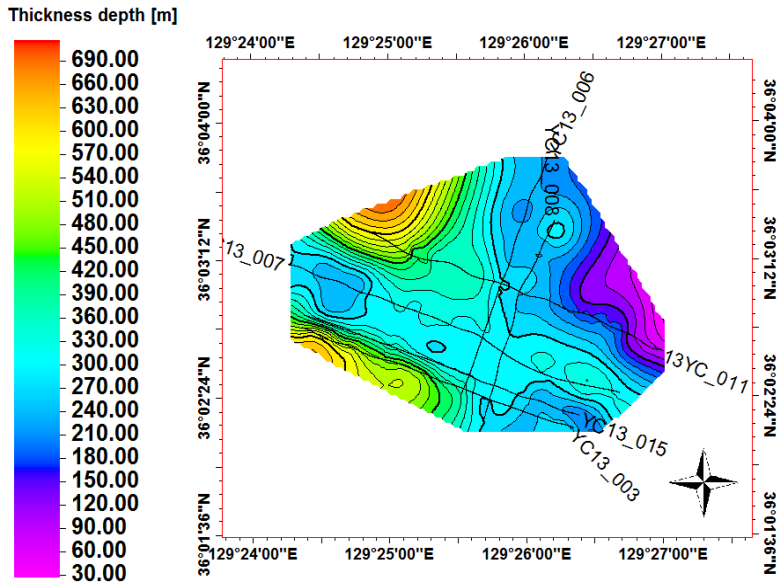

Figure 4. An isopach map indicating the thickness of Unit 1.