CSEM data analysis for Sleipner CO_2 storage

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Abstract

We present early-stage results of an on-going study where we interpret a set of controlled-source electromagnetic (CSEM) data collected above the Utsira formation at Sleipner in 2008. The aim is to provide a background resistivity model for future time-lapse survey and monitoring. The CO_2 storage reservoir at Sleipner is placed within the Utsira formation and is close to the Sleipner production platform where many pipelines are located on the seabed. In total 9 seabed pipelines are crossing the current CSEM survey line. This is making the CSEM data interpretation challenging.

From existing seismic data and literature we have reviewed the geological features of the Sleipner/Utsira site that are related to and useful for the CSEM data interpretation. A key feature is the evidence that the CO_2 storage reservoir at the Sleipner/Utsira site can be modelled as a medium with high-anisotropy resistivity. The anisotropy is caused by the alternating layering structure of thin layers of CO_2 gas underlying thin beds of mudstone. We have investigated the potential anisotropic resistivity through a synthetic data study, and we have learned that the anisotropy can be an important inversion parameter for the Sleipner CSEM data.

For the data inversion, we have performed to date simple 1D and pseudo 2D inversion, where we have not included the seabed pipelines in the forward modeling during inversion. In 2011, we will continue the current study and perform full 3D inversion where we will include the effect of the seabed pipelines during the inversion. The main objective of the simple 1D and pseudo 2D inversion was to provide a good initial resistivity model for the future full 3D inversion. From the pseudo 2D inversion, however, we can see already high-anisotropy resistivity anomaly which seems to be due to the alternating thin layers of CO_2 gas/mudstone. The result will be refined through full 3D inversion in 2011.

Figure 1 shows a pseudo 2D inversion result together with the measured CSEM data by means of so-called 2D attribute (or pseudo 2D section) plot. The 2D attribute plot herein is constructed in the following steps: (1) deciding a reference field; (2) obtaining the normalized amplitude-versus-offset (AVO) curves for all the receivers; (3) plotting all the normalized AVO curves at once in a 2D space in which the horizontal and vertical axes are the common-mid-point and the offset, respectively. The first 2D attribute plot in Figure 1 is for the measured data; the second and third ones are for the full 3D synthetic data that are created by importing pseudo 2D inversion result into a 3D forward modelling with seabed pipes and without seabed pipes. Plot (b) looks closer to Plot (a) than Plot (c) does, which shows that the effect of the seabed pipes is significant. However, the difference between Plots (a) and (b) is still large. Therefore, the

inversion study should be continued to include full 3D inversion (i.e. modelling seabed pipelines during inversion) and improve the 3D EM resistivity background model for the CO_2 plume at the Utsira formation.

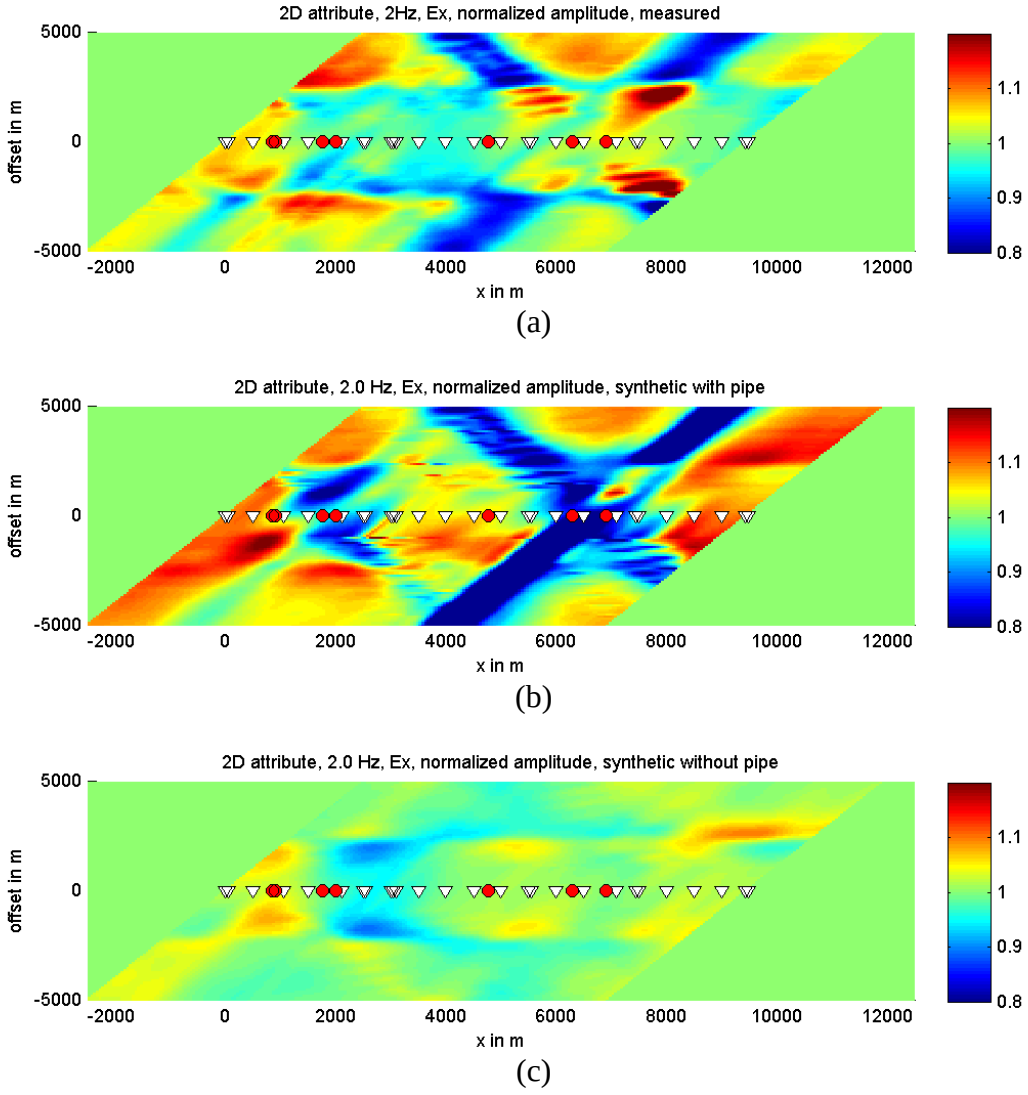

Figure 1. 2D attribute plots: (a) measured data; (b) synthetic data with simulating seabed pipes; (c) synthetic data without simulating seabed pipes