WS11_05

On the Challenges of Time-Lapse EM in a Production Environment: Lessons Learned From a Real-World Trial

R. Streich[1]*, A. Schaller[2], G. Drijkoningen[3], L. Liu[4]

[1] Shell Global Solutions International BV; [2] formerly Delft University of Technology; [3] Delft University of Technology; [4] Shell International Exploration and Production Inc

Summary

We will present results from a field trial of onshore time-lapse EM in a production environment, with special focus on the influence of well casings and pipelines on the acquired data, and lessons learned for future application of 4D EM.

Abstract

Time-lapse CSEM has been assessed in various synthetic studies, but the number of field applications to date is limited. Areas of interest for time-lapse studies often are production environments, where the presence of metallic well casings and pipelines complicates the acquisition and interpretation of EM data. At the same time, resolution requirements are higher than for reservoir detection, while time-lapse responses must be expected to be small, since 4D targets are small, can be strongly compartmentalized, and typically exhibit lower contrasts with their surroundings than exploration targets. This poses strong challenges to any time-lapse EM work, and leads most feasibility studies to make overly optimistic assumptions on target response strength, or deployable survey geometry, or noise levels, or a combination thereof.

To ground-truth the feasibility, or otherwise, of time-lapse EM by real data, and understand requirements for carrying out time-lapse measurements, we acquired time-lapse data in a producing oil field in the Netherlands. Three data sets were acquired at intervals of roughly one year. A novel geometry of vertically oriented electric field receivers deployed in shallow boreholes was tested in addition to more standard surface-based acquisition (Fig. 1).

Data analysis revealed a number of issues that were more severe than initially anticipated. Noise originating from production facilities and nearby industrial plants reduced the usable offset range significantly compared to initial predictions. Well casings and pipelines were observed to influence the data strongly. Observed electric field data and modeling of the metal infrastructure provide evidence that most severe impact came from a pipeline intersecting the survey area. The vertical receivers, as expected, picked up less noise than the horizontal ones, but still suffered from low S/N ratio due to low signal amplitudes (see also Streich, 2015). Although repositioning errors could be excluded, since electrodes were left in place between surveys, repeatability was less good than for the horizontal electric field. Electrode decay rates were higher than anticipated. Despite considering the exact, slightly tilted orientation of those receivers, their data could not be fitted as well as those of the horizontal receivers. In images derived from the data, the target reservoir could be seen clearly (Fig. 2), but time-lapse changes in the subsurface could not be interpreted confidently.

The experiment provided valuable insights for carrying out 4D surveys. Not surprisingly, it proved crucial to exactly repeat every part of the survey, including the positions of each receiver electrode as well as source layout and waveform. Even if the target volume is fairly small and known a priori, sufficient data coverage is important for localizing target features. For vertical electric field measurements, extra attention needs to be paid to instrument quality and setup verticality to be able to benefit from the theoretical advantage of increased target sensitivity. In addition, considering metal infrastructure in data interpretation is especially important for vertical receivers. To meet resolution requirements for reservoir surveillance, deployment of instruments closer to the target volume needs to be considered. In this context, the potential utility of existing well casings should be studied further.

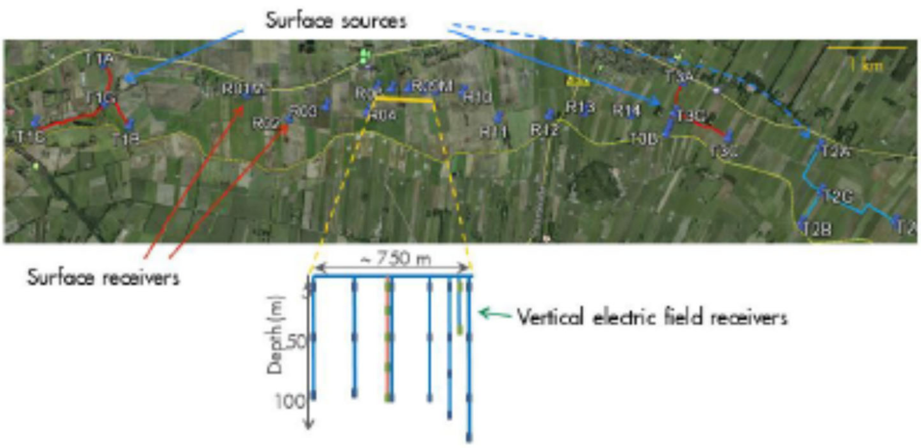

Figure 1 *Layout of trial time-lapse survey. Yellow line is Dutch-erman border. Red and blue lines indicate layout of transmitter cables.*

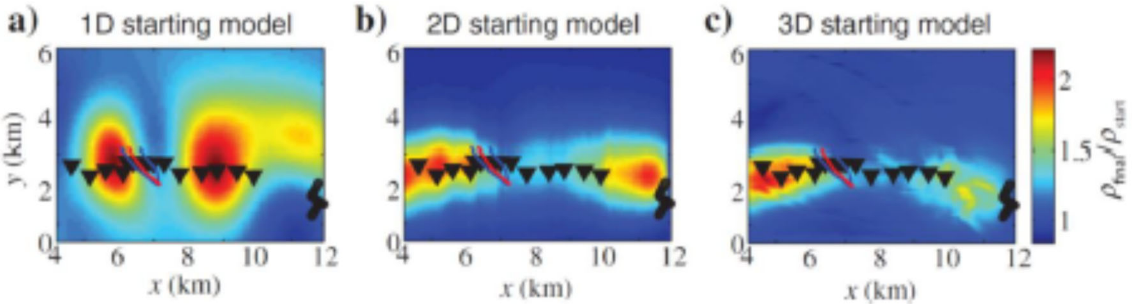

Figure 2 *Resistivity distribution inside reservoir zone obtained from different starting models, shown in terms of resistivity update done by inversion from constant resistivity at the depth level at which values are extracted (Schaller et al., 2018). Triangles indicate surface receivers. Red and blue lines indicate trajectories of a steam injection and two production wells, respectively.*

References

Schaller, A., Streich, R., Drijkoningen, G., Ritter, O., Slob, E., 2018, A land-based CSEM method for oil field exploration: An example from the Schoonebeek oil field, Geophysics 83(2), WB1 – WB17

Streich, R., 2015, Controlled-source electromagnetic approaches for hydrocarbon exploration and monitoring on land, Surveys in Geophysics, doi 10.1007/s10712-015-9336-0