Rock physics driven integration of seismic and controlled source electromagnetic data.

Lucy MacGregor, Amanda Alvarez, Pedro Alvarez, Francisco Bolivar, Rob Keirstead & Thomas Martin
Rock Solid Images.

The goal of a geophysical analysis is to constrain sub-surface structure and properties. However, many geophysical methods, when taken by themselves, fail to unambiguously address the questions that the interpreter may have. For example, seismic data can be inverted to provide estimates of porosity, lithology or other attributes, however may struggle to constrain fluid content or properties within sub-surface structures. The controlled source electromagnetic (CSEM) method provides a measure of sub-surface resistivity which can be linked to fluid properties, however structural resolution is limited. By integrating these methods, using a carefully calibrated rock physics framework, the ambiguities inherent in each when taken alone can be resolved.

Although integrated interpretation brings many benefits, there are a number of challenges to be overcome before such approaches can be robustly and routinely applied. Firstly, measurements made using very different physical processes must be combined and linked to the underlying rock and fluid properties in a consistent fashion. Secondly seismic and CSEM techniques sample the earth at very different scale. These different scales must be reconciled in an integrated interpretation or joint inversion approach. Finally, in order for an integrated interpretation approach to be successful, both seismic and CSEM methods must be sensitive to the interval of interest and changes in properties within it. Addressing these challenges requires a rock physics framework to be either numerically derived or empirically calibrated at well locations

The integration process itself can take many forms. The simplest qualitative techniques, such as co-rendering, are applicable everywhere and provide a first-look approach to data combination. However, they can be misleading since they fail to address the underlying cause of variations observed. Full quantitative joint inversion of seismic and CSEM data is in principle possible (for example Chen & Hoverston, 2012), but is complex and applicable in a narrower range of circumstances. An intermediate approach which seeks to integrate elastic and electric attributes derived from inversion of seismic and CSEM data respectively provides in many circumstances an effective way of addressing the challenges of data integration.

An example from the Hoop area of the Barents Sea is used to illustrate these ideas. A dataset consisting of nine lines of 2D GeoStreamer seismic and Towed Streamer EM data were acquired concurrently in 2015 by PGS. Two wells in the area provide calibration for the integrated analysis. Oil-bearing sands were encountered in the Realgrunnen interval at well 7324/8-1 (Wisting Central), whereas the same interval was dry in nearby well 7324/7-1S (Wisting Alternative). In the first stage the fast track processed pre-stack seismic and CSEM data were inverted separately for impedance and anisotropic resistivity respectively.

Rock property estimation from seismic data was carried out using the multi-attribute rotation scheme (MARS) described by Alvarez et al (2015). This methodology uses well log data to evaluate the relationship between all possible elastic attribute spaces and a target petrophysical property.

For this case study, MARS was used to estimate total porosity, clay content and litho-fluid facies volumes from seismically-derived volumes of P- and S-wave impedance. A cross-section of the resultant volume of litho-fluid facies along the Wisting Central and Alternative wells, with their Vclay (left) and Sw (right) curves, are shown in Figure 1 (top). The green-coloured areas may be related to clean oil or fizz gas sand – the seismic data alone cannot distinguish between commercial and non-commercial hydrocarbon saturation.

The final stage in the analysis is therefore to invert the seismic and CSEM derived properties within a rock physics framework. The inclusion of the CSEM resistivity information within the inversion approach allows for the separation of these two possible scenarios. Excellent correlation with known well results was achieved. The integration of seismic, CSEM, and well data predicts very high hydrocarbon saturations at Wisting Central, consistent with the findings of the well. There is no significant saturation at Wisting Alternative, again consistent with the findings of the well. Two further wells were drilled in the area and used as blind tests in this case: The slightly lower saturation at Hanssen (7324/7-2) is related to 3D effects in the CSEM data, but the positive outcome of the well is predicted correctly. At Bjaaland (7324/8-2), although the seismic indications are good (upper plot in figure 1), the integrated interpretation result again predicts correctly that this well was unsuccessful.

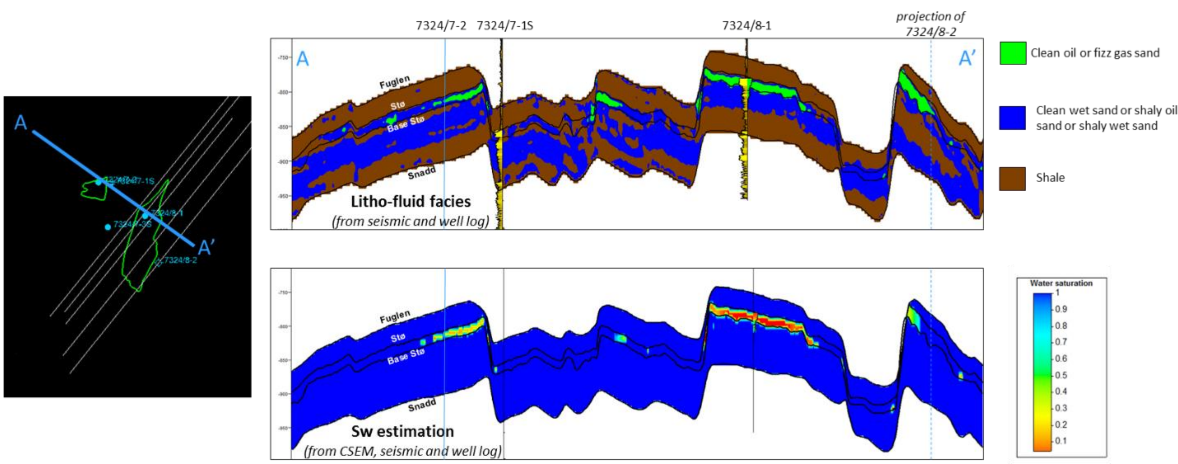

Figure 1: (Top) A cross-section of the resultant volume of litho-fluid facies obtained from seismic and well log data along a 2D line covering wells 7324/7-1S and 7324/8-1, with Vclay (left) and Sw (right) curves overlaid. (Bottom) A cross-section of the resultant volume of Sw obtained from a joint interpretation of CSEM, seismic and well log data, with Sw curves from wells 7324/7-1S and 7324/8-1.

Acknowledgements: RSI would like to thank PGS for providing the Towed Streamer EM and GeoStreamer seismic data used in this study.

References

Alvarez, P., Bolivar, F., Di Luca, M. & Salinas, T., 2015, Multi-attribute rotation scheme: A tool for reservoir property prediction from seismic inversion attributes, *Interpretation,* ***3****, SAE9-SAAE18*

Chen, J., and G. M. Hoversten, 2012, Joint inversion of marine seismic AVA and CSEM data using statistical rock physics and Markov random fields: Geophysics, **77**, no. 1, R65–R80