GEOPHYSICS PAPER 6

AN INTEGRATED APPROACH TO RESERVOIR APPRAISAL AND MONITORING USING WELL LOG, SEISMIC AND CSEM DATA.

Lucy MacGregor[1], James Tomlinson[2] & Skander Hili[2]

[1]OHM Rock Solid Images, The Technology Centre, Claymore Drive, Bridge of Don, Aberdeen, UK
[2]OHM Rock Solid Images, Level 23, Tower 2, eTiQa Twins, 11 Jalan Pinang, Kuala Lumpur, Malaysia

The controlled source EM method has developed into a tool that is often used in de-risking the exploration process. In this paper we demonstrate how the intrinsic sensitivity of the CSEM method to hydrocarbon saturation can be utilised within a framework of well and seismic data in prospect appraisal and reservoir monitoring applications. This will be illustrated with examples of the rock physics linking elastic and electrical properties along with recent case studies.

CSEM methods use a high powered marine source to generate an electro-magnetic field within the earth.. The detected response of the earth to this electro-magnetic field is recorded by an array of receivers located on the sea-floor. By interpreting the recorded response using forward modelling and inversion approaches, the resistivity structure of the subsurface can be determined. In many situations electrical resistivity is driven by the properties and distribution of fluids in the earth. Resistivity measurements in well logs often show that commercial hydrocarbon deposits may be many times more resistive than surrounding lithologies. In principal, such variations should be readily detected using CSEM receivers. In contrast, seismic data are sensitive to boundaries between lithologic units but are less sensitive to fluid changes within these units. Given high quality seismic data, well logs, sophisticated seismic inversion and rock physics tools, we have the potential to relate changes in seismic rock properties to saturation effects. Nevertheless, the change in resistivity caused by variations in saturation should be much easier to detect.

However, despite the increased sensitivity of resistivity data over seismic data for the determination of saturation, there are two inherent challenges to interpreting CSEM data. Firstly, the structural resolution of CSEM data is poor. Secondly, the cause of resistivity variations "anomalies" (particularly high resistivity features) cannot be uniquely linked to the presence of hydrocarbons in the subsurface when taken in isolation. In many situations these are equally likely to be caused by other highly resistivite material (for example, tight carbonates, salt bodies or volcanics). Both of these limitations must be addressed when considering the applicability of CSEM to answer a specific geophysical question, and as far as possible mitigated by the interpretation approach adopted.

CSEM data can, of course, be interpreted in isolation, and if there were no seismic data or wells in the vicinity of the CSEM dataset (for example if a survey were performed in a frontier area), then this would be necessary. However, with no constraints on this interpretation, the result will suffer from the non-uniqueness and ambiguity which blight unconstrained interpretation approaches. Although resistivity is imaged, the poor structural resolution of the method means that such images are diffuse and difficult to interpret. The uncertainty in the depth of features is large, so that they cannot be unambiguously attributed to a particular stratum. If there are multiple resistive features, these cannot be easily separated, and small resistive bodies are likely to be lost or smoothed into surrounding strata during the inversion process. Even assuming that localized resistivity anomalies can be found, the cause of these anomalies cannot be unambiguously linked to the presence of hydrocarbon.

In the presence of seismic and well information, the question that we are trying to answer with the CSEM data becomes significantly better posed. The question is no longer one addressed at finding a reservoir, but rather one of determining the content of a defined structure. Using seismic information the reservoir structure is known (but potentially not its content or extent), and we have independent constraints on the surrounding strata within which it is embedded. This is therefore a well constrained interpretation problem and one that the CSEM data are in a much better position to answer.

It is clear that a careful combination of all three data types can supply information that is not available, or is unreliable, from any one data type alone. By integrating complementary sources of information and exploiting the strengths of each, estimates of rock and fluid properties such as gas saturation and porosity can be obtained with greater confidence than from any one data type alone.

As we step from an exploration setting though to appraisal and monitoring of a reservoir the level of constraint on the geological model increases, and therefore so does our confidence in the CSEM interpretation. This increased confidence in the result transforms CSEM into a tool that can quantitatively map hydrocarbon distribution and time lapse changes in hydrocarbon saturation away from the well bore.