Integrated interpretation of electromagnetic and seismic data: challenges, open questions, possible solutions. A case history

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The main objective of a well posed integrated approach should be to reduce the level of uncertainty and indetermination about the knowledge of the system under study. That is the desirable result when complementary geophysical disciplines, such as seismic and electromagnetic methods, are combined with each other through an integrated interpretation work flow. That goal is reasonable if we assume that seismic and electromagnetic domains are linked in both data and model domains. That assumption implies that integration can be performed throughout data driven and model driven approaches. However several basic questions remain still unsolved, such as:

- 1) In what measure should seismic information drive electromagnetic interpretation without affecting the objectivity of the results?
- 2) How can electromagnetic models produce a useful feedback in the seismic domain?
- 3) What is the best way to link data sets and model spaces that show different accuracy, resolution power, sampling and spatial scale?

In order to solve, at least partially, the above (and many other) open problems Eni developed a “hybrid” integrated interpretation approach. Our approach is defined as “hybrid” simply because it is based, at the same time, on data driven and model driven approaches. The idea of this combined approach seems to be obvious. However how to optimize these two aspects (data and model driven) of the workflow is not trivial. The challenge is to fill the gap between what we know and what we believe we know. In order to test and to refine our hybrid approach we addressed many efforts in acquiring and interpreting jointly seismic and electromagnetic data, possibly with the support of additional independent information, such as gravity, composite logs, petrophysical and geological data and so on. An interesting case history is presented where our approach was applied.

An extensive CSEM (Controlled Source Electromagnetic) data set recently acquired was interpreted using the hybrid approach. The line discussed here shows several interpretation difficulties due to:

- a) High level of geological complexity
- b) Significant bathymetric variations
- c) Presence of hydrates in the area
- d) Multiple potential targets at variable depth

Good seismic data is available in the block. It was extensively processed and interpreted before acquiring CSEM data. Also seismic AVO analysis was performed.

The interpretation work flow of CSEM data started from an accurate analysis of the possible artifacts produced by significant variations of the source elevation above sea floor. After recognizing the presence of “false” electric anomalies, the interpretation continued throughout the analysis of several electromagnetic attributes. In particular the analysis of the asymmetry between the in towing and out towing response at each receiver was very useful. It allowed to us to identify significant lateral variations of the resistivity distribution. Occam inversion helped in defining the resistivity model in terms of resistivity vs. depth. The model was iteratively and interactively updated by recursive 3D forward modeling. The goal was to fit “roughly” the data at the maximum number of receivers, after having included the available seismic horizons in the model. Our intention was to explore extensively the 3D model space before running any final optimization (inversion), taking in account for the seismic data. A “perfect fit” is not required at this stage, but the trial and error modeling should lead towards a 3D model that is generally consistent with CSEM data and a priori information. The 3D model(s) obtained by the trial and error loop is called “best reference model” (BRM). It was used for driving the optimized 2.5D inversion. That represented a sort of fine tuning step of the process, aimed at producing a final resistivity model honouring, at the same time, CSEM data and a priori seismic (and geologic) information.