Integrating Basin Modelling with Geophysical Methods*

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Abstract

This article presents an approach and work flow for integrating basin modelling methods with geophysical exploration methods. In the exploration phase, seismic and electromagnetic data can be inverted for sediment velocity and resistivity. Using rock physics models, the velocity and resistivity data can be interpreted to give a prediction of porosity and hydrocarbon saturation in the prospect location. Basin modelling, on the other hand, is used to model sedimentation, compaction, temperature history, source rock maturation and hydrocarbon migration through geological time, and to give an independent prognosis of hydrocarbon saturation in the prospect location. Traditionally, geophysical methods and basin modelling have been applied separately. We have investigated methods for integrating basin modelling with geophysical methods to obtain an integrated and consistent exploration work flow. By constraining the rock physics modelling by basin modelling results, and constraining the basin model by the results of rock physics modelling, we attempt to improve the accuracy and reduce the uncertainty of estimated reservoir rock and fluid properties. The objective is to obtain an integrated prospect prediction. This approach can result in meaningful integration and a significant reduction of exploration risk compared to studies where rock physics and basin modelling are not linked. The integrated approach will also add value to situations where either the rock physics approach or the basin modelling approach are less sensitive on their own.

Modelling Methodology

Basin modelling can provide constraints to the rock physics analysis in several ways:

1. Burial history and temperature history:
   Mechanical compaction and sediment diagenesis (quartz cementation in sandstones, Smectite illitization in shales).

2. Hydrocarbon migration:
   Hydrocarbon saturation in the prospect from source rock maturation and hydrocarbon migration.

Sediment velocity and resistivity are dependent on the temperature and effective stress history that the sediments have experienced. However, well log-based in-situ rock physics modelling ignores these key rock forming parameters. Including burial and temperature modelling, together with modelling of sediment compaction and diagenesis into the rock physics analysis is therefore crucial for accurate prediction. Illustrations of model results are shown in Figure 1 where velocity-depth trends are plotted for shales and for sandstones.

Also for fluid identification in a prospect, basin modelling (hydrocarbon migration modelling) can provide valuable constraints. One example of results from hydrocarbon migration modelling is shown in Figure 2, showing the distribution and column height of gas in a prospect. The probability of finding gas can be used to constrain the fluid prediction from geophysical data. As a different example, the source rock present in the area may be only moderately mature, implying that it is more likely to find oil than gas in the prospect of interest. The probability distribution for the fluid phases received from probabilistic hydrocarbon migration modelling will be used to risk the rock physics fluid prognosis in order to obtain a final fluid and lithology prognosis for the prospect.

The modelled rock physics parameters allow for an improved description of the properties of the carrier layer (e.g. lithology, porosity). As examples, porosity, rock and hydrocarbon densities can be used as input in expulsion modelling and conductivity can provide constraints on porosity and water saturation, which in turn are important parameters in secondary migration modelling. In this way, saturations and porosity obtained from rock physics modelling will be compared and calibrated against values obtained independently from basin modelling.

The integrated software tools will include a library of different rock types, corresponding rock physics models, and a basin model including burial and temperature history, sediment compaction and diagenesis, source rock maturation and hydrocarbon migration. The specific burial and temperature history for the prospect location will be constructed. A selection of relevant rock types will be used in the modelling of rock properties in the prospect location. This will serve as the basis for interpretation of the seismic and electromagnetic data in terms of porosity and fluid saturation. The approach and work flow will be presented and illustrated with examples.

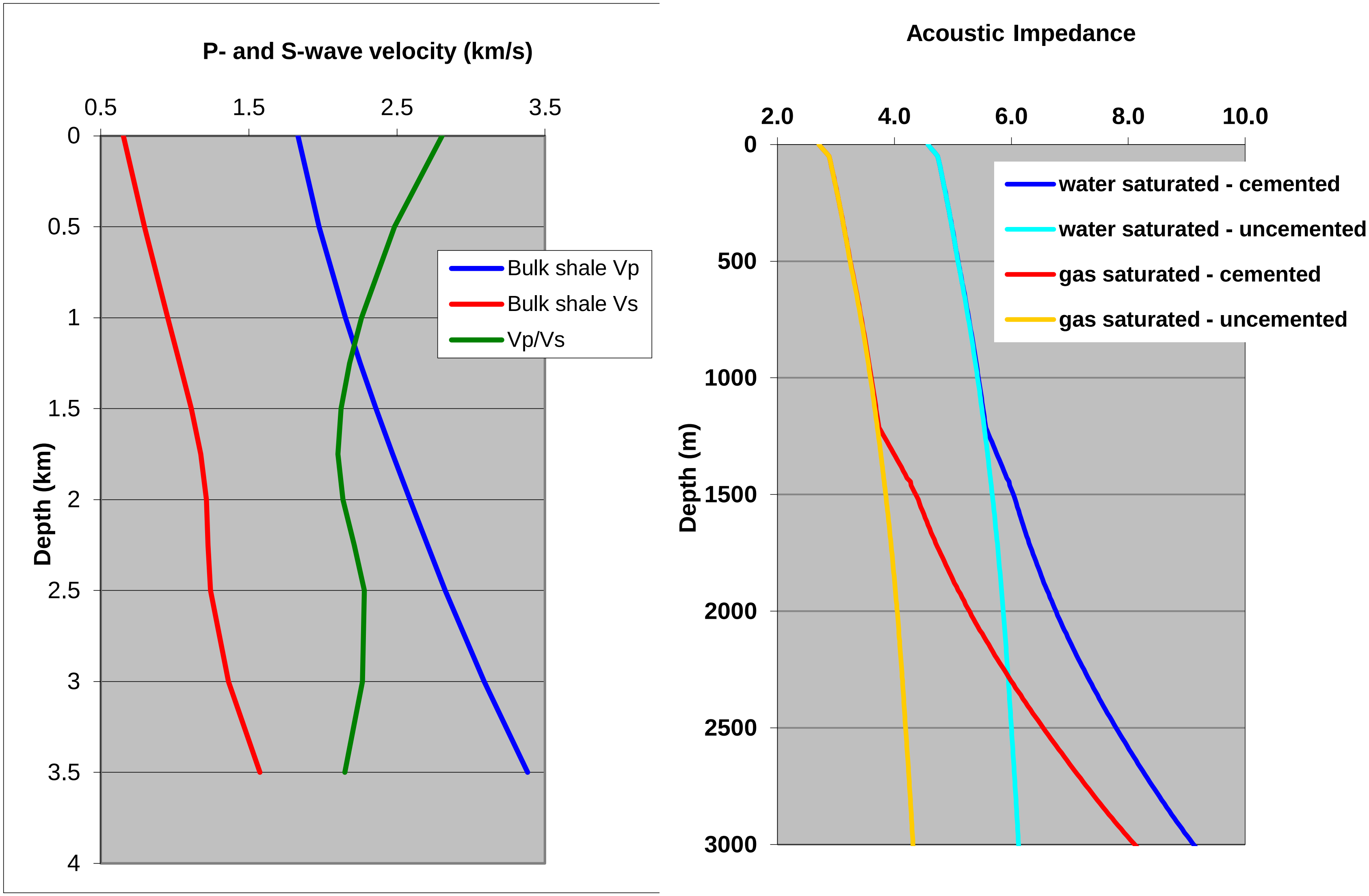

Figure 1. (left) Velocity-depth trends for shales honouring both mechanical compaction and chemical compaction (Smectite illitization). (right) Acoustic impedance for sandstones for different scenarios: gas/water saturated and cemented/uncemented.

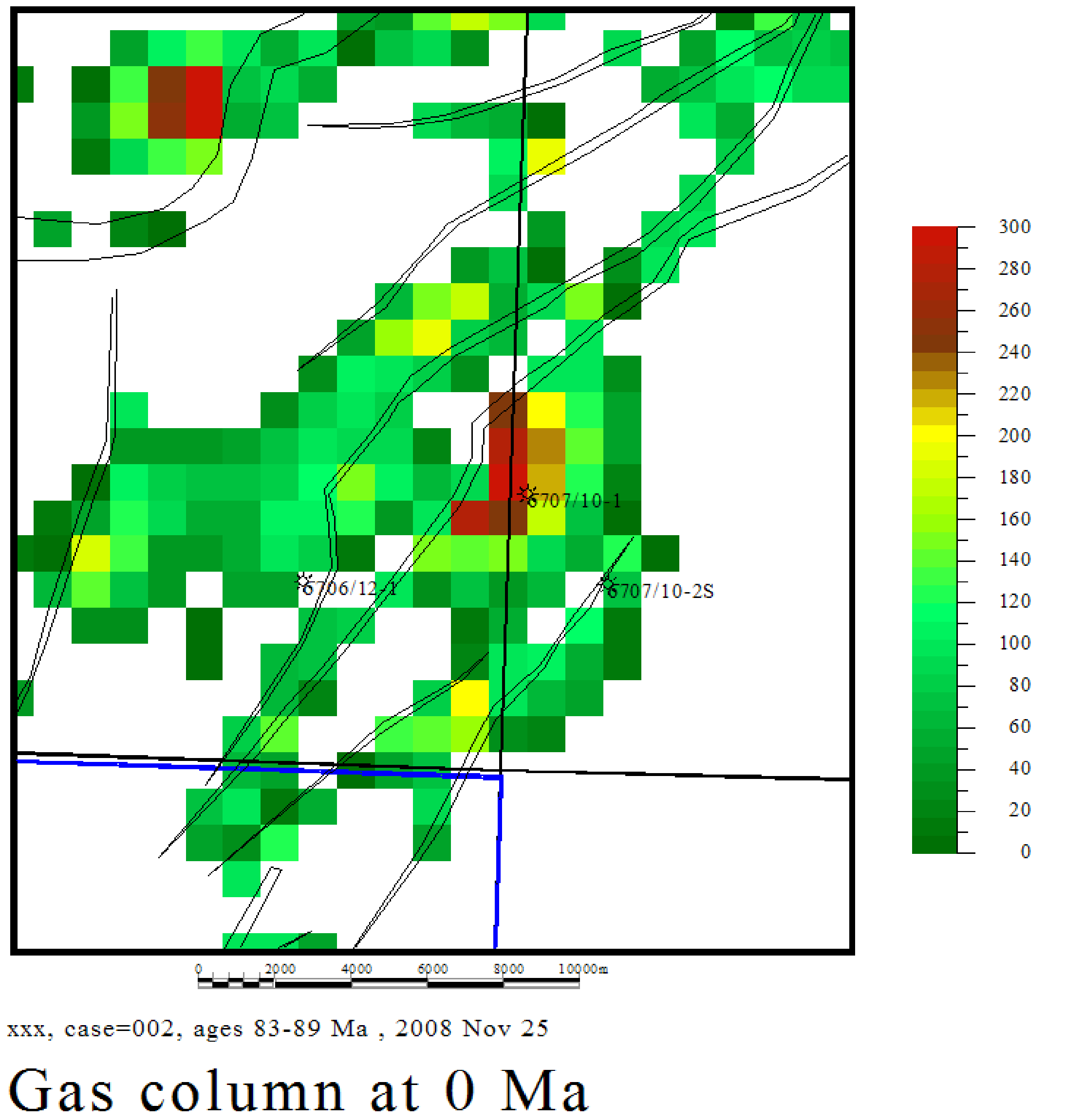

Figure 2. Gas column heights in traps from hydrocarbon migration modelling.