Rock Physics Diagnostics of Exhumed Reservoir Sandstone

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Introduction

Hydrocarbon exploration in complex tectonic province like Barents Sea is always challenging. Potential reservoir and cap rocks in exhumed basins have different rock properties compared to reservoir and cap rocks in normally consolidated basins due to their complicated burial history. The stress dependent mechanical compaction controls rock properties at shallower depth (below 60-70^{o}C) but with increasing temperature (above 60-70^{o}C) chemical compaction process controls by time-temperature integral (TTI) influence the rock properties due to quartz cementation. During uplift cement process can continues until temperature above 60-70^{o}C but the cementation ceases as temperature drops below 60-70°C and fracturing may occur until uplift stops. This study performs rock physics diagnostics of exhumed reservoir sandstone capped by a shaly unit situated in the Norwegian Barents Sea. The clean sandstone reservoir has experienced several phases of loading and unloading history. The present depth of the reservoir sandstone (temperature below 60-70^{o}C) is many hundred meters shallower than its maximum burial (temperature above 60-70^{o}C).

Methods

A suite of log data from three neighbouring exploration wells is utilized to perform rock physics diagnostics to discriminate lithology and pore fluids of target reservoir sandstone. The exploration wells proved both non-hydrocarbon (Well #1: Dry) and hydrocarbons (Well #2: Oil discovery and Well #3: Gas discovery) in the target reservoir sandstone capped by a shale unit. To investigate lithology and fluid effect on rock properties and seismic signature, rock physics diagnostic is performed using a rock physics templet (RPT). To generate the RPT first the Hertz-Mindlin contact theory (Mindlin, 1949) is used to construct the dry rock modulus at the high porosity end member. The modulus of the dry rock at zero porosity end member to be the modulus of the solid mineral. Between the high-porosity and zero-porosity end members, the modulus of dry rock is estimated based on Hashin-Shtrikman (1963) bounds, which give the theoretical predictions of the effective elastic modulus of a mixture of grains and pores. Finally, the Gassmann equation is applied to estimate the fluid substitution effect on rock physics templet and thereby the elastic modulus of saturated rocks. The reservoir fluid in this case is gas, oil and brine and I assume the fluid is uniformly distributed within the clean reservoir sandstone rather than patchy saturation.

Results and discussion

Crossplotting elastic properties in conjunction with the rock physics templets demonstrates that the reservoir sandstone in well#2 and well#3 are oil- and gas-saturated whereas some brine-filled data points from well#3 also fall on gas saturated zone (Fig. 1). Many data points of well#1 fall in hydrocarbon zone though the well is dry reflecting limitations of rock physics diagnostics. The cap rock data of well#1 and well#2 fall below the shale trend (towards the hydrocarbon-saturated zone) whereas some cap rock data of well#3 fall in gas saturated zone. The discrepancies of shale cap rock data points can be explained by organic-richness of the cap rock shale that may underwent early phase of maturation and expelled hydrocarbon at their maximum burial.

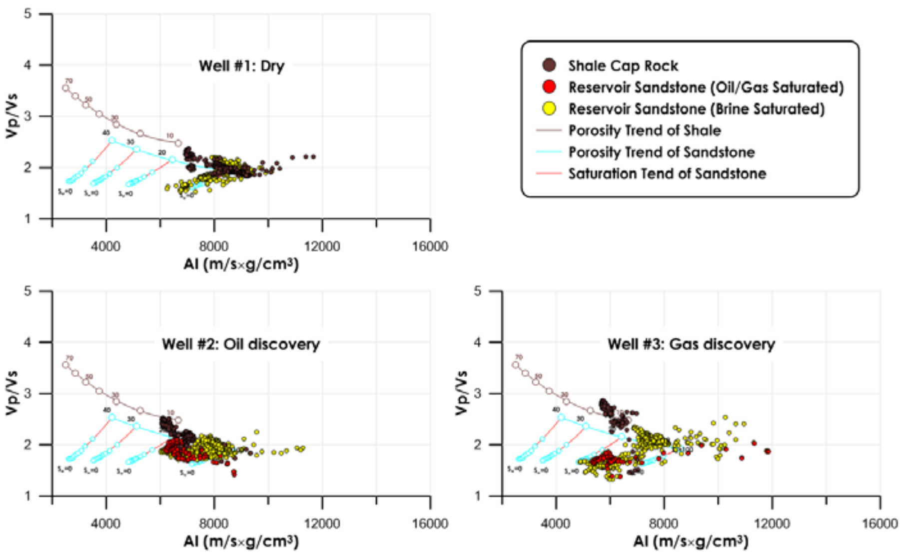

Figure 1: The rock physics templet posted in the crossplot of acoustic impedance versus Vp/Vs ratio calculated from three neighboring wells. Comparing the three wells, well#3 has higher porosity.

Conclusions

The lithology and fluid content of exhumed reservoir sandstone can be delineated using the crossplot of elastic properties with the rock physics templet. The prior knowledge such as maximum burial and exhumation history of the reservoir sandstone and composition of the cap rock shale can help to construct more efficient rock physics templet including the effects of pressure, temperature and fluid property.

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References

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