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Data Acquisition and Formation Evaluation Strategies in Anisotropic, Tight Gas Reservoirs of the Sultanate of Oman

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Abstract

In a time of declining production and increasing demand, geoscientists are challenged more and more often to develop new techniques and strategies for evaluation and appraisal of increasingly complex and deeper reservoirs.

This paper describes the subsurface challenges and how, through optimized data acquisition and application of integrated formation evaluation techniques, tight gas reservoirs have been characterized and the objectives of data acquisition programs have been met. Examples are illustrated with data from three recent wells.

The operating environment is very challenging, which affects the decisions for data acquisition. The use of salt-saturated mud systems creates a high resistivity contrast between mud and formation, affecting image and nuclear magnetic resonance data quality. The anisotropy in the stress field results in elliptical boreholes with breakouts. This leads to complex resistivity log responses, which require special corrections and a modeling approach. Furthermore, the data quality of wireline pad tools is compromised. The low-porosity formation affects the accuracy of water saturation calculations and fluid mobility ranges in the sub-md region make fluid sampling and the acquisition of formation pressures a complex task. Often completion decisions have to be based on basic formation evaluation data alone as acquiring pressure data or fluid samples is not possible. Only if borehole effects are sufficiently understood and corrected for can this basic formation evaluation be presented with some confidence. Trend analyses are, however, often more instructive than absolute averages of calculated pay summaries. Resulting porosity and saturation estimates should always be put in context of other well results and alternative data sources like borehole image and mud gas data.

Introduction

The exploration for deep gas in Oman started after a decision was made to deepen an exploration well targeting an oil reservoir at shallower stratigraphic levels. The Saih Nihayda gas-condensate field was discovered in 1989, followed by Saih Rawl (1990) and Barik (1991). Consequently exploration and development of gas and gas-condensate reservoirs has focused on deep reservoirs in the Haima Group in North Oman's Ghaba and adjacent Afar area (**Fig. 1**). The fields making up the Kauther cluster were discovered in 2001 and 2002 and are currently being developed. Following success in Ghaba basin exploration efforts have focused on the deeper still Haima formations in the Fahud Salt basin. As the reservoirs are typically relatively thick (~200m) and have low permeability (<0.1md) the developments are based on vertical wells that are stimulated with massive vertical fracs.

Formation evaluation is becoming increasingly challenging with increasing depth. Three factors that affect our ability to interpret downhole data are discussed in detail in this article. The first one, an abnormal pressure regime, results in severe borehole breakouts. The second, increasing temperatures with increasing depth, results in reduction of data quality, tool failures and a reduction in available downhole sensors. The third, decreasing porosity with depth, requires high accuracy in sensors to allow correct porosity evaluation as inaccuracy in porosity estimates leads to unacceptable uncertainty in fluid saturation estimates. Combined these three factors result in a difficult logging environment making it increasingly difficult to acquire a good quality data set for formation evaluation.

To overcome the challenges instigated by these borehole conditions several data acquisition strategies have been employed and these will be described in the first half of this article. The second part focuses on the interpretation of the data acquired in these sub-optimal conditions. The first step towards effective formation evaluation is a fit for purpose data acquisition strategy. The second, equally important, step is the understanding of, and correcting for, the effects of borehole conditions on tool responses. The third step, pushing the button on the evaluation routine and creating an evaluation as input for completion decisions, can only be done with confidence if the first two were successful. This article aims to describe the above process for the deep gas exploration wells in the Sultanate of Oman.