Integrated Reservoir Characterisation:
Case Study Results and Discussion on Interdiciplanary Teams

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Summary

This study was completed as part of the capstone project for the University of Calgary's Reservoir Characterisation Masters program. This is an interdisciplinary program that combines geology, geophysics and reservoir engineering. The project goal was to create a reservoir flow model from a real data set as a team. The team consisted of one member from each respective discipline. The study area was a small light oil carbonate reservoir in southeast Saskatchewan, Canada. The team was able to integrate the data set, which included: 3D seismic data, cores, field production and injection history, reservoir pressure data, and well logs. To accomplish this, the team effectively used seismic attributes to create a geological model, and then used a reservoir simulation program (CMG) to validate the geological model and history match over 40 years of field production and water flooding data. As well as a reservoir model, an additional outcome of the project was the learnings of an effective process of integrating these disciplines and getting people with different background to work together. Advantages and hinders of such collaborations are discussed and a list of prerequisites for an effective teamwork is suggested

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AAPG Search and Discovery Article #90171 CSPG/CSEG/CWLS GeoConvention 2009, Calgary, Alberta, Canada, May 4-8, 2009

Introduction

The integrated study as a part of reservoir characterization program was focused on the effective processes of building and maintaining competent interdisciplinary teams in an upstream oil and gas context. The aim is to create an effective environment to foster team efficiency. This increases overall productivity and creativity for problem solving. Team approaches allow for the integration and effective utilizing large volumes of data.

The study field is in southeast Saskatchewan and has been producing conventional light oil since 1962. The producing zone is the Alida bed of the Mission canyon formation, Madison Group. The filed has been water flooded since 1970 and has produced 4.8MMSTB of oil, 3.7 Bcf of gas and 6.9 MMbbl of water. The OOIP estimate is 42 MMSTB. There are currently 40 wells drilled in the field, 33 verticals and 7 horizontals. Core analysis is available for 18 of these, of which four were examined closely to determine depositional environment, facies distribution, and geological setting. A basic set of logs were available for each well and included Gama Ray, Sonic, SP and Conductivity logs. As most of the wells in the pool are older wells, only 2 of the wells had a modern log suite including Density and Neutron Porosity and PE curves.

Project Method

Initial evaluation of the logs showed that the reservoir consists of 3 to 4 zones. High resistivity zones at the top and bottom of the reservoir were interpreted and correlated as anhydrite, or anhydritized zones. The carbonate zone in the middle had two different facies types. The sonic response was used as the distinguishing log for separating the two main reservoir facies. The lower facies showed lower porosity (10-14%) and were present in most of the logs. The upper facies had high porosities (20-24%) and high permeability. This upper facies exists in the central core of the reservoir. Examining the cores showed that the lower facies consisted of a dolomitised micritic mudstone/wackstone with in-situ fossils indicating a low energy depositional environment. The higher facies consisted of a calcitic grainstone/packstone, which was slightly dolomitised and contained a large proportion of skeletal debris (Crinoids & Echinoderms) indicating a high-energy wash out environment.

Interpretation of 3D seismic showed a NE-SW trending elongate reservoir. The north east reservoir boundary is the Alida subcrop edge and there is a bounding water contact on the SW end of the pool. The upper boundary is an erosional surface of the Mississippian unconformity, and the top structure interpreted as paleotopography of the time. The lower boundary is the Tilston beds and is a conformable boundary.

Integration of seismic inversion data with the log and core information leaded us to geologically acceptable conceptual model. Maps of averaged acoustic impedance and seismic amplitude inside the reservoir zone were correlated with extents of the lower and higher porosity facies zones. Reservoir boundaries were also defined. From this a structural grid of the reservoir was built based on this conceptual model. To model the porosity distribution the, acoustic impedance was correlated with the well logs and the structural model was populated using collocated co-simulation (SIS). Permeability was modeled by using regression lines determined from the porosity perm relationship from the core analysis. There was a noticeably different porosity permeability relationship for each of the two facies types. The permeability then was collocated co-simulated with the porosity property determined from the seismic data.

Field fluid production and water injection history matching was achieved with limited global alterations of some parameters (mostly transmissibility) for over 40 years of field data. Individual wells matched with limited alteration of parameters according to well reports although some individual wells showed some deviation from historical data. The history match was used to validate the geological model.

Integrated Team Approach

Having a geologist, geophysicist and a reservoir engineer working together added value beyond individual achievement. The following discussion shows that how this project benefited from an integrated team approach, and also discusses the hindrances (and observed causes) of team problem solving.

Integrating seismic data with the facies analysis logs to separate two porous zones in the reservoir was a successful experience of this project. Production data were used to confirm the results. Analyzing cores and logs showed that the porous zone could be divided into two zones. Lower part of the porous zone was a lower porosity (12-14%) and permeability dolomitized micritic mudstone/wackstone. Where it exits, the upper zone is a higher porosity (19-24%) and permeability skeletal grainstone/packstone. Studying the existing literature on sedimentology of the Alida beds and facies sequence suggested a shoal/carbonate build up environment, surrounded by a lower energy carbonate mud. According to this conceptual model, the presence of a high porosity facies in the wells shows the approximate extent of the high porosity zone. AI mapping of the seismic inversion data correlated with the presence of this zone. Combining the information from both the wells and AI map lead the team to definable boundaries of each zone. The correlation between the AI map and average porosity of the wells directed the collocated co-simulation process to distribute porosity in the reservoir model.

Another specific problem which was solved through integration of geology and geophysics was an anomalous well in the centre of the pool. This well was anhydritized in its entire resulting in no porosity or permeability. The core analysis showed a solution collapse at the well location (in the thickest part of the reservoir) which presented carbonate breccia surrounded by anhydrite. Seismic forward modeling predicted very low amplitude in zero porosity zone and this agreed with the observation of 3D seismic data around the well. Using this correlation the extent of the solution collapse feature around the well was mapped and a similar spot in the filled were recognized as a high risk of no porosity interval.

According to the AI map absence of high porosity zone were expected in the middle of the reservoir were no well was drilled. This was closely agreed with the lack of communication between the injector and producer wells in this zone through analyzing water injection vs production increase history.

Integrated Team Approach Pitfalls

While benefiting from the integration, the experience also showed some of the possible hindrance in combining different disciplines.

One major point was the depth of understanding of each individual of the other disciplines. Lack of comprehensive understanding of limitations of other disciplines and inherent associated uncertainties cause unrealistic expectations. The process of clarifying those limitations and discussions associated with it was time consuming in some cases. More interaction and learning between disciplines will eventually solve this issue but it is an important time management factor to be considered in establishing a new integrated teams.

Personal motivations and drives of each individual affect team performance in several ways. I this project the team had the opportunity to work without the professional obligations of an industry job. As an educational project, personal objectives were the main drive of collaboration. Occasional weakening of these personal motivations during the project were observed which caused some distraction of team performance. Open communication and supportiveness alleviated this problem.

Time management was another important factor experienced in this project. All team members had other job and family commitments, and a definite deadline to finish the project. Combination of planning, self-management, commitment to work, and effective communication prevented a major deviation from timelines but in general overwhelming commitments were seen as a major risk for team performance.

Quality of the work is an interdependent product. In an integration team, the quality of final result can be downgraded to the capability and competency level of the weakest link in the team. Best performance is achievable by having comparably compatible members in the team.

Conclusions

The team was able to complete the project requirements of a realistic geological model and was able to generate a successful history match in a limited 4 month time period. This was accomplished by integrating the existing geological, geophysical, and engineering backgrounds of each of the team members.

Acknowledgements

Arc Resources, Crescent Point, University of Calgary, Schlumberger Information Solutions, CMG, Hampson-Russell (CGG-Veritas),