Impact of Heterogeneous Storm Event Deposits on Fluid Flow Behaviour of Late Jurassic Arab-D Reservoir, Saudi Arabia*

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Search and Discovery Article #51269 (2016)**
Posted August 8, 2016

*Adapted from poster presentation given at AAPG Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016
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Abstract

The Late Jurassic Arab-D reservoir is highly prolific in several supergiant oil and gas fields in the Middle East. An outcrop analogue of equivalent age in Central Saudi Arabia shows depositional facies and stratigraphic architecture similar to those inferred in the subsurface. This analogue is studied using a digital outcrop model, to understand and quantify facies and related rock property distributions, and their impact on flow behaviour in storm dominated, shallow-marine carbonates of the lower to middle Arab-D reservoir. Outcrops reveal a succession of thin (0.5-1 m) fining upward cycles formed by local scouring and reworking during storm events. Cycles typically comprise a coarse-grained rudstone-to-grainstone lower part that fines upward into a wackestone topped by a cemented firm ground cap. The mud dominated portions of the cycles commonly exhibit vertical variation with zones of different degrees of bioturbation-related fabrics. Cycles are separated by sharp-to-erosional bases of varying relief, which cause cycle thickness to vary laterally, grain dominated portions to pinch out and firm grounds to be locally removed. Locally, 1-3 m thick chaotically bedded conglomeratic intervals occur, produced by larger storm events. These contain overturned clasts up to 1 m in diameter and infill scours with steep-to-vertical walls that incise several meters into underlying deposits and connect coarse-grained facies from different cycles. Storm event deposits vary laterally and vertically in their geometry, spacing and connectivity. Few coarse-grained beds extend across an outcrop (<1 km), but instead pinch out laterally. In combination, these geometric relationships increase vertical connectivity and limit lateral continuity of coarse-grained facies, which presents challenges for characterizing inter-well volumes. Analysis of scour-and-fill geometries shows symmetrical and asymmetrical cross-sectional profiles, implying 3D variation in scour geometry and orientation. These observations were synthesized to develop geometrical templates for fining upward cycles and scours, including their internal variation, such as bioturbation, for implementation in surface-based reservoir models. These templates can be used to test the impact of the observed heterogeneity on the identification and correlation of reservoir flow units using well data, and on the effective properties of the flow units.
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1. Introduction

- Understanding the development of reservoirs and related rock properties distribution and connectivity.
- Understanding the impact on flow behaviour and predictability.

2. Geologic setting of study area

- Arab-D reservoir zones 2B and 3A
- North-South orientation

3. Outcrop observations

- Rudstone tracing
- Scour development
- Scour cross sections

4. Dataset and methods

- Imaging and detailed observations
- Outcrop geometries
- Scour cross sections

5. Observations and analysis of stratigraphic architecture

- Rudstone identity
- Scour geometry
- Geomechanical properties

6. Simulation

- Numerical simulation
- Fluid flow behaviour
- Heterogeneous storm-event deposits

7. Surface-based modeling of cycles & behavior

- NURBS (Non-Uniform Rational B-Splines)
- Complex geometries
- Modeling and simulation

8. Conclusions

- Flow behavior
- Heterogeneous storm-event deposits
- Reservoir characterization

References