Geometry, Spatial Arrangement and Connectivity of Grain-Dominated, Storm-Event Deposits in Outcrop Analogues of Upper Jurassic Arab-D Reservoir, Saudi Arabia*

Carl Jacquemyn¹, Matthew Jackson¹, Gary Hampson¹, Cédric John¹, Dave L.Cantrell², Rainer Zuhlke², Abdul Jaleel Abu Bshait², and Robert F. Lindsay²

Search and Discovery Article #51150 (2015)**
Posted September 21, 2015

*Adapted from presentation at 2015 AAPG Convention & Exhibition, Denver, Colorado, May 31-June 3, 2015
**Datapages © 2015 Serial rights given by author. For all other rights contact author directly.

¹Earth Science and Engineering, Imperial College, London, United Kingdom (c.jacquemyn@imperial.ac.uk)
²Saudi Aramco, Dhahran, Saudi Arabia

Abstract

The Upper Jurassic Arab-D reservoir, composed of the Arab-D Member of the Arab Formation and upper part of the underlying Jubaila Formation, 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 that are similar to those inferred in the subsurface. This analogue has been studied using a high-resolution digital outcrop model integrated with measured sections, in order to understand and quantify facies relationships in storm-dominated, shallow-marine carbonates. Outcrops of the lower to middle Arab-D reservoir reveal a succession of interbedded, muddy and grainy rocks that occur as a series of thin (0.5–1 m) fining-upward cycles. Cycles typically comprise a coarse-grained grainstone-to-rudstone lower part that contains muddy intraclasts and, locally, stromatoporoid and coral fragments, and that fines upward into a wackestone cap. The finer portions of these cycles are bioturbated, and swaley cross-stratification occurs locally in both mud- and grain-dominated beds. Cycles are separated by sharp-to-erosional bases of varying relief, which cause cycle thickness to vary laterally. Locally, 1–3-m thick chaotically bedded conglomeratic intervals containing overturned stromatoporoid and coral clasts up to 1 m in diameter infill scours with steep-to-vertical walls that incise several meters into underlying deposits. The fining-upward cycles are interpreted to result from storm events that locally scoured and reworked sediments. The occurrence of swaley cross-stratification suggests deposition below fair weather wave base but above storm wave base. Larger storm events produced steep-sided scours that were filled by conglomeratic debris transported offshore from shallower water settings. Storm-event deposits vary laterally and vertically in their geometry, spacing and connectivity. Few coarse-grained beds extend across outcrop (<1 km) but instead pinch-out laterally. Their lateral extent and degree of vertical amalgamation is controlled by erosional relief and paleotopography at bed boundaries. Conglomeratic scour fills show symmetrical and asymmetrical cross-sectional profiles, implying 3D variation in scour geometry and orientation. The heterogeneity observed in these outcrops has implications for the identification and correlation of reservoir flow units between wells and for the effective properties of the flow units.
References Cited


Geometry, spatial arrangement and connectivity of grain-dominated, storm-event deposits in outcrop analogues of Late Jurassic Arab-D reservoir, Saudi Arabia

1Carl Jacquemyn, Matthew Jackson, Gary Hampson, Cédric John
2Dave L. Cantrell, Rainer Zühlke, AbdulJaleel AbuBshait, Robert F. Lindsay

1Department of Earth Science and Engineering, Imperial College London
2Saudi Aramco, Dhahran, Saudi Arabia
Motivation

• Cores of lower Arab-D reservoir zones show rudstone intervals that are interpreted as storm reworking (Lindsay, 2006)
• Potentially great heterogeneity
• Uncertainty in lateral continuity, geometry, dimensions and distribution of rudstones
Aims

• Quantify the geometry, lateral continuity and spatial distribution of rudstone intervals exposed at outcrop
• Consider implication for flow
Geological setting

- Late Jurassic
- Carbonate shelf (1000x2000 km)
Geological setting

OUTCROPS
Carbonate shelf

Handford (2002); Lindsay et al. (2006)
Methodology

• digital outcrop model
• 4 sedimentary logs
Storm deposits

• Fining upward cycles
  – Base: Swaley cross stratified packstone
  – Fines into wackestone
  – Firmground cap

• Extensive bioturbation in upper part of cycles
Rudstone scours
Storm Channels

- **Proximal setting**
  - Deep channels

- **Distal setting**
  - Thin discontinuous lenses

© Imperial College London

Handford et al 2002
Storm Channels
Storm Channels

- **Proximal setting**
  - Deep channels

- **Distal setting**
  - Thin discontinuous lenses
Lateral connectivity

- Grain-dominated portion of cycles pinch out
- Rudstones are not continuous
Scour 2D geometry
Rudstone beds – conceptual geometry

Outcrop examples

Conceptual geometry

$W_r = 10\text{m} \text{ to } +400\text{m}$

$d_r = 10\text{cm}\text{ to } 1.5\text{m}$

$d_c = 0.5\text{m} \text{ to } 1.8\text{m}$

$W_c = 4.7\text{m} \text{ to } 17.7\text{m}$
Modelling 2D scour geometries

- 15 geometrical parameters
- Location parameters
  - Stratigraphic height
  - Lateral position
Outcrop measurements
Outcrop measurements
2D scour geometries

- **Box-shaped**
  - Flat based
  - Steep walls

- **V-shaped**
  - Walls less steep
  - Asymmetric

channel cross profiles

rescaled to same width
Scour 3D geometry
Scour 3D geometry
3D scour orientation

- NNW to SSE
Future work

- Impact on fluid flow
- Surface-based modelling and simulation
Future work

• Impact on fluid flow

• Surface-based modelling and simulation
Conclusions

• Lateral connectivity
  – Pinch outs

• Rudstone storm deposits geometry
  – Laterally extensive over 10-400+ m
  – Scour pit and wings extent and depth quantified
  – Symmetric vs. Asymmetric
  – N-S orientation

• Non layer cake correlation between wells

• Connections vertically

• Potential for complex sweep patterns