Insights from Quantitative Sequence Stratigraphic Analysis of Cyclic Peritidal Carbonates: Triassic, Sultanate of Oman*

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Abstract

The Triassic in the Northern Oman mountains consists largely of peritidal dolomites of a flat epeiric carbonate ramp. To unravel the sequence stratigraphic framework, different quantitative sequence stratigraphic analyses were applied:

1. A rooting index, quantifying the severity of rooting, was used to identify the order of a cycle boundary. High-order sequence boundaries (3rd-/2nd-order) tend to be heavier rooted and (karst-)brecciated than low-order cycle boundaries (5th-/4th-order).
2. Facies proportion curves were applied in combination with gamma-ray trends to establish a 3-fold cycle hierarchy. Since proximal facies in this peritidal environment typically show higher natural gamma radiation (K, Th), they can clearly be differentiated from distal grain-dominated facies of rather low GR values.
3. Stacking pattern diagrams visually accentuate facies changes through time and highlight high-frequency fluctuations in relative sea level. Interpreted medium-scale cycles (< 10 m) show lateral facies changes and occasionally pinch-outs on a scale of several kilometers.
4. Fischer plots provide a proxy for accommodation space. Pronounced peaks depict high accommodation space and therefore maximum flooding events; low peaks, sequence boundaries. Fischer plots were also compared regionally, revealing different behavior of the plots in different parts of the study area. These patterns are most likely due to locally varying subsidence and presumably indicate paleo-high or paleo-low structures.

Techniques of quantitative sequence stratigraphy are thus useful for establishing a solid high-frequency sequence stratigraphic framework. They complement each other and help to verify or falsify different scenarios of cycle picks, cycle hierarchies, and regional correlation. In some cases they can even be used as first-pass indicators for regional paleotectonic relationships. This has several implications for reservoir occurrence and quality--relevant for both regional exploration and field development.

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Selected Reference


Selected Website

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Goal: robust sequence stratigraphy
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
# General Stratigraphy & Study Area

![Map of the study area](http://www.metmuseum.org)

<table>
<thead>
<tr>
<th>Age</th>
<th>Period</th>
<th>Epoch</th>
<th>Stages</th>
<th>Form.</th>
<th>Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>Permian</td>
<td>Lopingian</td>
<td>Wuchiapingian</td>
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<tr>
<td>251.0</td>
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<td>Olenekian</td>
<td>Changhsingian</td>
<td>253.8</td>
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<td>Induan</td>
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<td>245.9</td>
<td>SAIQ</td>
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<td>237.0</td>
<td>Triassic</td>
<td>Middle</td>
<td>Anisian</td>
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<td>MAHIL</td>
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<tr>
<td>228.7</td>
<td></td>
<td>Upper</td>
<td>Ladinian</td>
<td></td>
<td>UPPER</td>
</tr>
<tr>
<td>216.5</td>
<td></td>
<td>Upper</td>
<td>Carnian</td>
<td>?</td>
<td>UPPER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper</td>
<td>Norian</td>
<td>Non-deposition - erosion?</td>
<td>UPPER</td>
</tr>
</tbody>
</table>
Location map – Oman Mountains

- Wadi Sahtan
- Wadi Bani Awtf
- Wadi Bani Kharus
- Saiq Plateau
- Wadi Mistal
- Wadi Hedek
- Wadi Muaidin

http://maps.google.com
Paleogeography

Early Triassic 237 Ma

Scotese (2001) – paleomap project
Depositional Environment & Facies

- epeiric carbonate ramp

- Supratidal
- Marsh
- Tidal flat
- Low-energy backshoal
- Mod.-energy backshoal
- Shoal
- Foreshoal
- Offshoal

Lateral range of Upper Mahil outcrop facies

- rooted mudstones
- microbial laminites
- peloidal/bioclastic packstones
- oolitic grainstones
Weathering profile indicates cyclicity

Cycle Type

G P W M

LFT

6e

2b

5a1

2a

1

20 cm

Wadi Sahtan
Small-scale cycle types

Lateral range of Upper Mahil outcrop facies

Supratidal  Marsh  Peritidal  Low-energy backshoal  Mod.-energy backshoal  Shoal  Foreshoal  Offshoal

cycle thickness: 0.8 m  1.0 m  2.5 m

increase in accommodation space (thicker cycles)

increase in grain-dominated facies
Multi-fold cyclicity

Cycle sets

Cycles
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
Facies proportions - principle

Regression

Transgression

proxy for accommodation space
Facies proportion curve
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
Stacking pattern diagram
Stacking pattern diagram

Dep. envir.:
- Marsh
- Peritidal
- Low-energy backshoal
- Mod-energy backshoal
- Shoal

Dunham Texture:
- R
- F
- B
- G
- P
- M

GR:
- 25 (cpd)
- 1000

Super-Seq. Sequences
Correlating stacking pattern diagrams

http://maps.google.com
Correlating stacking pattern diagrams

Wadi Sahtan

~ 23 km

Wadi Bani Kharus

marsh-dominated

landward trend
Multi-fold cyclicity

Cycles

Cycle sets

Sequences

10 m
Multi-fold cyclicity
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
Degree of rooting

Rooting index 5

Rooting index 3

Rooting index 1

Semiquantitative tool to determine order of a sequence boundary from outcrops & subsurface cores

Large-scale sequence boundaries

Small-scale cycle boundaries

Rooting index 5
in situ brecciation due to intensive rooting (> 75%)

Rooting index 4
strong rooting, incipient brecciation (50% - 75%)

Rooting index 3
roots abundant (25% - 50%)

Rooting index 2
roots common (5% - 25%)

Rooting index 1
rare rooting (< 6%)
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
Fischer plot - principle

Assumptions:

- peritidal environment with shallowing-upward cycles
- same cycle duration
- linear subsidence rate

→ cycle thickness reflects available accommodation space
Fischer plot – Wadi Muaidin

Based on cycles

Proxy for accommodation space
Fischer plot correlations

NW
Wadi Bani Kharus

SE

Cumulative departure from mean cycle thickness (m)

erosional unconformity

Wadi Muaidin

verification for correlation

~ 33 km
Outline

- Case Study
- Methodology
  - Facies proportions curves
  - Stacking pattern diagrams
  - Rooting index
  - Fischer plots
- Integrated Approach
Integrated Approach

- Facies proportion curves & stacking pattern diagrams
  - determination of sequence stratigraphic framework

- Rooting index
  - first-pass indicator of order of a seq. boundary

- Fischer plots
  - verification of correlation
Multiple criteria: robust seq. stratigraphy

- facies proportion curves
- stacking pattern diagrams
- rooting index
- fischer plots