The Contemporary Red Sea as an Analog for Ancient Carbonates in Rift Settings*

Sam J. Purkis1, Paul M. (Mitch) Harris2, and James Ellis3

Search and Discovery Article #51139 (2015)**
Posted September 7, 2015

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013.
Editor’s note: Please refer to related article by the authors, “Patterns of Sedimentation in the Contemporary Red Sea as an Analog for Ancient Carbonates in Rift Settings: Journal of Sedimentary Research, 2012, v. 82, p. 859-870.
**Datapages©2015 Serial rights given by authors. For all other rights contact authors directly.

1National Coral Reef Institute, Nova Southeastern University, Dania Beach, Florida (purkis@nova.edu)
2Chevron Energy Technology Company, San Ramon, CA (pmitchharris@gmail.com)
3Ellis Geospatial, Walnut Creek, CA; Lockport, NY (jellis@ellis-geospatial.com)

Abstract

In terms of its large size, the Red Sea is a unique contemporary analog for carbonate deposition in a marine rift setting. The Red Sea covers a full 20° of latitude, which is sufficiently long to display pronounced climate differences, and the clear tropical waters support vigorous coral reef growth and associated production of carbonate detritus. Six focus areas within the Red Sea, each covering 1600 sq. km, were selected to illustrate and analyze the variability of reefal and other carbonates in a rift setting. Five of the focus areas are located on a north-south transect along the sea’s western margin – (1) Gubal Straits (Egypt), (2) Shalatayn (Egypt), (3) Trinkitat (Sudan), (4) Dahlak (Eritrea), and (5) Halib (Eritrea); and one is from the eastern margin – (6) Farasan Banks (Saudi Arabia).

Using Landsat imagery, water depth, and two marine facies classes “reefal frameworks” and “sediments” were mapped. These two classes were lumped to define “carbonate bodies”, in turn analyzed for trends in orientation, as guided by local fault networks, and size-frequency distribution. Fault lineaments, which were digitized from the literature, are shown to direct the orientation of carbonate bodies with areas exceeding 5 km². Smaller bodies do not preferentially align with fault trends. Relationships between water depth and the occurrence of reefal frameworks and sediments were explored for the six focus areas. No deterministic relationship was found. Used as an analog, the assembled data from the contemporary Red Sea may provide insight into the orientation and scale of accumulation of carbonates in subsurface rift settings.

References Cited


Crane and Bonatti, 1987


The Contemporary Red Sea as an Analog for Ancient Carbonates in Rift Settings

Sam Purkis¹, Paul (Mitch) Harris² and Jim Ellis³

¹National Coral Reef Institute, Nova Southeastern University, Dania Beach, Florida, U.S.A.
²Chevron Energy Technology Company, San Ramon, California, U.S.A.
³Ellis GeoSpatial, Walnut Creek, California, U.S.A.
Rift basins provide many shallow-water sites for the establishment of carbonate platforms.

Carbonate-dominated marine rifts are common in the geological record.

Few well-documented ancient examples where facies distribution can be shown to be controlled by rift-related faulting (but see Burchette (1988), Cross et al. (1998) and Cross and Bosence (2008) for mid-Miocene onshore Gulf of Suez rift; Dorobek (2008) for several Tertiary and Mesozoic examples).

Red Sea potentially represents a modern analog for rift marine carbonate sedimentation - Possible insight into reservoir distribution.
The Database:
- Six focus areas, each 1,600 sq. km
- Satellite imagery, water depth maps, delineated "carbonate bodies", GIS
- Onshore fault lineaments digitized from literature

Aim:
- Use the Modern Red Sea to explore local and regional controls on shallow-water carbonate facies geometry
- Illustrate patterns that could provide insight into the geometry and scales of accumulation of carbonates in subsurface analogs

Key Insights:
- Fault lineaments are closely related to the orientation of carbonate bodies with areas >5 sq. km
- Smaller bodies do not preferentially align with fault trends
- At Landsat-scale, water depth and the occurrence of reefal frameworks and sediments are not systematically related
- At fine-scale, facies can better be used to constrain water depth ... but with caveats
For each of the six focus areas...

[2] Shalatayn

True-color Landsat

- Sediments (= skeletal grainstone)
- Reefal frameworks (= primarily boundstone)

Facies map

Carbonate bodies

Morphometric interrogation

Bathymetry map

Water depth

Minimum distance to periphery of carbonate body
Orientation of carbonate bodies

Trend of the recent Red Sea spreading axis (130° - 140°)
Crane and Bonatti (1987)

Tectonic grain (literature)
- Khalil and McClay ('02)
- Bott et al. ('92)
- Carbone et al. ('98)
- Crane and Bonatti ('87)
Orientation of the carbonate bodies

A

- [1] Gubal Straits
- [2] Shalatayn
- [3] Trinkitat
- [4] Dahlak
- [5] Halib
- [6] Farasan

Legend
- Carbonate body
- Orientation of fault lineaments grouped into 15° segments

B

Analysis of variance table

<table>
<thead>
<tr>
<th></th>
<th>Body area &lt; 5 sq. km</th>
<th>Body area &gt; 5 sq. km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p value (n)</td>
<td>p value (n)</td>
</tr>
<tr>
<td>[1] Gubal</td>
<td>0.01 (73)</td>
<td>0.57 (11)</td>
</tr>
<tr>
<td>[2] Shalatayn</td>
<td>0.00 (172)</td>
<td>0.85 (11)</td>
</tr>
<tr>
<td>[3] Trinkitat</td>
<td>0.34 (271)</td>
<td>0.89 (7)</td>
</tr>
<tr>
<td>[4] Dahlak</td>
<td>0.00 (58)</td>
<td>0.00 (7)</td>
</tr>
<tr>
<td>[5] Halib</td>
<td>0.00 (33)</td>
<td>0.31 (9)</td>
</tr>
<tr>
<td>[6] Farasan</td>
<td>0.00 (64)</td>
<td>0.52 (10)</td>
</tr>
</tbody>
</table>

Not significantly different at 95% CI (populations have equal means)
Significantly different at 95% CI (populations have unequal means)
Why is the orientation of carbonate bodies related to rift tectonics?

Fault-block platforms (Bosence '98)
BOSENCE et al. ’98 MPG 15:203-221
Salt-diapir platforms (Bosence '05)

Evaporite mobilization along fault planes modifies seafloor morphology.

Location of diapiric structures in the southern Gulf of Suez (after Orszag-Sperber et al '98)

Evaporite Mobilization along fault planes modifies seafloor morphology.

Trend of the recent Red Sea spreading axis (130° - 140°)
Crane and Bonatti (1987)

Bathymetry
0 m
-2,700 m

CP = Carbonate platform

Diapir (Miocene evaporites)
Indirect tectonic influence on environment

- Rift topography channels wind parallel to the trend of the spreading axis (credit Ian Sharp)
- Convergence of opposing wind fields from the N and S Red Sea causes wind direction in the vicinity of Dahlak to deviate from the orientation of the rift
- This is the only focus area where the alignment of carbonate bodies is unrelated to the local fault network
Trend of the recent Red Sea spreading axis (130° - 140°)
Crane and Bonatti (1987)

Populations have unequal means

Data credit: Gwilym Rowlands, NCRI
Facies-water depth relationships

- Sediments
- Reefal frameworks

[1] Dahiak
- Norah Is.
- Pleistocene cover
- Expansive promontories

[2] Shalatayn
- Deep water reentrant
- Dissolution collapse
- Salt tectonics create sinuous narrow shallow water banks

[3] Farasan
- Strike of rift
- Dissolution collapse
Facies-water depth relationships

Shallow ramp cycles Oselger '91
(Upper Cambrian)

Oselger '91, Geology
Facies-water depth relationships – at higher resolution

Landsat 30 m

Quickbird 2.5 m
Facies-water depth relationships – at higher resolution

By looking at a map of lithofacies, depth can be inferred.

Conclusions

- Fault lineaments are closely related to the orientation of carbonate bodies with areas >5 sq. km.
- Smaller bodies do not preferentially align with fault trends.
- Faults and diapirism relevant to predictability in orientation, as is rift influence on winds.
- Facies do display water-depth-dependent attributes; but relationship varies with depth (and palaeo-water depth !).
- Used as an analog, these data may provide insight into the orientation and scale of accumulation of carbonates in subsurface marine rifts.

Please refer to: Journal of Sedimentary Research, DOI: 10.2110/jsr.2012.77

Patterns of sedimentation in the contemporary Red Sea as an analog for ancient carbonates in rift settings

Sam J. Purkis, Paul M. (Mitch) Harris, and James Ellis