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

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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 km^2. 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

Bosence, D.W.J., N.E. Cross, and S. Hardy, 1998, Architecture and depositional sequences of Tertiary fault-block carbonate platforms; an analysis from outcrop and computer modeling: Marine and Petroleum Geology, v. 15, p. 203-221.

Bott, W.F., B.A Smith, G. Oakes, A.H. Sikander, and A.I. Ibraham, 1992, The tectonic framework and regional hydrocarbon prospectivity of the Gulf of Aden: Journal of Petroleum Geology, v. 15, p. 211–243.

Burchette, T.P., 1988, Tectonic control on carbonate platform facies distribution and sequence development: Miocene, Gulf of Suez: Sedimentary Geology, v. 59, p. 179–204.

Carbone, F., R. Matteucci, and A. Angelucci, 1998, Present-day sedimentation on the carbonate platforms of the Dahlak Islands, Eritrea, *in* B.H. Purser and D.W.J. Bosence, editors, Sedimentation and Tectonics in Rift Basins: Red Sea–Gulf of Aden: London, Chapman and Hall, p. 523–536.

Crane and Bonatti, 1987
Crane, K., and E. Bonatti, 1987, The role of fracture zones during early Red Sea rifting: structural analysis using Space Shuttle radar and Landsat imagery: Journal of the Geological Society, London, v. 144, p. 407–420.

Cross, N.E., and D.W.J. Bosence, 2008, Tectono-sedimentary models for rift-basin carbonate systems, *in* J. Lukasik and T. Simo, editors, Controls on Carbonate Platform and Reef Development: SEPM Special Publication 89, p. 83–105.

Cross, N.E., D.W.J. Bosence, and B.H. Purser, 1998, The tectono-sedimentary evolution of a rift margin carbonate platform: Abu Shaar, Gulf of Suez, Egypt, *in* B.H. Purser and D.W.J. Bosence, editors, Sedimentation and Tectonics in Rift Basins:Red Sea–Gulf of Aden: London, Chapman and Hall, p. 271–295.

Dorobek, S.L., 2008, Tectonic and depositional controls on syn-rift carbonate platform sedimentation, *in* J. Lukasik and T. Simo, editors, Controls on Carbonate Platform and Reef Development: SEPM Special Publication 89, p. 57–81.

Khalil, S.M., and K.R. McClay, K.R., 2002, Extensional fault-related folding, northwest Red Sea, Egypt: Journal of Structural Geology, v. 24, p. 743–762.

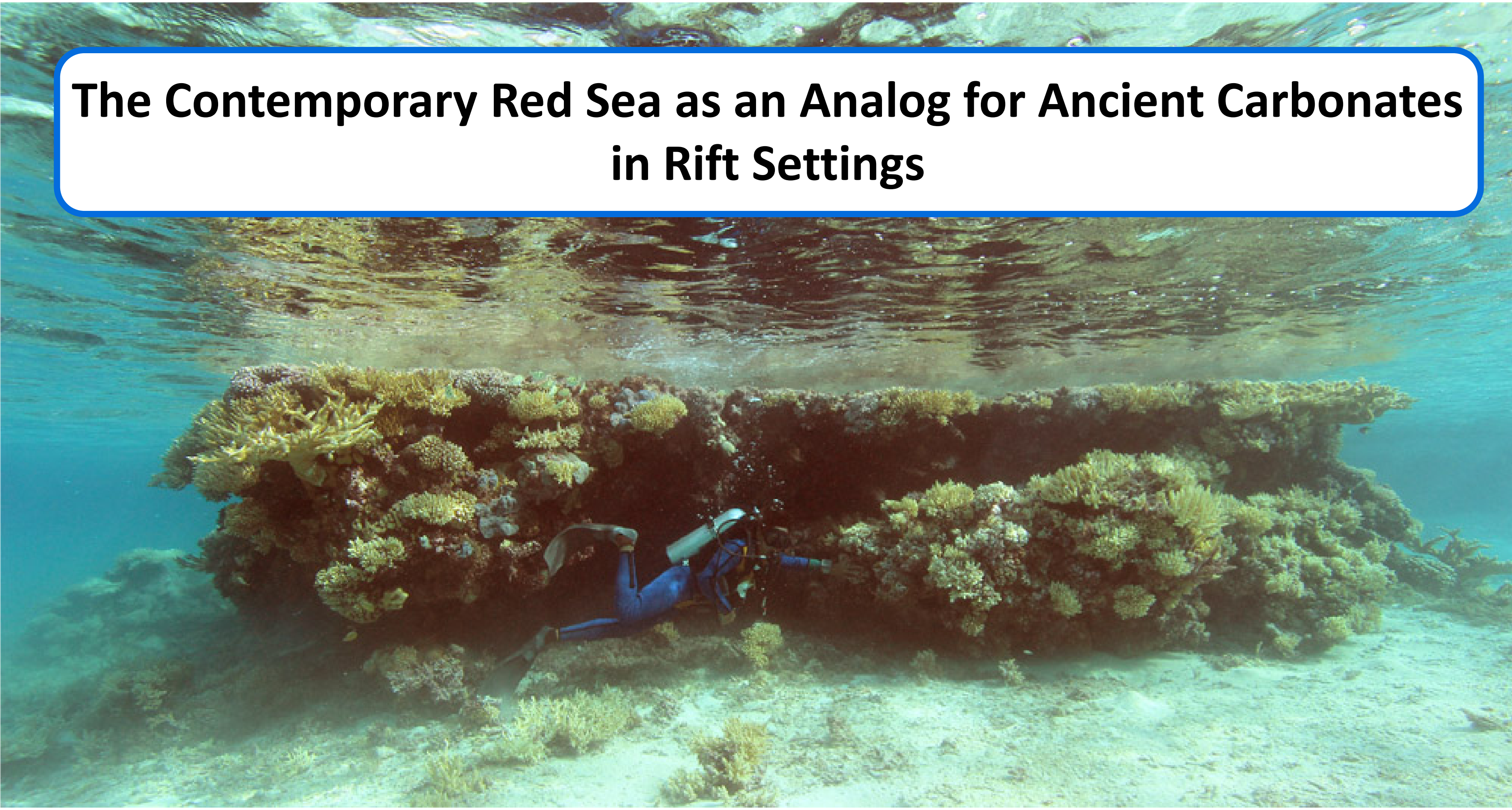
Orszag-Sperber, F., G. Harwood, A. Kendall, and B.H. Purser, 1998, A review of the evaporites of the Red Sea–Gulf of Suez rift, *in* B.H. Purser, and D.W.J. Bosence, editors, Sedimentation and Tectonics in Rift Basins: Red Sea–Gulf of Aden: London, Chapman and Hall, p. 409–425.

Osleger, D.A.**,** 1991, Subtidal carbonate cycles: Implications for allocyclic versus autocyclic controls: Geology, v.19, p.917-920.

Purkis, S.J. , P.M. Harris, and J. Ellis, 2012, 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. Website accessed August 27, 2015, http://archives.datapages.com/data/sepm/journals/082/082011/859_gsjsedres820859.htm?q=%2BauthorStrip%3Apurkis+%2ByearSort%3A%5B2012+TO+2012%5D+-isMeetingAbstract%3Amtgabsyes.

Rankey, E.C., 2004, On the interpretation of shallow shelf carbonate facies and habitats: how much does water depth matter?: Journal of Sedimentary Research, v. 74, p. 2–6.

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



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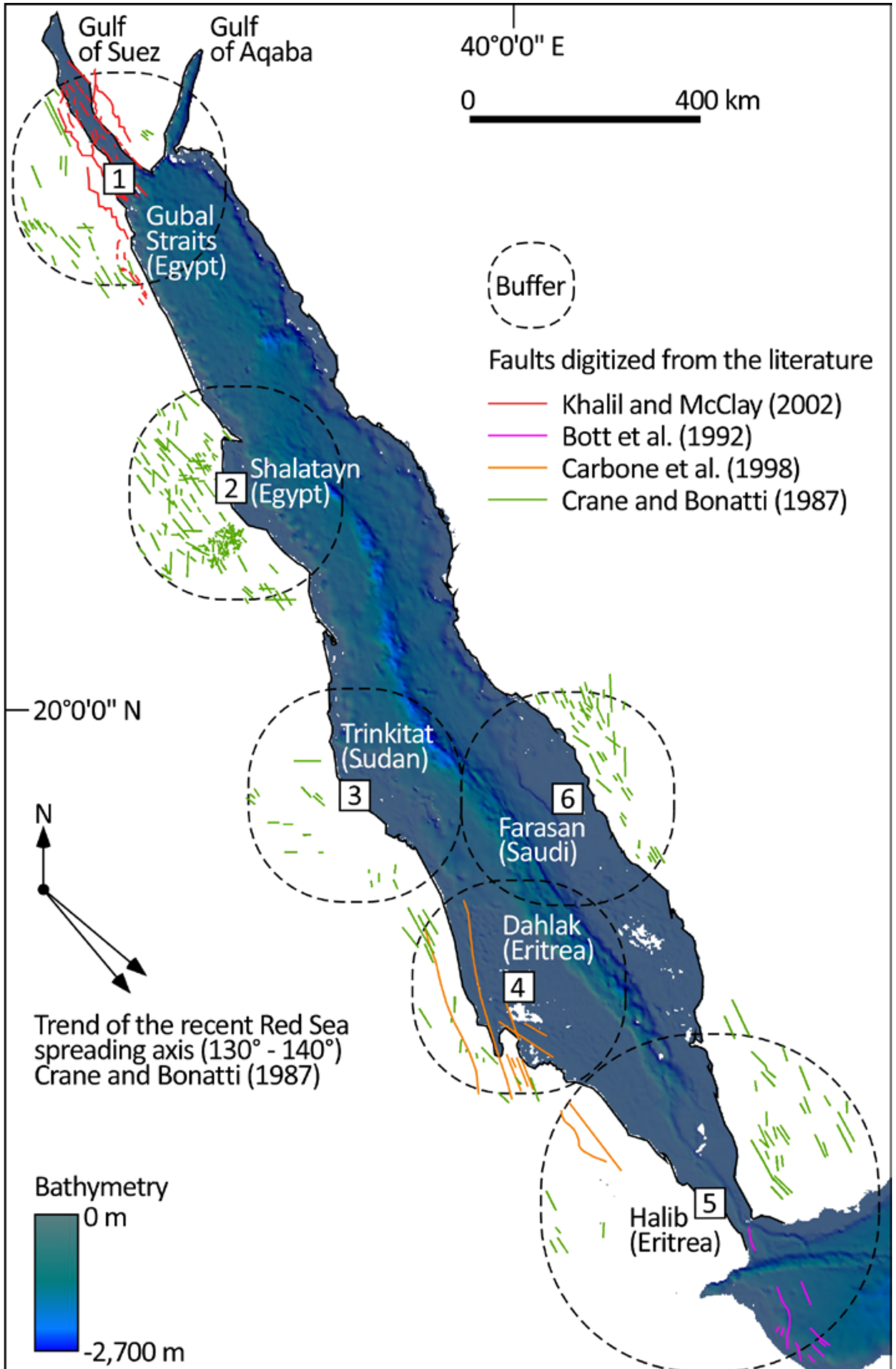
- Rift basins provide many shallow-water sites for the establishment of carbonate platforms
- Carbonate-dominated marine rifts are common in the geological record
- Few well documented ancient examples where facies distribution can be shown to be controlled by rift-related faulting (*but see* Burchette (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:

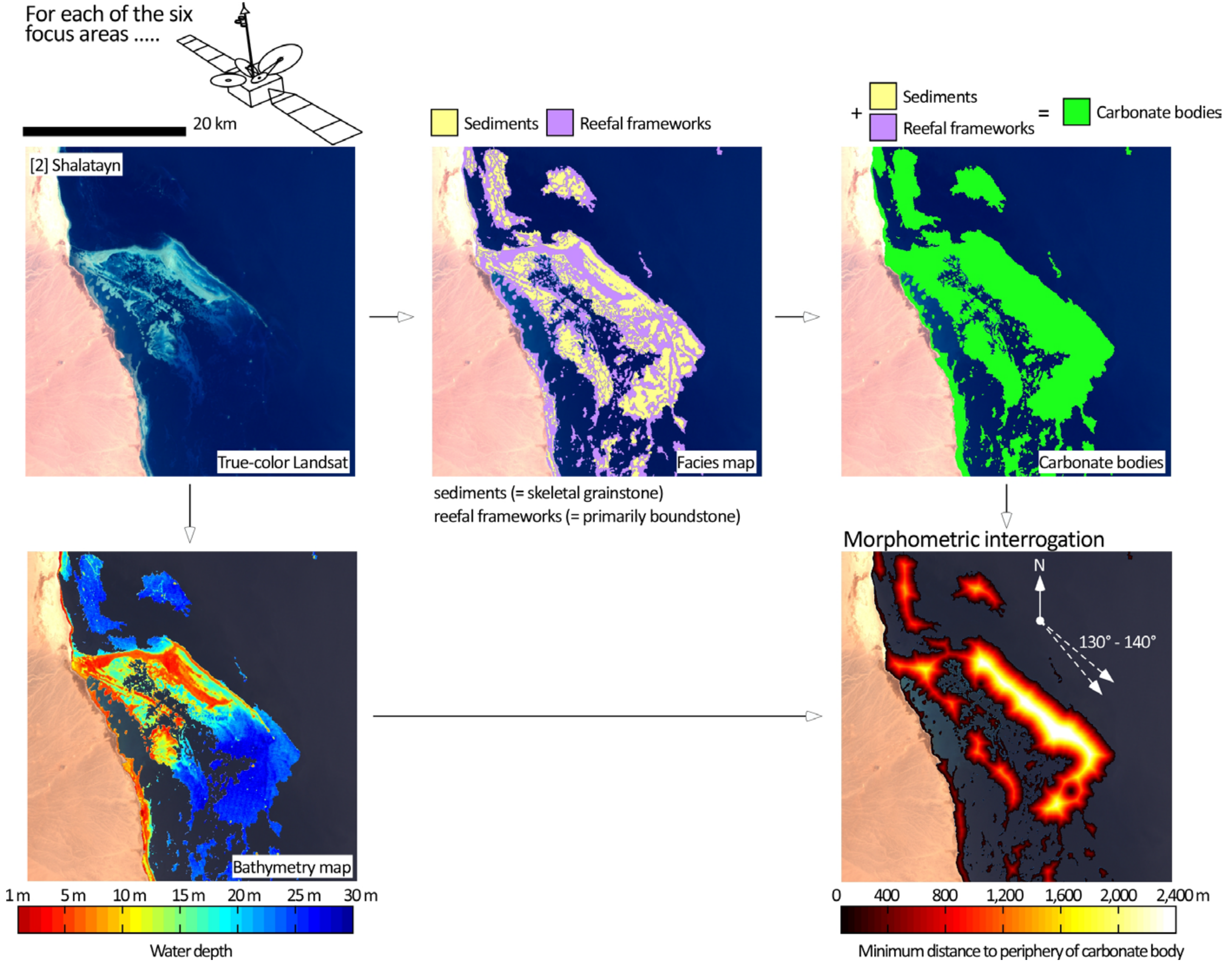
- Six focus areas, each 1,600 sq. km
- Satellite imagery, water depth maps, delineated "carbonate bodies", GIS
- Onshore fault lineaments digitized from literature

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

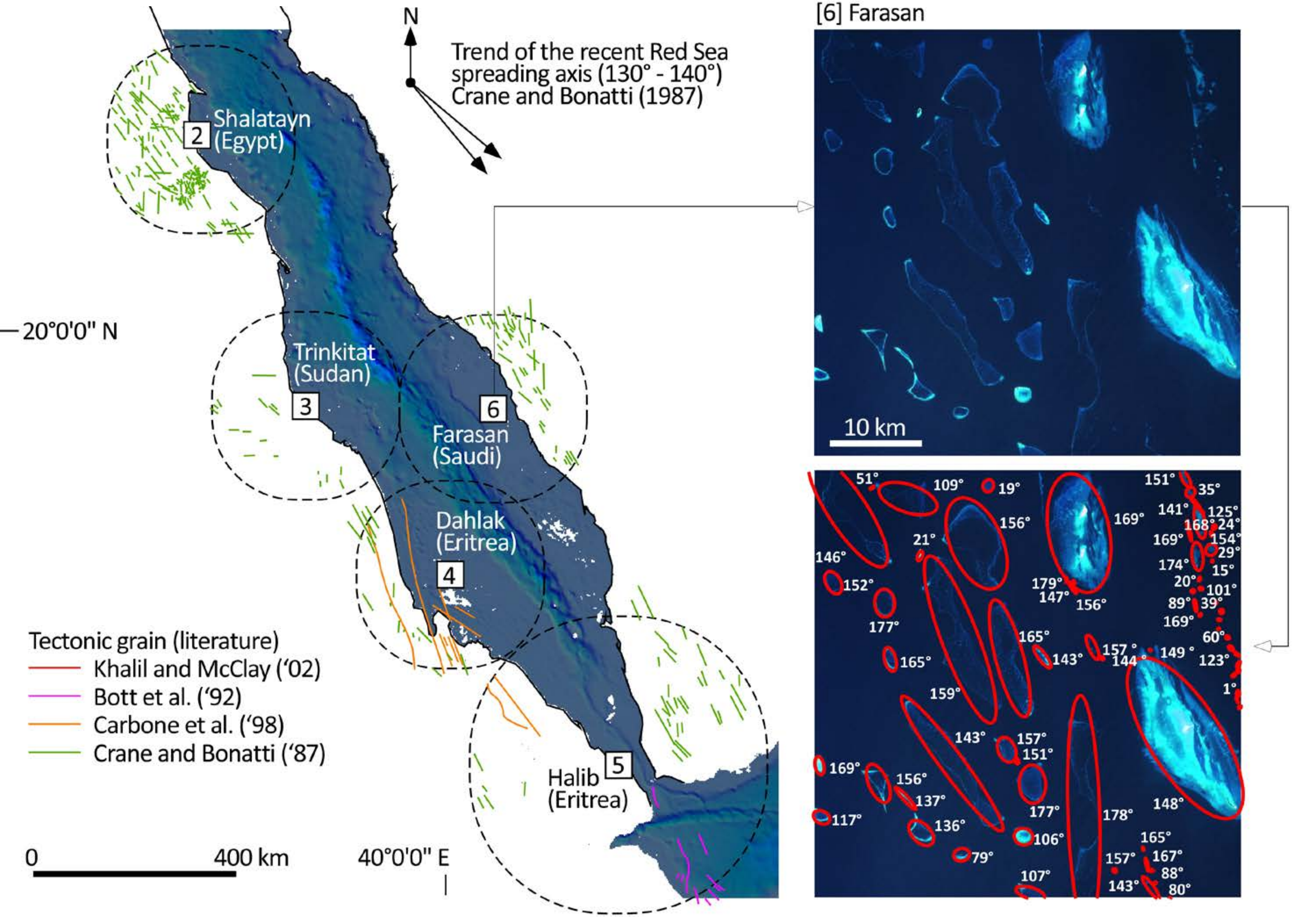
Key Insights:

- 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

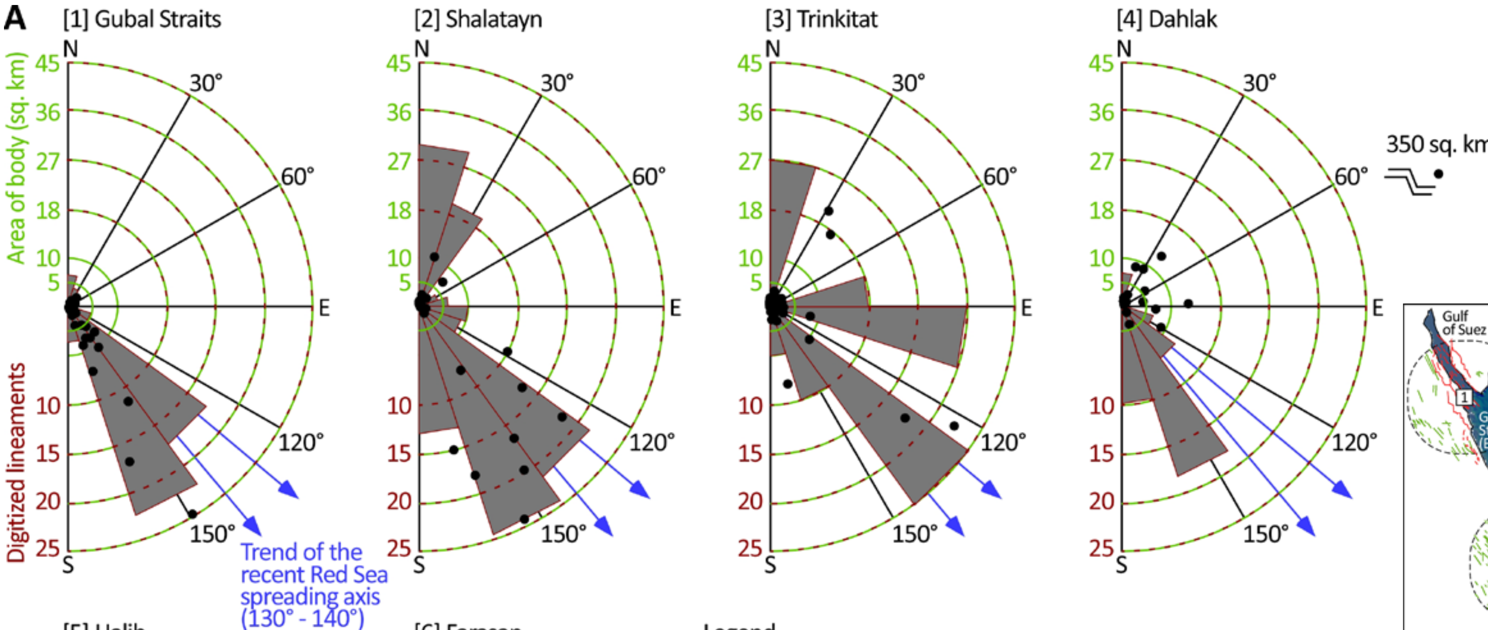


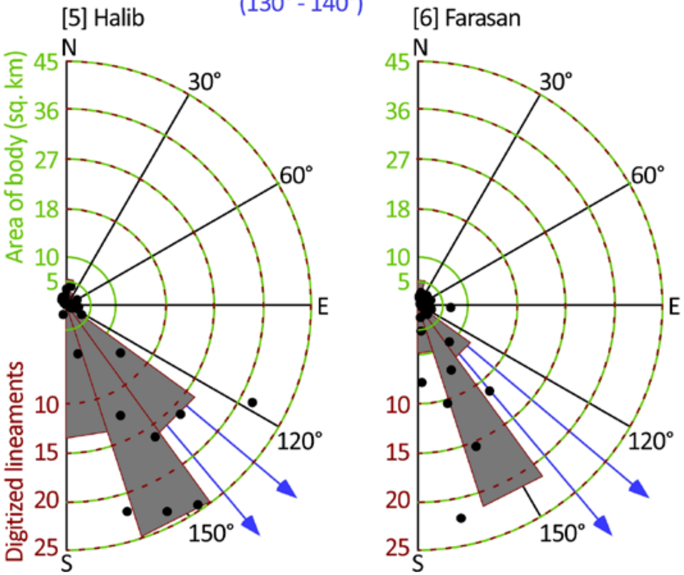
For each of the six focus areas .....
20 km
[2] Shalatayn
True-color Landsat
Sediments
Reefal frameworks
Facies map
sediments (= skeletal grainstone)
reefal frameworks (= primarily boundstone)
+
Sediments
Reefal frameworks
=
Carbonate bodies
Carbonate bodies
Bathymetry map
1 m
5 m
10 m
15 m
20 m
25 m
30 m
Water depth
Morphometric interrogation
N
130° - 140°
0
400
800
1,200
1,600
2,000
2,400 m
Minimum distance to periphery of carbonate body

Orientation of carbonate bodies



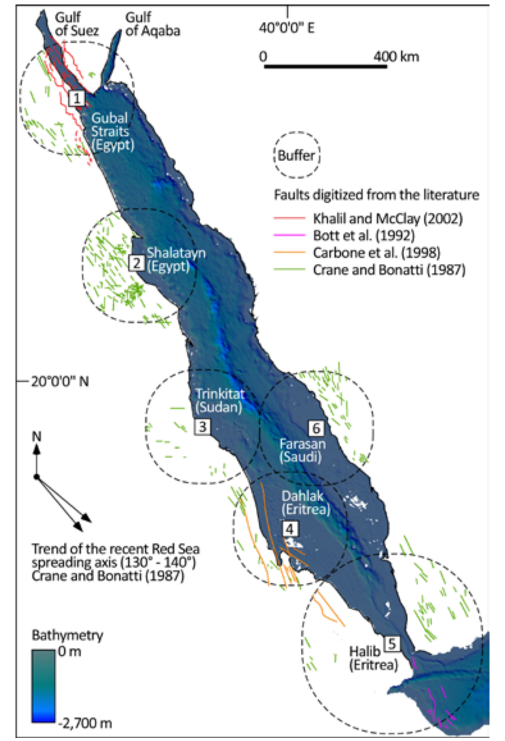
Orientation of the carbonate bodies





Legend

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

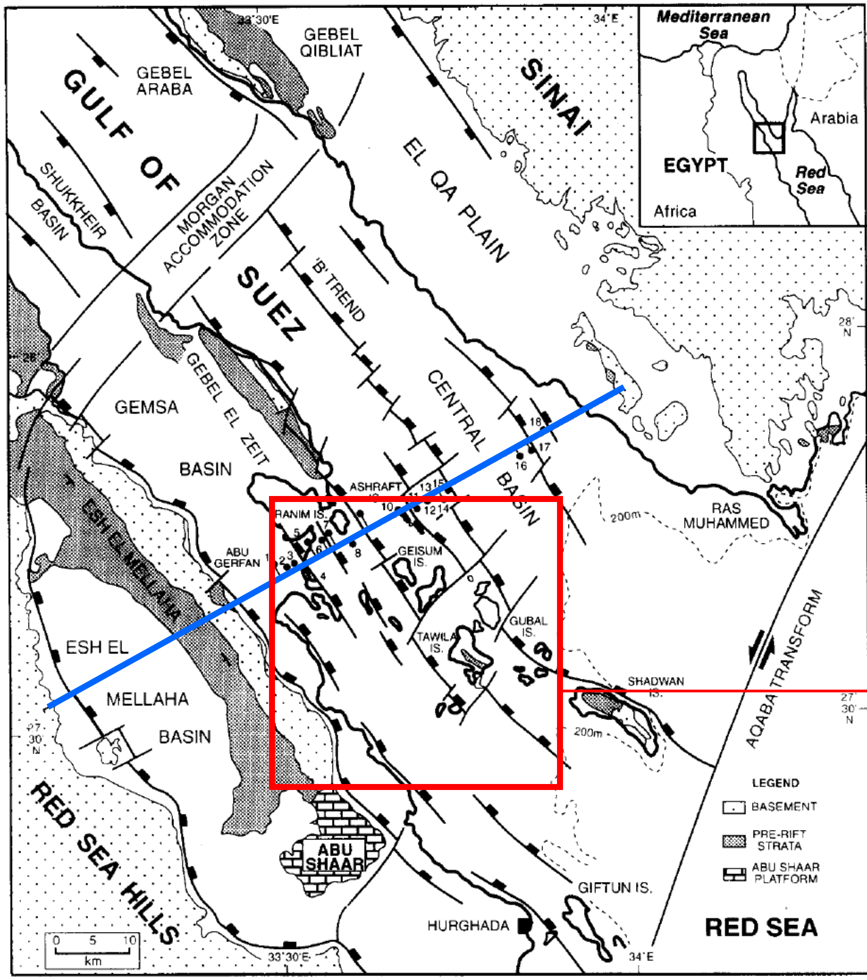


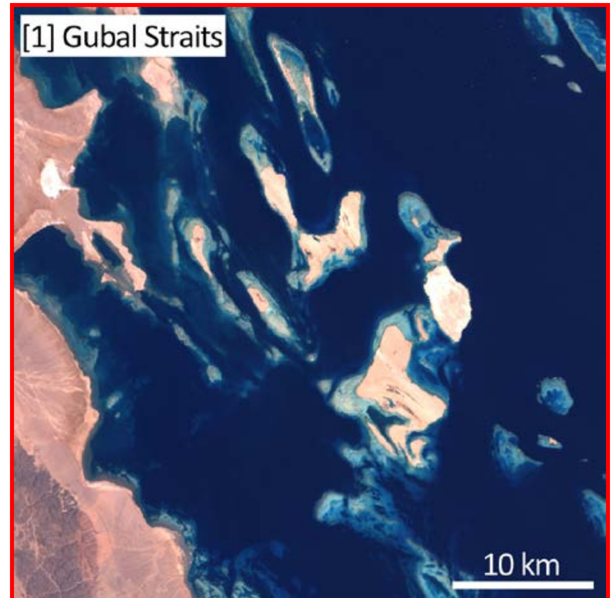
B Analysis of variance table

	Body area < 5 sq. km *p* value (*n*)	Body area > 5 sq. km *p* value (*n*)
[1] Gubal	0.01 (*73*)	0.57 (*11*)
[2] Shalatayn	0.00 (*172*)	0.85 (*11*)
[3] Trinkitat	0.34 (*271*)	0.89 (*7*)
[4] Dahlak	0.00 (*58*)	0.00 (*7*)
[5] Halib	0.00 (*33*)	0.31 (*9*)
[6] Farasan	0.00 (*64*)	0.52 (*10*)

Not significantly different at 95% CI (populations have equal means)
Significantly different at 95% CI (populations have unequal means)

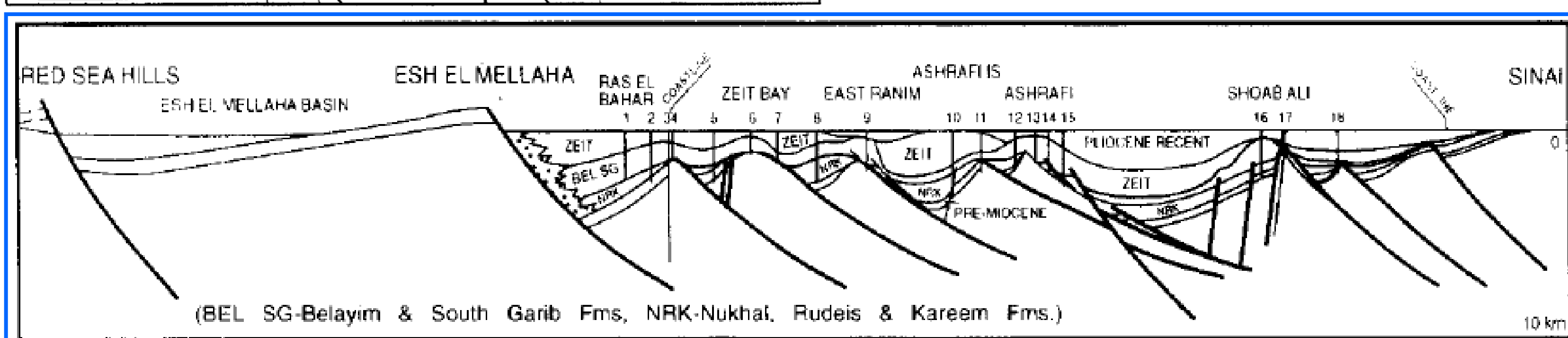
Why is the orientation of carbonate bodies related to rift tectonics?



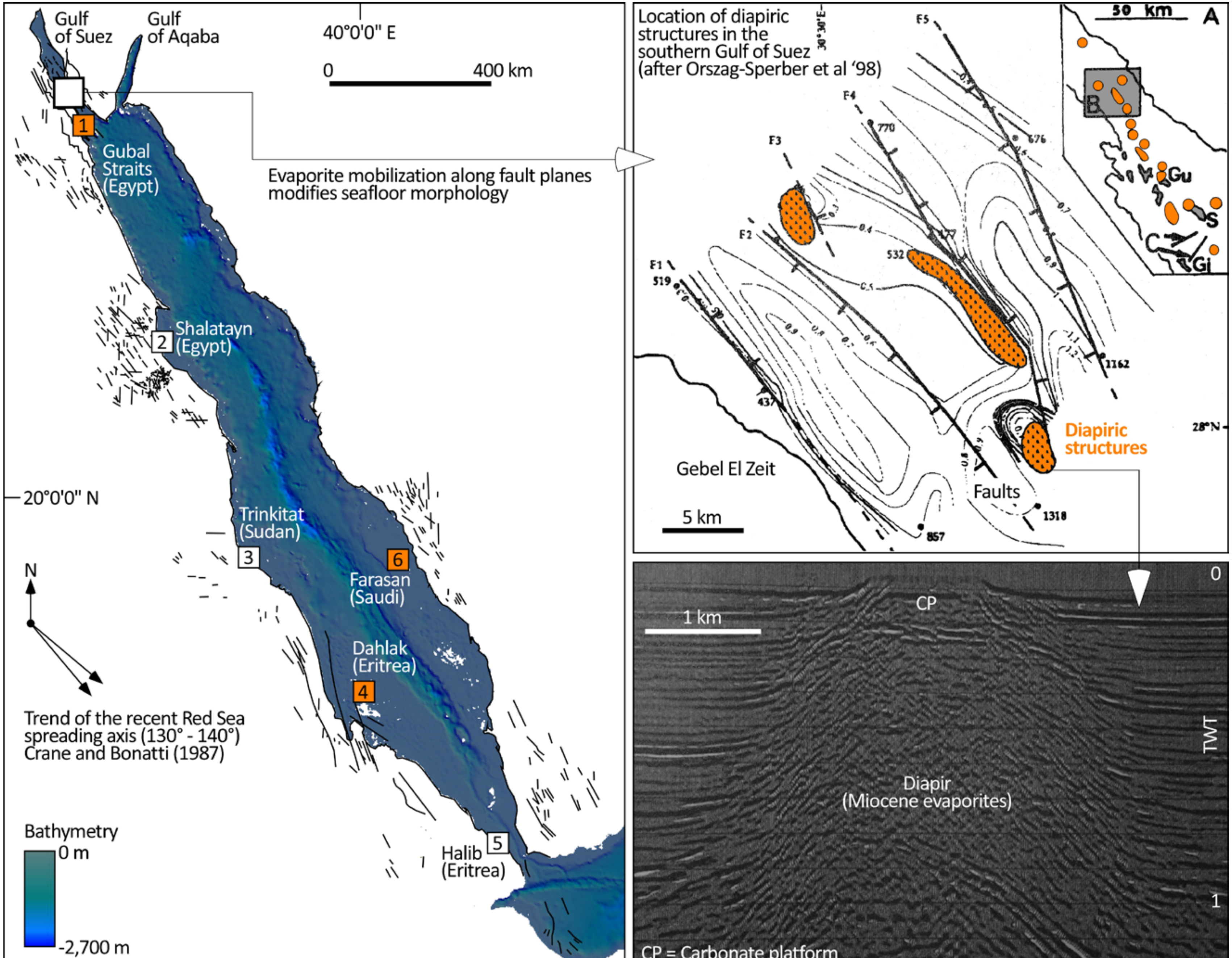


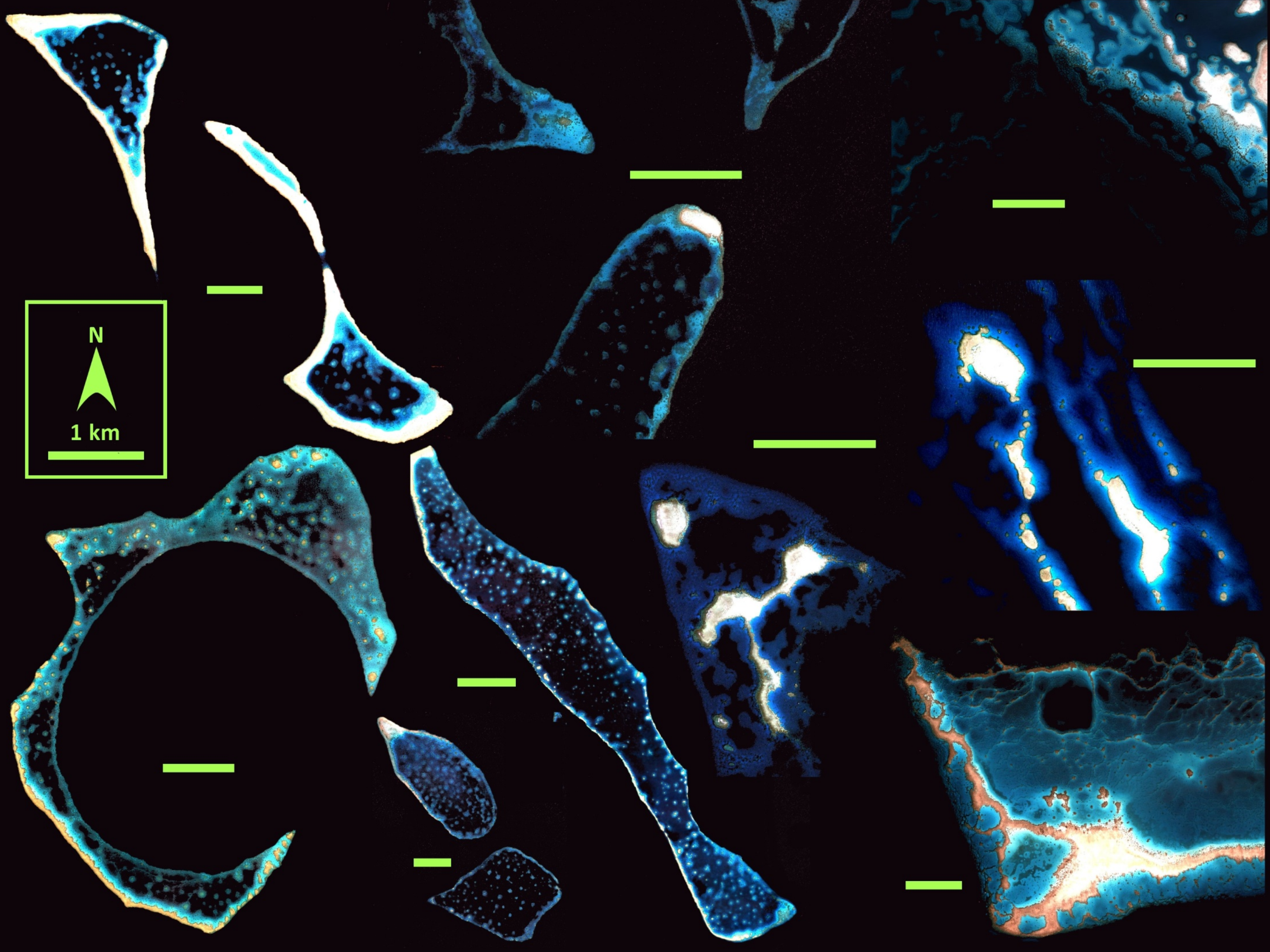
Fault-block platforms (Bosence '98)

BOSENCE et al. '98 MPG 15:203-221



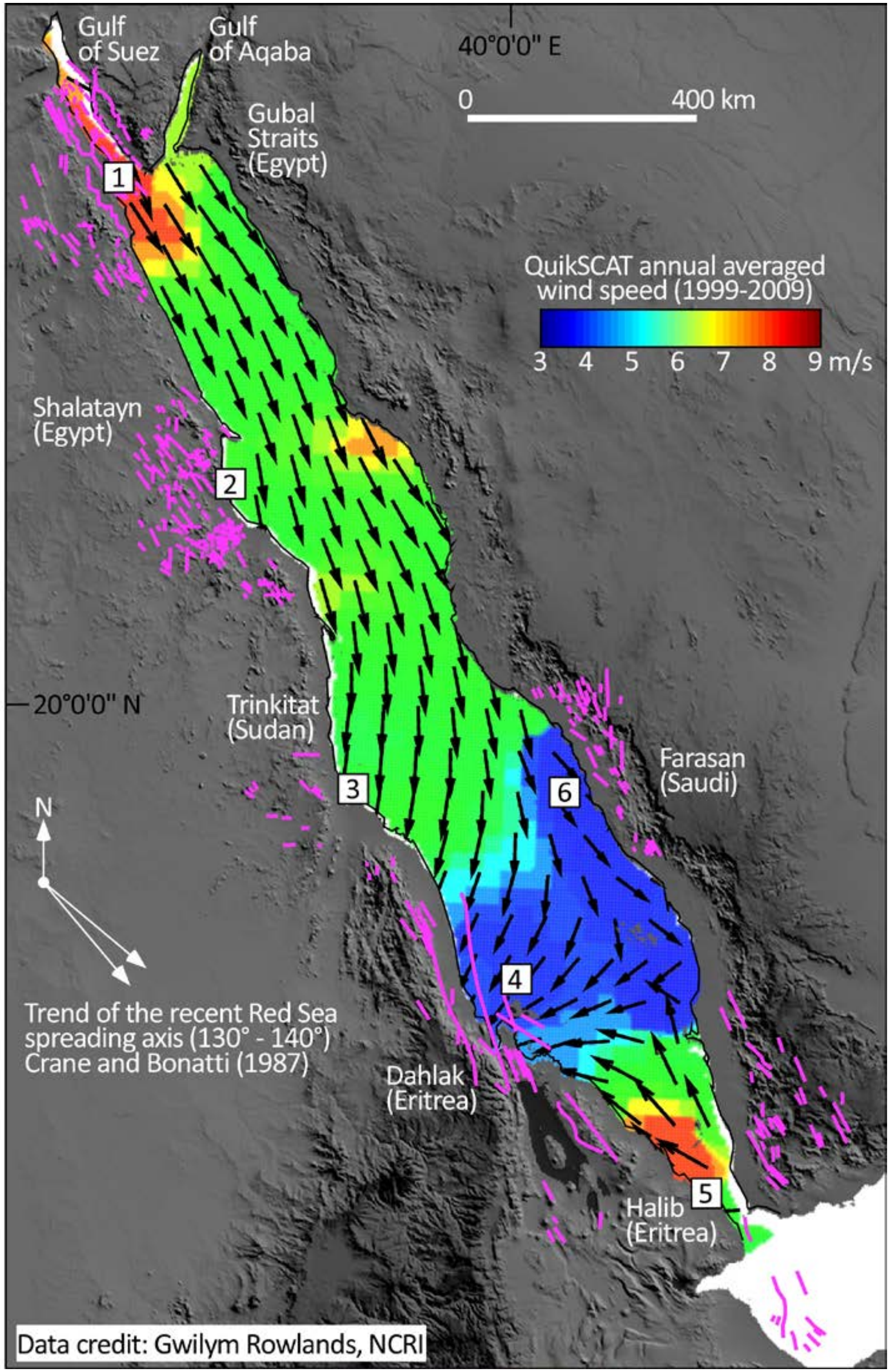
Salt-diapir platforms (Bosence '05)

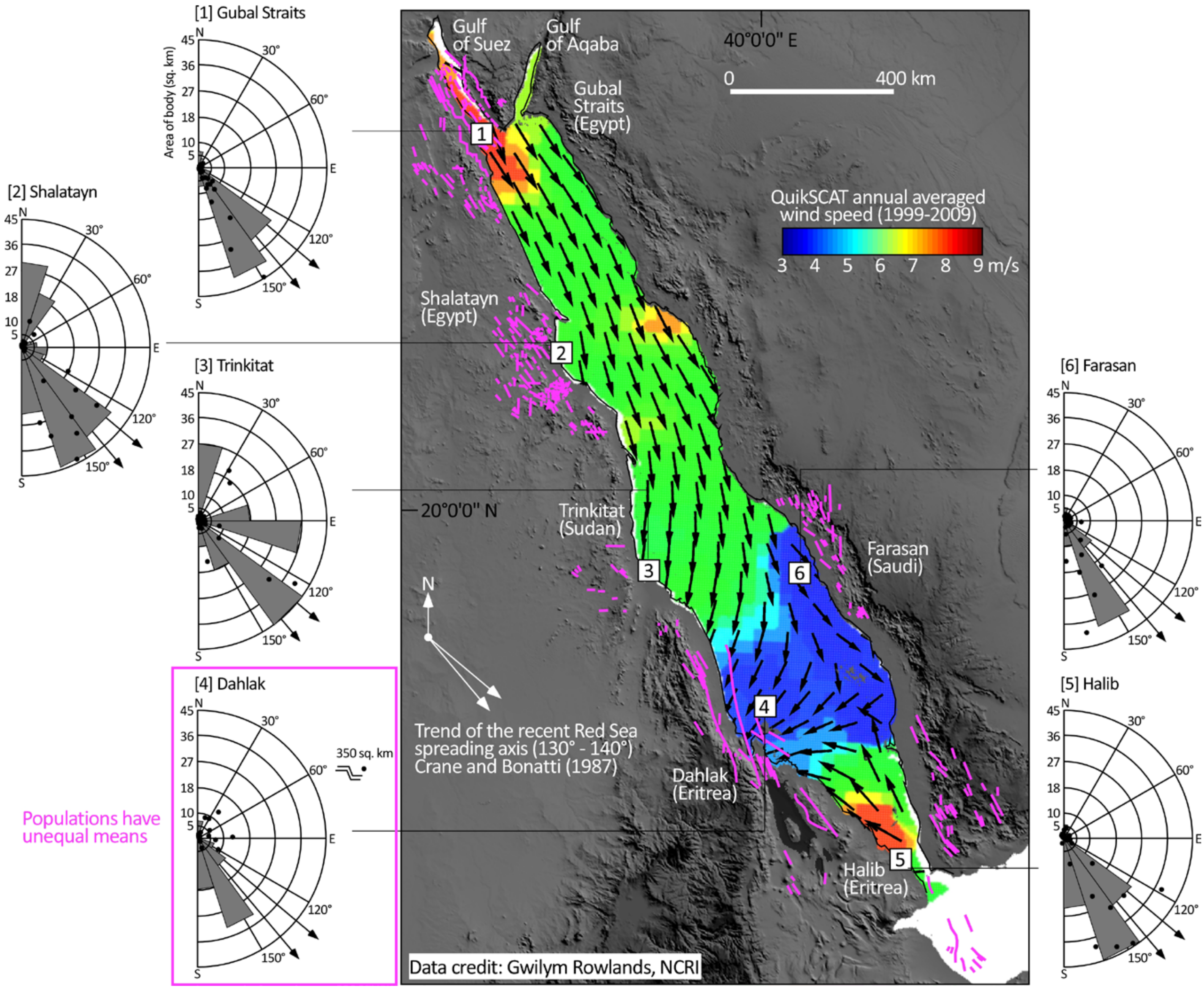



N
1 km

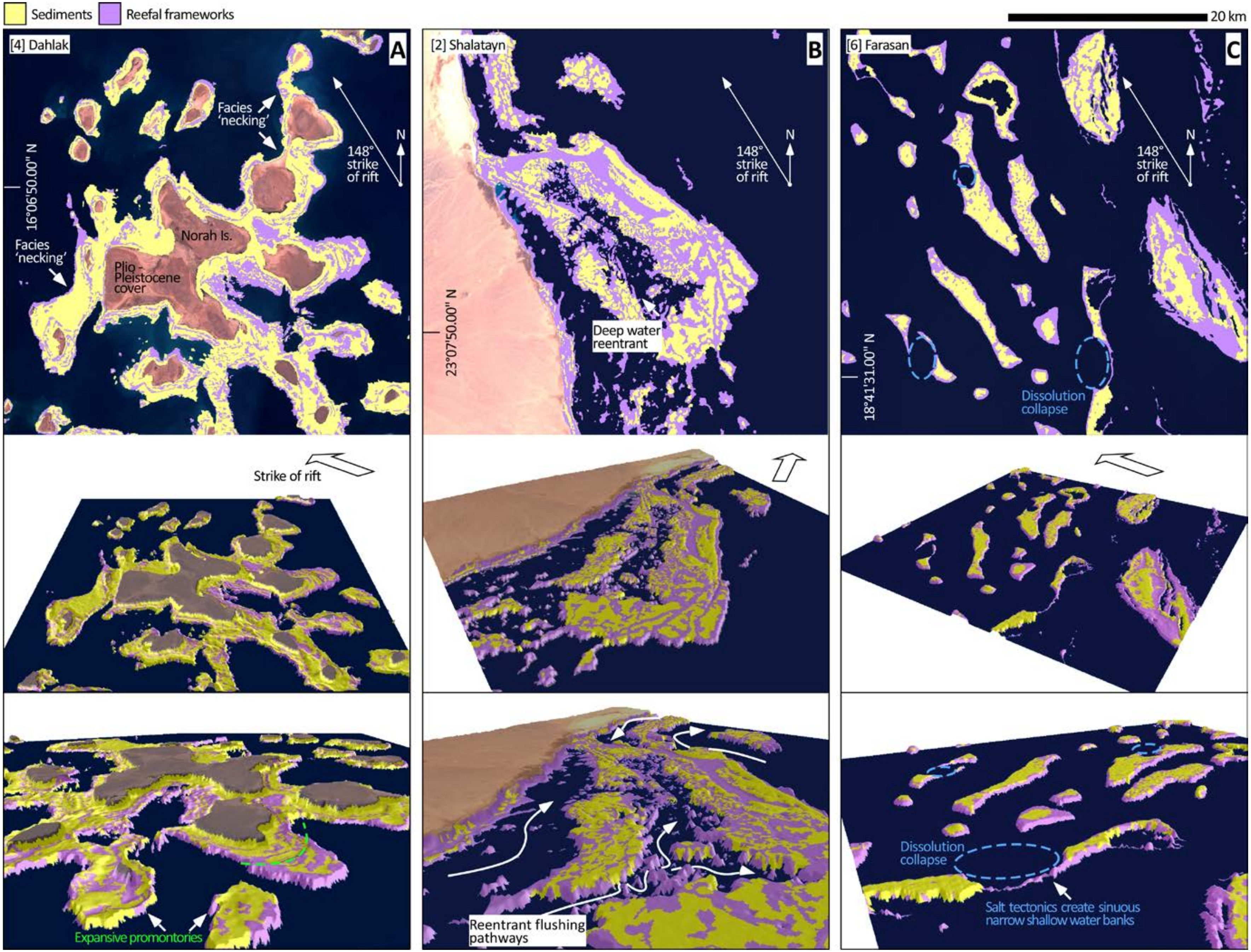
Indirect tectonic influence on environment

- 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

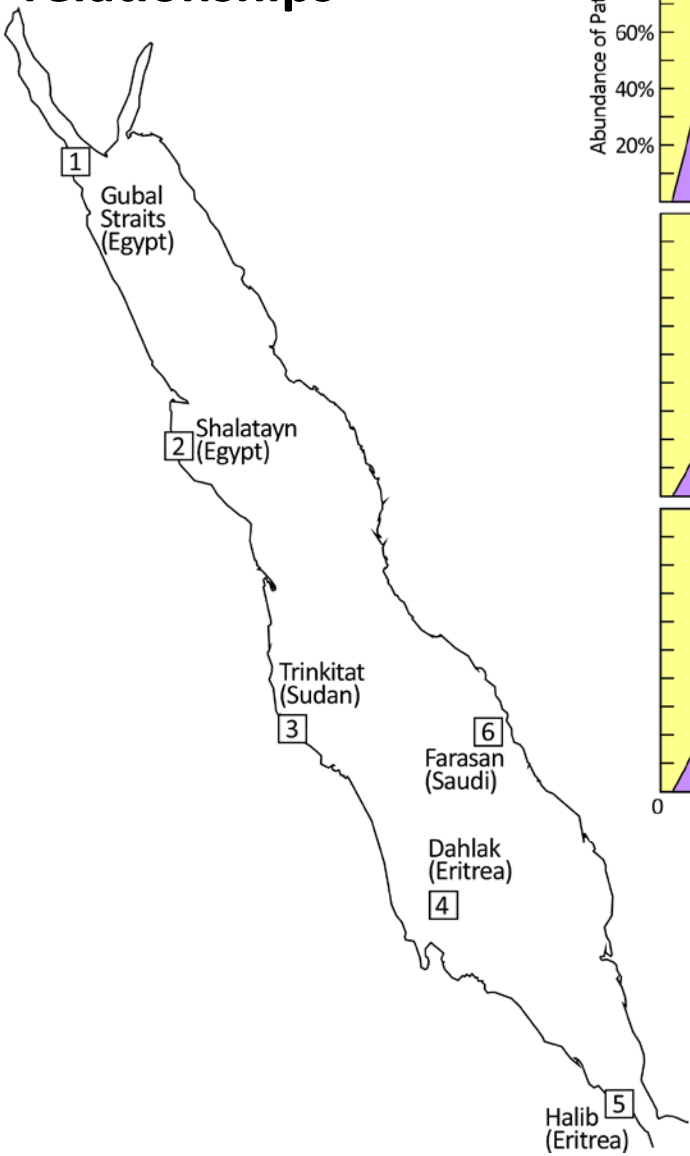


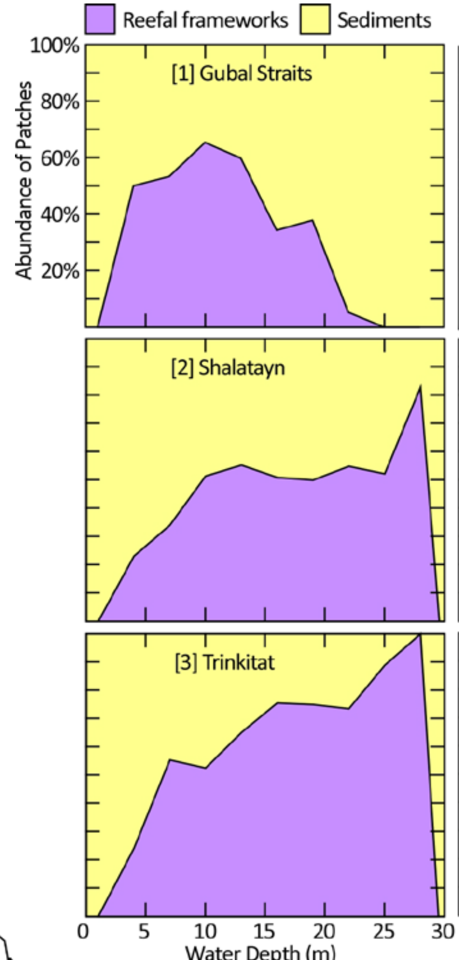

[1] Gubal Straits
[2] Shalatayn
[3] Trinkitat
[4] Dahlak
[5] Halib
[6] Farasan
Area of body (sq. km)
350 sq. km
Populations have unequal means
Gulf of Suez
Gulf of Aqaba
Gubal Straits (Egypt)
Shalatayn (Egypt)
Trinkitat (Sudan)
Farasan (Saudi)
Dahlak (Eritrea)
Halib (Eritrea)
40°0'0" E
20°0'0" N
0 400 km
QuikSCAT annual averaged wind speed (1999-2009)
3 4 5 6 7 8 9 m/s
Trend of the recent Red Sea spreading axis (130° - 140°) Crane and Bonatti (1987)
Data credit: Gwilym Rowlands, NCRI

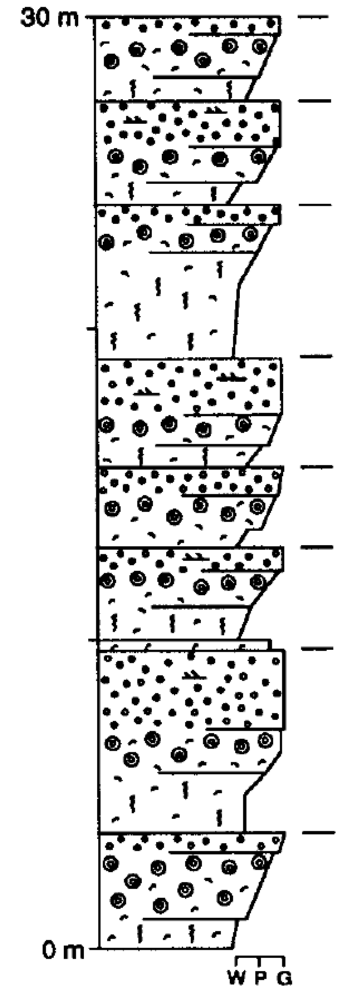
Facies-water depth relationships



Facies-water depth relationships



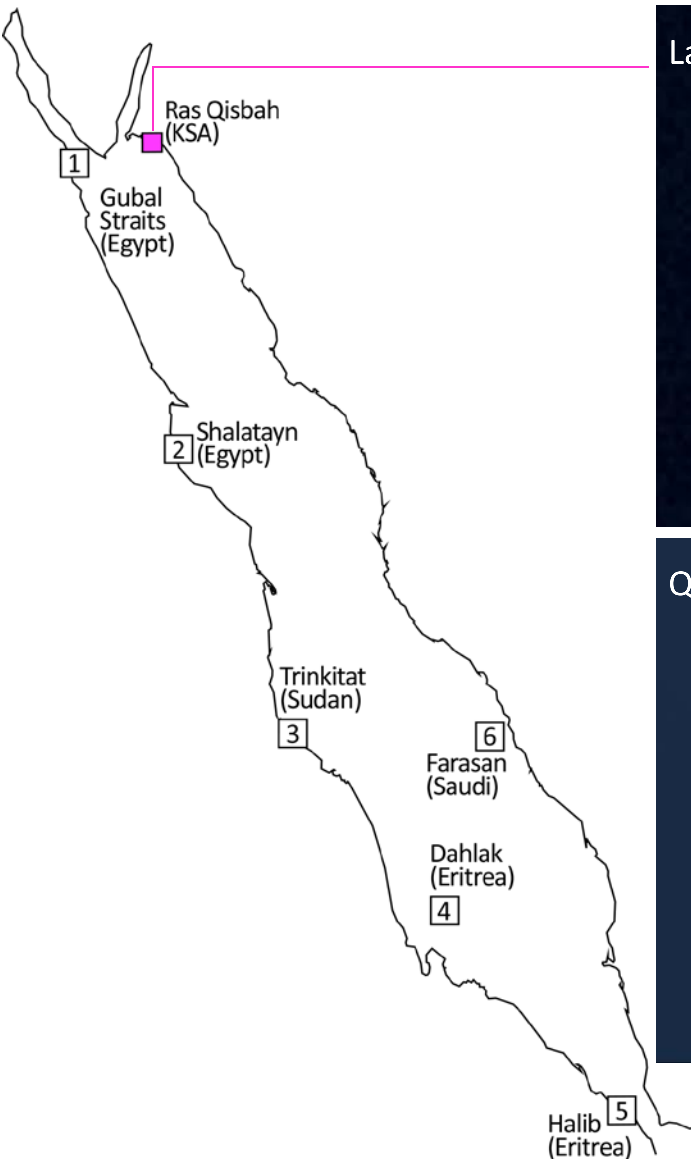


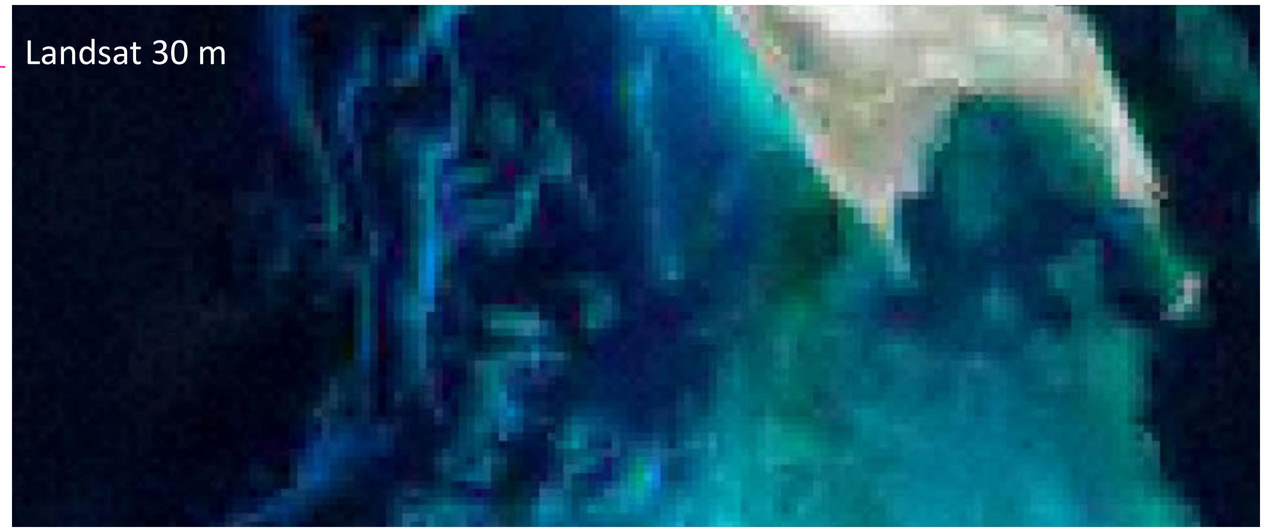


Shallow ramp cycles Oselger ’91 (Upper Cambrian)

Oselger ‘91, Geology

Facies-water depth relationships – at higher resolution





1 km

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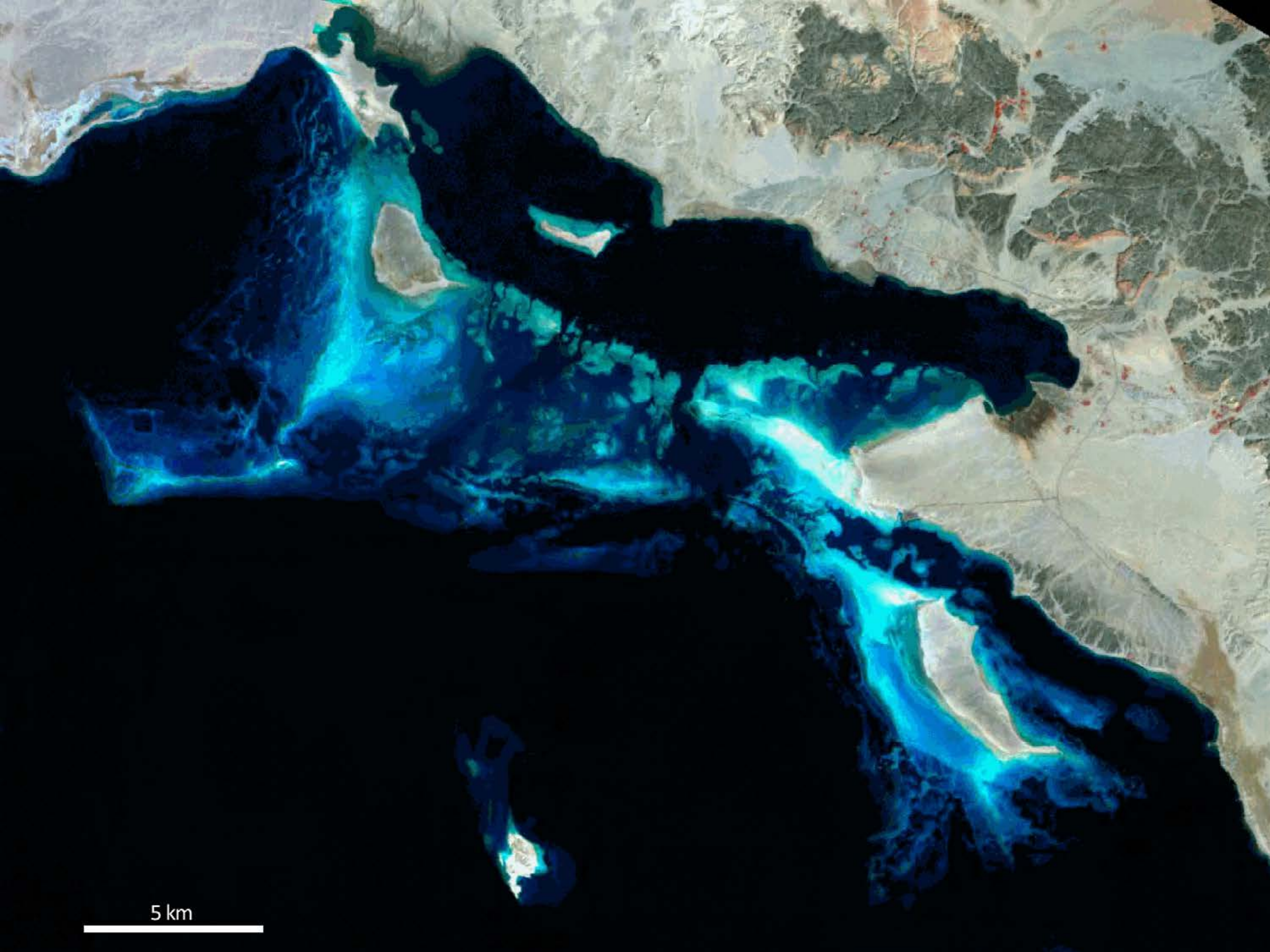
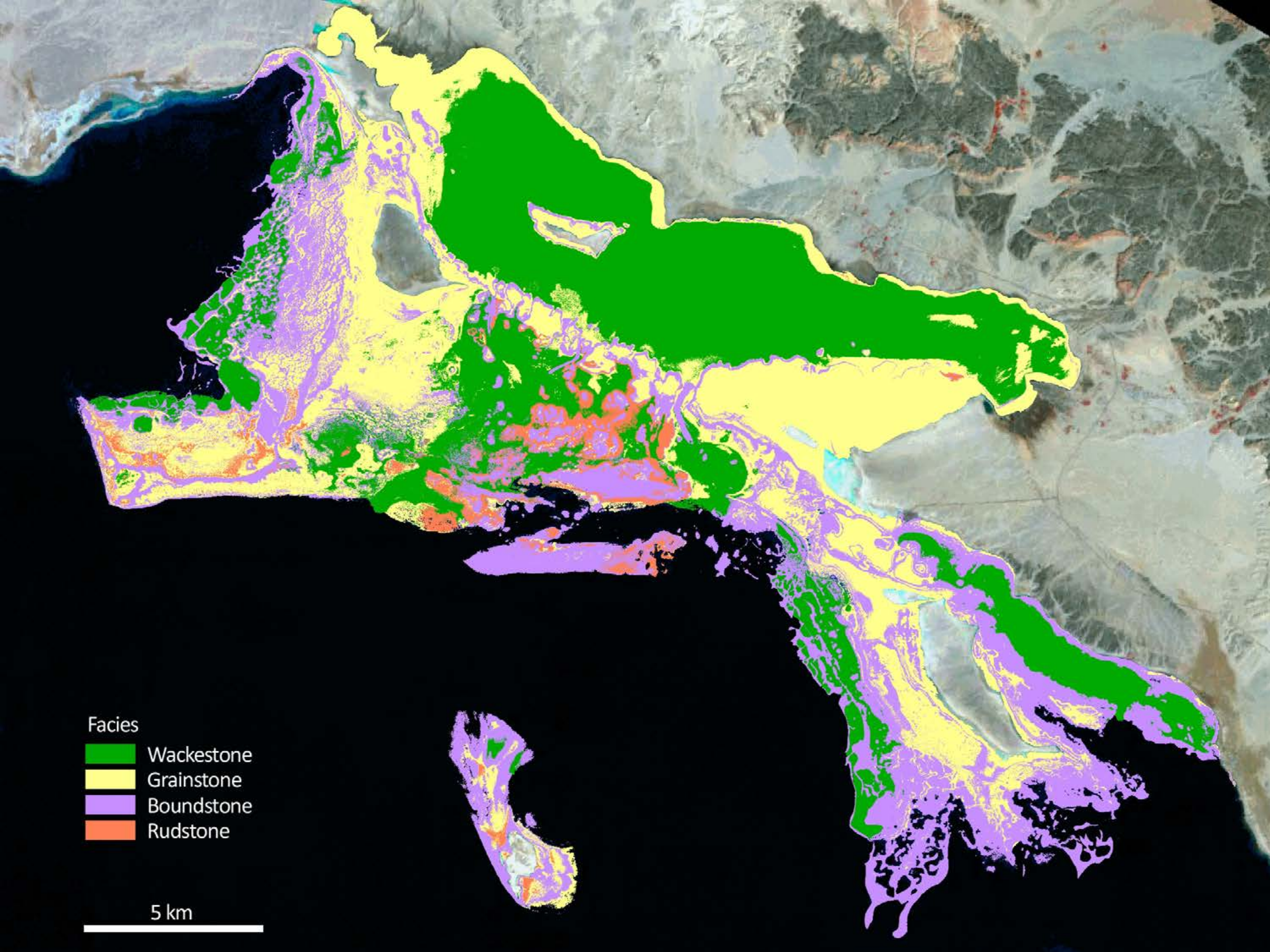
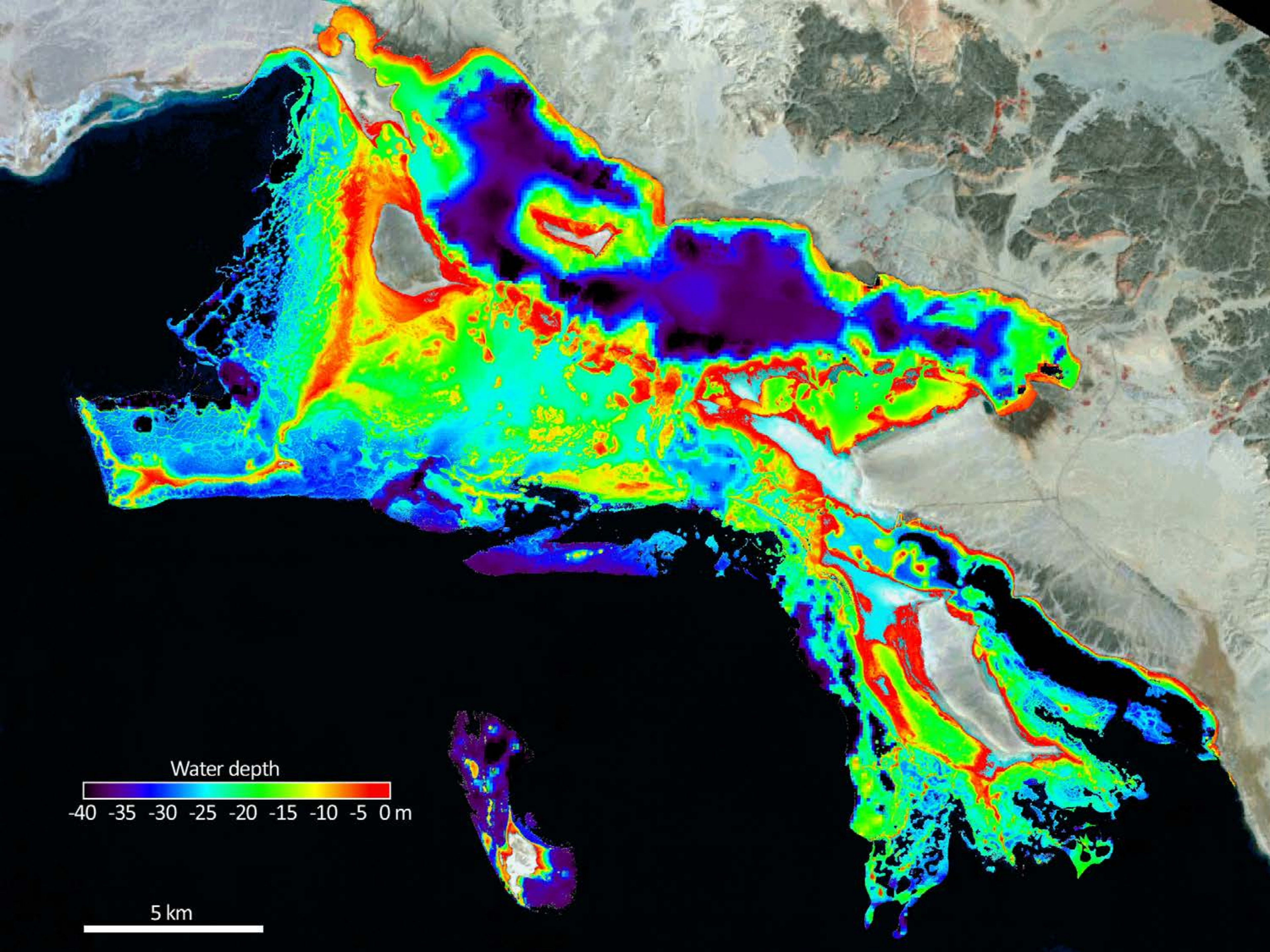
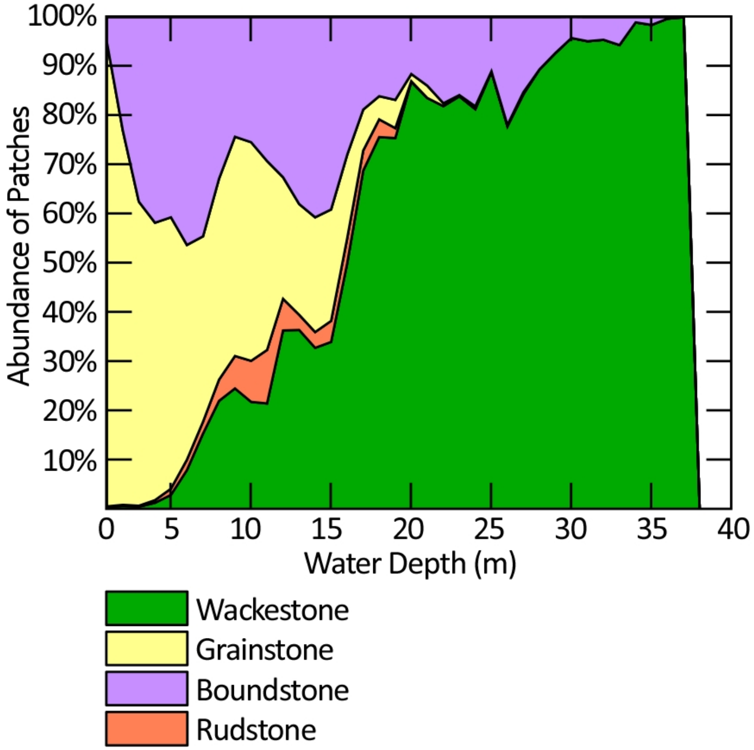

5 km

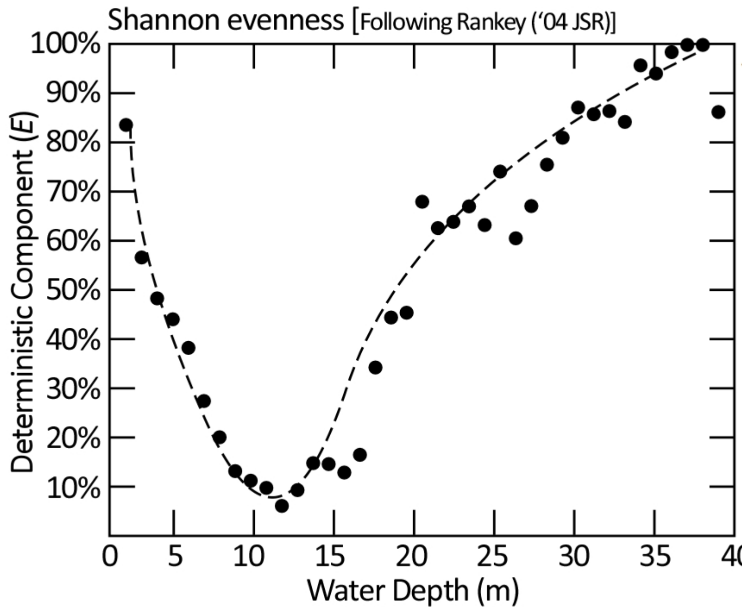
Acoustic depth sounding (>2 million)
Seafloor observation (500)
5 km


Facies
Wackestone
Grainstone
Boundstone
Rudstone
5 km

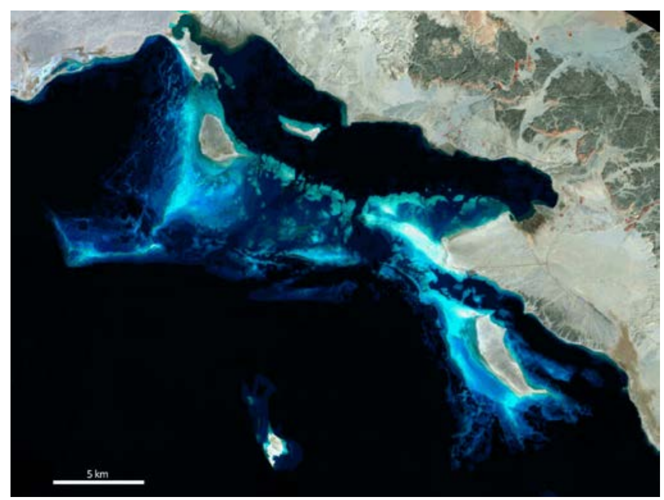

Water depth
-40 -35 -30 -25 -20 -15 -10 -5 0 m
5 km

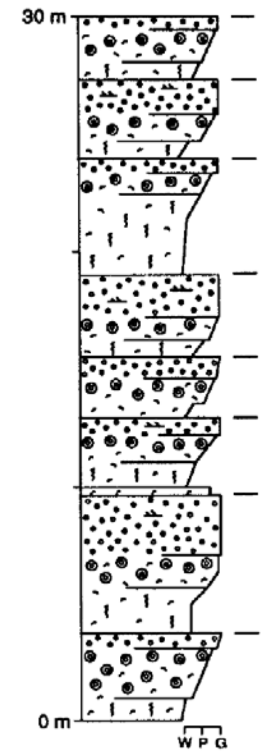
Facies-water depth relationships – at higher resolution





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





Rankey, E.C., '04, Journal of Sedimentary Research, v. 74, p. 2–6

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

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Research Article
DOI: 10.2110/jsr.2012.77

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PATTERNS OF SEDIMENTATION IN THE CONTEMPORARY RED SEA AS AN ANALOG FOR ANCIENT CARBONATES IN RIFT SETTINGS

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