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[EA]Quantitative Comparative Sedimentology - Value Added for a Refined Interpretation*

Paul (Mitch) Harris[1] and Sam J. Purkis[1]

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[1]CSL – Center for Carbonate Research, Department of Marine Geosciences, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida (pmitchharris@gmail.com)

Abstract

Key Findings

• The quantitative interrogation of carbonates adds value to a description and facilitates an improved interpretation of the depositional environment.

• Whether analyzing modern or fossil examples, the quantitative approach produces results and insight that can improve an understanding of subsurface examples, potentially lead to better correlations between wells, and facilitate better geological and geocellular models.

Significance

The quantitative interrogation of modern and outcropping carbonates is a relatively new approach that adds value to a description and facilitates an improved interpretation of the depositional environment. Three examples are discussed to highlight the value added by a quantitative comparative sedimentology approach: (a) a modern sand body comparison undertaken by Harris et al. (2011), (b) a modern reef comparison by Purkis et al. (2012), and (c) a comparison of modern and fossil sand bodies by Purkis and Harris (2017). Whether analyzing modern, outcropping or subsurface examples, the quantitative approach produces results and insight that can improve an understanding of subsurface examples, and lead to better correlations between wells and to better geological and geocellular models.

Methods and Preliminary Results

Modern sand bodies on Great Bahama Bank (GBB) (Figure 1) were examined using Landsat and morphometric tools to compare their size, shape, complexity, distribution, orientation and topography. Profiles and spatial analysis tools enabled sandbar and channel spacing, position relative to the platform margin, connectedness, separation distances and density to be characterized. Certain aspects behave in a systematic and hence predictable manner, highlighting the potential to impart considerable insight to the characterization of grainstone systems because the examples are disparate in their overall extent and depositional settings.

Six focus areas illustrating the variability of spatial patterns in reefal and related carbonates in Red Sea rift setting (Figure 2) were mapped using Landsat imagery to define ‘‘carbonate bodies’’ that were analyzed for trends in orientation, relation to local fault networks, and size-frequency distribution. Fault lineaments are closely related to the orientation of carbonate bodies with areas exceeding 5 sq. km. Water depth and the occurrence of reefal frameworks and sediments are not systematically related. Used as an analog, these data from the contemporary Red Sea may provide insight into the orientation and scale of accumulation of carbonates in subsurface marine rift settings.

An airborne LiDAR DEM and select outcrops show that the Pleistocene Miami Oolite (MO) sand body in South Florida consists of shoals (or bars) separated by tidal channels and is partly bounded on the ocean-facing side by a prograding barrier bar. Comparing the quantitative interrogation of the MO with that of the GBB sand bodies (Figure 3) shows the Exumas to be a particularly compelling analogue with respect to length and overall visual comparison between the sand body morphology, shoal shape, number of tidal channels, channel length and width, and islands. The MO validates the concept of quantitative comparative sedimentology and in particular emphasizes how results from the modern can improve the interpretation of a fossilized example.

Implications

The three examples focused on here have hopefully illustrated that a quantitative interrogation approach can add value to a description and interpretation of the depositional environment. We feel that a quantitative approach to analyzing modern or fossil examples, therefore quantitative comparative sedimentology, produces results and insight that can improve an understanding of subsurface examples. As an example, Purkis et al. (2015) compared Upper Paleozoic carbonate buildups from the Norwegian Barents Sea with the modern Alacran Reef of Campeche Bank, Mexico. They highlight the numeric similarity between the reticular patterning of reefal buildups in both settings, and argue that despite the enormous changes in biota, climate, sea level, water chemistry and other factors that have taken place since the Palaeozoic, the fundamental metabolic requirements of reef builders remain constant through geological time. For this reason, and because of hydrodynamic effects, reef builders routinely strive to inhabit the edge position of topographic highs and it is this preference that yields reticular reef patterns, created through the conjoining of reef patches, at the point that accommodation becomes limited. This example of quantitative comparative sedimentology can potentially lead to better characterization of facies below seismic resolution to create more realistic facies distribution models, and should serve as an example for other subsurface studies.

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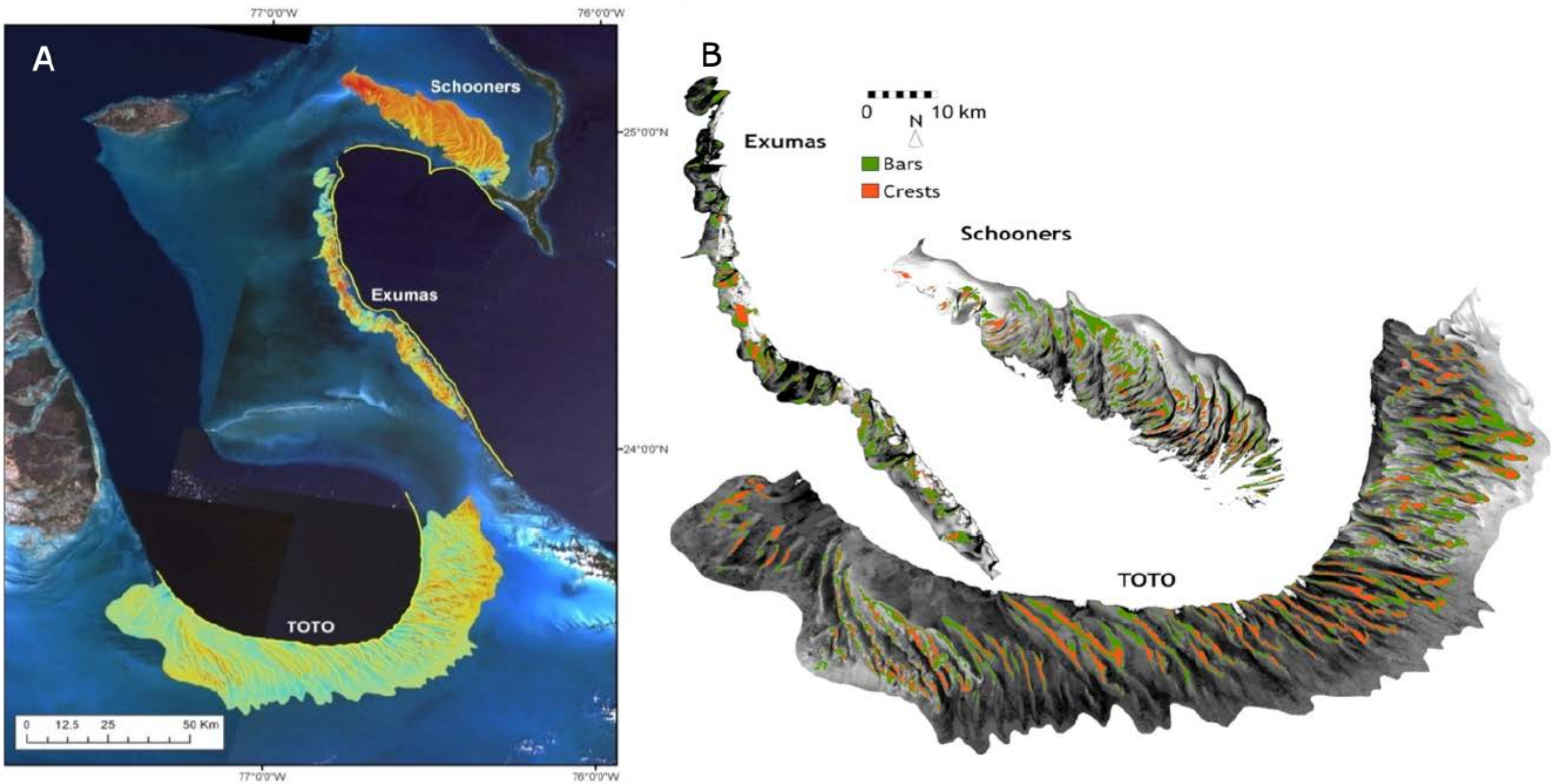

Figure 1. Modern sand bodies on Great Bahama Bank that were quantitatively examined by Harris et al. (2011). (A) Landsat imagery identifying the three sand deposits (TOTO, Schooners, and Exumas). The sand deposits are highlighted by showing in color their respective digital elevation models (DEMs). (B) DEMs for each sand body are further annotated to highlight sand bars and bar crests.

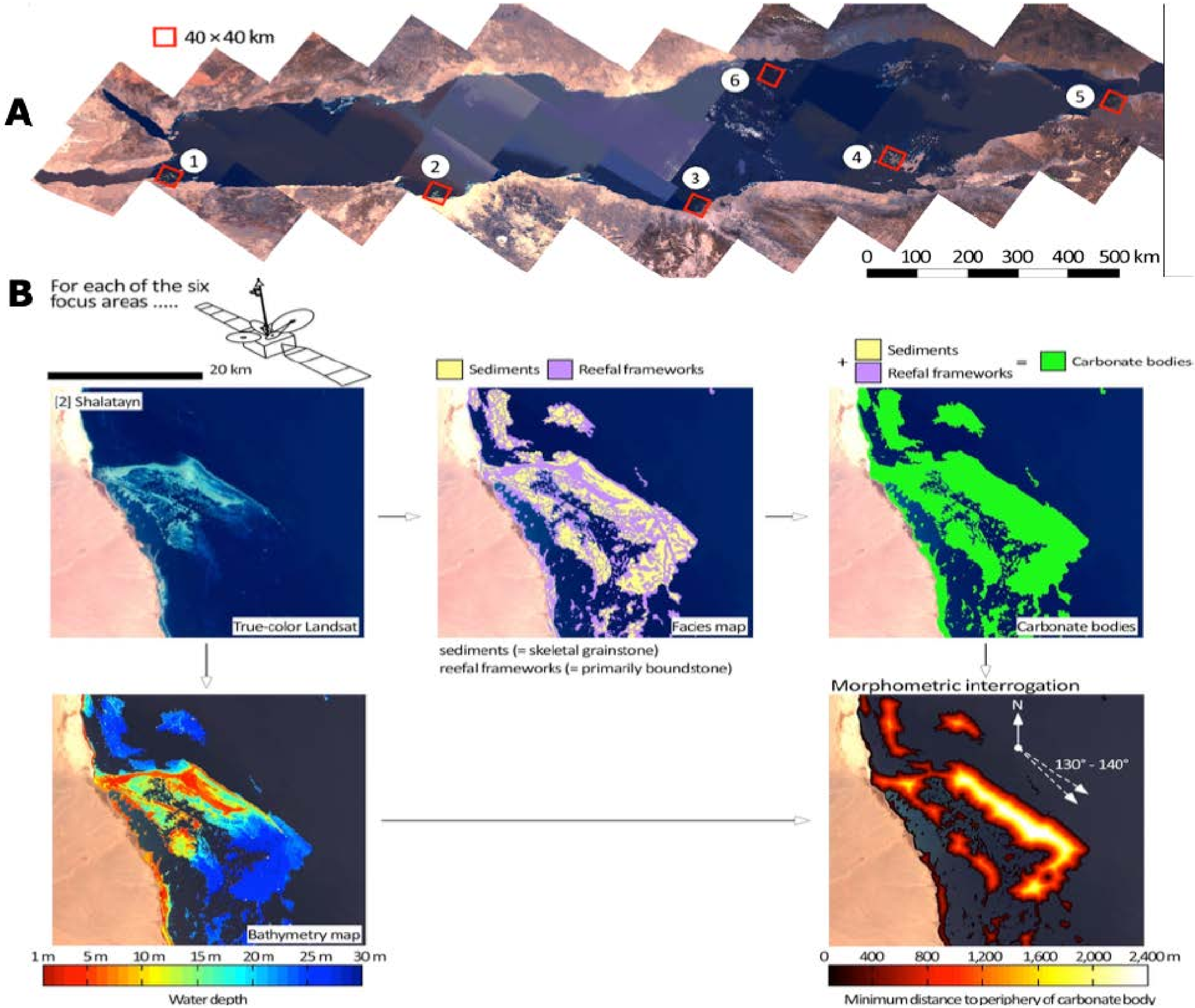

Figure 2. Modern reefs from the Red Sea that were quantitatively examined by Purkis et al. (2012). (A) Landsat imagery locating the six reef areas down the length of the Red Sea Rift: 1- Gubal Straits (Egypt), 2- Shalatayn (Egypt), 3 - Trinkitat (Sudan), 4 - Dahlak (Eritrea), 5 - Halib (Eritrea), and 6 - Farasan (Saudi Arabia). (B) Examples of attributes mapped for each of the areas.

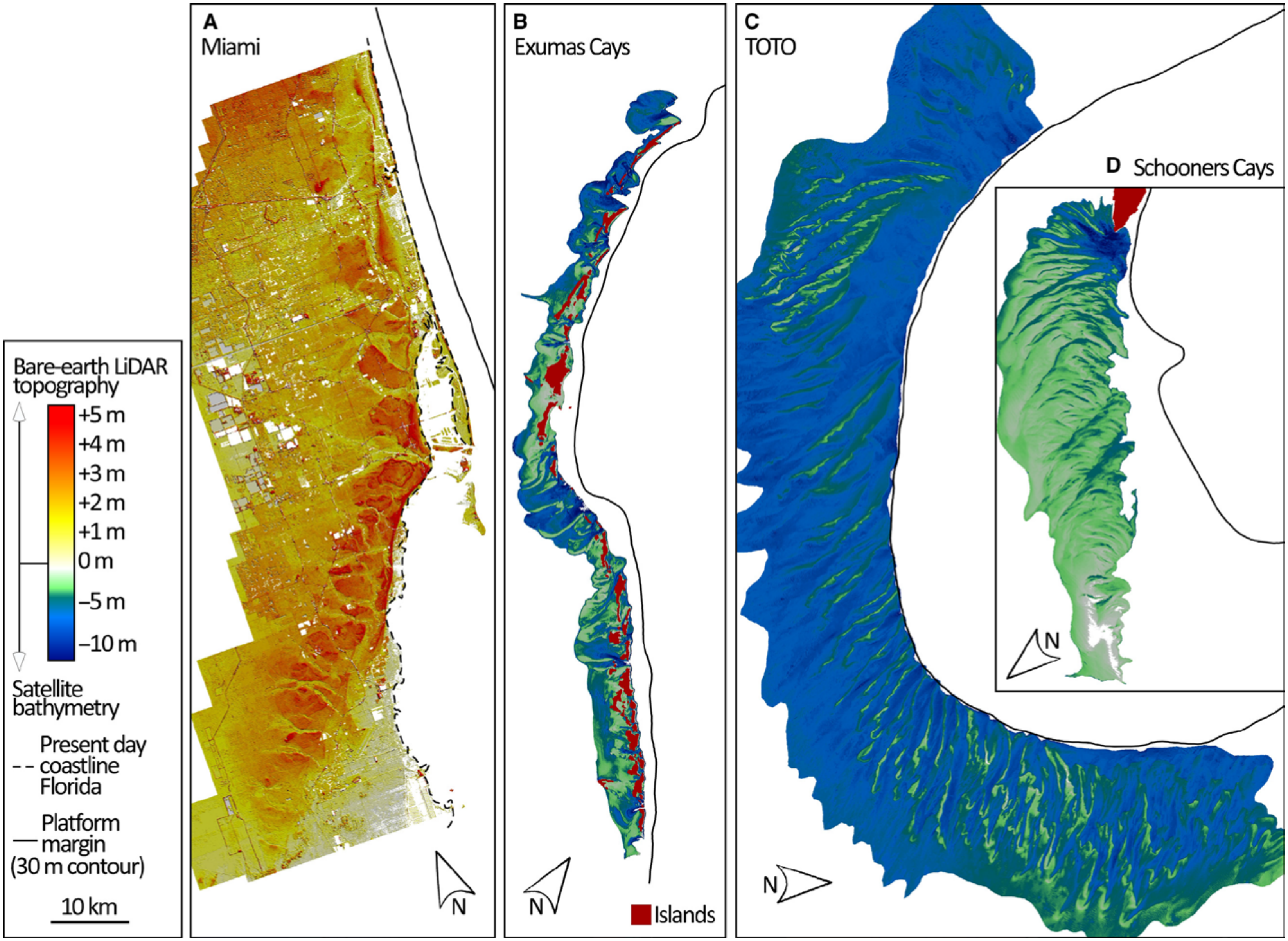

Figure 3. Part of the comparison between modern and fossil sand bodies by Purkis and Harris, 2017. Digital elevation models (DEMs) for the Miami Oolite (A), the Exumas Cays (B), the Tongue of the Ocean (TOTO) (C) and the Schooners Cays (D). See Figure 1 for locations. Terrain for the Miami oolite is gridded bare-earth LiDAR topography. For the three modern systems, terrain is optically derived from Landsat ETM+ imagery calibrated by single-beam sonar soundings (for details, see Harris et al., 2011). The plots have been orientated such that open water is to the right of the platform (or shelf) margins. North as indicated. Scales identical.