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# Sediments of the Dry Tortugas, south Florida, USA: Facies distribution on a ramp-like isolated carbonate platform

Eberhard Gischler [a,*], Anja Isaack [a], J. Harold Hudson [b]

[a] Institut für Geowissenschaften, Goethe-Universität, Altenhöferallee 1, 60438 Frankfurt am Main, Germany
[b] ReefTech Inc., 8325 SW 68th Street, Miami, FL 33143, USA

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ABSTRACT

Four sedimentary facies may be delineated based on quantitative analysis of texture and composition of modern surface sediments on the Dry Tortugas carbonate platform. These include (1) mollusk-*Halimeda* wackestone, (2) mollusk packstone-to-grainstone, (3) coralgal-*Halimeda* grainstone, and (4) coralgal grainstone. Even though the Tortugas platform is characterized by an open circulation due to deep, broad marginal channels and a lack of a continuous surface-breaking marginal reef, facies are not distributed at random and show bathymetrical zonation. Also, facies appear to cover wide belts rather than forming a mosaic. Mollusk-*Halimeda* wackestone occurs in protected platform interior areas ca. 10–18 m deep. Mollusk packstone-to-grainstone occurs in more open platform interior settings adjacent to channels and in deeper outer reef areas of 14–25 m water depth. Coralgal-*Halimeda* grainstone is found on shallow marginal shoals (1–11 m deep), and coralgal grainstone on the somewhat deeper (3–16 m), seaward edges of these shoals. However, there is bathymetrical overlap of facies in intermediate depths of ca. 5–17 m. This limitation has implications for the interpretation of the fossil record, because changes in water depth are commonly thought to be reflected in facies changes, e.g., in sequence stratigraphy. Comparison with previous sediment studies of the 1930s, 1960s, and 1970s in the area exhibit a decrease in coral fragments and increases in coralline algal and mollusk shell fragments. These observations might be a result of environmental changes such as coral decline and die-outs during temperature events, disease, and the increase in macroalgae (due to the ecological extinction of the echinoid *Diadema*). The results suggest that more long-term studies are needed that further explore the influence of environmental change on reef sediment composition. Dry Tortugas surface sediments consist of lower portions of *Halimeda* plates and mollusk shell fragments and higher percentages of coralline algal fragments as compared to sediments of the adjacent Florida Reef Tract, possibly as a consequence of differences in platform morphology and exposure to waves and currents.



## 1. Introduction

Patterns of sedimentary facies distribution in modern, shallow-water carbonate depositional environments form the basis of studies in depositional processes, sediment dynamics, sedimentary budgets, taphonomy, diagenesis, or reservoir modelling. Numerous surface sediment studies have been conducted in modern carbonate platforms, reefs, and ramps in all ocean basins (Milliman, 1973; Maxwell, 1973; Ginsburg and James, 1974; Schmitt and Gischler, 2017; and references therein). A focus of early sediment studies was the western Atlantic including, e.g., south Florida (Thorp, 1935; Ginsburg, 1956; Swinchatt, 1965; Enos, 1974, 1977), the Bahamas (Thorp, 1935; Illing, 1954; Purdy, 1963; Traverse and Ginsburg, 1966), and Belize (Purdy 1974). Some of these classic study areas such as south Florida have been revisited to quantify constituent particle distribution on individual reef locations (Lidz et al., 1985), to include additional areas (Shinn et al., 1990), and to evaluate changes to earlier sediment distribution patterns along the entire reef tract (Lidz and Hallock, 2000). The Belize reef system has been revisited in order to include the offshore atolls and to delineate modern facies based on sediment texture and composition with the aid of multivariate statistical analyses (Purdy and Gischler, 2003). Great Bahama Bank has been re-sampled at much higher resolution (Reijmer et al., 2009; Harris et al. 2015) as compared to the early studies, however, sediment grain composition has not been quantified. In addition, sedimentary facies of other Bahamian platforms have been analyzed (e.g., Wanless et al., 1989; Dravis and Wanless, 2008; Rankey and Reeder, 2010).

General patterns of sediment distribution that have emerged based on these and other modern sediment studies include the occurrence of abundant grainy coralgal-rich sediments at platform margins as opposed to finer-grained sediments rich in mollusk shells, foraminiferal tests, and non-skeletal grains (ooids, peloids, aggregates) in platform interiors. In addition, there are apparently more occurrences of non-

* Corresponding author.
*E-mail address:* gischler@em.uni-frankfurt.de (E. Gischler).

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skeletal grains in western Atlantic as compared to Indo-Pacific reefs and platforms (Milliman, 1969, 1974). Non-skeletal grain abundance was also identified in shallow ramp sediments of the Arabian-Persian Gulf (Emery, 1956; Wagner and van der Togt, 1973; Gischler and Lomando, 2005). It turned out, however, that non-skeletal grains may also be abundant locally in Pacific reefs and platforms (Davies and Martin, 1976; Rankey and Reeder, 2009; Gischler, 2011). Preconditions of formation include elevated temperature, salinity and carbonate saturation, low sedimentation rates, sediment stability, and time (Tucker and Wright, 1990, p. 1–13, 325–327; and references therein).

More recent studies conducted in the south Florida and Bahamas regions have focussed on the questions as to whether facies are randomly distributed, facies transitions are ordered, and, whether facies distribution may be related to water depth (Wilkinson et al., 1999; Rankey, 2002, 2004; Bosence, 2008; Purkis et al., 2015). These questions are not only significant in the modern but also for studies in the fossil record, because they are related to the widely-held concept of the straightforward correlation between water depth and facies. Scale apparently matters in that large-scale studies usually show clear relationships between facies and water depth, whereas results from smaller areas and depth ranges do not seem to exhibit clear-cut relationships (Rankey, 2004; Harris et al., 2015; Purkis et al., 2015). Sampling density appears to be of importance as well, because highly resolved sediment maps are commonly more heterogenous with facies mosaics instead of broad, homogenous facies belts (Kaczmarek et al., 2010; Purkis and Harris, 2016).

There are studies of modern sediments in the Dry Tortugas, however, they concentrated on selected parts of the platform only or the results were not published. Thorp (1935) investigated surface sediments from the Bahamas and south Florida, including the Dry Tortugas. Twenty-six samples from the south-central platform interior area of the Tortugas platform were studied quantitatively with regard to texture and grain composition. Coarse-grained, skeletal sediments rich in calcareous algae and mollusk shells as well as mud-rich sediments were identified. Jindrich (1972) analyzed 106 sediment samples and also concentrated largely in the south-central part of the Dry Tortugas platform and only found grain-supported textures. A set of sediment taphonomy, sediment geochemistry, geotechnical, and geophysical studies were conducted in a small area (5 × 7 km) south of Southeast Channel, located outside of the platform (Lavoie et al. 1997; Mallinson et al., 1997; Walter et al., 2002; and references therein). Therefore, it is the aim of this study to investigate systematically the sedimentary facies of the entire Dry Tortugas platform. The platform is especially interesting as its geomorphology does neither resemble an atoll nor a typical isolated carbonate platform, but could be described as an isolated ramp-like platform. Due to the lack of a continuous, surface-breaking marginal reef, the existence of wide channels connecting the platform interior with the surrounding open waters, and gentle-sloping margins, sediment distribution patterns different from those in common carbonate platform types can be anticipated. Furthermore, it is the aim of this study to evaluate the correlation between the occurrence of depositional facies and water depth, and, whether facies patterns are characterized by order or randomness.

## 2. Study area

The Dry Tortugas are located some 115 km west of Key West at the southwestern margin of the west Florida shelf, a large, distally steepened ramp (Hine et al., 2003, 2008) (Fig. 1). The shelf margin from the Tortugas platform to the Key West area is characterized by sand shoals and a lack of shelf-margin reefs (Shinn et al., 1990). From the Key West to the Miami areas, the shelf margin is occupied by the Florida Reef Tract (Lidz et al., 2008). The Tortugas platform forms a horseshoe-shaped complex of carbonate shoals and reefs the long axis of which trends northeast-southwest (Fig. 2). Along this trend, the platform is up to 27 km long and 12 km wide (Lidz and Zawada, 2013). The area above

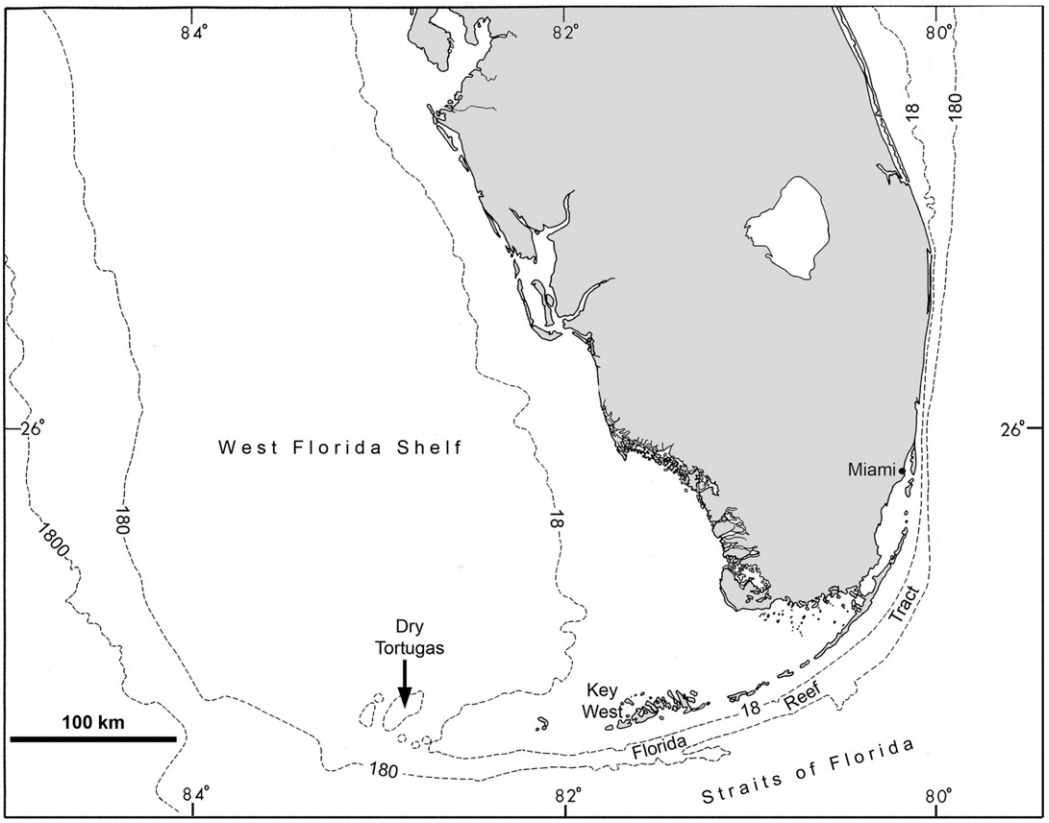


**Fig. 1.** Map of south Florida including west Florida shelf, Dry Tortugas, and Florida Reef Tract; redrawn after Enos (1977). Depths are in meters.