Impact of facies and diagenetic variability on permeability and fluid flow in an oolitic grainstone—Pleistocene Miami Oolite

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Abstract
The Miami Oolite of South Florida is representative of a grainstone-rich carbonate unit that has been surficially karsted, and therefore may be considered as an analogue for subsurface reservoirs/aquifers with ‘high’ permeability extremes. The deposit can potentially serve to improve a conceptual understanding of heterogeneity imparted by shallow-marine facies changes and early meteoric diagenetic modification. Reviewed here are recent studies of the Miami Oolite with the intent to emphasize those key aspects of the facies and early diagenesis that most impact permeability and fluid flow. The Miami Oolite displays the preserved morphology of a fossilized ooid sandbody, even though it has been subaerially exposed in a tropical climate since its deposition approximately 120 kyr BP during the last interglacial highstand. The depositional motif is one of a dip-oriented, tidal bar belt of shoals and shallow channels fronted by a strike-oriented barrier bar. The barrier bar comprises cross-stratified grainstones and locally burrowed grain/packstones, while the tidal shoals and channels are more commonly burrowed pack/grainstones. Surficial karst features (dolines and stratiform caves) have been added during the ca 120 kyr of subaerial exposure, but of more significance is the associated solution-enhancement of the widespread burrowed facies. Since the Miami Oolite is the uppermost portion of the Biscayne Aquifer, there is also an understanding of fluid flow through the deposit that sheds valuable insight on the larger scale, shallow subsurface plumbing. The pore system comprises matrix pores (interparticle and separate vugs) and touching-vug macropores that are commonly associated with burrowed [Ophiomorpha] intervals. Ground-penetrating radar, well and flow test data indicate that matrix porosity provides most of the groundwater storage, whereas the touching vug macropores account for the majority of flow. The dolines and shallow caves seem to be sufficiently spaced as to generally not be in direct connection, with the result that they are less important in terms of regional flow than the prevailing pore system.

KEYWORDS
Eogenetic karst, macropores, Ophiomorpha, permeability
1 INTRODUCTION—RATIONALE FOR REVIEW

Exposures of the Miami Oolite (MO) in the vicinity of Miami, Florida, USA, which are equivalent to the oolitic facies of the Miami Limestone of Hoffmeister et al. (1967), provide excellent examples of preserved primary sedimentary features and subsequent diagenetic changes of a relatively young, yet ‘fossilized’, carbonate sandbody. This Pleistocene-age formation, deposited approximately 120 kyr BP during the last interglacial highstand (Marine Isotope Stage 5e or MIS 5e), serves as a reference example for comparison to Holocene sand units in the Bahamas (Purkis and Harris, 2017), and more importantly, to subsurface hydrocarbon reservoir and aquifer examples in the geological record. Continued interest in modern and outcrop analogues for carbonate sand reservoirs, like the MO, is warranted based on the substantial number of carbonate hydrocarbon reservoirs that produce from grainstones and packstones (Wilson, 1975; Harris, 1984; Roehl and Choquette, 1985; Keith and Zuppann, 1993; Harris and Weber, 2006). From a reservoir analogue perspective, the MO is representative of a high-frequency sequence (ca 100 kyr duration) and grainstone-rich reservoir layer-equivalent that has been surficially karsted (eogenetic karst), and can potentially serve to illustrate heterogeneity in this type of reservoir or aquifer, as imparted by facies changes and early meteoric diagenetic alteration.

Outcrops and cores of the MO have been the focus of facies, stratigraphic and diagenetic studies for more than half a century. There is also an understanding of fluid flow through the deposit which sheds insight regarding the kilometre-scale permeability patterns as the MO is the uppermost portion of the aquifer providing water to the region. Previous studies of the MO are reviewed here with the aim of merging surface and subsurface views and identifying the key aspects of facies and early diagenesis that most impact permeability and fluid flow in the hopes of making the reservoir/aquifer analogue aspect of the MO even more robust.

2 DEPOSITIONAL FACIES OF THE MIAMI OOLITE—AN ABUNDANCE OF BURROWING

The MO preserves the morphology of a fossilized ooid sandbody (Figure 1) even though it has been subaerially exposed in a tropical climate since its deposition during MIS 5e when sea level was ca 6–7 m higher than today (Osmond et al., 1965; Hoffmeister et al., 1967; Halley et al., 1977; Waelbroeck et al., 2002; Usdun, 2014; Purkis and Harris, 2017). The MO throughout south-eastern Florida has a wedge-shaped form in three dimensions, reaching its maximum thickness of approximately 11 m along its seaward edge (Figure 1B), whereas the more widespread equivalent platform interior to the west is only 4–5 m in thickness (Hoffmeister et al., 1967; Halley and Evans, 1983; Evans, 1984). The resultant sandbody as mapped from an airborne LiDAR digital terrain model (DTM) by Purkis and Harris (2017) extends 95 km from north to south and varies from 10 to 15 km in dip width. Halley et al. (1977), Halley and Evans (1983), Evans (1984), Usdun (2014) and Purkis and Harris (2017) divided the sandbody into two distinct regions based on geometries and physiographic differences (Figure 1C): (a) a shoal (or bar) and channel system where the main orientation of the individual depositional elements is perpendicular to the overall trend of the sandbody, and dimensions of individual shoals vary between 1 and 4 km in length and 1 and 3 km in width and (b) a barrier bar, approximately 35 km in length and averaging 1 km or slightly less in width, oriented parallel to the strike trend of the sandbody.

Morphological observations of the LiDAR DTM (Figure 1A) and from previous studies suggest that the shoal–channel portion of the MO sandbody represents the early stages of its development, whereas the barrier bar developed later (Evans, 1984; Usdun, 2014; Purkis and Harris, 2017). The geometry and orientation of accretion ridges visible on Figure 1A,C,D indicates southerly and easterly growth of the barrier bar, which confirms the earlier observations by Halley et al. (1977), Evans (1984) and Usdun (2014). Ground-penetrating radar (GPR) has been used in the MO to investigate shallow carbonate sedimentary structures (Grasmueck et al., 2004), and to visualize the 3D sedimentary architecture (Neal et al., 2008). From select outcrops and the GPR studies, the internal facies architecture and bedding dip directions of the barrier bar corroborate that it formed via alongshore accretion to the south (Halley et al., 1977; Grasmueck and Weger, 2002; Neal et al., 2008; Purkis and Harris, 2017). With the progressive growth of the barrier bar under the influence of longshore currents, tidal flow became more restricted across and through the barrier bar, and the shoals and channels behind it became increasingly less active. Halley and Evans (1983), Evans (1984), Grasmueck and Weger (2002), Usdun (2014), and Purkis and Harris (2017) used the Joulter Cays sandbody from Great Bahama Bank (Figure 2) to illustrate how cross-bedded and burrowed ooid sands can be coeval and to show the diversity of sand movement directions (cross-bedding) formed in areas dominated by ebb, flood and longshore currents. Evans (1984) further used the results of coring in the Joulter Cays from Harris (1979) as an analogue to interpret the facies relationships and developmental history of the MO, showing that the shoal-channel belt matured into a burrowed sand flat similar to that at Joulter, and later the complex was fronted by the barrier bar.

Variation in ooid-rich sediments has been documented on outcrops and in cores between the subenvironments of
the MO (Evans, 1984; Usdun, 2014), similar to the variability documented by coring in Joulters and other modern sand shoal equivalents (Dravis, 1977; Harris, 1979; Sparks and Rankey, 2013; Cruz and Eberli, 2019). For example, cross-bedded and relict-bedded (cross-bedding discernable but texture nearly obliterated by burrowing) oolitic–peloidal grainstones typify the shoals of the MO and burrow-mottled ooid–peloid packstones to grainstones occur in the channels (Figure 3). As mentioned, tidal channels became increasingly stabilized due to restricted tidal flow with the growth of the prograding barrier bar, and as a result, organisms burrowed tidal channel sediments. This evolution of depositional environments produced a facies mosaic of relict-bedded oolitic facies juxtaposed with burrow-mottled ooid–peloid packstone and grainstone facies throughout the shoal and channel region. The stabilized sand flat portion of the Joulters sandbody (Figure 2B,E) illustrates one possible scenario for this facies juxtaposition.

Cross-bedded, well-sorted oolitic grainstones are found in the barrier bar of the MO (Figure 3), as illustrated by an often-visited ‘classic’ outcrop exposure along the Coral Gables Waterway (Figure 4A, outcrop location shown on Figure 1C). But even at this locality, there are indications that the barrier bar is not exclusively cross-bedded. Burrowed sands are present at the base of the outcrop at this locality (Figure 4B,C) and are even more dominant at others, as illustrated by the nearby ‘classic’ barrier bar outcrop at Alice Wainwright Park (Figure 4D, outcrop location shown on Figure 1C). Here the
exposed outcrop is ca. 2.7 m in height; the upper 2.1 m is extensively burrowed, and only a ca. 60 cm thick unit below preserves the original cross-beds. Cores evaluated by Evans (1984) and Usdun (2014) show the combined thickness of the relict-bedded and cross-bedded facies is 6–11 m in the barrier bar and approximately 1–8 m in the shoal and channel areas. The thickness of the burrowed facies is up to 4 m. Trace fossils recognized in the Alice Wainwright Park and other outcrops include Ophiomorpha (a Callianassa-type shrimp burrow network), abundant horizontal rod-type burrows from an unidentified organism, as well as rare Phyllactis conguliegia sea anemone burrow structures. The surface between the underlying cross-bedded unit and overlying burrow-mottled unit of the Alice Wainwright Park outcrop is transitional, suggesting that cross-bedded ooid sand deposited under the influence of tidal currents in an active portion of the barrier bar was subsequently stabilized in a setting probably characterized by seagrass meadows and an extensive community of burrowing organisms—a stabilized sand flat (Halley and Evans, 1983; Usdun, 2014; Purkis and Harris, 2017). Shinn (1968) and Curran and Martin (2003) proposed that the depth limit of burrowing Callianassa shrimp is approximately 2 m; thus, suggesting that original physical structures, for example, cross-bedding, can be preserved below a depth of 2 m in a stabilized oolitic setting (Harris, 1979; Evans, 1982).

Ophiomorpha burrows (Figure 5) like those observed in the MO have outside diameters typically 1–3 cm or larger and exhibit thick walls that are distinctly pelLETED on their exterior surfaces and smooth on the interior. The burrow networks commonly form multigenerational complex patterns in 3D (see Shinn, 1968) with burrows filled or partly filled with sediment or preserved completely open. The burrows common remain unfilled, thus Ophiomorpha may be associated with touching-vug macropores (Figure 5C,D) and permeability (Cunningham et al., 2009).

At the broad scale, Ophiomorpha is the dominant trace fossil in the MO (Evans, 1982; Cunningham et al., 2009; Usdun, 2014). As mentioned, burrowed sediments up to 4 m
in thickness typify the shoal and channel region of the MO, where they manifest with bioturbated, mottled or relict-bedded appearances. The mottled and relict-bedded textures are widely present in the barrier bar as well; Evans (1982) estimated from cores that 40% of the barrier bar and 70% of the shoal and channel areas contain burrowed facies. The barrier bar and shoal and channel regions of the MO together occupy approximately 1,500 km² of South Florida, establishing a large area over which burrowing is a common theme. The equivalent shelf interior facies to the MO, the bryozoan-rich facies of Figure 1B, is even more extensively burrowed and covers an area more than three times larger (5,000 km²).

3 | DIAGENETIC OVERPRINT IN THE MIAMI OOLITE—IMPACT ON BURROWED INTERVALS

Porosity and permeability variations and patterns occur in the MO at all scales, with those occurring at scales larger than can be assessed from a core or an outcrop presenting perhaps the greatest challenge to understanding the more regional controls on fluid flow. Evans (1984) and Evans and Ginsburg (1987) illustrated the nature of meteoric diagenesis of the MO in thin sections from select outcrops and cores. They described the diagenesis in terms of: (a) non-fabric-selective processes that result in dissolution from the surface, producing microkarstic sinkholes, erosional remnants and insoluble residues; (b) fabric-selective processes that are readily observable on the scale of both grains and sedimentary structures, that are the result of primary fabric controls on cementation and the preservation and development of porosity (preferential cementation); and (c) fabric influenced diagenesis that is important in later alteration, including the development of large-scale channel and cavern type pores. As important as this framework is for capturing the range of diagenetic overprint, the relative importance and spatial distribution of the various features remain poorly constrained.

The grainstones and packstones of the barrier bar and shoals likely had ca 44% primary depositional porosity and several thousands of millidarcys permeability based on measurements of equivalent modern sediments (Halley and Harris, 1979; Enos and Sawatsky, 1981; Enos, 1991). After the prolonged period of surficial meteoric diagenesis, measured core porosities from the MO range from 17% to 67% and still average 43% (Robinson, 1967; Evans, 1984; Hester and Schmoker, 1985; Evans and Ginsburg, 1987) and...
permeability is highly variable. Large variation in pore types and sizes can be observed in outcrop, for example, Figure 4, and in cross-sections of cores (Figure 3). Given the widespread occurrence of vugs and larger secondary pores it is obvious that core-scale measurements of porosity and permeability are unlikely representative estimates for the larger volume. In most instances, traditional sampling such as coring will not capture this macro-scale heterogeneity and therefore its impact on regional permeability and fluid flow must be derived from more areally extensive observations (like outcrops, GPR or seismic).

Some aspects of larger scale dissolution features and their spatial distribution in the MO have been recently addressed. Use of GPR has delineated spatial distributions of porosity using reflection amplitudes (Cunningham, 2004), assessed meteoric water infiltration (Truss et al., 2007), and quantified porosity and its distribution (Mount et al., 2017). Florea et al. (2015) successfully demonstrated the use of electrical resistivity tomography to delineate the small caves within the barrier bar and infer whether they were air filled or water filled. The ‘young’ outcropping surface of the MO as viewed on the high-resolution airborne LiDAR DTM is indeed insightful from a depositional perspective as shown by the quantitative comparison to modern counterparts by Purkis and Harris (2017), but at the same time the DTM and select outcrops (Figure 1D) show a depositional surface that is locally modified by surficial karst features, primarily dolines and a few shallow caves as shown in Figure 6 (Halley and Evans, 1983; Cressler, 1993; Florea et al., 2008, 2015; Cunningham and Florea, 2009; Harris et al., 2018; Meeder and Harlem, 2019). Harris et al. (2018) analysed the dolines for their size and depth, their lateral

**FIGURE 4** Key outcrops of the barrier bar of the MO illustrating sedimentary structures as discussed in text; figures modified from Usdun (2014). Outcrops are located on Figure 1C. (A–C) Photographs of Coral Gables Waterway outcrop displaying bi-directional cross-bedded and burrowed facies. Westward dips in (A) indicate deposition under a flood current regime whereas eastward dips relate to ebb currents. Yellow dashed line in (B) and (C) separates cross-bed sets from underlying burrow-mottled facies. Close-up (C) shows individual cross-bed sets separated by second-order bounding surfaces (terminology from Halley and Evans, 1983, indicated by red dashed lines). (D) Photograph and corresponding line drawing of Alice Wainwright Park outcrop shows cross-bedded sand at the base, overlain by a dominant burrow-mottled unit. Yellow dashed line indicates transitional boundary between the two units.
distribution and relationship to depositional topography, and the separation distance between them. The areal extent and depth of dissolution of the dolines are well described by simple mathematical functions, and the depth of the dolines increases as a function of their size. Doline distribution on the barrier bar is clustered because of the control exerted on dissolution by depositional topography, whereas patterning of dolines in the platformward lower relief shoals is statistically indistinguishable from random (Harris et al., 2018). Statistical pattern analysis of the dolines shows that their average separation distance and average density on the strike-oriented barrier bar versus dip-oriented shoals-channels is statistically inseparable.

The caves in the MO (Figure 1D) generally occur on or along the flanks of the barrier bar and along the edges of palaeo-tidal channels that cut through the barrier bar, locally termed Transverse Glades (i.e. narrow valleys or channels in which the soils and vegetation are similar to those in the Everglades) (Cunningham et al., 2012; Florea et al., 2015). Meeder and Harlem (2019) propose that the palaeo-tidal
channels are karst valleys, being entirely the product of collapsed subsurface conduits. It is argued here that the similarity in channel characteristics between those of the MO and modern examples from Great Bahama Bank (Purkis and Harris, 2017), along with depositional facies changes observed from outcrop and core between channel and sand bar (Evans, 1984; Usdun, 2014) support a dominantly depositional origin, with subsequent diagenetic modification only serving to widen the channels, locally change their profile, and add dissolution features.

The caves in the MO are largely confined to stratiform high-permeability zones associated with extensive Ophiomorpha-burrowed intervals. Cunningham et al. (2009, 2012) hypothesized that burrow-related pores provided preferential pathways for groundwater and concentrated dissolution (see fig. 8 of Cunningham et al., 2012). The cave system in Deering Glade (Figure 1D) is one example of caves in the stratiform, burrowed zones within the barrier bar. Here, a transverse cut through the barrier bar was partly mapped by Cressler (1993) and investigated more thoroughly by Florea et al. (2015); an interior view of one of the caves (Cunningham et al., 2009) shows the preponderance of burrows. The highly burrowed zone in the vicinity of Deering Glade was interpreted by Cunningham et al. (2012) to have been deposited in a stabilized sand flat later buried by cross-bedded oolitic barrier bar deposits. The primary burrow-related porosity within the stabilized sand flat deposits (Figure 5 shows solution-enhanced burrow-related pores on outcrop and core) provided a template for later fabric-selective dissolution by focusing groundwater dissolution to produce the ‘razor rock’ of Cressler (1993).

Cunningham et al. (2009), recognizing the importance of the widespread burrowed zones from a porosity/permeability perspective, divided the pore system of the MO into matrix pores (interparticle and separate vugs) and touching-vug macropores that are ichnologically influenced. As mentioned previously, reported core-measured porosity of the MO averages 43% while ranging from 17% to 67%. Cunningham et al. (2009) measured porosity and permeability from cores together with X-ray CT scans of core samples with a particular focus on capturing the impact of the touching-vug micropores. They calculated a macroporosity of 50% and permeability ca. $3.5 \times 10^7$ Darcies, as estimated from vertical hydraulic conductivity $= 34.6$ m/s. Cunningham et al. (2006, 2009, 2012) suggested that the touching-vug macropores manifest as stratiform high-permeability zones within the MO associated with Ophiomorpha intervals. The burrow tubes remain open or were later cleared of fill via fabric-selective dissolution, generating intra-burrow macropores. Dissolution can proceed beyond the periphery of a burrow fill to also include the pellet-lined wall of the burrow (Gameil and Sadek, 2010). Intra-burrow and inter-burrow macropores commonly develop together, creating an exceptionally permeable rock.

### 4 REGIONAL PERMEABILITY AND FLUID FLOW IN THE MIAMI OOLITE—IMPORTANCE OF SOLUTION-ENHANCED BURROWED INTERVALS

The MO shares characteristics with age-equivalent oolitic sites found throughout the Bahamas (Mylroie and Carew, 1995; Carew and Mylroie, 1997; Mylroie et al., 2012; Purkis and Harris, 2016, 2017; Purkis et al., 2019), with an important characteristic of direct relevance to the early diagenetic history being their high porosity which results in rapid infiltration of meteoric water (Schlager and Purkis, 2015). But differences exist within the region that impact the early diagenesis, especially the nature of surface and near-surface dissolution features. Average rainfall is higher in the Miami area than on the islands to the east; for example, rainfall amounts to $ca. 1500$ mm per year in Miami but only $1200$ mm in Nassau, $1100$ mm in Eleuthera and San Salvador, $800$ mm in Mayaguana, and just $650$ mm in Great Inagua. Another important characteristic that fundamentally sets the MO apart from its contemporaries in the region is its regional setting as a land-attached shelf as opposed to an isolated platform. The significance of the MO occupying a land-attached shelf is enhanced runoff from the vast area of the Everglades thereby enhancing potential meteoric diagenetic alteration.

The MO is the uppermost portion of the Biscayne Aquifer, therefore there is a rich understanding of fluid flow through the deposit which sheds valuable insight to the larger scale permeability patterns. The Biscayne Aquifer is a highly transmissive unconfined aquifer that provides the bulk of potable water for the region’s six million inhabitants (Parker et al., 1955; McPherson et al., 2000). The hydrology of the Biscayne Aquifer behaves as a dual porosity eogenetic karst aquifer (Florea et al., 2008). As demonstrated by Florea and Vacher (2006), Cunningham et al. (2006) and Florea et al. (2008) using well, GPR and flow test data, interparticle and separate vug pores provide most of the groundwater storage whereas the various types of touching-vug macropores provide much of the groundwater flow (Figure 7A). This dual porosity aspect of groundwater storage and flow is markedly different from telogenetic karst situations wherein the relative contribution by matrix porosity to flow is commonly minimal (Vacher and Mylroie, 2002; Budd and Vacher, 2004).

Cunningham et al. (2012) provide convincing evidence for concentrated groundwater flow in the Biscayne Aquifer through the stratiform touching-vug zones where the macropores related to Ophiomorpha-dominated burrowed intervals are both primary intra-burrow and secondary fabric-selective intra-burrow and inter-burrow (see Cunningham et al., 2009 for definitions of porosity terms). Cunningham et al. (2006, 2009) and Cunningham and Sukop (2011) have produced geologically based correlations of the porous zones and evidence for preferential groundwater flow within these zones has
been corroborated by multiple methods, including geophysical borehole logs, computational methods and hydraulic and chemical tracer tests (Renken et al., 2005, 2008; Cunningham et al., 2006, 2009; Shapiro et al., 2008; Cunningham and Sukop, 2011). Geophysical, tracer and temperature measurements across 64 flow zones in 16 boreholes discussed by Cunningham et al. (2012) show that touching-vug macropores associated with burrowed intervals form stratiform, aerially extensive high-permeability and high-flow zones (‘super K’ zones). The macroporous Ophiomorpha zones extend over a lateral distance greater than 8 km in the MO and underlying deposits, as shown by well correlations in Figure 7B, and are even more widely distributed in the shelf interior facies equivalent to the MO. Cunningham et al. (2009) estimate that an area exceeding 345 km² has been overprinted with touching-vug macroporosity to create high-permeability zones, whereas the dolines and shallow caves of the MO are sufficiently spaced to have minimal impact on regional flow.

5 | DISCUSSION

Although the modifications to depositional texture resulting from burrowing are relatively well understood, the spatial distribution of such modification and its effect on variations of porosity and permeability are less well constrained (Pemberton and Gingras, 2005; Tonkin et al., 2010; Gingras et al., 2012; La Croix et al., 2012, 2013; Leaman and McIlroy, 2017). Mapping of the spatial patterns of bioturbation and burrowing can, in many instances, enhance the understanding of preferred flow pathways and permeability in carbonate reservoirs and aquifers (Cunningham et al., 2009; Tonkin et al., 2010; Eltom and Hasiotis, 2019). The MO and underlying limestone of the Biscayne Aquifer contain prime examples of stratiform biogenic macroporosity and permeability for comparison with other carbonate systems, and as such enhance even further the role of the MO as an analogue for reservoirs and aquifers (Cunningham et al., 2009; Cunningham and Sukop, 2011). An important implication of the interplay between facies and diagenesis of the MO as documented here is that a depositional facies (burrowed intervals) has directed early-stage dissolution to create touching-vug macropores and produce the stratiform high-permeability zones that dominate flow at the larger scale. Thus, a profound implication for analogous grainy, karsted reservoirs and aquifers is to reinforce the notion that a fundamental understanding of depositional facies variation remains critical for characterizing reservoir quality and performance, even in cases of substantial diagenetic overprint.
Stratiform, touching-vug *Ophiomorpha*-dominated zones can also influence the development of large karst features (e.g., caves, sinkholes and vertical solution pipes), which if sufficiently abundant and spaced closely enough may also locally impact permeability and fluid flow. Examples of these zones and related caves have been identified in outcrops within the barrier bar and shoal and channel portions of the MO. The cave system at Deering Glade (Figure 1D) is perhaps the most striking example. Here, the primary burrow porosity within the stabilized sand flat deposit provided a template for fabric-selective dissolution by focusing aggressive groundwater dissolution, which produced caves within the limits of the burrowed interval. The oolitic barrier bar forms the ceilings of many of these caves as dissolution was minimized due to relatively lower primary porosity and permeability compared to the burrowed sand flat.

6 | CONCLUSIONS

Given that the depositional facies, stratigraphic framework and diagenetic alteration of the MO have been closely investigated and there is an understanding of fluid flow through the deposit from studies of the main aquifer providing water to the region, a review of select findings potentially provides insight regarding the key aspects of facies and early diagenesis that most impact permeability and fluid flow. The goal of this effort is to make the reservoir/aquifer analogue aspect of the MO even more robust.

1. The MO is a relatively young, yet fossilized, carbonate sandbody covering approximately 95 km along strike by 15 km in width and formed of two distinct regions: a shoal-channel system oriented perpendicular to the overall trend of the sandbody and a strike-oriented barrier bar. An evolution of depositional environments produced a facies mosaic of relict-bedded oolitic facies juxtaposed with burrow-mottled, ooid–peloid pack/grainstone, resulting in burrowed facies being widespread—40% of the barrier bar and 70% of the shoal and channel areas contain burrowed facies.

2. The widespread burrowed zones are important from a porosity and permeability perspective, as dissolution associated with meteoric diagenetic alteration produced touching-vug macropores that manifest as stratiform high-permeability zones associated with the burrowed intervals.

3. Shallow subsurface data from studies of the Biscayne Aquifer provide evidence for concentrated groundwater flow through the touching-vug macroporous zones. These intervals associated with burrowed intervals are stratiform, aerially extensive high-permeability and high-flow zones (equivalent to ‘super K’ zones).

4. The MO can potentially serve as a guide for analogous grainy, karsted reservoirs and aquifers in the subsurface. The review of facies, diagenesis and fluid flow aspects of the MO serves to reinforce that even in reservoirs/aquifers where substantial diagenetic overprint has occurred, an understanding of depositional facies variation cannot be neglected during studies of reservoir quality and performance.

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CONFLICT OF INTEREST

Authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

All data are from public sources.

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