Spongiform Texture and Pipe Structures in Holocene Grainstones from the Bahamas: Implications for Porosity and Permeability Development and Evolution*

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Abstract

Highly porous carbonate layers characterized by an intricate network of openings with variable morphology, referred to as spongiform textural fabric, are commonly found within Bahamian Holocene eolian and beach grainstone deposits (Figure 1 and Figure 2). The texture of sand with spongiform features ranges from fine grained and well sorted to very poorly sorted with fine to very coarse grains. Sand composition also varies from predominantly skeletal (e.g., Eleuthera Island) to oolitic (e.g., Cat Island; Figure 3). The presence of menisci and thin rims of clear equant meteoric calcite cement results in clumps and clusters of generally poorly lithified sand (Figure 3). Pores in between are commonly irregular in shape and <1 cm wide, some are circular or elliptical, and others are tubular and up to several cm long. In some cases the pores are visible only in weathered exposures. Besides some faint lamination, there are no other obvious sedimentary structures. In some field examples, spongiform texture is found in eolian deposits with large vertical cylindrical pipes, commonly up to 10-15 cm in diameter and 1.5-2 m in height (Figure 1 and Figure 4). Pipes can be closely spaced (20-30 cm apart) and individual examples have relatively uniform diameter without any obvious evidence for branching or tapering. In most cases the pipe walls are well defined, some with better-lithified rims, and with sediment-free or partially infilled interiors (Figure 4).

Modern analogs suggest that accumulation of marine algae (e.g., *Sargassum*; Figure 5) and growth of grass and shrub vegetation in coastal zones can produce spongiform texture by the trapping and lithification of sand around small but dense roots, stems, and organic litter with various microbial, fungal, and insect communities (Figure 6). This is consistent with the observed morphology and distribution of pores and with the texture of sand. Associated vertical pipes may represent molds of tree trunks (e.g., palms; Figure 7),

clusters of larger vertical roots (Figure 8), or have other origin mechanisms (e.g., dissolution). Weathering and erosion can enhance the expression of spongiform texture and vertical pipes because sand cemented around moisture retaining organic material is more firmly lithified than sediment infilling pores created by organic matter decay. Spongiform texture may indicate moist periods with vegetated landscape whereas the interbedded laminated eolianites likely represent active dune migration over dry, barren terrain, and/or rapid deposition during major storm events. Understanding the origin, distribution, and diagenesis of grainstone with spongiform texture and pipe structures texture can offer insights into the dynamics of vegetation, sedimentation, and climate during the Holocene in the Bahamas, and is also important for characterizing the reservoir quality of these strata because of their potential for abundant large-scale porosity and permeability relative to interbedded laminated grainstone.

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Figure 1. An outcrop along the southern coast of Cat island displaying abundant spongiform texture in deposits that grade upwards from beach into eolian grainstone. Large vertical pipes are common in the upper part of the exposure. Clipboard for scale = 30 cm tall.

Figure 2. Close up view of the spongiform texture characterized by an intricate network of openings of variable size and morphology.

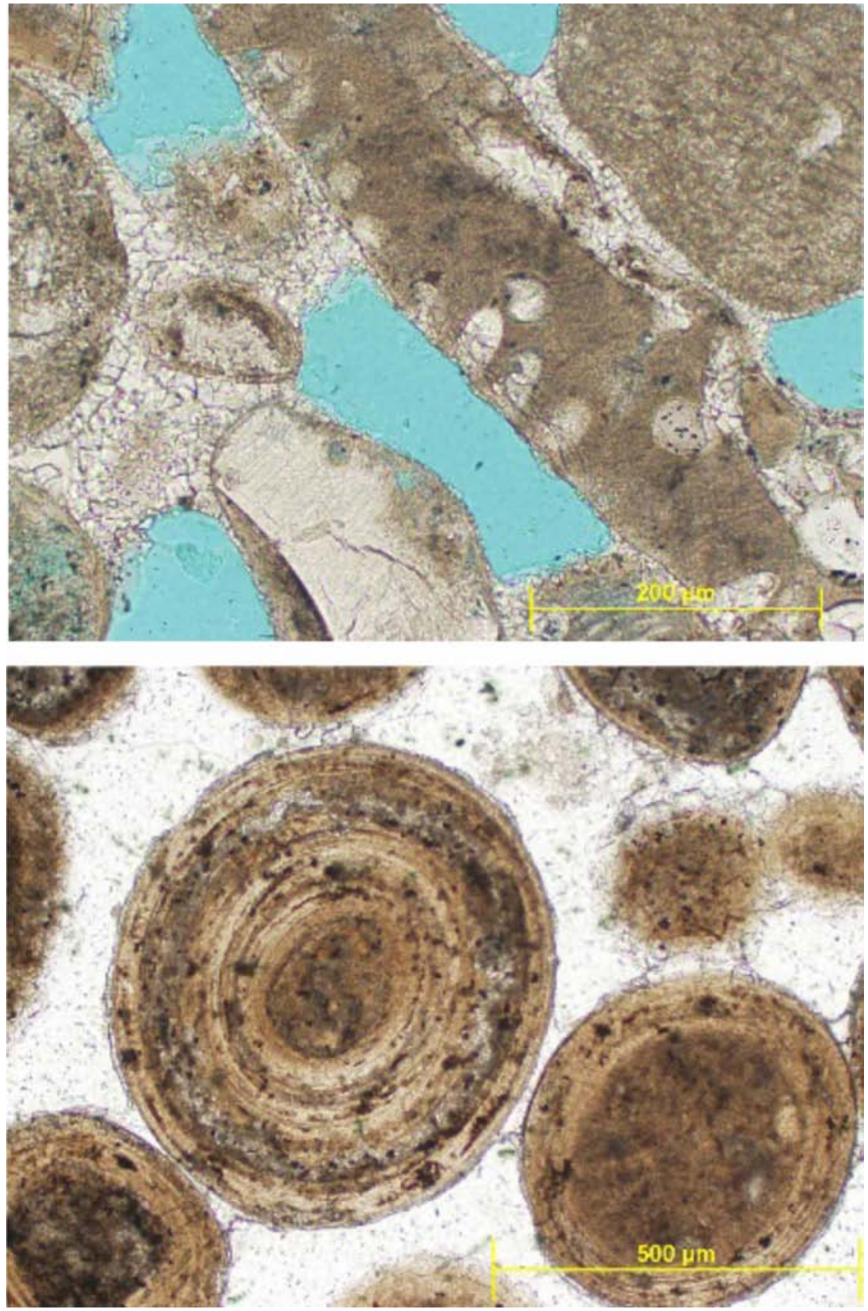

Figure 3. Sand with spongiform features is predominantly skeletal (e.g., Eleuthera Island; blue epoxy; upper photograph), and/or oolitic (e.g., Cat Island; clear epoxy; lower photograph), and generally poorly lithified with menisci and thin rims of clear equant meteoric calcite cement.

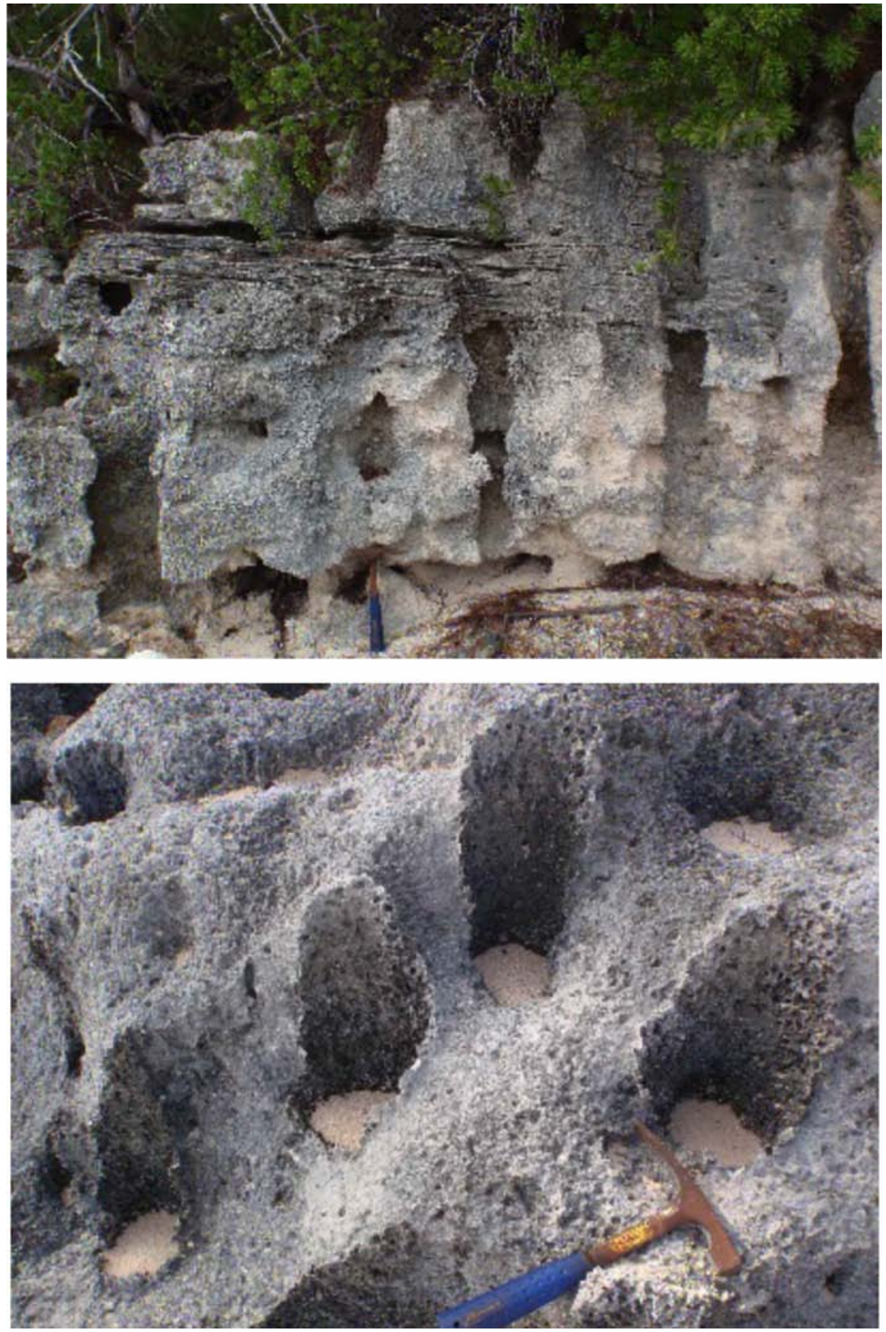

Figure 4. Large vertical cylindrical pipes with well-defined rims are commonly found in deposits with spongiform texture.

Figure 5. Accumulation and burial of *Sargassum* and other marine algae and seagrasses in beach and dune sand can be responsible for formation of spongiform texture in some grainstones.

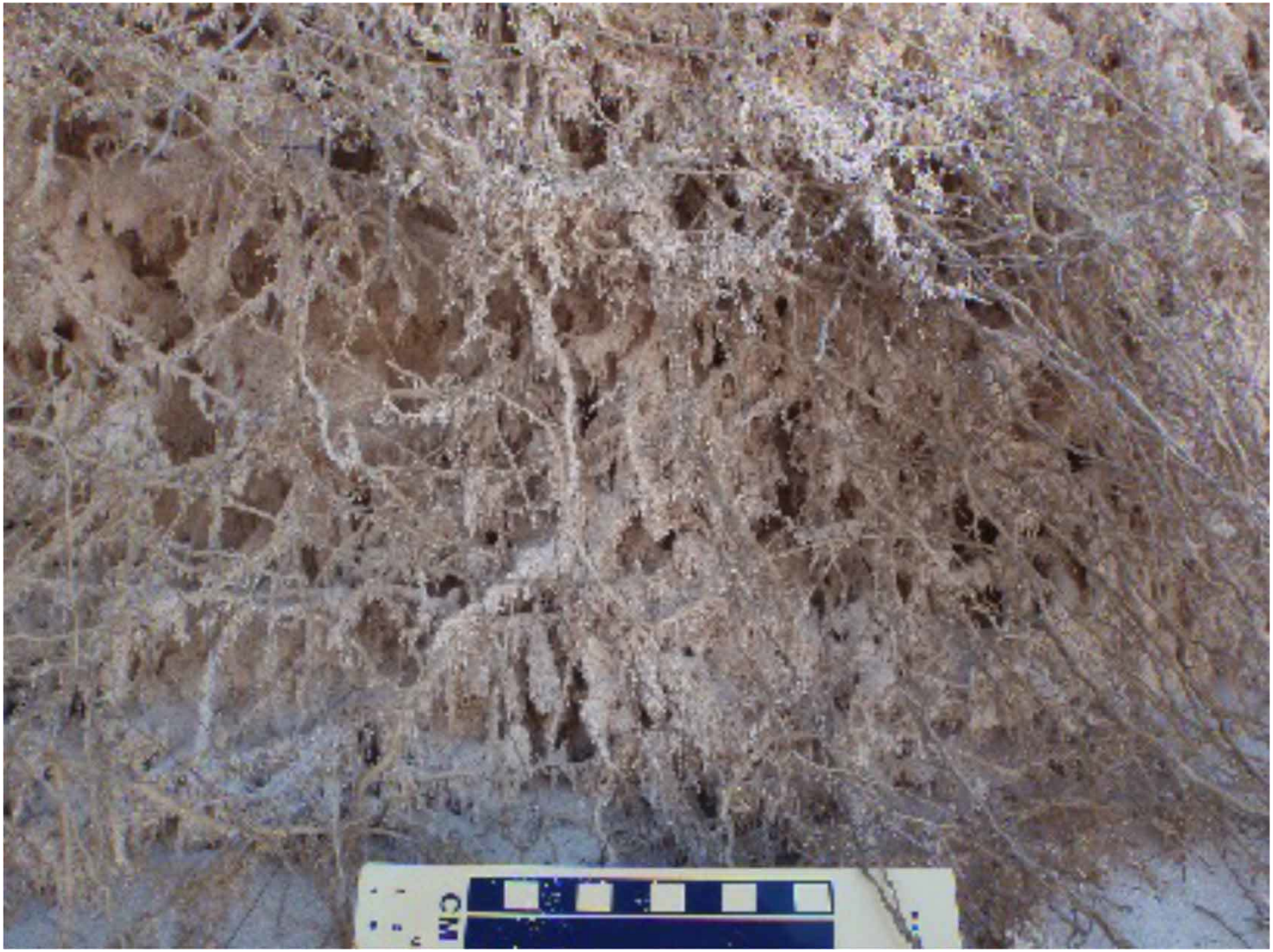

Figure 6. Trapping and lithification of sand by roots and stems of shrub and grass vegetation produce the clumpy texture of sand similar to that found in deposits with spongiform fabric.

Figure 7. Open cylindrical structures (vertical pipes) from the Quaternary deposits of the Bahamas (Lee Stocking Island (White and Curran 1993; Kindler 1995), Long Island (Curran et al. 2004, 2006), and Eleuthera (Kindler et al. 2010)) and Bermuda (Hearty and Olson, 2011) have been interpreted as molds of tree trunks. One possible modern analog - silver thatch palm (*Coccothrinax argentata*) - is shown here.

Figure 8. Some pipes can also represent larger diameter vertical roots may also exploit pre-existing pathways created by dissolution and possibly other mechanisms.