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Three-Dimensional Pore Connectivity Evaluation in a Holocene Microbialite Head

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Microbial carbonates have complex pore geometries and networks. Depositional pores related to microbial textures have properties that reflect biological processes rather than mechanical sedimentation of loose grains (Ahr, 2008). These pore systems require detailed descriptions of the fundamental characteristics, such as texture and fabric, for an appropriate evaluation of the petrophysical properties. However, much more geological insight is needed to describe the pore system in the three-dimensional space. Conventional methods of fundamental rock characteristic description are insufficient to elucidate the high heterogeneity of pore geometries observed in microbial carbonates. For instance, pore-pore throat ratio, pore throat sizes and coordination numbers commonly are misunderstood and simplified to fit previous pore system models. Several research (Ehrlich *et al.* 1991; Anselmetti *et al.*, 1998; Xu *et al.*, 1999; Ashbridge *et al.,* 2003; Hidajat *et al.*, 2004; Okabe, 2004; Okabe & Blunt, 2006; Pahdy *et al.,* 2006; Glemser, 2007; Al-Kharusi & Blunt 2008; Căpek *et al.* 2009) has been done to better understand how these relationships record or influence permeability changes in conventional and complex reservoirs. A common tool used is X-ray computed tomography (CT scan) to scan rock samples, and build volumes in density units. The main purpose of building density volumes has been to predict the petrophysical parameters and model their results, a major objective in the reservoir characterization. Nevertheless, the use of the geologic information is reduced to lithology and pore type classification, while much more could be added to make better predictive models related to depositional and diagenetic settings. Thus, CT scan volumes are a powerful tool that allows for the recognition of fundamental rock characteristics and pore system elements to a degree not matched by conventional methods. Carbonate reservoirs are influenced by depositional and diagenetic processes which control texture, fabric and pore geometries. The degree of influence of each one define different rock types (Ahr, 2008). However, depositional and diagenetic characteristics must be analyzed in separate to build the initial knowledge for a specific group of complex lithologies, such as microbial carbonates. This paper presents data on how depositional processes control petrophysical parameters. A Holocene microbialite head was used for this study because its diagenetic processes are minor and do not affect depositional patterns. The microbialite head is 25 cm tall for 30 cm wide, and grew in a hypersaline lagoon (*Lagoa Salgada*) located in Campos dos Goytacazes, Rio de Janeiro, Brazil. The lagoon was formed 3780 ±170 BP, by sea level rise and formation of the *Paraíba do Sul* River Delta, during the Late Quaternary (Srivastava, 2002). The microbialites formed only on the west side of the lagoon (Silva e Silva *et al*, 2007), where low slope angle, and relatively higher energy supported the microbiological activity. Changes in environmental conditions caused variations in the microbialite growth rate (Coimbra *et al*. 2000), which formed different textures and fabrics on the microbialite head control the depositional porosity and permeability distribution patterns. The use of geologic descriptions and stratigraphic analysis provides insight about reservoir quality, and also predictions about rock type distribution in reservoirs with low diagenetic textural overprint. Two growth cycles (figure 1) formed on the microbialite head, they are separated by an erosional surface. The older cycle starts with planar stromatolites that became domal upward and grades upward into thrombolite and is capped by small digitate stromatolites. Gastropodintraclast grainstone formed in channels between heads, in this older cycle. The second cycle begins with large digitate stromatolites, grades upwards into thrombolites, and is capped by small digitate stromatolites. The texture and fabric of each facies created differences in pore geometries and pore connection patterns that are better evaluated on CT scan volumes. The planar stromatolite, large digitate stromatolite, small digitate stromatolite and thrombolite facies were isolated on the three-dimensional volume (figure 2), and their pore network was described. The thrombolites have the highest porosity with a well-connected pore network, inherited from the irregular and high growth rate pattern during periods of environmental stress. The plug porosity and permeability values 40.6% and 6.9D respectively in this facies reflect these characteristics. The pore geometries are complex and changes in pore diameters, pore throat sizes and coordination numbers are common. The planar stromatolites have a simple and horizontal pore geometry that interferes with vertical connection between the porous layers, whereas the digitate stromatolites have a more complex vertical pore geometry. The porosity and permeability values for a plug in the large digitate stromatolites was 30.7% and 92.1 mD. The small digitate stromatolites have few pores, which are small and poorly connected due to the close packing of the digits, which is more narrow than in the large digitate stromatolites. These differences also are observed in pore size distribution, where the thrombolites have the largest pores compared to the other facies. Thus, the four rock types each has their own fundamental rock properties and petrophysical characteristics. Some depositional features, such as channels, formed connection pathways along the microbialite head. In conclusion, the complete description and analysis of facies and their pore systems are extremely helpful to understand microbialite reservoirs. Microbialites pore systems are very complex and difficult to describe, so the use of volumetric techniques, such as CT scan, are really necessary. Furthermore, pore volumes serve to detail the fractions of connected and non-connected pores, evaluate the pore-pore throat ratio and the relationship between the volume and specific surface of the pore system, and allow their results to be upscaled during reservoir modeling exercises.

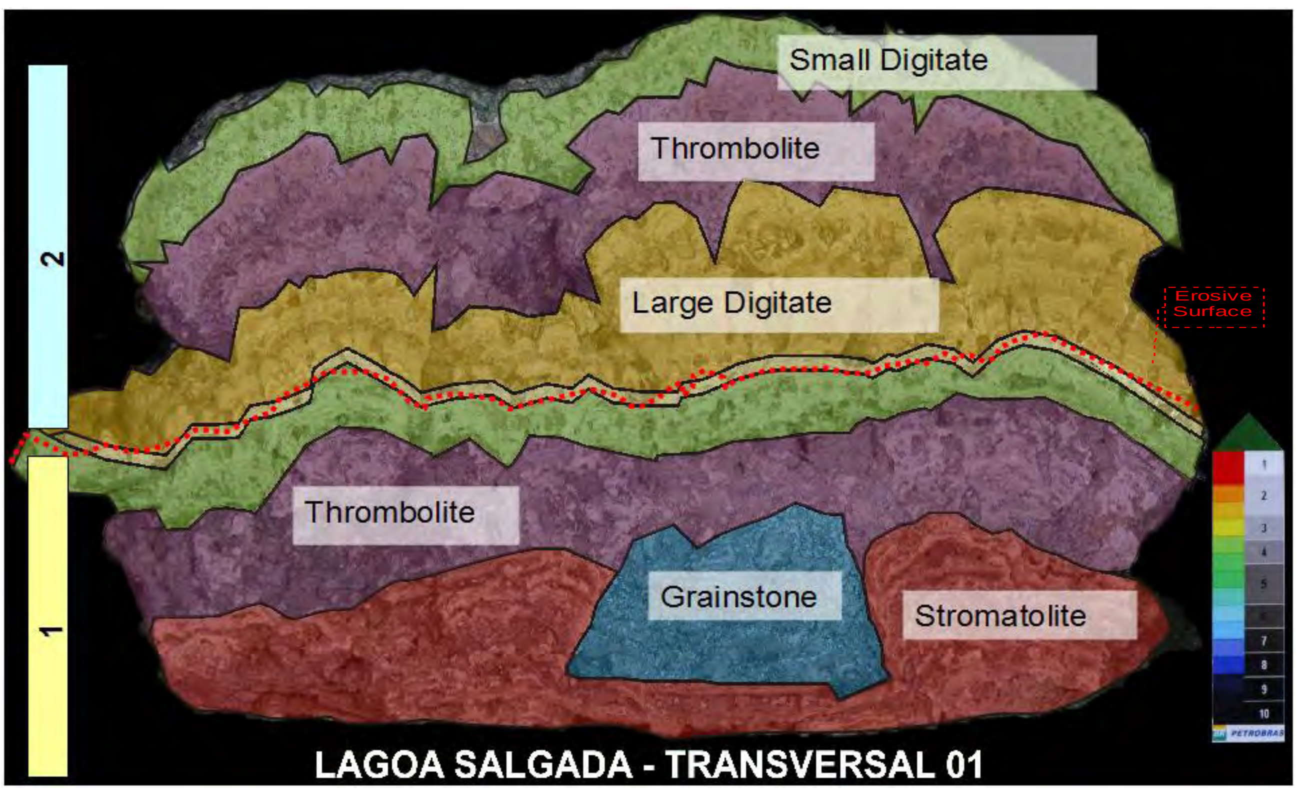

Figure 1 – Transversal Section on the microbialite head with markers for the two growth cycles and the lithofacies described.

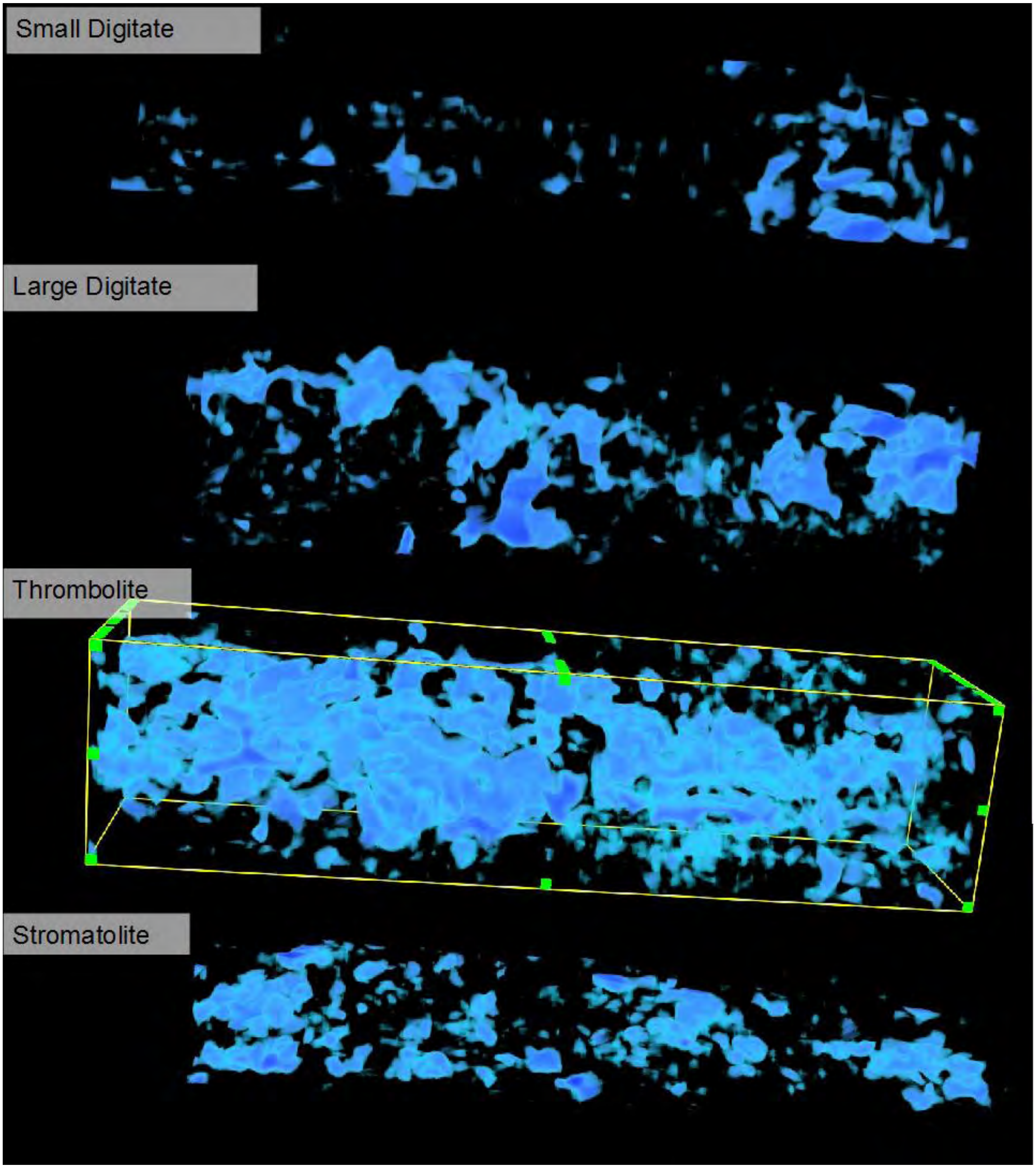

Figure 2 – Pore networks isolated for the facies Small Digitate Stromatolites, Large Digitate Stromatolites, Thrombolites and Planar Stromatolites. The pores are the blue elements on the image.

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