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**Carbonate Rock-Forming Processes in the Pre-salt “Sag” Successions of Campos Basin,
Offshore Brazil: Evidence for Seasonal, Dominantly Abiotic Carbonate Precipitation,
Substrate Controls, and Broader Geologic Implications**

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Lacustrine carbonate facies comprise the unique reservoirs of the pre-salt “sag” successions in Campos Basin, offshore Brazil. The sag carbonate rocks are typically described as microbialite facies, which suggests that microbial organisms played important roles in sediment production and accumulation. Observations of cores and sidewall cores, however, indicate that abiotic precipitation of different carbonate phases formed most of the important reservoir facies at many locations in the Campos Basin.

Primary aragonite, calcite, and dolomite were precipitated along the floor of the pre-salt lakes, as well as *within* previously deposited sediment by displacive crystal growth. Non-skeletal grain types (i.e., ooids, spherules, lithoclasts, and composite grains) are most common, which indicates the important role of abiotic precipitation and cementation on grain formation. Lake-floor precipitation also formed morphologically complex, framestone fabrics (shrub-like features that formed rigid frames) in shallow, high-energy environments. In contrast, fibrous and micritic precipitates formed (sub)millimeter-thick crusts in sub-wave base settings. These thin crusts of nearly pure carbonate within deeper water facies are locally draped by silt-rich and pyritic layers, which suggest alternating times of carbonate accumulation, followed by deposition of very fine-grained siliciclastic sediment when the lake floor was dysoxic or anoxic. In shallower water framestone facies, slightly thicker crusts of precipitated micritic carbonate cover detrital carbonate sediment that filled between frame-building elements, forming regularly spaced laminations of carbonate grainstone/packstone and precipitated carbonate that bridge between 2 to 5 mm-thick growth bands within the frame. Alternating “couplets” of 0.2 to 1.0 mm-thick laminations of dense, fibrous precipitates that are followed by highly microbored laminations with abundant micropeloids and microbial remnants are also commonly found within frame-building precipitates.

Similar scales and types of carbonate layering are observed in other facies and suggest that carbonate precipitation was dominantly abiotic, apparently quasi-periodic, and was likely seasonal in nature in most depositional environments within the highly alkaline pre-salt lakes. Pure carbonate layers may indicate times of seasonal input of oversaturated water to the lake systems (more wet? more lake overturn?), which were followed by times when wind-blown silt was supplied to far-offshore lacustrine environments and the lake bottom became highly reducing so that pyrite could form (more arid? more stratified water column?). If these

microfabrics are indicative of seasonally controlled carbonate precipitation along the lake floor, then sag carbonate facies accumulated at average annual rates of 200 microns to 5 mm per year. These are exceptionally fast accumulation rates for shallow-water carbonate successions and suggest that much of the sag succession along the conjugate margins of the South Atlantic could have been deposited in 1 Myr or less.

We also recognize that although there is abundant microbial evidence within the various precipitated carbonate fabrics, other cryptic fabrics within many of the precipitated carbonate forms (i.e., framestone fabrics and spherules) indicate the former presence of possible soft-bodied organisms, most likely some type of macroalgae. We suggest that many of the framestone fabrics in the sag carbonates of the South Atlantic might owe their origins to “passive” coating and encrustation of precipitated carbonate onto macroalgae or other organic substrates. Microbes, although present and commonly entombed in the precipitated carbonate fabrics, may not have been essential for carbonate precipitation.

In summary, the various types of regularly layered, sediment fabrics have important implications for reservoir quality, reservoir model-building strategies, and estimates of long-term sediment accumulation rates in the sag lacustrine environments of offshore Brazil.

