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Carbonate-associated sulfate constrains on the Cretaceous Barra Velha Formation

ANTOINE CRÉMIÈRE[1], THEODORE PRESENT[1], KRISTIN BERGMANN[2], KELSEY R MOORE[1], JOHN GROTZINGER[1], ALEX SESSIONS[1], JOHN EILER[1], WOODWARD FISCHER[1], ERWIN ADAMS[3], JOACHIM E. AMTHOR[4] AND JESS ADKINS[1]

[1]California Institute of Technology
[2]Massachusetts Institute of Technology
[3]Shell
[4]Shell Brasil Petróleo Ltda
Presenting Author: cremiere@caltech.edu

The rifting of southwest Gondwana during Early Cretaceous time led to the separation of South Africa and South America and subsequent opening of the southern Atlantic Ocean. Simultaneously, a series of syn- and post-rift sedimentary formations known as “pre-salt” units were deposited in a hydrothermally influenced alkaline lacustrine environment prior to evaporite deposition associated with seawater incursion. In the Santos Basin, offshore Brazil, the Barra Velha Formation is constituted of pre-salt carbonates deposited in a sequence of alternating Mg-clays, spherulites and shrubs. However, the source of fluid and the nature of processes leading to the deposition of those exotic but extensive lacustrine petroleum reservoirs are not fully understood.

This study presents a suite of carbonate-associated sulfate (CAS) concentration and sulfur isotopic composition measurements of the lacustrine rift to post-rift strata from 10 wells in the Santos Basin. Both CAS concentration and δ^{34}S values range widely, from 12 to 2,500 ppm, and from -9.3 to 38.5 ‰ VCDT, respectively. In mudstone and some spherulite samples, we observe a decreasing δ^{34}S values with increasing CAS concentration trend, a pattern typical for post-depositional oxidation of ^{34}S-depleted sedimentary pyrite. In contrast, increasing CAS concentration with δ^{34}S values reaching ~ 20 ‰ in mudstones underlying the evaporite deposits possibly represent a signature of Cretaceous seawater incursion into the lake. The best-preserved carbonate fabrics identified petrographically and with µ-XRF elemental mapping have lower CAS contents, from few tens of ppm to 400 ppm. Such remarkably low CAS content is consistent with equilibrium partition of sulfate into calcite at low aqueous sulfate to carbonate ion activity ratios—on the order of 10—in agreement with deposition of those carbonate facies under alkaline conditions. Some $^{\delta 34}$S values of shrub textures are isotopically higher than any source of sulfate thus suggesting a loss of ^{34}S either as burial of sulfide minerals and sulfurized organic matter or degassing of volatile sulfur compounds.