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Petroleum geochemistry of South Atlantic equatorial margin oils: ACT Cretaceous sources, multiple signals of maturity, and migration

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The aim of this research is to better recognize the origin, thermal maturity and migration constraints on oils from equatorial margin basins including offshore Cote d'Ivoire, Nigeria and Senegal, as well as northern Brazil, Guyana/Suriname and Trinidad. GC/MSMS techniques (combined gas chromatography with multiple mass spectrometers), not previously applied to these oils, show both enhanced source rock depositional environment designations using, e.g., C40 carotenoid distributions, and multiple maturity signals calculated from terpenoid biomarkers, alkyl aromatic ratios and diamondoid abundances.

Early generated oil, rich in heavy-end biomarkers, migrates first with oil vitrinite reflectance equivalence based on biomarkers (VREB) representing the source maturity during initial expulsion and early migration. With continuing source rock burial, expulsion and migration, lighter hydrocarbons (lean in biomarkers) mix with the early oil along migration routes or in the reservoir. This subsequent maturity signal, VREQ (based on 13 thermally dependent alkyl aromatic ratios), represents a mid-range maturity estimation. Diamondoid concentrations increase with VREQ, which have been calibrated using oils from onshore unconventional petroleum systems. Excess diamondoids above that expected from VREQ levels suggest mixing of gas from higher maturity sources and potentially increased GORs.

For this presentation, we emphasize the results from the Gulf of Guinea, offshore eastern Cote d'Ivoire, but also include examples from the Guyana, Para-Maranhao, and Foz do Amazonas basins. Using traditional terpane and sterane biomarkers, as well as stable carbon isotopic compositions, it has been determined that there are three Cretaceous (ACT) marine oil families offshore Cote d'Ivoire. The western-most Lion oil field samples (members of oil family 'ICM2'), reservoired mostly in Albian sands between about 2,900 to 3,900 m, are suspected to have been generated by late Albian (OAE1) sources. Interestingly, there also appears to be a small Early Cretaceous lacustrine-sourced component in the Lion oils. The VREB maturity ranges from 0.74-0.78% while the VREQ values are much higher, 0.99-1.08% and the diamondoids concentrations match the VREQ levels. In contrast, more eastern IVCO oils belong to oil family 'ICM1' and are reservoired in Senonian/Maastrichtian sands (~1,700-2,400 m), likely charged from Cenomanian/Turonian (OAE2) marine sources. VREB values for these oils are only ~0.70%, with VREQ maturity between 0.80- 0.85%. However, the diamondoid content is far above that expected from the VREQ level of 0.85%. These 'extra' diamondoids imply higher maturity, gas window generation from deeper sources, mixing with the less mature oils in the reservoir, and perhaps yielding higher than expected GORs. Fields in this area are often classified as gas fields. Both Guyana and Foz do Amazonas basin oils are somewhat less mature than the Lion oils (0.07% VREB vs. 1.0% VREQ). Cote d'Ivoire Espoir field oils, as well as Tano and West Tano oils offshore neighboring Ghana, also belong to family 'ICM1', and importantly, so does the oil from the Para-Maranhao basin offshore Brazil. The few oils from the Cote d'Ivoire Gazelle field are members of oil family 'ICM3', from another Cretaceous

marine source facies with slightly higher Pr/Ph ratios and isotopically more depleted than families ‘ICM1’ and ‘ICM2’ oils.

The large maturity range measured in the Lion/Guyana/Foz do Amazonas oils (Delta VREQ-B) reflects the accumulative time of oil charging a given reservoir, with lower Delta VREQ-B values having less time to fully charge the reservoir, while the larger differences suggest more available time for a reservoir to receive migrating fluids, and conceivably, more reservoired oil.

In summary, the new GC-MS/MS (a.k.a. QQQ) oil data provide 1) better sterane biomarker compositions, both saturate and aromatic, one key in determining marine Cretaceous source age, 2) carotenoid biomarkers to aid in source rock age determination and degree of preservation (i.e., source rock quality), and 3) oil maturity based on lighter aromatic markers (VREQ) versus heavier sterane/terpane biomarkers (VREB); the difference in these oil maturity signals predicts the range in source rock maturity during reservoir charging.