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ABSTRACT

LATE CRETACEOUS PALAEOGEOGRAPHY OF NORTH-EASTERN SOUTH AMERICA: IMPLICATIONS FOR SOURCE AND RESERVOIR DEVELOPMENT

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Revised palaeogeographic models for north-eastern South America suggest that local climatic, oceanographic, and bathymetric conditions played a critical role in source rock deposition and preservation, and reservoir development during the Cretaceous. Interpretations derived from outcrops, wells, and seismic data suggest that Late Albian – Early Cenomanian source rock deposition was primarily focused along an anoxic palaeo-slope. The conditions necessary for source rock deposition and preservation appear to have been in place by the Late Albian, and included the presence of warm, saline bottom waters, seasonal wind-driven upwelling, and cyclic high nutrient flux to the surface water column. In contrast, Early Cenomanian – Santonian source rock deposition was characterised by prolonged periods of shelf anoxia, and cyclic but geographically extensive periods of anoxia developed along the Trinidad and Suriname palaeo-slopes, and within a large submarine canyon system observed offshore northern Suriname. Potential reservoir units deposited during the Late Albian – Early Cenomanian are characterised by fine to medium-grained sandstones. These sandstones are thicker and more massive than younger (Turonian – Santonian) units and contain a greater amount of shelf-derived material. We believe this is indicative of the presence of proximal shelf-margin deltas, which funnelled siliciclastics into slope and basinal settings through a series of slope channels and through mass transport complexes (slumps and debris flows). Thinner and less extensive sandstones deposited during the Turonian – Santonian reflect continued flooding of shelfal areas and the landward retreat of the large Early Cretaceous delta systems.

Extended periods of shelf anoxia (millions of years) as observed in north-eastern South America are rare in the geologic record, and generally require some type of bathymetric barrier be present to initiate, enhance, and maintain a restricted/stagnant water mass. Conceptually and practically, it is difficult to maintain such conditions in an open shelf environment. The primary reason for this is that normal tide or storm-induced mixing of

the water column will “flush” the system and re-oxygenate surface and bottom water masses in geologically instantaneous intervals. Examples of modern shelf anoxia clearly demonstrate that periods of high fresh water runoff (seasonally-induced) are needed in order to develop and maintain restricted bottom waters. These areas are highly temporally and spatially limited, are temperature dependent, and are modulated by local bathymetric and oceanographic conditions. As a result of these factors, we propose that the barrier that allowed the development and maintenance of this system in north-eastern South America during the Late Cretaceous was the Lower Cretaceous carbonate shelf margin, which has since been largely removed by later Tertiary erosion/tectonism.

In addition to the development of a bathymetric barrier, a relatively high organic matter flux must be maintained in order to develop thick sections of laterally extensive high-TOC sediments, and redox conditions within the upper sediment layers must be conducive to the inhibition of scavenging by bottom dwelling organisms. Traditional concepts of coastal upwelling suggest that a similar system may have functioned on a seasonal basis along the Trinidad – Suriname palaeo-slope, and was most likely coincident with wet-dry cycles in continental north-eastern South America. Our model suggests that upwelling may have been the predominant supplier of nutrients to the sediment column during “dry” cycles. Nutrient flux would have been augmented during “wet” cycles by the supply of large amounts of terrestrial organic matter. Stratification of surface water layers by the rapid outflow of fresh/brackish water would have led to mid- and/or bottom water anoxia, helping to preserve organic matter in shallow sub-bottom sediments. Seasonal wet-dry cycles (supply variations) can also explain the cyclic nature of sandstone deposition into slope and basinal settings without the need for invoking changes in eustatic sea level (e.g., the concept of “low-stand” fan deposition). However, we cannot completely rule out the concept of “low-stand” deposition in this area.

Predicting the present geographic extent of “effective” source rocks is difficult because the precise palaeogeographies of Upper Cretaceous units are still not clearly understood. ODP/DSDP data suggest that many of the well known source units (Querecual, Cuche, Gautier, Naparima Hill, Canje, and New Amsterdam) are coincident with well documented Oceanic Anoxic Events (OAE’s). Unfortunately, the central North Atlantic OAE’s were responsible only for the deposition of thin-bedded organic carbon-rich sediments, and not the 10’s – 100’s meter thick units observed in north-eastern South America. Rather, these rocks were deposited in coast-proximal settings which were highly dependent on local climatic, oceanographic, and bathymetric conditions as well as organic matter flux. Hence, the expectation that “effective” Cretaceous source rocks span the entire eastern part of the Central Atlantic is unsupported by the available data. What is clear from our work is that a “down-dip” stratigraphic limit of “effective” Atlantic Basin-derived source rocks should occur within deep-water areas of northern and eastern Trinidad, as well as offshore Guyana and Suriname. However and perhaps more surprisingly, a “down-dip” stratigraphic limit of Upper Cretaceous sandstone reservoirs may be more difficult to predict and could be more extensive than previously assumed.