Geologic Evolution Of Conjugate Volcanic Passive Margins: Influence on the Petroleum Systems of the South Atlantic

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Two contrasting types of passive margins are 1) thick-crusted volcanic margins and 2) thin-crusted nonvolcanic margins. Examples of conjugate nonvolcanic margins in the South Atlantic Ocean are the Santos and Campos basins along the Brazilian margin and Kwanza and offshore Lower Congo basins along the African margin (Fig. 1).

In these basins, the ocean-continent transition is marked by crustal thinning caused by to extensional deformation preceding the continental breakup. During extension, normal synthetic faulting generated half-graben systems in Campos Basin and offshore Lower Congo and Kwanza basins during the Neocomian (Fig. 2), with deposition of thick syn-rift fluvio-lacustrine deposits (Syn-Rift I). A second phase of rifting, developed during the Barremian (Syn-Rift II), is marked by thermal subsidence and minor extension (Fig. 2). The Syn-Rift II sediments are referred to as the Lagoa Feia Formation in the Campos Basin (Brazil) and Sag phase (e.g., Henri et al., 1995) or Pre-Salt Wedge (e.g., Wilson et al., in press) along the African margin and are characterized by transitional sediments with increasing marine influence in the upper portion (e.g., Rodrigues and Takaki, 1988; Silva-Telles, 1996; Wilson et al., 1997). The rift deposits are the major source of hydrocarbons in the South Atlantic. After breakup, evaporites were deposited during the early drift phase. Salt movement during Cretaceous and Cenozoic generated salt pillows and domes, deforming the sediments deposited during the drift phase.

Volcanic passive margins are a major type of large igneous provinces, characterized by seaward-dipping reflectors (SDRS), normally associated with subaerially emplaced basalt flows and intercalated at least in part with continental sediments. In the South Atlantic, the volcanics extend laterally for hundreds of kilometers and can reach a thickness of about 15 kilometers. A number of questions remain concerning their formation. These include the influence of hotspots, the timing of volcanic emplacement with respect to continental breakup, the nature of the crust associated with the volcanics, and the symmetry of the volcanics with respect to the breakup axis.

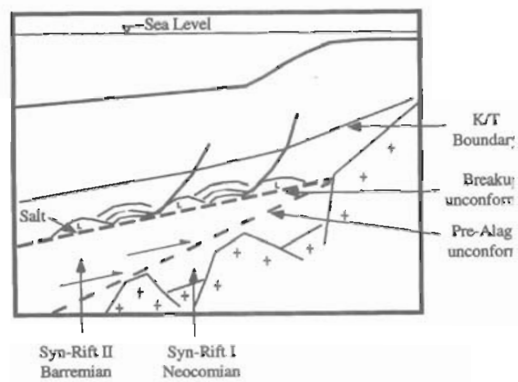

Figure 2: *Schematic dip section from Kwanza Basin showing the two Lower Cretaceous phases of rifting.*

The Paran-Etendeka flood basalts and the SDRS of the Pelotas and Walvis basins (Fig. 1) are the result of the rifting and subsequent breakup of the South American and African plates under an initial influence of the Tristan da Cunha hotspot. The SDRS wedges were probably emplaced after continental breakup at least partially over an extended continental crust. The Pelotas and Walvis SDRS wedges are part of two major SDRS provinces in the South Atlantic: Santos-San Jorge (South America) and Walvis-Orange (Africa) provinces (Fig. 1). These provinces form a broad and symmetrical volcanic complex, extending over more than 3,000 km linearly in the South Atlantic. It is proposed that these SDRS provinces were emplaced as a subaerial oceanic ridge, representing the initial stage of formation of the oceanic crust in most passive margins.

The subsidence in the Pelotas and Walvis basins started in the continental/initial oceanic crust transition. The oceanic crust

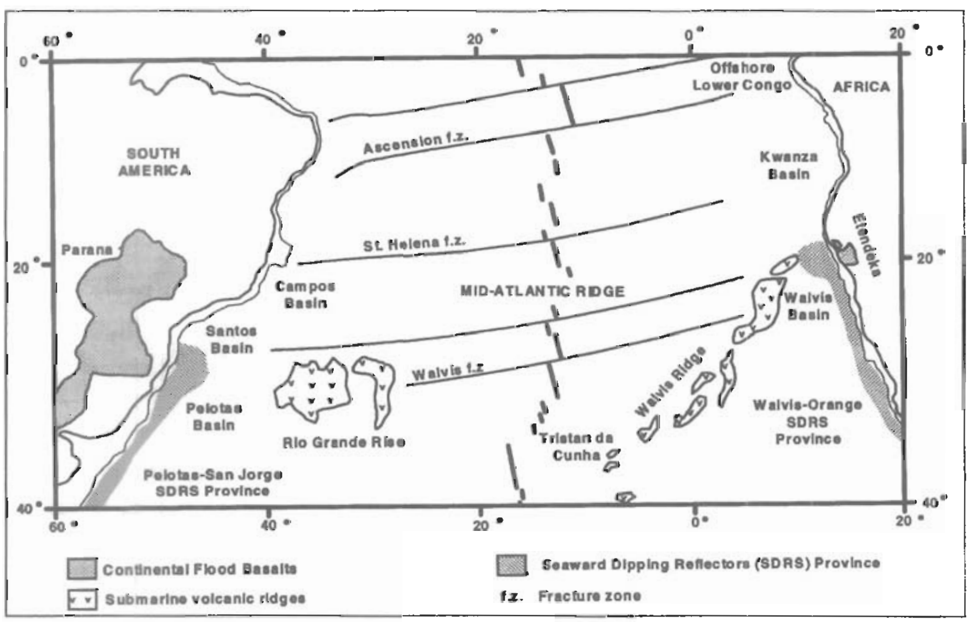

Figure 1: *Present configuration of the South Atlantic showing the basins discussed in this study, the thick volcanic ridges of the Rio Grande Rise and Walvis Ridge, and the Mid-Atlantic Ridge.*

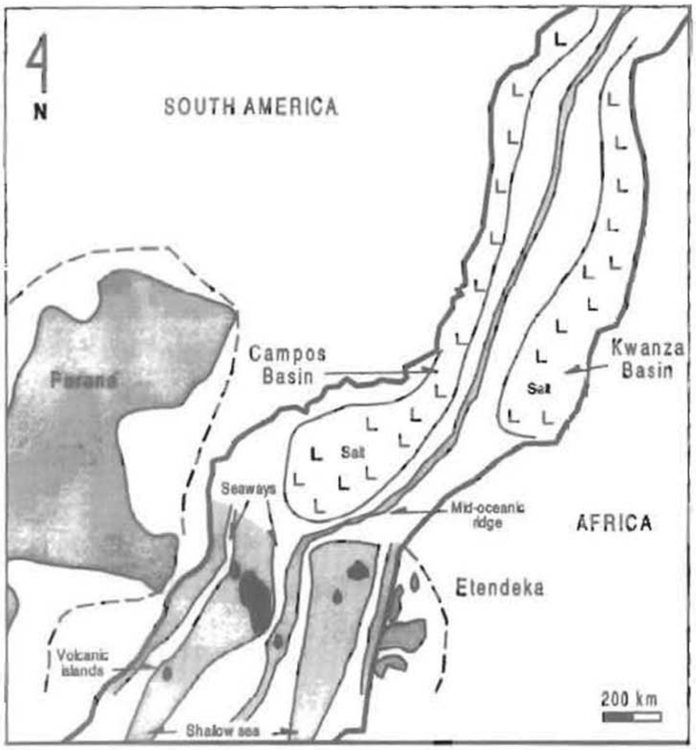

Figure 3: *Paleogeographic reconstruction for the lowermost Aptian showing the distribution of volcanics and salt deposits in the South Atlantic. SDRS formed a shallow basement in the early Aptian, restricting a wide connection to the ocean for the basins to the North and allowing the deposition of salt in the South Atlantic.*

kept close to sea level or in shallow water depths almost until the Turonian, at least in the northern portion of the Pelotas and Walvis basins. The subsidence close to the continental crust generated a narrow seaway parallel to the coast in both margins. The initial oceanic crust formed a broad and shallow platform in both margins since the Barremian, creating a barrier between the South Atlantic and the Southern Ocean during the early Aptian.

During the Barremian, while continental breakup started in Pelotas and Walvis basins with the emplacement of a subaerial mid-oceanic ridge, the second phase of rifting (Syn-Rift II or Pre-Salt Wedge) dominated the northern basins of the South Atlantic. Geochemical and paleontological data from the Brazilian margin (Rodrigues and Takaki, 1987; Silva-Telles, 1996) and observations from Angola (Burwood et al., 1992; Wilson et al., in press) suggest an increase of marine influence toward the top of the section in a time that precedes continental breakup and oceanic crust formation in the Campos and Kwanza basins. One explanation for the presence of marine strata in the rift section of Campos and Kwanza basins is the fast subsidence rate during the Syn-Rift II combined with marine invasions through the seaways in the Pelotas and Walvis basins during periods of high sea level in the Barremian. Marine waters could invade the northern basins of the South Atlantic during the sea-level high in the Barremian, transgressing over transitional sediments and infilling depressions formed by the second phase of rifting, allowing restricted deposition of marine evaporites and carbonates.

Limited circulation occurred along the seaways and the sides of the shallow oceanic ridge since the Barremian in the Pelotas and Walvis basins. After continental breakup and oceanic crust emplacement in the Campos and Kwanza basins, periods of low sea level during the early Aptian would practically have isolated the South Atlantic from the Southern Ocean, allowing seawater evaporation and salt precipitation in a broad area along the South Atlantic continental margins (Fig. 3).

BIOGRAPHICAL SKETCH

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Vitor Abreu received his B.S. (1984) and M.S. (1989) at the Federal University of Rio Grande do Sul in Brazil. Abreu has worked for Petrobras since 1987 and was previously the manager of biostratigraphy and paleoecology. Currently, Abreu is at Rice University studying for a Ph.D. on the topic "Geologic Evolution in Conjugate Volcanic Passive Margins: Pelotas Basin, Brazil, and offshore Namibia, Africa." His research interests include sequence stratigraphy in passive margins and stable isotope stratigraphy.

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