The Tectonic and Geological Environment of Coastal South America

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1 Introduction

The tectonic history and geological factors, such as the present-day geomorphology and vertical motions of the coastline, influence the coastal and marine ecosystems of South America. The continent's Phanerozoic tectonic history is dominated by its separation from Africa and the Mid-Miocene uplift of the Andes. Tectonically, South America is divided into two parts, the Andean chain to the west and a vast stable platform to the east, consisting of exposed Precambrian rocks and shallow sedimentary cover rocks. The Pacific Andean coastline is characterized by high relief, a relatively narrow shelf bordering a deep trench, small drainage basins, and rapid vertical motions of the coast. Low relief, a broad shelf, and extremely large drainage basins and alluvial fans characterize the Atlantic coastline. Today, approximately 93 % of South America's drainage is to the Caribbean and the Atlantic away from the Andes and provides the world's best example of present-day continent-scale drainage control by plate tectonics (Inman and Nordstrom 1971; Hoorn et al. 1995; Potter 1997).

2 The Atlantic Continental Margin

2.1 Physiographic Features

The breakup of Western Gondwana in the Mesozoic (Rabinowitz and LaBrecque 1979) is characterized by aborted rifts in the onshore northeastern region of Brazil (e.g., Reconcavo-Tucano-Jatobá Rift System) and several rifts that evolved to form one of the world's largest series of passive basins (e.g., Pelotas, Santos, Campos, Espírito Santo, Mucuri, Cumuru-

Ecological Studies, Vol. 144
U. Seeliger and B. Kjerfve (eds.)
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xatiba, Jequitinhonha, Camamu-Almada, Jacuípe, and Sergipe/Alagoas) along continental margins. A shallow platform with Tertiary sediments onlapping the Precambrian basement to the west, a deep rift trough filled with Neocomian to Aptian sediments, and thinner rift sequences from the slope towards the boundary between continental and oceanic crust characterize sedimentation along the continental margin (Mohriak et al. 1998). Salt tectonics is expressed by thin subhorizontal layers in the proximal regions near the boundary faults or hinge lines that correspond to the western limits of the rift troughs. Towards the slope and deep waters, salt and extensional tectonics affecting the overburden dominate the basin architecture (Mohriak et al. 1995). Gravity-driven compressional tectonics may be found towards the boundary between the continental and oceanic crust (Demercian et al. 1993; Cobbold et al. 1995). The thermal phase of subsidence may result in thick depocenters in some basins (e.g., Santos and Espírito Santo Basin), whereas other basins are characterized by an abrupt shelf-edge and by thin sequences overlying tilted rift blocks or oceanic crust in deep water regions (e.g., Jacuípe Basin).

Physiographic features related to the tectonic framework of the South Atlantic Ocean are (1) the spreading ridge between the South American and the African continents, located closer to the coastline in the northern basins of the South American Margin, and (2) segments of the South Atlantic Margin that are about perpendicular to the ridge (Fig. 1). Linear tectonic features are the Walvis Ridge in Africa, the Vitória-Trindade Ridge in the Eastern Brazilian Margin, and the Florianópolis Fracture Zone, northwest of the Rio Grande Rise. The continental platform is wide in the southern basins and in the northernmost provinces (in front of the Amazon Cone), but is rather narrow in the northeastern margin.

Some major tectonic features in the Eastern Brazilian Margin include the Rio Grande Rise south of the Florianópolis Lineament and the São Paulo Plateau, which is characterized by a large salt diapir province. In the deep water region, salt tectonics is responsible for mini-basins and evacuation troughs, expressed in the sea bottom as concave irregularities. Basinwards from the outer limit of the salt diapir province, several structures with a circular outline correspond to volcanic plugs, such as the Almirante Saldanha Seamount (Fig. 1). Bathymetric and potential field data are helpful to characterize volcanic features, such as the Rio Grande Rise and the Rio Grande Fracture Zone, in the oceanic domain of the Pelotas Basin (Gamboa and Rabinowitz 1981). The Florianópolis lineament (north of the Rio Grande Rise and south of the São Paulo Plateau) is the western prolongation of the Rio Grande Fracture Zone. It is aligned in an E-W direction, and is associated with several igneous plugs (São Paulo or Florianópolis Ridge). The abyssal plain, the continental rise and the platform of the San-

Fig. 1. Main physiographic features of the Brazilian margin. (Modified from Asmus and Baisch 1983)

tos and Campos basins are crossed by a major NW-trending lineament that extends along the Jean Charcot seamounts, and advances onland towards the Cabo Frio region (Souza et al. 1993).

The southeastern segment of the Brazilian margin (Fig. 1) is characterized by several E–W inflections of the coastline along Rio de Janeiro State. This province (Cabo Frio region between the Campos and Santos basins) is characterized by the deflection of the pre-Aptian hinge line from the more general NE trend, and by widespread post-rift volcanic activity (Mohriak et al. 1995). The offshore and onland alkaline plugs are aligned in an E-W direction, from Poços de Caldas to Cabo Frio, and they have been dated as Late Cretaceous to Early Tertiary, with a peak of magmatic activity in the Eocene (Misuzaki and Mohriak 1992).

A major tectonic feature in the eastern Brazilian Margin is the Vitória-Trindade Ridge, an E–W lineament probably associated with a hot-spot (Fig. 1). There are several submarine seamounts adjacent to the Abrolhos Volcanic Complex, and towards the abyssal plain, volcanic islands may reach the seafloor (e.g, Trindade and Martin Vaz Islands). Other volcanic seamounts are aligned along E-W and NW-SE directions, off Bahia, Sergipe, and Alagoas states. The southern portions of the Espírito Santo and the Cumuruxatiba basins correspond to reentrants of the bathymetry (concavities from sea to land), approximately westward from the prolongation of the volcanic features in the oceanic crust. Dating (K-Ar) of the Abrolhos and Royal Charlotte volcanic complexes indicates that they contain mainly Tertiary basaltic rocks, which intruded into the continental platform and extruded above previously deposited sedimentary rocks, masking the possible occurrence of salt layers above the rift.

Northeastern Brazil is characterized by one large onshore rift (Recôncavo-Tucano-Jatobá Rift System), which failed to develop a thermal phase of subsidence, and by the elongated Jacuípe and Sergipe-Alagoas basins, which correspond to rifts that evolved as continental margin sedimentary basins (Ojeda 1982; Matos 1992). The platform in the northeastern margin is characterized by an abrupt shelf-break and by a continental-oceanic crust boundary very close to the shelf-edge (Mohriak et al. 1998).

2.2 Structural and Stratigraphic Evolution

The tectonic evolution of the basins can be divided into pre-rift, rift, protoceanic and continental margin phases (Asmus and Ponte 1973; Ponte and Asmus 1978). Stratigraphic divisions, which take tectonic phases into account, establish four megasequences (pre-rift, continental, transitional, and marine) that are normally separated by erosional unconformities. The pre-rift megasequence occurs only in the northeastern margin (both onshore and offshore) and is subdivided into Paleozoic and Jurassic supersequences. The marine megasequence may be divided into restricted and open marine supersequences. The transitional megasequence is characterized by salt tectonics, which imparts one of the most important controls on the evolution of all the sedimentary basins along the Eastern Brazilian Margin, with the exception of the Pelotas Basin (Chang et al. 1992). The sedimentary fill and structural styles of the basins along the Brazilian Margin are intrinsically related to basement-involved rift phases and basement-detached drift phases that were created during the separation of the South American and African tectonic plates.

The rift phase in most Eastern Atlantic sedimentary basins is characterized by a mosaic of N–S or NE/SW down-stepping synthetic faults, sometimes interrupted by antithetic faults creating a network of half-grabens with internal highs. E-W or NW-SE transfer fault systems accommodate the different stretching rates between the basins. The drift phase started when the stretching and rifting of the continental crust ceased and accretion of oceanic crust began. Salt movements, affecting the overlying rocks, created a series of listric growth faults in the evacuation zones, intraslope sub-basins surrounded by piercing salt domes, salt walls, and thrust faults. The distribution of the salt along the Brazilian and African margins is very irregular. Huge diapirs and salt walls (e.g., Santos and Campos offshore Brazil, Kwanza and Gabon offshore Africa) characterize some basins whereas others have much smaller quantities of evaporites (e.g., Sergipe-Alagoas in Brazil, Rio Muni and Douala in Africa). Lithospheric stretching and rifting ceased in the Eastern Brazilian Margin with the onset of seafloor spreading in the early to middle Cretaceous (probably by late Aptian – early Albian), but there are some indications (e.g., offsets at the base of the Aptian salt and other younger reflectors) of localized reactivations of basement-involved normal faults in the Sergipe-Alagoas and Jacuípe basins up to late Cretaceous time. In these basins, the transition between the continental and marine environments is characterized by recurrent tectonic activity, with concomitant magmatic activity.

The drift phase is characterized by a shallow-water Albian to Cenomanian carbonate platform in most basins, and the Upper Cretaceous is characterized by a major transgression which culminates with drowning of these platforms and predominance of bathyal environments (Chang et al. 1992; Rangel et al. 1994). As a consequence of thermal subsidence and the initiation of oceanic spreading in the South Atlantic, bathymetric depths increased progressively. The late Cretaceous/early Tertiary deepwater sedimentary environments predominated in a number of basins (e.g., Campos Basin). This time interval (Cenomanian to Paleocene) is characterized by predomi-