2 Geological Background: A Tectonic Panorama of Brazil

Fernando Flecha de Alkmim

Abstract

The landforms and landscapes discussed in this book developed in a variety of terrains, which together express the diversity of the geological background of the Brazilian territory. Located essentially in the old and relatively stable nucleus of the South American plate (known as the South American platform), Brazil comprises seven major categories of tectonic units, which are as follows: cratons, Brasiliano orogenic systems, Palaeozoic sag basins, equatorial margin basins, eastern margin basins, sub-Andean basins, and Tertiary rifts. The cratons together with the Brasiliano orogenic systems form the Precambrian basement of the continent. Exposures of these units comprise three distinct morphotectonic domains, namely the Guianas, central Brazil, and Atlantic shields. The four cratons delimited in Brazil represent stable lithospheric pieces that escaped the effects of the collisional processes responsible for the amalgamation of Gondwanaland, the large landmass from which South America and other southern continents derived. The Brasiliano orogenic systems form a network of collisional belts between the cratons, which were stitched together by the end of the Neoproterozoic Era. The Phanerozoic basins of Brazil record the long residence of South America in Gondwana and Pangaea, the breakup of the supercontinent during the Early Cretaceous, and subsequent processes. Large Palaeozoic sags cover a substantial portion of the Brazilian interior, whereas the eastern and equatorial margins host Cretaceous to Recent sedimentary successions. The tectonic units distinguished in the Brazilian territory have distinct expressions in the large-scale topographic relief. The lowlands are underlain by the cratons and covered by Palaeozoic sag basins. The highlands correspond to the Neoproterozoic orogenic systems, on which Phanerozoic structures such as arches, plateaus, and uplifts are superimposed.

Keywords

South American platform • Cratons • Brasiliano orogenic systems • Phanerozoic basins • Brazil

2.1 Introduction

From a geological Brasiliano orogenic systemsstandpoint, the geomorphological provinces focused in this book correspond to regional and local land surface expressions of rock assemblages and structures that characterize the various tectonic units exposed in the Brazilian territory. Together, these landscapes can be considered a manifestation of the Brazilian geodiversity.

Brazil is almost entirely located in the old and relatively stable nucleus of the South American plate known as the South American platform (Fig. 2.1). Defined as the portion of the continent that escaped the effects of the Andean orogenies (Almeida 1967; Almeida et al. 1981, 2000), the South American platform is underlain by Precambrian rocks and surrounded by the younger terrains of the continent,

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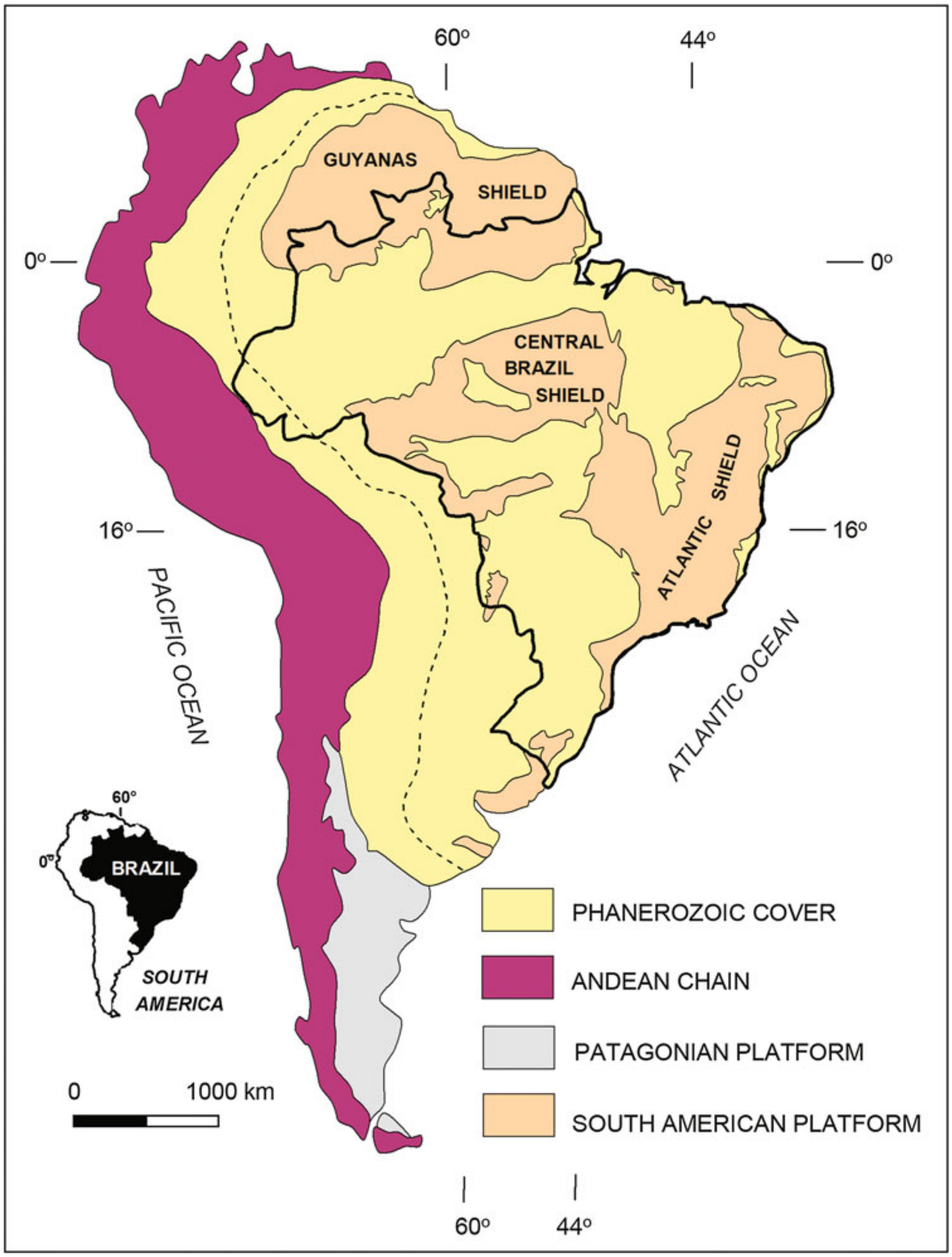

Fig. 2.1 Simplified tectonic map of South America, showing the South American platform and its shield areas (modified from Almeida et al. 1981)

represented by the Patagonian platform, the Andean chain, as well as the Pacific and Atlantic continental margin systems. Only a small portion of westernmost Brazil, the Acre basin (see next section), lies in the sub-Andean domain.

A substantial part of the South American platform is covered by Phanerozoic sedimentary successions. The areas of the platform, where the Precambrian basement is exposed, are collectively referred to as the Brazilian shield. Actually, the Brazilian shield comprises three distinct morphotectonic domains: the Guyanas, central Brazil (or Guaporé), and Atlantic shields (Fig. 2.1).

2.2 Tectonic Units of Brazil

In the Brazilian geological literature, each individual component of the South American platform and its Phanerozoic cover is traditionally portrayed as a structural province, defined as a geographically continuous domain, which differs from the adjacent terrains in terms of stratigraphy, tectonic evolution, metamorphic history, and age (Almeida et al. 1981; Bizzi et al. 2001). For simplicity, the building blocks of Brazilian geological framework are here discriminated on the basis of their tectonic function and age. Accordingly, seven categories of tectonic units can be recognized in the Brazilian territory: (i) cratons, (ii) Brasiliano orogenic systems, (iii) Palaeozoic sag basins, (iv) equatorial margin basins and associated intracontinental rifts, (v) eastern margin basins and associated intracontinental rifts, (vi) sub-Andean basins, and (vii) Tertiary rifts (Fig. 2.2).

Cratons and Brasiliano orogenic systems, corresponding to two distinct lithospheric types, are the fundamental components of the Precambrian nucleus of South America. The Precambrian core of the continent was amalgamated as various plates converged and collided to form the large Gondwanaland by the end of the Neoproterozoic and beginning of the Palaeozoic Era (Brito Neves et al. 1999; Cordani and Sato 1999; Campos Neto 2000; Almeida et al. 2000; Alkmim et al. 2001). The cratons of the South American platform, defined as old and stable lithospheric pieces that were not affected by the Neoproterozoic collisional processes, correspond to the internal parts of the plates that converged during the assembly of West Gondwana, i.e., South America and Africa. The so-called Brasiliano/Pan-African orogenic systems, forming a network of collisional belts between the cratons, represent the margins of those plates, as well as micro-continents and magmatic arcs also involved in the amalgamation of West Gondwana (Campos Neto 2000; Almeida et al. 2000; Alkmim et al. 2001) (Fig. 2.3).

At the very end of the Palaeozoic, around 250 Ma, Gondwana joined Laurasia to form Pangaea. Pangaea remained as a supercontinent for ca. 120 Ma, until the end of the Jurassic Period, when it started to break apart, giving rise to present-day continents and oceans. The Palaeozoic, continental margin, sub-Andean, and Tertiary basins make up the Phanerozoic cover complex of the South American platform and its margins. These basins record the residence of the Precambrian nucleus of the continent in Gondwana and Pangaea, the break up history of the supercontinent, and tectonic events occurring after individualization of the South American plate. As a consequence of the dispersal of Pangaea and generation of the South Atlantic in the Lower Cretaceous, some cratons and Brasiliano/Pan-African orogenic systems split in two. Their counterparts are now exposed in the eastern Brazilian and western African shields (Porada 1989; Trompette 1994) (Fig. 2.3).

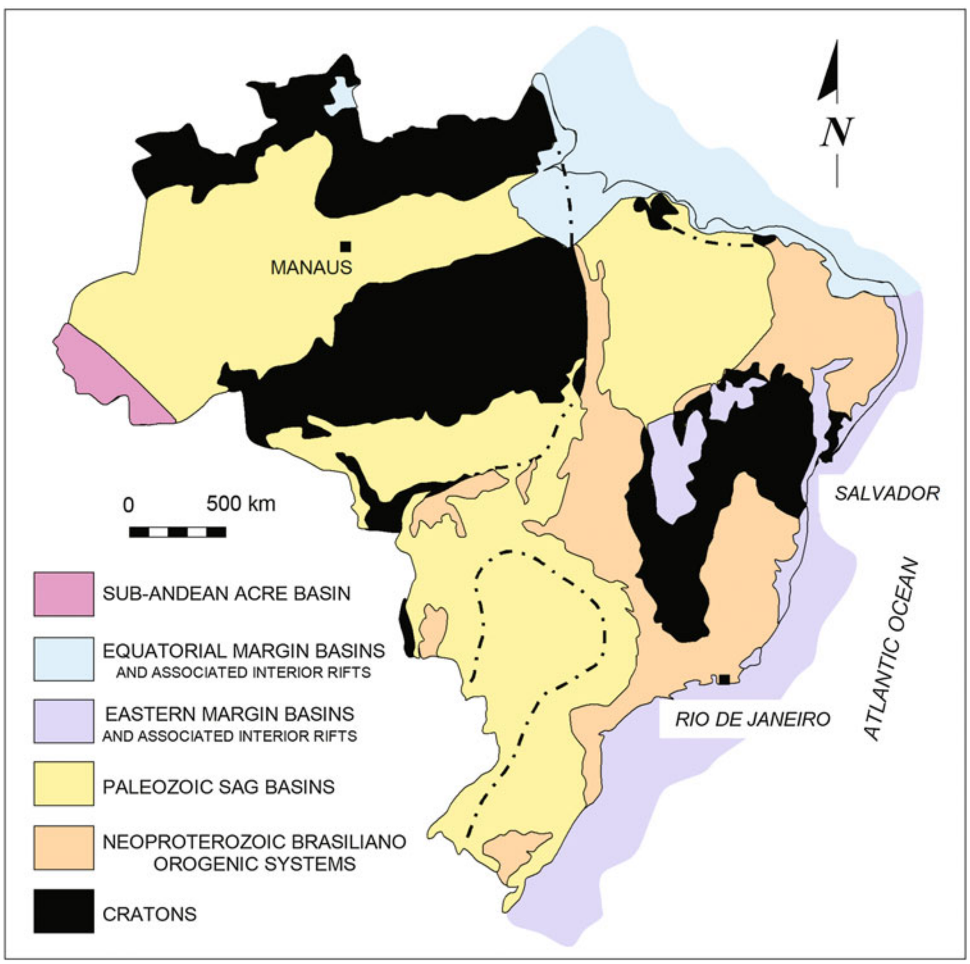

Fig. 2.2 Simplified tectonic map of Brazil, showing the distribution of the various categories of tectonic units

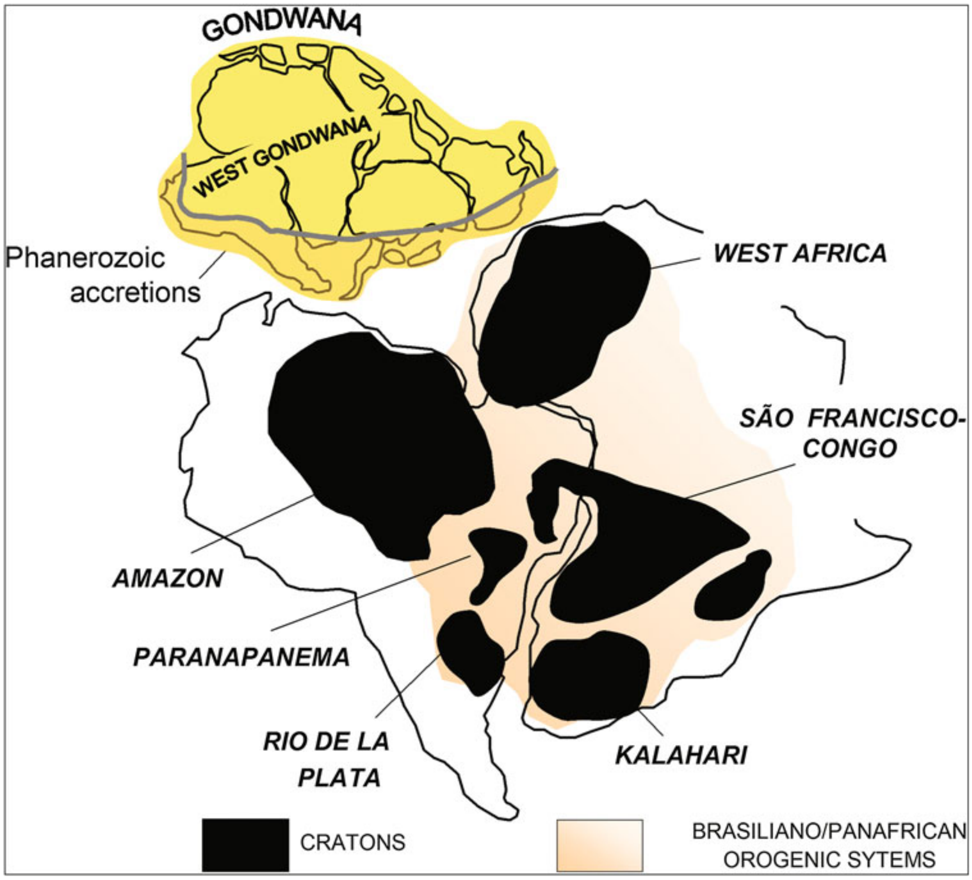

Fig. 2.3 Schematic map of West Gondwana, showing the cratons and Brasiliano/Pan-African orogenic systems (modified from Alkmim and Martins-Neto 2004)

2.2.1 Cratons

The South American platform contains four cratons (Almeida et al. 1981, 2000) (Fig. 2.4). The large Amazon[1] craton, extending far beyond the Brazilian borders, consists of an Archaean core—the so-called central Amazonian province—bounded by Palaeoproterozoic and Mesoproterozoic terranes, respectively, to the northeast and southwest (Tassinary et al. 2000; Santos et al. 2000; Santos 2003). The intracratonic Solimões and Amazon Basins cutting across the structural grain of the basement separate the Guyanas and central Brazil shield areas.

The São Francisco craton is the best exposed and one of the most intensively studied Precambrian terrains of South America. Located in eastern Brazil, it is made up of an Archaean and Palaeoproterozoic basement older than 1.8 Ga and a sedimentary cover that includes Proterozoic and Phanerozoic strata. Reconstructions of West Gondwana indicate that the São Francisco craton was connected to the Congo craton that underlies a vast segment of central West Africa (Almeida 1977; Alkmim 2004; Alkmim and Martins-Neto 2012) (Fig. 2.3).

The only exposure of the São Luis craton consists of a Palaeoproterozoic granite–greenstone terrain. Fringed to south by the Neoproterozoic Gurupi orogenic belt, the São Luis apparently represents a small fragment of the West African craton that remained in South America as the West Gondwana split apart (Trompette 1994; Brito Neves et al. 1999; Cordani et al. 1999; Campos Neto 2000; Almeida et al. 2000).

The existence of a cratonic mass beneath the large Paraná Basin in south Brazil (Fig. 2.4) has been inferred on the basis of geophysical studies. Previously portrayed as an extension of the Rio de la Plata craton partially exposed in Uruguay and northern Argentina, this piece of crust, called Paranapanema craton, is now interpreted a distinct crustal block (e.g., Almeida et al. 2000; Schobbenhaus and Brito Neves 2003).

2.2.2 Brasiliano Orogenic Systems

The Brasiliano Tocantins, Borborema, and Mantiqueira systems form a network of interfering orogens developed as the plates represented by the cratons of the platform were stitched together during the assembly of West Gondwana between 640 and 500 Ma, i.e., in the course of the Ediacaran and Cambrian periods of the Neoproterozoic and Palaeozoic eras, respectively (Brito Neves et al. 1999; Campos Neto 2000;

[1] Originally referred to as the Amazonian craton.

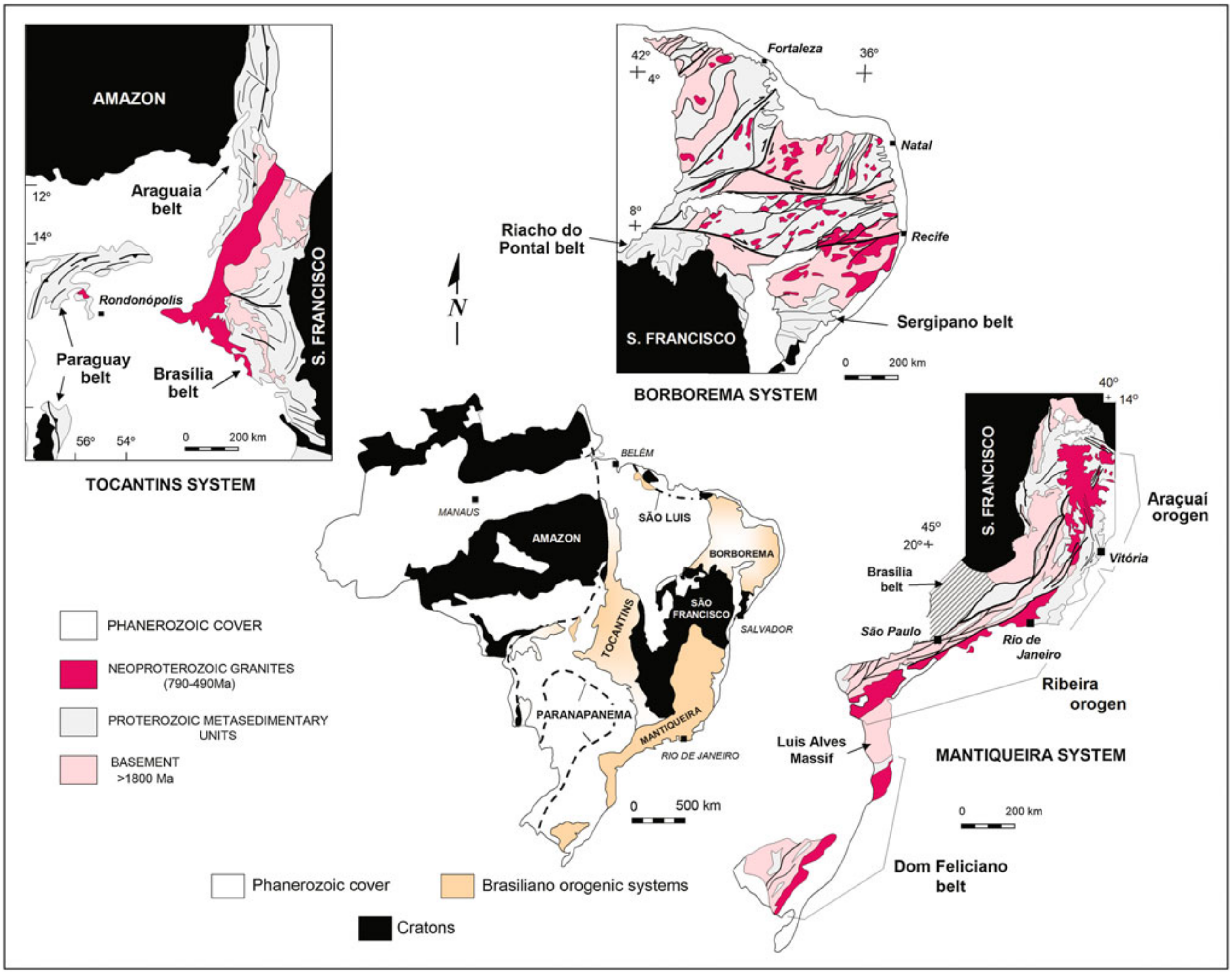

Fig. 2.4 Cratons and Brasiliano orogenic systems exposed in Brazil (detail maps based on Bizzi et al. 2001)

Almeida et al. 2000; Schobbenhaus and Brito Neves 2003) (Figs. 2.3 and 2.4). The Tocantins system in central Brazil encompasses the Araguaia and Paraguay belts developed along the margin of the Amazon craton, as well as the Brasília belt that fringes the São Francisco craton to west (Pimentel et al. 2000; Alvarenga et al. 2000; Dardenne et al. 2000) (Fig. 2.4). The diachronic collisions of the paleocontinents Paranapanema, São Francisco–Congo, and Amazonia, also involving a magmatic arc and a micro-continent (Pimentel et al. 2004; Valeriano et al. 2004), resulted in the consumption of the Goianides ocean (Brito Neves et al. 1999) and uplift of the Tocantins mountain system, The ca. 1,200-km-long and 150-km-wide Araguaia belt is made up of an Archaean and Palaeoproterozoic basement overlain by Neoproterozoic metasedimentary successions. N–S-trending faults and folds promoted tectonic transport of these units toward the Amazon craton (Alvarenga et al. 2000). Separated from the Araguaia belt by the Neoproterozoic Goiás magmatic arc and the Archaean Crixás-Goiás block, the Brasília belt corresponds to an up to 300-km-wide and 1,200-km-long orogenic zone, in which a Archaean/Palaeoproterozoic basement and Proterozoic metasedimentary successions younger than 1,800 Ma locally cut by granitic rocks are folded and thrust toward the São Francisco craton (Pimentel et al. 2004; Valeriano et al. 2004). As the youngest branch of the Tocantins system, the Paraguay belt describes a pronounced curve along the southeastern edge of the Amazon craton and involves a thick succession of Late Neoproterozoic sedimentary rocks (Alvarenga et al. 2000).

The Mantiqueira system straddles the southeastern coastal region of Brazil, forming a ca. 2,500-km long Neoproterozoic collisional domain composed of the Araçuaí orogen, the Ribeira orogen, and the Dom Feliciano belts, whose African counterparts are the West Congolian and the Kaoko belts (Fig. 2.4). Closure of the so-called Adamastor ocean that separated the paleocontinents Paranapanema and São

Francisco-Congo led to the generation of the Mantiqueira system (Brito Neves et al. 1999; Campos Neto 2000; Heilbron et al. 2004). The Araçuaí orogen corresponds to northern segment of the system. It consists of an external fold–thrust belt (also called Araçuaí belt) that curves along the eastern margin of the São Francisco craton, and an internal zone made up of high grade metamorphic and granitic rocks. In the external Araçuaí belt, the Archaean basement is covered by Proterozoic metasedimentary rocks which are intensively folded and thrust toward the São Francisco craton. The N–S-trending structures of the Araçuaí orogen bend toward NE and merge with the characteristic fabric elements of the Ribeira orogen around 21S latitude (Pedrosa-Soares and Wiedemann-Leonardos 2000; Pedrosa-Soares et al. 2001; Alkmim et al. 2006). The Ribeira orogen, partially dominated by a system of NE-trending dextral strike-slip shear zones, involves a Palaeoproterozoic basement, high grade Proterozoic metasedimentary units, the Neoproterozoic Rio Negro magmatic arc, and a considerable volume of granitic rocks (Trouw et al. 2000; Heilbron et al. 2004). The Luiz Alves gneiss massif separates the Ribeira orogen from the Dom Feliciano belt, which also consists of a Palaeoproterozoic basement, Meso- to Neoproterozoic sedimentary succession, and Neoproterozoic granitoids (Basei et al. 2000; Heilbron et al. 2004) (Fig.2.4).

Differently from all previously described Brasiliano orogenic zones, the Borborema in northeastern Brazil comprises a gigantic system of strike-slip shear zones, which apparently roots in the Tocantins system (Fig. 2.4). The fanlike array of dextral shear zones anastomoses around various basement massifs covered by Proterozoic metasedimentary units and intruded by a large volume of Neoproterozoic granites. The system also contains two fold–thrust belts, the Riacho do Pontal and Sergipano belts that bound the São Francisco craton to the north (Brito Neves et al. 2000)

2.2.3 Palaeozoic Sag Basins

Some regions of West Gondwana started to subside soon after its assembly, being converted into the initial depocenters of the large and long-lived Solimões, Amazonas, Parnaíba, Paraná, and Parecis intracontinental basins (Pedreira et al. 2003; Milani et al. 2007). The triggering mechanism of the initial subsidence of these basins between 470 and 450 Ma (Meso- to Neo-Ordovician) is still controversial, though evidence for precursor rifts has been documented in all of them (Tankard et al. 1998; Milani et al. 2007).

The Palaeozoic basins of Brazil share a series of common features. Their overall architectures are characterized by the uniform shallow dips of the infill strata toward the center and the presence of regional arches and highs. They all correspond to successor and polyhistoric depocenters, filled by major stratigraphic sequences bounded by regional unconformities of approximately the same age. Their fill units record important tectonic and climatic events affecting West Gondwana in the course of the Palaeozoic, such as major marine incursions during the Silurian, Devonian and Early Permian, the Silurian and Permo-Carboniferous glaciations (documented in the Solimões and Paraná Basins, respectively), as well as arid climatic conditions that predominated during Late Permian, Triassic, and end of the Jurassic. Besides this, the Amazonas and Paraná Basins also host thick Upper Jurassic and Eo-Cretaceous flood basalts and related intrusions, the magmatic event precursor of the West Gondwana breakup (Zalán 2004; Milani et al. 2007).

2.2.4 Equatorial, Eastern Margin, and Associated Intracontinental Rifts

The dispersal of West Gondwana in the Eo-Cretaceous, following the disaggregation of Pangaea, led to the opening of the Atlantic ocean and the generation of passive and transform margin basins along the borders of newly individualized South American and African continents.

The eastern continental margin of Brazil comprises a series of typical passive margin basins, whose development evolves from south to north with the formation of a complex system of interconnected rifts. The rift phase is recorded in these basins by a succession of Neocomian lacustrine sediments. The subsequent transitional phase is marked by the deposition of terrigenous sediments and carbonates during the Aptian, followed by the drift phase, which starts with the formation of a vast salt basin in the region that extends from the Santos to the Sergipe-Alagoas Basin and the equivalent area in the African margin (Fig. 2.5). The advanced stages of the drift phase are recorded by transgressive and regressive marine sequences of Neo-Cretaceous and Tertiary ages, respectively (Mohriak 2003; Zalán 2004; Milani et al. 2007).

The Brazilian equatorial margin evolved as a transform margin during the opening of the Atlantic. Consequently, significant differences in structural styles and nature of fill successions exist between the equatorial and eastern margin basins. Dextral strike-slip motions along E–W-trending fault zones punctuate the evolution of the equatorial margin basins from their onset in the Aptian to the full development stage in the Tertiary (Matos 2000; Mohriak 2003)

Considerable areas of the continental interior also experienced the effects of extensional tectonics that resulted in the generation of the Atlantic. Basement structures were reactivated, leading to the nucleation of intracontinental rifts such as the Tacutu, the Recôncavo-Jatobá-Tucano, and Potiguar onshore basins (Fig. 2.5).

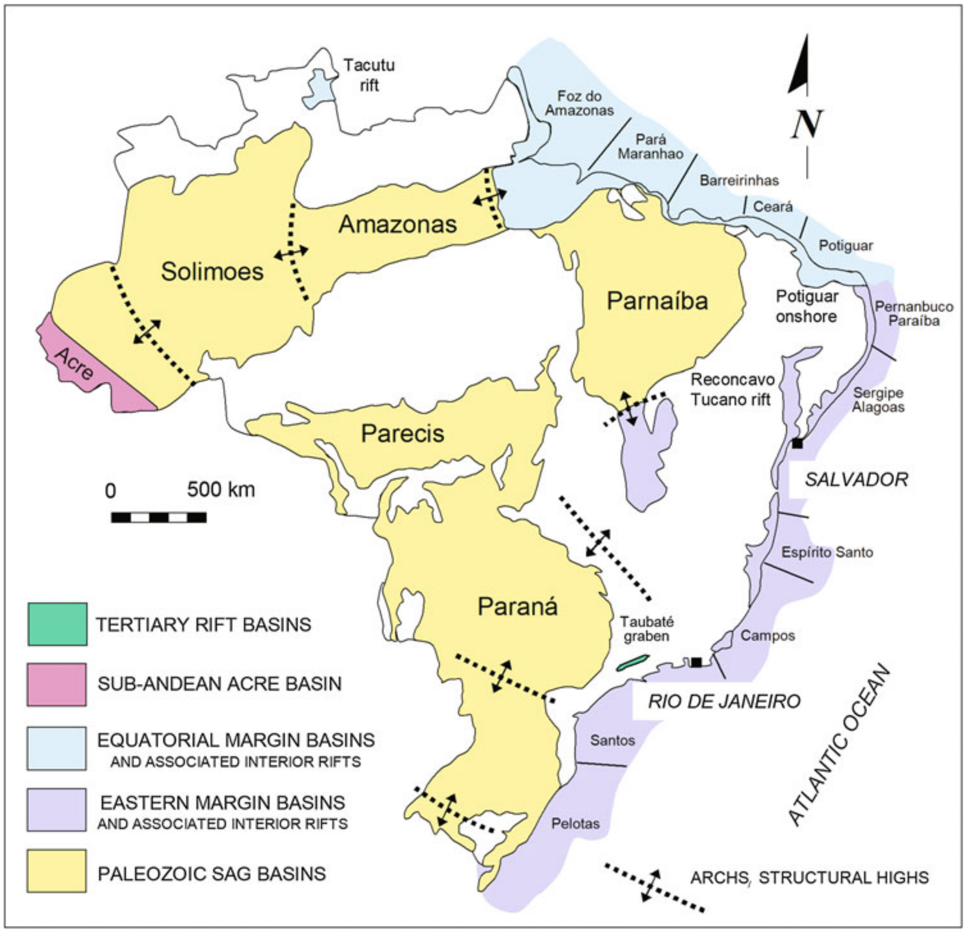

Fig. 2.5 Tectonic units of the South American platform cover complex, i.e., basins of the Brazilian territory (based on Milani et al. 2007)

2.2.5 The Sub-Andean Acre Basin

Located along the border to Peru, the Acre basin, like the adjacent Solimões sag, experienced a long development history that started by the end of the Silurian. By the end of the Eo-Cretaceous, the Acre basin was caught by the so-called Juruá orogenic front that caused its deformation along reverse faults and thrusts, as well as its conversion in an Andean foreland basin. During the Andean uplift pulses in the Tertiary, especially in the course of the Miocene-Pliocene Quechua phase, a thick package of terrigenous sediments accumulated in the basin (Pedreira et al. 2003; Cunha 2007).

2.2.6 Tertiary Rifts

A substantial area of southeastern Brazil was affected by extensional deformation between the end of the Eocene and beginning of the Miocene. Reactivation of eastern margin basin structures, reorganization of drainage systems, and nucleation series of rifts, such as the Taubaté and Resende basins (Zalán and de Oliveira 2005), are the main manifestations of this episode, whose causes are not yet clearly understood.

2.3 Tectonic Units and Their Topographic Expression

A comparison of the tectonic and topographic maps of Brazil reveals a good correspondence between the previously described tectonic units and large-scale topographic features (Alkmim and Martins-Neto 2004) (Fig. 2.6). The lowlands are underlain by the cratons and host the Palaeozoic sag basins as well as large river systems, such as the Amazon, Paraná, and São Francisco. The highlands, on the other hand, correspond to the Brasiliano orogenic systems, on which Phanerozoic structures such as arches, plateaus, and uplifts are superimposed. Among these, the most prominent features are the Alto Paranaíba arch, the Serra do Mar uplift, the Mantiqueira range, and the Borborema plateau.

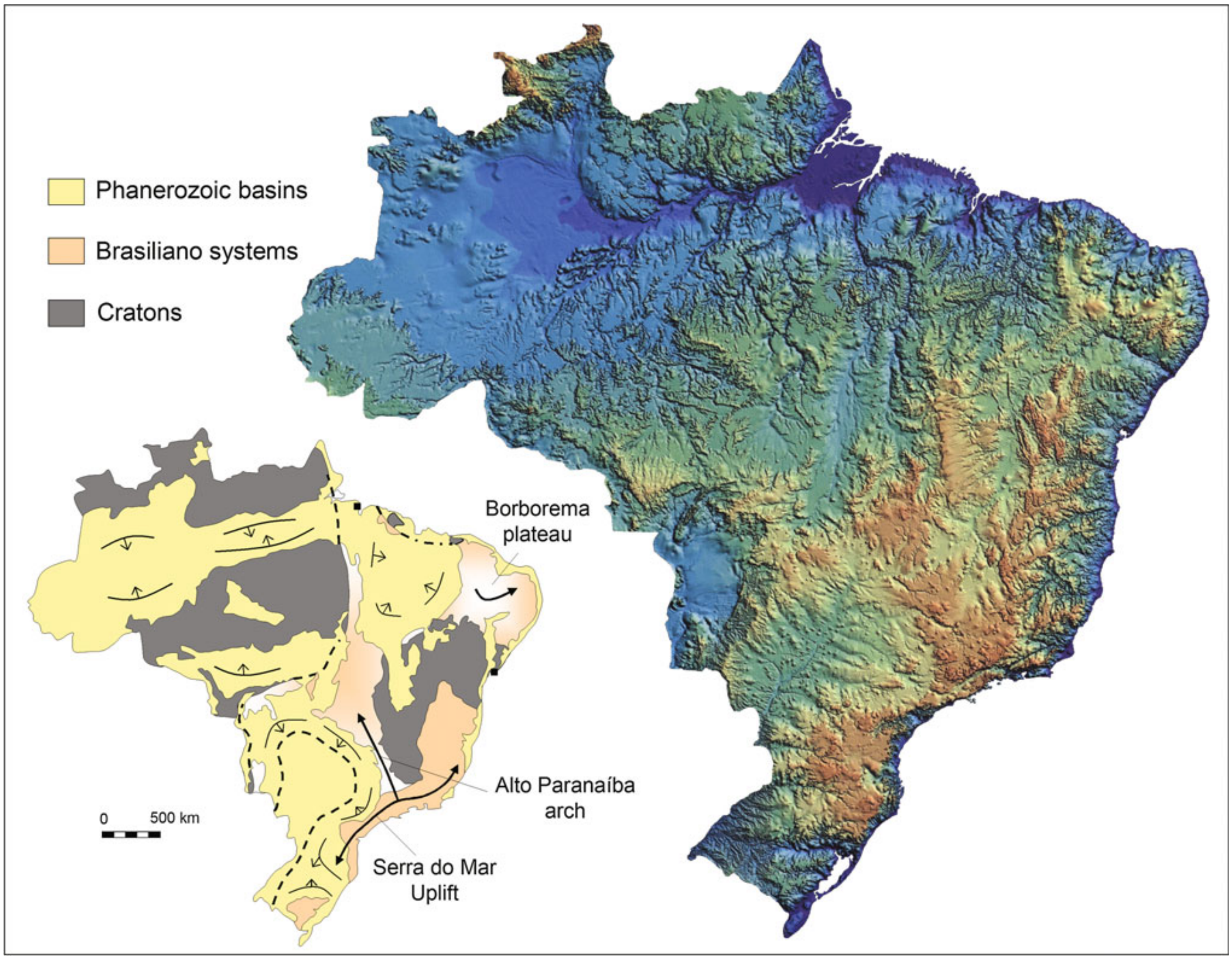

Fig. 2.6 Tectonic units and large-scale structures and their expression in the topographic relief of Brazil (modified from Alkmim and Martins-Neto 2004)

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