11 The Dom Feliciano Belt in Southern Brazil and Uruguay

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Abstract

The Dom Feliciano Belt is an orogenic association that extends from southern Brazil to Uruguay parallel to the Atlantic coastline for over 1100 km. It was assembled in the Neoproterozoic, during the Brasiliano orogenic cycle, and is the result of interaction between the Río de la Plata, Congo and Kalahari cratons, together with several microplates, juxtaposed along major shear zones. Along its extension, the Dom Feliciano Belt is exposed in three sectors: in the Brazilian states of Santa Catarina and Rio Grande do Sul, and in Uruguay. The blocks that acted as direct forelands to the belt in South America are smaller fragments to the main cratons: Luís Alves and Nico Pérez. Three main lithotectonic domains are recognized in the belt, from east to west: a granitic batholith, a metasedimentary sequence and an association of foreland basins. Basement inliers are common, and evidence intense reworking and magmatism during the Neoproterozoic. Cryogenian to Ediacaran granitogenesis is widespread and voluminous, and usually displays an evolutionary tendency from medium- to high-K calc-alkaline, finishing with alkaline magmatism. The early evolution of the Dom Feliciano Belt is recorded in the São Gabriel Terrane, in which convergent tectonics is associated with intense juvenile magmatism, ophiolite complexes and accretion between 870 and 680 Ma. This is followed by two more deformational phases, identified in all three sectors. A convergent phase is associated with the deformation of the metavolcano-sedimentary complexes, shear zone nucleation and granitic magmatism associated with high-grade collisional metamorphism. This stage is constrained between *c*. 650–620 Ma in Santa Catarina and Rio Grande do Sul, and between *c*. 630–600 Ma in Uruguay. The last stage marks a transition to strike-slip deformation, with common shear zone reactivation associated with refolding in the metamorphic associations and widespread post-collisional granitic and volcanic magmatism. This phase is predominant from 610 to 550 Ma. The opening of the foreland basins was initiated during this period, probably associated with transtension along the main structures. Late-stage deformation and magmatism is common until 550–540 Ma. Abundant geochronological data have been added to the Dom Feliciano Belt in the last decades, leading to more precise time constraints for most of the geologic processes in the orogen. Details of its tectonic model, however, are still matters of debate, in terms of both the setting of its main units and its position into the assembly of southwestern Gondwana.

Keywords

Dom Feliciano Belt • Neoproterozoic • Brasiliano Pan-African • Gondwana

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11.1 Introduction

The Mantiqueira Province is the biggest mobile belt association in Brazil, extending for over 3000 km with a northeast to southwest direction parallel to its southern and eastern coast and into Uruguay (Almeida et al. 1973). It was formed in the Neoproterozoic during the Brasiliano-Pan African orogenic cycle, and was one of the most significant orogenic systems during the assembly of Southwestern Gondwana (Fig. 11.1). It is divided into three orogenic belts which are,

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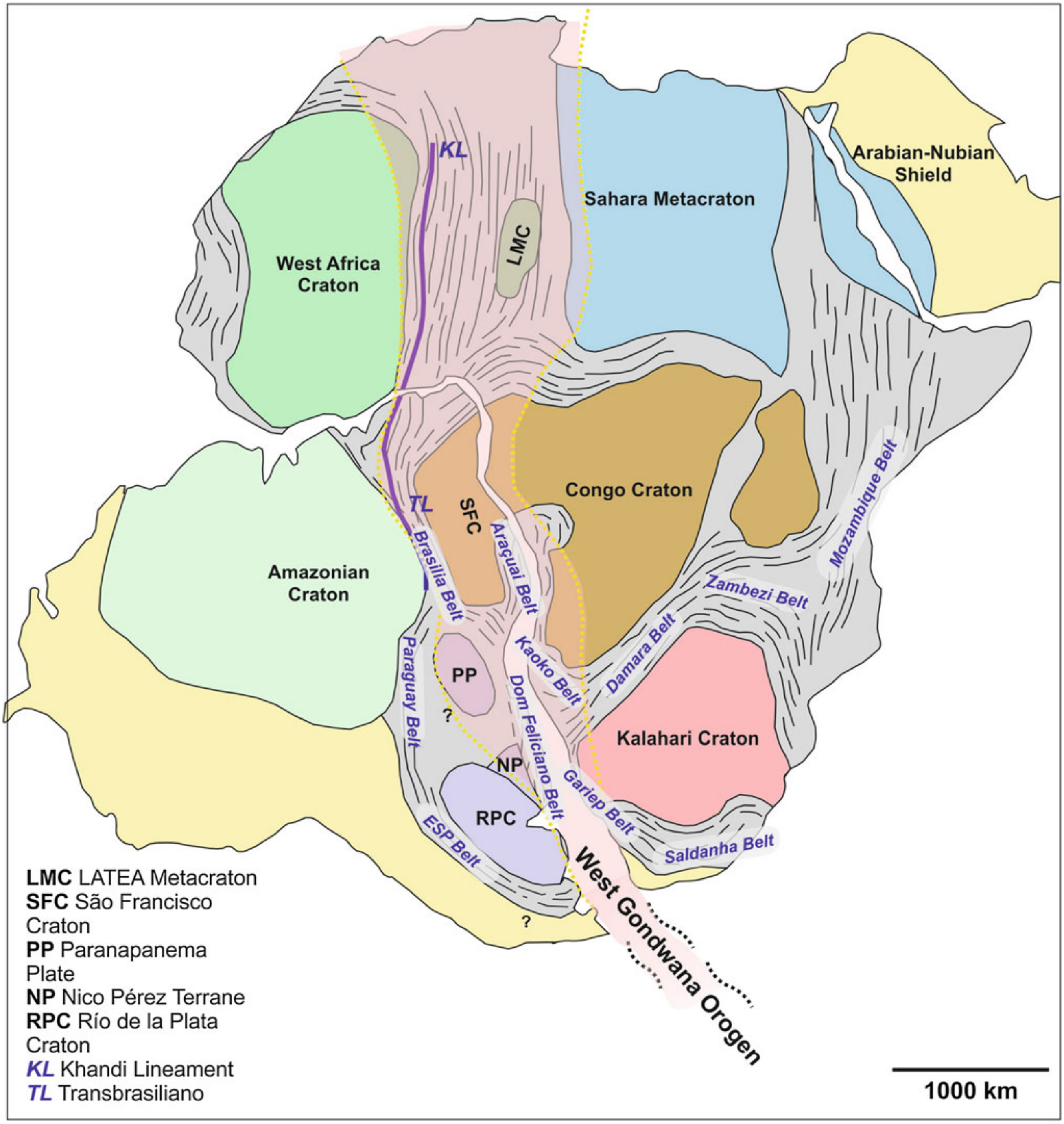


Fig. 11.1 Position of the Dom Feliciano Belt in relation to the surrounding cratons and other orogenic belts in Gondwana. ESP Belt—Eastern Sierras Pampeanas Belt. Modified from Oriolo et al. (2017)

from north to south: Araçuaí, Ribeira and Dom Feliciano (e.g.: Heilbron and Machado 2003; Silva et al. 2005a). At the African side of the Atlantic, its counterparts are the Saldania-Gariep, Damara, Kaoko and West Congo belts (Porada 1989; Basei et al. 2008, Oyhantçabal et al. 2011b).

In the southernmost portion of the Mantiqueira Province, the Dom Feliciano Belt extends for more than 1100 km, striking northeast to southwest to northnortheast to south-southwest, roughly following the coastline and with a maximum width of *c*. 200 km (Fig. 11.2). It is limited to the north by the cratonic Luís Alves Terrane, to the east by the shore of the South Atlantic Ocean and associated marine sediments, and to the south by the Río de la Plata estuary between Uruguay and Argentina. To the west, it is

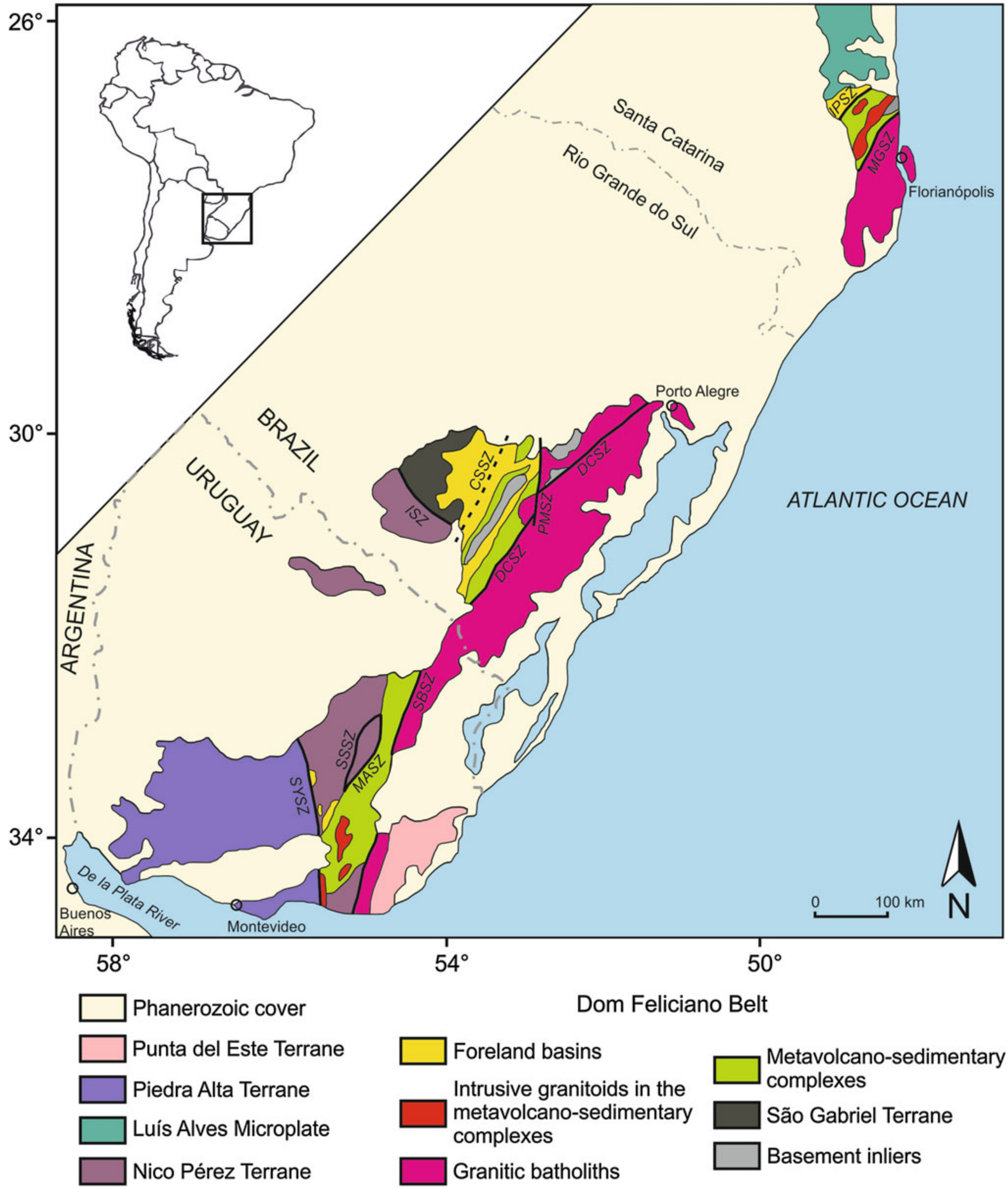


Fig. 11.2 Tectonic map of the Dom Feliciano Belt (Modified from Basei et al. 2000; Hueck et al. 2016). IPSZ - Itajaí-Perimbó Shear Zone; MGSZ - Major Gercino Shear Zone; DCSZ - Dorsal do Canguçu Shear Zone; PMSZ - Passo do Marinheiro Shear Zone; CSSZ - Caçapava do Sul Shear Zone; ISZ - Ibaré Shear Zone; SBSZ - Sierra Ballena Shear Zone; MASZ - Maria Albina Shear Zone; SSSZ - Sierra de Sosa Shear Zone; SYSZ - Sarandí del Yí Shear Zone

commonly covered by the Paleo- to Mesozoic sedimentary succession of the Paraná Basin, but locally it is in contact with foreland basement blocks such as the Nico Pérez Terrane. The belt is exposed in three structural windows, also known as shields, in different areas, from north to south, in the Brazilian states of Santa Catarina and Rio Grande do Sul, and in Uruguay. Each sector has its own particularities and has been the focus of recurrent research.

This chapter aims to revise the extensive bibliography accumulated in the last decades around the Dom Feliciano Belt. Each sector is described individually, with a synthesis of the main local units. When detail studies are present, the latest findings in terms of structural geology, geochemistry, isotopic geochemistry and geochronology are reviewed. This is followed by a discussion of the current tectonic models and interpretations of the origins and evolution of the belt, and its significance in the assembly of Gondwana.

11.2 Santa Catarina Sector

The northernmost occurrence of the Dom Feliciano Belt is exposed in the Brazilian state of Santa Catarina. It constitutes a *c*. 60 km wide corridor along the South Atlantic coastline, south of the city of Penha, covered to the west and to the south by Phanerozoic sediments of the Paraná Basin. The orogenic belt is limited, to the north, by the Luís Alves Microplate, a cratonic block that acted as a foreland during the Neoproterozoic orogenic event in this sector.

In Santa Catarina, the architecture of the Dom Feliciano Belt is especially clear, and since its original recognition (Basei 1985) it has been extended to the remaining portions of the belt (Basei et al. 2000). It is divided into three domains (Figs. 11.3 and 11.4): southeastern (internal), central and northwestern (external). Each domain has a characteristic lithological association and is separated from the bordering terrane by major shear zones.

The southeastern domain is an association of voluminous granitic intrusions, called the Florianópolis Batholith. It consists of several granitic suites with local occurrences of crystalline basement. The central domain is characterized by a metavolcano-sedimentary fold-and-thrust belt, the Brusque Group. Its crystalline basement, the Camboriú Complex, is exposed in the northeastern extremity of the domain. Both units are intruded by numerous granitic intrusions. Finally, the northwestern domain corresponds to the foreland Itajaí Basin, deposited on top of the Luís Alves Microplate.

Each unit will be detailed in the following sections, followed by a short discussion on the deformation history of the Dom Feliciano Belt in the Santa Catarina sector. The individual shear zones that mark the boundaries between the domains are described and discussed in an individual chapter (Oriolo et al. 2018).

11.2.1 The Cratonic Foreland

The cratonic foreland to the Dom Feliciano Belt in Santa Catarina is the Paleoproterozoic Luís Alves Microplate (Fig. 11.5a) (Basei et al. 2000, 2009; Hartmann et al. 2000a, 2003a). It comprises most of the northern segment of the Precambrian exposition in Santa Catarina, occurring north of the city of Penha. Its southern limits are covered by the Itajaí Foreland Basin, while the northern border is tectonic, along which it is juxtaposed to the Curitiba Microplate. Both terranes are described in detail by Passarelli et al. (2018).

11.2.1.1 Basement Inliers

The main exposure of pre-Brasiliano inliers in the central domain of the Dom Feliciano Belt in Santa Catarina is the Camboriú Complex (Basei et al. 2000). This association crops out in the northeastern extremity of the domain, along the South Atlantic coast, and is interpreted to represent the crystalline basement of the Brusque Group, although the contact relationship between both units seems to suggest a tectonic juxtaposition (Philipp et al. 2004).

The region comprises two main units. The first one consists of gneisses and stromatic migmatites, commonly identified as the Camboriú Complex proper (e.g., Hartmann et al. 2003a; Philipp et al. 2004; Peternell et al. 2010; Florisbal et al. 2012a), or alternatively the Morro do Boi Migmatites (Basei et al. 2013a) (Fig. 11.5b). Migmatitic rocks predominate in the unit, characterized by the presence of more than one generation of leucosome and associated with amphibolite. The unit has a NE-SW orientation and has been folded into a major antiform with numerous subordinate parasite folds. The second unit is a large monzogranitic to granodioritic intrusion characterized by abundant mafic enclaves and xenoliths from the migmatites, referred to as Itapema Granite (Hartmann et al. 2003a; Bitencourt and Nardi 2004; Philipp et al. 2004; Peternell et al. 2010) or, alternatively, Ponta do Cabeço Granite (Basei 2000; Basei et al. 2013a). It is a sheet-like body, intruded in the base of the migmatites and exposed in the center of the regional fold, and corresponds to schollen-rich diatexite originated from the main migmatization event in the Camboriú Complex. Later generations of granitic magmatism unrelated to the main migmatization event also intrude the unit and are either associated with narrow shear zones, such as the Corre-Mar Granite (Martini et al. 2015), or are part of the large granitic intrusions that also affect the Brusque Group (Florisbal et al. 2012a; Hueck et al. 2016).

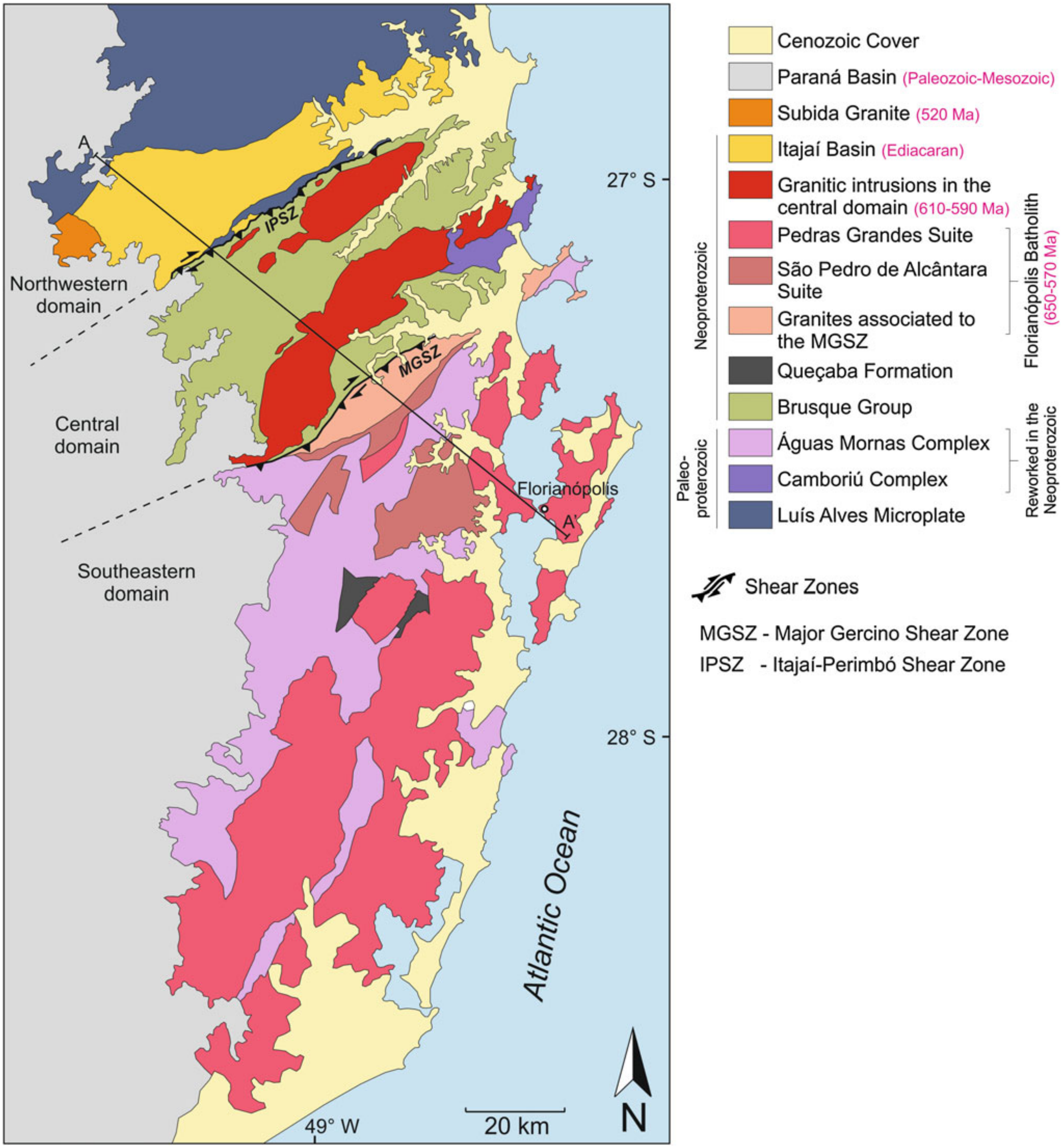


Fig. 11.3 Simplified geological map of the Santa Catarina sector of the Dom Feliciano Belt. Profile A-A′ is presented in Fig. 11.2. Modified from Basei et al. (2000, 2006), Silva et al. (2005b), and Wildner et al. (2014)

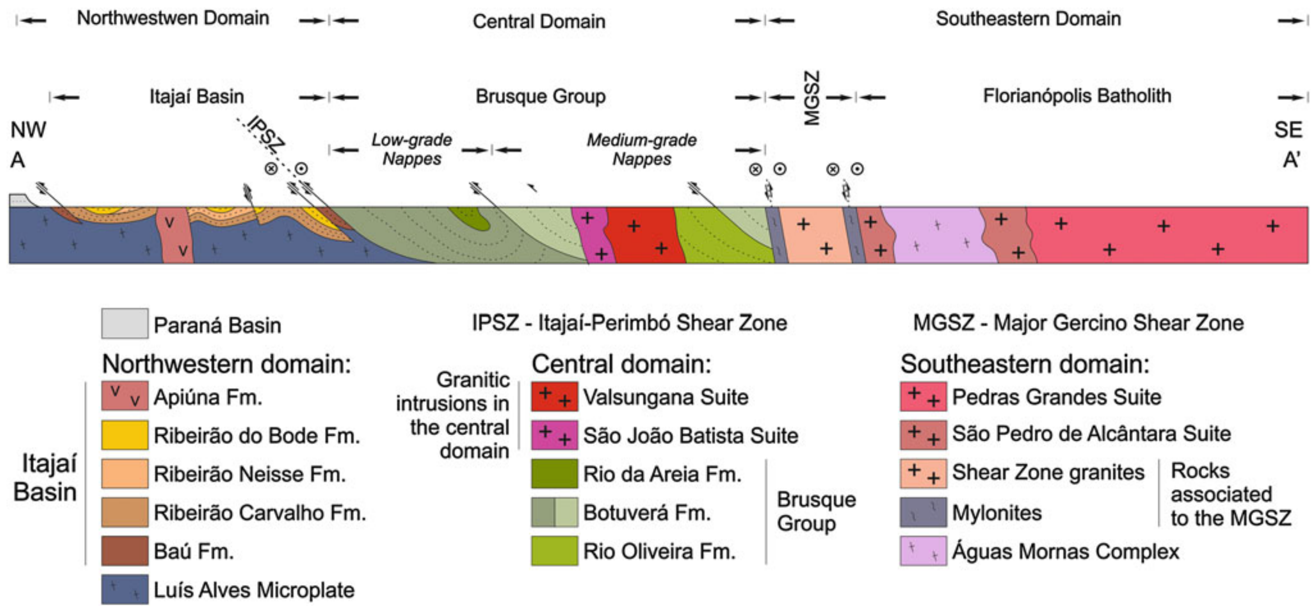


Fig. 11.4 Schematic geologic profile of the Dom Feliciano Belt in the Santa Catarina sector. Details of the stratigraphy of the Brusque Group and Itajaí Basin presented in this figure were omitted from Fig. 11.1 in order to comply with the scale of the map. Modified from Basei et al. (2006, 2011a, b)

U-Pb zircon dating in most lithologies of the Camboriú Complex yield predominantly Paleoproterozoic ages between 2.0 and 2.2 Ga (Silva et al. 2000, 2005b; Hartmann et al. 2003a; Basei et al. 2013a). Abundant Archean signatures have also been recognized, both in Nd and Hf T_{DM} model ages of the Sm-Nd and Lu-Hf isotopic systems and in widespread inherited zircon nuclei (Basei et al. 2013a). This is interpreted as the main extraction age for juvenile material. A third group of ages corresponds to the Neoproterozoic (640–610 Ma), including analyses performed in the neosome of the migmatites, in the Itapema Granite and on rims of inherited zircon crystals (Hartmann et al. 2003a; Silva et al. 2000, 2005b; Basei et al. 2013a; Martini et al. 2015). The significance of the geochronological data have been subject to alternative interpretations. Silva et al. (2000), Bitencourt and Nardi (2004) and Hartmann et al. (2003a) interpret the Paleoproterozoic ages to correspond to the event responsible for the migmatization of the Camboriú Complex and formation of the Itapema Granite, and attribute the Neoproterozoic ages to metamorphic overgrowth during the Brasiliano orogenic cycle. On the other hand, Silva et al. (2005b) acknowledges further melt generation during the Neoproterozoic, interpreted as the crystallization age of anatectic granodiorites. Finally, Basei et al. (2000, 2013a) consider the Paleoproterozoic ages to represent the crystallization age of the protoliths of the Camboriú Complex, and attribute the generation of the migmatites and of the Itapema Granite to the Neoproterozoic.

In the southeastern domain of the Dom Feliciano Belt, basement inliers within the Florianópolis Batholith are grouped into the Águas Mornas Complex. They occur predominantly in the northern portion of the domain, and are intruded by the diverse Neoproterozoic granites that constitute the batholith. Silva et al. (2000, 2002b, 2005b) recognize two main lithological associations. The first comprises restitic orthogneisses of tonalitic composition associated with amphibolites (G1), while the second includes foliated monzogranites of anatectic origin (G2), intrusive in the former. This second generation was dated by SHRIMP and yielded an age of *c.* 2.20 Ga, predominantly in magmatic zircon cores (Silva et al. 2005b). Two other zircon crystallization events were recognized by the same authors, the earliest one responsible for cores with metamorphic appearance dated at *c.* 1.75 Ga, while the latest one is responsible for the generation of new magmatic zircons and overgrowth rims around the earlier phases, dated at 592 ± 5 Ma. This last phase is interpreted as an intense reworking of the unit during the formation of the Dom Feliciano Belt, responsible for widespread melting and migmatization of the unit, similar to that proposed in the Camboriú Complex (Basei et al. 2000, 2013a; Silva et al. 2005b). An alternative designation for the basement rocks intruded by granites of the Florianópolis Batholith in its northeastern extremity is the Porto Belo Complex (Florisbal et al. 2012b, c). In this region, Neoproterozoic melts hosted in the gneisses have yielded a U-Pb zircon age of

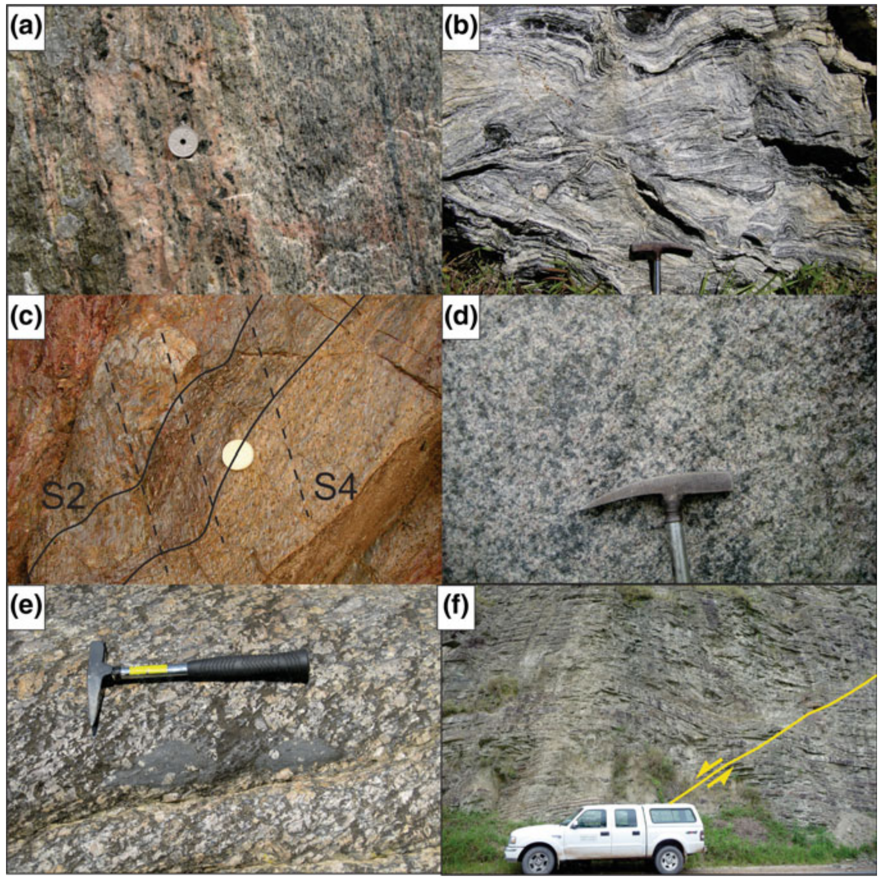


Fig. 11.5 Some field aspects of rocks from the Santa Catarina sector of the Dom Feliciano Belt. **a** Granulitic rocks overprinted by retrograde metamorphism, Luís Alves Complex; **b** Folded migmatites of the Morro do Boi unit, Camboriú Complex; **c** Metapelitic rocks from the Botuverá Formation, Brusque Group. Note that the compositional layering (S_2) is transposed by a pervasive crenulation foliation (S_4); **d** Late isotropic leucogranite of the Pedras Grandes Suite. **e** Mafic enclave in porphyritic Southern Valsungana Batholith, part of the granitic intrusions in the Brusque Group. Note cm-sized K-feldspar megacrysts within a coarse, biotite-rich matrix; **f** Turbidites of the Ribeirão Carvalho Formation, Itajaí Basin. Note the normal fault in the lower right corner of the picture

649 ± 10 Ma (Chemale et al. 2012), related to the early phases of migmatization and anatexis.

Alternatively, Basei et al. (2000, 2006) consider the Águas Mornas Complex to be the oldest intrusive Suite of the Florianópolis Batholith. In this interpretation, the magmatic rocks in it would predominantly be the product of Neoproterozoic melting, while the gneissic rocks would represent xenoliths or restites of the original Paleoproterozoic basement.

11.2.2 The Metavolcano-sedimentary Complex

The Brusque Group is the main geological unit of the central domain of the Dom Feliciano Belt in Santa Catarina. It corresponds to a volcano-sedimentary association that went through more than one phase of deformation and metamorphism (Basei 1985; Silva 1991; Caldasso et al. 1995a, b; Basei et al. 2000, 2008, 2011a; Philipp et al. 2004). The unit forms a *c*. 40 km-wide corridor with a northeast to southwest orientation, segmented by the intrusion of voluminous granitic plutons, in particular those of the Valsungana Suite. Both of its extremities are marked by tectonic contacts. The northwestern limit is the Itajaí-Perimbó Shear Zone, along which the Brusque Group is thrust over the foreland Itajaí Basin. From the other side, the dextral transcurrent Major Gercino Shear Zone separates the central domain from the Florianópolis Batholith to the southeast (Bitencourt and Kruhl 2000; Passarelli et al. 2010, 2011a, b; Oriolo et al. 2018). The only exposure of the crystalline basement of the metasupracrustal succession is the Camboriú Complex, on the northeastern portion of the central domain. An alternative designation commonly used in the literature is Brusque Metamorphic Complex (e.g., Silva 1991; Philipp et al. 2004).

Based on detailed mapping of the Brusque Group, Basei et al. (2006, 2011a) propose a stratigraphic division of the sequence into three formations: Rio Oliveira, Botuverá and Rio da Areia. This division takes as reference the main metamorphic foliation of the sequence which transposes the original sedimentary bedding. Nonetheless, primary structures such as grain size variations between layers can be recognized locally (Philipp et al. 2004). It should be noted that some works on the Brusque Group opt to separate the sequence only in terms of lithology, instead of individual formations (e.g., Philipp et al. 2004; de Campos et al. 2012a, b), which may lead to the encompassing of rocks from different formations within a same unit.

The basal unit of the Brusque Group is the Rio Oliveira Formation. Its area of occurrence is limited to the eastern extent of central domain, south of the main Valsungana intrusion, where it is wedged between the pluton and an overthrusting nappe of metasediments (Silva 1991). It is divided into four units, from the oldest to the youngest: metavolcanic and calc-silicatic, volcanic-exhalative, metapelitic and metapsammitic units. The metavolcanic rocks include amphibolite and local metaultramafites (tremolite schists), while the main lithology in the volcano-exhalative unit is tourmalinite. Whole-rock geochemistry and isotopic geochemistry indicate that both the basic and ultramafic volcanic rocks have similar signatures and were probably generated in the same setting, and both contributed to the volcanoclastic components of the sedimentary associated metasediments (de Campos and Philipp 2007; de Campos et al. 2012a). Detailed geochemical characterization of the tourmalinites indicates more than one source for the hydrothermal fluids responsible for their generation (Garda et al. 2013). The metapelites are mostly mica-schists with quartz, garnet and andalusite, and the metapsammites include quartzites and paraconglomerates. Subordinate occurrences of acid metavolcanic rocks, mostly metarhyodacites, have also been identified in this formation (Silva 1991; Silva et al. 2002a).

In an intermediate position, the Botuverá Formation is the largest unit of the Brusque Group, and occupies most of the central domain both to the south and to the north of the large Valsungana intrusions. Three lithologic associations are recognized: metapelites (Fig. 11.5c), metarhythmites and metapsammites (Basei et al. 2011a). The metamorphic conditions to which these rocks were submitted vary from low to medium grade, leading to different associations of rocks. The lower metamorphic assemblage is predominant in the northern portion of the metamorphic complex, and consists of a gradation from sericitic schists to phyllites and metarhythmites to quartzites and mica quartzites. The medium-grade rocks transition from biotite schists with garnet and muscovite to an intercalation of mica schists with quartz schist and quartzite.

Finally, the uppermost unit of the association is the Rio da Areia Formation, which constitutes the metavolcano-sedimentary sequence of the northern portion of the Brusque Group. Four units are recognized: metapelitic-carbonatic, metacarbonatic, quartzitic and metavolcanic (Basei et al. 2011a). The first one is the largest, and corresponds to an association of metamarls, calc-schist and metalimestones. Large occurrences of metacarbonatic rocks, mostly comprising limestones and dolomites, are dismembered from this unit in map scale. In a similar position, the most significant incidences of quartzite can be singled out as an individual unit, in which massive quartzites are locally intercalated to micaceous and feldspatic layers. The topmost unit of the Rio da Areia Formation encompasses its metavolcanic rocks, mostly an association of basalts, tuffs and ultramafites metamorphosed into chlorite schists and tremolite schists.

From early studies onwards, the metamorphism of the Brusque Group has been characterized by high-temperature and low-pressure conditions (e.g., Basei 1985; Silva 1991; Caldasso et al. 1995a, b). The most recent detailed research on the metamorphic evolution of the unit (Philipp et al. 2004; Basei et al. 2011a) agree in a number of aspects but diverge in others. The consensus is that the structural and metamorphic evolution of the Brusque Group was polyphasic and can be characterized by two main stages. The first is associated with the development of the main foliation, which is a S_2 that transposes both the original sedimentary surface (S_0) and an early foliation (S_1). The second is related to the intrusion of voluminous granitic intrusions in the Brusque Group, of which the Valsungana Suite is the main example.

According to Philipp et al. (2004), the first stage corresponds to two metamorphic phases (M_1 and M_2), and is characterized with metamorphic conditions of low-pressure greenschist to lower amphibolite facies, also indicated by geothermometry of the metabasic rocks (de Campos and Philipp 2007; de Campos et al. 2012a). Progressive burial and heating of the sequence would then eventually lead to conditions capable of promoting partial melting of the metasedimentary sequence, associated with outcrop-scale granitic bodies interpreted as syn-D_2 (Philipp and Campos 2010). Philipp et al. (2004) also interpret the distribution of the metamorphic zones to be irregular and disrupted, and point to it as an evidence of tectonic reworking of the metamorphic framework preceding the intrusion of the granitic magmatism. Following partial exhumation of the sequence, the late metamorphic event (M_3) is triggered by the intrusion of the granitic plutons (Phillipp et al. 2004). During this phase, the contact metamorphism aureoles reached a width of up to 4 km and had temperature conditions varying from the albite-epidote hornfels facies to the pyroxene-hornfels facies.

In the model proposed by Basei et al. (2011a), the transition from S_1 to S_2 foliation was gradual and corresponds to the regional metamorphic event. Two paragenetic assemblages indicating greenschist-facies conditions record this event, which was followed by a slight retrogression due to D_2 thrusting (Fig. 11.4), associated with exhumation.

A second prograde sequence, with the development of four more typical parageneses, is coeval to the intrusion of the granites, which is described as syn- to late kinematic in relation to S_2. It was accompanied by reburial of the sequence, promoted by the emplacement of the biggest Valsungana Batholiths, and affects predominantly the southern portion of the Brusque Group. This event started from initial conditions close to 570 °C and 2.5 kbar and reached 760–850 °C and 4–5 kbar.

Both models described above agree that the time interval between the development of the main S_2 foliation and the intrusion of the granites in the Brusque Group must have been relatively short. They also have in common the observation that the S_2 is further affected by two more deformational events, although with different characteristics. Basei et al. (2011a) describe D_3 as a regional inverse folding event verging to the northnorthwest with development of plane-axial schistosity, while D_4 corresponds to smaller asymmetric folds associated with a persistent crenulation cleavage (Fig. 11.5c). On the other hand, Philipp et al. (2004) interpret D_3 to be a transcurrent event accompanied by normal folding, followed by a D_4 characterized by kink banding and open chevron folds. These late phases of deformation, in particular D_3, are likely coeval to the intrusion of the granitic magmatism.

The age of the sedimentation of the Brusque Group is also still unclear. Zircon SHRIMP dating of metabasic rocks from the Rio do Oliveira Formation yield an age of 936 ± 40 Ma (Basei et al. 2011a), interpreted by these authors as representative of mafic intrusions associated with the initial taphrogenesis of the Brusque Basin. Nd signatures from other samples of the same unit evidence a mantellic source contaminated with crustal material, yielding model ages between 1028 and 1762 Ma, suggestive of a Neoproterozoic extraction (de Campos et al. 2012a). Another constraint for the rift phase of the Brusque is the emplacement of the A-type Morro do Parapente Granite, also dated by SHRIMP at *c.* 840 Ma (Basei et al. 2008). Detrital zircon crystals are mostly limited to ages of 2.0–2.2 Ga (Hartmann et al. 2003a; Basei et al. 2011a), indicating fairly consistent sources for the sedimentary input. Nonetheless, some crystals from the Botuverá Formation reported by Basei et al. (2008) have younger Paleoproterozoic (1.7–2.0) and Mesoproterozoic (1.1–1.5 Ga) ages. An upper limit for the deposition of the Brusque Group is that of syn-sedimentary acid metavolcanic rocks, dated to around 640 Ma by SHRIMP (Silva et al. 2002a; Basei et al. 2011a). Diabase and lamprophyre dikes in the volcano-sedimentary sequence of the Rio da Areia Formation represent early magmatic intrusion after the development of the main foliation, and were dated by LA-ICP-MS in zircon at 618 ± 9 Ma (de Campos et al. 2012b). Thus the best estimate for the age of the regional metamorphism (syn-S_2) of the Brusque Group is given by the interval between the *c.* 640 Ma syn-depositional acid volcanism and the intrusion of the *c.* 620 basic rocks. The intrusion of the massive granitic magmatism is constrained to 610–590 Ma (Silva et al. 2002b, 2003, 2005b; Vlach et al. 2009; Basei et al. 2011a; Florisbal et al. 2012c; Hueck et al., in preparation).

Silva (1991) postulate a tectonic setting in which the metavolcano-sedimentary sequence of the Rio do Oliveira Formation would correspond to a mature rift system with generation of oceanic crust in a deep environment, later evolving to a marine setting corresponding to the main metasedimentary package (Botuverá Formation). Basei et al. (2011a) follow a similar interpretation, noting that although the metamorphic conditions of the Brusque Group most closely resemble those of a back-arc environment, this setting is incompatible with their model, which positions the Brusque basin to the west of a continental arc association. On the other hand, Philipp et al. (2004) propose a marine sedimentation in a continental rift system, without generation of oceanic crust, evolving to a passive margin. In this context, the volcanic association corresponds to an intraplate magmatic event, with tholeiitic to alkaline signatures indicating crustal contamination (de Campos and Philipp 2007; de Campos et al. 2012a).

11.2.3 Neoproterozoic Granitic Magmatism

11.2.3.1 Florianópolis Batholith

More than half of the exposition of the Dom Feliciano Belt in Santa Catarina corresponds to its southeastern domain, the Florianópolis Batholith. It comprises a large association of granitic intrusions grouped into different suites. While its eastern, southern and western limits are masked either by the coastline of the South Atlantic Ocean or by the sedimentary cover of the Phanerozoic Paraná Basin, its northern boundary is tectonic and sharply defined by the Major Gercino Shear Zone, separating it from the central domain (Bitencourt and Nardi 1993; Bitencourt and Kruhl 2000; Passarelli et al. 2010, 2011a, b; Oriolo et al. 2018)

The lithostratigraphic division of the various granites into intrusive suites has some variations in the literature devoted to the subject. Many divisions apply geochemical criteria, separating earlier calc-alkaline granites from later alkaline ones (Bitencourt and Nardi 2000; Silva et al. 2002b, 2005b). In addition, granites from the northern part of the batholith, associated with the Major Gercino Shear Zone, are commonly addressed separately from the rest of the batholith, owing to their close relationship to the development of this structure (Basei et al. 2000, 2006; Bitencourt and Kruhl 2000; Passarelli et al. 2010, 2011a; Florisbal et al. 2012b). Nonetheless, the isotopic signature of these rocks is compatible to that of the remaining Florianópolis Batholith, instead of the bordering units of the central domain (Basei et al. 2000; Hueck et al. 2016). The granites associated with the shear zone are exposed in two distinct areas. The oldest are found in the coastal region, and correspond to early melts hosted in the crystalline basement of the region (Porto Belo Complex), dated at 649 ± 10 Ma (Chemale et al. 2012). The interior portion is enveloped by two mylonitic bands and comprises two calc-alkaline intrusions, Fernandes and Rolador, dated by U-Pb TIMS at 614 ± 2 and 609 ± 16 Ma respectively (Passarelli et al. 2010, 2011a). Comparable signatures and ages were obtained in the coastal sector of the shear zone, where the Mariscal and Quatro Ilhas granites yield U-Pb zircon ages between 625 and 610 Ma (Bitencourt and Kruhl 2000; Chemale et al. 2012; Florisbal et al. 2012b, 2012c). This early magmatism is followed in the same region by the Estaleiro Granite, an intrusion with shoshonitic affinity strongly correlated with the mylonitic deformation, dated at 602 ± 4 Ma (Bitencourt and Kruhl 2000; Chemale et al. 2012). The same authors identify a last granitic intrusion in the coastal portion, associated with the late alkaline magmatism of the batholith, the Zimbros Suite, with ages between 589 and 586 Ma.

In the stratigraphy proposed by Basei et al. (2000, 2006) for the main portion of the Florianópolis Batholith it is divided into three units, the oldest of which is the Águas Mornas Complex. Different from the traditional interpretation of this unit as the exposure of the Paleoproterozoic basement within the Batholith (e.g., Silva et al. 2000, 2002b, 2005b), these authors consider it to be an essentially Neoproterozoic unit, in which extensive reworking during the formation of the Dom Feliciano Belt was responsible for widespread magmatism. The original protoliths are commonly preserved as xenoliths and restites. In this conception, this unit includes rocks alternatively associated with the Paulo Lopes Suite (e.g., Zanini et al. 1997; Silva et al. 2002b, 2005b; Bitencourt et al. 2008; Florisbal et al. 2009). Predominant in the southern part of the batholith, such as in the Garopaba region, this association is characterized by the common presence of coeval basic rocks (Bitencourt et al. 2008) and is the result of the interaction of mantle-derived mafic magmas with abundant crustal contaminants (Florisbal et al. 2009). The best geochronological constraint for this suite is the SHRIMP age of 626 ± 8 Ma, obtained in the Paulo Lopes Granite (Silva et al. 2003).

In an intermediate stratigraphic position, the São Pedro de Alcântara Suite includes diverse granodiorites to monzogranites. Most rocks are gray to pink with medium-grained equi- to inequigranular textures, though porphyritic varieties may also occur. They usually show slight deformation. This unit has mostly calc-alkaline signatures and corresponds to most varieties with these signatures otherwise grouped into the Maruim Suite (e.g., Zanini et al. 1997; Silva et al. 2002b, 2005b). The geochronological record of this unit consists of SHRIMP ages ranging from *c*. 610 Ma in the Forquilha Granite (Silva et al. 2002b), to 579 ± 8 Ma in the Alto da Varginha Granite (Silva et al. 2002b).

Finally, the late alkaline magmatism is grouped into the Pedras Grandes Suite by Basei et al. (2000, 2006), and corresponds to the final stage of granitic magmatism in the Florianópolis Batholith. In this sense, it includes associated volcanic and subvolcanic rocks alternatively identified as the Cambirela Suite (e.g., Zanini et al. 1997; Bitencourt et al. 2008). The suite comprises a number of different rocks, but the predominant lithology corresponds to isotropic gray to pink or red leucocratic granites with medium to coarse granulation (Fig. 11.5d), such as the Serra do Tabuleiro and Ilha granites. Most volcanic rocks associated with this suite occur as rhyolitic flows and tuffs, besides numerous dikes intruding into older suites (Zanini et al. 1997; Bitencourt et al. 2008). SHRIMP dating of the Tabuleiro Granite has produced an age of 597 ± 9 Ma (Silva et al. 2003, 2005b).

Metasedimentary rocks occur sporadically overlying the Florianópolis Batholith, grouped into the Queçaba Formation (Basei 1985; Zanini et al. 1997). They correspond to quartzites associated with mica schists, quartz schist and phyllites, tectonically juxtaposed with the granites.

11.2.3.2 Granite Intrusions in the Central Domain

Both the Brusque Group and its exposed basement, the Camboriú Complex, were intruded by numerous granitic plutons during the Brasiliano orogenic cycle. Centimeter- to meter-thick bodies of peraluminous granites concordant with the metasupracrustal sequence were interpreted by Philipp and Campos (2010) as related to the main deformational event of the Brusque Group in a collisional context, and represent an early phase of granitic magmatism. Much more voluminous intrusions affect the domain after the main deformational phase in the metamorphic association and are associated with the sequence's thermal climax (Philipp et al. 2004; Basei et al. 2011a). A total of *c*. 40 individual intrusions from this event are recognized, including two large batholiths many tens of kilometers long. The intrusions are grouped into three different suites: São João Batista, Valsungana, and Nova Trento (Basei et al. 2000, 2011a; Hueck et al. 2016). An early division of the intrusions into Valsugana and Guarbiruba suites, after Trainini et al. (1978), is still followed in some publications (e.g. Silva et al. 2005b; Hartmann et al. 2003a).

According to the division proposed by Basei et al. (2000, 2006) and Hueck et al. (2016), the São João Batista Suite is the oldest of the three suites, and includes fine- to medium-grained leucocratic isotropic granitoids. The suite has characteristic peraluminous mineralogy, with widespread igneous muscovite and accessory minerals such as garnet and tourmaline. The suite with the largest intrusions, by far, is the Valsungana Suite. It includes the two batholiths that occupy much of the central domain of the Dom Feliciano Belt in Santa Catarina. The most striking characteristic of the suite is its porphyritic texture, with K-feldspar megacrysts up to several centimeters long, within a medium- to coarse-grained matrix (Fig. 11.5e). Most rocks are leucocratic to mesocratic gray granites, with some varieties having pink K-feldspars. The main mafic mineral is biotite. Lastly, the Nova Trento Suite comprises numerous plutons, usually intruding in or around the main Valsungana batholiths. Rocks from this suite are mostly fine to medium grained, and have colors between gray and pink. Biotite is the most common mafic mineral, and common accessories include muscovite and, in the northernmost intrusions, hornblende.

With the exception of the rocks from the São João Batista Suite, most intrusions have magmatic foliations along their borders that are parallel to the orientation of their host rocks. Deformation in magmatic to submagmatic conditions that eventually evolve to solid-state deformation during magma cooling is indicated in microstructures (Peternell et al. 2010; Florisbal et al. 2012a; Hueck et al. 2016). This has been interpreted as evidence for a transcurrence-controlled emplacement (Peternell et al. 2010; Florisbal et al. 2012a), but might alternatively reflect magma-initiated strain localization (Hueck et al. 2016, in preparation).

All suites share a slightly peraluminous signature and have high-K calc-alkaline affinity (Castro et al. 1999; Florisbal et al. 2012a; Hueck et al. 2016). There is a geochemical distinction of some of the northernmost intrusions from the Valsungana and Nova Trento suites that suggest they underwent more oxidizing conditions (Castro et al. 1999; Hueck et al. 2016). A strong crustal signature is suggested for the granitic intrusions in the central domain by their isotopic signature (Florisbal et al. 2012a; Hueck et al. 2016). Nd and Hf T_{DM} model ages largely indicate Paleoproterozoic ages, with some early Mesoproterozoic and Archean influence as well. Mantellic input was limited to the Valsungana Suite, as suggested by the presence of mafic enclaves (Fig. 11.5e) and slightly less negative εNd values (Florisbal et al. 2012a).

Field relationships such as intrusive contacts and the presence of xenoliths are used to recognize the relative stratigraphy between the three suites (Basei et al. 2000, 2006, 2011a; Hueck et al. 2016). Nonetheless, most recent U-Pb dating of the granites obtained widely overlapping age intervals for all three suites of around 610–590 Ma (Silva et al. 2002b, 2003, 2005b; Vlach et al. 2009; Basei et al. 2011a; Florisbal et al. 2012c; Hueck et al., in preparation), suggesting a long-lasting magmatic event on which magmas of all three suites crystallized coevally (Hueck et al., in preparation). Although multiple sources were likely responsible for the generation of the granitic magmas (Florisbal et al. 2012a), both the isotopic record and zircon inheritance link them to the partial melt of rocks from the central domain of the Dom Feliciano Belt; that is, the Brusque Group and its crystalline basement, such as the exposed Camboriú Complex (Hueck et al. 2016, in preparation). The peraluminous São João Batista Suite probably had a bigger influence of paraderived source rocks, while the Valsungana and Nova Trento Suite might have had some degree of magmatic interaction (Hueck et al. 2016).

11.2.4 The Foreland Basin

The northwestern domain of the Dom Feliciano Belt in Santa Catarina is the Itajaí Basin. It is deposited on top of the Luís Alves Microplate and has an elongated shape, constituting a corridor up to 25 km wide, oriented east-northeast to west-southwest. The basin is asymmetric, with increasing thickness from north to south, where it reaches a sedimentary package as thick as 5000 m (Rostirolla et al. 1999; Guadagnin et al. 2010; Basei et al. 2011b; Costa and Nascimento 2015). Its northern contact is characterized by normal depositional contact, with the basal units of the Basin lying on top of the granulites from the Luís Alves Microplate. The southern limit, on the other hand, is tectonic in origin, and is characterized by the thrusting of the metavolcano-sedimentary rocks of the Brusque Group over the basin along the Itajaí-Perimbó Shear Zone (Basei 1985; Silva 1991; Rostirolla et al. 1992, 1999; Guadagnin et al. 2010; Oriolo et al. 2018).

The stratigraphy of the Itajaí Basin has been affected by thrust tectonics, causing local folding and numerous repetitions (Basei et al. 2011b). As a consequence, the total thickness of the sedimentary stack does not correspond to its stratigraphic thickness. The package has traditionally been designated as Itajaí Group (e.g., Silva and Dias 1981; Basei 1985) and most recent studies in the area identify three to four sedimentary units intruded by felsic volcanic rocks (Rostirolla et al. 1999; Guadagnin et al. 2010; Basei et al. 2011b; Costa and Nascimento 2015). The stratigraphy described below follows that of Basei et al. (2011b).

The basal unit corresponds to the Baú Formation, and comprises mainly polymitic conglomerates overlain by red massive sandstones. It has a thickness between 1 and 1.4 km and represents a system of continental fan deltas. Subordinate levels of volcanic tuff occur associated with the sandstones, and some layers of conglomerate are rich in felsic volcanogenic clasts. Further above is the Ribeirão Carvalho Formation, which consists of a 650–1000 m thick package of rhythmites, corresponding to a turbiditic system (Fig. 11.5f). This association transitions gradationally into the Ribeirão Neisse Formation, which mostly includes immature arkosic sandstones. This unit has a thickness of *c*. 1000 m. Finally, the upper sedimentary unit is the Ribeirão do Bode Formation, a 1500 m-thick alternation of silty-argillitic and silty-sandy layers, occasionally associated with massive green siltites and polymitic conglomerates. After its deposition, the Itajaí Group was affected by the intrusion of rhyolites, grouped into the Apiúna Formation. They affect the two uppermost units of the sedimentary package, occurring as dikes and domes. Finally, the eastern portion of the basin was intruded by the Subida Granite in the early Cambrian.

Alternative lithostratigraphic divisions of the Itajaí Basin do not divide it into formations, but rather into depositional tracts (Costa and Nascimento 2015) or into facies associations ordered from A to D (Rostirolla et al. 1999; Guadagnin et al. 2010). In the case of the latter, while facies association A and B agree well to the Baú and Ribeirão Carvalho Formations described above, facies association C is described as dominated by shales and rhythmites, which would most likely correspond to the Rio do Bode Formation. This alternative column also interprets an additional unit (facies association D) characterized by the return of a prograding continental sequence mainly composed of sandstones associated with conglomerates. Basei et al. (2011b) interpret the same rocks as a tectonic recurrence of the basal Baú Formation (Fig. 11.4) and point to the similar isotopic signatures and detrital zircon pattern of both continental associations.

After deposition, the Itajaí Basin went through two phases of deformation (Basei 1985; Rostirolla et al. 1992, 1999; Schroeder 2006; Basei et al. 2011b). None of them led to transposition of the original depositional surfaces, which preserve its primary structures. The first event (D_1) is associated with the thrust tectonics responsible for juxtaposing the Brusque Group with the Itajaí Basin. It is recorded in regional open folds with an east to west to northeast to southwest orientation, coupled to the development of an oblique cleavage (Basei et al. 2011b). Furthermore, this phase also developed thrusting parallel to bedding and oblique strike-slip faults (Fig. 11.4) (Rostirolla et al. 1999). The second phase is usually associated with extensional tectonics (Fig. 11.5f), and is responsible for refolding the previous structural framework, this time with a north to south orientation, along with reactivation of previous faults (Rostirolla et al. 1999; Basei et al. 2011b). In contrast with the sedimentary succession, the rhyolites of the Apiúna Formation are affected only by the D_2 deformational phase, as indicated by its magnetic fabrics, and were therefore intruded after the D_1 event (Raposo et al. 2014).

The main source areas for the sediments of the Itajaí Basin are the rocks from the other domains of the Dom Feliciano Belt and the Luís Alves Microplate, as evidenced by isotopic signatures, detrital zircons and paleocurrent indicators (Guadagnin et al. 2010; Basei et al. 2011b; Costa and Nascimento 2015). There is, however a distinction between the provenance of the basal Baú Formation and the remaining superior sequences, reflected in contrasting whole-rock geochemical and isotopic signatures. Furthermore, the detrital record of the zircons from the lower sequence reveals a more pronounced Paleoproterozoic and Archean inheritance. Based on this evidence, Basei et al. (2011b) propose that the continental deposits from the Baú formation are mostly associated with basement rocks such as the Luís Alves Microplate and the Camboriú Complex, while in the superior sequence the Dom Feliciano Belt and its Neoproterozoic magmatism were the main source areas.

Geochronological constraints to the deposition of the Itajaí Basin derive from U-Pb zircon analyses of its detrital content, volcanic intrusions and volcanogenic components. Guadagnin et al. (2010) attribute the age of the youngest detrital zircons found in the basin, at *c*. 563 Ma, as a maximum age for the sedimentation of the basin. On the other hand, Basei et al. (2011b) interpret the volcanoclastic components of the basal Baú Formation as reworked syn-depositional volcanism, and consider its age of *c*. 595 Ma to be the lower limit for the Itajaí Basin. The intrusion of rhyolitic dikes and domes in the upper sequences of the sedimentary package establishes a minimum age to its deposition. These are dated at *c*. 550 and 560 Ma, by Guadagnin et al. (2010) and Basei et al. (2011b) respectively. This upper limit is in disagreement with Cambrian ages previously proposed for the basin, based on its limited fossil content (Paim et al. 1997). The late Subida Granite was dated by U-Pb in zircon at 520 Ma (Basei et al. 2011b).

11.2.5 Deformation History of the Dom Feliciano Belt in Santa Catarina

As this chapter aims to describe the evolution of the Dom Feliciano Belt, the previous geological history recorded in the cratonic foreland and basement inliers will not be discussed in detail here. It should be noted, however, that all basement units are characterized by widespread Paleoproterozoic magmatism and deformation (Fig. 11.5b), particularly in the period from the Rhyacian to the Orosirian (Basei et al. 2000, 2009, 2013a; Hartmann et al. 2000a, 2003a; Silva et al. 2000, 2002b, 2005b).

The first stages of deformation associated with the Neoproterozoic evolution of the Dom Feliciano Belt in Santa Catarina are characterized by a compressional regime with an important thrust component (650–620 Ma). This is most evident in the central domain, in which the transposition foliation (S_2) of the Brusque Group was developed during regional metamorphism (Philipp et al. 2004; Basei et al. 2011a). In addition, basement inliers both in the central and in the southern domains (Camboriú and Águas Mornas complexes, respectively) were intensively reworked in this phase, generating flat-lying structures such as the gently-dipping antiform of the Camboriú Complex migmatites (Basei et al. 2000, 2013a; Bitencourt and Kruhl 2000; Philipp et al. 2004; Peternell et al. 2010; Chemale et al. 2012; Florisbal et al. 2012a, b). Geochronological constraints of this oldest event are given by the earliest Neoproterozoic melts recorded in the Camboriú and Porto Belo complexes, dated at 650–640 Ma (Chemale et al. 2012; Basei et al. 2013a). In the Brusque Group, the maximum age for the beginning of the thrust-related deformation (Fig. 11.4) is given by the syn-sedimentary metamorphosed acid volcanic rocks dated at 640 Ma (Silva et al. 2002a; Basei et al. 2011a). Conversely, this event should have ended by 620 Ma, as indicated by the intrusion of basic dikes (de Campos et al. 2012b) and by the first intrusions of transcurrent-associated granitic intrusions in the Florianópolis Batholith, along the Major Gercino Shear Zone (Passarelli et al. 2010, 2011a; Chemale et al. 2012; Florisbal et al. 2012c).

Following this initial stage, the deformation pattern transitioned to a transpressive setting (625–585 Ma). The earliest granites in the Florianópolis Batholith are associated with this period and intruded along the most significant structure of the region, the Major Gercino Shear Zone (Bitencourt and Kruhl 2000; Passarelli et al. 2010, 2011a, b; Florisbal et al. 2012b). Early stages of transcurrence in this structure indicate a transition from a convergent setting and span from 625 to 610 Ma (Passarelli et al. 2010; Chemale et al. 2012; Florisbal et al. 2012c), also recorded in limited shear zones in the Camboriú Complex basement inlier (Martini et al. 2015). Magmatism along the shear zone continued until *c*. 585 Ma (Bitencourt and Kruhl 2000; Chemale et al. 2012). The compressive component of this event is better recognized in the Brusque Group, in which the D_3 deformation phase led to the development of regional inverse folds (Basei et al. 2011a) locally evolving to transcurrent shear zones (Philipp et al. 2004). This stage of deformation in the metasupracrustal sequence is coeval with its second metamorphic phase, caused by the emplacement of large granitic intrusions between 610 and 590 Ma (Philipp et al. 2004; Basei et al. 2011a; Hueck et al. 2016, in preparation). The latter authors point out that this magmatic input led to strain localization along the intrusions. Concurrently, the latest granitic intrusions in the Florianópolis Batholith that are not associated with the Major Gercino Shear Zone are isotropic (Zanini et al. 1997; Basei et al. 2000, 2006; Bitencourt et al. 2008), indicating that the transcurrent deformation had relatively little impact outside high-strain zones. Considering a lower limit of 595 Ma for the sedimentation of the Itajaí Basin (Basei et al. 2011b), the effect of strike-slip faulting in its initial installation as advocated by Guadagnin et al. (2010) might be related to a transtensional component at the end of this stage.

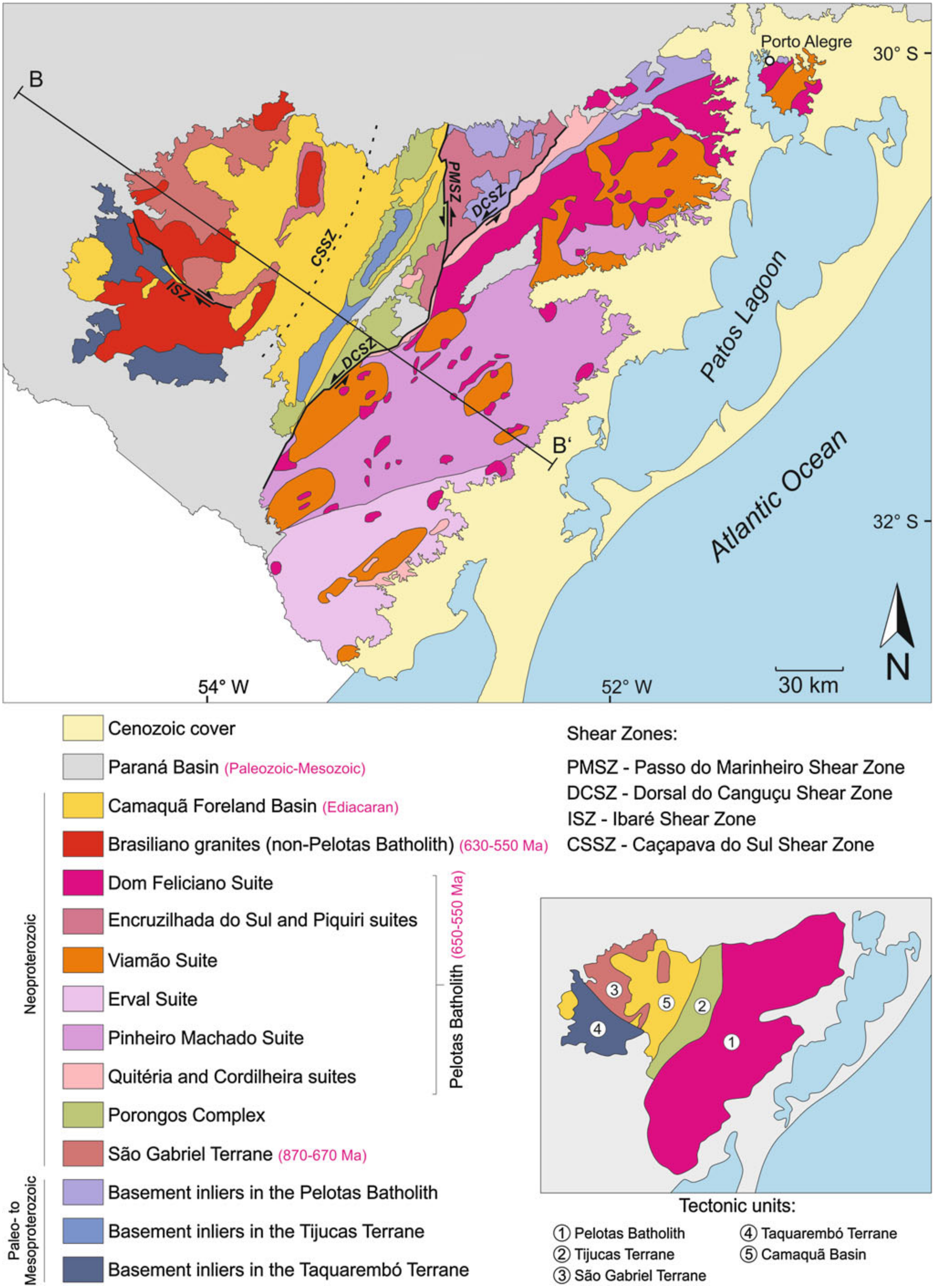
Late stages of deformation are best evidenced in the thrusting that led to the placement of the Brusque Group on top of the Itajaí Basin (585–550 Ma). It corresponds to the D_1 event in the basin (Rostirolla et al. 1992, 1999; Schroeder 2006; Basei et al. 2011b) and is responsible for open folding associated with an oblique cleavage and recurrent thrusting, causing stratigraphic repetitions (Fig. 11.4). This event is constrained between the deposition of the sedimentary package of the basin and the intrusion of rhyolitic domes which were not affected by this phase (Raposo et al. 2014), dated between 560 and 550 Ma (Basei et al. 2011b; Guadagnin et al. 2010). It might correspond to the development of the D_4 deformation in the Brusque Group, characterized by abundant small folds and persistent cleavage (Fig. 11.5c) (Basei et al. 2011a). It is also synchronous to late-stage deformations along the Major Gercino Shear Zone and numerous K-Ar cooling ages from both muscovite and biotite in its associated granitic intrusions (Passarelli et al. 2010; Basei et al. 2011a).

Finally, the last significant deformation recorded in the Dom Feliciano Belt in Santa Catarina is an extensional event (550–520 Ma), responsible for the D_2 deformation recorded in the Itajaí Basin (Rostirolla et al. 1999; Basei et al. 2011b). This stage is associated with the refolding of the depositional package and the reactivation of previous faults.

11.3 Rio Grande do Sul Sector

The Dom Feliciano Belt in Rio Grande do Sul is part of the Precambrian Sul-rio-grandense Shield, an association of terranes juxtaposed in the Brasiliano orogenic cycle and composed of various geotectonic units with distinct characteristics. This wide area is bounded to the north and to the west by the Paleozoic sequences of the Paraná Basin, resting in sedimentary contact over the shield rocks, while to the east it is covered by the Cenozoic coastal sediments close to the South Atlantic shore. In its southern extremity it crops out across the national border into the Uruguayan sector of the Dom Feliciano Belt.

The Sul-rio-grandense Shield is traditionally divided into four geotectonic units, namely the Taquarembó, São Gabriel and Tijucas terranes, together with the Pelotas Batholith (Figs. 11.6 and 11.7). They are overlain by the Ediacaran to Cambrian Camaquã Basin (Chemale 2000; Philipp et al. 2016a). Each domain is separated from its neighbor by large shear zones, although not all are exposed. The Taquarembó Terrane is part of the Nico Pérez Terrane and constitutes the main foreland basement associated with the Dom Feliciano Belt in the region. On the other hand, the São Gabriel Terrane is a particularity of the Dom Feliciano Belt in Rio Grande do Sul, and corresponds to a juvenile Neoproterozoic


B
B‘
Porto Alegre
30° S
32° S
54° W
52° W
30 km
N
PMSZ
DCSZ
CSSZ
ISZ
DCSZ
Patos Lagoon
Atlantic Ocean
Cenozoic cover
Paraná Basin (Paleozoic-Mesozoic)
Camaquã Foreland Basin (Ediacaran)
Brasiliano granites (non-Pelotas Batholith) (630-550 Ma)
Dom Feliciano Suite
Encruzilhada do Sul and Piquiri suites
Viamão Suite
Erval Suite
Pinheiro Machado Suite
Quitéria and Cordilheira suites
Pelotas Batholith (650-550 Ma)
Porongos Complex
São Gabriel Terrane (870-670 Ma)
Neoproterozoic
Basement inliers in the Pelotas Batholith
Basement inliers in the Tijucas Terrane
Basement inliers in the Taquarembó Terrane
Paleo- to Mesoproterozoic
Shear Zones:
PMSZ - Passo do Marinheiro Shear Zone
DCSZ - Dorsal do Canguçu Shear Zone
ISZ - Ibaré Shear Zone
CSSZ - Caçapava do Sul Shear Zone
1
2
3
4
5
Tectonic units:
① Pelotas Batholith
② Tijucas Terrane
③ São Gabriel Terrane
④ Taquarembó Terrane
⑤ Camaquã Basin

◀ **Fig. 11.6** Simplified geological map of the Rio Grande do Sul sector of the Dom Feliciano Belt. Profile B-B′ is presented in Fig. 11.7. Modified from Wildner et al. (2006), Saalmann et al. (2011) and Philipp et al. (2016a)

terrane accreted to it during the earliest stages of the Brasiliano orogenic cycle. It contains the remnants of two magmatic arcs, besides ophiolitic sequences and metasedimentary passive margin deposits associated with its evolution.

The remaining domains roughly correspond to those recognized in the threefold division of the belt (Basei et al. 2000). The eastern domain comprises the Pelotas Batholith, part of the large granitic association that is one of the main characteristics of the orogenic belt. It is the largest unit in the Precambrian shield, corresponding to almost half of its area. The Tijucas Terrane represents the central domain of the Dom Feliciano Belt in Rio Grande do Sul, and is composed of a metavolcano-sedimentary complex associated with basement inliers, represented by Paleoproteozoic gneiss complexes. Finally, the western domain corresponds to the foreland Camaquã Basin, a thick sedimentary package with subordinate volcanic rocks deposited predominantly during the Ediacaran.

The following sections will describe the main lithostratigraphic units of each terrane, summarizing the state of the art in terms of geological knowledge. A short discussion of the shield's deformational history is also presented. A detailed description of the São Gabriel Terrane and a discussion of its significance in the Dom Feliciano Belt is presented in an individual chapter (Philipp et al. 2018), as is the Taquarembó Terrane, along with the rest of the Nico Pérez Terrane (Oyhantçabal et al. 2018). In addition, another chapter describes and discusses the main shear zones of the shield (Oriolo et al. 2018).

11.3.1 The Cratonic Foreland

11.3.1.1 Basement Inliers

Crystalline rocks of varied age are locally exposed in close connection with the new units generated during the Brasiliano orogenic cycle, representing the basement of the Dom Feliciano Belt in Rio Grande do Sul.

The basement inliers of the Tijucas Terrane are exposed in the core of large-scale antiforms known as the Santana da Boa Vista and Vigia domes. These basement rocks are composed by Paleoproterozoic TTG gneisses, the Encantadas and Vigia complexes, associated with the Statherian Seival Metagranite and the Calymmian Tupi Silveira Amphibolite (Jost 1981; Saalmann et al. 2006; Camozzato et al. 2013; Philipp et al. 2016a). The contact between these units and the metavolcano-sedimentary Porongos Complex is defined by low-angle ductile shear zones marked by mylonites, which obliterate the original stratigraphic relationships.

The Encantadas Complex is a Paleoproterozoic unit composed of tonalitic to trondhjemitic and dioritic gneisses (Fig. 11.8a) with minor amphibolite. The gneisses are metaluminous to slightly peraluminous, with medium-K calc-alkaline composition, representing a typical high-Al TTG association (Philipp et al. 2008; Lusa et al. submitted). This metamorphic complex is intruded by mylonitic monzo- and syenogranitic gneisses (Philipp et al. 2010; Lusa et al. submitted), and was metamorphosed under upper amphibolite facies conditions (Hartmann et al. 2003b; Philipp et al. 2008). The tonalitic gneisses have mostly Siderian crystallization zircon ages between 2.35 and 2.1 Ga, the intrusive

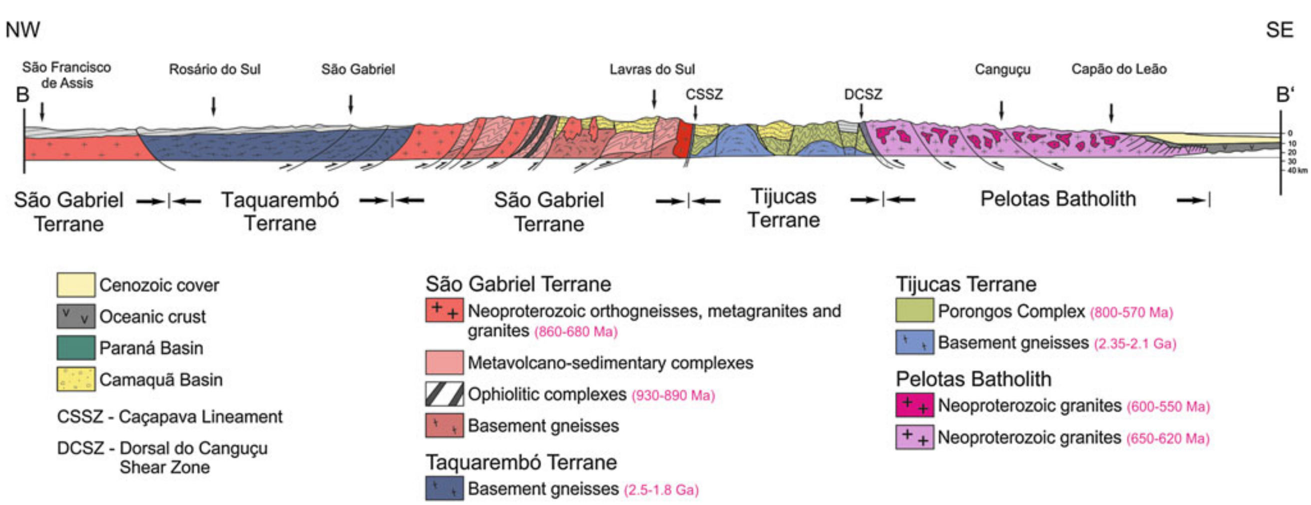


Fig. 11.7 Schematic geologic profile of the Dom Feliciano Belt in the Rio Grande do Sul sector

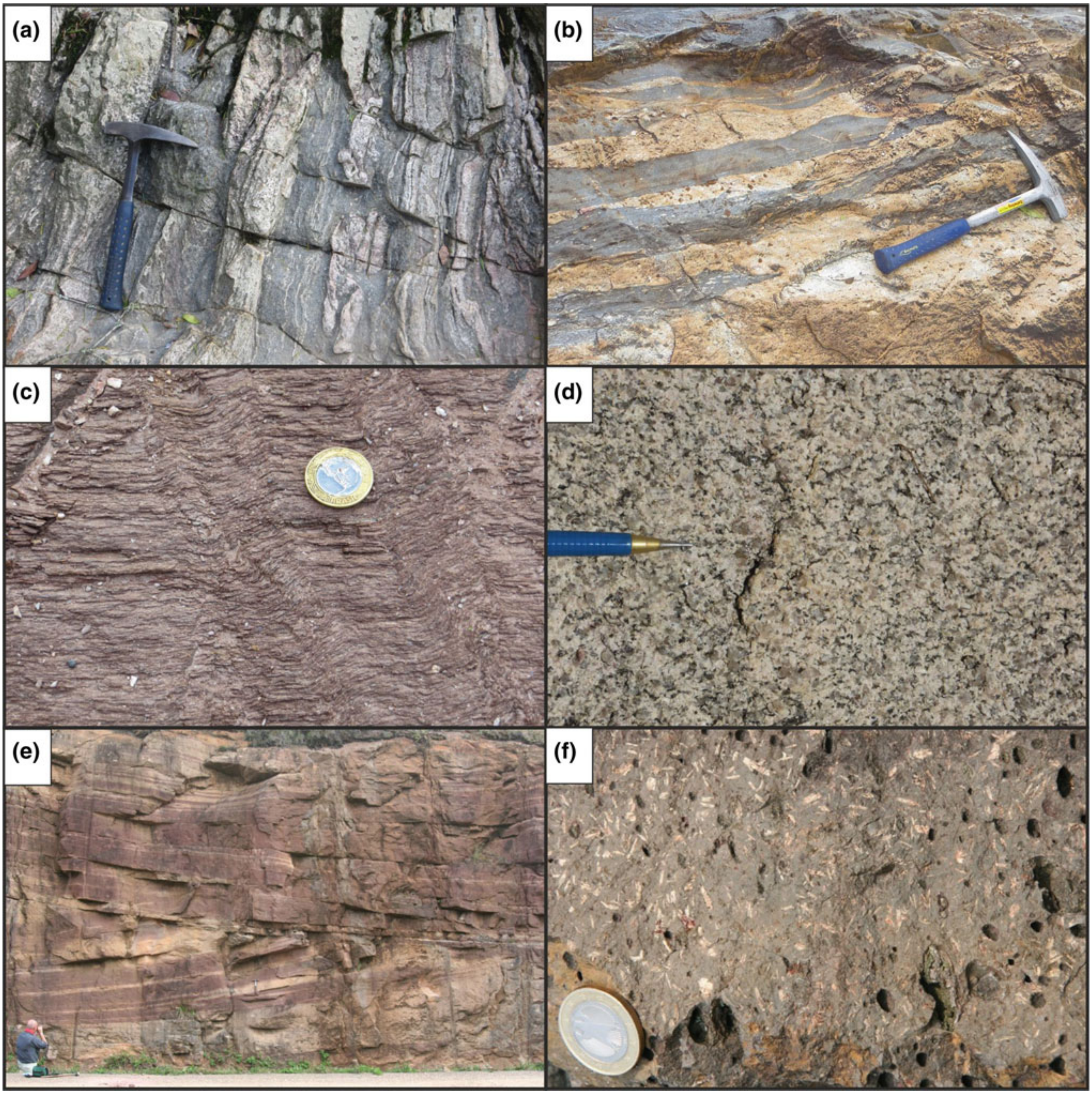


Fig. 11.8 Some field aspects of rocks from the Rio Grande do Sul sector of the Dom Feliciano Belt. **a** Banded gneiss of the Encantadas Complex; **b** Migmatitic paragneiss of the Várzea do Capivarita Complex; **c** Finely laminated phyllite of the Porongos Complex. Note the presence of kink bands representing late-stage deformation; **d** Fine- to medium-grained granite of the peraluminous Cordilheira Suite; **e** Arenites with metric cross-beddings ofthe Pedra Pintada Formation, Guaritas Group, Camaquã Basin; **f** Andesite of the Hilário Formation, Bom Jardim Group, Camaquã Basin

mylonitic gneisses present Rhyacian zircon ages varying from 2.17 to 2.15 Ga, and the metamorphism was dated in the Orosirian (2.06–2.02 Ga) (Hartmann et al. 2003b; Saalmann et al. 2011; Camozzato et al. 2013, submitted; Lusa et al., submitted).

The Vigia Complex is a Paleoproterozoic (Orosirian) unit composed of dioritic, tonalitic and trondhjemitic gneisses with subordinate amphibolite exposed at the southern portion of the Tijucas Terrane (Camozzato et al. 2013). Geochemical data indicate that these rocks are metaluminous to slightly peraluminous, with medium- to high-K calc-alkaline nature, similar to that of the Encantadas Complex (Camozzato et al. 2013, submitted). The age of this complex is constrained by LA-MC-ICPMS U-Pb crystallization ages in zircons at *c*. 2.05–2.0 Ga (Camozzato et al. 2013, submitted).

This metamorphic complex is intruded by the Seival Metagranite and by the Tupi Silveira Amphibolite. The former is a 40 × 10 km pluton elongated in the N30°E direction in the southeastern portion of the Vigia Dome. The monzogranitic to granodioritic rocks of the intrusion have a high-K calc-alkaline composition, with metaluminous to slightly peraluminous nature and trace elements characteristics similar to those of evolved arc-related associations (Camozzato et al. 2013). U-Pb LA-MC-ICPMS ages between 1.78 and 1.76 Ga place it as the only known Statherian granitic magmatism in southern Brazil (Camozzato et al. 2013, submitted; Philipp et al. 2016a). The Tupi Silveira Amphibolite crops out in the southern portion of the Vigia Dome, comprising two bodies about 1–2 km in length, elongated in the N10°E and N30°E directions. The amphibolites present a regular and continuous banding of millimetric thickness and polygonal granoblastic texture defined by plagioclase, hornblende, garnet and rare diopside. U-Pb zircon age of one sample revealed a crystallization age of 1,567 ± 21 Ma (Camozzato et al. 2013, submitted). It represents a Calymmian anorogenic magmatic event characterized by basic and ultrabasic layered complexes (Philipp et al. 2016a), to which the Capivarita Meta-anorthosite in the Pelotas Batholith might be associated (Chemale et al. 2011). After crystallization, both units were affected by collisional metamorphism under granulite facies, between c. 650 and 630 Ma (Philipp et al. 2016a, b).

Basement inliers in the Pelotas Batholith are represented by medium- to high- grade metamorphic rocks, captured as xenoliths and “roof pendants” during the ascent and emplacement of the granitic suites. Their dimensions vary from up to several kilometers across in large areas in the northern portion of the domain to enclaves of centimetric to decametric dimensions in the central and southern areas. Petrographic, geochemical and structural data for these xenoliths show that they are comparable to the adjacent metamorphic units of the Nico Pérez Terrane in RS and correlate with the basement occurring in Uruguay. The main exposures are within granites of the Encruzilhada do Sul Suite, and are xenoliths of paragneisses of the Várzea do Capivarita Complex and orthogneisses of the Arroio dos Ratos Complex (Fernandes et al. 1992).

The Arroio dos Ratos Complex is an association of orthoderived rocks, including tonalitic to granodioritic gneisses which underwent metamorphism under upper amphibolite to granulite facies conditions (Leite et al. 1998; Lima et al. 1998; Tickyj et al. 2004; Philipp and Campos 2004; Gross et al. 2006; Gregory et al. 2011, 2015; Martil et al. 2011). Three rock associations were identified in the field (Gregory et al. 2015), which are interpreted to represent successive magmatic pulses that mark the evolution of a Paleoproterozoic continental magmatic arc. Tectonic contacts separate this unit from the paraderived Várzea do Capivarita Complex. This latter complex mostly comprises pelitic migmatite (Fig. 11.8b), with subordinate calc-silicate gneiss, marble and rare quartzite (Philipp et al. 2016b). Structurally, the main S_2 foliation is a crenulation cleavage, responsible for transposing a previous S_1 banding. A later regional deformational event generated normal open F_3 folds. Both units record collisional metamorphism under upper amphibolite to granulite facies conditions (Fernandes et al. 1992; Lima et al. 1998; Gross et al. 2006; Philipp et al. 2010, 2013; Chemale et al. 2011). Based on pseudosection modeling for the paragenesis garnet-cordierite-sillimanite-biotite of the Várzea do Capivarita Complex, this metamorphism occurred at 720–820 °C and pressure of 8–9 kbar (Philipp et al. 2013).

The Capivarita Meta-anorthosite represents an intrusive association into the high-grade metamorphic rocks. The main lithology is a homogeneous light gray anorthosite, but subordinate varieties include garnet anorthosites, metagabbros and amphibolites (Philipp et al. 2010; Chemale et al. 2011). Structurally, the main foliation corresponds to that of the Várzea do Capivarita and Arroio dos Ratos complexes, and is defined by irregular and discontinuous millimeter-thick banding. This magmatism may represent an episode of continental accretion in an extensional setting during fragmentation of a supercontinent in the Early Mesoproterozoic, and is coeval with the intrusion of the Tupi Silveira Amphibolite in the Tijucas Terrane (Chemale et al. 2011; Philipp et al. 2016a).

The orthogneisses of the Arroio dos Ratos Complex have magmatic ages spreading around *c*. 2.2–2.0 Ga and juvenile signatures (Leite et al. 2000; Silva et al. 2005a; Gregory et al. 2015). The intrusion of the Capivarita Meta-anorthosite is constrained by magmatic zircon crystals dated at 1,573 ± 21 Ma (Chemale et al. 2011), with Lu–Hf model ages distributed into two clusters: from 1.81 to 2.03 Ga (εHf from +2.2 to +6.4) and from 2.55 to 2.62 Ga (εHf from −4.59 to −5.64). Neoproterozoic metamorphic overprint is recorded in all basement units between 650 and 600 Ma. Metamorphic zircon grains of gneisses from the Várzea do Capivarita Complex were dated at 620 ± 4 Ma, associated with the intrusion of a peraluminous leucogranite at 612 ± 5 Ma (Philipp et al. 2016b). Similarly, metamorphic zircon growth was dated at 631 ± 13 Ma (Silva et al. 2005a) in the Arroio dos Ratos Complex, while the Capivarita Meta-anorthosite yield metamorphic zircons dated at 606 ± 6 Ma and titanite grains with ages of 651 ± 9 and 601 ± 5 Ma (Chemale et al. 2011).

Gneissic rocks in the region of Porto Alegre have commonly been correlated with the Arroio dos Ratos Complex (Philipp and Campos 2004). Recently, however, Koester et al. (2016) presented a Tonian U-Pb SHRIMP zircon age of 789 ± 13 Ma for the Chácara das Pedras orthogneiss, suggesting a new arc generation, similar to other signatures identified recently in the Dom Feliciano Belt (Lenz et al. 2011, 2013; Masquelin et al. 2012; Martil et al. 2017). Xenoliths of tonalitic gneiss inside the dated unit present a LA-MC-ICPMS U-Pb zircon age of 1,993 ± 25 Ma, probably related to inheritance of Arroio dos Ratos-type gneisses (Philipp et al., submitted).

11.3.2 The Metavolcano-sedimentary Complexes

The metavolcano-sedimentary complexes in Rio Grande do Sul are part of the Tijucas Terrane, which constitutes the central domain of the Dom Feliciano Belt in the region. It is elongated in the N30°–40°E direction, extending for 170 km with a width of between 15 and 30 km, in tectonic contact with the neighboring units by means of important shear zones (Chemale 2000; Philipp et al. 2016a; Oriolo et al. 2018). To the west, it is limited from the São Gabriel Terrane by the Caçapava do Sul Shear Zone, covered by the Camaquã Basin. The eastern boundary, with the Pelotas Batholith, is marked by the ductile strike-slip Dorsal do Canguçu Shear Zone. The northeastern contact of the Tijucas Terrane with the Pelotas Batholith is further affected by the brittle north to south Passo do Marinheiro Shear Zone.

The supracrustal rocks of this domain are grouped into the Porongos Complex. This comprises two distinct depositional sequences, as evidenced by petrographic, geochemical and U-Pb zircon data both in detrital crystals of metasediments and magmatic ones in metavolcanic rocks (Saalmann et al. 2006; Pertille et al. 2015a, b; Philipp et al. 2016a). The central-southern sequence is exposed in the Santana da Boa Vista, Pinheiro Machado and Hulha Negra areas and consists of a pile of quartzite, pelitic schists (Fig. 11.8c) and marble lenses, interlayered with Late Tonian metarhyolites, metadacites and meta-andesites, with subordinate ultramafic rocks (magnesian schists and serpentinites). This unit has traditionally been the most studied of the two. The schists have variable degrees of weathering, maturity and a mix of Paleoproterozoic to Neoproterozoic sources (Hartmann et al. 2004; Basei et al. 2008; Gruber et al. 2011; Pertille et al. 2015b). The lower and the dominant part of the complex were derived from the erosion of Archean, Paleo- and Mesoproterozoic sources with ages between 2.9 and 2.0 Ga, and between 1.6 and 1.0 Ga (Hartmann et al. 2004; Gruber et al. 2011; Pertille et al. 2015a, b). The first LA-MC-ICPMS U-Pb analyses in zircons of the metavolcanic rocks from Santana da Boa Vista area presented an age of 770 ± 14 Ma for a meta-andesite and 789 ± 74 Ma for a metarhyolite, with Nd T_{DM} model ages of *c*. 3.2 Ga, and later SHRIMP U-Pb zircon ages of 783 ± 6 Ma were obtained in a metarhyolite (Chemale Jr. 2000; Hartmann et al. 2000b). Recently, new SHRIMP U-Pb zircon analyses of metadacites and meta-andesites of the Santana da Boa Vista and of metarhyolites of the Piratini region yielded ages between 795 and 810 Ma (unpublished data).

On the other hand, the northern sequence, exposed in the Capané (Cachoeira do Sul) area, is younger and consists of metapelites and quartzites intercalated with Ediacaran fine-grained crystal metatuffs and metadacites intruded by alkaline granite (Marques et al. 1998a; Gollmann et al. 2008; Saalmann et al. 2011; Zvirtes et al. 2017). The metamorphism ranges from greenschist to amphibolite facies with medium pressure conditions (Jost 1981; Marques et al. 1998b). Detrital zircon ages of the Capané area range from Mesoproterozoic (pelitic schists) to Neoproterozoic ages (chlorite schist), and the whole rock geochemical parameters show mantellic affinity (Pertille et al. 2015a). However, the major Ediacaran population of zircon grains indicates exclusively reworked sources with strong similarity with the syn- to post- collisional granites of the Pelotas Batholith or with the Neoproterozoic calc-alkaline to alkaline granitic suites of the Taquarembó Terrane (Pertille et al. 2015a; Philipp et al. 2016a; Camozzato et al. submitted). Despite the mantellic affinity of the chlorite schists, the dated samples have minimum U-Pb ages of around 580 Ma. It is suggested that this part of the Porongos Complex represents a foreland basin that was deformed and metamorphosed (Pertille et al. 2015a).

11.3.3 Neoproterozoic Granite Magmatism

The Pelotas Batholith is the foremost expression of the extensive post-collisional granitic magmatism in the Dom Feliciano Belt, occupying most of the Sul-rio-grandense Shield. The Tijucas Terrane exhibits less abundant granitic intrusions, possibly associated with the main batholith. In addition, numerous granites with ages corresponding to the Dom Feliciano Belt intrude the São Gabriel and Taquarembó terranes, evidencing some degree of reworking of these domains. Their evolution, however, is more closely related to the magmatism of the Camaquã Foreland Basin, and will be discussed in the corresponding section.

11.3.3.1 Pelotas Batholith

The Pelotas Batholith is composed of a set of Upper Cryogenian to Ediacaran granite suites, generated during and after the orogenic climax of the Dom Feliciano Belt, between 650 and 550 Ma. It comprises a multi-intrusive 400 × 120 km plutonic complex including granite, diorite and gabbro, as well as rhyolitic to basaltic (Philipp and Machado 2005).

The granitic suites are elongated in the N50°–70°E direction, and their generation and emplacement were controlled by high angle ductile transcurrent shear zones (Fig. 11.7) (Fernandes et al. 1992; Philipp et al. 1993, 2002, 2003; Koester et al. 2001a, b). These structures were active during the batholith's development and are defined by mylonitic belts with subvertical foliation, accompanied by subhorizontal stretching lineation (Philipp et al. 2003). The structural evolution of the intrusive rocks suggests episodes of compressional ductile movements, followed by an extensional period with ample transcurrence. Large crustal xenoliths and roof pendants represent the basement inliers in the northern portion of the batholith, while xenoliths of schist, quartzite and marble of the Porongos Complex occur in the Herval and Pedro Osório regions.

The granitoids can be divided into an early generation of high-K calc-alkaline suites with metaluminous to peraluminous affinity, followed by alkaline magmatism and, finally, less voluminous peralkaline intrusions (Philipp and Machado 2005; Philipp et al. 2016a). High $^{87}Sr/^{86}Sr$ initial ratios and negative εNd values, with Nd T_{DM} model ages in the interval between 1.1 to 2.1 Ga, indicate anatexis of the Paleoproterozoic continental crust, associated with coeval mafic magmatism, as evidenced by mingling processes with dioritic rocks (Koester et al. 2001a, b; Philipp et al. 2003, 2007, 2013, 2016a).

The lithostratigraphic sequence of the batholith begins with the Quitéria Granite, followed by the Cordilheira Suite, Pinheiro Machado Complex, and the Viamão, Erval, Piquiri, Encruzilhada do Sul, Dom Feliciano and Itapuã suites (Koester et al. 2001a, b; Philipp et al. 2002, 2003, 2013).

The Quitéria Metagranite is the oldest granite in the batholith, with a U-Pb SHRIMP zircon age of 658 ± 4 Ma (Frantz et al. 2003). In the Quitéria region, the peraluminous granites of the Cordilheira Suite (Fig. 11.8d) have U-Pb SHRIMP zircon ages between *c*. 634 and 625 Ma (Cordilheira and Francisquinho granites) and 605 ± 8 Ma (Figueiras granite) (Frantz et al. 2003). In addition, new LA-MC-ICPMS U-Pb zircon ages of peraluminous leucogranite related to the Cordilheira Suite intrusive in migmatitic pelitic gneiss of the Várzea do Capivarita Complex indicate crystallization at 620 ± 6 Ma (Philipp et al. 2016b). Both suites are closely associated with the development of the Dorsal do Canguçu Shear Zone, and represent the early stages of formation of the Pelotas Batholith (Philipp et al. 2013, 2016a).

Following this early magmatism, the orogenic peak of the Dom Feliciano Belt was controlled by compression and new shear episodes, associated with the generation of acid to basic magmas, suggesting important anatexis. This event culminated in the generation of the granites of the Pinheiro Machado Complex and Viamão Suite. These suites present U-Pb and Pb-Pb TIMS zircon ages between 630 and 620 Ma, with the exception of the Arroio Moinho Granite, from the Viamão Suite, dated at 595 ± 1 Ma (Babinski et al. 1997; Philipp et al. 2002, 2003; Silva et al. 1997). More recent LA-MC-ICPMS U-Pb analyses yielded ages of 630 ± 6 Ma for the Viamão Granite and 627 ± 16 Ma for the Barão do Triunfo Granite (Philipp et al., submitted).

Late- to post-collisional reactivation of the shear zones between *c*. 610 and 550 Ma resulted in the emplacement of the alkaline and peralkaline Piquiri and Encruzilhada do Sul suites, and high-K calc-alkaline to alkaline granites of the Dom Feliciano Suite (Philipp et al. 2003, 2016a). Zircon crystals from syenites of the Piquiri Suite were dated by Pb-Pb evaporation TIMS method, with ages of 611 ± 3 and 612 ± 3 Ma (Philipp et al. 2002), while granites of the Encruzilhada do Sul Suite have the U-Pb TIMS zircon age of 595 ± 4 Ma (Babinski et al. 1997). New U-Pb LA-MC-ICPMS zircon analyses yielded an age of 595 ± 8 Ma for the porphyritic facies of the same granite (Philipp et al., submitted). The northern portion of the Pelotas Batholith is dominated by the voluminous post-collisional leucogranites of the Dom Feliciano Suite, emplaced at the end of the Neoproterozoic. The Ponta Grossa Granite has a U-Pb TIMS zircon age of 600 ± 9 Ma, and a pegmatoid leucogranite associated with this suite intruding basement gneisses in the Porto Alegre region yielded a crystallization age of 585 ± 6 Ma (Philipp et al., submitted).

Finally, the subvolcanic component traditionally associated with this suite is separated into the Itapuã Suite (Oliveira et al. 2001). It comprises granites, syenogranites, quartz syenites and subordinate syenites, as well as a dike swarms of comenditic rhyolite to basalt with alkaline to peralkaline affinity (Oliveira et al. 2015). A U-Pb SHRIMP zircon age of 600 ± 3 Ma was reported for the Santana Granite (Koester et al. 2001c), while new U-Pb LA-MC-ICPMS zircon data indicate ages of around 550 Ma for the felsic dikes, determining the youngest magmatism of the Pelotas Batholith (Oliveira et al. 2015; Zanon et al. submitted).

11.3.3.2 Granitic Intrusions in the Tijucas Terrane

Two groups of granite intrusions are recognized in the Tijucas Terrane. The first is represented by deformed bodies emplaced along the regional foliation of the Porongos Complex; these have a peraluminous composition, with muscovite, garnet and tourmaline. Compositional and textural characteristics suggest that they can be correlated with the Cordilheira Suite of the Pelotas Batholith (Camozzato et al. 2012). The second group of intrusions is associated with high-angle shear zones in the Capané and Candiotinha regions. They have alkaline compositions and comprise leucogranites with biotite and/or sodic pyroxene. The Capané Granite was investigated by conventional U-Pb zircon by Chemale (2000) yielding an age of 543 ± 6 Ma. More recently, new U-Pb LA-MC-ICPMS zircon ages indicate crystallization at 589 ± 25 Ma for the Candiotinha Metagranite and 601 ± 7 Ma for the Capané Metagranite (Camozzato et al. 2013, submitted; Zvirtes et al. 2017). It is interpreted that these granites represent distinct orogenic settings: granites of the first group are coeval with collisional metamorphism, and the younger are late orogenic and associated with transcurrence along the high-angle shear zones internal to the Tijucas Terrane (Camozzato et al. 2013; Zvirtes et al. 2017).

11.3.4 The Foreland Basin

The plutonic-volcano-sedimentary Camaquã Association represents the late- to post-collisional stage of the Dom Feliciano Belt (Paim et al. 2000; Chemale 2000; Philipp et al. 2016a). The main unit of this association is the Camaquã Basin, formed by four different sedimentary and three volcano-sedimentary units. They are grouped into four depositional successions, separated from each other by angular or erosional unconformities of regional character. The basin was filled and deformed during the late stages of the Brasiliano orogenic cycle, between 620 and 540 Ma (Paim et al. 2000; Chemale 2000; Almeida et al. 2012; Janikian et al. 2012; Bicca et al. 2013; Oliveira et al. 2014).

The basin was initiated with the deposition of the Maricá Group in a marine environment. It is interpreted to correspond to a retro-arc foreland basin due to the collision of the Rio de la Plata Craton and the Encantadas microcontinent (Borba et al. 2006, 2008). This was followed by a transition between marine and lacustrine conditions during the deposition of the Bom Jardim and Santa Bárbara Groups. The former was associated with transpressive tectonics (Paim et al. 2000), while the latter marks the transition to the upper section of the Camaquã Basin, a transtensional rift basin developed when amalgamation of the shield was already completed (Bicca et al. 2013; Oliveira et al. 2014). In this context, the last sedimentary sequence, the Guaritas Group, was deposited in fluvial and lacustrine environments with aeolian facies (Fig. 11.8e).

In the last three sequences, activity of the main shear zones and extensional faults reached the mantle and lower crust levels to generate the volcanic rocks that characterize the upper Camaquã Basin. Large shoshonite to high-K calc-alkaline magmatism is represented by elongated volcanic bodies parallel to the main transcurrent fault systems. The volcanic evolution of the basin started with the eruption of volcanic rocks with tholeiitic, high-K calc-alkaline to shoshonitic compositions (Fig. 11.8f, Hilário Formation, Bom Jardim Group). Afterwards, the volcanism changed to magmas with bimodal tholeiitic to sodic alkaline signatures, as represented by the Acampamento Velho Formation, part of the Santa Barbara Group (Matté et al. 2016). Finally, alkaline basaltic volcanic rocks finish the succession (Rodeio Velho Formation, Guaritas Group) (Wildner et al. 2002; Sommer et al. 2005; Janikian et al. 2012).

Two main granitoid suites intruding into the São Gabriel and Taquarembó terranes are linked to this magmatism, first a shoshonitic to high-K calc-alkaline association followed by alkaline granites. The emplacement of the shoshonitic granitoids, such as the Lavras do Sul intrusion, is correlated with the deposition of the Bom Jardim Group. On the other hand, the sedimentary and volcanic rocks of the Santa Barbara Group are contemporaneous with the emplacement of the Acampamento Velho Formation rhyolites and high-K calc-alkaline granitoids such as the Caçapava do Sul Granite and of alkaline granitoids such as the Jaguari, Ramada, Cerro da Cria and São Sepé granites. The high-K calc-alkaline plutons have SHRIMP and LA-MC-ICPMS U-Pb ages between 598 and 570 Ma, whereas the alkaline plutons crystallized between 570 and 560 Ma (Philipp et al. 2016a).

11.3.5 Deformation History of the Dom Feliciano Belt in Rio Grande do Sul

The impact of the Dom Feliciano orogeny in the Sul-rio-grandense Shield cannot be overstated, as it was responsible for reworking most of the preceding units of the area and producing a voluminous granitogenesis that affects most of the shield. However, most domains record the evolution of previous orogenic events, representing a complex array of superposed deformational phases lasting from the Paleoproterozoic to the Early Cryogenian. As a consequence, it is sometimes difficult to separate the effect of the Dom Feliciano orogeny from earlier orogenic processes.

The initial construction of the Dom Feliciano Belt in Rio Grande do Sul is recorded in the São Gabriel Terrane, and begins with the formation of the Passinho and São Gabriel arcs during the closure of the Charrua Ocean between 890 and 680 Ma. This was followed by the collision between the arc systems and the western margin of the Nico Pérez Terrane, deforming the sedimentary rocks deposited at its western passive margin. This stage of the orogeny is discussed in detail by Philipp et al. (2018).

The main orogenic phase in the Dom Feliciano Belt comprises the Late Cryogenian and the Ediacaran periods, and can be best evaluated by analyzing the units that were generated during this period, in particular the granitic intrusions. The early evolution of the Pelotas Batholith magmatism corresponds roughly to the period from 650 to 620 Ma (Babinski et al. 1997; Silva et al. 1997; Frantz et al. 2003; Philipp et al. 2002, 2003, 2016a, b, submitted). The structural pattern observed in the granites of this period is dependent on the position relative to the different strain partition domains. Intrusions located closest to the main shear zones, and in particular those associated with the Dorsal do Canguçu Shear Zone, have syn-deformational characteristics and indicate a transcurrent displacement, as evidenced by detail studies on both the Quitéria and Cordilheira suites, besides smaller intrusions in the same context (Fernandes et al. 1993; Philipp et al. 1993, 2016a; Tommasi et al. 1994; Fernandes and Koester 1999; Philipp and Machado 2005; Fontana et al. 2012; Knijnik et al. 2012). On the other hand, the period between 630 and 620 Ma marks the intrusion of the large Pinheiro Machado Complex and of the Erval and Viamão suites. In particular in the Pinheiro Machado Complex, most structural characteristics indicate a transpressional (oblique) deformation, with vergence to the northwest (Fernandes et al. 1992, 1993; Philipp et al. 1993; Philipp and Machado 2005).

This pattern indicates an important degree of strain partitioning in a transpressive context in the early evolution of the Dom Feliciano Belt in Rio Grande do Sul (650–620 Ma), with coeval intrusions developing different structural features according to the strain intensity under which they were emplaced (Fig. 11.7). This process is commonly interpreted to have evolved during the peak of the oblique collision that formed the Dom Feliciano Belt, which, in the case of the granitogenesis, was responsible for promoting anatexis in the continental crust and assisting the emplacement of the Pelotas Batholith (Chemale et al. 2011; Philipp et al. 2013, 2016a, b; Gregory et al. 2015).

Late-stage magmatism in Rio Grande do Sul encompasses intrusions and associated volcanism between 610 and 550 Ma (Babinski et al. 1997; Philipp et al. 2002, 2003, 2016a, submitted; Oliveira et al. 2015; Zanon et al. 2017). Intrusions related to this stage are not restricted to the Pelotas Batholith, but also occur in the Tijucas Terrane, and are coeval to the volcanic components of the Camaquã Basin and the post-collisional granitic intrusions in both the São Gabriel and Taquarembó Terranes (Philipp et al. 2016a). Reactivation of the main shear zones probably played an important role in this late-stage magmatism (Philipp et al. 2003, 2016a), as is exemplified by the Capané and Candiotinha mylonitic granitoids, intruded along shear zones in the Tijucas Terrane and dated at 600–590 Ma (Camozzato et al. 2013; Philipp et al. 2016a; Zvirtes et al. 2017). However, outside the areas directly influenced by the shear zones, rocks associated with this event are mostly isotropic.

The other major lithostratigraphic unit affected by the Dom Feliciano orogeny in Rio Grande do Sul is the metasupracrustal Porongos Complex. Some detailed structural studies of this unit propose a multistage evolution, in which the earliest deformational phases, recorded in successive isoclinal folding, would correspond to the late stages of the orogenic assembly of the São Gabriel Terrane and a tectonic interaction between this domain and the Tijucas Terrane (Saalmann et al. 2005, 2006, 2007, 2011). The same authors, however, note that the same sequence was also affected by the Dom Feliciano Belt, and recognize a phase of thrusting and stacking of the metavolcano-sedimentary sequence, followed by the development of sinistral strike-slip shear zones. As described above, this two-fold pattern is in agreement with the deformational history recorded in the Pelotas Batholith. Later deformations are also recognized (Fig. 11.8c).

11.4 Uruguay Sector

The southernmost outcrops of the Dom Feliciano Belt are exposed in eastern Uruguay over more than 300 km. The belt probably continues in the continental shelf up to the Mar del Plata Terrane, in Argentina, where it has been identified below the Paleozoic cover in the Punta Mogotes drill hole (Rapela et al. 2011). The belt is in tectonic contact to the west with the Archean–Paleoproterozoic Nico Pérez Terrane (Oyhantçabal et al. 2018) representing its cratonic foreland, while to the east the outcrops continue up to the Atlantic Ocean coastline.

The belt can be divided into two main domains, western and eastern (Figs. 11.9 and 11.10), bounded by the Sierra Ballena Shear Zone (Oriolo et al. 2016a). The Western Domain comprises the metavolcano-sedimentary association, basement inliers from the Nico Pérez Terrane and widespread Ediacaran granite intrusions. The Eastern Domain (also known as Punta del Este Terrane, Basei et al. 2011c) includes the Aiguá Batholith, the Cerro Olivo Complex and the Rocha and Sierra de Aguirre formations. The latter three units constitute a peculiarity of the Dom Feliciano Belt in Uruguay, as they are the only wide exposures of rocks to the east of the granite batholith. Widespread transcurrent shear zones are a common feature of both domains, as well as relics of foreland basin deposits. In contrast to the other sections of the Dom Feliciano Belt, however, these deposits do not constitute a single continuous domain. In this way, the Uruguayan sector differs from the traditional threefold division of the belt (Basei et al. 2000).

A general description of the main units of the belt in Uruguay is given in the next sections. Controversial aspects about stratigraphic details will be avoided when possible and focus placed on main tectonic units and their meaning for the evolution of the belt.

11.4.1 The Cratonic Foreland

In the Uruguayan sector of the Dom Feliciano Belt, the terrane that acted as cratonic foreland for the generation of the belt is known as Nico Pérez Terrane. It is exposed to the

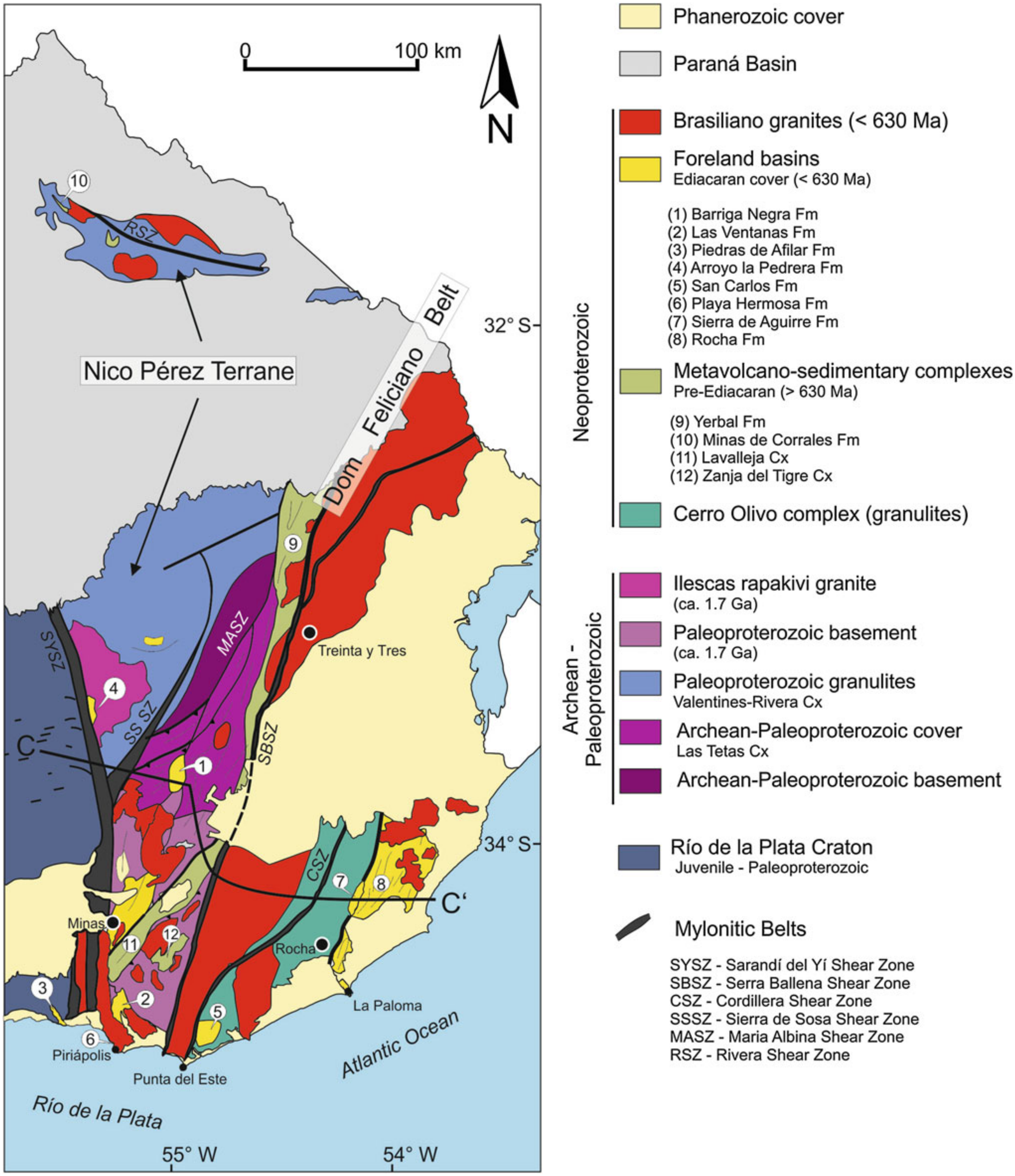


Fig. 11.9 Simplified geological map of the Uruguay sector of the Dom Feliciano Belt. Profile C-C′ is presented in Fig. 11.10. Shear Zones: SYSZ: Sarandí del Yí Shear Zone; SSSZ – Sierra de Sosa Shear Zone; MASZ: Maria Albina Shear Zone; RSZ: Rivera Shear Zone

west of the Dom Feliciano Belt in Uruguay and its western limit is the Sarandí del Yí Shear Zone, which separates it from the juvenile Paleoproterozoic Río de la Plata Craton. The Nico Pérez Terrane includes relics of Archean orthogneisses and of Archean to Paleoproterozoic supracrustal rocks, widespread areas of Paleoproterozoic orthogneisses

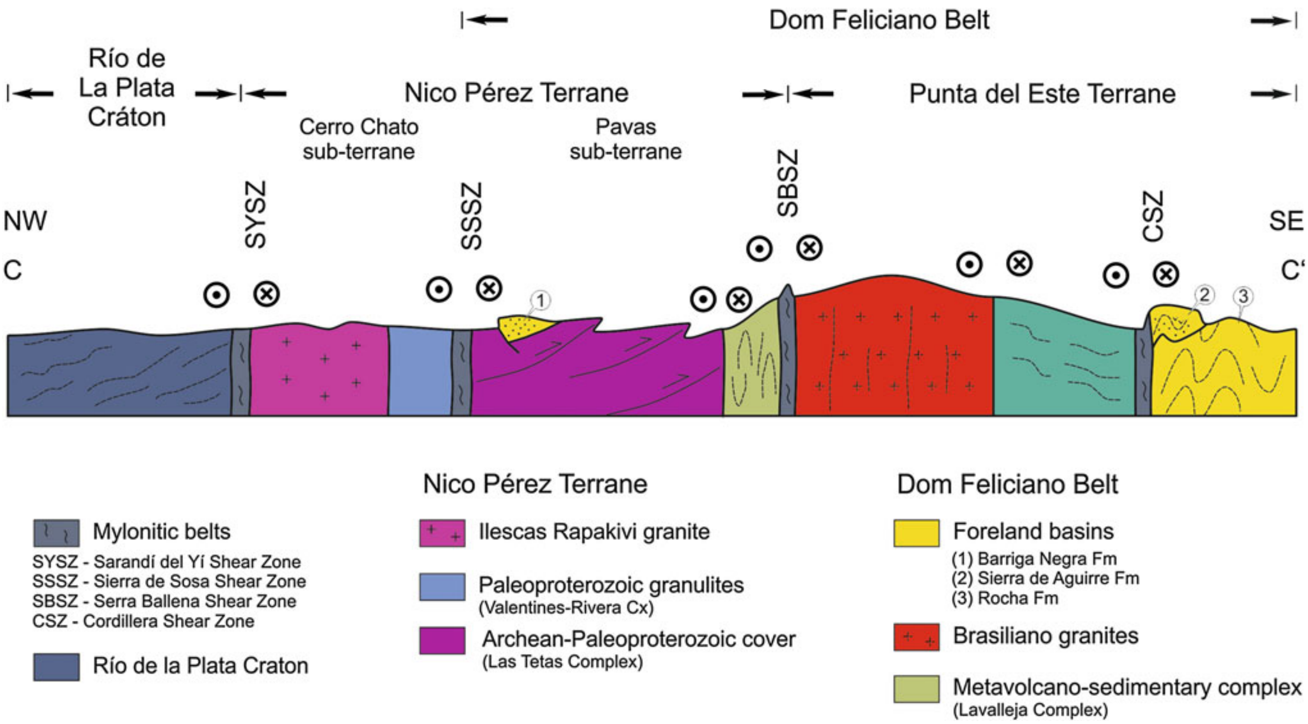


Fig. 11.10 Schematic geologic profile of the Dom Feliciano Belt in the Uruguay Sector

and a Mesoproterozoic metavolcano-sedimentary cover, and has experienced widespread reworking during the Brasiliano orogeny. This terrane is discussed in detail in an individual chapter (Oyhantçabal et al. 2018).

Another large exposure of basement rocks associated in the area is the Cerro Olivo Complex, an association of ortho- and paraderived rocks metamorphosed at high-grade conditions. They are part of the Punta del Este Terrane, which is discussed below.

The main basement inlier that can be considered a constituent part of the Dom Feliciano Belt proper in Uruguay is the Campanero Unit. It constitutes an association of orthogneisses, calc-silicatic gneisses, amphibolites, mica schists, BIFs and migmatites (Oyhantçabal 2005), and occurs in the southeastern portion of the western domain of the belt in Uruguay, south of the main expositions of the Lavalleja Complex.

11.4.2 The basement of the Punta del Este Terrane

A peculiarity of the Uruguayan sector of the Dom Feliciano Belt is the occurrence of basement rocks on the eastern side of the Aiguá Batholith, associated with a second metasedimentary association located further to the east of these rocks. The basement, known as Cerro Olivo Complex (Masquelin et al. 2012), contains high-grade metamorphic rocks comprising ortho- and paraderived granulites and migmatites (Fig. 11.11d). The orthoderived rocks yield protolith ages between c. 800 and 770 Ma, and zircon xenocrysts showing ages between c. 1.0 and 1.3 Ga. On the other hand, metamorphic overgrowths in the magmatic zircons provided ages at c. 650 Ma allowing to constrain the age of the granulite-facies metamorphism (Oyhantçabal et al. 2009; Basei et al. 2011c; Lenz et al. 2011; Masquelin et al. 2012). Similar ages in high-grade metamorphic rocks were identified in the Rio Grande do Sul sector of the Dom Feliciano Belt, in rocks associated with the basement inliers of the Pelotas Batholith (Gross et al. 2006; Koester et al. 2016; Philipp et al. 2016b; Martil et al. 2017). A continental magmatic-arc setting was suggested for the orthoderived rocks in both areas, based on their geochemistry (Lenz et al. 2011, 2013; Masquelin et al. 2012; Koester et al. 2016; Martil et al. 2017). The Cerro Olivo Complex is intruded by minor granite intrusions and is in tectonic contact with late Ediacaran folded metasediments.

11.4.3 The Metavolcano-sedimentary Complexes

The metavolcano-sedimentary complexes in Uruguay are considered to include different Mesoproterozoic to Cryogenian volcano-sedimentary successions affected by Brasiliano deformation and metamorphism, grouped by Masquelin et al. (2017) in the Lavalleja Complex. This association is up

Fig. 11.11 Some field aspects of rocks from the Uruguay sector of the Dom Feliciano Belt. **a** Compositional layering of metasediments and metabasic rocks of the Lavalleja Complex; **b** Stretched mafic enclaves in the syn-tectonic Maldonado Granite, of the Aiguá Batholith. Note the strong foliation in the rock; **c** Conglomerate of the San Carlos Formation; **d** Folded orthogneiss of the Cerro Olivo Complex; **e** Folded metasediments of the Rocha Formation; **f** Double enclave in the post-tectonic Santa Teresa Granite

to 40 km wide, and crops out in Uruguay with a north-northeast strike for more than 250 km. To the east the metavolcano-sedimentary complexes are mostly bounded by the Sierra Ballena Shear Zone, except in its southernmost part where it is in tectonic contact with the Paleoproterozoic orthogneisses of the basement inlier of the Campanero Unit.

The oldest succession of the belt is the Mesoproterozoic Zanja del Tigre Formation (Sánchez-Bettucci and Ramos 1999; Basei et al. 2008), which corresponds partially to the Parque UTE and Mina Verdún groups of Chiglino et al. (2008, 2010). This formation comprises metapelites, dolomitic marbles, metamarls, metatuffs, metagabbros and mafic and felsic metavolcanic rocks (Poiré et al. 2003, 2005; Chiglino et al. 2008, 2010; Poiré and Gaucher 2009). Interbedded volcanoclastic rocks (Fig. 11.11a) dated at 1429 ± 21 Ma (U-Pb ID-TIMS zircon, Oyhantçabal et al. 2005) and 1461.8 ± 3.9 Ma (U-Pb SIMS in zircon; Gaucher et al. 2014a) constrain the age of these successions. Additionally, metagabbros intruding the succession yielded an age of 1492 ± 4 Ma (U-Pb ID-TIMS zircon, Oyhantçabal et al. 2005). These successions are interpreted as a Mesoproterozoic cover above the Nico Pérez Terrane, in the context of a stable platform (Oyhantçabal et al. 2018).

The age of the pre-Ediacaran Neoproterozoic successions is not well constrained. One of the best exposed areas, located northwest of the Treinta y Tres city, comprises metapelites (Yerbal Formation; Gaucher 2000) and limestones (wrongly included in the Polanco Formation by Gaucher et al. (2000); the latter is presently considered of Paleoproterozoic age, see Cabrera et al. 2014). U-Pb detrital zircon data and the ages of intrusive granites constrain the deposition between *c*. 1000 and 650 Ma (Pecoits et al. 2016). The tectonic setting for these metavolcano-sedimentary successions was probably a passive continental margin (Pecoits et al. 2016). Nevertheless, basic volcanic rocks interbedded with sediments are common in the southern part of the belt, and their geochemistry suggests the possibility of a back-arc setting (Sánchez-Bettucci and Ramos 1999) that later evolved to a passive margin.

11.4.4 Neoproterozoic Granite Magmatism

Similarly to the other section of the Dom Feliciano Belt, the orogen is characterized in Uruguay by voluminous and widespread magmatism, intruding in all domains associated with the fold belt. The biggest intrusive association is the Aiguá Batholith, the Uruguayan continuation of the granitic intrusions that also constitute the Florianópolis and Pelotas batholiths. Granitic magmatism is also common in the western domain of the belt, intruding into both the metavolcano-sedimentary complexes and its associated basement. Additional granitic intrusions also occur to the east of the Aiguá Batholith, intruding other units of the Punta del Este Terrane.

11.4.4.1 Aiguá Batholith

The central domain of the Dom Feliciano Belt in Uruguay corresponds to a large granitic area extending in a north-easterly direction from the surroundings of Punta del Este to the border with Brazil. The batholith comprises several plutons with different ages and geochemistry.

In the southern part of the Dom Feliciano Belt in Uruguay several plutons are recognized in the Aiguá batholith: Maldonado, Aiguá, Florencia, Valdivia, Puntas del Arroyo de Rocha and Cerrillos (Masquelin 1990; Spoturno et al. 2012). Most of these plutons correspond to equigranular to porphyritic biotite granites, with titanite as common accessory. A protomylonitic foliation parallel to the strike of the main shear zones of the area is frequently observed. The Florencia pluton is a very elongated and strongly deformed body (*c*. 5 × 50 km) oriented N30°E. The main lithology is a leucocratic alkali feldspar granite with biotite as the main accessory. Whole-rock geochemistry of the Aiguá pluton (Gómez Rifas 1995) indicates a highly fractioned high-K calc-alkaline signature. The Maldonado Granite (Masquelin 1990) is a strongly deformed and elongated pluton emplaced parallel to the Sierra Ballena Shear Zone (Fig. 11.11b). The most extended facies are porphyritic biotite monzogranite, granodiorite and leucogranite. The geochemical signature of the Maldonado Granite shows transitional features between highly fractionated calc-alkaline and alkaline (Oyhantçabal et al. 2007). U-Pb geochronological data in zircon for the Aiguá Batholith range from 616 to 564 Ma (Basei et al. 2000; Oyhantçabal et al. 2007; Gaucher et al. 2014; Lara et al. 2016).

Basei et al. (2000) suggest an important crustal component in the genesis of the granites of this batholith based on Sm-Nd data that yield very negative εNd between −9.8 and −12.6 and Nd T_{DM} model ages between 2.1 and 1.4 Ga. For the northern sector of the batholith, Peel et al. (2015) report U-Pb zircon ages (LA-ICP-MS) for high- K calc-alkaline granites that range from *c*. 625 Ma, interpreted as the time of initial magma generation, to *c*. 600 Ma, interpreted as the emplacement age. Nd isotopes in the same samples yielded εNd values from −4.2 to −6.4 and $^{87}Sr/^{86}Sr$ initial ratios between 0.708 and 0.718.

11.4.4.2 Granite Intrusions in the Western Domain

Numerous granite bodies are emplaced into the metavolcano-sedimentary association and in its cratonic foreland (the Nico Pérez Terrane). The ages of these intrusions range from 634 ± 7 Ma (Sierra de los Caracoles Granite, U-Pb LA-ICPMS in zircon, Lara et al. 2017) to 583 ± 7 Ma (Mangacha Granite, U-Pb SIMS in zircon, Gaucher et al. 2008). Most of these intrusions show high-K calc-alkaline, metaluminous to slightly peraluminous compositions and several of them can be classified as high Ba and Sr granites (Lara et al. 2016, 2017; Fort et al. 2016; Gallardo et al. 2016). An important crustal component and recycling of Paleoproterozoic to Late Archean sources for the genesis is indicated by intermediate $^{87}Sr/^{86}Sr$ initial ratios (0.7077–0.7090), very low initial Nd values (−15.8 to −19.3), old Nd T_{DM} model ages (2.2–2.8 Ga) and zircon inheritance ages (Lara et al. 2017). Shoshonitic granites have also been identified (Cortez Blanco pluton, Lara et al. 2016), as well as metaluminous to peralkaline intrusions associated with volcanic rocks of the Sierra de las Ánimas Complex, dated at 575–590 Ma (Oyhantçabal et al. 2007; Rapalini et al. 2015).

Most authors suggest a post-collisional environment for this high-K calc-alkaline to alkaline granitic magmatism (Oyhantçabal et al. 2007; Lara et al. 2017; Fort et al. 2016; Gallardo et al. 2016).

11.4.4.3 Granite Intrusions East of the Aiguá Batholith

The main granitic intrusions in the Punta del Este Terrane are the Santa Teresa Granite Complex (543 ± 7 Ma, U-Pb in zircon, LA ICPMS, Basei et al. 2013b) and the José Ignacio Granite (590 ± 25 Ma; 87Sr/86Sr initial ratio 0.708, Umpierre and Halpern 1971). For the Santa Teresa Complex (Fig. 11.11f), Muzio and Arthur (1999) defined a peraluminous suite, with muscovite, biotite, tourmaline, ilmenite and monazite, and a medium- to high-K calc-alkaline suite with biotite, titanite, allanite, magnetite and microgranular enclaves.

11.4.5 The Foreland Basins

The Uruguayan sector of the Dom Feliciano Belt distinguishes itself for not having a single, wide sedimentary foreland basin, such as the Itajaí and Camaquã successions in Santa Catarina and Rio Grande do Sul. Instead, the Ediacaran cover occurs as relicts covering different units throughout the Uruguayan Shield, leading to difficulties in chronostratigraphically correlating these units. This section describes the main occurrences and applies the latest nomenclature.

11.4.5.1 Playa Hermosa Formation

The Playa Hermosa Formation (Masquelin and Sánchez-Bettucci 1993) is a volcano-sedimentary unit that crops out close to the city of Piriápolis, in the southernmost Dom Feliciano Belt in Uruguay. Pazos et al. (2003) recognized two facies: a proximal association including breccias, conglomerates, sandstones and minor mudstones and a distal association with diamictites, rhythmites, sandstones and mudstones. These sedimentary facies show also evidences of glacial influence, such as dropstones and coarse-grained rhythmite intervals, representing rain-out processes from icebergs and deposition in a tectonically active basin (Pazos et al. 2003, 2011). Fambrini et al. (2003) recognized hummocky cross-stratification and consider the sedimentation to have occurred in shallow waters, probably in a shallow marine environment, but a lake environment is not ruled out.

Detrital zircons from the Playa Hermosa Formation show a main peak at 2.0 and 2.2 Ga and a secondary peak at around 600 Ma, without Archean ages (Rapalini et al. 2015; Pecoits et al. 2016). The main peak could indicate contribution of the basement of the Río de la Plata Craton (e.g., Oyhantçabal et al. 2011a), which is further supported by southwest-trending paleocurrent directions (Pazos et al. 2011).

The youngest U-Pb detrital zircon age from sediments of the Playa Hermosa Formation constrain maximum depositional age of deposition to 594 ± 16 Ma (Rapalini et al. 2015) or 563 ± 13 Ma (n = 6, Pecoits et al. 2016), while the age of the felsic dikes cutting the formation is *c*. 580 Ma (Rapalini et al. 2015). Evidence of interaction between magma and wet sediments, such as peperites (Sánchez-Bettucci et al. 2009), suggests that dike emplacement occurred a short time after deposition and therefore a sedimentation at *c*. 580 Ma is assumed. The formation can be correlated with the Maricá Formation of the Camaquã Basin from southern Brazil. Considering these age constraints, these sediments can be associated with the Gaskiers glaciation (Rapalini et al. 2015).

11.4.5.2 Barriga Negra Formation

The Barriga Negra Formation was defined by Midot (1984), Gaucher (2000), Blanco et al. (2009), Fambrini et al. (2005) and Nuñez et al. (2016) for sediments occurring in the central portion of the western domain.

According to Nuñez et al. (2016), the formation is a *c*. 3000 m thick volcano-sedimentary succession comprising (from bottom to top) felsic volcanic and volcanoclastic rocks, orthoconglomerates, calcareous breccia, clast-supported conglomerates, sandstones and pelites. All authors agree these deposits represent alluvial fan/braided rivers and fan-delta successions.

Detrital zircon age patterns (Blanco et al. 2009; Pecoits et al. 2016) reflect a major contribution from the basement of the Nico Pérez Terrane (main peaks at c. 0.58, 1.75, 2.1–2.2 and 2.6–3.4 Ga), and constrain the maximum age of deposition to *c*. 580 Ma (youngest peak age). Fambrini et al. (2005) considers this succession correlate with the Santa Bárbara Group of the Camaquã Basin in southern Brazil.

11.4.5.3 Las Ventanas Formation

The Las Ventanas Formation (Midot 1984) is a volcano-sedimentary succession comprising, from bottom to top, conglomerates, sandstones and pelites, and is exposed in the southern portion of the western domain. The association records the evolution from an alluvial fan-dominated environment to shallow marine conditions (Blanco and Gaucher 2005).

Based on the microfossil content, Blanco and Gaucher (2005) suggested an Ediacaran age, later corroborated by a 573 ± 11 Ma age in a felsic volcanoclastic rock of this unit ($^{207}Pb/^{206}Pb$ SHRIMP in zircon, Oyhantçabal et al. 2009). Detrital zircon age patterns of the Las Ventanas Formation show three main peaks at 2.7, 2.1 and 0.59 Ga (Pecoits et al. 2016), evidencing sources in the basement of the Nico Pérez Terrane. The youngest peak age is 548 ± 19 Ma, which overlaps within error with the age obtained for the volcaniclastic rocks.

11.4.5.4 San Carlos Formation

The San Carlos Formation (Masquelin 1990) is a volcano-sedimentary sequence comprising conglomerates (Fig. 11.11c), sandstones, pelites and felsic volcanics in the southern portion of the eastern domain (Pecoits et al. 2008; Gaucher et al. 2010). Locally, a steep and strong foliation parallel to the Sierra Ballena Shear Zone is observed, especially in the westernmost outcrop area (Oyhantçabal et al. 2010). In this area, metamorphism reached at least lower greenschist facies conditions.

Detrital zircon age patterns show mainly Neoproterozoic peaks (0.55, 0.65 and 0.76 Ga) and minor Meso- and Paleoproterozoic contribution (Pecoits et al. 2008; Gaucher et al. 2010). The *c*. 0.76 and 0.65 Ga ages could represent a local source in the Cerro Olivo Complex, corresponding respectively to the igneous protolith and the high-grade metamorphism ages recorded in this basement, while older ages may correlate to inherited zircon grains recorded in the granulites of this complex (Oyhantçabal et al. 2009; Lenz et al. 2011; Masquelin et al. 2012). A maximum depositional age for the unit is constrained by a youngest zircon cluster at *c*. 552 Ma (Pecoits et al. 2016).

11.4.5.5 Sierra de Aguirre Formation

The Sierra de Aguirre Formation (Masquelin and Tabó 1988) is a volcano-sedimentary succession including felsic pyroclastic rocks, interbedded with lavas of basaltic to rhyolitic composition and siliciclastic sediments (Campal and Schipilov 2005; Fantin 2003). It is located in the central portion of the eastern domain. The succession is folded, a slaty cleavage is frequently observed, and the unit is in tectonic contact with the metasediments of the Rocha formation.

Chondrite-normalized trace-element patterns of the volcanic rocks show moderate enrichment in LILE with negative Nb anomalies and moderate enrichment in LREE with negative Eu anomalies. The age of Sierra de Aguirre is constrained by a 571 ± 8 Ma age (U-Pb—SHRIMP in zircon) in a dacitic pyroclastic rock (Hartmann et al. 2002). Campal and Schipilov (2005) have suggested a late extensional tectonic setting related to the Brasiliano orogenic cycle.

11.4.5.6 Rocha Formation

The Rocha Formation occurs as a north to northeast-striking folded belt with a width of c. 30 km east of the Cerro Olivo Complex (Sánchez-Bettucci and Burgueño 1993; Basei et al. 2011c). Blanco et al. (2014) describe the unit as a turbiditic sequence composed by sandstones, wackestones and mudstones affected by metamorphism in greenschist facies conditions (Fig. 11.11e). The maximum deposition age of the formation is constrained by the youngest detrital zircons (629 ± 17, 668 ± 20, 670 ± 18 Ma, Basei et al. 2005) and the minimum by the age of the intrusion of the Santa Teresa Granite in the transition of the Ediacaran to the Cambrian (Basei et al. 2013b). Basei et al. (2005) consider the Rocha Formation as the stratigraphic equivalent of the Oranjemund Group (Frimmel et al. 2002) split by the opening of the Atlantic Ocean.

11.4.6 Deformation History of the Dom Feliciano Belt in Uruguay

As observed in the other sectors of the Dom Feliciano Belt, most authors acknowledge two main deformation events associated with characteristic structures in the Uruguayan sector of the orogen (Oyhantçabal et al. 2009; Oriolo et al. 2016a, b; Masquelin et al. 2017). The older structures include southwest-verging northeast to southwest trending thrusts (Campal and Schipilov 1999; Oyhantçabal et al. 2009). These occur as recumbent folds with subhorizontal mylonitic foliation and a flat-lying stripped foliation, recognized in the Archean orthogneisses of the La China Complex (Masquelin et al. 2017), in the Paleoproterozoic orthogneisses of the Campanero Unit (Oyhantçabal et al. 2009) and in the quartzites and metaconglomerates of the Las Tetas Complex (Fig. 11.10). This event does not affect the late Ediacaran foreland basins, and available geochronological data from several isotopic systems allow a rough constraint on the period of 630–600 Ma (Oriolo et al. 2016a, b). This event can be correlated with the collision between the Río de la Plata and Congo cratons, leading to the reworking of the Nico Pérez cratonic foreland and the closure of the Lavalleja Complex basin.

The final architecture of the belt is controlled by younger structures including northwest-verging thrusts and north-northeast striking sinistral transcurrent shear zones, with subhorizontal stretching lineation parallel to the fold axis of the metasediments in the low-strain domains (Oyhantçabal et al. 2009; Oriolo et al. 2016a). This event affects the late Ediacaran foreland basin sequences (Figs. 11.10 and 11.11e), is well constrained by different isotopic systems in multiple minerals between 600 and 550 Ma, and is probably related to the convergence of the Kalahari Craton and the Río de la Plata-Congo cratons (Oyhantçabal et al. 2009, 2011b; Oriolo et al. 2016a).

11.5 Discussion and Final Remarks

11.5.1 Deformation Patterns in the Dom Feliciano Belt

It is evident that the main structural pattern of the Dom Feliciano Belt is the result of the transition from an early convergent setting to a later transcurrent one. This observation is not new (e.g., Fernandes et al. 1992) and has been abundantly documented, as described in the sections dedicated to each sector of the orogen. The first is responsible for the main folding phase in the metavolcano-sedimentary complexes, the nucleation of the main shear zones and the intrusion of the first granitic suites in the batholiths. The second stage is characterized by a transition to strike-slip deformation, a process that led to the reactivation of the previous shear zones associated with widespread granitic magmatism and a refolding of the metavolcano-sedimentary rocks. Some transtensional or even truly extensional episodes probably occurred during this protracted transpressional phase and were responsible of the opening of the foreland basins.

The geochronological constraints for each of these stages are well supported by extensive dating using various isotopic methods, including on granites that intruded during each phase. The initial convergent phase has been well recorded in both Santa Catarina and Rio Grande do Sul by the ages of the earliest granites associated with the belt dated at *c*. 650 Ma, and continues up to *c*. 620 Ma (Babinski et al. 1997; Silva et al. 1997; Frantz et al. 2003; Philipp et al. 2002, 2003, 2016a, b, submitted; Chemale et al. 2012; Basei et al. 2013a). In Uruguay, this stage was recorded a little later, mostly in the interval between 630 and 600 Ma (Oriolo et al. 2016a, b).

The second deformation stage is dominant from 610 Ma onwards in both Santa Catarina and Rio Grande do Sul, while in Uruguay it is recorded starting at 600 Ma (Babinski et al. 1997; Philipp et al. 2002, 2003, 2016a, submitted; Passarelli et al. 2010; Basei et al. 2011a; Oyhantçabal et al. 2011b; Chemale et al. 2012; Florisbal et al. 2012c). In Rio Grande do Sul and Uruguay this phase is commonly extended to the latest deformations and intrusions identified in the belt, up to *c*. 550 Ma, which in the latter is immediately followed by cooling to low-temperature ranges (Hueck et al. 2017). In Santa Catarina, two later phases were identified from 585 Ma onwards both in the Brusque Group and in the foreland basins (Rostirolla et al. 1992, 1999; Basei et al. 2011b; Raposo et al. 2014). The first one is compressional (585–550 Ma) and the second one is extensional (550–520 Ma).

11.5.2 Tectonic Evolution of the Dom Feliciano Belt

The popularization of modern geochronological tools in the last decades has led to the addition of abundant new data to the Dom Feliciano Belt, as reviewed in the items above. Consequently, most of the geologic processes in the orogeny have been well constrained recently, enhancing the understanding of the timing of the orogeny. Nonetheless, there is still an ongoing debate on the significance of these processes and on the tectonic evolution of the belt.

The interpretation of the tectonic significance of the Dom Feliciano Belt necessarily has to consider its entire extension. However, the discontinuous exposure of the belt, the administrative borders cut by it and the sheer size of the orogen have caused most tectonic models to focus on individual sectors. Consequently, particularities of each area may be overrepresented or underrepresented in models focusing more strongly on one of the regions, complicating the integration of the different hypotheses. This section aims to present the different evolutionary models proposed in the recent decades, highlighting their eventual similarities and differences.

The discussion will focus exclusively on the processes that led to the formation of the main domains that constitute the orogen (granite batholiths, metavolcano-sedimentary complexes, foreland basins and basement inliers). The early evolution of the cratonic blocks that acted as foreland to the collision that formed the Dom Feliciano Belt, such as the Luís Alves and Nico Pérez terranes, is the focus of individual chapters of this book (Passarelli et al. 2018; Oyhantçabal et al. 2018), as well as that of the exotic São Gabriel Terrane (Philipp et al. 2018).

From the early works on the Dom Feliciano Belt, its evolution has been tentatively interpreted in terms of tectonic processes. In the original definition of the belt, Fragoso-Cesar (1980, 1991) proposed for it a continental margin setting, in which the granitic batholiths and metavolcano-sedimentary associations would constitute a collisional continental magmatic arc and a back-arc association, respectively. This would represent the effect of the closure of the Adamastor Ocean, with subduction from east to west under the belt. This model has been very influential since its original proposition, in particular in its interpretation of the granitic belt as a collisional continental magmatic arc, still an integral part of many current models (e.g., Basei et al. 2000, 2005, 2008; Silva et al. 2005b; Passarelli et al. 2010, 2011a, b; Frimmel et al. 2011; Saalmann et al. 2011).

A more recent interpretation proposes that the granitic arc association formed on the eastern (African) side of the system, over an east-dipping subduction zone during the closure of the Adamastor Ocean (Basei et al. 2000, 2005, 2008, 2011a; Passarelli et al. 2011a; Frimmel et al. 2011). In the later variations of this model, an initial compressional regime of the belt would have developed during the pre-collisional stage of the collision, forming the early granitic suites of the granite batholiths and the nappe development in the metavolcano-sedimentary complexes. The actual collision was oblique and caused the transition to a transpressive setting with abundant strike-slip deformation around *c*. 615 Ma, during which the remaining intrusions would have formed. A consequence of this model is the presence of an old suture zone between the granitic batholiths and the metasupracrustal associations, represented by the Major Gercino-Dorsal do Canguçu-Sierra Ballena-Lineament (Passarelli et al. 2011a). This model is in part based on contrasting isotopic signatures observed in both sides of this lineament, especially in the Santa Catarina sector (e.g., Basei et al. 2005, 2008, 2011a; Hueck et al. 2016).

An alternative conception of the Dom Feliciano Belt interprets the vast majority of the Neoproterozoic granitogenesis to correspond to post-collisional magmatism (e.g., Fernandes et al. 1992; Bitencourt and Nardi 1993, 2000; Bitencourt and Kruhl 2000; Oyhantçabal et al. 2007, 2009; Peternell et al. 2010; Florisbal et al. 2012a, b, c; Philipp et al. 2016a; Lara et al. 2017). In this model, the convergent phase of the Dom Feliciano belt represents the syn- to late-collisional stage of the orogeny, and is set from the early generations of the major batholiths, dated between 650 and 620 Ma in Brazil and 630–600 Ma in Uruguay (Frantz et al. 2003; Oyhantçabal et al. 2009; Chemale et al. 2012; Florisbal et al. 2012c; Oriolo et al. 2016a, b). This transition from a collisional to a within-plate setting led to the melting of the crustal rocks associated with the development of a system of deep shear zones, which contributed with variable contribution of mantellic material. The later transition of the deformation to a transcurrent setting promoted the development of shear zones and further granitic magmatism with more evolved continental signatures.

The models briefly exposed above have consequences in the tectonic setting of the metavolcano-sedimentary complexes. An east-dipping subduction with generation of a continental arc to the east of the metavolcano-sedimentary complex implicates in a deposition of this sequence at the passive margin of the western continent (Luís Alves or Nico Pérez), later juxtaposed along the old suture zone. This is in accordance with the setting proposed for this unit by Basei et al. (2008, 2011a). In the case of the Brusque Group, in Santa Catarina, it would agree with the suggestion that the volcanic components of the sequence correspond to the generation of oceanic crust (Basei et al. 2011a). On the other hand, alternative settings suggested for these units include back-arc basins and continental rifting without generation of oceanic crust (Philipp et al. 2004; Sánchez-Bettucci et al. 2010; de Campos et al. 2012a), both of which can be accommodated into a model proposing subduction from east to west.

The integration of the foreland basins into the tectonic models of the Dom Feliciano Belt is mostly based on correlations between the deformation observed in the basins with that of the remaining portions of the belt. Most authors consider the initial formation of the basins to represent the consequence of strike-slip tectonics within a transtensional-transpressive system (Paim et al. 2000; Borba et al. 2006, 2008; Basei et al. 2011b; Guadagnin et al. 2011; Pecoits et al. 2016), which are tentatively correlated with the second (transcurrent) deformation phase of the belt. Even later stages are responsible for folding and faulting of these sediments, an event that can be correlated with structures recognized in the metasupracrustal rocks (Rostirolla et al. 1999; Basei et al. 2011b; Masquelin et al. 2017). On the other hand, an alternative interpretation includes the same basins as part of a continental rift system developed in southern Brazil starting from 600 Ma, associated not with transpression, but with simple extensional tectonics (Almeida et al. 2010, 2012). In this interpretation, the strike-slip deformation recognized in this basin would represent later reactivation of the extensional structures, and not basin-forming processes. The implication of this model is that the Dom Feliciano Belt would have to be completely assembled and on the verge of collapse by 600 Ma.

A controversial aspect in the literature on the Dom Feliciano Belt that should be noted is the possible presence of an early arc association in the Tonian, between 800 and 770 Ma. The orthogneisses of the Cerro Olivo Complex, in the Punta del Este Terrain in Uruguay, are considered to be its main expression, but similar ages were recently recognized in zircon cores of strongly reworked basement inliers of the Pelotas Batholith in Rio Grande do Sul, associated with similar geochemical signatures (Lenz et al. 2011, 2013; Masquelin et al. 2012; Koester et al. 2016; Philipp et al. 2016a; Martil et al. 2017). One implication of this model proposed by some authors (Fernandes et al. 1995a, b; Fernandes and Koester 1999; Koester et al. 2001c) is an intraplate setting for the generation of the Pelotas Batholith, associated with the development of shear zones including the Dorsal do Canguçu Shear Zone, which would be generated by the reactivation of the old Tonian suture zone, the so-called Porto Alegre Suture.

Last, but decidedly not least, there is much debate regarding what continental blocks were involved in the assembly of the Dom Feliciano Belt. This discussion can be divided into two parts: the South American and the African sides of the collision. The South American part of the debate is straightforward, as there is some continuity between the rocks of the belt and their foreland associations. Initially, those domains were associated with the Río de la Plata and Paranapanema Cratons. Over the years, smaller continental blocks have consistently been recognized and separated from the major structural provinces, so that now the domains that are interpreted as forelands to the Dom Feliciano Belt in South America are considered microplates accreted to the main cratonic cores: Luís Alves in Santa Catarina and Nico Pérez in Rio Grande do Sul and Uruguay (Basei et al. 2000, 2008; Oyhantçabal et al. 2011a, 2012; Saalmann et al. 2011; Oriolo et al. 2016c; Philipp et al. 2016a).

Based on isotopic data, Philipp et al. (2016a) suggest that many of the basement fragments identified in different domains of the Rio Grande do Sul sector might all correspond to pieces of a single paleocontinent, associated with the Nico Pérez Terrane (Philipp et al. 2016a). Furthermore Oriolo et al. (2016c) suggest that this terrane has similarities with the Congo Craton in Western Africa. Taken together, these evidences might indicate a setting in which many fragments of a same paleocontinent were separated in a rifting event, only to be later reworked and juxtaposed during the formation of the Dom Feliciano Belt. Some other models propose that parts of the main domains in the belt acted as individual microplates during the collision, such as the so-called Arachania Terrane (Frimmel et al. 2011), corresponding approximately to the Aiguá Batholith.

From the African side, many authors propose that the Kalahari Craton acted as foreland for the collision that generated the Dom Feliciano Belt (e.g., Basei et al. 2000, 2005, 2008, 2011c; Frimmel et al. 2011; Saalmann et al. 2011; Philipp et al. 2016a), a model endorsed by correlations proposed between the Dom Feliciano Belt and the Gariep Belt in Namibia (e.g., Basei et al. 2008). On the other hand, similarities between the crystalline basement of the Punta del Este Terrane in Uruguay and orthogneisses of the Coastal Terrane in the Kaoko Belt have led some authors to propose a link between this African belt and the Dom Feliciano Belt (e.g., Oyhantçabal et al. 2011b). Additionally, Konopásek et al. (2016) propose that the *c*. 620 and 580 Ma granitic suites of the coastal terrane of the Kako Belt represent the continuation of the Florianópolis Batholith on the African side. As a consequence, part of the evolution of the Dom Feliciano Belt would be related to a collision involving the Congo Craton while the last orogenic events are associated with a collision against the Kalahari Craton and the late Ediacaran closure of the Rocha-Gariep basin (Oyhantçabal et al. 2011b).

Oriolo et al. (2016a, 2017) propose a multistage process for the formation of the belt including all three cratonic blocks. In this model, the paleocontinents involved in the collision that formed the belt in Uruguay are the Congo Craton (from the east) and the Nico Pérez Terrane, accreted to the eastern Río de la Plata margin (from the west). This event would be responsible for the generation of the first (convergent) deformation stage of the orogeny. Afterwards, the onset of the convergence between the Congo Craton and Kalahari cratons around 600 Ma (Lehmann et al. 2016) would have triggered the transition to the transcurrent stage of deformation in the belt.

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