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Provenance of metasedimentary rocks of the western Dom Feliciano Belt in Uruguay: Insights from U–Pb detrital zircon geochronology, Hf and Nd model ages, and geochemical data

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ABSTRACT

New isotopic and geochemical data for the Paleo- Meso- and Neoproterozoic metasedimentary cover of the southern Dom Feliciano Belt (Brasiliano/Pan-African) are presented and evaluated combined with published information. Whole-rock major and trace element geochemistry indicates that the dominant source for all the units had a composition similar to average upper continental crust. The geochemistry is similar even for late Ediacaran successions with a source component from slightly older Ediacaran granites, due to the crustal origin of these granites. Age constraints based on detrital zircon, fossil content, interbedded volcanic rocks and isotope geochemistry confirm Paleo-, Meso-, and Neoproterozoic successions, despite uncertainties remain in some cases. Detrital zircon data show the dominance of Archean (3.3–2.8 Ga) to Paleoproterozoic (2.2–1.9 Ga), and subordinated Mesoproterozoic (1.5–1.3 and 1.1 Ga) and Neoproterozoic (0.5–0.6 Ga) ages. Lu–Hf zircon and Sm–Nd whole-rock model ages confirm that the Archean and the Paleoproterozoic were the major crustal growth periods for the source areas. U–Pb detrital zircon age distributions and model ages demonstrate that the Nico Pérez Terrane and not the Río de la Plata Craton was the source for most metasedimentary rocks of the western Dom Feliciano Belt. Likewise, comparison of Archean, Paleo-, Meso- and Neoproterozoic events supports that the Nico Pérez Terrane could represent a fragment of the Congo Craton.

1. Introduction

The Neoproterozoic Dom Feliciano Belt of eastern Uruguay and southern Brazil is one of the Brasiliano/Pan-African orogenic belts recording the history of the assembly of western Gondwana. The evolution of this belt is connected to that of the Kaoko, Gariep, and Damara belts in Africa, and resulted from the convergence of the Río de la Plata, Kalahari, and Congo cratons. Despite most large-scale reconstructions indicate that the Río de la Plata, Kalahari and Congo-San Francisco cratons were affected by the ca. 750 Ma rifting and later reamalgamated during Gondwana accretion, many details of this history are still controversial (Jacobs et al., 2008; Li et al., 2008; Frimmel et al., 2011; Oyhantçabal et al., 2011a, b; Rapela et al., 2011; Konopásek et al., 2014; Foster et al., 2015; Rapalini et al., 2015; Konopásek et al., 2020).

An outstanding feature of the Dom Feliciano Belt in Uruguay is that strongly reworked Archean to Paleoproterozoic basement and its Paleo- to Mesoproterozoic cover are preponderant in the western part of the belt (Hartmann et al., 2001; Chiglino et al., 2010; Oriolo et al., 2016a, 2019), while the clear identification of a Neoproterozoic schist belt has been so far elusive and problematic. The Neoproterozoic sedimentary record in the western Dom Feliciano Belt seems to be restricted to minor isolated late Ediacaran post-collisional basins. A better understanding of this paucity of sedimentation related to a possible convergent Neoproterozoic setting is critical to discriminate between the diverse proposed tectonic models (Basei et al., 2018; Konopásek et al., 2020; De Toni et al., 2020).

We present new geochemical, whole–rock Sm–Nd, and U–Pb and Lu–Hf isotope zircon data from metasedimentary rocks of the western Dom Feliciano Belt in Uruguay. The results are integrated with available data from metasedimentary units of the study area. The aim is to unravel

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the provenance of these sequences and to refine the tectonic evolution of the Dom Feliciano Belt and the associated crustal blocks.

2. Geological setting

Basei et al. (2000, 2011a) describe the Dom Feliciano Belt as composed of three tectonic domains from west to east: foreland basins, a Schist Belt and a Granite Belt. In Uruguay, the Dom Feliciano Belt can be divided into two main domains, the western Nico Pérez Terrane and the eastern Punta del Este Terrane, separated by the Sierra Ballena Shear Zone (Hueck et al., 2018 and references therein). The Nico Pérez Terrane comprises an Archean to Paleoproterozoic basement, Archean to Paleo- and Mesoproterozoic sedimentary successions (Hartmann et al., 2001; Oriolo et al., 2019), and widespread Ediacaran granite intrusions and shear zones (Oriolo et al., 2016b; Lara et al., 2017, 2020). On the other hand, the Punta del Este Terrane (Basei et al., 2011b) includes a high-grade metamorphic basement, the Cerro Olivo Complex, with Tonian igneous protolith ages and metamorphism at ca. 650 Ma (Oyhantçabal et al., 2009; Masquelin et al., 2012), the Ediacaran Aiguá Batholith (Basei et al., 2000; Lara et al., 2020), and wide exposures of Neoproterozoic supracrustal assemblages, i.e., the Rocha and Sierra de Aguirre formations. Finally, on the western side of the Sarandí del Yí Shear Zone, the Paleoproterozoic Río de la Plata Craton (Fig. 1) crops out, which remained essentially unaffected by Brasiliano orogenic events. Nevertheless, a single granite intrusion at 587 ± 8 Ma (La Paz Granite; Cingolani et al., 2012), hydrothermal activity of Late Neoproterozoic age reported in the Tandil area of Argentina (Martínez et al., 2013) and Neproterozoic lower intercepts of discordant U–Pb data in Martin García Island (Santos et al., 2017) have been ascribed to far-field effects of the Brasiliano orogeny.

2.1. *The metasedimentary cover of the Dom Feliciano Belt*

Several authors have studied the metasedimentary rocks from the western domain of the Dom Feliciano Belt in Uruguay in the last years (Gaucher, 2000; Gaucher et al., 2008a, 2008b; Pecoits et al., 2008; Blanco et al., 2009; Frei et al., 2013; Aubet et al., 2014; Pecoits et al., 2016; among others) and different lithostratigraphic units have been proposed for this metasedimentary cover. Lithologies and ages assigned for the main units are schematically presented in Table 1. However, due to non-optimal field exposures, complex deformation structures and scarcity of detailed regional geological maps there is still no consensus about the distribution, correlations and age of most of them (Sánchez Bettucci et al., 2010; Aubet et al., 2014; Nuñez Demarco et al., 2019). Due to this controversy, in this contribution we avoid the use of lithostratigraphic units of higher hierarchy, like the Arroyo del Soldado Group (Gaucher et al., 1996; Blanco et al., 2009) or the Maldonado Group (Pecoits et al., 2004). Instead, we use the original definitions of sections and formations with geographic continuity and try to assign the outcrop areas to three main geochronological units: Archean to Paleoproterozoic, Mesoproterozoic and Neoproterozoic. The regional distribution, based on this information and recent advances in geological mapping at 1:100,000 scale (Spoturno et al., 2012, 2019b), is shown in Fig. 1.

A pre-Neoproterozoic sedimentary record is well preserved in the western Dom Feliciano Belt, including the Cebollatí Complex (Oyhantçabal et al., 2019; also named Las Tetas Complex, Hartmann et al., 2001) and the Zanja del Tigre Complex (Sánchez Bettucci and Ramos, 1999; Oriolo et al., 2019; Spoturno et al., 2019b). The remaining units are all regarded as Neoproterozoic or, at the most, Cambrian, but there is no consensus about the tectonic setting in the framework of the Brasiliano evolution (Blanco et al., 2009; Sánchez Bettucci et al., 2010; Frimmel et al., 2011; Zimmermann, 2011).

The Cebollatí Complex (OyhantçabalSpoturnoFaraone, 2019), also considered a lithostratigraphic group by Gaucher at al. (2010), is an association of metaquarzite, micaschist, metaconglomerate and marble, which is strongly deformed and affected by amphibolite facies metamorphism, as evidenced by paragenesis with garnet and sillimanite (Oyhantçabal and Vaz, 1990) and garnet and staurolite (Hartmann et al., 2001). It represents the oldest metasedimentary sequence, due to its metamorphism and the absence of detrital zircons younger than 2717 ± 24 Ma (Hartmann et al., 2001). The minimum depositional age is constrained by an Ar/Ar phlogopite age in marble of 621.4 ± 1.0 Ma and Ar/Ar and K–Ar muscovite ages between ca. 630 and 600 Ma in quartz-micaschist (Oriolo et al., 2016b).

The Mesoproterozoic cover is represented by the Zanja del Tigre Complex (Sánchez Bettucci and Ramos, 1999; Sánchez Bettucci et al., 2001; Oyhantçabal et al., 2005, 2018; Basei et al., 2008; Hueck et al., 2018; Oriolo et al., 2019), a sequence composed of metapelite, dolomitic marble, metamarl, metatuff, metagabbro and metarhyolite, parts of which were defined as the Parque UTE and Mina Verdún groups (Poiré et al., 2003, 2005; Chiglino et al., 2010; see Table 1). Age constraints for this sequence were obtained in metagabbros (1492 ± 4 Ma, U–Pb ID-TIMS in zircon, Oyhantçabal et al., 2005; and 1479 ± 4 and 1482 ± 6 Ma, U–Pb LA-ICP-MS in zircon, Oriolo et al., 2019) and felsic metavolcanic and metavolcanoclastic rocks (Oyhantçabal et al., 2005, 1429 ± 21 Ma, U–Pb ID-TIMS in zircon; Gaucher et al., 2014, 1461.8 ± 3.9 Ma, U–Pb SIMS in zircon and Gaucher et al., 2011, 1433 ± 6 Ma U–Pb LA-ICP-MS in zircon). Based on geological mapping, Spoturno et al. (2019a) report the prolongation of this unit until the city of Mariscala, near 50 km north-east from the type locality that is located south of the city of Minas (see Fig. 1). A recent age determination in an interbedded metarhyolite (1457 ± 2.5 Ma, U–Pb LA-ICP-MS in zircon; Gilberg, 2020) confirms the suggested prolongation of the unit.

The Lavalleja Group is a lithostratigraphic unit proposed by Bossi et al. (1965) to include all pre-Devonian low-grade metamorphic rocks of eastern Uruguay without a precise chronostratigraphic position. Basei et al. (2000, 2008) redefined this unit as the Lavalleja Complex and considered it an equivalent of the Porongos (Rio Grande do Sul) and Brusque (Santa Catarina) complexes of southern Brazil. Nevertheless, Tonian to Cryogenian rocks predominate in the Brazilian counterparts, while in Uruguay most sections in the Schist Belt demonstrated Ediacaran or Mesoproterozoic ages. In the present state of knowledge, the term Lavalleja Complex should be considered just as an equivalent of the tectonic unit Schist Belt of Basei et al. (2000), including Meso-as well as Neoproterozoic metasedimentary rocks.

The sedimentary cover related to the post-collisional stage of the Brasiliano orogeny (<650 Ma) includes several Ediacaran units, characterized by relatively well-preserved sedimentary structures and subgreenschist to greenschist metamorphic facies conditions. Basei et al. (2000) consider this cover as related to foreland basins. In the western domain of the Dom Feliciano Belt, this cover comprises the Barriga Negra (Midot, 1984), Piedras de Afilar (Jones, 1956), Playa Hermosa (Masquelin and Sánchez Bettucci, 1993) and Las Ventanas formations (Midot, 1984). Age constraints for these units are summarized in Table 3, while for lithological details the reader is referred to the respective cited publications. The main outcrop areas of Ediacaran metasedimentary rocks are shown in Fig. 1.

On the other hand, on the southeastern side of the Sierra Ballena Shear Zone, the metasedimentary cover crops out in small areas and comprises the Rocha, Sierra de Aguirre and San Carlos formations (Fig. 1). The Rocha Formation is a folded turbidite sequence, including essentially slate and meta-arenite (Sánchez Bettucci and Mezzano, 1993) metamorphosed under greenschist facies conditions. Constraints on sedimentation age of the Rocha Formation are the age of the youngest cluster of detrital zircon (ca. 630 Ma; U–Pb SHRIMP in zircon; Basei et al., 2005) and the age of the Santa Teresa granite (543 ± 5 Ma; U–Pb LA-ICPMS in zircon; Basei et al., 2013), which intrudes these metasedimentary rocks. The Sierra de Aguirre Formation (Masquelin and Tabó, 1988; Campal and Schipilov, 2005; Fantín, 2003; Silva Lara et al., 2021) consists of felsic volcaniclastic rocks (tuffs and ignimbrites) and felsic lavas. Hartmann et al. (2002) dated a dacitic pyroclastic rock of

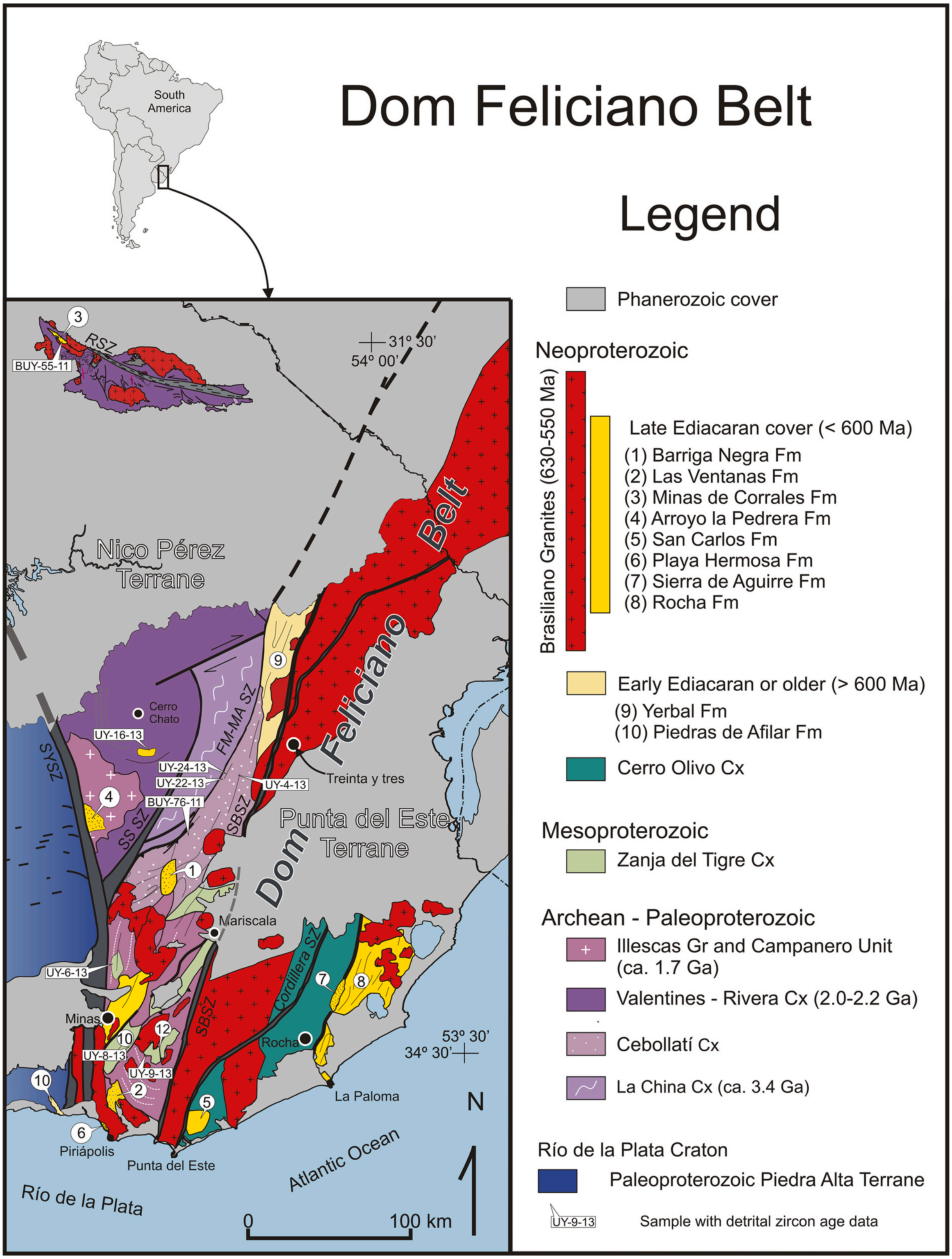

Fig. 1. Schematic geologic map of the Southern Dom Feliciano Belt (modified after Oyhantçabal et al., 2011a, 2011b; 2012; Spoturno et al., 2012, Spoturno et al., 2019a) with location of the studied samples. SBSZ = Sierra Ballena Shear Zone; SS SZ = Sierra de Sosa Shear Zone; FM-MA SZ = Fraile Muerto-María Albina Shear Zone; RSZ = Rivera Shear Zone; SYSZ = Sarandí del Yí Shear Zone.

Table 1
Main references (including original definition) and lithologies for the main units of the cover of the western Dom Feliciano Belt in Uruguay.

Age	Unit	References	Lithologies
Neoproterozoic	Barriga Negra Fm.	Midot (1984), Blanco et al. (2009); Pecoits et al., (2016)	Conglomerate, sandstone and pelite. (1)
	Las Ventanas Fm.	Midot (1984), Masquelin and Bettucci (1993), Pecoits et al. (2008, 2016).	Conglomerate, sandstone and pelite. (1)
	Playa Hermosa Fm.	Preciozzi et al. (1985), Masquelin and Bettucci (1993), Pazos et al. (2011), Pecoits et al. (2016), Rapalini et al. (2015)	Diamictite and rhythmite (1)
	Arroyo la Pedrera Fm.	Montaña and Sprechmann (1993)	Arenite, mudstone and stromatolitic carbonate (1)
	Piedras de Afilar Fm.	Jones (1956), Spoturno et al. (2005), Pecoits et al. (2008)	Arenite, pelite, carbonate (1)
	Minas de Corrales Fm.	Arrighetti et al. (1981), Preciozzi et al. (1985)	Pelite, arenite, acid volcaniclastic rocks, dolostone and conglomerate (1)
	Yerbal Fm.	Gaucher and Sprechmann (1998)	Pelite (1)
Mesoproterozoic	Zanja del Tigre Fm.	Sánchez Bettucci (1998)	Micaschist, marble, felsic volcanic rocks.
	Lavalleja Gr.	Bossi et al. (1965)	Greenschists, marble, dolomitic slate, phyllite
	Mina Verdún Gr.$^{(3)}$	Poiré et al. (2003), 2005;	Slate, marl, limestone, and dolomite
	Parque UTE Gr.$^{(4)}$	Chiglino et al., 2008, 2010	Felsic volcaniclastic, dolomitic, and carbonate-siliclastic rocks
Archean to Paleoproterozoic	Polanco Fm.	Goñi and Hoffstetter (1964), Gaucher (2000), Aubet et al. (2012)	Calcitic and dolomitic marble (2)
	Las Tetas Cx	Hartmann et al. (2001)	Metaconglomerate, metaquartzite, micaschist, marble (2)

(1) Metamorphism ranges from sub-greenschist to greenschist facies. The protolith is indicated.
(2) Metamorphism ranges from greenschsit to amphibolie facies.
(3) Proposed for part of the Lavalleja Group of Bossi et al. (1965).
(4) Proposed for part of the Zanja del Tigre Formation of Sánchez Bettucci (1998).

this formation at 572 ± 8 Ma (U–Pb SHRIMP in zircon) and Silva Lara et al. (2021) constrained the age of the filling of the basin between 582 ± 5 and 571 ± 8 Ma (U–Pb SHRIMP-IIe in zircon). The San Carlos Formation comprises fluvial–lacustrine conglomerates, sandstones, pelites and felsic volcanic and volcaniclastic rocks (Masquelin, 1990; Pecoits et al., 2008; Oyhantçabal et al., 2013) and is considered Cambrian by Gaucher et al. (2014) based on the youngest detrital zircon (535 ± 7 Ma).

3. Samples and analytical techniques

3.1. Geochemistry

Seventeen samples of metasedimentary rocks were analysed for major, trace element and Nd isotope composition (see Appendix). Depending on grain size about 1–5 kg per sample were processed and aliquot ground to <200 mesh. Major elements and Ba, Cr, Nb, Ni, Rb, V, Y and Zr were analysed by XRF from powder disks and Ba, Co, Cs, Nb, Pb, REE, Sc, Ta, Th, Y and W by ICP-MS and ICP-AES from solution. Results were checked by internal and external standards. Neodymium and Samarium whole-rock isotope compositions were analysed by conventional isotope dilution technique. Before dissolution in a mixture of HF and HNO3 with a Teflon PicoTrace digestion system, the samples were spiked with suitable amount of a^{150}Nd-^{149}Sm spike solution to achieve optimal sample-spike homogenisation. The solutions were processed for purification of Nd and Sm fractions. The Nd and Sm were loaded on pre-conditioned Re filaments and analysed at isotopic ratios by a ThermoFinnigan Triton mass spectrometer in static mode (GZG Göttingen). Repeated measurement of the La Jolla Nd standard yielded a^{143}Nd/^{144}Nd ratio of 0.511840 ± 3 over the course of the study. The obtained Nd isotopic ratios of the samples were normalized to a^{146}Nd/^{144}Nd ratio of 0.7219. The $\varepsilon_{\mathrm{NdCHUR}}$ values were calculated for the assumed sedimentation ages.

3.2. U–Pb detrital zircon geochronology

Zircon grains were mounted in epoxy resin together with the standard Temora and then polished to expose the internal crystal texture. Prior to analysis, cathodoluminescence (CL) and transmitted images were obtained so that sites for analysis could be chosen. Age determinations by LA-ICP-MS were performed at the Geochronological Research Center (University of São Paulo, São Paulo, Brazil) and at the Department of Earth Sciences of the, Stellenbosch University of South Africa, according to standard procedures (Compston et al., 1984; Williams, 1998; Stern, 1998; Sircombe, 2000). All U–Pb ICP-MS data are shown in Appendix 1.

All Lu–Hf zircon analysis was carried out at the Institute of Geosciences, University of São Paulo, on a Neptune multicollector inductively coupled plasma mass spectrometer equipped with a laser-ablation Photon system. Lu–Hf isotopic analyses were performed on the same zircon grains that were previously dated by SHRIMP or LA-ICP-MS. The spot used was 39 μm in diameter; ablation time of 60s; repetition rate of 7 Hz, and He was used as carrier gas. ^{176}Hf/^{177}Hf ratios were normalized to ^{179}Hf/^{177}Hf = 0.7325. Zircon Hf isotopic data are presented in Appendix 1. The isotopes ^{172}Yb, ^{173}Yb, ^{175}Lu, ^{177}Hf, ^{178}Hf, ^{179}Hf, ^{180}Hf and ^{176}(Hf + Yb + Lu) were collected simultaneously on Faraday cups. ^{176}Lu/^{175}Lu ratio of 0.02669 was used to calculate ^{176}Lu/^{177}Hf. Mass bias corrections of Lu–Hf isotopic ratios were done using the variations of GJ1 standard. A decay constant for ^{176}Lu of 1.867×10^{-11} a^{-1} (Söderlund et al., 2004), the present–day chondritic ratios of ^{176}Hf/^{177}Hf = 0.282772 and ^{176}Lu/^{177}Hf = 0.0332 (Blichert–Toft and Albarède, 1997) were adopted to calculate $\varepsilon_{\mathrm{Hf}}$ values. A two-stage continental model (T_{DM2}) was calculated using the initial ^{176}Hf/^{177}Hf of zircon and the ^{176}Lu/^{177}Hf = 0.022 ratio for the lower continental crust (Griffin et al., 2004).

3.3. Samples

Nine samples from the metasedimentary units of the western Dom Feliciano Belt were analysed using U–Pb detrital zircon geochronology. Location of the samples is shown in Fig. 1 and coordinates are presented in Appendix I.

3.4. BUY–55–11

Sample BUY–55–11 is a metapelite of the Minas de Corrales

Formation. This unit is one of the remnants of the foreland basin on the Nico Pérez Terrane. Zircon grains are 50–150 μm long and present dominance of prismatic crystal faces. Oscillatory zoning is frequent; whereas sector zoning and homogeneous dark rims are sometimes present (Fig. 2).

3.5. BUY–76–11

Sample BUY–76–11 is a deformed metaconglomerate from the Cebollatí Complex, which is made up mostly of quartz, muscovite and scarce fuchsite. Zircon grains comprise typically 100–250 μm–long anhedral fragments with bright luminescence (Fig. 2). Oscillatory zoning, though not very frequent, is also present in prismatic crystals.

3.6. UY–4–13

Sample UY–4–13 corresponds to a metapelite of the Zanja del Tigre Complex. Prismatic to ovoid 50–150 μm–long zircon grains are the most frequent and present oscillatory zoning (Fig. 2).

3.7. UY–6–13

Sample UY–6–13 corresponds to a garnet–bearing micaschist from an outcrop located ca. 20 km north of the city of Minas. This area is assumed to correspond to the Zanja del Tigre Complex. Zircon grains are 50–100 μm long and prismatic, and exhibit oscillatory and subordinated sector zoning (Fig. 2).

3.8. UY–8–13

Sample UY–8–13 is a calcareous schist from the Zanja del Tigre Complex, included in the reference outcrop area of the Lavalleja Complex. Prismatic 50–150 μm–long zircon grains with oscillatory zoning dominate (Fig. 2). Ovoid, round and fragmented crystals are also present.

3.9. UY–9–13

Sample UY–9–13 is a fine–grained quartz–sericite schist sampled in the reference section of the Zanja del Tigre Complex. Zircon grains are 50–200 μm long and prismatic crystals with oscillatory zoning are the most frequent, though anhedral crystal fragments and sector zoning are also observable (Fig. 2).

3.10. UY–16–13

Sample UY–16–13 corresponds to a metasandstone from one of the remnants of the foreland basin on the Nico Pérez Terrane located near the village of Valentines. Masquelin (2006) correlates this outcrop with the Cerros San Francisco Formation. Zircon grains are up to 200 μm long and typically prismatic, whereas sector zoning is locally present (Fig. 2).

3.11. UY–22–13

Sample UY–22–13 corresponds to a quartz–rich micaschist with muscovite from the Cebollatí Complex. Zircon grains are 100–200 μm

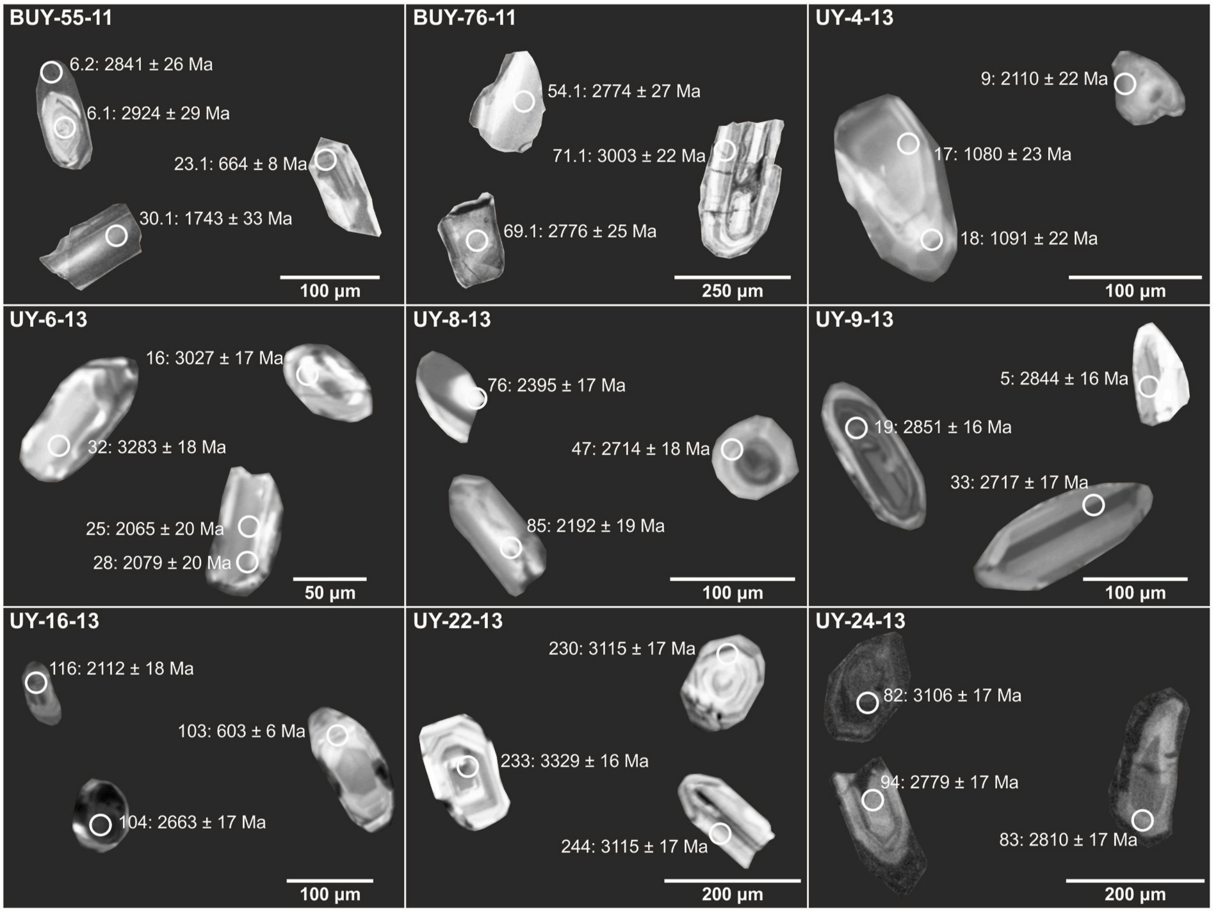

Fig. 2. Cathodoluminescence images of representative detrital zircons for the studied samples. The smaller circles show LA-ICP-MS dating spots and corresponding U–Pb ages.

long and present prismatic to ovoid habits with oscillatory zoning (Fig. 2).

3.12. UY–24–13

Sample UY–24–13 is a mylonite of the María Albina Shear Zone constituted by quartz, feldspar and muscovite. The protolith of the mylonites is the metasedimentary rocks of the Cebollatí Complex. Up to 300 μm long prismatic to ovoid zircon grains with oscillatory zoning are dominant, though dark overgrowths are recognizable as well (Fig. 2).

4. Results

4.1. Geochemistry

Major and trace element composition was determined for 17 samples of metasedimentary rocks from the western Dom Feliciano Belt of Uruguay. The sample data set includes metapelites, quartzites, phyllites and micaschists. The data from these samples were combined with a compilation of published geochemistry data of 52 samples from the western Dom Feliciano Belt (Blanco et al., 2009; Pamoukaghlian, 2012) (see appendix). Data were plotted using the Geochemical Data Toolkit (GCDkit) of Janoušek et al. (2006).

Whole-rock sediment geochemistry is a valuable tool for determining provenance, though the mobility of major elements related to weathering, diagenesis and metamorphism can overprint the composition of source areas (McLennan et al., 1993). On the other hand, immobile trace elements such as La, Th, Sc, Co, and Zr are only slightly affected by weathering or low-grade metamorphism and are therefore useful to characterize crustal recycling or discriminate sources and tectonic settings (Bhatia and Crook, 1986; McLennan et al., 1990).

In order to enable comparisons, a suite of major and trace elements normalized to the average Upper Continental Crust (UCC) (Taylor and McLennan, 1995) is presented in Fig. 3. Most of the samples, regardless of their Paleo-, Meso- or Neoproterozoic age, display compositions similar to the UCC, although slight to moderate negative anomalies are observed for Nb, Ta and Sr. The negative Nb and Ta anomalies suggest a component of subduction-related rocks in the source area, while the Sr anomaly is probably related to plagioclase fractionation in the source rocks. The rather similar normalized abundance diagrams of Paleo- Meso- and Neoproterozoic metasedimentary rocks suggest that they share a major main source area, possibly of Paleoproterozoic or older age, in agreement with large basement areas of this age cropping out in the Nico Pérez Terrane.

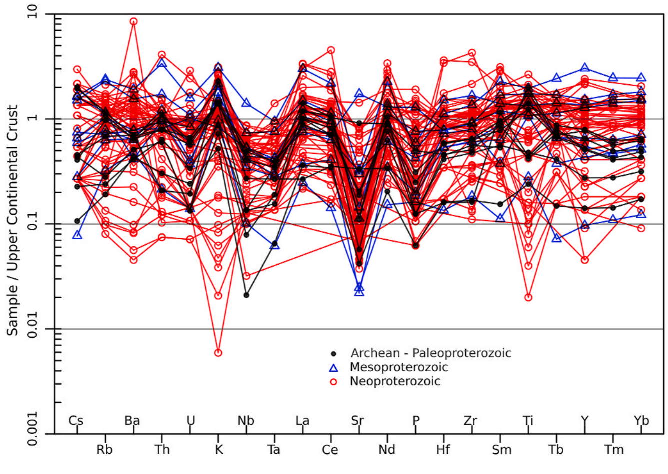

Fig. 3. Major and trace element abundances normalized to the abundance in the average Upper Continental Crust (UCC) (Taylor and McLennan, 1995) for the Western Dom Feliciano Belt.

A significant difference between metasedimentary rocks of different age is observed in the Cr/Th ratio. A high Cr/Th value is considered a proxy for early Precambrian component in the source area of the detrital material in metasedimentary rocks (Condie and Wronkiewicz, 1990). The Cebollatí Complex (Cr/Th interquartile range (IQR) = 7.33–36.45; Table 2) displays a higher ratio that is consistent with the nature of its Archean basement (La China Complex), which also contains slivers of ultramafic rocks (i.e. Hartmann et al., 2001; Oyhantçabal et al., 2018). The Meso- and Neoproterozoic rocks, in contrast, display lower values for this ratio.

The Ti/Zr ratio (Table 2), as well as the Hf versus La/Th diagram (Floyd and Leveridge, 1987) show the predominance of felsic sources with some trends towards mixed and andesitic sources (Fig. 4a). In a similar way, the Nb/Y versus Zr/Ti diagram (Pearce, 1996) confirms a mix of felsic and mafic sources with sub-alkaline to slightly alkaline affinity (Fig. 4b).

The ratio Zr/Sc is related to zircon enrichment in the sediments and is therefore an indicator of crustal recycling (McLennan, 1989). The Th/Sc ratio, on the other hand, is an indicator of igneous differentiation (Th is incompatible while Sc is compatible with mantle compositions). Th/Sc ∼1 is characteristic for the UCC, while values ∼0.1–0.2 are characteristic of andesitic arc sources (McLennan et al., 2003). All samples display similar Zr/Sc and Th/Sc ratios (Table 2), comparable to those of the UCC, although rocks of Archean to Paleoproterozoic age show the higher Th/Sc values, while the Neoproterozoic rocks show higher Zr/Sc ratios and the wider range. Some Neoproterozoic samples evidence a strong continental recycling, while others plot along the igneous differentiation trend (Fig. 4c).

In the tectonic discrimination diagrams Th–La-Sc and Sc-Th-Zr/10 (Bhatia and Crook, 1986), samples from rocks of all ages plot in similar areas, mainly in the continental island arc and passive margin fields (Fig. 5).

Selected REE spidergrams for samples of the Dom Feliciano Belt in Uruguay are shown in Fig. 6, compared with the North American shale composite (NASC, Gromet et al., 1984), the Post- Archean average Australian sedimentary rock (PAAS, Taylor and McLennan, 1985) and the average Upper crust (McLennan, 1989). The REE parameters Eu/Eu*, LaN/YbN, Gd_N/Yb_N and $\sum$REE (see Table 2) indicate moderate LREE enrichment and are consistent with a source in an upper continental crust. On the other hand, the Gd_N/Yb_N ratios reflect the contribution of Archean rocks (McLennan et al., 1993; Maslov, 2007), with average Gd_N/Yb_N of 2.1 for the Archean to Paleoproterozoic Cebollatí Complex, and 1.4 for the Meso- to Neoproterozoic units. The negative Eu anomalies in most of the samples are consistent with the observed Sr negative anomalies and indicate fractionation of plagioclase in the source rocks. The REE compositions compared with those of greywacke and mudrocks of Australia reported by Bhatia (1985) is also consistent with sources related to active continental margin or a continental island arc.

To summarize, available data for the geochemistry of metasedimentary rocks from the western Dom Feliciano Belt evidence source areas of average upper crust composition with subduction-related signature (Ta and Nb negative anomalies) and predominance of felsic compositions. In the samples of the Cebollatí Complex, an important Archean signature component is indicated by Cr/Th and Gd_N/Yb_N ratios. Low TiO_2 and Fe_2O_3t + MgO and usually high Th/Sc ratio and, particularly, the lithological association of quarzite, micaschist, mono- and oligomictic conglomerates and marble, suggest a passive margin tectonic setting for this complex. For the Meso- and Neoproterozoic metasedimentary rocks, the geochemical signature does not define a precise tectonic setting and suggests a detrital mix from sources originated in different settings with a dominant source in older, recycled Precambrian basement.

Table 2
Summary of geochemical characteristics of Archean to Paleoproterozoic, Mesoproterozoic and Neoproterozoic sequences of the western Dom Feliciano Belt in Uruguay. The interquartile range for the parameters is indicated.

Age	Cr/Th	Th/Sc	Ti/Zr	Zr/Sc	Nb/Y
Proxy	Archean detritus	Fractionation	Mafic vs. felsic	Reworking	Alkalinity
Archean-Paleoproterozoic	7.33–36.45	0.76–2.72	19.23–38.54	9.97–25.50	0.21–0.63
Mesoproterozoic	7.51–12.76	0.70–1.31	20.57–32.05	8.89–15.27	0.49–0.91
Neoproterozoic	6.09–13.97	0.76–2.50	11.84–23.08	11.75–48.21	0.40–0.80
Age	Eu/Eu*	LaN/YbN	GdN/YbN	∑REE	
Archean-Paleoproterozoic	0.66–0.76	15.97–25.79	1.78–2.37	79.27–140.95	
Mesoproterozoic	0.62–0.73	6.46–13.49	1.17–1.45	86,25–161.56	
Neoproterozoic	0.67–0.73	8.68–16.33	1.06–1.80	81.15–166.98	

4.2. *U–Pb detrital zircon geochronology*

Age spectra of detrital zircon from the samples analysed in this investigation and those from previously published data (Hartmann et al., 2001; Mallmann et al., 2007; Basei et al., 2008; Gaucher et al., 2008a; Blanco et al., 2009; Rapalini et al., 2015; Pecoits et al., 2016; Gilberg, 2020) are presented as kernel density estimation plots (KDE) and histograms plotted using DensityPlotter (Vermeesch, 2012), grouped in three age groups in Figs. 7–9. The age groups: Archean to Paleoproterozoic, Mesoproterozoic and Neoproterozoic, were defined based on field criteria, geological mapping, fossil content and the evaluation of geochronological data.

4.3. *Maximum depositional ages based on U–Pb ages of detrital zircons*

In order to avoid ages younger than the true depositional age due to field or laboratory contamination or lead loss (Coutts et al., 2019; Andersen et al., 2019), we will use the youngest peak age calculated

Table 3
Maximum depositional age based on detrital zircon data calculated using the youngest peak age and additional age constraints.

Age	Unit name used in this work	Youngest peak age (n ≥ 3)	Other age constraints
Ediacaran	Barriga Negra Fm	589 Ma (n = 10) Blanco et al. (2009) 581 ± 6 Ma (n = 42) Blanco et al. (2009)	Volcaniclastic rock at the base of the formation: 633 ± 3 Ma Nuñez Demarco et al. (2019)
	Las Ventanas Fm	590 ± 5 Ma (n = 42) Pecoits et al. (2016)	Interbedded volcaniclatic rock: 573 ± 11 Ma, Oyhantcabal et al. (2009). Ediacaran fossil content, Gaucher (2000)
	Playa Hermosa Fm	612 Ma (n = 11) Rapalini et al. (2015) 563 ± 13 Ma (n = 11) Pecoits et al. (2016)	Interbedded rhyolite 582 ± 3 Ma, Rapalini et al. (2015)
	Minas de Corrales Fm	705 Ma (n = 3) This work	Ediacaran fossil content, Gaucher (2000)
	Arroyo la Pedrera Fm	2018-2194 (n = 24) Ma Blanco et al. (2009) (1) 2188 Ma (n = 25) Gaucher et al. (2008a, 2008b) (1)	Fossil content Montaña and Sprechmann (1993)
Neoproterozoic	Piedras de Afilar Fm	1009 Ma (n = 3) Gaucher and Poire (2009)	
	Yerbal Fm	1036 Ma (n = 5) Blanco et al. (2009)	
Mesoproterozoic	Zanja del Tigre Cx	2143 (n = 3) Sample UY-06-13 This work 2056 (n = 13) Sample UY-08-13 This work 1890 (n = 13) Sample UY-09-13 This work 2093 (n = 16) Gilberg, 2020 2447 Ma (n = 86) Gaucher and Poire (2009) (2) 2180 Ma (n = 4); Basei et al. (2008)(3) 2100 (n = 8) Mallmann et al. (2007) (3) 2023 Ma (n = 3); Basei et al. (2008)	Interbedded metagabbros 1479 ± 4 and 1482 ± 6 Ma Oriolo et al. (2019) and metarhyolites 1461.8 ± 3.9 Ma (Oyhantçabal et al., 2005) and 1433 ± 6 Ma (Gaucher et al., 2011) Interbedded felsic volcanic rock (Gilberg, 2020)
Archean to Paleoproterozoic	Cebollatí Cx	2764 Ma (n = 16); Hartmann et al. (2001) 2765 Ma (n = 25) sample BUY 76–11 this work 2793 Ma; (n = 9) sample UY 24–13 this work.	Sr isotope age constraints in marble Cabrera et al. (2014) (4)

Lithostratigraphic name used in the referenced paper.
(1)Cerros San Francisco Fm; (2) Yerbal Fm; (3)Lavalleja Complex; (4)Mangera Azul Fm.

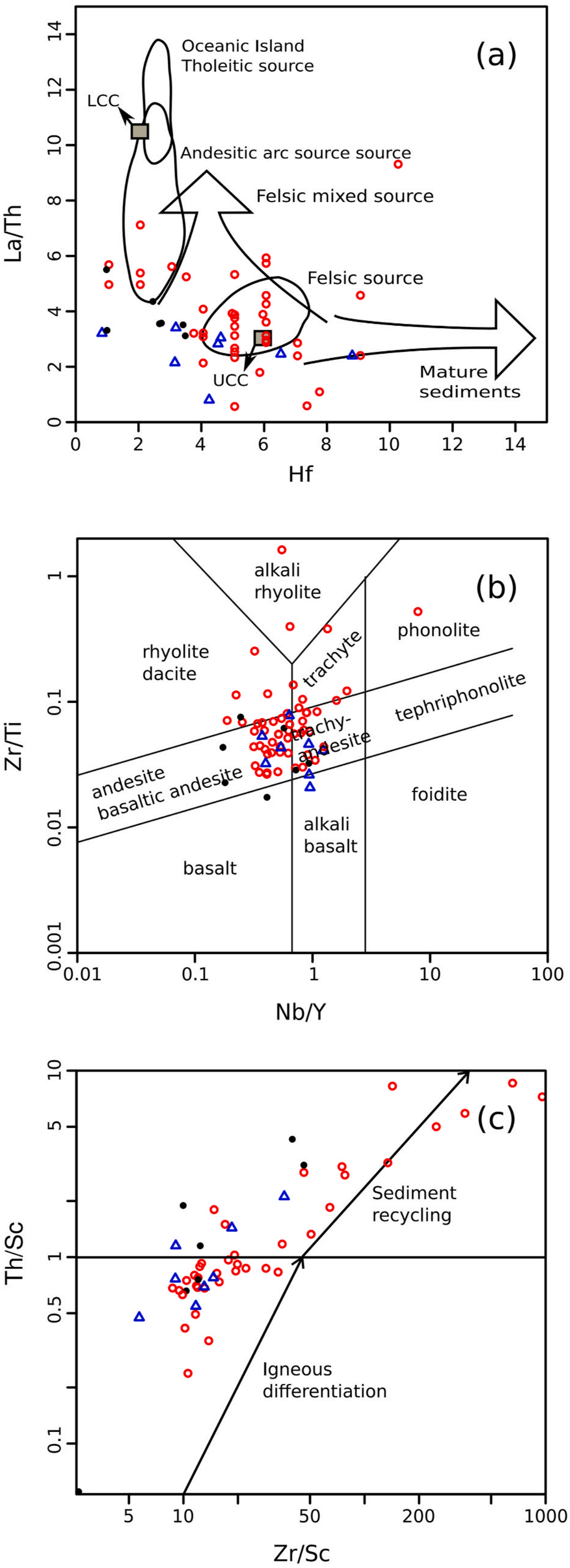

Fig. 4. a) Hf versus La/Th diagram (Floyd and Leveridge, 1987) showing the predominance of felsic and mixed sources. b) Nb/Y versus Zr/Ti diagram (Pearce, 1996) evidence the mix of felsic and intermediate sub-alkaline to slightly alkaline sources. c) Zr/Sc versus Th/Sc diagram (McLennan et al., 1993). Plotting symbols are as in Fig. 3.

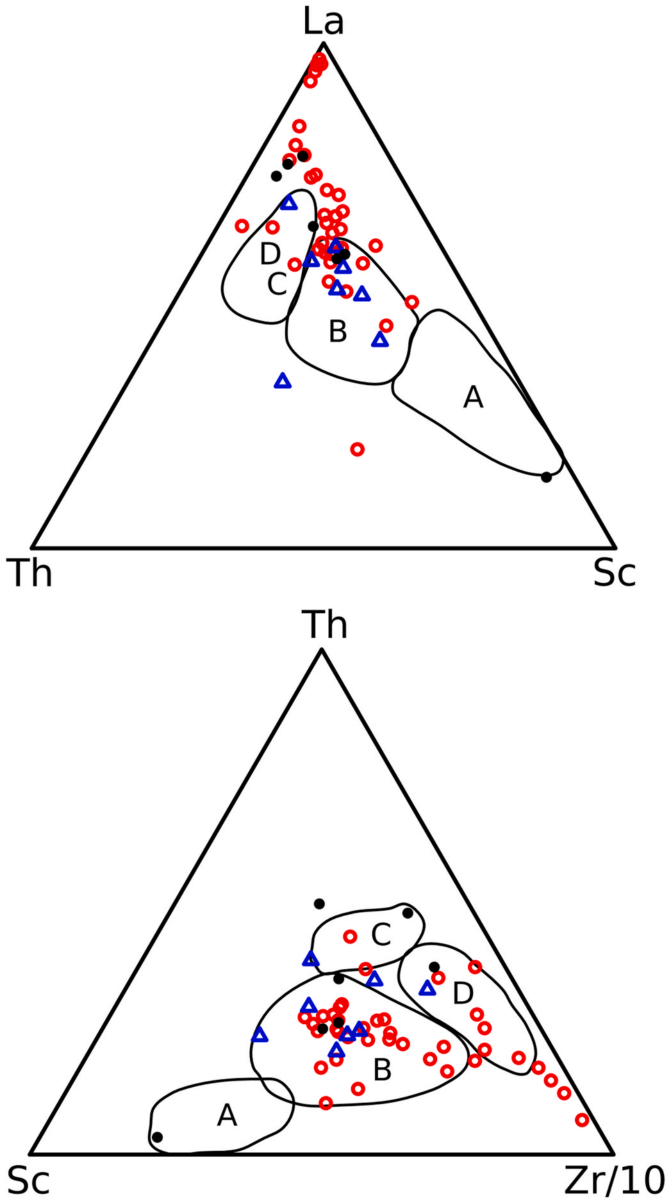

Fig. 5. Th–La-Sc (a) and Sc-Th-Zr/10 (b) discrimination diagrams (Bhatia and Crook, 1986) for units of the Western Dom Feliciano Belt. A) Oceanic island arc; B) Active continental margin; C) Continental island arc; D) Passive margin.). Plotting symbols are as in Fig. 3.

with the AgePick spreadsheet of the University of Arizona LaserChron Center (www.geo.arizona.edu/alc), including age probability contributions from at least three analyses, to constraint the deposition age of the lithostratigraphic units (Table 3). These youngest peak ages were evaluated together with independent criteria such as the age of interbedded volcanic rocks, metamorphism, deformation and intrusive bodies.

All samples from Cebollatí Complex (BUY 76–11, UY 22–13 and UY 24–13) are characterized by the lack of Paleo-, Meso- and Neoproterozoic detrital zircon grains, in concordance with preliminary data reported by Hartmann et al. (2001). The youngest age in detrital zircon of this unit continues to be 2717 ± 24 Ma (Hartmann et al., 2001) and AgePick give a similar result (2764 Ma; 16 grains). Similar or older ages are reported in this study (2765 Ma, 25 grains, sample BUY 76–11 and 2793 Ma; n = 9, sample UY 24–13). The minimum age of this complex is constrained by an Ar/Ar phlogopite age in marble (621.4 ± 1.0 Ma) and Ar/Ar and K–Ar data in muscovite in the range 630–600 Ma (Oriolo et al., 2016b).

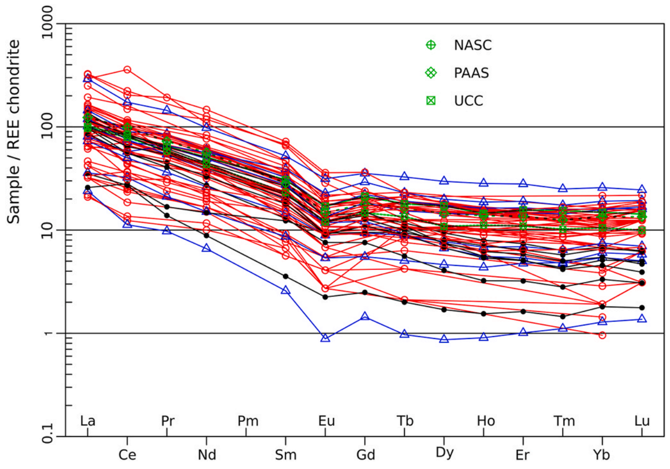

Fig. 6. Rare earth element spider diagrams (normalized to chondrite composition from Boynton (1984), for samples of the western Dom Feliciano Belt in Uruguay. NASC = North American shale composite (Gromet et al., 1984), PAAS = Post- Archean average Australian sedimentary rock (Taylor and McLennan, 1985), UCC = average Upper crust (McLennan, 1989). Plotting symbols are as in Fig. 3.

All samples from the Mesoproterozoic Zanja del Tigre Complex show Paleoproterozoic maximum depositional ages. The Mesoproterozoic age of the units included in this complex has been constrained based on the age of interbedded felsic volcanic and volcaniclastic rocks (Oyhantçabal et al., 2005; Gaucher et al., 2011, 2014; Gilberg, 2020), associated metagabbros (Oyhantçabal et al., 2005; Oriolo et al., 2019) and carbon isotope data (Chiglino et al., 2010).

Several metasedimentary rocks of the lithostratigraphic units of the post-collisional basins (Barriga Negra, Las Ventanas and Playa Hermosa) show Ediacaran maximum deposition robust ages. These data confirm that the Brasiliano magmatism (640–550 Ma) contributed to the detrital input of these basins. For the samples from other units (Cerros San Francisco and Minas de Corrales formations, the low grade metasedimentary rocks near Valentines, and the outcrops of the northern section of the Yerbal Formation), maximum deposition ages based on detrital zircon are much older than the Ediacaran ages based on other criteria (e.g., fossil content, field evidences, etc.; Gaucher et al., 2003; Pecoits et al., 2008; Gaucher et al., 2008b, 2009). Most probably this reflects sampling bias or the influence of debris input to the basins from different basement source areas, as illustrated by Zimmermann et al. (2015) for the Herrería Formation in the Cantabrian Mountains of Spain. On the other hand, age constraints of granites intruding these units indicate that the sedimentary fill is older than Cambrian, which is also consistent with the fossil content present in some of them.

4.4. Detrital zircon sedimentary provenance

Samples from the Cebollatí Complex present only Archean zircon grains, which range in age between 2.7 and 3.8 Ga (Fig. 7). A main peak at 2.7–2.8 Ga is observed in three samples (BUY–76–11, UY–24–13 and that of Hartmann et al., 2001), whereas sample UY–22–13 shows a main peak at ca. 3.3 Ga. Considered together, the samples from the Cebollatí Complex indicate two main age peaks at about 3.2–3.3 Ga and 2.8–3.0 Ga. The source of the Archean detrital zircon population most likely correspond to orthogneisses of the La China Complex (Fig. 1) cropping out in the Nico Pérez Terrane. This confirms preliminary data and the interpretation for this unit published by Hartmann et al. (2001).

Samples from the Mesoproterozoic Zanja del Tigre Complex show a dominance of Archean and Paleoproterozoic zircon grains with scarce contribution of Mesoproterozoic grains (Fig. 8). The most abundant zircon age peaks are at 3-0-3.1, 2.5–2.7, 2.1–2.2 and 1.4–1.5 Ga. Mesoproterozoic and 1.7 Ga (Statherian) peaks are usually subordinated except in sample LA227, where a prominent ca. 1.4 Ga peak attributed to a volcaniclastic component is observed, in a rock that contains a mixture of volcaniclastic and epiclastic zircon grains (Gilberg, 2020).

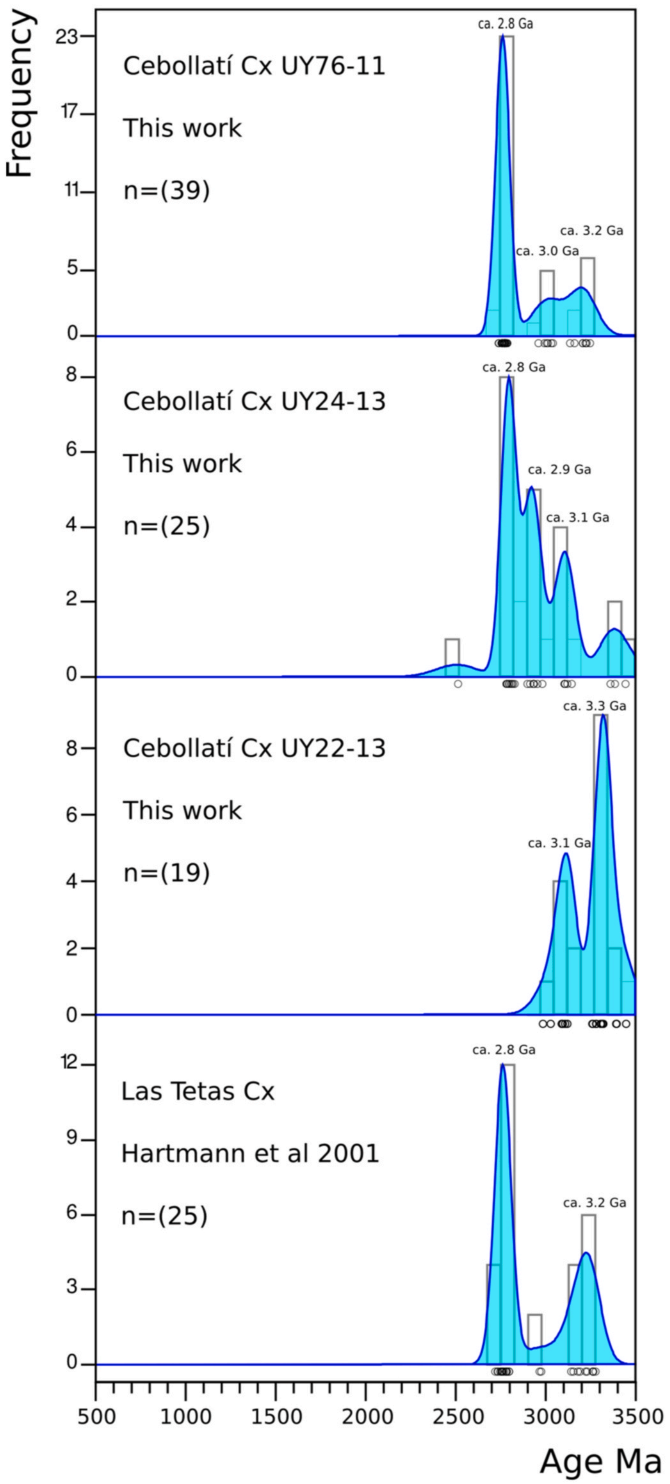

Fig. 7. Kernel density curves and histograms of detrital zircon U–Pb data for metasedimentary rocks from the Archean to Paleoproterozoic Cebollatí Complex. For previously published data, the unit name on the original publication is indicated. Data shown are concordant in the range of 90–110%. ^{207}Pb/^{206}Pb ages are used for analyses older than 1 Ga and ^{206}Pb/^{238}U ages for grains younger than 1 Ga.

The samples from the Ediacaran foreland basins show several peaks at 2.6–2.7, 2.0–2.2, 1.6–1.7, 1.3–1.4 and 0.55–0.6 Ga. Basement rocks of

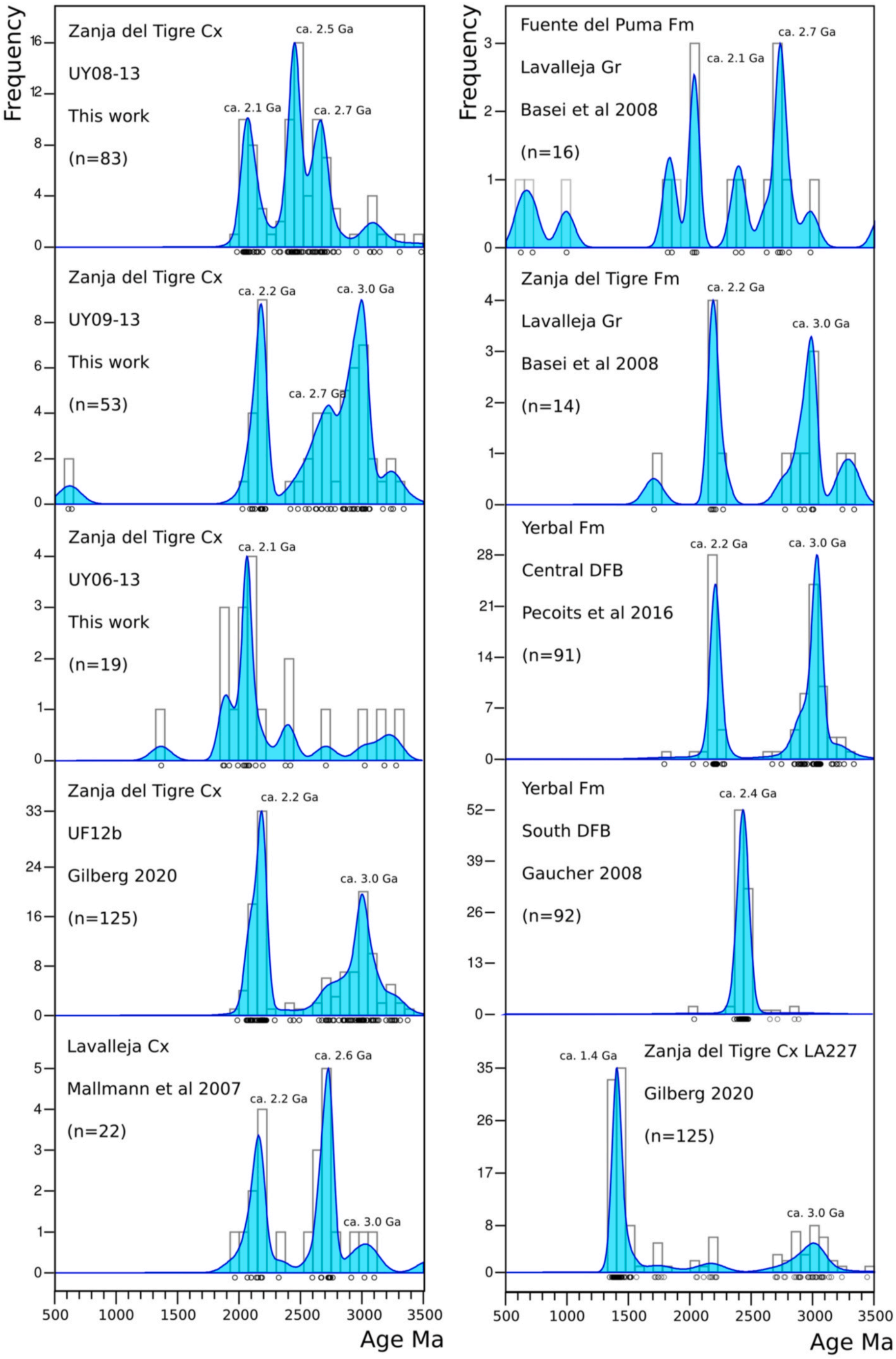

Fig. 8. Kernel density curves and histograms of detrital zircon U–Pb data for metasedimentary rocks from the Mesoproterozoic Zanja del Tigre Complex. For previously published data, the unit name on the original publication is indicated. Data shown are concordant in the range of 90–110%. ^{207}Pb/^{206}Pb ages are used for analyses older than 1 Ga and ^{206}Pb/^{238}U ages for grains younger than 1 Ga.

all of these ages have been recorded in the Nico Pérez Terrane. The sample of the Minas de Corrales Formation (BUY–55–11) stands out as it shows several Mesoproterozoic peaks between 1.2 and 1.55 Ga as well as a second major Paleoproterozoic peak at 1.7–1.8 Ga. Archean and Neoproterozoic zircon grains in this sample are subordinated (Fig. 9).

4.5. *Sm–Nd and Lu–Hf ages of the metasedimentary cover*

Sm–Nd isotopic ratios and their elemental concentrations from 16 samples of metasedimentary rocks from the Dom Feliciano Belt are presented in electronic appendix. The obtained data were integrated with 94 previously published data (see Appendix) from Mallmann et al. (2007), Blanco et al. (2009), Frei et al. (2013), and Oyhantçabal et al. (2011a).

The samples from the Cebollatí Complex show only Archean model ages, with T_{DM} values ranging between 2.74 and 3.29 Ga (mean = 3.07 Ga). The Mesoproterozoic metasedimentary rocks show younger model ages ranging from 1.94 to 2.53 Ga (mean = 2.26 Ga). The Neoproterozoic units present a dominance of Paleoproterozoic model ages, though values scatter from 1.18 to 3.13 Ga (mean = 2.16 Ga). In any case, Paleoproterozoic and subordinated Archean model ages are clearly the most frequent. Mesoproterozoic model ages are present as well in the

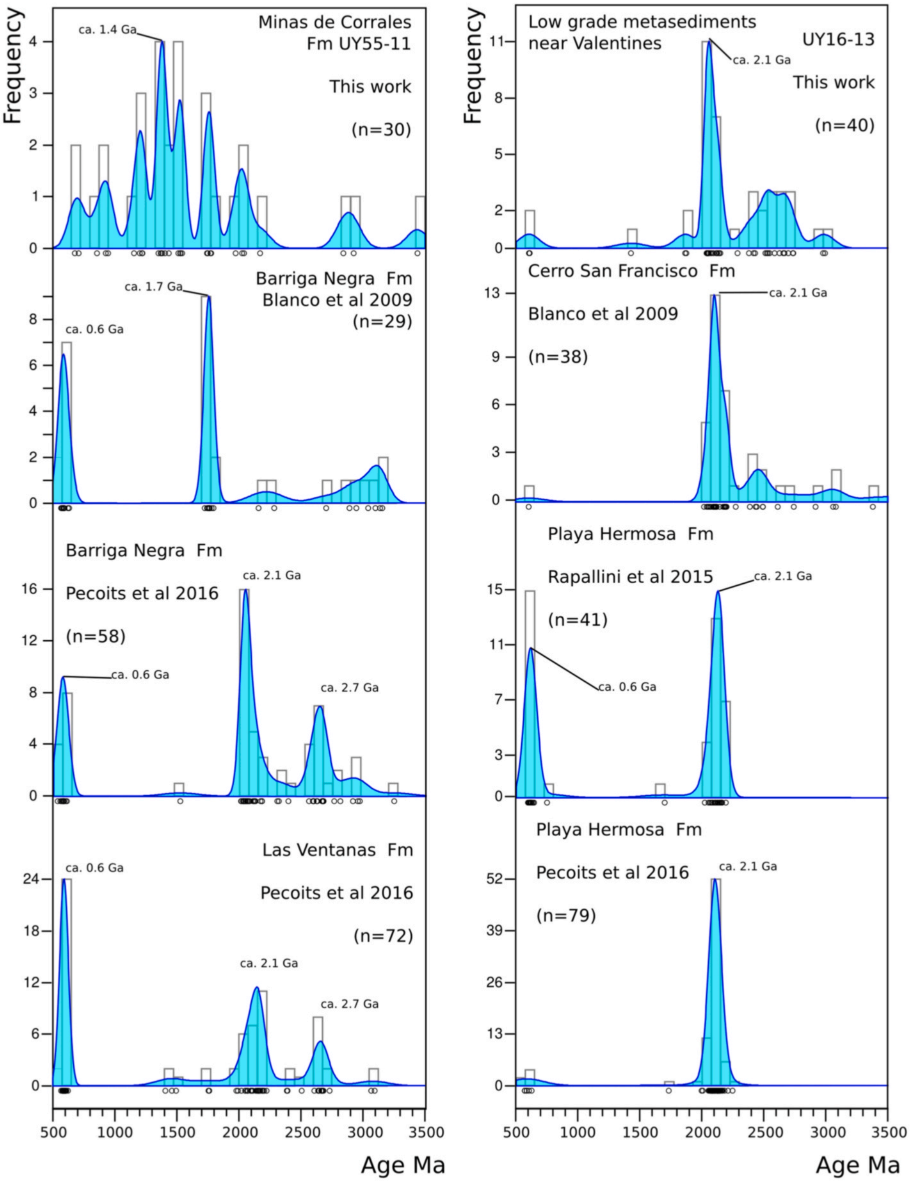

Fig. 9. Kernel density curves and histograms of detrital zircon U–Pb data for Neoproterozoic metasedimentary rocks of the western Dom Feliciano Belt. For previously published data, the unit name on the original publication is indicated. Data shown are concordant in the range of 90–110%. ^{207}Pb/^{206}Pb ages are used for analyses older than 1 Ga and ^{206}Pb/^{238}U ages for grains younger than 1 Ga.

Ediacaran metasedimentary rocks, but are really scarce. Comparison of Sm–Nd model ages and main zircon age peaks evidence a reasonable concordance between both provenance criteria (Table 4).

Zircon Lu–Hf isotope analyses were obtained for two samples (BUY–55–11 and BUY–76–11), which were also analysed parallel to U–Pb geochronology (Appendix). Archean zircon grains show $T_{Hf\ DM}$ between 2.96 and 3.47 Ga as well as ε_{Hf} ranging between slightly negative for zircons younger than 2.9 Ga (from $\varepsilon_{Hf(t)} = -4.92$) and slightly positive for those older than 2.9 Ga (up to $\varepsilon_{Hf(t)} = 5.54$). On the other hand, Mesoproterozoic zircon grains present Paleoproterozoic T_{DM} ages ranging from 1.73 to 2.32 Ga and $\varepsilon_{Hf(t)}$ values from −2.73 to 7.10. The two Neoproterozoic zircon grains obtained in the mineral concentrate of sample BUY-55-11 show $T_{Hf\ DM}$ of 0.77 and 0.79 Ga with highly positive $\varepsilon_{Hf\ (t)}$ values of 11.88 and 12.04 (Fig. 10).

Neoarchean grains seem to be derived from recycled Meso– to Eoarchean crust, as it is indicated by the dominance of Meso– to Paleoarchean $T_{Hf\ DM}$ ages and the presence of grains up to ca. 3.8 Ga old. Addition of Archean juvenile material, however, cannot be discarded due to the presence of slightly positive $\varepsilon_{Hf(t)}$ values as well as similar crystallization and model ages in some grains. In comparison, Mesoproterozoic grains show only Paleoproterozoic model ages and more positive $\varepsilon_{Hf(t)}$ values, indicating a more significant contribution of juvenile material. Neoproterozoic crystals derive, in turn, from Cryogenian juvenile crustal material.

5. Discussion

5.1. *Geochemical approach to provenance*

As mentioned in the geological setting, three main geochronologic units are considered in this work based on a combination of field criteria, geological mapping continuity, fossil content and detrital zircon evidence: Archean to Paleoproterozoic, Mesoproterozoic and Neoproterozoic. An outstanding result of the geochemical comparison is that

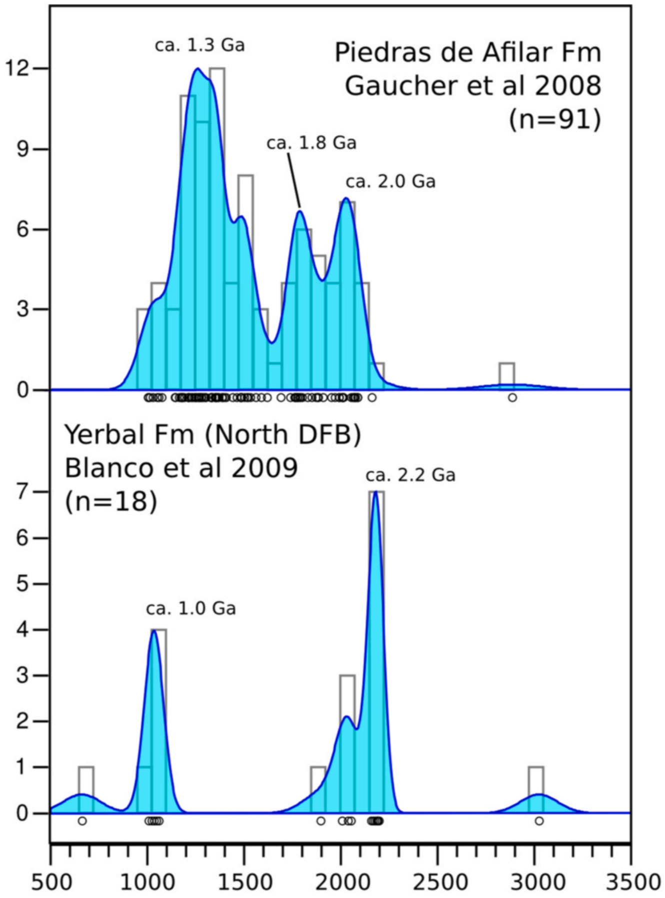

Fig. 9. (*continued*).

Table 4
Nd model ages and main age peaks recorded in the Archean to Paleoproterozoic, Meso- and Neoproterozoic sequences of the western Dom Feliciano Belt in Uruguay.

Age	TDm				Detrital zircon age peaks (Ga) numbers in parentheses indicate peak importance								
	n	Min	Mean	Max									
Archean-Paleoproterozoic	5	2.74	3.07	3.29	3.2–3.3 (2)	2.8–3.0 (1)							
Mesoproterozoic	10	1.94	2.26	2.53		3-0-3-1 (3)	2.5–2.7 (2)	2.1–2.2 (1)		1.4–1.5 (4)			
Neoproterozoic	3	1.76	1.95	2.17				2.0–2.2 (1)	1.7–1.9 (3)		1.2–1.4 (2)	1.0–1.1 (4)	
Ediacaran	91	1.18	2.16	3.13			2.6–2.7 (4)	2.0–2.1 (1)	1.6–1.7 (3)	1.3–1.4 (5)			0.5–0.6 (2)

all units show rather similar composition, close to that of the average Upper Continental Crust (UCC) (Taylor and McLennan, 1995). The provenance of the Archean to Paleoproterozoic Cebollatí Complex is the Archean La China Complex of the Nico Pérez Terrane, as evidenced by the detrital zircon age peaks, and it shows all geochemical characteristics typical of sediments sourced in an old upper continental crust (average TDM = 3.07 Ga; Eu/Eu* ≈ 0,7; Th/Sc > 1 and high La_N/Yb_N). Additionally, higher Cr/Th values (Condie and Wronkiewicz, 1990) and Gd_N/Yb_N (McLennan et al., 1993; Maslov, 2007) are consistent with the Archean source area of this unit.

The Mesoproterozoic rocks also show geochemical characteristics suggesting a source in rocks with the composition of old upper continental crust, as it is expected considering that an extensional setting was proposed for the Mesoproterozoic units of the Dom Feliciano Belt (Oriolo et al., 2019), and that the main source of the detritus in rift basins is the local basement, whereas the input of detritus sourced in coeval magmatic rocks is normally minor (Cawood et al., 2012). In contrast with the Cebollatí Complex, the main detrital zircon peaks in the Mesoproterozoic units are Rhyacian and Orosirian and, consistently, the general geochemical characteristics are similar, though Cr/Th, Gd_N/Yb_N and La_N/Yb_N show lower values.

A remarkable situation is observed in the case of the Ediacaran units, which show detrital zircon spectra with age peaks resulting from basement rocks, but also an important contribution of detrital zircon grains derived from only slightly older to coeval Ediacaran magmatic rocks that are widespread in the western Dom Feliciano Belt (Oyhantçabal et al., 2007; Lara et al., 2017). Nevertheless, most of the geochemical characteristics are those of sediments sourced in old upper continental crust. The geochemistry of the Ediacaran granites that acted as source for the detrital mix indicates that they are highly differentiated and were generated by the melting of old crust with an only minor mantle component (Lara et al., 2020, and references therein). It is therefore expected that this source component did not lead to a significant change in the composition. In a similar way, widespread Early and Late

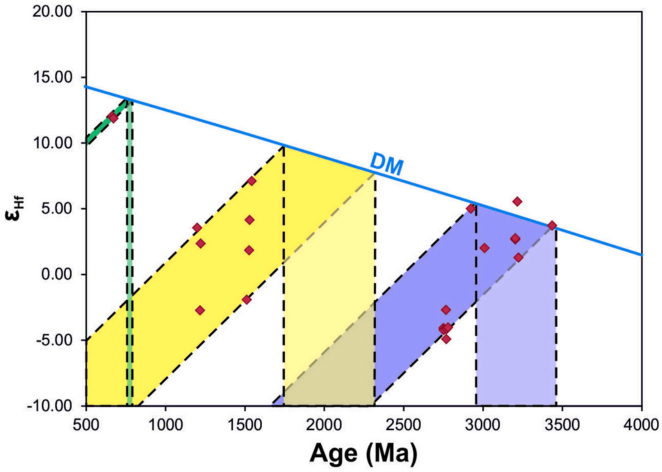

Fig. 10. U–Pb age versus initial εHf for detrital zircons from the Western Dom Feliciano Belt.

Paleoproterozoic intrusions show a similar trend, showing recycling of older, dominantly Archean crust (Oyhantçabal et al., 2012; Oriolo et al., 2015; 2019). Both geochemical and isotopic data thus indicate that in the Nico Pérez Terrane, the Proterozoic magmatic pulses reworked Archean basement, or older Proterozoic intrusions already derived from it. This may also explain the similarities observed in the metasedimentary record, implying reworking of geochemically comparable intrusions and (meta)sedimentary rocks derived from them.

For all the studied metasedimentary sequences, the geochemical signature reflects a detrital mix with a main component sourced in the Archean to Paleoproterozoic basement. This lack of specific geochemical features determine that the composition do not allow any sound discrimination of the tectonic setting, since it actually represents the geochemistry of the source(s) and recycling processes. The latter is particularly evident in the Neoproterozoic sequences.

5.2. *Detrital zircon provenance*

All new data together with previous results of detrital zircons from the western Dom Feliciano Belt (Mallmann et al., 2007; Basei et al., 2008; Gaucher et al., 2008a; Blanco et al., 2009; Rapalini et al., 2015) are summarized in Figs. 7–9.

Main peaks at 3.2–3.3 and 2.8–3.0 Ga are recognizable in the Cebollatí Complex. Archean rocks are present in the La China Complex (Hartmann et al., 2001; Gaucher et al., 2011). The absence of Rhyacian or Orosirian zircon grains is remarkable, despite this is the dominant age peak in all other units and that Rhyacian protolith ages are widespread in the basement of the Nico Pérez Terrane. This rather confirms that this unit is most probably of Neoarchean or, at most, Siderian age.

The Mesoproterozoic metasedimentary rocks show a dominant age peak at 2.1–2.2 Ga and other main peaks at 2.5–2.7 and 3.0–3.1 Ga. The Paleoproterozoic peaks match ages recorded in the basement of the Nico Pérez Terrane, which underlies the metasedimentary sequences. Ages about 2.0–2.2 Ga are recorded in the Valentines–Rivera Granulitic Complex (Santos et al., 2003; Oyhantçabal et al., 2012; Oriolo et al., 2016a). The Campanero Unit and the Illescas Granite account for the subordinated 1.7–1.8 Ga detrital ages (Campal and Schipilov, 1995; Mallmann et al., 2007; Oriolo et al., 2019). Additionally, the observed 1.4–1.5 Ga zircon grains most probably represent the contribution of roughly coeval volcanic and volcaniclastic rocks interbedded with the metasedimentary rocks (Oyhantçabal et al., 2005; Gaucher et al., 2011; Gilberg, 2020).

In the Ediacaran metasedimentary rocks, an Ediacaran age peak at 0.5–0.6 Ga is frequently observed and may derive from the widespread Ediacaran magmatism recorded in the area (e.g., Hartmann et al., 2002; Oyhantçabal et al., 2007; 2009; 2012; Lara et al., 2017). In case of the Playa Hermosa Formation, a main age peak is observed at 2.0 and 2.2 Ga and a secondary peak at around 600 Ma, while Archean and Mesoproterozoic ages are lacking (Rapalini et al., 2015; Pecoits et al., 2016). The main peak could represent ages of the basement of the Río de la Plata Craton (e.g., Cingolani, 2011; Oyhantçabal et al., 2011a, 2011b; 2018; Santos et al., 2017), which is consistent with SW paleocurrent directions (Pazos et al., 2011) and the ca. 630 Ma accretion of the Río de la Plata Craton to the Nico Pérez Terrane (Oriolo et al., 2016a). The detrital zircon record of the Piedras de Afilar Formation (Gaucher et al., 2008a), on the other hand, shows age peaks at 1.0–1.1, 1.2–1.5, 1.7–1.9 and 2.0–2.1 Ga and one single Archean grain. These age peaks indicate contribution from Nico Pérez Terrane sources. This pattern is also observed in other Ediacaran units, including the Barriga Negra and Las Ventanas formations. Consequently, the Playa Hermosa Formation may represent the only metasedimentary unit of the western Dom Feliciano Belt that truly reflects provenance from the Río de la Plata Craton, being thus the basement of the Nico Pérez Terrane the dominant source for all other metasedimentary sequences.

5.3. *Sm–Nd and Lu–Hf ages*

Sm–Nd model ages of the metasedimentary cover of the western Dom Feliciano Belt show a wide spectrum from Mesoproterozoic to Archean. This is in contrast with Sm–Nd model ages reported for the Río de la Plata Craton suggesting a Paleoproterozoic juvenile origin for this craton (Peel and Preciozzi, 2006; Oyhantçabal et al., 2011a, 2018b). On the other hand, Archean and Paleoproterozoic model ages are reported for the Nico Perez Terrane (Mallmann et al., 2007; Blanco et al., 2009; Oyhantçabal et al., 2011a; Oriolo et al., 2016a).

Archean and Paleoproterozoic whole-rock Sm–Nd and zircon Hf model ages suggest that these were the major crustal growth periods for the source areas. Compared with U–Pb and Hf model ages in detrital zircon for the Damara Belt reported by Foster et al. (2015), data from the western Dom Feliciano Belt suggest an African signature, either from the Congo or Kalahari cratons.

The two Cryogenian grains observed in sample BUY-55-11 show juvenile Hf-isotope compositions. The São Gabriel Block present evidence of Cryogenian magmatism (Saalmann et al., 2005) and may account as possible sources for the obtained model ages. The São Gabriel Block, on the other hand, can be thus interpreted as the source for these grains, as it is made up of juvenile material (Saalmann et al., 2005; Lena et al., 2014). On the other hand, Pertille et al. (2015b) report Hf T_{DM} model ages between 1.55 and 2.22 Ga ($n = 4$) for Cryogenian detrital zircons of the Porongos Group, indicating that probably Cryogenian zircons from juvenile as well as reworked sources occur in the Dom Feliciano Belt.

As indicated by U–Pb geochronology, Hf data show a significant contribution of old crust, which was mostly generated during the Paleo– and Eoarchean. Nevertheless, Neo– and Mesoarchean addition is also noticeable. This may reflect the role of the Archean rocks of the foreland basement in the western Dom Feliciano Belt (e.g. La China Complex; Hartmann et al., 2001; Gaucher et al., 2011) as detritus source for the metasedimentary rocks and as magma source for basement and granitic rocks derived from it.

5.4. *Regional implications*

The Dom Feliciano Belt in Uruguay is traditionally considered as composed of two terranes, Nico Pérez and Punta del Este, bounded by the Sierra Ballena Shear zone (Fig. 1) (Hueck et al., 2018 and references therein). Fig. 11 shows the pooled detrital zircon age spectra for Nico Pérez and Punta del Este terranes. Although the detrital zircon distribution patterns are dominated by similar major age fractions, some significant differences also exist. Meso- and Paleoarchean ages are scarce or absent in the Punta del Este Terrane, while a prominent Stenian

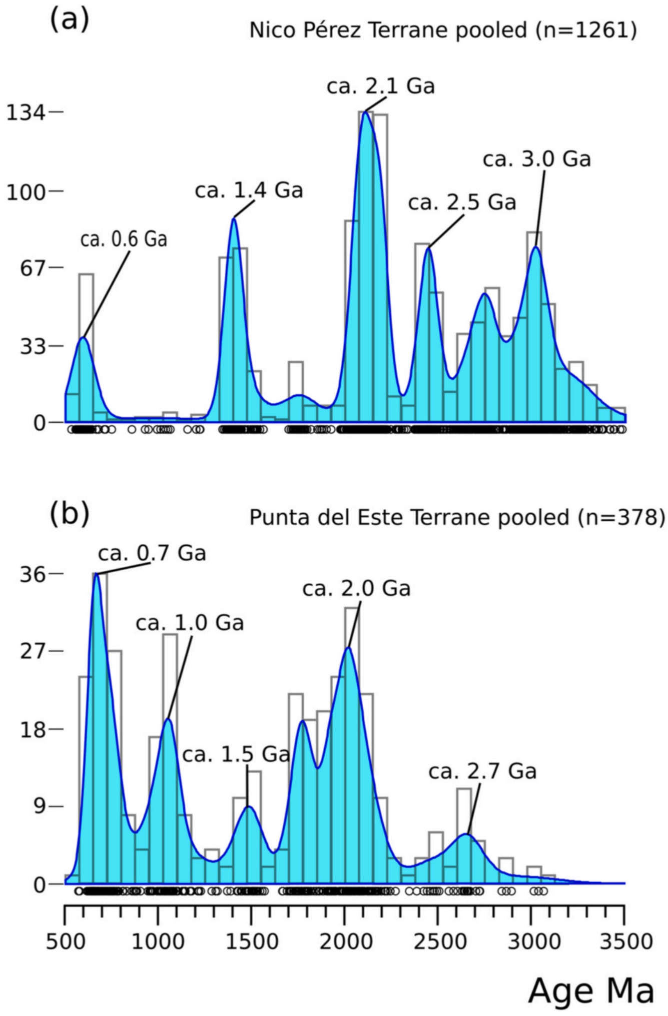

Fig. 11. Pooled detrital zircon age kernel density curves and histograms for samples from the Nico Pérez (western Dom Feliciano Belt) and Punta del Este terranes (eastern Dom Feliciano Belt) in Uruguay: a) western Dom Feliciano Belt (data from this work complemented by those from Hartmann et al., 2001; Mallmann et al., 2007; Basei et al., 2008; Gaucher et al., 2008a; Blanco et al., 2009; Rapalini et al., 2015; Pecoits et al., 2016; Gilberg, 2000) and b) eastern Dom Feliciano Belt, samples from Rocha Formation (Abre et al., 2020), Cerro Olivo Complex (Konopásek et al., 2017) and Paso del Dragón Complex (Peel et al., 2018). Data shown are concordant in the range of 90–110%. $^{207}Pb/^{206}Pb$ ages are used for analyses older than 1 Ga and $^{206}Pb/^{238}U$ ages for grains younger than 1 Ga.

age peak, not present in Nico Pérez, is observed. This supports the contribution of sources from the Kalahari Craton as indicated by Basei et el. (2005) and Abre et al. (2020).

In Rio Grande do Sul (southern Brazil), the traditional Porongos Complex comprises quarzite, schist and marble and its Tonian age is well-constrained by interbedded felsic to intermediate Tonian volcanic rocks. The detrital zircon provenance shows Archean, Paleo- and Mesoproterozoic rocks in the source areas (Hartmann et al., 2004; Basei et al., 2008; Gruber et al., 2011; Pertille et al., 2015b; Hueck et al., 2018). Nevertheless, other outcrops of the Porongos Complex (the Porongos II sequence of Höfig et al., 2018) show a main Ediacaran age peak together with Archean, Paleo- and Mesoproterozoic age peaks (Pertille et al., 2015a; Höfig et al., 2018), constraining an Ediacaran maximum deposition age. The contribution of Höfig et al. (2018) demonstrates that a unit traditionally considered a single unit can contain imbricated Tonian and Ediacaran sequences. In the Ediacaran Santa Bárbara and Guaritas groups of the same area, Paleo- and Neoproterozoic detrital zircon grains prevail and show dominant Archean and Paleoproterozoic Hf model ages (Oliveira et al., 2014). Despite the different abundances in the detrital zircon age distributions, Archean, Paleo- and Mesoproterozoic age peaks are similar to those observed in Uruguay in the western Dom Feliciano Belt and are consistent with the prolongation of the Nico Pérez Terrane in Rio Grande do Sul, as proposed by Oyhantçabal et al. (2018) and Oriolo et al. (2019), among others.

Zircon ages of the basement of the Nico Pérez Terrane of Uruguay include Paleoarchean to Neoarchean rocks (Hartmann et al., 2001; Santos et al., 2003; Gaucher et al., 2011; Oriolo et al., 2016a). Late Paleoproterozoic events in this terrane are well recorded in the Campanero Unit (1754 ± 7 Ma, Mallmann et al., 2007 and 1735 + 32/-17 Ma; Sánchez Bettucci et al., 2004) and the Illescas Granite (~1.78 ± 5 Ga, ^{207}Pb–^{206}Pb zircon age, Campal and Schipilov, 1995; Oriolo et al., 2019). Mesoproterozoic U–Pb zircon ages are reported for a metagabbro (1492 ± 4 Ma; Oyhantçabal et al., 2005; Oriolo et al., 2019) and volcaniclastic rocks interbedded in volcanosedimentary successions in Uruguay (1429 ± 21 Ma, Oyhantçabal et al., 2005; 1433 ± 6 Ma, Gaucher et al., 2011 and 1462 ± 4 Ma, Gaucher et al., 2014; Gilberg, 2020). Neither granites nor metamorphism of this early Mesoproterozoic age are observed, and geochemical and isotopic data show similarities with intraplate magmatism (Oriolo et al., 2019). This 1.4–1.5 Ga event is clearly represented in the Congo Craton but is missing in the Kalahari Craton, where the Mesoproterozoic record is younger than 1.38 Ga (Oriolo and Becker, 2018). Zircon ages in the Congo Craton in north-western Namibia and south-western Angola and basement inliers of the associated Kaoko Belt also include Archean granitic gneisses (ca. 2.6 Ga) and Paleoproterozoic granitoids of 1.9–2.0 Ga (Seth et al., 1998). Late Paleoproterozoic (1.7–1.85 Ga) orthogneisses and granites are common in the Epupa area of the Congo Craton and in the Kamanjab inlier of the Kaoko Belt. A Mesoproterozoic extensional regime and its associated magmatism are recorded in anorthosites of the Mesoproterozoic Kunene Complex (1.37–1.38 Ga; Mayer et al., 2004; Drüppel et al., 2007), intrusive granites in the Epupa Complex, dated by a U–Pb SHRIMP age of 1374 ± 5 Ma (Seth et al., 2005) and is also well-represented across the Congo Craton in the Kibaran extensional tectono-magmatic event (Tack et al., 2010). A possible correlation between this extensional magmatism and the early Mesoproterozoic anorogenic rocks in Uruguay was indicated by Oriolo et al. (2019).

A comparable scenario is observed in Rio Grande do Sul in southern Brazil, as the Porongos Complex shows provenance indicating reworking of Meso- to Neoarchean and Paleoproterozoic basement amalgamated to the Sao Gabriel Block after ca. 700 Ma (Saalmann et al., 2011). For the Santa María Chico Complex, Girelli et al., 2018 reported protolith ages of 2430–2290 Ma and 2240–2120 Ma in meta-igneous and metasedimentary rocks with dominant Archean zircon Hf model ages. Likewise, Rhyacian and Siderian ages are indicated for the Encantadas Complex (Hartmann et al., 2000; Leite et al., 2000).

Conclusive correlations between South American and African cratons and belts cannot be unquestionably established. However, the allochthony of the Nico Pérez Terrane and its similitude regarding Archean, Paleo-, Meso- and Neoporoterozoic events suggests that it probably represents a fragment of the Congo Craton, as several authors have proposed (Rapela et al., 2011; Oyhantçabal et al., 2011a; Oriolo et al., 2016a, 2017; Konopásek et al., 2018, 2020). The dominance of Archean and early to middle Paleoproterozoic ages in both the Nico Pérez Terrane and the overlying metasedimentary sequence, which are widespread in the south-western Congo Craton (e.g., Hanson, 2003; McCourt et al., 2013; Gärtner et al., 2014; Jelsma et al., 2018) and contrast significantly with the western Kalahari Craton and the zircon pattern of the Gariep Belt (e.g., Basei et al., 2005; Hofmann et al., 2014; Frimmel, 2018; Oriolo and Becker, 2018), may support an origin from the Angola Block of the Congo Craton.

6. Conclusions

Whole rock geochemistry data of metasedimentary cover of the western Dom Feliciano Belt in Uruguay indicate most units have compositions similar to the average upper continental crust. Hf contents, Ti/Zr and La/Th ratios, on the other hand, indicate that the source was dominated by felsic sub-alkaline to slightly alkaline compositions. REE patterns display slight LREE enrichment and weak negative Eu anomalies and are also similar to those of the upper continental crust. The geochemistry is also similar even in the Ediacaran metasedimentary rocks, which show contribution of detritus from slightly older Ediacaran granites, due to the crustal origin of these highly differentiated granites. Therefore, the geochemistry seems to record the crustal signature of mainly Archean to Paleoproterozoic sources and recycling processes.

For the Barriga Negra, Las Ventanas and Playa Hermosa formations, detrital zircon data confirm Ediacaran maximum deposition age and in consequence a post-collisional setting, as suggested by Basei et al. (2000), Fambrini et al. (2005) and Almeida et al. (2010). In the case of the Minas de Corrales, Arroyo la Pedrera, the northern section of Yerbal, and Piedras de Afilar formations, a Cryogenian to Tonian maximum deposition age is indicated by detrital zircon data. The question arises if these units could be related to pre-collisional basins or represent Ediacaran post-collisional sequences lacking in intrabasinal sources (i.e., Ediacaran magmatism).

Detrital zircon population data show dominance of Archean and Paleoproterozoic sources. Sm–Nd and Lu–Hf isotope indicate Paleoproterozoic and subordinated Archean model ages are dominant, while Mesoproterozoic model ages are scarce. Comparison of U–Pb detrital zircon age distributions and model ages from potential source regions indicate the Nico Pérez Terrane and not the Río de la Plata Craton, as defined by Oyhantçabal et al. (2011a), was the source of detritus for all sequences of the western Dom Feliciano Belt, excepting for the Playa Hermosa Formation. The similitude of Archean, Paleo-, Meso- and Neoproterozoic events recorded in the Nico Pérez Terrane support the model of Rapela et al. (2011) and Oriolo et al. (2015), which indicates that it represents a fragment of the Congo Craton.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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