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ORIGINAL ARTICLE

The Ichnological Record of Araraquara Sidewalks: History, Conservation, and Perspectives from This Urban Paleontological Heritage of Southeastern Brazil

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Abstract
The city of Araraquara in southeastern Brazil is unique regarding its paleontological record. Flagstones have been quarried from eolianites (Botucatu Formation, Lower Cretaceous) since the beginning of the twentieth century and used to pave and cover public and private spaces of the city. As a consequence, fossil tracks and traces (ichnofossils) of invertebrates, early mammals, and dinosaurs are widely distributed in the flagstones that pave the sidewalks of the city, right under the feet of Araraquara's inhabitants. In this paper we aimed to characterize this unique fossil record, focusing on the main trace morphotypes and their conservation. In a survey conducted in 2007–2008, 585 trace fossil-bearing flagstones were identified across Araraquara, much of which are moderately to poorly preserved. Nevertheless, optimally preserved (elite) traces of very high scientific potential were also recorded. The present study also includes a history of investigations conducted regarding these materials and discusses different aspects, difficulties, and peculiarities of conservation efforts towards this urban paleontological heritage, including some recently achieved goals.

Keywords Paleontological heritage · Ichnology · Dinosaur tracks · Botucatu Formation · Cretaceous · Urban heritage

Introduction

The Botucatu Formation (Lower Cretaceous of the Paraná Basin, Brazil) is known by its abundant ichnofauna composed by invertebrate traces, tetrapod tracks, and other less obvious ichnofossils (e.g., Leonardi 1980, 1981, 1994; Leonardi and Godoy 1980; Leonardi and Sarjeant 1986; Fernandes et al. 1990; Fernandes et al. 2004; Fernandes and Carvalho 2007, 2008; Leonardi et al. 2007; Francischini et al. 2015). The optimal preservation of some of these specimens achieved international recognition, making this unit an important comparison basis for studies on ancient fauna in desert environments (e.g., Lockley and Hunt 1995; Lockley 2011; Krapovickas et al. 2016).

The outcropping deposits of the Botucatu Formation have been widely explored in several municipalities of the central region of the state of São Paulo (southeastern Brazil), where flagstones and boulders of these silicified eolian sandstones have been used to pave public sidewalks, courtyards, squares, private residences, and churches (Fig. 1; Leonardi 1984, 1994; Fernandes and Corrêa 2007; Fernandes et al. 2008; Francischini et al. 2018a). Therefore, in addition to a real tracksite (i.e., the Ouro Ichnosite, sensu Leonardi and Carvalho 2002a) where ichnofossils occur in situ, the presence of fossil tracks and trackways in the flagstones used to pave public sidewalks of cities in this region is a common phenomenon.

Trace fossils have been previously surveyed, identified, and described in flagstones used in public spaces of other

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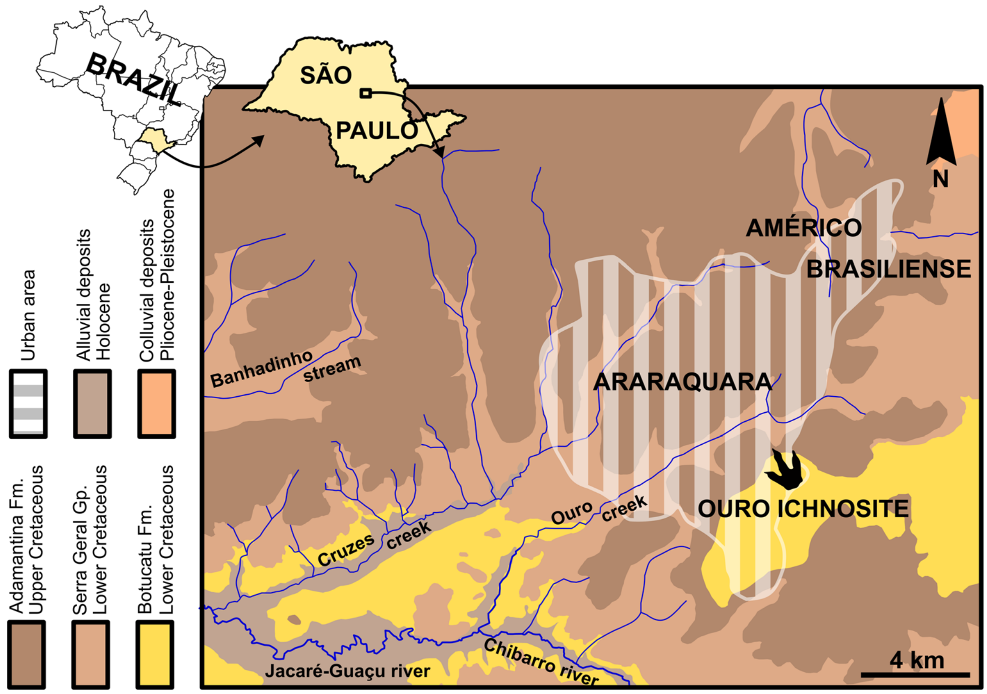

Fig. 1 Geologic map of the Araraquara region (São Paulo state, Brazil) and the location of the Ouro Ichnosite. Modified from Piuci and Diniz (1985)

Brazilian cities (Leonardi and Godoy 1980; Leonardi and Sarjeant 1986; Marconato and Bertini 1999; Fernandes and Corrêa 2007; Lacerda and Dias 2008). However, it is in the flagstones that pave the public sidewalks of Araraquara (São Paulo state; Fig. 1) that these materials occur most frequently (Leonardi 1980). As a non-renewable element of geologic origin and high scientific relevance (see below), the Araraquara trace fossils are considered part of local geodiversity (see definitions in Borba and Sell 2018; Araraquara 2019) and Brazilian Cultural Heritage (Brasil 1988). Based on the importance of these materials and considering that the first step to preserve a tracksite is to have it documented (Agnew et al. 1989), the main goals of this contribution were to characterize the trace fossils found on the public sidewalks of Araraquara, to present a history of earlier research on these materials, and to discuss some aspects of the conservation and protection of this *urban tracksite*.

Geological and Paleontological Settings

The Botucatu Formation consists of fine-grained, rounded, and opaque sandstones with medium- to large-sized (1–30 m) tangential cross-bedded strata, representing aggregations of eolian dunes of a *paleoerg* commonly known as the *Botucatu Desert* (e.g., Almeida 1954; Bigarella 1979; Scherer 2000, 2002; Scherer and Lavina 2006; Scherer and Goldberg, 2007). This *erg* represents the apex of the Gondwanan aridization trend during the Mesozoic (Almeida et al. 2012). Deposits in Uruguay (Rivera Member of the Tacuarembó Formation; Perea et al. 2009), Paraguay (Misiones Formation; Bigarella 1979), Argentina (San Cristóbal Formation; Padula and Mingramm 1967), and Namibia (Twyfelfontein Formation; Stollhofen 1999) indicate that this desert occupied a wide area in Western Gondwana. In Brazil, the Botucatu Formation occupies an area larger than 1,500,000 km^2, covering the states of Mato Grosso, Mato Grosso do Sul, Goiás, Minas Gerais, São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul and is defined at its base by an unconformity that extends across all the Paraná Basin (Faccini et al. 1989; Milani et al. 1998).

Faccini et al. (1989) proposed that the Botucatu Formation is related to only one depositional sequence, because any of the underlying units would have enough quartzose grains to supply this *paleoerg* and, thus, the source area of this desert would be beyond the geographic limits of the Paraná Basin. The eolian paleocurrents of the Botucatu dunes have a N–S direction in the northern part of the Basin, while at the south, the main direction is SW–NE, forming a confluence zone near paleolatitude 24°S (Scherer 2000; Scherer and Goldberg, 2007; Perea et al. 2009). These data support the hypothesis that the deposition of the Botucatu Formation was controlled by wind patterns ruled by a monsoonal climate (Scherer and Goldberg, 2007).

The end of the Botucatu Formation deposition is related to a fissural volcanism event, resulting from the Early Cretaceous Gondwana breakup, whose deposits compose the Paraná-Etendeka Igneous Province (Rossetti et al. 2018 and references therein). The igneous rocks (basalts, andesites, dacites, and rhyolites) derived from this event are stratigraphically ordered within the Serra Geral Group (Rossetti et al. 2018). The age of this event was obtained by several authors using radiometric dating and magnetostratigraphic data (e.g., Renne et al. 1992; Turner et al. 1994; Ernesto et al. 1999; Tamrat and Ernesto 2006; Janasi et al. 2011; Thiede and Vasconcelos 2010; Pinto and Hartmann 2011; Baksi 2018), which suggest that the entire Serra Geral Group was deposited between the Valanginian and the Hauterivian (Early Cretaceous). The interfingering between the upper deposits of the Botucatu Formation and the lower deposits of the Serra Geral Group (i.e., the Torres Formation), the preservation of dune morphologies by lava flows, and the presence of lapilli tuffs and volcanic bombs within intertrap sandstones indicate that the Botucatu eolian dunes were active during the volcanism event and provide a more accurate age for the end of the *paleoerg* deposition, based on radiometric dating of the oldest igneous rocks (Waichel et al. 2008; Almeida et al. 2012). Even though the exact period when paleodesert deposition began remains unknown, Scherer (2000) argued that based on the intimate relationship between igneous rocks and eolian sandstones, the relatively low thickness of the latter, and the lack of super surfaces in the dune fields of the Botucatu Formation, the paleodesert was probably deposited over a period no longer than some hundreds of thousands of years, suggesting that the age of this unit is basically the same as that of the Serra Geral Group.

The body fossil record of the Botucatu Formation seems to be restricted to silicified logs (Suguio and Coimbra 1972; Pires et al. 2011) found on the northern border of the paleodesert. Conchostracans, ostracods, and lycopsids have also been described in the lacustrine beds of the Rio Claro and Serrana regions (both in the state of São Paulo) (Almeida 1950; Souza et al. 1971; Würdig and Pinto 2001), but it is more likely that these belong to the Pirambóia Formation (Francischini et al. 2018b). On the other hand, the trace fossil record of the Botucatu Formation is much more profuse. Invertebrate-related ichnogenera found in this unit include *Ancorichnus*, *Arenicolites*, *Beaconites*, *Hexapodichnus*, *Octopodichnus*, *Paleohelcura*, *Scoyenia*, *Skolithos*, and *Taenidium* (Faccini et al. 1989; Fernandes et al. 1990, 2002; Fernandes and Fernandes 2010; Peixoto and Fernandes 2010). Mammal, ornithopod, and theropod dinosaur tracks have been extensively reported (e.g., Leonardi 1977, 1980, 1981; Leonardi and Godoy 1980; Leonardi and Sarjeant 1986; Leonardi and Lima 1990; Fernandes and Carvalho 2007, 2008; Fernandes et al. 2014; Francischini et al. 2015; Buck et al. 2017a, 2017b; Porchetti et al. 2018), among which is the so-called *Brasilichnium* Leonardi, 1981 ichnogenus. Another noteworthy record is the presence of micturalites (sensu Hunt and Lucas, 2012; formerly "urolites") attributed to dinosaurs (Fernandes et al. 2004).

Tetrapod tracks can occur in several modes of preservation. True tracks are very common, as revealed by the presence of expulsion rims (sand crescents) preserved around the border of footprints as well as the association with raindrops and ripple marks at the same level (Leonardi 1996, 1997; Fernandes et al. 2014). Undertracks and underprints have also been reported (Fernandes 2005) but distinguishing them from modified tracks (sensu Marty et al. 2016) is not easy, especially when the track-bearing slab is out of its original context (i.e., in sidewalks). Natural molds (convex hyporeliefs) do not occur naturally in the quarries, but they are commonly found in the sidewalk flagstones.

Material and Methods

The flagstones of Araraquara were visually sampled, walking through the city's public sidewalks in order to identify places where the Botucatu sandstones were used for paving and which slabs presented trace fossils. Sampling was conducted between 2008 and 2009 in the older neighborhoods of the city (Centro, Vila Xavier, Vila Santana, Vila Santa Maria and Jardim Silvânia), where a previous analysis indicated high concentrations of sidewalks paved with Botucatu flagstones. Whenever found, trace fossils were photographed, classified according to their degree of conservation, and their location was registered (i.e., the address of the building adjacent to where the sidewalk was found). The criteria used to classify the degree of conservation of the ichnofossils are provided in Table 1.

A preservation scale for tetrapod tracks was proposed (Belvedere and Farlow 2016) and recently improved (Marchetti et al. 2019). Using an alphanumeric scale, these authors proposed to classify fossil tetrapod tracks based on the qualitative preservation of their morphological characteristics (Belvedere and Farlow 2016; Marchetti et al. 2019). However, even though this new system is very useful to classify and evaluate the fossil track record, it was difficult to apply to the Araraquara sidewalks because these flagstones have remained exposed and under the influence of a plethora of anthropic-related destructive processes for probably a century (O Estado de São Paulo 1909). These damages include breakage, physical erosion (mainly abrasion, especially the tracks preserved as convex hyporeliefs), weathering, painting, and even filling with cement (in the case of concave epireliefs). Some tetrapod tracks are now indistinguishable as a result of the processes affecting their morphological preservation during both the ichnostratinomy phase (i.e., prior to the burial) and after the flagstone being used for pave the sidewalks. Therefore, for practical purposes, we used our own (and much more simplified) classification system (Tab. 1).

Table 1 Main criteria used to classify the conservation of fossiliferous slabs found in the sidewalks of Araraquara, Brazil

Degree of conservation	General aspects	
	Morphological details of the trace fossils	Signs of anthropic-related damage
Optimal	Well-preserved morphology	Incipient
Median	Unpreserved (or less preserved) morphology	Incipient to intermediate
Poor	Unpreserved (or less preserved) morphology	Advanced

The classification of trace fossils in morphotypes was done a posteriori, comparing photos taken in the field with materials observed firsthand in paleontological collections and described in the literature. For that, we examined materials from the following collections: Federal University of São Carlos (UFSCar), Geological Survey of Brazil (CPRM), Federal University of Paraná (UFPR), Valdemar Lefèvre Geological Museum (MUGEO), and National Museum of Brazil and Geosciences Institute, both of the Federal University of Rio de Janeiro (UFRJ). Each of the proposed morphotypes combines different trace fossils according to their morphology and may include more than one ichnotaxon. The use of an ichnotaxonomic classification proved to be ineffective for the purposes of the present study, since the objective here was to analyze materials with different degrees of preservation and conservation, which resulted in a high number of specimens that lack diagnostic morphological details. Therefore, as a work hypothesis, we proposed six morphotypes of trace fossils (invertebrate meniscate traces, invertebrate non-meniscate traces, invertebrate epistratal trackways, dinosaur tracks, mammal tracks, and indeterminate tetrapod tracks), whose classification criteria can be found in Table 2.

Results

History of the Research on the Araraquara Ichnofossils

The occurrence of ichnofossils in the Botucatu Formation was first reported by Joviano A.A. Pacheco, who found and collected two track-bearing slabs (IG-037-V and IG-038-V; Fig. 2a–c) from the sidewalks of the city of São Carlos (about 40 km away from Araraquara) (Pacheco 1913). According to data from the collection of the Valdemar Lefèvre Geological Museum (MUGEO, where both slabs are currently exhibited), these materials were found and sent to the Geographic and Geological Commission of the State of São Paulo (currently named the Geological Institute of São Paulo) in 1911 and their inferred origin is an unnamed quarry located 3 km northwards from the center of the municipality of São Carlos (location currently unknown). These tracks apparently represent the first vertebrate ichnofossils collected in South America (Leonardi 1994). A proper description of the tracks present in one of these slabs was only made in 1931, when Friedrich von Huene described specimen IG-038-V (Fig. 2b–c). However, unlike the data provided by MUGEO, Huene (1931) interpreted that this slab originated from the Ouro locality (in the municipality of Araraquara). Huene (1931) attributed trackway IG-038-V to a non-mammalian cynodont (Therapsida), in part because the Botucatu Formation was considered Triassic at the time. These materials were subsequently mentioned and/or figured by Mendes (1944), Mezzalira and Wohlers (1952), Mezzalira (1966), Haubold (1971), Casamiquela (1975), and Leonardi (1979, 1980). Haubold (1971) was the first to conduct an ichnotaxonomic classification of the trackway described by Huene (1931) and considered it as belonging to *Tetrapodichnus*, an ichnogenus currently considered *nomen nudum*. Leonardi (1981) later erected the ichnospecies *Brasilichnium elusivum* and considered specimen IGC-038-V as its paratype. However, Leonardi (1980) considered that these slabs could have originated from the Pirambóia Formation.

Invertebrate traces were firstly reported by Pacheco (1913), occurring in situ in an indeterminate quarry located north from São Carlos. In spite of being mentioned and/or figured in other contributions (Mezzalira and Wohlers 1952; Mezzalira 1966, 1989), these materials (IG-293-I, IG-295-I, IG-308-I, and IG-309-I) were only described in detail by Fernandes et al. (1990), who identified the ichnospecies *Taenidium satanassi* and *T. serpentinum*. Traces of invertebrates were also found in situ in other localities where the Botucatu Formation crops out (Almeida 1954; Bjornberg and Tolentino 1959; Paraguassu 1970).

New materials (either in situ or ex situ) were found in successive expeditions conducted by Giuseppe Leonardi between 1976 and 1986 to the quarries and urban areas of Araraquara and other cities of the north-central region of the state of São Paulo (Leonardi 1977, 1980, 1994; Leonardi and Godoy 1980; Leonardi and Sarjeant 1986; Leonardi et al. 2007). Regarding the municipality of Araraquara, invertebrate traces and tetrapod tracks were found in situ in (at least) seven different quarries (Califórnia, Cerrito Novo, Cerrito Velho, Corpedras, Santa Águeda, São Bento, and São Domingos) in the region that was later named the Ouro Ichnosite (originally called *Jazigo Icnofossilífero do Ouro*) by Leonardi and

Table. 2 Main criteria used to classify trace fossils found in the sandstone slabs of sidewalks in Araraquara, Brazil

	Morphotype	Description	Included ichnotaxa
1	Invertebrate meniscate traces	Endostratal tunnels of variable length and orientation, which can be curved, sinuous, or straight. Menisci are present. Burrow wall lining can occur.	*Ancorichnus*, *Scoyenia*, *Taenidium*
2	Invertebrate non-meniscate traces	Endostratal tunnels of variable length and orientation, which can be curved, sinuous, or straight. Menisci and burrow wall lining are lacking.	*Arenicolites*, *Cochlichnus*, *Skolithos*
3	Invertebrate epistratal trackways	Trackway composed of sets of tracks.	*Hexapodichnus*, *Octopodichnus*, *Paleohelcura*
4	Mammal tracks and trackways	Tracks of quadrupedal and heteropod animals (*manus* tracks are rarely preserved). Tetradactyl, paraxonic to ectaxonic, plantigrade to semi-plantigrade tracks. Can occur either isolated or forming trackways. Low pace angulation (105°–159°) in relation to Morphotype 5.	*Brasilichnium* (including asymmetrical gait and other mammaloid morphotypes) and larger ichnotaxon (i.e., the therapsidian/theromorphoid morphotype of Leonardi and Oliveira, 1990 and Leonardi et al., 2007)
5	Dinosaur tracks and trackways	Tridactyl, mesaxonic, and digitigrade tracks of bipedal animals. Can occur isolated or forming trackways. High pace angulation (about 180°) in relation to Morphotype 4.	Theropod morphotypes 1–4 (Fernandes et al., 2009) and ornithopod tracks (Fernandes and Carvalho 2011).
6	Indeterminate tetrapod tracks	Tracks in which the dactyly, axony, and grady are not clearly visible. Often occur isolated (not forming trackways).	–

Carvalho (2002a). These quarries are located in a region covering about 0.75 km^2, southeastwards from the urban area of Araraquara (Fig. 1; Leonardi and Carvalho 2002a). The beginning of the quarries' activities dates back to the early twentieth century (O Estado de São Paulo 1909). Among them, the São Bento (Corpedras) Quarry was the most productive regarding the extraction of track-bearing slabs, including epistratal and endostratal invertebrate traces and tetrapod tracks found during successive prospection and collection activities (e.g., Leonardi 1980, 1981, 1986; Leonardi and Godoy 1980; Leonardi and Carvalho, 2002a; Fernandes and Carvalho 2007; Leonardi et al. 2007).

The activities of these quarries comprised the extraction of flagstones used as pavement slabs, which are profusely found in the sidewalks of Araraquara (Leonardi 1980, 1981; Leonardi and Godoy 1980). Leonardi and Sarjeant (1986) estimated the abundance of track-bearing slabs in these sidewalks as five to ten slabs for every 100 m. About 60 slabs were collected directly from the sidewalks of Araraquara in subsequent years and were sent to several scientific institutions of Brazil (e.g., National Museum of Brazil and Geosciences Institute of the Federal University of Rio de Janeiro, Federal University of Paraná, Federal University of Espírito Santo, Federal University of Pernambuco, and Paleontology Museum of Monte Alto). The materials originally sent to the National Mining Agency (ANM; formerly the National Department of Mineral Production, DNPM; Leonardi 1994) have recently been relocated to the collection of the Brazilian Geological Survey (CPRM), in Rio de Janeiro. Further details of Leonardi's expeditions to Araraquara during the last three decades of the twentieth century can be found in Leonardi (1979, 1984, 1994), Leonardi and Sarjeant (1986), Mezzalira et al. (1989), and Leonardi et al. (2007). The pioneering efforts of Leonardi allowed starting discussions regarding the conservation of this important heritage (Fernandes et al. 2008).

Representativity and Conservation of Materials Found on the Sidewalks

A total of 585 track-bearing slabs were found on the sidewalks of Araraquara (Table 3; Figs. 3, 4, and 5). Among the proposed morphotypes, the most abundant were dinosaur tracks (N = 219, 37.43%), followed by mammal tracks (N = 162, 27.69%) and invertebrate meniscate traces (N = 110, 18.80%). All other morphotypes reached a total of 77 occurrences (26.31%). Seventeen slabs (2.90%) presented more than one morphotype. Regarding trace fossil conservation, only 9.91% of specimens found (N = 58) had an optimal degree of conservation. Most materials were either moderately (N = 371, 63.41%) or poorly (N = 156, 26.66%) conserved (Table. 3).

Discussion

On Some Novel and Relevant Materials

First record of the ichnogenus *Cochlichnus* Among the traces classified as Morphotype 2 (invertebrate non-meniscate

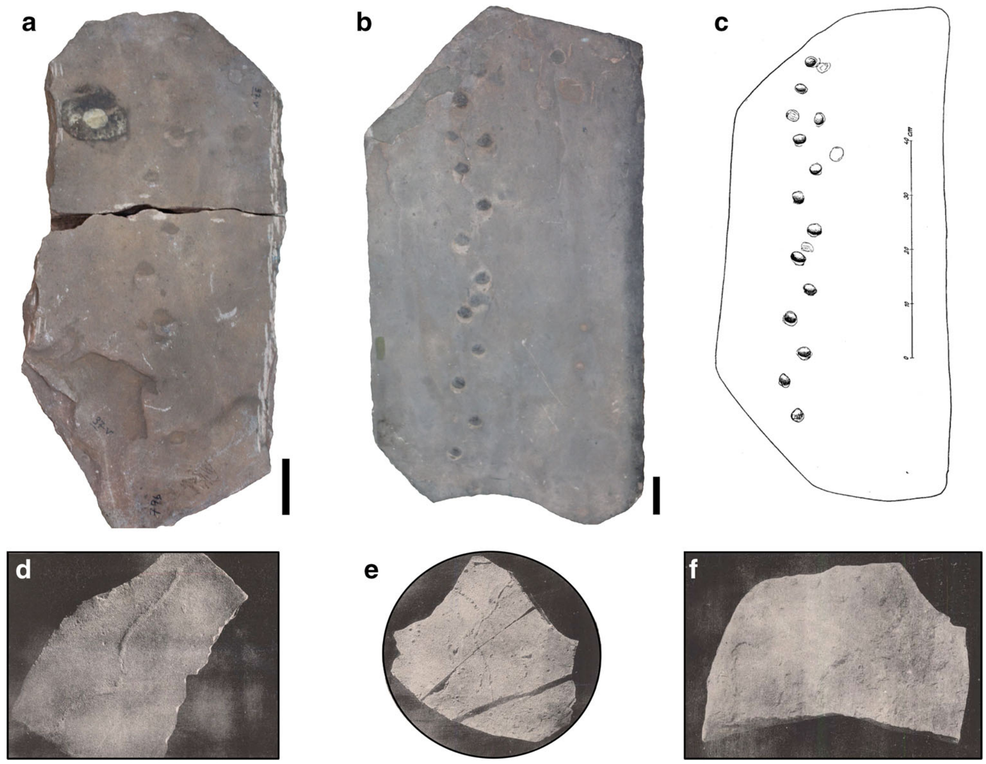

Fig. 2 The first trace fossil records from the Botucatu Formation: slabs found in the sidewalks of São Carlos by Joviano A. A. Pacheco in 1911. **a** Specimen IG-037-V, with tracks cf. *Brasilichnium*. **b** Specimen IG-038-V, with *Brasilichnium elusivum* (paratype). **c** Schematic drawing of IG-038-V, as published by Huene (1931). **d** Specimen IG-295-I with *Taenidium satanassi*. **e** Unnumbered specimen, with indeterminate invertebrate traces. **f** Specimen IG-309-I with *Taenidium satanassi*. Scales: a–b. 5 cm; c. 40 cm; d–f. not in scale. Credits: a–b. Photos by Heitor Franciscchini; c. Modified from Huene (1931); d–f. Modified from Pacheco (1913)

Table 3 Summary of the trace fossils found in slabs from the sidewalks of Araraquara, Brazil

Morphotype	Number of slabs		
	Total	By degree of conservation	
1	110 (18.80%)	Optimal	81
		Median	18
		Poor	11
2	33 (5.64%)	Optimal	1
		Median	29
		Poor	3
3	4 (0.68%)	Optimal	0
		Median	3
		Poor	1
4	162 (27.69%)	Optimal	11
		Median	103
		Poor	48
5	219 (37.43%)	Optimal	23
		Median	132
		Poor	64
6	40 (6.83%)	Optimal	1
		Median	16
		Poor	23
Total	568 (100%)	Optimal	58
		Median	371
		Poor	156

traces), we highlight the presence of simple, horizontal, and highly sinuous tunnels, characteristic of the ichnogenus *Cochlichnus* Hitchcock, 1858 (Fig. 3e). This ichnogenus occurs in several marine and continental (including eolian interdunes) deposits worldwide, ranging from the Proterozoic to the Holocene (Fernandes et al. 2002). Apparently, this specimen is the first and only record of *Cochlichnus* in the entire Botucatu Formation. These tunnels were preserved as convex hyporeliefs, and their degree of conservation was considered optimal, though there is evidence of abrasion in some regions (Fig. 3e). The mean width of these tunnels is 3.54 mm, and their wave length is 10.58 mm. Stiletto fly (Therevidae) and biting midge (Ceratopogonidae) larvae, thrips (Phlaeothripidae), and roundworms (Nematoda) produce similar traces in modern continental facies, including dry soils and eolian dunes (Sandstedt et al. 1961; Chamberlain 1975; Eiseman and Charney 2010).

An elite track of *Brasilichnium elusivum* Some mammal tracks (Morphotype 4) could be classified as belonging to the ichnospecies *Brasilichnium elusivum* Leonardi, 1981. Among the more relevant specimens, there is a trackway composed by four subsequent *pedes* tracks, one of which is exceptionally well preserved (Fig. 4d). It is plantigrade, tetradactyl, clearly paraxonic and does not present claw marks or digit drag marks. The sole pad is lens-shaped and is separated from the digits by a ridge. This feature is often related to

Fig. 3 Invertebrate traces with and without menisci (Morphotypes 1–2) found in slabs from the sidewalks of Araraquara, Brazil. Scale bars in centimeters

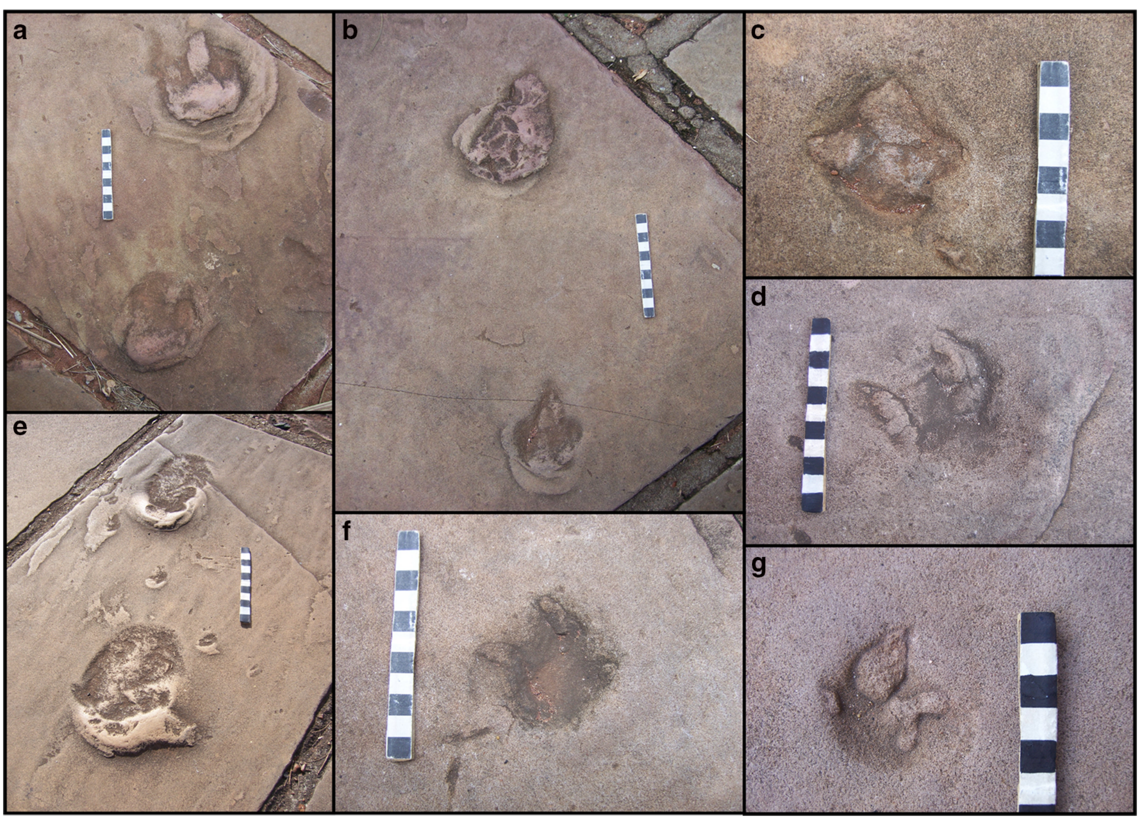

Fig. 4 Mammal tracks (Morphotype 4) found in slabs from the sidewalks of Araraquara, Brazil. Scale bars in centimeters

Fig. 5 Dinosaur tracks (Morphotype 5) found in slabs from the sidewalks of Araraquara, Brazil. Scale bars in centimeters

the digital arcade (i.e., ventral inclination of the distal phalanges in relation to the proximal ones, maintained during progression; Kümmel and Frey 2012), a common condition in fossil and modern therapsids. This diagnostic feature had never been reported for *Brasilichnium* tracks of the Botucatu Formation, probably due to preservation restrictions imposed by the eolian substrate, and thus reinforces the attribution of this ichnotaxon to a mammalian-grade trackmaker.

Theropod tracks Theropod dinosaur tracks are recognizable in the sidewalks of Araraquara (Fig. 5a–g). They present typical theropod configuration: tridactyl, digitigrade, and mesaxonic, and are often longer than wider. In most of them, digit III is more evident than digits II and IV. The hypex is V-shaped. There is a bulge in the proximal portion of digit III, tapering distally towards the ungual region. Interdigital angles vary highly and, according to Thulborn (1990), this variation is directly related to variations on substrate consistency. Some of the dinosaur tracks found present strong mesial inflection on digits II–III (i.e., towards the trackway midline; Fig. 5d, f–g). However, it is not clear if this feature is related to the trackmaker's anatomy or to substrate conditions. The theropod tracks of the Botucatu Formation varied between 3.3 and 22.5 cm in length. The ichnotaxonomy of these tracks is still being studied, but the high variation in track morphology points to a more diverse ichnofauna than previously proposed.

Morphotype Representativeness

Our data indicate that the most common ichnofossils found on the Araraquara sidewalks are dinosaur tracks (Morphotype 5: 37.43%), mammal tracks (Morphotype 4: 27.69%), and invertebrate meniscate traces (Morphotype 1: 18.80%). Other invertebrate-related morphotypes (2–3) occurred at a smaller proportion (6.32%), and 6.83% of the total was represented by indeterminate tetrapod tracks (Morphotype 6). When compared with previous surveys on the Araraquara sidewalks conducted by Leonardi and Oliveira (1990), Leonardi (1994) and Leonardi et al. (2007), our data show a very distinct proportion of morphotypes. The previous authors found the following proportion of tracks: 66.7% of mammal tracks (which at that time were subdivided in therapsidian/theromorphoid and mammaloid forms, comprising, respectively 29.2% and 37.5% of the total amount of trackways) and 33.3% of dinosaur tracks.

The data presented by Leonardi and Oliveira (1990), Leonardi (1994), and Leonardi et al. (2007) differ from the present findings mainly in three aspects: (i) these authors did not include invertebrate traces and trackways (our morphotypes 1–3) in their surveys, although Leonardi et al. (2007) indicated that they are remarkably rarer than tetrapod tracks; (ii) surveys conducted by Leonardi and Oliveira (1990), Leonardi (1994), and Leonardi et al. (2007) included specimens collected directly from the Ouro Ichnosite (i.e., in situ, from several quarries) and from the sidewalks (ex situ); (iii) the tracks used for statistical comparison (in their studies) were established a priori, probably introducing a bias towards well-preserved tracks (while our survey included indeterminate tetrapod tracks in Morphotype 6). On the other hand, the data gathered in the present investigation was influenced by the removal of materials from the sidewalks either by Leonardi's team (see Leonardi and Sarjeant 1986 for more details) or during a three decade-long period of constant removal of flagstones for sidewalk fixing or renovation purposes and carelessness of civic and political authorities (time considered since the first *discovery* by Leonardi, 1977; Leonardi 1984; Leonardi and Sarjeant 1986).

Similar data gathered from sidewalks of other cities in the region are also divergent when compared with those presented here. Fernandes and Corrêa (2007) found 156 flagstones in the sidewalks of São Carlos in which most of the ichnological record comprised invertebrate tracks and traces (64.09%, including all three morphotypes proposed in the present study). Mammal (20.51%) and dinosaur (15.38%) tracks were also found, but at a smaller rate when compared with the reports for Araraquara. However, this comparison does not reflect any kind of natural pattern, because it is unknown if the flagstones used to pave sidewalks in São Carlos came from the Ouro Ichnosite, from the quarries located in this municipality (e.g., Migliato, Araújo, Mangerona, and Itaguaçú quarries; Leonardi and Godoy 1980, Leonardi et al. 2007), or both.

Problems and Perspectives in Conservation

The Constitution of the Federative Republic of Brazil (Brasil 1988, Article 216, Item V) established that "urban aggregations and sites of historic, scenic, artistic, archeological, paleontological, ecological, and scientific value" are part of the Brazilian Cultural Heritage. Heritage is a polysemic concept that can be broadly understood as a group of things, places, expressions, knowledge, and natural elements with significant and exceptional values for an individual, a social group, or the whole humankind that must be interpreted in the present and preserved for future generations (Prats, 1994; Gonçalves 2005; Chagas 2007). Among the several branches of particular interests to society, geological heritage (or geoheritage) is understood as "places that are key locations for unveiling and understanding Earth's geological history" (Brilha 2016, p.119), including paleontological (or fossil) heritage as one of its sub-categories (Meléndez and Soria-Llop 2000; Ponciano et al. 2011; Henriques and Pena dos Reis 2015; Brilha 2016).

As part of the architectonic, scenic, and historic structure of Araraquara, and due to their unquestionable paleontological relevance, the trace-bearing slabs in the sidewalks of this city fit very clearly in the legal framework of what can be characterized as Brazilian Cultural Heritage, as established by the Brazilian Constitution (Brasil 1988). Moreover, these fossiliferous slabs were considered by the Municipal Council for the Preservation of the Historic, Architectonic, Paleontological, Ethnographic, Archival, Bibliographical, Artistic, Scenic, Cultural and Environmental Heritage of the Municipality of Araraquara (COMPPHARA; Araraquara 2003) as elements that demand permanent attention. As elements of local geodiversity with exceptional scientific value, the trace fossils of Araraquara's sidewalks (especially those classified as "optimally conserved") can be considered part of the city's geoheritage. Their importance is further highlighted by the association of these fossils to local cultural and historical values, precisely because they occur within the urban landscape of Araraquara. Therefore, strategies that aim for geoconservation and patrimonial education are necessary to assure protection for these materials and free access to their scientific value and historic memory.

Legal support for the protection of Brazilian fossiliferous deposits began in 1937 with Law Decree No. 25 (Brasil 1937), which determined that movable and immovable properties of artistic and historic importance, as well as natural monuments and notable sites and landscapes located in the country are considered part of the Brazilian Artistic and Historic Heritage. Still according to this Law Decree, the protection of this type of Heritage is of public interest and the Brazilian unions, states, and municipalities are responsible for legal actions towards protection and conservation through the registry and inventory of sites (Brasil 1937). Moreover, political awareness related to the protection of fossiliferous sites began with Law Decree No. 4146 (Brasil 1942), which discusses in its first article the belonging of fossiliferous deposits to the union and determined that fossil collections inside national territory depend on previous authorization and inspection of the ANM (formerly DNPM). The protection of this heritage is, therefore, under the jurisdiction of the union, states, federal district, and municipalities, which must prevent their evasion, destruction, and mischaracterization (Article 23, Clauses III–IV of the Constitution; Brasil 1988). Protection encompasses the inventorying, recording, inspecting, registering, and expropriation by public policies (Brasil 1988, Art. 216, §1) and imposing that any damage caused to the heritage is subject to punishment (Brasil 1988, Art. 216, §4). As protective measures, the Brazilian Criminal Code (Brasil 1940) allows the prosecution of illegal fossil collection and trading activities through articles 163 (damage), 165 (damage to property of artistic, archeological or historic value), 166 (modification of especially protected locality), 180 (receiving), 318 (smuggling or embezzlement facilitation), and 334 (smuggling or embezzlement).

Nevertheless, international concern with the preservation of the geologic component of nature only strengthened in the Brazilian academic sphere during the 1990s. In March 1997, the former DNPM established the Brazilian Committee for Geological and Paleontological Sites (SIGEP), aiming for the protection of national geological and paleobiological sites (Schobbenhaus et al. 2002). Recognizing also their cultural value, the DNPM included the National Institute of Historic and Artistic Heritage (IPHAN) as one of the institutions that compose this committee. Among the main goals of SIGEP, we can highlight the creation of inventories regarding the main impact craters and sites of paleontological, paleoenvironmental, sedimentological, geomorphological, marine, igneous, speleological, and historic (regarding the history of Geology) value and the promotion of preservation and conservation activities for these sites (Schobbenhaus et al. 2002). The group of quarries that compose the Ouro Ichnosite was included in the SIGEP inventory by Leonardi and Carvalho (2002a), but the fossiliferous slabs removed from this region and used to pave sidewalks were not, despite their scientific and historic relevance and inclusion in Brazilian Cultural Heritage, following the Constitution (Brasil 1988). Other ichnofossiliferous sites inventoried by SIGEP include the dinosaur tracksites of the Rio do Peixe basin (Lower Cretaceous of Paraíba; Leonardi and Carvalho 2002b), the surroundings of the Porto Primavera hydroelectric powerplant (Upper Cretaceous of São Paulo; Fernandes et al. 2009), the Cristal paleoburrow (Quaternary of Rio Grande do Sul; Buchmann et al. 2013), and the Predebon Site (Upper Triassic of Rio Grande do Sul; Silva et al. 2013), besides several localities with Pre-Cambrian stromatolites in the states of Bahia, Minas Gerais, Rio de Janeiro, and São Paulo. However, although these sites have been included in the SIGEP inventory, few, if any, protection has apparently been ensured for their ichnological materials and, currently, SIGEP's activities have been suspended.

The collection of some types of trace fossils (such as tetrapod tracks, paleoburrows, and large-sized stromatolites) is unviable (and occasionally impossible), making these materials more susceptible to the lack of protection. An example of the constant threat to this particular type of fossils is the presence of constructions along the same site where material representing the *Megaichnus* ichnogenus is found (Buchmann et al., 2013; Lopes et al. 2017) in the municipality of Cristal (state of Rio Grande do Sul), which recently completely obstructed access to the paleoburrow (HF, personal observation). Ponciano et al. (2011) highlighted several main threats to fossil heritage, some of which are applicable to the Araraquara trace fossils and were identified in the present survey: vandalism, unfamiliarity of the population (or some part of it), urban and demographic growth, and construction and renovation of buildings and structures (Fig. 6). However, it is important to consider that these damages can also occur to in situ materials (e.g., Bird 1954; Leonardi 1984; Arman 2014) and that concern with the conservation of ichnosites is a global phenomenon (e.g., Agnew and Oxnam, 1983; Marty et al. 2004; Henriques et al. 2005; Santos et al. 2008; Agnew and Demas 2016; Bordreau et al. 2020).

Regarding the occurrence of geoheritage, Ponciano et al. (2011), Schemm-Gregory and Henriques (2013), and Brilha (2016) defined the concepts of ex situ and in situ paleontological heritages: while the former is represented by fossils that were collected and accommodated in scientific collections, the latter is represented by the entirety of fossils still present in a particular region and their scientific, didactic, and cultural values. Thus, following these definitions, the fossiliferous sidewalks of Araraquara can be considered a unique type of heritage. While the slabs are no longer in their original stratigraphic position in the Botucatu Formation (consequently, the fossil materials are ex situ), the presence of trace fossils in the urban context of Araraquara converts them to an in situ fossil heritage, given the intimate proximity to the municipality's inhabitants. This proximity is an inherent component to the understating of these track-bearing slabs as municipal cultural, architectonic, and historic heritage. However, the uniqueness of Araraquara's urban ichnological record hinders risk evaluations following what has been used in other tracksites. For example, Mampel et al. (2009) evaluated the heritage value of 11 Jurassic–Cretaceous dinosaur tracksites from the Teruel Province of Spain using a threefold set of parameters: scientific value, socio-cultural value, and deterioration risk. Based on this approach, they could rank the sites and establish conservation priorities. Lockley (2010) presented a similar method for tracksites in the USA. However, part of the values (e.g., site size, number of tracks and trackways, number of track levels, and visitation) used by Mampel et al. (2009) and Lockley (2010) is not applicable to the Araraquara track record, since these materials are placed ex situ and different flagstones (artificially trimmed in the quarries and laid out in various parts of the city) could contain portions of the same trackway. However, if we consider that each flagstone represents at least one potential trackway (which translates as 438 potential tetrapod trackways) and that they came from the same site, Araraquara would figurate among the largest tracksites in world, together with Cal Orck'o (Bolivia), Goseong (South Korea), and Lark Quarry (Australia) (Alcalá et al. 2016). At the same time, the cultural

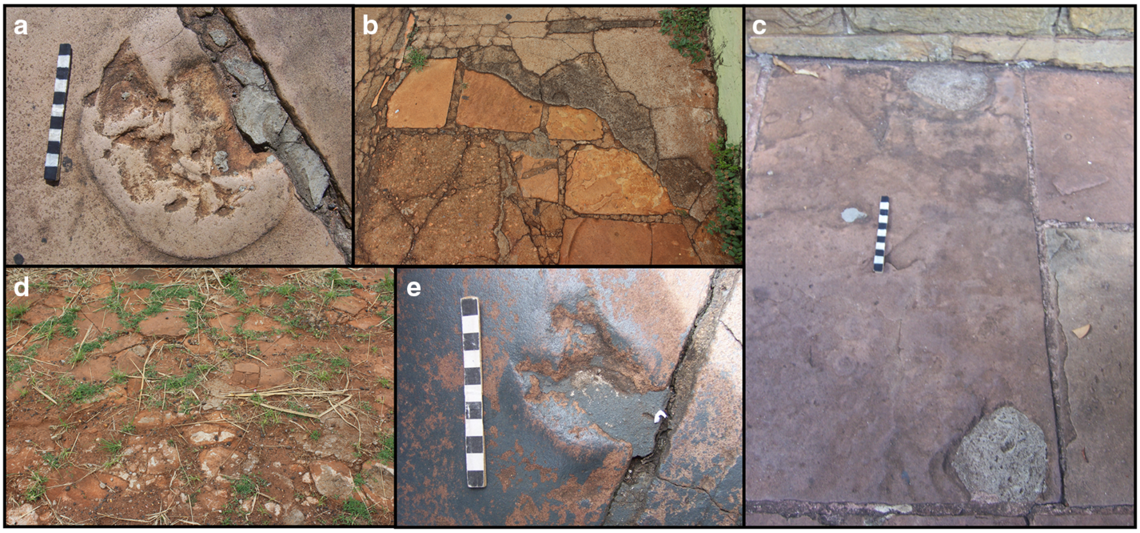

Fig. 6 Examples of damages to the paleontological heritage of Araraquara (Brazil). Scales: 10 cm

value and deterioration risk of Araraquara tracks are higher, as the Botucatu flagstones are part of the city's architecture and history and are constantly submitted to anthropogenic alteration (Fig. 6).

Recently, after a participative movement of the population, engaged in the protection of paleontological heritage, the Municipal Chamber of Araraquara approved Law No. 9503 on March 18, 2019 (Araraquara 2019), which regard procedures for the removal, refurbishment, remodeling, readjustment, disposal, painting, and other activities involving public sidewalks paved with flagstones from the Botucatu Formation. This new law aims to protect and safeguard the sandstone slabs, especially those that have trace fossils, and came into effect as of March 21, 2019. In addition to protection measures, all slabs removed from the sidewalks should be sent to the Araraquara Museum of Archeology and Paleontology (MAPA), where they go through technical and administrative procedures required for inventorying and incorporation into MAPA's public collection. Furthermore, the creation of a permanent open-air exhibition (called informally "Open-Air Museum") on the sidewalks of the Voluntários da Pátria Street, around MAPA's main building allowed maintaining specimens of lower scientific value on the sidewalks, allowing free access to the population. Temporary and permanent exhibitions related to the Araraquara fossil geoheritage (current exhibition named *Areias do Passado*, *Marcas do Presente*), short courses, lectures and talks, and educational activities targeting non-academic audience—such as a supervised tour for the "fossil addresses of the city" combined with an updated inventory (activity named *As Pegadas da Minha Rua*; Fig. 7)—are among the main activities developed by MAPA.

The importance of housing paleontological materials in collections that allow open access to researchers and that provide conditions for their conservation is clear within the debate of fossil protection and management. Track-bearing slabs

Fig. 7 Children and adults participating in the activity *As Pegadas da Minha Rua* performed by Fundação Araporã in association with MAPA and the Municipality Hall of Araraquara in 2019. Photos from Fundação Araporã's archive

of high scientific value (such as those with optimal degree of conservation) must be collected and accommodated in a proper collection (for example, in MAPA), allowing their conservation and study. However, for Ponciano et al. (2011) one of the greatest disadvantages of maintaining paleontological heritage exclusively ex situ (e.g., a fossil collection) is its *distancing* from the community. Therefore, maintaining part of the fossiliferous slabs on the sidewalks of Araraquara is crucial for preserving the identity of this heritage. The idea of an open-air exhibition proposed by Leonardi et al. (2007), Fernandes and Corrêa (2007), and Fernandes et al. (2008) not only contemplates the conservation of the scientific value of these slabs (assuring them protection and accessibility) but also reinforces the cultural, architectonic, and urban character of this peculiar fossil heritage.

Urban geotourism is very well established and successful in other urban areas around the world. For example, Palacio-Prieto (2015) described several urban geosites in the Mexico City, which include buildings (such as the *Palacio de Bellas Artes*) constructed with numerous types of marble and onyx quarried in distinct localities of the country. In this context, the *Palacio de Bellas Artes* geosite, provides an easy access to a collection of several types of rocks from Mexico and the history of the country, being visited by around 1.3 million persons per year (Palacio-Prieto 2015). In Brazil, Del Lama et al. (2015) tracked the history of São Paulo old center occupation based on the use of metamorphic, igneous, and sedimentary (including Botucatu flagstones) rocks as feedstock for masonry and construction of buildings and proposed a geotouristic route. Other examples in Brazil come from Curitiba (Liccardo et al. 2008), Rio de Janeiro (Mansur and Silva 2011), and Salvador (Liccardo et al. 2012). Urban geoturism is usually related to non-paleontological geological aspects (Hose 1995), like in the above mentioned examples, but the presence of dinosaur tracks and other trace fossils on the sidewalks of Araraquara could act as a charismatic argument to implement urban touristic routes. The conservation of tracksites and their use for multiple purposes (tourism, science, education, etc.) varies around the world (Marty et al., 2007, Agnew and Demas 2016, Bordreau et al. 2020). The urban vocation of the Araraquara trace fossil record offers a unique opportunity to discuss multiple visions of management and conservation of paleontological heritage.

Future Perspectives and Conclusions

In this contribution we present a survey conducted on the fossiliferous slabs of sidewalks in the municipality of Araraquara, Brazil. These slabs have been extracted from (at least) seven quarries at the Ouro Ichnosite since the beginning of the twentieth century. These quarries are outcrops of paleodunes from the Botucatu Formation (Lower Cretaceous). In the region surveyed, we found 585 slabs with trace fossils, most comprising dinosaur (37.43%) and mammal (27.69%) tracks. Invertebrate traces were less abundant (18.80%). These materials were also classified according to their degree of conservation, with 26.66% of slabs presenting an advanced degree of mischaracterization related to anthropic damage. On the other hand, 9.91% of slabs have high scientific potential, due to their optimal degree of conservation and good preservation of traces. Among them, we highlight the presence of *Cochlichnus* and dinosaur and mammal elite tracks.

MAPA has been a reference in the conservation of fossil heritage in Araraquara, as well as in scientific communication to locals and visitors based on educational activities (such as lectures, short-courses, mediated visits to the museum exhibition, and supervised tours by the Botucatu flagstone-made sidewalks). In addition, the approval of municipal Law No. 9503 legitimizes the protection of track-bearing slabs in the sidewalks. The conservation of specimens in sidewalks is essential to plan activities with educational and urban geotourism purposes (such as patrimonial education, scientific communication, and sustainable tourism). Thus, the open-air exhibition of MAPA serves as a model for the rest of the city, suggesting that the conservation of the track-bearing flagstones on the sidewalks is an important resource for geotouristic and educational activities. In the near future, it is expected that optimally conserved and more representative materials will be collected and housed in MAPA, but most slabs must be kept with right conservation and interpretation measures on the sidewalks, where their historic, architectonic, touristic, educational, and scientific value makes Araraquara a location of unique heritage.

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References

Agnew N, Demas M (2016) Fossil tracks and trackways: the dilemmas of preservation. J Paleontol Techn 15:3–21

Agnew N, Griffin H, Wade M, Tebble T, Oxanam W (1989) Strategies and techniques for the preservation of fossil tracksites: an Australian example. In: Gillette DD, Lockley MG (eds) Dinosaur tracks and traces. Cambridge University Press, Cambridge, pp 397–407

Agnew N, Oxnam WB (1983) Conservation of the lark quarry dinosaur trackway. Curator 26(3):219–233

Alcalá L, Lockley MG, Cobos A, Mampel L, Royo-Torres R (2016) Evaluating the dinosaur track record: an integrative approach to understanding the regional and global distribution, scientific importance, preservation, and management of tracksites. In: Falkingham PL, Marty D, Richter A (eds) Dinosaur tracks: the next steps. Indiana University Press, Bloomington, pp 100–114

Almeida FFM (1950) Uma faunula de crustáceos bivalvos do Arenito Botucatú no estado de São Paulo. Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia (Boletim 134), Rio de Janeiro

Almeida FFM (1954) Botucatu, um deserto Triássico da América do Sul. Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia, Notas Preliminares e Estudos (Boletim 86), Rio de Janeiro

Almeida FFM, Assine ML, Carneiro CR (2012) A megadesertificação mesozoica. In: Hasui Y, Carneiro CR, Almeida FFM, Bartorelli A (orgs) Geologia do Brasil. Beca, São Paulo, pp 419–428

Araraquara (2003) Lei Municipal no. 6.055. Dispõe sobre a criação do Conselho Municipal de Preservação do Patrimônio Histórico, Arquitetônico, Paleontológico, Etnográfico, Arquivístico, Bibliográfico, Artístico, Paisagístico, Cultural e Ambiental do Município de Araraquara - COMPPHARA e dá outras providências. Accessed in 16 May 2019

Araraquara (2019) Lei Municipal no. 9.503. Dispõe sobre o procedimento de remoção, reforma, remodelação, readequação, descarte, pintura e outras obras envolvendo áreas destinadas ao passeio público (calçadas) revestidas de lajes de arenito da Formação Botucatu. Accessed in 30 August 2019

Arman S (2014) It's time to stop the fossil trade in its tracks—and here's how. The Conversation. https://theconversation.com/its-time-to-stop-the-fossil-trade-in-its-tracks-and-heres-how-26330.

Baksi AK (2018) Paraná flood basalt volcanism primarily limited to ~1 Myr beginning at 135 Ma: new $^{40}Ar/^{39}Ar$ ages for rocks from Rio Grande do Sul, and critical evaluation of published radiometric data. J Volcanol Geoth Res 355:66–77

Belvedere M, Farlow JO (2016) A numerical scale for quantifying the quality of preservation of vertebrate tracks. In: Falkingham PL, Marty D, Richter A (eds) Dinosaur tracks: the next steps. Indiana University Press, Bloomington, pp 92–98

Bigarella JJ (1979) Botucatú and Sambaiba Sandstones of South America (Jurassic and Cretaceous). In: McKee ED (ed) A study of global sand seas. United States Government Printing Office, Washington, pp 233–236

Bird RT (1954) We captured a 'live' brontosaur. Natl Geogr 105(5):707–722

Bjornberg AJS, Tolentino M (1959) Contribuição ao estudo da geologia e águas subterrâneas em São Carlos, S.P. Bol Soc Bras Geol 8(2):5–33

Borba AW, Sell JC (2018) Uma reflexão crítica sobre os conceitos e práticas da geoconservação. Geogr Merid 4(1):02–28

Bordreau D, Santucci V, Widrig K, Nebel M, Miller A, Colvin R, Besom K, Hyde C (2020) Grand Canyon National Park paleontological resources management and protection. In Santucci VL, Tweet JS (eds) Grand Canyon National Park: centennial paleontological resource inventory (non-sensitive version). Natural Resource Report NPS/GRCA/NRR–2020/2103. National Park Service, Fort Collins, pp 465–500

Brasil (1937) Decreto-Lei n° 25, de 30 de novembro de 1937. Organiza a proteção do patrimônio histórico e artístico nacional. http://www.planalto.gov.br/ccivil_03/decreto-lei/Del0025.htm. Accessed in 27 September 2019

Brasil (1940) Decreto-Lei n° 2.848, de 07 de dezembro de 1940. Código penal. https://www2.camara.leg.br/legin/fed/declei/1940-1949/decreto-lei-2848-7-dezembro-1940-412868-publicacaooriginal-1-pe.html. Accessed in 27 September 2019

Brasil (1942) Decreto-Lei n° 4.146, de 04 de março de 1942. Dispõe sobre a proteção dos depósitos fossilíferos. http://www.planalto.gov.br/ccivil_03/decreto-lei/1937-1946/Del4146.htm. Accessed in 27 September 2019

Brasil (1988) Constituição da República Federativa do Brasil de 1988. http://www.planalto.gov.br/ccivil_03/Constituicao/Constituicao.htm. Accessed in 27 September 2019

Brilha J (2016) Inventory and quantitative assessment of geosites and geodiversity sites: a review. Geoheritage 8(2):119–134

Buchmann FS, Lopes RP, Caron F (2013) Paleotoca do município de Cristal, RS. Registro da atividade fossorial de mamíferos gigantes extintos no sul do Brasil. In: Winge M, Schobbenhaus C, Souza CRG, Fernandes ACS, Berbert-Born M, Salun Filho W, Queiroz ET (eds) Sítios Geológicos e Paleontológicos do Brasil, vol 3. DNPM/CPRM/SIGEP, Brasília, pp 201–210

Buck PV, Ghilardi AM, Fernandes LBR, Fernandes MA (2017a) A new ichnotaxon classification of large mammaliform trackways from the Lower Cretaceous Botucatu Formation, Paraná Basin, Brazil. Palaeogeogr Palaeocl 485:377–388

Buck PV, Ghilardi AM, Peixoto BCPM, Fernandes LBR, Fernandes MA (2017b) A new tetrapod ichnotaxon from Botucatu Formation, Lower Cretaceous (Neocomian), Brazil, with comments on fossil track preservation on inclined planes and local paleoecology. Palaeogeogr Palaeocl 466:21–37

Casamiquela RM (1975) Nuevo material y reinterpretación de las icnitas mesozoicas (Neotriásicas) de Los Menucos, Provincia de Rio Negro (Patagonia). Anales del 1^er^Congreso Argentino de Paleontología y Biostratigrafía, Tucumán, pp 555–580

Chagas MS (2007) Casas e portas da memória e do patrimônio. Em Questão13(2): 207–224

Chamberlain CK (1975) Recent lebensspuren in nonmarine aquatic environments. In: Frey RW (ed) The study of trace fossils. Springer-Verlag, New York, pp 431–458

Del Lama EA, Bacci DLC, Martins L, Garcia MGM, Dehira LK (2015) Urban geotourism and the Old Centre of São Paulo City, Brazil. Geoheritage 7(2):147–164

Eiseman C, Charney N (2010) Tracks and sign of insects and other invertebrates: a guide to north American species. Stackpole, Mechanicsburg

Ernesto M, Raposo MIB, Marques LS, Renne PR, Diogo LA, de Min A (1999) Paleomagnetism, geochemistry and $^{40}Ar/^{39}Ar$ dating of the north-eastern Paraná Magmatic Province: tectonic implications. J Geodyn 28:321–340

Faccini UF, Paim PSG, Netto RG, Nowatzki CH (1989) A seqüência deposicional Botucatu (RS). Anais do 11° Congresso Brasileiro de Paleontologia, Curitiba, pp 183–194

Fernandes ACS, Borghi L, Carvalho IS, Abreu CJ (2002) Guia dos Icnofósseis de Invertebrados do Brasil. Interciência, Rio de Janeiro

Fernandes ACS, Carvalho IS, Netto RG (1990) Icnofósseis de invertebrados da Formação Botucatu, São Paulo (Brasil). An Acad Bras Ciênc 62(1):45–49

Fernandes LA, Sedor FA, Silva RC, Silva LR, Azevedo AA, Siqueira AG (2009) Icnofósseis da Usina Porto Primavera, SP. Rastros de dinossauros e de mamíferos em rochas do deserto neocretáceo Caiuá. In: Winge M, Schobbenhaus C, Souza CRG, Fernandes ACS, Queiroz ET, Berbert-Born M, Campos DA (eds) Sítios Geológicos e Paleontológicos do Brasil, vol 2. DNPM/CPRM/SIGEP, Brasília, pp 479–487

Fernandes MA (2005) Paleoicnologia em ambientes desérticos: análise da icnocenose de vertebrados da pedreira São Bento (Formação Botucatu, Jurássico Superior-Cretáceo Inferior, Bacia do Paraná), Araraquara, SP. PhD Thesis, Universidade Federal do Rio de Janeiro

Fernandes MA, Carvalho IS (2007) Pegadas fósseis da Formação Botucatu (Jurássico Superior–Cretáceo Inferior): o registro de um grande dinossauro Ornithopoda na Bacia do Paraná. In: Carvalho IS, Cassab RCT, Schwanke C, Carvalho MA, Fernandes ACS, Rodrigues MAC, Carvalho MSS, Arai M, Oliveira MEQ (eds) Paleontologia: Cenários de Vida. Interciência, Rio de Janeiro, pp 425–432

Fernandes MA, Carvalho IS (2008) Revisão diagnóstica para a icnoespécie de tetrápode Mesozóico *Brasilichnium elusivum* (Leonardi, 1981) (Mammalia) da Formação Botucatu, Bacia do Paraná, Brasil. Ameghiniana 45(1):167–173

Fernandes MA, Corrêa RC (2007) Patrimônio icnofossilífero das vias públicas da cidade de São Carlos, SP: resgate histórico, científico e cultural como referência para um museu a céu aberto. In: Carvalho IS, Cassab RCT, Schwanke C, Carvalho MA, Fernandes ACS, Rodrigues MAC, Carvalho MSS, Arai M, Oliveira MEQ (eds) Paleontologia: Cenários de Vida. Interciência, Rio de Janeiro, pp 151–162

Fernandes MA, Fernandes LBR (2010) The ichnogenus *Paleohelcura* from the Botucatu paleodesert (Neocomian), Brazil. Libro de Resúmenes del 1er Simposio Latinoamericano de Icnología, São Leopoldo, p 35

Fernandes MA, Fernandes LBR, Souto PRF (2004) Occurrence of urolites related to dinosaurs in the Lower Cretaceous of the Botucatu Formation, Paraná Basin, São Paulo State, Brazil. Rev Bras Paleontolog 7(2):236–268

Fernandes MA, Francischini H, Carvalho IS (2008) Paleoicnologia Urbana: o patrimônio fossilífero de Araraquara, Estado de São Paulo, Brasil. Mem Not 3:455–462

Fernandes, MA, Ghilardi, AM, Carvalho, IS, Leonardi, G (2011) Pegadas de dinossauros Theropoda do paleodeserto Botucatu (Jurássico Superior - Cretáceo Inferior) da Bacia do Paraná. In: Carvalho IS, Srivastava NK, Strohschoen Jr. O, Lana CC (eds). Paleontologia: Cenários de Vida, vol 4. Interciência, Rio de Janeiro, pp 609–621

Fernandes MA, Ghilardi AM, Carvalho IS (2014) Paleodeserto Botucatu: inferências ambientais e climáticas com base na ocorrência de icnofósseis. In: Carvalho IS, Garcia MJ, Lana CC, Strohschoen O (eds) Paleontologia: Cenários de Vida, vol 5. Interciência, Rio de Janeiro, pp 71–80

Francischini H, Dentzien-Dias PC, Fernandes MA, Schultz CL (2015) Dinosaur ichnofauna of the Upper Jurassic/Lower Cretaceous of the Paraná Basin (Brazil and Uruguay). J S Am Earth Sci 63:180–190

Francischini H, Dentzien-Dias P, Gobbi V, Fernandes MA (2018a) As lendas e a ciência por trás dos répteis gigantes de Araraquara. Rev Biol 18(1):31–36

Francischini H, Dentzien-Dias P, Lucas SG, Schultz CL (2018b) Tetrapod tracks in Permo-Triassic eolian beds of southern Brazil (Paraná Basin). PeerJ 6:e4764

Gonçalves JRS (2005) Ressonância, materialidade e subjetividade: as culturas como patrimônio. Horizontes Antropológicos 11(23):15–36

Haubold H (1971) Ichnia Amphibiorum et Reptiliorum fossilium. In: Kuhn O (ed) Handbuch der Paläoherpetologie, Teil, vol 18. Gustav Fischer Verlag, Stuttgart, pp 1–124

Henriques MHP, Azerêdo AC, Duarte LV, Ramalho MM (2005) Jurassic Heritage and Geoconservation in Portugal: selected studies. IV International Symposium ProGEO on the Conservation of the Geological Heritage, Coimbra, 86 p

Henriques MHP, Pena dos Reis R (2015) Framing the palaeontological heritage within the geological heritage: an integrative vision. Geoheritage 7(3):249–259

Hitchcock E (1858) Ichnology of New England. A report on the sandstone of the Connecticut Valley, especially its fossil Footmarks. William White, Boston

Hose TA (1995) Selling the story of Britain's stone. Environ Interpret 10: 16–17

Huene FF (1931) Verschiedene mesozoische Wirbel tierreste aus Südamerika. Neues Jb Miner 66(B):181–198

Hunt AP, Lucas SG (2012) Classification of vertebrate coprolites and related trace fossils. New Mex Mus Nat Hist Sci Bull 57:137–146

Janasi VA, Freitas VA, Heaman LH (2011) The onset of flood basalt volcanism, Northern Paraná Basin, Brazil: a precise U-Pb baddeleyite/zircon age for a Chapecó-type dacite. Earth Planet Sc Lett 302:147–153

Krapovickas V, Mángano MG, Buatois LA, Marsicano CA (2016) Integrated ichnofacies models for deserts: recurrent patterns and megatrends. Earth-Sci Rev 157:61–85

Kümmel SB, Frey E (2012) Digital arcade in the autopodia of Synapsida: standard position of the digits and dorsoventral excursion angle of digital joints in the rays II–V. Palaeobio Palaeoenv 92(2):171–196

Lacerda MB, Dias EV (2008) Icnofóssil atribuído a *Brasilichnium elusivum* Leonardi, 1981 identificado no *campus* da Universidade Positivo, Curitiba (Paraná-Brasil). Rev Univ Pos Biol Saúde 1(3): 76–83

Leonardi G (1977) On a new occurrence of tetrapod trackways in the Botucatu Formation in the State of São Paulo, Brazil. Dusenia 10(3):181–183

Leonardi G (1979) A comparative glossary of vertebrate ichnology in Portuguese and the history of this science in Brazil. Cadernos Univ 17:1–55

Leonardi G (1980) On the discovery of an abundant ichno-fauna (vertebrates and invertebrates) in the Botucatu Formation s.s. in Araraquara, São Paulo, Brazil. An Acad Bras Ciênc 52(3):559–567

Leonardi G (1981) Novo icnogênero de tetrápode mesozóico da Formação Botucatu, Araraquara, SP. An Acad Bras Ciênc 53(4): 793–805

Leonardi G (1984) Rastros de um mundo perdido. Ciência Hoje 3(15): 48–60

Leonardi G (1994) Annotated atlas of South America tetrapod footprints (Devonian to Holocene) with an appendix on Mexico and Central America. Brasília, Companhia de Pesquisa de Recursos Minerais

Leonardi G (1996) Le piste di dinosauri dei Lavini di Marco (Rovereto, TN, Italia) e alcune questioni generali sull'icnologia dei Tetrapodi. Atti Acc Rov Agiati 6(B):65–104

Leonardi G (1997) Problematica actual de las icnitas de dinosaurios. Rev Soc Geol España 10(3–4):341–353

Leonardi G, Carvalho IS (2002a) Jazigo Icnofossilífero do Ouro, Araraquara, SP. Ricas pistas de tetrápodes do Jurássico. In: Schobbenhaus C, Campos DA, Queiroz ET, Winge M, Berbert-Born M (eds) Sítios Geológicos e Paleontológicos do Brasil, vol 1. DNPM/CPRM/SIGEP, Brasília, pp 39–48

Leonardi G, Carvalho IS (2002b) Icnofósseis da Bacia do Rio do Peixe, PB. O mais marcante registro de pegadas de dinossauros do Brasil. In: Schobbenhaus C, Campos DA, Queiroz ET, Winge M, Berbert-Born M (eds) Sítios Geológicos e Paleontológicos do Brasil, vol 1. DNPM/CPRM/SIGEP, Brasília, pp 101–111

Leonardi G, Carvalho IS, Fernandes MA (2007) The desert ichnofauna from Botucatu Formation (Upper Jurassic-Lower Cretaceous), Brazil. In: Carvalho IS, Cassab RCT, Schwanke C, Carvalho MA, Fernandes ACS, Rodrigues MAC, Carvalho MSS, Arai M, Oliveira MEQ (eds) Paleontologia: Cenários de Vida. Interciência, Rio de Janeiro, pp 379–391

Leonardi G, Godoy LC (1980) Novas pistas de tetrápodes da Formação Botucatu no estado de São Paulo. Anais do 31° Congresso Brasileiro de Geologia, Balneário Camboriú, pp. 3080–3089

Leonardi G, Oliveira FH (1990) A revision of the Triassic and Jurassic tetrapod footprints of Argentina and a new approach on the age and meaning of the Botucatu Formation footprints (Brazil). Rev Bras Geoc 2(K1-4): 216–229

Leonardi G, Sarjeant WAS (1986) Footprints representing a new Mesozoic vertebrate fauna from Brazil. Mod Geol 10:73–84

Liccardo A, Piekarz G, Salamuni E (2008) Geoturismo em Curitiba. Mineropar, Curitiba

Liccardo A, Mantesso-Neto V, Piekarz G (2012) Geoturismo urbano – educação e cultura. Anuário Inst Geociênc UFRJ 35(1):133–141

Lockley MG (2010) Dinosaur Ridge ranks tops among America's largest dinosaur tracksites! Dinosaur Ridge Report 22(3):16–19

Lockley MG (2011) The ichnotaxonomic status of *Brasilichnium* with special reference to occurrences in the Navajo Sandstone (Lower Jurassic) in the Western USA. New Mex Mus Nat Hist Sci Bull 53:306–315

Lockley MG, Hunt AP (1995) Dinosaur tracks and other fossil footprints of the Western United States. Columbia University Press, New York

Lopes RP, Frank HT, Buchmann FSC, Caron F (2017) *Megaichnus* igen. nov.: giant paleoburrows attributed to extinct Cenozoic mammals from South America. Ichnos 24(2):133–145

Mampel L, Cobos A, Alcalá L, Luque L, Royo-Torres R (2009) An integrated system of heritage management applied to dinosaur sites in Teruel (Aragón, Spain). Geoheritage 1:53–73

Mansur KL, Silva AS (2011) Society's response: assessment of the performance of the "Caminhos Geológicos" ("geological paths") project, State of Rio de Janeiro, Brazil. Geoheritage 3:27–39

Marty D, Ayer, J, Becker, D, Berger J-P, Billon-Bruyat J-P, Braillard L, Hug WA, Meyer CA (2007) Late Jurassic dinosaur tracksites of the Transjurane highway (Canton Jura, NW Switzerland): overview and measures for their protection and valorisation. Bull Angew Geol 12(1):75–89

Marchetti L, Belvedere M, Voigt S, Klein H, Castanera D, Díaz-Martínez I, Marty D, Xing L, Feola S, Melchor RN, Farlow JO (2019) Defining the morphological quality of fossil footprints. Problems and principles of preservation in tetrapod ichnology with examples from the Paleozoic to the present. Earth-Sci Rev 193:109–145

Marconato LP, Bertini RJ (1999) Avaliação preliminar do panorama icnofossilífero nas vias públicas da cidade de São Carlos (SP). Boletim de Resumos do 16° Congresso Brasileiro de Paleontologia, Crato, p 65

Marty D, Cavin L, Hug WA, Jordan P, Lockley MG, Meyer CA (2004) The protection, conservation and sustainable use of the Courtedoux dinosaur tracksite, Canton Jura. Switzerland Revue Paléobiol 9:39–49

Marty D, Falkingham PL, Richter A (2016) Dinosaur track terminology: a glossary of terms. In: Falkingham PL, Marty D, Richter A (eds) Dinosaur tracks: the next steps. Indiana University Press, Bloomington, pp 399–402

Meléndez G, Soria-Llop C (2000) Protecting the palaeontological heritage in Spain: public awareness and legislation, and the role of the Spanish Palaeontological Society. Lectures, 3rd International Symposium Progeo on the Conservation of the Geological Heritage, Madrid, pp 184–201

Mendes JC (1944) Bibliografia geológica, mineralógica, petrográfica e paleontológica do estado de São Paulo. Instituto Geográfico e Geológico, São Paulo, 57 pp

Mezzalira S (1966) Os fósseis do Estado de São Paulo. Bol Inst Geogr Geol 45:5–132

Mezzalira S (1989) Os fósseis do Estado de São Paulo. São Paulo, Instituto Geológico

Mezzalira S, Maranhão MSAS, Vieira PC (1989) Bibliografia analítica da paleontologia do Estado de São Paulo. Bol Inst Geol 8:9–235

Mezzalira S, Wohlers A (1952) Bibliografia da geologia, mineralogia, petrografia e paleontologia do estado de São Paulo. Bol Inst Geogr Geol 33:5–62

Milani EJ, Faccini UF, Scherer CMS, Araújo LM, Cupertino JA (1998) Sequences and stratigraphic hierarchy of the Paraná Basin (Ordovician to Cretaceous), southern Brazil. Boletim IG-USP, Série Científica 29:125–173

O Estado de São Paulo (1909) Os Municipios. Report from 20 October 1909, p 3

Pacheco JAA (1913) Notas sobre a geologia do valle do Rio Grande a partir da fóz do Rio Pardo até sua confluência com o Rio Paranahyba. Anais do 1° Congresso de Geografia e Geologia do Estado de São Paulo, São José dos Dourados, pp 33–38

Palacio-Prieto JL (2015) Geoheritage within cities: urban geosites in Mexico City. Geoheritage 7(4):365–373

Paraguassu AB (1970) Estruturas sedimentares da Formação Botucatu. Min Met 51(301):25–30

Padula E, Mingramm A (1967) Sub-surface Mesozoic red-beds of the Chaco-Mesopotamian region, Argentina and their relatives in Uruguay and Brazil. Gondwana Stratigraphy, Proceedings of the IUGS Symposium, Buenos Aires, pp 1053–1067

Peixoto BCPM, Fernandes MA (2010) Ocorrência de *Hexapodichnus* sp. em arenitos da Formação Botucatu, Jurássico-Cretáceo da Bacia do Paraná (Araraquara, São Paulo, Brasil). Libro de Resúmenes del 1er Simposio Latinoamericano de Icnología, São Leopoldo, p 50

Perea D, Soto M, Veroslavsky G, Martínez S, Ubilla M (2009) A Late Jurassic fossil assemblage in Gondwana: biostratigraphy and correlations of the Tacuarembó Formation, Parana Basin, Uruguay. J S Am Earth Sci 28:168–179

Pinto VM, Hartmann LA (2011) Flow-by-flow chemical stratigraphy and evolution of thirteen Serra Geral Group basalt flows from Vista Alegre, southernmost Brazil. An Acad Bras Ciênc 83(2):425–440

Pires EF, Guerra-Sommer M, Scherer CMS, Santos AR, Cardoso E (2011) Early Cretaceous coniferous woods from a paleoerg (Paraná Basin, Brasil). J S Am Earth Sc 32:96–109

Piuci J, Diniz HN (1985) Conhecimento do Aqüífero Botucatu na cidade de Araraquara – SP. Rev Inst Geol São Paulo 6(1/2):23–37

Ponciano LCMO, Castro ARSF, Machado DMC, Fonseca VMM, Kunzler J (2011) Patrimônio Geológico-Paleontológico *in situ* e *ex situ*: definições, vantagens, desvantagens e estratégias de conservação. In: Carvalho IS, Srivastava NK, Strohschoen O Jr, Lana CC (eds) Paleontologia: Cenários de Vida. Interciência, Rio de Janeiro, pp 853–869

Porchetti SD, Bertini RJ, Langer MC (2018) Proposal for ichnotaxonomic allocation of therapsid footprints from the Botucatu Formation (Brazil). Ichnos 25(2–3):192–207

Prats L (1994) Antropología y Patrimonio. Ariel, Barcelona

Renne PR, Ernesto M, Pacca IG, Coe RS, Glen JM, Prévot M, Perrin M (1992) The age of Paraná flood volcanism rifting of Gondwanaland, and the Jurassic–Cretaceous boundary. Science 258:975–979

Rossetti L, Lima EF, Waichel BL, Hole MJ, Simões MS, Scherer CMS (2018) Lithostratigraphy and volcanology of the Serra Geral Group, Paraná-Etendeka Igneous Province in southern Brazil: towards a formal stratigraphical framework. J Volcanol Geoth Res 355:98–114

Sandstedt R, Sullivan T, Schuster ML (1961) Nematode tracks in the study of movement of *Meloidogyne incognita incognita*. Nematologica 6:261–265

Santos VF, Silva CM, Rodrigues LA (2008) Dinosaur track sites from Portugal: scientific and cultural significance. Oryctos 8:77–88

Schemm-Gregory M, Henriques MH (2013) The Devonian brachiopod collections of Portugal— a palaeontological heritage. Geoheritage 5(2):107–122

Scherer CMS (2000) Eolian dunes of the Botucatu Formation (Cretaceous) in southernmost Brazil: morphology and origin. Sediment Geol 137:63–84

Scherer CMS (2002) Preservation of aeolian genetic units by lava flows in the Lower Cretaceous of the Paraná Basin, southern Brazil. Sedimentology 49:97–116

Scherer CMS, Goldberg K (2007) Paleowind patterns during the latest Jurassic–earliest Cretaceous in Gondwana: evidence from aeolian cross-strata of the Botucatu Formation, Brazil. Palaeogeogr Palaeocl 250:89–100

Scherer CMS, Lavina EL (2006) Stratigraphic evolution of a fluvial-eolian succession: the example of the Upper Jurassic–Lower

Cretaceous Guará and Botucatu formations, Paraná Basin, southernmost Brazil. Gondwana Res 9:475–484

Schobbenhaus C, Campos DA, Queiroz ET, Winge M, Berbert-Born MLC (2002) Sítios Geológicos e Paleontológicos do Brasil. DNPM/CPRM/SIGEP, Brasília

Silva RC, Godoy MM, Binotto RB, Zerfass H (2013) Sítio fossilífero Predebon, Quarta Colônia, RS. Pegadas de vertebrados triássicos no sul da Bacia do Paraná. In: Winge M, Schobbenhaus C, Souza CRG, Fernandes ACS, Berbert-Born M, Salun Filho W, Queiroz ET (eds) Sítios Geológicos e Paleontológicos do Brasil, vol 3. DNPM/CPRM/SIGEP, Brasília, pp 225–234

Souza A, Sinelli O, Gonçalves NMM (1971) Nova ocorrência fossilíferas na Formação Botucatu. Anais do XXV Congresso Brasileiro de Geologia, São Paulo, pp 281–295

Stollhofen H (1999) Karoo Syndrift-Sedimentation und ihre tektonische Kontrolle am entstehenden Kontinentalrand Namibias. Deutsche Geologische Gesellschaft 149:519–623

Suguio K, Coimbra AM (1972) Madeira fóssil silicificada na Formação Botucatu. Ciênc Cult 24:1049–1055

Tamrat E, Ernesto M (2006) Paleomagnetic constraints of the age of the Botucatu Formation in Rio Grande do Sul, southern Brazil. An Acad Bras Ciênc 78(3):591–605

Thiede DS, Vasconcelos PM (2010) Paraná flood basalts: rapid extrusion hypothesis confirmed by new ^{40}Ar-^{39}Ar results. Geology 38(8): 747–750

Thulborn T (1990) Dinosaur tracks. Chapman and Hall, London

Turner S, Regelous M, Kelley S, Hawkesworth C, Mantovani M (1994) Magmatism and continental break-up in the South Atlantic: high precision ^{40}Ar-^{39}Ar geochronology. Earth Planet Sc Lett 121:333–348

Waichel BL, Scherer CMS, Frank HT (2008) Basaltic lava flows covering active aeolian dunes in the Paraná Basin in southern Brazil: features and emplacements aspects. J Volcanol Geoth Res 171:59–72

Würdig NM, Pinto ID (2001) New data on limnic Mesozoic Ostracoda of Botucatu Formation from São Paulo State, Brazil. Acta Geol Leopold XXIV(52/53): 207–226

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CORRECTION

Correction to: The Ichnological Record of Araraquara Sidewalks: History, Conservation, and Perspectives from This Urban Paleontological Heritage of Southeastern Brazil

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In spite of the correction made by the authors, this paper was published online in its non-corrected proof version. Although the typo and formating errors do not affect the validity of the results and discussion presented, we feel they can be rectified here.

The correct order of the Figs. 4 and 5 was switched. The correct way in which they should appear is provided below.

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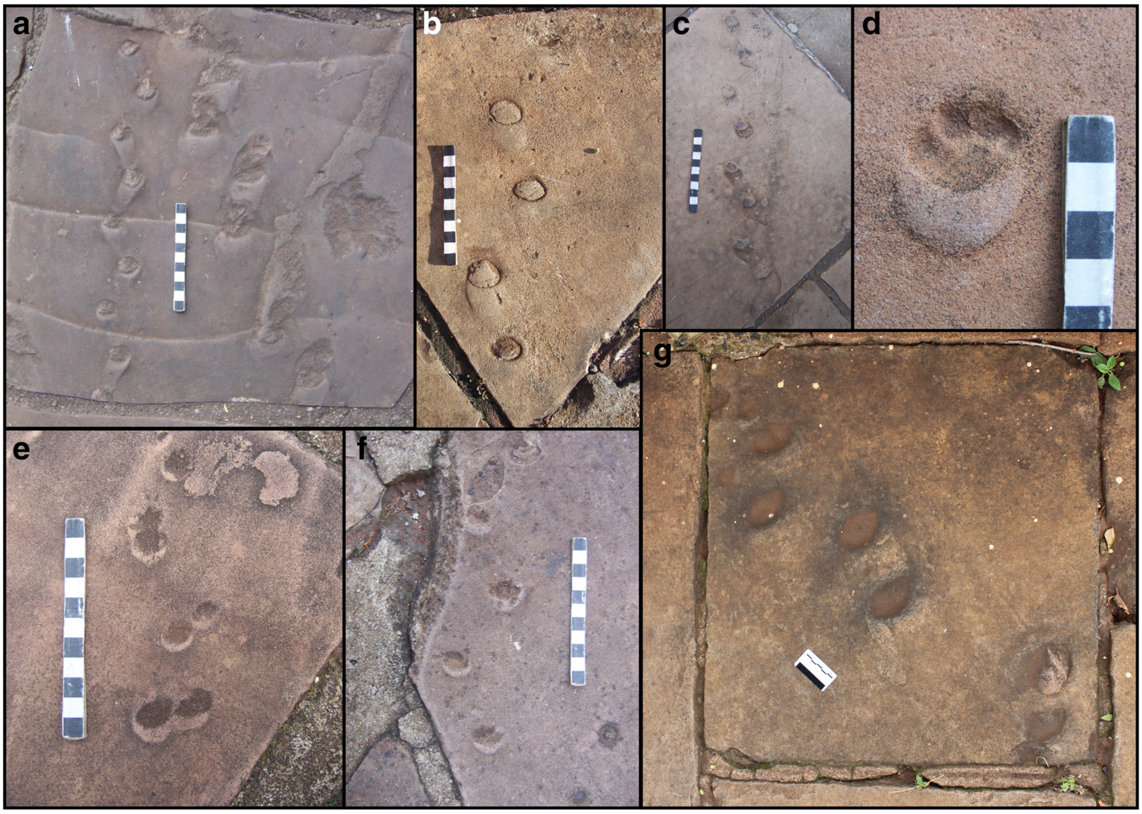

Fig. 4 Mammal tracks (Morphotype 4) found in slabs from the sidewalks of Araraquara, Brazil. Scale bars in centimeters

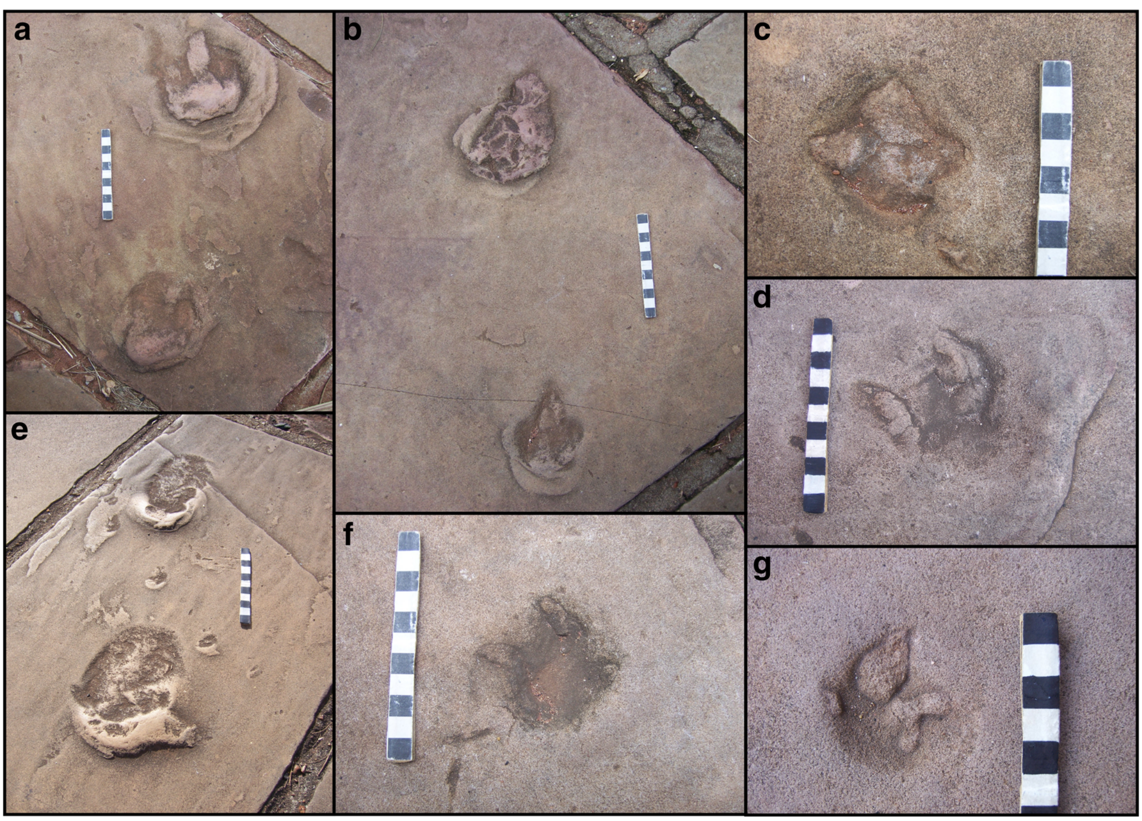

Fig. 5 Dinosaur tracks (Morphotype 5) found in slabs from the sidewalks of Araraquara, Brazil. Scale bars in centimeters