Geoheritage (2022) 14:107
https://doi.org/10.1007/s12371-022-00737-1

ORIGINAL ARTICLE

The Invisibles of Science and the Paleontological Heritage: the Brazilian Study Case

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Received: 30 May 2022 / Accepted: 19 August 2022

Abstract
Paleontology, as a science of discoveries, mainly prioritizes those that describe new fossils, in general, as the work of individuals disconnected from the social and economic reality in which they are inserted. The discovery of the new transfers one into the possibility of social recognition and therefore into the record of the individual's proper memory. However, the paleontological research has a complexity that transcends the intellectual work restricted to the office or laboratory, involving chance, manual work, the capacity for critical discernment, and the actions of several individuals who work in the regions where fossils are found. In this way, the concept of the Invisibles of Science emerges: they are indigenous, enslaved, riverside populations, workers operating in mines and quarries, the population of the villages where fossils are found, field or laboratory assistants who have volunteered or contractually contributed to the assistance of scientists. For paleontological studies, this kind of collaboration is fundamental to the discovery of new fossils, the optimization of field and lab work and the advancement of knowledge of the science of fossils, contributing to the geoheritage preservation. This study carries out a critical reflection on the importance of the Invisibles of Paleontology, analyzing the relationship between the enrichment of science collections, the preservation of heritage and the need for a new relationship with those who support scientific development in Brazil. The aim is to contribute to a historical understanding of the relevance of local populations in the protection of the Brazilian paleontological heritage and a need to revise the legislation, avoiding the criminalization of scientific activity.

Keywords Invisibles of Science · Paleontology · Fossils · Geological heritage · Fossils and people

Introduction

In the history of the Natural Sciences, the presence of lay people, who acted as assistants in the collections of naturalists, with a focus on biology and geology, has always shown itself to be a factor of great relevance for new discoveries and the expansion of collections of museums and educational institutions around the world (Moreira 2020). These field or laboratory assistants, whose names are not included in the publications or annals of science, are responsible for some of the great discoveries of Brazilian Paleontology. They need to be recognized by the entire community of researchers and educators. These are the Invisibles of Science, which comprise indigenous people, enslaved people, riverside populations, workers of mines and quarries, and the population of the villages or towns where fossils are found and which contributed voluntarily or contracted for the assistance of scientists.

Since the foundation of Paleontology in Brazil, as a science, we have observed the work of this type of collaborator. In the nineteenth century, the work of enslaved people along with naturalists, such as the Danish Peter Wilhem Lund (1801–1880), made it possible to build a vast collection of fossils and to understand the diversity of the biota of the Earth's past. Lund, who worked in Lagoa Santa (State of Minas Gerais) and is the Father of Brazilian Paleontology, also worked for some decades with the community of Lagoa Santa and practical workers trained by him, which enabled the collection of thousands of fossils related to

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Published online: 14 September 2022

the Quaternary megafauna (Fig. 1). In a period of 9 years (1835–1844), he researched and studied more than 800 caves, where were collected about 12 thousand fossils and bone fragments, in the search for proof of the Catastrophistical Theory of Georges Cuvier. These fossils were sent to Denmark in 1845 as a donation to King Christian VIII and the Danish people, which would ensure their preservation and study with state support (Luna Filho 2007).

The research in Paleontology does not result from an isolated work, disconnected from the information and support that can be provided by the population of the regions where the fossils are found. The informal or formal work of those who assist the research activity must be recognized as of fundamental importance for the advancement of knowledge, aiding in the construction of hypotheses and meanings for inert and hitherto ignored objects (Figueirôa 1997, 2009). The objective of the analysis carried out in this study is to give voice and recognition to the Invisibles of Science, rescuing the social memory of those who have contributed so much to the discoveries made in Brazil and who are systematically underestimated and disqualified (Fig. 2).

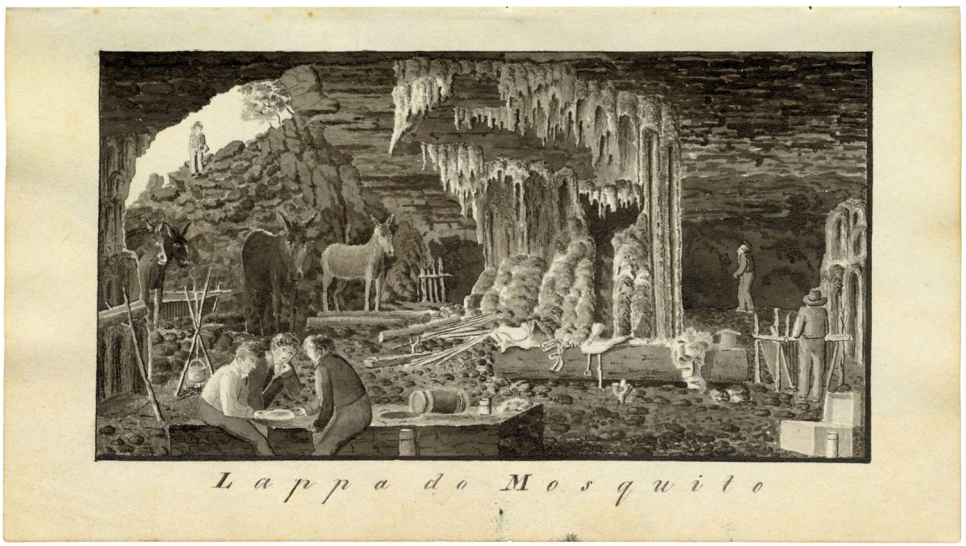

Fig. 1 Lapa do Mosquito with the researchers in the foreground (possibly including Peter Lund) and workers who assisted him in the background. Engraving by Peter Andreas Brandt, 1835. Repository Statens Naturhistoriske Museum, Zoologisk Museum (Copenhagen). Image courtesy of Castor Cartelle Guerra

Fig. 2 Image of the Expedition of the Geological Commission of the Brazilian Empire, in which is observed the collaboration of several workers to support the activities of field collection and also in the well-being of the researcher. José dos Reis Carvalho Watercolor titled Passagem do Rio Madeira; Ceará, second half of nineteenth century. Museu Dom João VI da Escola de Belas Artes da UFRJ

Denialism in Paleontology

In any area of scientific knowledge, the main objective is the discovery of the new or the reinterpretation of the facts that enable the understanding of the events and territories that surround us. The production of scientific information presupposes an intellectual integrity, and in Paleontology implies a knowledge of the provenance of fossils, the prevention of the deliberate destruction of specimens, and the non-falsehood and manipulation of the data obtained. It is the basis for the construction of sustainable concepts and hypotheses and has a function for both theoretical knowledge and application in situations where fossils have a function of prospecting natural resources.

The invention of a parallel reality, disconnected from real facts and only noticeable to those who create it, generates a system of denial of knowledge. This situation almost always demonstrates a maladroit adaptation to the time and geographical space in which one lives, thus giving rise to fixed, irrational, and in general obsolete ideas. This is denialism, which is reinforced by the coordinated dissemination of false information and promoted through social networks. There are people in this situation, for example, who deny that the shape of planet Earth is geoid, that is, an almost spherical shape, but with various deformations, dependent on different gravity, the planet's rotation as well as differences in mountain altitude and ocean depths. These are the so-called "Terraplanists." Since the Greeks of antiquity, at the end of the sixth century B.C., it was known that the Earth was not flat, but spherical. Aristotle (384–322 B.C.) clearly believed this, and Eratosthenes of Cyrene (276–194 B.C.) came to calculate with good approximation the circumference of this sphere through trigonometric calculations. Note that "terraplanism" cannot be justified even for biblical reasons, and the Bible never claims the earth to be flat, nor does it claim to be spherical. The concern of God and of those who wrote the various biblical texts was not to write a treatise on geography or geology, but rather a religious text. Moreover, almost always, in the biblical text, when using the term "אֶרֶץ, éretz," or "earth," the clear intention is to speak in the region (Mesopotamia, the land of Cana'an, Judea, etc.), not of the planet. Then, the denialism changes the role of science to society, in a process that turns science invisible and without importance, based on false notions.

However, the denialism in paleontology extrapolates the negation of concepts and theories consolidated, such as the emergence and evolution of species, beyond the duration of geologic time. Such denial often has religious foundations, or rather pseudo-religion, and religious persons with poor or no catechesis have the concern that paleontologists and other scientists use science, especially paleontology and geology, in particular, to deny the creation of the universe and the world by God the Creator. Historically, the controversy has existed for more than a century and a half, since the times of Charles Darwin (1809–1882) and his disciples and collaborators. The theory of evolution and the faith in the creation of the world by God are not necessarily antithetical. The first acts at the level of physical observation; the second at the level of philosophical system (eventually) and above all at the level of faith. Denialism in the area of evolution often also depends on an obsolete knowledge of the way the Bible is interpreted. The schools of biblical exegesis interpret it, today and for a long time, in the faith, but fitting the text within the cultures of the respective times, through the historical–critical method, the Theory of Forms, the analysis of literary genres, and the philological studies of Semitic and Greek languages.

The denialism in the area of Paleontology is also consolidated in a perception of the self-sufficient, pathfinder, and solitary paleontologist, whose discoveries result from the individual work, isolated from the social and economic reality that surrounds him. This situation leads to a new concept, that of Toxic Paleontology, in which the reality of paleontological discovery is restricted to the author(s) of the description and scientific publication, in a narrative in which the reality of discovery is only seen from its own creation. The narratives of fossil discoveries, in which there is no recognition of the importance of the action of lay and eventual collaborators, make it impossible to have a consistent discussion about the best mechanisms of preservation of fossiliferous heritage in situ and ex situ. In addition, it prevents the generation of new meanings for fossils, which induce conservation actions and management of paleontological heritage. It is not the great individuals who produce science, but the cooperation between many people: in our case mainly paleontologists and geologists. In an enlarged vision, scientists and people, thus covering researchers, technicians, drivers, field and laboratory assistants, informants, field experts, designers, artists, photographers, surveyors, and computer technicians. To these, we must also consider the people who live and work in the countryside.

Currently, another type of denialism, quite common and fashionable, is to judge past facts and actions in a historical context different from the present, based on elements and evaluations of the present. This is a tendency to historical revisionism, quite common, in which one only accepts the perception of the present world, denying the historical past, which is very different from the present time.

The Invisibles of Paleontology

Paleontology research presupposes a vast knowledge of different aspects of geosciences and biosciences. The field work is a stage of any research, and a large part of the study will be developed later with the preparation of fossils in the laboratory, their description, identification, and comparative analysis. There is in general a differentiated valuation for these work stages, in which the manual activity, prospective, done in the field, represents the lower value when compared with the so-called brain work activity. This, in our opinion, does not correspond to the truth. It is not uncommon that the laborious prospecting activity in the field, which results in the materials that will be analyzed later, is perceived as a result of chance and without effective relevance to the study. If such perception exists even with scientists working in the field, performing the mapping of fossil occurrences and the stratigraphic contextualization of the specimens, the same is amplified when the discovery is performed by laymen (Fig. 3).

The relationship between the finding of fossils by lay people and the Brazilian Academy demonstrates an explicit prejudice about the importance of the occasional discovery of fossils by quarry workers, civil works, or the general population. Those responsible for the discoveries are rarely cited, without due record in the register books of the institutional collections or information present in the descriptive publications of new specimens. Lima (1990) in his study about the pros and cons of fossil commercialization evaluated this important aspect for Brazilian paleontology, which is the involvement of the local population. However, this omission is deliberate and shows a repulsion in recognizing the relevance of local communities to scientific discoveries. Such a situation generates a large universe of people, in general, workers from regions where there is a great movement of rocks, used in the construction, or in industrial activities, which when they have contact with a significant volume of rock revolved and, when they find the fossils, are excluded from the scientific world. They are here called the Invisibles of Science or the Invisibles of Paleontology. The oral testimonies of these quarrymen, located in the mining district of Nova Olinda (State of Ceará, Araripe Basin) and recorded by the House of Science (Casa da Ciência 2008) in the documentary movie "Workers of Pedra Branca Quarry," give the dimension of this problem. The reports of local workers and the analysis of records in register books of university institutions and museums indicate the deliberate exclusion of those who discover the fossils in the Mina Pedra Branca and who make up the collections of some of the main museums of Brazil and foreign countries (Fig. 4). These are the reports of workers who work in the quarries of Nova Olinda (State of Ceará, Brazil) and who indicate their daily difficulties and their relationship with the universe of paleontology. The reflection on the content of the video and the evaluation of how much we owe to the workers of the limestone quarries of Nova Olinda must be a priority for the advancement of Brazilian Paleontology.

Fig. 3 Quarry in the Araripe Basin, in Brazil, where slabs of rocks are produced for construction and industrial use. The discovery of fossils by laymen is common on this and other mining fronts throughout Brazil. However, the names of the workers involved in the discoveries are deliberately omitted, either as a form of protection against possible criminalization of the discovery, or the lack of intellectual integrity of researchers who constructs a narrative in which the reality of discovery is only seen from their own creation. Blurred faces to prevent any kind of judicial retaliation by paleontologists who work in the region of the Araripe Basin and linked to federal and state public institutions

Fig. 4 Occasional discovery of fossils in the mining district of Nova Olinda (Ceará State, Araripe Basin) by quarrymen during the extraction and preparation of Pedra Cariri. Despite the enormous contribution made by the mining workers in the region, the names of their discoverers are deliberately omitted by researchers in Paleontology in the region

At the international level, the story of the English Mary Anning (1799–1847) is quite illustrative of the situation of the Invisibles of Science. Since her youth, she has been collecting fossils in the region of Lyme Regis, West Dorset, England, as a way of keeping her family alive. The specimens were sold to different "patrons of science," who referred them to researchers from British educational and research institutions, who generally omitted the names of the collectors. Mary Anning discovered the first skeleton of *Ichthyosaurus* and later numerous other fossils that proved extremely relevant from the scientific point of view, such as a complete *Plesiosaurus*. Until 1995, the skull belonging to this specimen was in the Natural History Museum, London (Reg. no. R 1158), without any official recognition or information about its history (Torrens 1995).

At this time, the activity of fossil prospecting was also carried out by other collectors, whose findings are now part of important collections such as those of the Oxford University Museum, Museum of the Royal College of Surgeons in London, and British Museum. Despite the arduous and dangerous work, in areas of wide tides and steep slopes, the actions of Mary Anning as a great collaborator in the development of Paleontology only had the due recognition—very partial indeed—in her later years of life (Goodhue 2005; Torrens 1995; Noè et al. 2019). The initial denial of her work as a fossil collector has a direct relationship with the status quo centered on the academic researcher, which does not recognize the direct or indirect importance that others have for the development of their studies.

One of the few historical records of the name of field assistants, who worked in the paleontological research in Brazil, can be found in the reports in the correspondence of Peter W. Lund. The freedman Henrique is mentioned by name as a guide and responsible for the expedition that started on October 12, 1833, which had a route through the states of São Paulo, Goiás, and the northwest of Minas Gerais. Later, during the cave excavations in the region of Lagoa Santa (State of Minas Gerais), the hiring of several workers organized in groups under the direction of a collaborator with experience in evaluating fossil bones took place. In this case, the closest collaborator was called Estulano (Holten and Sterll 2011). The registration of the names of workers in the field is rare in the historiography of Brazilian Paleontology, but demonstrates a concern of Peter W. Lund in the reliable documentation of all his scientific activities.

The Historical Relationship Between Mining and Fossil Discovery

Mining activities due to the opening of outcrops and exposure of many bedding surfaces potentiate the discovery of fossils.

Although the oldest records of the presence of fossils in Brazil date back to the eighteenth century (Fernandes 2020; Fernandes et al. 2013; Mello-Leitão 1941), it was saltpeter prospecting in the early nineteenth century that made possible a large number of new discoveries. The Napoleonic Wars cut off the trade flow of saltpeter from Europe, and it was important to produce that material which met mainly national demand. In this way was founded the Powder Factory in Rio de Janeiro, and stimulated the prospection and extraction of this mineral, which allowed an autonomy in the production of gunpowder.

The fossils of the Araripe Basin identified by João da Sylva Feijó (1760–1824), in the state of Ceará, were found in this context of demand for a mineral associated with carbonates and sedimentary regions (Fig. 5). In 1799, being appointed sergeant-major of the captaincy of Ceará, he arrived in Fortaleza with the function of economic exploitation of nature, especially in what concerns the prospection of saltpeter deposits (Pereira and Santos 2012). The discovery of this mineral in Ceará would represent an advantage for the export towards Lisbon (Portugal), given the shortest distance in relation to the southern Brazilian territory (Nobre 1997). From November 1799, Feijó made several incursions into the interior of what is now the State of Ceará, having visited the locality of Engenho da Gameleira (Jamacaru, municipality of Missão Velha), and found numerous fossils in carbonate nodules of the Cretaceous period (Carvalho et al. 2021).

A similar situation occurred with the discovery of fossils in the caves of the region of Lagoa Santa (State of Minas Gerais). From the early nineteenth century, the expeditions commanded by John Mawe (1764–1829), Wilhem Ludwig

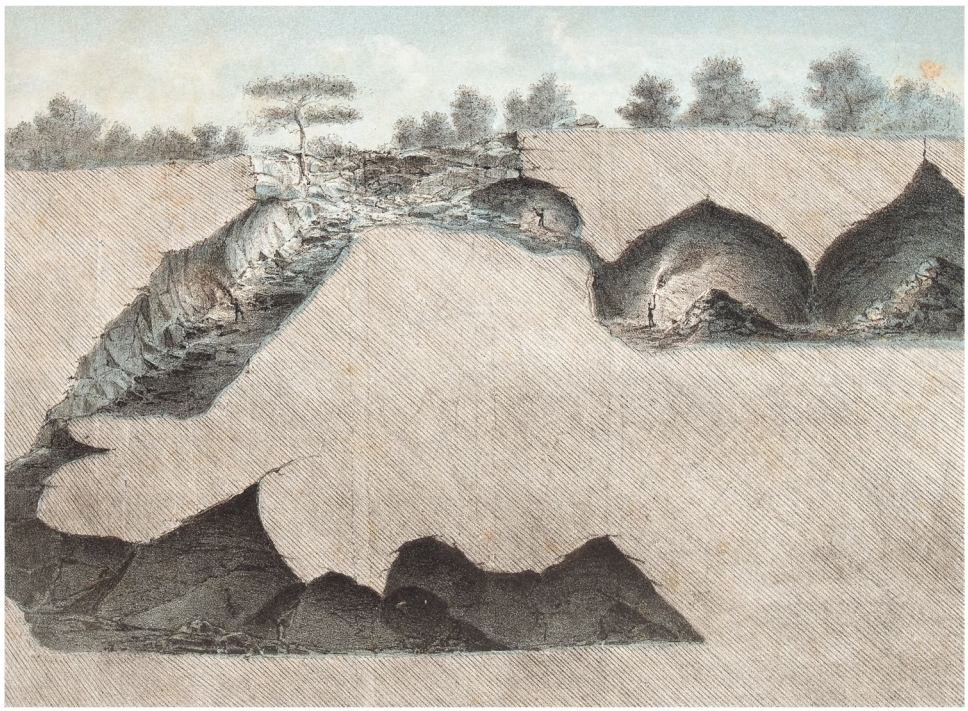

Fig. 5 Mining activity in the nineteenth century in the Araripe Basin. Active excavation for mineral resources has been the main responsible for the discovery of fossils in Brazil. It is undeniable the contribution of the workers of the mining companies and the population of the surrounding fields to the increase of paleontological knowledge of the Brazilian territory. Lithograph entitled "Talhados do Araripe" (=underground excavations of Araripe), drawn by Guilherme Capanema during the expedition to Ceará by the Geological Commission of the Empire (1859–1861). National Library Collection, Rio de Janeiro

von Eschwege (1777–1855), Johann Baptiste Emmanuel Pohl (1782–1834), Carl Friedrich Philipp von Martius (1794–1868), and Johann Baptist von Spix (1781–1826) had already observed the existence of large bones in the limestone caves of Minas Gerais (Luna Filho 2007). The exploitation of the saltpeter was accomplished through the removal of the earth from the caves, with the dissolution in water and later separation of the saltpeter by evaporation. It was in this way that Peter Lund became aware of the large bones that were removed along with the extraction of saltpeter-bearing sediments (Holten and Sterll 2011).

This relationship between mineral exploration and fossil discovery will continue throughout the twentieth century, especially in basins with carbonatic rocks, such as the Potiguar, Araripe, Bauru, and Paraná basins. In this context, the contribution of the local populations and workers of the quarries has always been shown to be of fundamental importance for the advancement of the knowledge of Brazilian Paleontology. It is thus a work of empirical observation, practical knowledge, and enormous physical effort that made possible the constitution of many of the main paleontological collections of Brazil, without this representing a condition of dilapidation of the fossil heritage. On the contrary, it represented the most important contribution that the Brazilian population offered to Paleontology, without having the documental and nominal record of each of the collaborators that made possible the subsequent cabinet studies.

Araxá: the Foundations of a Hotel and the Record of Megafauna

The contemporary history of Brazilian Paleontology is closely related to the construction of a hotel, in the Parque do Barreiro, in Araxá (State of Minas Gerais). It is the Grand Hotel of Araxá, work started in 1938 and inaugurated in 1944. The hotel is integrated into a set of thermal baths and is surrounded by a large area of gardens designed by the famous landscape architect Burle Marx (Fig. 6). At the time of the construction of the hotel, Brazil was ruled by Getúlio Vargas (dictatorial period from 1937 to 1945) after a coup d'état. The regime implemented was characterized by strong political repression, censorship of the press, institutionalized government propaganda, and centralization of the main economic and industrial activities by the state (Garcia 2005).

During the creation of the gardens around the hotel and the construction of a ditch for a sulfurous water source, the workers who labored there found on March 3, 1944, a huge amount of fossil bones belonging to mammals of the Quaternary megafauna. At the request of the engineer José Ferreira de Andrade Júnior, paleontologists Llewellyn Ivor Price and Rubens da Silva Santos were sent to Araxá, both from the Division of Geology and Mineralogy of the National Department of Mineral Production (DNPM) of Rio de Janeiro to rescue and study the fossils found (Riff 2017). During the activities of

Fig. 6 The Grande Hotel do Barreiro, Araxá (State of Minas Gerais, Brazil). The creation of the gardens surrounding the hotel (**A**) allowed the discovery of fossils of the Quaternary megafauna in the area of mineral sources, currently in glass exhibitors (**B**), and the subsequent drafting of the Decree-Law 4,146 of 1942 that still governs the protection of the Brazilian fossil heritage. Photos by Douglas Riff

excavating the bones, President Getúlio Vargas visited the building yard of the hotel. An informal conversation with Llewellyn Ivor Price led to the publication in 1942 of Decree-Law 4,146 (Brasil 1942). This presidential decree established the basis for later legal understandings related to the protection of fossil heritage in Brazil (Carvalho 1993). Following the conception of a centralizing state, as was the so-called Estado Novo (period 1937–1945) during the dictatorship of Getúlio Vargas, the legal basis indicated that the fossils were state heritage: "Fossil Deposits are Property of the Nation and, as such, the Extraction of Fossil specimens depends on prior Authorization and Inspection by the DNPM" (Brasil 1942). At no time is it indicated the impediment to the remuneration for the collections or the impediment to a legal authorization of extraction. There is, however, an important issue that is the distortion of understanding of the fossil from this historical context. The fossil was perceived as an object capable of dissociation from the rock matrix of its surroundings and essentially related to vertebrate macrofossils, the bones of which were clearly distinguished from the sediment that encompassed them.

About the workers who participated in this discovery during the excavations for the civil work of the hotel in Araxá, there is no record, only the name of José Ferreira de Andrade Júnior, the responsible engineer.

The Mines of Limestones of Mossoró

The limestones from the Potiguar Basin (State of Rio Grande do Norte) comprise highly fossil-bearing rocks that are used in the production of lime, mortar, concrete, and ornamental rocks. The resistance and esthetic character of these carbonates, with their fossils, make it possible to even use them on floors and walls in public institutions, such as the "Museum of Tomorrow," located in Rio de Janeiro (Polck et al. 2018). The fossils are mainly molds and countermolds of gastropods, bivalve, and echinoids, which record the Central Atlantic Sea ingressions during the Late Cretaceous and final stages of the opening of the South Atlantic Ocean.

In the municipality of Mossoró (State of Rio Grande do Norte) are located the main historical quarries of limestone extraction of the Potiguar Basin. In particular, those containing the largest number of fossils are generally exploited manually and for the purpose of lime production. This fact is related to the differentiated character of the carbonatic filling of the molds of the gastropods *Tylostoma* Sharpe, 1849, which are generally micritic and result in a lime of better industrial quality. The advance of the extractive activity, even without industrial character, led progressively to the disappearance of fossils, which occurred by a material selectivity during the burning process. The observation of this situation by the agronomist Jerônimo Vingt-un Rosado Maia (1920–1995) made possible an innovative action for the preservation of these fossils.

In addition to the actions for the development of an agronomy focusing on the growth of the semi-arid of the Brazilian Northeast, which led him to idealize the Higher School of Agriculture of Mossoró (ESAM), the current Federal Rural University of the Semi-arid (UFERSA 2020), Vingt-un Rosado was an important protagonist for Brazilian Paleontology, although not being a paleontologist. Through the Higher School of Agriculture of Mossoró, he re-edited classic publications about the fossils of Northeastern Brazil and gave important contributions to the collection and protection of fossils found in the Potiguar Basin (State of Rio Grande do Norte). After the recognition of the differentiated collection of fossil-bearing carbonates, he established a program with the workers of the lime mines so that all fossils (especially those of *Tylostoma* sp.) were separated and stored, with regular payments, as a form of retribution for the work and the material collected (Maria Eugênia de

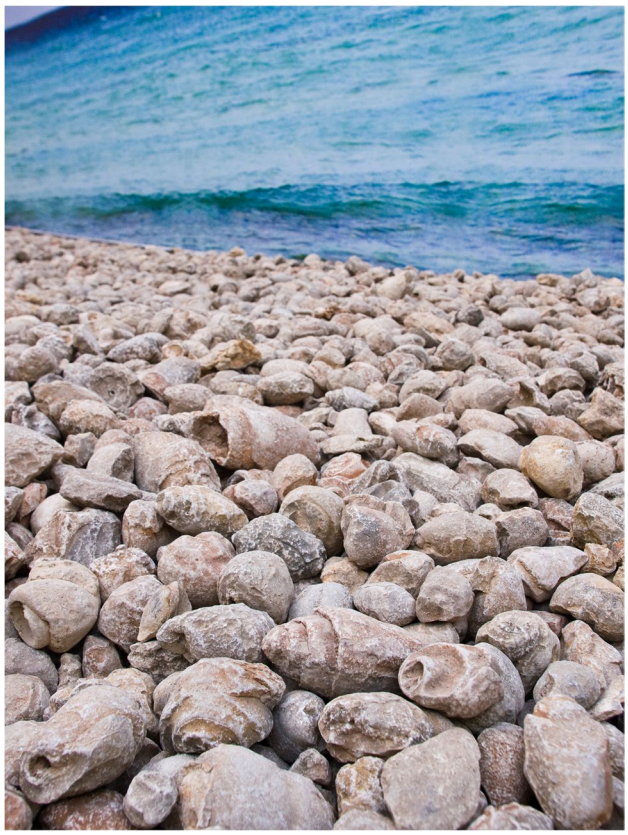

Fig. 7 Vingt-un Rosado Maia conducted the first experiment of collecting fossils with workers of the lime quarries of Mossoró (Potiguar Basin) so that all fossils (especially those of *Tylostoma* sp.) were separated and stored, with regular payments, as a form of retribution for the work and the material collected. Today this collection is protected and preserved in the Museum of Geodiversity, Federal University of Rio de Janeiro

Carvalho Marchesini Santos, personal information 2001). Although initially resembling an inefficient mechanism for protecting fossil heritage, today the largest collection of fossils in the Potiguar Basin is composed of hundreds of these fossils, guarded for decades by Vingt-un Rosado and later donated by the Higher School of Agriculture of Mossoró to the Museum of Geodiversity (Federal University of Rio de Janeiro, Fig. 7). Currently, with the virtual inexistence of manual limestone mining and the industrialization of the extractive process, the collection of these fossils becomes increasingly rare and difficult to obtain. The collaboration and financial retribution to the workers of the limestone mines proved to be an effective way of preservation, because the fossils are attributes of the rocks, and as such susceptible to mining and its use for industrial and constructive purposes.

Rio do Peixe: in the Middle of the Road, There Was a Footprint

Over the past 47 years (1975–2022), the regular presence of researchers and classes of undergraduate and graduate students in Geosciences, and the dissemination of news about the existence of dinosaur tracks in and around the municipality of Sousa, led residents to change their perception of the relevance of scientific research in the region. During this period, paleontological discoveries underway captured the popular imagination. There was a progressive influence of vertebrate ichnology in commerce, social, sports, cultural, and fun activities such as carnivals. Symbols and images of dinosaurs and their tracks became emblematic of the municipality, even in the personalized logos of shops and firms, awakening a new identity for the region, which was previously known primarily for its cotton farming (Leonardi and Carvalho 2021b). It has thus been possible to preserve the region's ichnological heritage through public policies, increased tourism in the region, the development of local museums, emphasis on areas of scientific and cultural importance, support for scientific research, and engagement of the local population through a greater appreciation of ichnofossils as important objects for the economy (Carvalho and Leonardi 2007; Fernandes and Carvalho 2008; Santos 2014: Santos et al. 2016; Santos and Santos 1987a, b a; Leonardi 2021; Leonardi and Carvalho 2021a, b).

From 1975, with the first expedition and the first fieldwork season in Sousa (Leonardi 1979a, b), there was always a cordial and friendly contact between the population of the municipality of Sousa and researchers, as well as with many local politicians. However, the consolidation of a perception on the relevance of the research work in development took place from September 1983 with the publication of a book rich in content, wonderfully illustrated, containing previous results and new results from the Ligabue expedition in the region. This book had been published by the same Ligabue Foundation (Bonaparte et al. 1984; Leonardi 1984). In this way, the relationship between local support and the dissemination of scientific knowledge was consolidated, with support coming from the collaboration of the region's population. One can attribute the relationship with the population as one of the successful elements for the validation of Paleontology work in Sousa. The attention was given to all residents of rural areas, with special attention to children and their families, which enabled year after year the discovery of new ichnosites and the expansion of knowledge about the dinosaur footprints of the region.

The workers who collaborated as eventual field assistants for excavations, for clearing the land before the study, as drivers, or for other tasks, were in part employees of the

municipality of Sousa. However, they were also people from the farms where the excavations were being carried out, especially during the years of drought; with food and payment sometimes done informally, at the personal expense of the second author. Those who helped most in the physical discovery of the Sousa tracks, aside from the salaried workers of the prefectures or sometimes hired formally or informally, for an excavation or for cleaning the land, with its heavy job, were some citizens of the municipality of Sousa, such as Espedito, a young villager from the Ilha farm, when the classic ichnofossilíferous site of Passagem das Pedras (= The ford of stones) was first brought to light. His work was important to the research work developed in this area, collaborating in a dedicated way. Subsequently, Robson Araújo Marques, an employee of the municipality of Sousa, in addition to contributing to the work of guidance and excavations, later became for decades caretaker and informal curator of the Parque Vale dos Dinossauros. Two young brothers from the city of Sousa, José Nilton de S. Cavalcante and Francisco W. de S. Cavalcante, from 1985, participated with a temporary contract for about 3 years, and with great passion and skill, as technicians in the laboratory maintained by the National Council

Fig. 8 José Nilton de S. Cavalcante e Francisco W. de S. Cavalcante (in the background), citizens of Sousa, who, since 1985, participated in the production of life-size replicas of dinosaurs for the future Parque Vale dos Dinossauros

Fig. 9 Fence in flagstones with fossil footprints and sedimentary structures in the locality of Cabra Assada, Sousa Basin. The use of sedimentary rocks with fossils and ichnofossils is routine in sedimentary basins and the use of these materials cannot be subject to criminalization

for Research, to produce life-size replicas of dinosaurs for the future Dinosaur Valley Park (Fig. 8).

An interesting case is the site of Cabra Assada, located in the municipality of São João do Rio do Peixe. In this locality, on December 30, 1984, it was recognized by the second author that the protective fences of a farm had been made with sandstone flagstones (Santos and Santos 1987a, b), which showed large footprints of theropod and ornithopod dinosaurs, in addition to sedimentary features as ripple marks (Fig. 9). The owner of the ranch, Pedro Alexandre Alves Neto, later donated this material to the Câmara Cascudo Museum (Federal University of Rio Grande do Norte, State of Rio Grande do Norte), accepting only a refund for the costs of manual labor for the extraction of slabs and their transport, which should not be confused with the payment for slabs with the fossil footprints for marketing purposes. An example of availability and collaboration between aware people and science. The slabs of Cabra Assada are currently on display in a special room of the Câmara Cascudo Museum, and were published in the same year of their removal (Santos and Santos 1987a, b).

The action of members of the local community, such as Luiz Carlos da Silva Gomes, who founded in Sousa the cultural group Movissauros, and lawyers, such as Neuricélia Teodoro Lima Moreira, collaborated a lot providing information about new locations with fossil footprints and heritage preservation. The community's involvement also took place through dissemination actions carried out by journalists, such as Julieta Gadelha, or teachers, such as Maria Auxiliadora Figueiredo, who contribute to the popularization of knowledge and expand the possibilities of new discoveries. Also noteworthy is the technical support of surveyors Sebastião Duarte Vieira and Pedro L. Lucena, who made it possible to map the areas with records of dinosaur tracks and footprints.

Rare were cases of ichnological material vandalized by unidentified. However, the greatest damage was caused by the neglect of some public managers, who let destroy or abandoned to the complete destruction of whole ichnosites.

It should be remembered in addition that, initially, when the possibility of a park and local museum in Sousa was not considered yet, a few loose track-bearing slabs found in the bed of the Rio do Peixe, particularly from the Piau place, were stored in Geosciences institutions (Federal University of Pernambuco in Recife, Federal University of Sergipe in Aracaju, Federal University of Espírito Santo in Vitória), while others were recovered by the Câmara Cascudo Museum of the Federal University of Rio Grande do Norte. In the beginning, some slabs with footprints were entrusted by the second author to the works sector of the city of Sousa (1979) to be stored, aiming at a future collection and local exhibition, and were lost.

It is considered that due to the heritage education received by the population, the footprints and fossil tracks, so abundant, are generally respected and defended by the local residents thus avoiding major damage to the paleontological heritage.

The heritage situation of the fossil tracks found in the Sousa Basin is exemplary with regard to the rights of territoriality. The rescue of the specimen must prevail, that is, the fact that it, by logistical facilities, of convenience, of the existence of an appropriate repository, of the possibility of transport, so that the specimen can be preserved, studied, analyzed, valued by the discoverer, or by a suitable school of Geosciences which is deemed appropriate. The function of the paleontologist is to seek the means to better protect the patrimony, whether in situ or ex situ. It is a professional assignment to assess the local conditions for this preservation to occur.

Araripe: an Oasis of Life

One of the main fossiliferous regions of Brazil is in the Araripe Basin (states of Ceará, Pernambuco, and Piauí), in deposits of the Lower Cretaceous. Despite the existence of fossils in several stratigraphic units, the most abundant and best preserved are found in carbonatic rocks (Crato and Romualdo formations), comprising two conservation and concentration Lagerstätten (Martill 1997; Martill et al. 2007). The abundance of fossil plants, invertebrates, and vertebrates allows that in the areas of occurrence of sedimentary successions where Crato and Romualdo Lagerstätten occur there is a frequency of exceptional fossiliferous occurrences. In addition, the microbial character of rocks also enables the preservation of an endless number of microscopic organisms.

The exceptional situation of the Araripe Basin generates an anomalous circumstance for quarrying extractive activities related to construction, agriculture, or urban expansion, since in any excavation or even in loose blocks on the surface there is in general a large amount of fossils (Andrade 2007). The specimens are thus elements inherent to the rock itself, as an attribute of carbonatic lithologies and that are sometimes its main constituents as in the case of microbials and coquinas.

The contribution of the local population occurs in two different ways. The first occurs through the sporadic collection by farmers, who, by turning the surface of their field or by superficial excavations, find carbonatic nodules related to Lagerstätten Romualdo, which for many years were traded as objects of scientific curiosity. Due to the abundance of fossil fish found in these nodules (ichthyolites), its collectors were designated "peixeiros" (= fishmongers). Currently, this denomination has a pejorative connotation and social

disqualification, as it is associated with heritage crime, even if the fossils occur on farmers' properties and result from fortuitous encounters. An example of a museum constituted from the collection of these specimens was the Museum of Paleontology of Jamacaru (municipality Missão Velha, Jamacaru district, State of Ceará) founded in 1967 in association with the Educandário Padre Amorim by Neri Feitosa, priest and religious educator, whose life work has always been focused on education and social actions. This museum was the first constituted in the State of Ceará dedicated exclusively to the preservation of paleontological materials of the Araripe Basin, with a thematic collection of fossils found in Jamacaru, Missão Velha district, the region where the first fossils of the Araripe Basin were collected 200 years ago, and nearby locations such as Porteiras and São Felipe. In 1970, the collection of fossils under the responsibility of this museum had about 6000 specimens and was the largest existing in relation to the fossils of the Brazilian Cretaceous. Even with the collaboration of important scientists such as Geraldo da Costa Muniz, Antônio Campos e Silva, Luiz Eurico Moreira, Mario de Biase, Enio Soliani Junior, and Frederic Nagy, in addition to the declaration of public utility by the Municipality of Missão Velha, State of Ceará (Monteiro et al. 2009), the work of Father Neri Feitosa was criminalized, on the grounds that the materials were purchased from local farmers. The museum was dismantled (1973) and the collection was partially destined for the Museum of Paleontology of Santana do Cariri and the National Department of Mineral Production (Rio de Janeiro and Crato) on the grounds that the then existing institution did not have the infrastructure conditions to maintain that collection. It is observed here a direct relationship between the interests of local politics, of the federal inspection bodies, with the involvement of Brazilian paleontologists interested in the materials of the Jamacaru Museum for their own research. Currently, the records of which fossils were destined to institutions headquartered in Rio de Janeiro and Ceará are missing (Carvalho et al. 2021). However, a new perception about the value of the work of "fishmongers" can be found in the statements presented on television by CGTN America (2021). The Araripe Geopark recognizes the empirical knowledge of these workers at the finding of fossils, and in this way performs the hiring of them for a collection directed to institutional collections.

Another way of contribution of the population to paleontological knowledge comes from the work carried out by the workers in the laminated limestone quarries of Crato Lagerstätten, commercially known as Pedra Cariri (=Cariri stone; Carvalho et al. 2020; Henriques et al. 2020; Henriques and Carvalho 2022). The rocks of the mining district of the municipality of Nova Olinda (State of Ceará), which covers an area of approximately 25 km^2, and its surroundings, are finely laminated limestones used mainly in civil building, for the coating of floors and walls. Other uses are the manufacture of geoproducts (tables, chairs, household ornaments) and educational actions, through geotourism (Andrade 2007). The extraction of this rock is the main source of income of the municipalities of Nova Olinda and Santana do Cariri, with an estimated employability of 1500 workers, in a monthly production of 100,000 m^2 of squared stone tiles (Castro 2009; Castro et al. 2009). The opening of large quarrying fronts, generating daily millions of new bedding surfaces, enhances the discovery of fossils. These occur in a succession 70 m thick, throughout the area of the quarrying district, as well as in other places of outcrops of this laminated limestone. There are no active excavations for the extraction of fossils, but these are a by-product of the quarrying waste, which is normally disposed of and then used for landfill, fertilizer production, or the cement industry. The use

Fig. 10 Quarrying district of Nova Olinda (State of Ceará, Araripe Basin). Tons of rocks bearing thousands of fossils are cut daily for use in construction (**A**) and mining waste crushed for cement production (**B**). An efficient way of preserving the heritage would be the sorting of waste for the collection of fossils, including regular payment for this type of work of great relevance to paleontology

Fig. 11 Plácido Cidade Nuvens, first director of the Museum of Paleontology of Santana do Cariri, whose educational action and integration with the mineral productive sector of the mining district of Nova Olinda, made possible the constitution of the institutional collection. In the figure, an explanation in July 2014 to the students of the Federal University of Rio de Janeiro about the importance of education for the socioeconomic revolution in Brazil

of quarrymen or any worker to separate the fossils from the waste that will be destroyed is shown to be an efficient and an important way of preserving the heritage, allowing the recovery of specimens that would otherwise be destroyed by industrial reuse (Fig. 10).

It is due to an amateur paleontologist, who dedicated his life to valuing and saving the remarkable fossils of the Santana Formation, in the service of the people and knowledge, the implementation of important educational actions in the Araripe Basin. Plácido Cidade Nuvens (1943–2016), a citizen of Santana do Cariri (State of Ceará), had a high academic background, in an area of distinct knowledge, but a great passion for fossils and the people of his land. He was mayor of Santana do Cariri, where he founded the "Museum of Paleontology of Santana do Cariri," later donated to the Regional University of Cariri (Fig. 11). The immense collection of fossils from the Crato and Romualdo formations collected over many years is an important monument to the people of the Cariri, delight and culture of visitors, and now a monument to Placido's memory. Plácido Cidade Nuvens willingly placed the collection at the disposal of the researchers, who he welcomed with great cordiality. He had a clear perception of the importance of the men who worked in the quarries and who found in them the potential for new discoveries. His action was similar to that of Vingt-un Rosado: both were not paleontologists, but promoted Paleontology through institutional acquisitions through financial rewards to the quarry workers. The recognition of the importance of the quarriers and local populations as contributors to the protection and collaboration with science is shown as the best results forheritage actions in mineral extraction areas.

Peirópolis: Opening of Roads, Wells, and Mining

In the hamlet of Mangabeira, 30 km north of the city of Uberaba (State of Minas Gerais), in the farm Cassu belonging to Col. José Caetano Borges, was found in 1945 by the workers who operated in the rectification of the Mogiana Company's railroad the first records of dinosaur bones and a dinosaur egg, the first in South America. Engineer Jesuíno Felicíssimo Jr., then responsible for the work, notified the Geology and Mineralogy Division of the Ministry of Agriculture about the discovery. This later enabled Llewellyn Ivor Price, paleontologist of the Paleontology Section, to analyze these fossils and to establish from 1946 a program of systematic paleontological excavations in the region of the Peirópolis neighborhood, about 25 km east of the city of Uberaba. This locality had highlighted the activity of limestone exploration from the year 1900, for the production of virgin lime used in civil construction, at a time when the manufacture of this material did not yet exist in the country (Ribeiro 2014; Ribeiro and Carvalho 2009). A continuous action of collecting fossils began, initially by contractors of the Division of Geology and Mineralogy, such as Alberto Lopa and later by Langerton Neves da Cunha, who performed excavations and collected materials in the quarries. In addition to these employees, local workers who assisted

in obtaining the fossil specimens, such as Saulo Messias da Silva, who contributed for almost a decade to this arduous task, were provided with temporary services. This work lasted until 1976, having ceased with the death of L. I. Price in 1980. In this way, it was possible to expand the collection of the Paleontology section of the National Department of Mineral Production, whose fossils today constitute much of the collection of vertebrates from the Brazilian Cretaceous of the Museum of Earth Sciences, in Rio de Janeiro.

The excavation and collection activities carried out by numerous workers operating in limestone quarrying or in the programs established by the Paleontology section of the National Department of Mineral Production, the City Hall of Uberaba, and the Federal University of Triângulo Mineiro prevented the destruction of fossils, allowing them to be safeguarded for scientific knowledge and diverse actions. The importance of Peirópolis has led to new programs of prospection, collection, protection, education, and dissemination of knowledge of fossils, initially funded by the Uberaba City Hall through the creation of the Llewellyn Ivor Price Paleontological Research Center, work currently exercised by the Federal University of Triângulo Mineiro. Thanks to these actions, the fossils have gained a new value and application, being transformed into elements of socioeconomic and cultural revitalization through geotourism, guaranteeing income generation, jobs, and quality of life to the residents of Peirópolis. In 2014, the entire territory of Uberaba began to compose the Uberaba Geopark—Terra dos Dinossauros do Brasil (Ribeiro et al. 2014). The excavation and collection activities carried out by numerous workers working in limestone mining or in the programs established by the Paleontology section of the National Department of Mineral Production, the City Hall of Uberaba, and the Federal University of Triângulo Mineiro (Fig. 12) prevented the destruction of fossils, allowing them to be preserved for scientific research and subsequent educational actions.

Irati: a Lake of Death

The Irati Formation is a Permian deposit in the Paraná Basin. This is a succession of laminated limestones and oil shales, whose fossiliferous content is extremely relevant from a historical and paleontological point of view. Some of the fossils of this lithostratigraphic unit, such as the Proganosauria *Mesosaurus brasiliensis* and *Stereosternum tumidum*, proved to be fundamental for the formulation in 1912 of the theory of continental drift postulated by Alfred Wegener (1880–1930). These small aquatic reptiles would not be able to disperse over the long distances of the present Atlantic, and its occurrence also in the African continent (Namibia) made it possible to be considered one of the reinforcing elements of Wegener's theory.

Proganosauria skeletons, found from quarries located mainly in the states of São Paulo and Paraná, were commonly found when the extraction activity was essentially manual or with little mechanization. From the 1990s on, the high mechanization and rapid advance of mining led to the almost total impossibility of discovering new specimens

Fig. 12 Temporary workers, hired by the Federal University of Triângulo Mineiro, with the support of the State of Minas Gerais Research Foundation, in regular excavation activities for the collection of fossils along highways and in civil construction areas

Fig. 13 Mechanization of the quarrying of the rocks of the Irati Formation (Permian, Paraná Basin) led to the disappearance of the fossils of Proganosauria and others. The revolving of a large volume of rejects without direct human intervention makes it impossible to discover new fossils (photo by Fábio Reis)

(Fig. 13). The previous manual and participatory work of the quarriers made it possible to discover the fossils and keep them in educational institutions and museums.

Botucatu: Walking on the Sands of a Desert

The history of vertebrate ichnology in Brazil and South America began with a slab of the Botucatu Formation (Lower Cretaceous, Paraná Basin), with footprints in the sandstone, discovered and registered by the mining engineer Joviano Pacheco (Pacheco 1913). It was part of the paving of the sidewalks of the city of São Carlos, not far from Araraquara, in the center of the State of São Paulo. Between 1976 and 1989, there was intense prospecting of these tracks by Giuseppe Leonardi, who evaluated quarries and sidewalks of the Botucatu sandstone (Leonardi 1980; Leonardi 1981a,b; 1994; Leonardi and Godoy 1980; Fernandes and Carvalho 2008; Fernandes et al. 2008; Leonardi and Carvalho 2021b) and also in the Paraná River Formation of the Caiuá Group (Leonardi 1977). The research and heritage education actions carried out by the Universidade Estadual Paulista (UNESP, Rio Claro campus), Museu de Arqueologia e Paleontologia de Araraquara (MAPA), Universidade Federal de São Carlos (Ufscar), Universidade Federal do Rio de Janeiro (Departamento de Geologia, UFRJ), and Companhia de Pesquisa em Recursos Minerais (CPRM) resulted in the enactment of municipal legislation in Araraquara that protects sidewalk slabs with fossil footprints (Fernandes et al., 2008). Recently, the municipality of Araraquara promulgated Decree No. 12,095 of October 7, 2019, that established the evaluation of the sandstone slabs of the Botucatu Formation by the Museum of Archaeology and Paleontology of Araraquara (MAPA).

For the research in this area, and especially in Araraquara, the collaboration of the "Invisibles of Science" was fundamental. The quarries in the region are found in sandstones of the Botucatu Formation, which were accumulated in desertic environments and constituted the paleodesert of Botucatu (Scherer 2000; Leonardi and Carvalho 2002; Leonardi et al. 2007). The workers of the São Bento quarry and later the CORPEDRAS quarry, as good assistants, always separated and selected the best samples. They sometimes received small gratuities, especially when they were tasked with cutting slabs with the same exact shape (irregularly, not rectangular, and therefore more difficult to reproduce) to replace slabs with footprints on the city's old pavement.

The systematic ichnological research in the São Bento-Corpedras quarries was extremely supported by the family of Oswaldo Grosso, owner of the quarries, and his sons and successors, mainly José Francisco Grosso and Isabel Grosso. The Grosso opened generous collaboration, including a donation of all slabs collected in their quarries, free labor for slab cutting, and use of vehicles to transport sandstone slabs to be transferred to public institutions (DNPM and National Museum, Federal University of Rio de Janeiro). Such a contribution is absolutely invaluable, also for another important reason: due to the fact that there would be no public

Fig. 14 Front of excavation of the quarry São Bento-Corpedras in Araraquara (State of São Paulo, Paraná Basin). The slabs of sandstone with fossil footprints, removed by the workers, made possible the knowledge of the diversity of the biota of the Cretaceous of the paleodesert of Botucatu

financial resources or research funds, for the revolving of about 100,000 m^3 of sandstone, in 10 years (1976–1985), work done by the quarrying company's excavations. This approximate amount of rock is estimated considering the front of the excavation of about 100 m; the average height of 20 m of the fossil dune where the vertebrate ichnofossils were found (Leonardi 1980; and the approximate calculation of 5 m/year of the progress of the excavation (Fig. 14).

An important analogue to be performed is what is observed in the Araripe Basin. In 70 square hectares of the area of the mining district of Nova Olinda (State of Ceará), where there is an exploitation of laminated limestone, about 4000 fossils per day were counted (October 2016). These are discarded and found superficially as residue from the quarry. Considering a year with 240 working days of mining, we would have 960 thousand fossils obtained superficially in the

Fig. 15 A set of sandstone slabs with fossil tracks of the Botucatu Formation separated by the workers of the quarries of Araraquara (State of São Paulo). The collaboration of the Grosso family, owner of the quarries, and of the local workers was fundamental for the preservation of an important ichnological collection

waste. However, the area of the concession of quarrying for the laminated limestone of the Crato Formation corresponds to 711.8 square hectares. If the same pattern of abundance in the control area occurs throughout the mining district, we would have 9 million and 60 thousand fossils per year that are destroyed by the subsequent use of waste in the cement industry.

The collaboration of the Grosso family and the workers of the São Bento and Corpedras quarries was essential for the preservation of the paleontological heritage represented by the fossil footprints of the Cretaceous Botucatu Formation. At that main moment of activity of the mining areas, until 1983, the successive public administrations of the municipality of Araraquara did not collaborate with the research activity. So, without the voluntary collaboration of lay people, the whole history of the biota of the Botucatu desert would have disappeared and its ex situ registration in museums and universities would not currently exist (Fig. 15).

The Araucaria' Forests of the Triassic: Walter Ilha and Daniel Cargnin, Visionaries of the Brazilian Paleontology

The great actions of preservation of the Brazilian paleontological heritage have always been in conflict with the existing guidelines in the legislation. This clearly demonstrates the inadequacy of restrictive legislation to recognize the importance of fossil deposits as part of the natural elements that make up the daily life of the population (Henriques and Carvalho 2022).

The region where Walter Ilha and Daniel Cargnin worked are areas with paleontological records of the Triassic of the Paraná Basin. In addition to a variety of herpetofauna, rocks are abundant in paleobotanical records, in particular silicified coniferous fossil plants, composed of logs up to 30 m long. Although currently recognized as an important heritage with applications for regional tourism development (Minello 1995; Carvalho and Stock da-Rosa 2008), during the years 1970 to 1990, they were intensely mined (raw material for decorative objects) and or destroyed by farming activity. In this context were Walter Ilha, in São Pedro do Sul, and Daniel Cargnin, in Mata. Walter Ilha preached a policy of awareness to the population of São Pedro do Sul, using, for this, the media and lawsuits. Cargnin, as parish priest of Mata, encouraged the population to protect the paleobotanical heritage through the construction of squares and use as ornaments in the buildings, thus preventing the removal of fossils from the municipality. From these actions, it is that the communities involved started to protect their heritage through community centers, museums, and establishment of municipal laws (Guerra-Sommer and Scherer 2002).

Fig. 16 **A**. A large fossil tree log in exhibition at the square of Santo Antônio church; **B**. Entrance of the Daniel Cargnin Museum lined with fossils; **C**. Paleobotanical garden, a paleontological heritage with fossil tree logs in the surrounding of Mata city. Daniel Cargnin's heterodox preservation action in Mata (State of Rio Grande do Sul) made it possible to preserve the paleontological heritage in an integrated way to community interests (images Mata City hall, https://www.mata.rs.gov.br/municipio/pontos-turisticos. Access March, 1.st 2022)

An example of how the academic and legal principles of paleontological preservationism need to be reviewed is given to us by the action of Daniel Cargnin (1930–2002), a religious and educator who acted in favor of the Paleontology of Rio Grande do Sul. Initially, Cargnin worked in the municipality of Santa Maria (1964–1969), having contributed significantly to the collection of fossils to the Vicente Pallotti Museum (Santa Maria, Rio Grande do Sul), Pontifical Catholic University (Porto Alegre, Rio Grande do Sul), and the Federal University of Rio Grande do Sul (Porto Alegre, Rio Grande do Sul). However, its most important action took place in the city of Mata, from 1976. The action of large mining companies led to a rapid loss of the main

paleobotanical deposits of chalcedony fossil wood found in the municipality of Mata. Despite the repeated official requests for protection of these deposits, little practical effect arose due to the high prices in the domestic and international market of the objects, of high esthetic impact, produced with the polished fossil wood. Cargnin, as parish priest, acted even in his Sunday sermons, in the defense of the paleontological patrimony. Without finding institutional support for his claims, he began to stimulate the collection of fossils in the field and fixing them in buildings (including the local church, Fig. 16A) and squares, calling attention immediately to their unorthodox action of heritage conservation (Familia Cristã 1990; Carvalho 1993; Carvalho and Stock da-Rosa 2008). Despite the criticisms at the time, and even considering it unjustifiable from the legal texts, it should be recognized that it was through actions such as this that one of the main paleobotanical patrimonies of Rio Grande do Sul and Brazil was not completely lost, currently preserved in museums (Fig. 16B), in open public spaces and in the field (Fig. 16C).

Discussion

The main document of heritage protection to the fossils in Brazil is the Decree-Law 4,146 (Brasil 1942; Ghilardi et al. 2022), which indicates that the fossils are the patrimony of the Union. Although it is 80 years old, since its signature during the dictatorial regime of the Estado-Novo, there has never been a regulation of it. However, it is observed that the understanding that fossils are State heritage, their commercialization would be prevented and thus liable to criminalization. This interpretation was reinforced from Carvalho's analysis (1993) about the legal aspects of fossil commercialization in Brazil. There is currently the indiscriminate use of Decree-Law 4,146 as a punitive mechanism to any type of activity, even non-commercial, for the collection of fossils by academics or the occasional discovery by the population or workers (Kuhn et al., 2022a,b). This situation results from aspects directly linked to the interests of academic researchers, who seek exclusivity over geographical areas in the national territory. Such a situation leads to legal complaints, distribution of false information, and a criminalization of any activity that involves paying for services for the excavation, prospection, and collection of fossils, even for public museums and universities. A very striking example was the public disqualification of Father Neri Feitosa and the destruction of the Museum of Paleontology of Jamacaru, to serve interests other than the public good aimed at science and education. There is also an aspect that has been disregarded by legislators, which is related to the Brazilian Code of Mines (Brasil 1967). The State, by granting the mining right of a region, cedes to the concessionaire the right over the mining assets in the area of mineral extraction. The fossil is a lithological attribute, and thus the mining or quarrying rocks that may contain fossils should be considered as part of the concession granted by the state itself, not applying in this way the Decree-Law 4,146 (Brasil 1942).

In several situations, such as those observed in areas of continuous rock extraction for the production of materials for industrial use or construction, it is common for fossils to occur in the course of mining or quarrying. It is not a question here of a mine or quarry intended to extract fossils, but these, as part of the rock matrix, can be abundant, as in the case of the basins of Araripe, Potiguar, and Paraná. The workers' job of quarrying and cutting the rock, occasional discovery in rejecting or sorting rocks with fossils must be remunerated, enabling a greater number of specimens to be preserved ex situ in museums and universities (Carvalho 2018; Carvalho and Fernandes 2004; Carvalho and Leonardi 2007; Kunzler et al. 2014).

Fossils are the constituent elements of rocks that make it possible to interpret the evolution of ecosystems and the biological transformations that life has undergone in geological time. As part of rocks, fossils are used as ornaments, in construction, industry, and even for other purposes, such as ceremonial or pharmacological (Barreto and Polck 2021; Fernandes, 2005; Francischini et al. 2020; Gesicki and Santucci 2011; Polck et al. 2018; Henriques and Pena dos Reis 2019; Zoboli et al. 2021). Its wide occurrence in the rocks of sedimentary basins should be considered a natural resource of collective interest and non-restrictive use. The perception that fossils are special elements of heritage interest and unrestricted preservation is not compatible with the other uses in our daily life.

The wide diversity of fossilized organisms, including bacteria, fungi, plants, invertebrates, vertebrates, and even the record of paleobiological activity represented by ichnofossils, should be considered as memory records of the Earth, which in specific cases should have a differentiated conservation, in particular through museums and educational and research institutions. An important factor of this question is that the preservation or not of this type of object must be defined by geoscientists qualified to identify aspects that make them objects of scientific or educational interest. It is therefore not only a legal issue, but mainly the knowledge arising from the analysis of fossils and their importance in the construction of knowledge (Henriques and Pena dos Reis 2019; Henriques et al. 2011, 2012; Lima and Carvalho 2020a,b, c).

Despite the existence of a broad theoretical discussion about the adequacy of fossil commercialization (Barrett et al. 2021; Besterman 2001; Carvalho 1993; 2018; Davis 2001; Jasper 2010; Larson 2001; Larwood 2001; Lima 1990; Marcon et al. 2014; Martill 2001), which is not the scope of this study, it must however be considered that the

contribution to this knowledge is closely related to the manual job of workers on mining fronts, on agriculture, or in the construction activity. It is quite often through the daily task of revolving of a large volume of rocks that it becomes possible the discovery of fossils, whether new species, ichnospecies, or others already known, but possessing some special character of relevance. This type of work, as well as the workers who perform it, not directly linked to traditional studies in laboratories and offices, needs to be recognized, either as a form of the right to memory or as a financial reward for the work done. The denial of the recognition of workers who are involved or who help in the discovery of new fossils is a denial of the right to memory. It represents a form of oppression by the obligation to free labor and a denial of the social recognition of those who contribute to scientific development, but who are not part of formal academic cadres. An unacceptable situation that can no longer last within the scope of Brazilian Paleontology.

Paleontological research in Brazil becomes a difficult and sometimes even dangerous undertaking for a number of reasons that depend not only on the elements of nature, but on elements of bad politics. In the areas of the Rio do Peixe and Araripe basins, as in the corresponding states, and in others, there is also the obsolete phenomenon of the "colonels" (land owners), characters who control the territory: owners of farms, public agents, and local politicians and even university professors, who also believe that they are masters and owners of the people, science, culture, and geological heritage. The relationship between political parties, public agents, and local interests

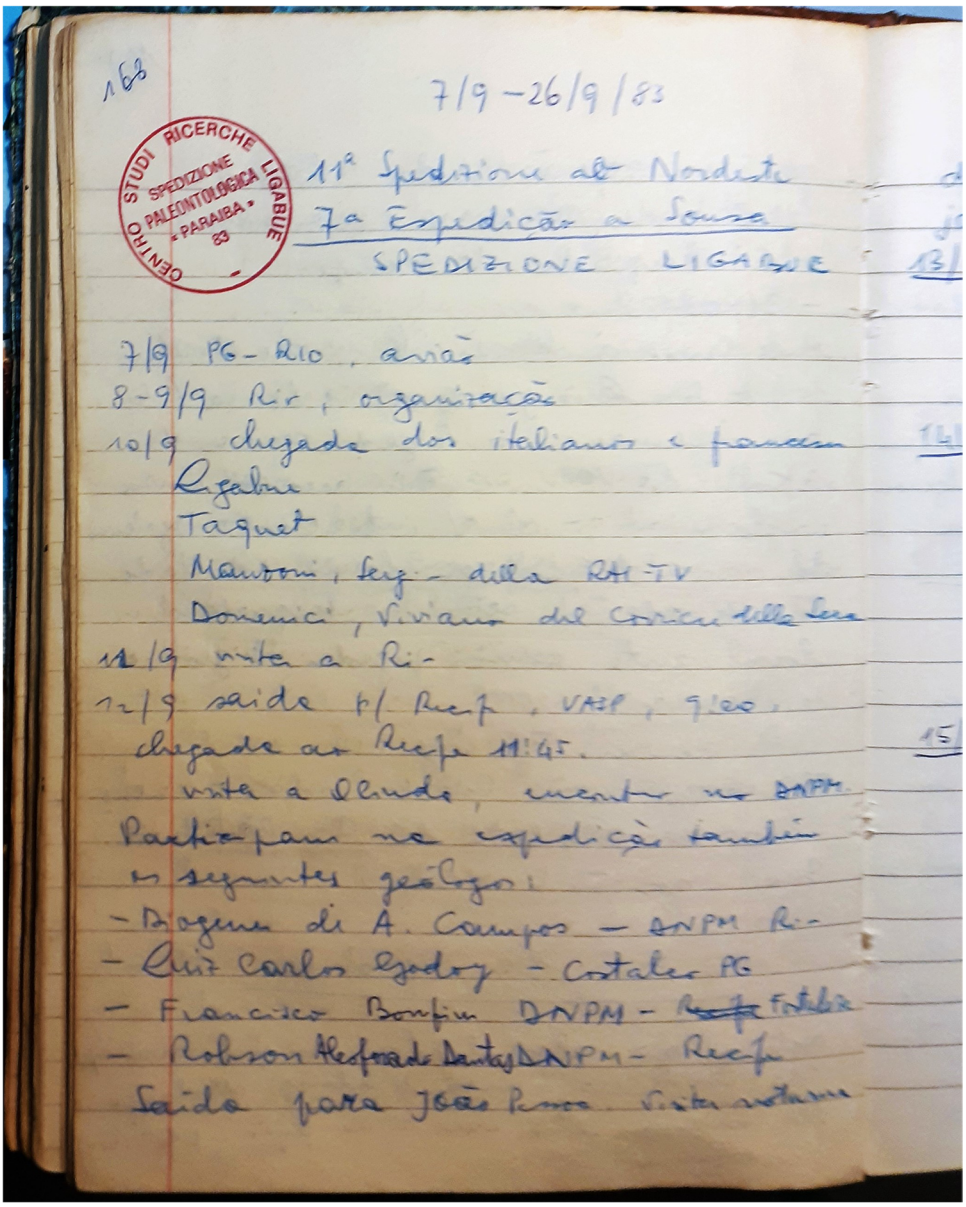

Fig. 17 Original rubber stamp in Giuseppe Leonardi's field log showing the correct denomination: "Centro Studi Ricerche Ligabue - Spedizione Paleontologica Paraiba 83". The use of the term "Expedition Ligabue-Leonardi" aims at professional disqualification with the presumed action of illegal removal of fossils from Brazil

detached from science destroys collections, dismantling local museums, and especially alienating experienced and competent people. In the most dangerous cases, there is the attack on researchers with false information, true fake news, provided to the local press and sometimes denouncing researchers to justice. An example of such an anomalous situation in the Brazilian academic field is the Ligabue Expedition. This is an international paleontological expedition carried out in September 1983, organized and funded by the "Centro Studi Ricerche Ligabue," today "Fondazione Ligabue," in Venice (Italy), with the authorization of the National Council for Scientific and Technological Development (CNPq, Brazil) and the then National Department of Mineral Production (DNPM, currently the National Mining Agency, ANM). The expedition included renowned Brazilian and foreign paleontologists (from the Muséum d'Histoire Naturelle of Paris, for example), including some of those responsible for the National Department of Mineral Production at the national level and other districts of the Northeast of Brazil. Although the expedition is called "Spedizione Paleontologica Paraiba," organized by Centro Studi Ricerche Ligabue as stated on the stamp of the expedition (Fig. 17) and as such approved by the CNPq and the DNPM, some newspapers in Ceará State (Brazil) still insist on calling it, recurrently and falsely, "Expedition Ligabue-Leonardi," with the clear objective of humiliation and professional disqualification, seeking justifications for the donations of fossils legally carried out in the exchange program.

Regarding the press (written and even televised), it was noted that, in the last 10 years, printed newspapers and electronic and local television channels, mainly from the State of Ceará, alerting about the alleged smuggling of fossils from the Romualdo Formation, do not accuse export trading companies or traders, Brazilian or foreign. They opt for the criminalization of researchers, placing them under the doubt of smoothness and inducing investigations and lawsuits.

Another case, significant, was the "2nd International Dinosaur Valley Festival" held in Sousa (PB) on August 10–13th 2005, in which the enmity between local politicians, land owners, and regional parties aggressively harmed a cultural and scientific event in the "Dinosaur Valley" organized with the support of the mayor of Sousa County (Paraíba State, Brazil). One of the results was that, during this event, the Natural Monument "Vale dos Dinossauros" was interdicted, "for security reasons" by the state police, even with the restriction of displacement of the participants (Fig. 18).

Conclusions

The paleontological documentary makes it possible to record some of the memories of geological time. As a lithological attribute, fossils record information about biological, environmental, climatic, and geographical transformations since the birth of life on Earth. Sometimes, they are sparse elements in the rock matrix; in other situations, they constitute completely the rock itself. Inherent in fossils is an element

Fig. 18 Field activity in Sousa, Sousa Basin during the 2nd International Dinosaur Valley Festival, in the Natural Monument "Dinosaur Valley." Due to local political interests, the movement of the participants in the park area was restricted, with the use of police force

that is also the desire of all human beings, the recognition of their own existence. An existence that occurs through the documentation of our actions or that materializes by the discovery of the new.

The paleontological discoveries and the resulting knowledge cannot be considered an isolated work of the researchers who analyze the fossils. The contribution of local populations, farmers, building workers, and quarries should be valued, with formal recognition through the documentary record in the collections, as well as in scientific texts that are published. The recognition of the Invisibles of Paleontology becomes fundamental for the advancement of knowledge, stimulation to meet new fossils, and representing one of the mechanisms of heritage protection, in particular as regards the destruction by urban sprawl or industrial and commercial use of fossiliferous rocks. It is noteworthy that the right to scientific knowledge cannot be hampered by misinterpretations of legislation, with discriminatory use on the population and scientists, based on extemporaneous political interests.

Thus, it is essential that the existing legal order does not represent a hindrance to donations and even remuneration in occasional discoveries, rewarding those who contribute to the advancement of knowledge. There is also a need for greater integration of educational institutions and museums with companies that perform mineral extraction and civil works in sedimentary areas, potentially fossiliferous. In particular, in the case of rock extraction, the right obtained through the concession of quarrying on fossils that may be found should be assessed. It is a legal right of the miner on the goods that constitute one of the attributes that are part of the rocks, and which were therefore authorized by the State for their extraction and marketing. Then, this situation is a clearly ambiguous juridic situation and should be adequately analyzed and discussed.

Acknowledgements In the 200th anniversary of Brazil's Independence (1822-2022). We thank all the workers and the population of the areas of fossiliferous occurrences that collaborated with the construction of the Brazilian paleontological knowledge. To the freedman Henrique, who guided Peter Lund through the backwoods of Brazil and Estulano, who, thanks to his practical knowledge, coordinated many of the excavations in Lagoa Santa (Minas Gerais State, Brazil).

To the citizens of Sousa (Paraíba State) such as farmer Espedito, Robson Araújo Marques, José Nilton de S. Cavalcante, Francisco Wellington de S. Cavalcante, Luiz Carlos da Silva Gomes, Neuricélia Teodoro Lima Moreira, Julieta Gadelha, Fernando Péricles de Araújo, Maria Auxiliadora Figueiredo, Tibério Felismino de Araújo, and Pedro Alexandre Alves Neto, who contributed to the popularization of knowledge and expanded the possibilities of new discoveries of ichnofossils in the Sousa Basin. Also noteworthy is the technical support of surveyors Sebastião Duarte Vieira and Pedro L. Lucena, who made it possible to map the areas with records of dinosaur tracks and footprints. To Claude Luiz A. Santos, Maria de Fátima C.F. Santos, Maria Dolores Wanderley, and Lenice do Vale, who contributed to the prospection, collection, and preservation of the first discoveries of fossil footprints in the Sousa Basin. Thank you to the successive mayors of Sousa—Gilberto de Sá Sarmento (1972–1976), Clarence Pires de Sá (1977), Sinval Gonçalves (1978–1982), Nicodemos de Paiva Gadelha (1983–1988), and Salomão Benevides Gadelha (2002–2008)—all in their respective times; José Nilton Fernandes, mayor of São João do Rio do Peixe (1983–1989); Geraldo Nogueira de Almeida, mayor of Uiraúna (1983–1988); and their administrations and collaborators helped very much with logistical support. Many thanks also to José Queiroga de Mello, Secretary of Works in Sousa. Still in Sousa, the drivers, Miguel Barros, Francisco Estrela Gomes, José Nobre de Araújo, and Bezaleel de Souza deserve thanks. To Deverson Silva (Pepi), Ariel Milani Martine, Franco Capone, José Henrique Gonçalves de Melo, Gilberto Raiz, and Guilherme Gehr for providing data and illustrations on the fossils from Sousa basin.

To the workers of the quarries of Nova Olinda, in the Araripe Basin, Adalberto Raimundo da Silva, Adriano dos Santos, Aílton Antônio, Alcides Cardoso da Silva, Antônio Edvaldo, Antônio Ferreira, Antônio Fortunato de Souza, Antônio Gilvan Silva, Antônio Lourenço, Antônio Marcos, Antônio Osías Costa Lima, Antônio Paulo Nogueira, Antônio Pereira Silva Filho, Arlindo Cardoso, Cícero Alves, Cícero Amorim Souza, Cícero Evandro Soares da Silva, Cícero John, Cícero Luís Nogueira, Cícero Paulo, Cícero Pereira, Cícero Salviano, Cláudio Pereira da Silva, Danilo Pereira, Delando Pereira da Silva, Edimar Alencar, Edimar da Silva, Edinar da Silva, Epifânio Pereira, Edivaldo Hermínio de Souza, Edval Hermínio de Souza, Edvaldo Bandeira da Silveira, Eldo da Silva, Elias Dantas, Eliezê Dantas, Elton de Souza, Elúsio Dantas da Silva, Epifânio Barbosa, Erandy Simão Oliveira Júnior, Erismar Gomes de Matos, Expedito Silvestre Matos, Francisco Alves Batista, Francisco Cenildo, Francisco Domingos de Moura, Francisco Edvan Bezerra da Silva, Francisco Francinildo, Francisco Gomes de Souza, Francisco Ismael Silva, Francisco Pereira Barbosa, Francisco R. G. de Souza, Francisco Rodrigo Ribeiro, Francisco Simão de Oliveira, Francisco Sebastião Gonçalves de Lima, Francisvaldo Ferreira Neves, Francinaldo Souza Oliveira, Fred da Silva Alves, Gilmar, Gilson Alves da Silva, Iranildo Pereira de Souza, Isélio de Oliveira, Jarbel Ferreira Moura, João Paulo da Silva, João Soares, Jonas Pereira Leandro, José Alexandrino, José Eido, José Givaldo da Silva, José Júnior da Silva Alves, José Lima, José Luís Nogueira, José Marcelino Neves dos Santos, José Roberto Raimundo Nonato da Silva, José Soares da Silva, Leônidas Macedo, Lorinaldo Cazuza da Silva, Marcelo Pereira da Silva, Napoleão Maia de Souza Neto, Pedro Miguel da Silva, Reginaldo Souza Oliveira, Ubiratan Moreira de Souza, Wallace Oliveira, and William Gouveia, Wilson, who are robbed of their right to recognize the important contribution they make to Brazilian Paleontology and the training of new researchers. To Neri Feitosa (Jamacaru county) and Plácido Cidade Nuvens, who recognized the importance of the quarry workers of Nova Olinda and honored the Brazilian Paleontology with dignity, recognizing that knowledge is the agent of social transformation that is necessary in Brazil.

For the team of excavations of the Llewellyn Ivor Price Paleontological Research Center, located in Peirópolis (State of Minas Gerais), who worked in the collection and preparation of fossils in Uberaba and Triângulo Mineiro in the last 50 years. Alberto Lopa, Langerton Neves da Cunha, Saulo Messias da Silva, Vanderlon Messias da Silva, João Ismael da Silva, Fabiano Isa de Morais, Vanderlei Messias da Silva, Evaldo Messias da Silva, Saulo Messias da Silva Neto, Carlos Humberto da Silva, Luiz Humberto da Silva, Omilton Ribela, José Eduardo da Silva Santos, Reinaldo da Silva Santos, Batista da Silva Sobrinho. Marcelo Nicolau, Rodrigo Humberto da Silva, Marcio Humberto da Silva. Amauri da Silva, Tony Fernandes Santana. Luiz Carlos Borges Ribeiro for his determination to transform Peirópolis into a tourist hub and international recognition for its fossils and its Geodiversity.

To the workers of the quarries of Mossoró, in the Potiguar Basin, who carried out the arduous work of selecting the fossils of *Tylostoma* sp., and that allowed the preservation of this material in the scientific collections of Brazil. Vingt-un Rosado Maia for his visionary action in the preservation of fossils previously used in the production of lime.

To the Oswaldo Grosso family and their sons, mainly José Francisco Grosso, owners of the quarries in the region of Araraquara, and to the workers who worked in them, who helped in the discovery of the main

records of the Cretaceous biota of the paleodesert of Botucatu. To Walter Ilha and Daniel Cargnin that preserved the Triassic fossils of Rio Grande do Sul State in an integrated way to community interests.

To the drivers of Rio de Janeiro Federal University, Damião Batista dos Santos, Ednaldo Vital dos Santos, Eduardo dos Santos Carvalho, Jorge Luiz Ignacio, José Neri (Zinho), Manoel José Coelho da Costa, Sidnei da Conceição Belarmino, and Wanderlei Andrade de Sousa, for their helpful support in the field work.

To Antônio Carlos Sequeira Fernandes, Douglas Riff, Fábio Reis, Ildeu de Castro Moreira, Isabela Degani-Schmidt, Francisco Idalécio de Freitas, Hermínio Ismael de Araújo Jr., José Artur Gomes de Andrade, Luiz Carlos Borges Ribeiro, Maria Eugênia de Carvalho Marchesini Santos, Margot Guerra-Sommer for the important information about the invisible history of Brazilian Paleontology. To Andrea Balduíno, Andrea Jakobsson, Castor Cartelle Guerra, Diana Ramos, Lorelai Kury, Marize Malta, and Silvia Fernanda de Mendonça Figueirôa, National Library, and D. João VI Museum for the cession of historical illustrations.

Funding This study was supported by Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (Proc. E-26/200.828/2021, Brazil) and by Conselho Nacional de Desenvolvimento Científco e Tecnológico (CNPq 303596/2016–3, Brazil), as well as many of the field, laboratory and office activities.

Declarations

Conflict of Interest The authors declare no competing interests.

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