



Are Fossils Mineral or Cultural Heritage? The Perspective of Brazilian Legislation

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Received: 23 November 2021 / Accepted: 13 June 2022
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Abstract

Fossils have great potential for elucidating and popularizing geosciences among all age groups. Brazil, due to its continental dimension and wide geodiversity, has many internationally important fossiliferous sites, which include rocks from the Pre-Cambrian to the Quaternary eras. Thus, in this study, we analyse the legislation and public policies related to the extraction, use, or protection of fossils and palaeontological sites in Brazil. This research examines the legal and infra-legal normative documents and numerous publications on the subject. Our results show that fossils are considered a heritage of the union, i.e. mineral heritage according to the mining code or, exceptionally, cultural heritage when they are related to human culture. Although the sale of fossils as a main product of mineral extraction is not regulated, it is possible and legal to sell material extracted from rocks formed basically by fossils. Hence, it is common to observe the use of such fossiliferous rocks as landfill, construction and paving materials, agricultural inputs, or other types of industrialized products. Mining and civil works, by exposing layers of fresh or slightly weathered rocks and expanding available observation areas, contribute to the advancement of palaeontological knowledge. Accordingly, we evaluate the absence of clear criteria for differentiating whether a fossil is a rare specimen or a common occurrence, entailing the necessity for the proposal of new norms for the preservation of Brazilian fossil heritage. Our study demonstrates that a new legal framework concerning the extraction of mineral resources is crucial to ensure a better preservation of Brazilian fossil heritage and to provide legal certainty for both professionals who research these natural assets and mining companies or those who develop construction projects in sedimentary basins.

Keywords Fossils · Legislation · Brazil heritage

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Introduction

Since human prehistory, there has been a relationship between human activities and the discovery of fossils, usually involving residence construction or mineral extraction (Baucon et al. 2020; Fernandes 2005; Francischini et al. 2020; Zoboli et al. 2021). In contrast to archaeology, whose records are contained only in superficial layers, in palaeontology, cases in which the excavation of large volumes of rocks is essential to expose surfaces with fossiliferous content, where the fossils exhibit good preservation conditions, are common. Thus, mining fronts are excellent sites for palaeontological discoveries (Gesicki and Santucci 2011; Henriques et al. 2012; Sá et al. 2021; Henriques and Carvalho 2022). Barreto and Polck (2021) have therefore postulated that mining and palaeontological research must be integrated through public policies and specific projects that defend the presence of specialists in palaeontology amid these economic activities for the collection and rescue of relevant materials.

In the Brazilian scientific literature, discussions of the discovery and collection of fossils in mining or civil works are common. Rocha-Campos (1966) reported the importance of engineering projects for the discovery of fossils, e.g. the quarries of the Santa Catarina Highway Department. Martins Neto and Ramalho (2010), Ricardi-Branco et al. (2008), and Gesicki and Santucci (2011) cited the importance of limestone mining in the Irati Formation (Fig. 1) for the discovery of mesosaurid, fish, arthropod, and plant remains in the municipality of Rio Claro, São Paulo. Schefler et al. (2010) reported the influence of studies related to iron, manganese, and limestone deposits among the Jacadigo and Corumbá groups, which resulted in the discovery of fossils in the state of Mato Grosso do Sul. In the municipality of Uberaba (Minas Gerais), mining activities carried out in limestone layers fostered the discovery of vertebrate fossils, especially dinosaur fossils (Santos et al. 2010). In the

Araripe Geopark, for example, the Triunfo Mine, a deactivated fossiliferous limestone quarry, is one of the region's geosites (Bétard et al. 2018).

In Brazil, the system of legal protections and legal orders referring to fossils, first implemented 80 years ago (Brazil 1942), is currently ineffective for the preservation of Brazilian's palaeontological heritage. Many decree-laws, ordinances, and state and municipal laws (Brazil 1967, 1973, 1988, 1994, 1999, 2000, 2016, 2017, 2018, 2021; IPHAN 2018; SBP 2021; Ghilardi et al. 2021), often conflicting and legally questionable, have led to extensive judicialization regarding palaeontological heritage, especially when compared to mining law (Santos et al. 2010) (Fig. 2). Although fossils can be considered part of Brazilian cultural heritage (IPHAN 2018) and are therefore subject to preservation and protection (Viana and Carvalho 2019), they are also a mineral resource and are thus not necessarily subject to current geoconservation models, as suggested by Carmo et al. (2010), Carvalho (2018), Carvalho et al. (2021), De Miguel et al. (2021), Fidalgo and Fernández-Martínez (2021), Henriques and Pena dos Reis (2015, 2019), Henriques et al. (2011), Kauffman et al. (2013), and Page (2003, 2018).

Legal conflicts involving mining, the preservation of palaeontological heritage, and the advancement of scientific knowledge have had enormous international public visibility. Disputes involving specimens from different countries that are displayed in museums or sold abroad are related to the extraction of mineral resources (Barrett et al. 2021). This situation demonstrates the need for clear legislation that is integrated with new social and economic demands and to establish criteria to define the relevance fossiliferous materials for purposes of natural heritage preservation.

In this study, we attempt to provide a critical analysis of the existing regulations in Brazil and present infra-legal suggestions to contribute to the formulation of a new legal framework that addresses fossils and relevant

Fig. 1 Relationship between mining and fossil discovery. Mining front (A) in the Irati Formation (Paraná Basin, State of São Paulo). (B) *Mesosaurus brasiliensis*, a fossil specimen belonging to the Irati Formation



Brazilian legislation affecting paleontology

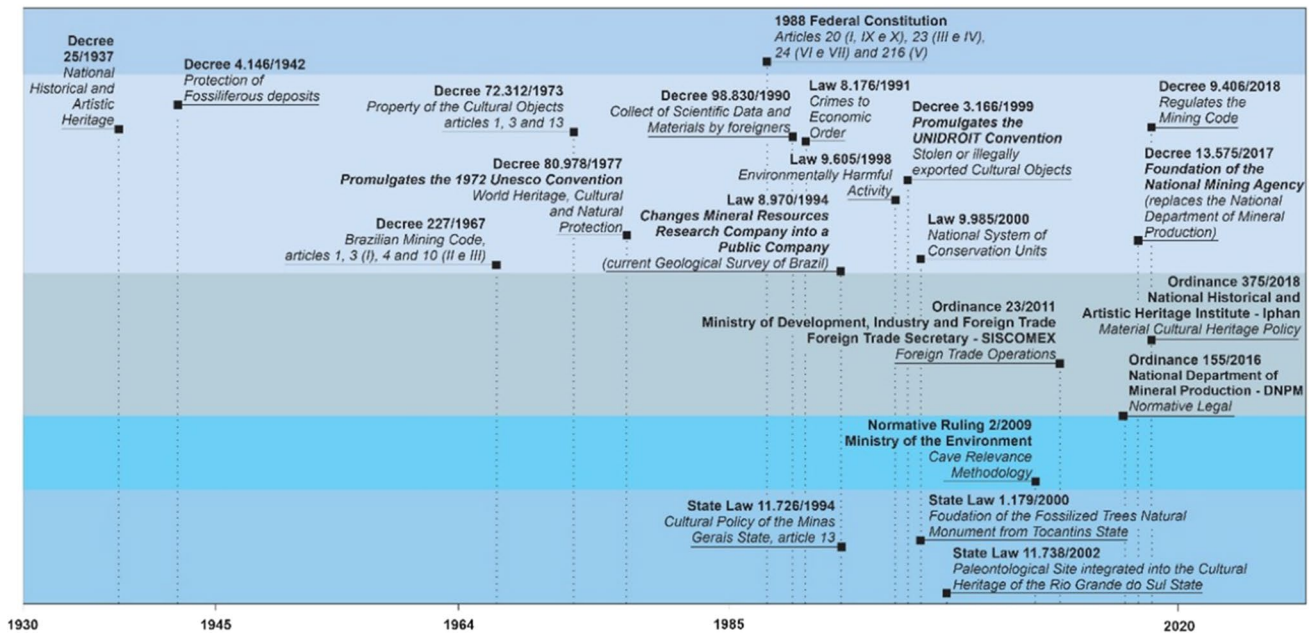


Fig. 2 Main legal provisions and regulations for fossil protection of palaeontological heritage in Brazil. Many of the laws and normative guidelines are conflicting and legally questionable, which has led to

palaeontological sites to effectively differentiate what constitutes Brazilian palaeontological heritage.

Method

This research was performed using the websites of Brazil’s federal government, national congress, public bodies, and organized civil societies to identify the laws and infra-legal documents that regulate the extraction, use, or protection of fossils and palaeontological sites in Brazil. We also evaluated the applications of the legislation and possible improvements to that legislation via case studies that we selected to exemplify the existing legal problems and challenges.

Legislation

Decree-Law No. 4,146/1942, promulgated by President Getúlio Vargas, was the first legal regulation dealing with fossils. It resulted from a visit to the works of the Grande Hotel do Barreiro in Araxá (state of Minas Gerais), where the president, observing the recovery of vertebrate macrofossils from soil, consolidated his initial idea that past life remains could be elements dissociated from such rocks (Carvalho 1993). Hence, the postulate that “fossil deposits are property of the nation and, as such, the extraction of fossil

the judicialization of palaeontological heritage, especially when compared to mining law

specimens depends on prior authorization and inspection by the DNPM” (Brazil 1942).

The management of fossiliferous heritage has always been the responsibility of government bodies to control mineral extraction, linked to the Ministry of Mines and Energy. The need for the standardization and management of this type of natural resource led to the publication, in 2014, of the National Department of Mineral Production (DNPM) Ordinance No. 542 (DNPM, 2014), which established the procedures for the prior authorization and communication of the extraction of fossils, pursuant to Decree-Law No. 4.146 of 1942. Later, Ordinance No. 155 of May 12, 2016, was published, instituting the electronic control of palaeontological research (COPAL), with the objective of providing and enabling palaeontological research requirements in three categories: (1) communication of the extraction of fossil specimens; (2) authorization for the extraction of fossil specimens; and (3) authorization for palaeontological rescue (DNPM, 2016).

The definition of fossils as a mineral resource was established in the Mining Code, created in 1940, and was revised by Decree-Law No. 227/1967. The first article establishes, as a competence of the union, the administration of mineral resources, extending, in the first paragraph, this legal text to the “rights over the individual masses of mineral or fossil substances found on the surface or in the interior of the earth, forming the mineral resources from the country”. Furthermore, Article 4 defines a deposit as “any individual mass

of mineral or fossil substance outcropping on the surface or existing in the interior of the earth (sic), which has economic value, and mine or mine deposit, even if suspended". Finally, Article 10 states that "The following shall be governed by special laws: I—deposits of mineral substances that constitute a state monopoly; II—mineral or fossil substances of archaeological interest; III—mineral or fossil specimens, destined for museums, educational establishments and other scientific purposes; [and] IV—mineral waters..." (Brazil 1967). This definition is reinforced by Law No. 8.970/1994, which transformed the Mineral Resources Research Company (CPRM) into the Geological Survey of Brazil (SGB/CPRM). According to the respective law, mineral resources are deemed "the individual masses of mineral or fossil substances found on the surface or in the interior of the earth (sic), as well as on the underwater platform". The same legislation is established as a function of the geological service: "II – to encourage the discovery and use of the country's mineral and water resources; III – to guide, encourage and cooperate with public or private entities in carrying out research and studies aimed at the exploitation of the country's mineral and water resources" (Brazil 1994). Notably, according to Brazilian laws, fossils are mineral heritage.

However, between the most current revision of the 1967 Mining Code and the redefinition of the role of the Geological Survey of Brazil, Decree No. 72,312/1973 was implemented. It formalized the commitment to the "Convention on Measures to be Adopted to Prohibit and Prevent the Import, Export and Transfer of Illicit Ownership of Cultural Property", an event promoted by UNESCO in Paris in 1970. Thus, a new perception of the meaning of fossil heritage was instituted. In this Convention, the expression "cultural property" is applied to "the collections and rare specimens of zoology, botany, mineralogy and anatomy and objects of palaeontological interest" (Brazil 1973). A second international meeting, promoted by the government of the Italian republic, the UNIDROIT Convention of 1995 on "Stolen or Illicitly Exported Cultural Goods", produced a new understanding of the need to protect rare specimens of palaeontological interest, as expressed in Decree No. 3.166/1999 (Brazil 1999). Notably, both conventions addressed collections and specimens of zoology, botany, and mineralogy; however, in Brazil, such thematic collections are the responsibility of different public agencies, with specific rules concerning these international conventions. Moreover, these conventions did not intend, nor find it reasonable, to transform all these natural assets into cultural heritage; they merely intended to create international mechanisms for the protection of materials that are specifically valuable for human culture. Otherwise, all mineral, zoological, or botanical samples would be considered cultural heritage.

Among the assets of the union listed in Article 20 of the Brazilian Magna Carta are "X—mineral resources, including

underground" and "XI—natural underground cavities and archaeological and prehistoric sites" (Brazil 1988). The cultural aspect was later expanded from the Brazilian Constitution (Brazil 1988) in Article 216, where palaeontological sites are considered the cultural heritage of Brazil:

Art. 216. The material and immaterial assets of a Brazilian cultural heritage, taken individually or together, bear reference to the identity, action, [and] memory of the different groups that make up Brazilian society, which include

I - forms of expression;

II - ways of creating, doing and living;

III - scientific, artistic and technological creations;

IV - works, objects, documents, buildings and other spaces intended for artistic and cultural manifestations;

V - urban complexes and sites of historical, scenic, artistic, archaeological, palaeontological, ecological, and scientific value.

§ 1 The public power, with the collaboration of the community, will promote and protect Brazilian cultural heritage through inventories, records, surveillance, registration and expropriation and other forms of precaution and preservation.

§ 2 It is incumbent upon the public administration, in accordance with the law, to manage government documentation and take steps to facilitate its consultation to those who need it.

§ 3 The law will establish incentives for the production and knowledge of cultural goods and values.

§ 4 Damages and threats to cultural heritage will be punished in accordance with the law. (Brazil 1988)

Accordingly, the Federal Constitution of 1988 indirectly included what had already been foreseen in the extant enforced legislation. Among the goods of the union were "IX—mineral resources, including those in the subsoil; and X – natural underground cavities and archaeological and prehistoric sites". On the other hand, in Article 216, part of Brazilian cultural heritage includes "the urban complexes and sites of historical, scenic, artistic, archaeological, palaeontological, ecological and scientific value" (Brazil 1988). However, it limits what has cultural value to goods that are considered relevant but not specifically fossils, as was proposed by Getúlio Vargas in his Decree-Law of 1942.

Another piece of legislation related to fossil heritage is Law No. 9,985/2000, which instituted the National System of Nature Conservation Units (SNUC). In Item VII of its Article 4, it includes among the objectives of this system the protection of "the characteristics that have geological, geomorphological, speleological, archaeological, palaeontological and cultural relevance". At the federal level, the Chico Mendes Institute for Biodiversity Conservation (ICMBio) is the managing body that is responsible for the SNUC, but there are

also state and municipal conservation units. In some cases, in Brazil, conservation units have been created to protect geodiversity, e.g. the Natural Monument of Fossilized Trees in Tocantins (MNAFTO) (Kauffmann et al. 2013). Another case where this legal instrument was used was the Sousa Basin. According to Santos et al. (2019), this most relevant geosite in terms of the fossil record of dinosaur footprints was designated, in 1992, a natural monument, but there are still many actions needed to protect these fossil tracks from rain, floods of the Peixe River, and trampling by cattle.

Another noteworthy aspect is that the identification and registration of sites of palaeontological interest receive far less attention than those of archaeological sites, which currently account for 27,582 sites registered in the National Registry of Archaeological Sites–CNSA (Brazil 2021a, b). Certainly, one of the main reasons for this discrepancy between the two disciplines is the lack of objective criteria for classifying palaeontological sites. This gap, in addition to making it difficult to effectively protect the palaeontological heritage that has actual value for understanding the history of the planet, facilitates legal instability among the holders of mineral exploration rights that derive from public concessions.

The Management Structure for the Protection of Fossils in Brazil

Four different public bodies are responsible for the management or protection of fossils in Brazil: the National Mining Agency (ANM), the Institute of Historical, Artistic and Cultural Heritage (IPHAN), the Geological Service of Brazil, and the Chico Mendes Institute for Biodiversity Protection (ICMBio) (Fig. 3).

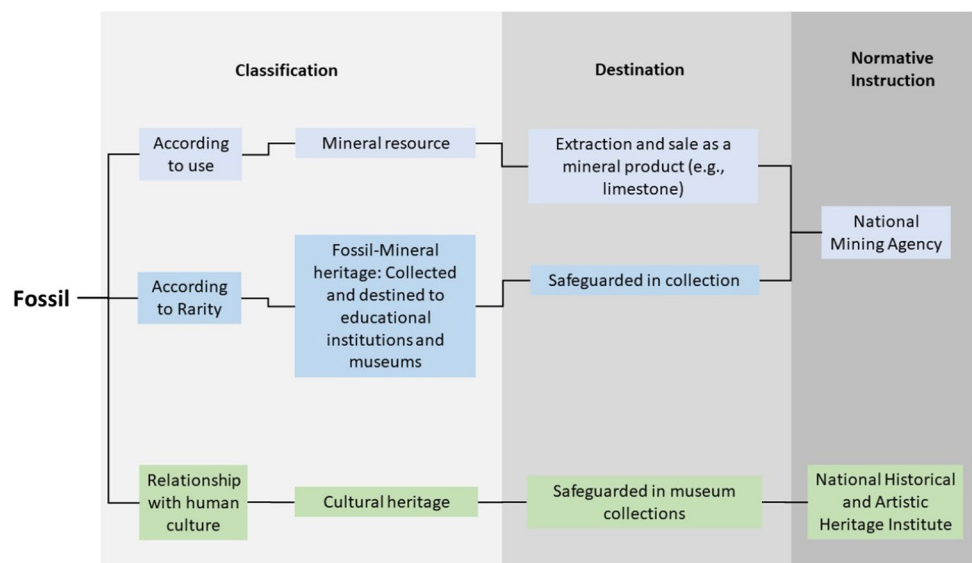
The Geological Survey of Brazil (CPRM), although it plays a fundamental role in promoting palaeontological research and geodiversity in Brazil, does not have a normative character (Kuhn et al. 2022). Initiatives, such as the Brazilian Commission on Geological and Paleobiological Sites (SIGEP), contribute to the dissemination of Brazilian natural heritage in the field of geology but have no practical legal effect. The Chico Mendes Institute for Biodiversity Protection (ICMBio) is a body for the administration, development, control, and inspection of Brazilian protected areas within the restricted scope of the National System of Conservation Units (SNUC) and, within these, of any relevant palaeontological area, without interference from mining activities.

In turn, the National Mining Agency (ANM), which through Law No. 13.575/2017 replaced the National Department of Mineral Production (DNPM), has the following functions, among others:

- I - implement the national policy for mining activities;
- II - establish norms and standards for the use of mineral resources, observing the sectorial planning policies defined by the Ministry of Mines and Energy and the best practices of the mining industry;
- III - provide technical support to the Ministry of Mines and Energy;
- IV - request, store and manage data and information on research and mining activities produced by holders of mining rights;
- V - manage mining rights and titles for the purpose of taking advantage of mineral resources. (Brazil 2017)

Item XII of Article 2 of the law that created the ANM explains that its powers are to “regulate, guide and supervise the extraction and collection of fossil specimens, referred to in Item III of the main section of Art. 10 of Decree-Law

Fig. 3 Classification of fossils according to the Brazilian legal system. ANM, National Mining Agency; IPHAN, National Historical and Artistic Heritage Institute



No. 227 of February 28, 1967 (Mining Code), and Decree-Law No. 4,146 of March 4, 1942, and to adopt measures to promote their preservation”.

The protection of national historical and artistic heritage in Brazil is regulated by Decree-Law No. 25/1937, and its managing body is IPHAN, which conceptualizes and acts on heritage through listing:

Art. 1. The national historical and artistic heritage constitutes (sic) the set of movable and immovable property existing in the country and whose conservation is of public interest, either because of its link to memorable facts in the history of Brazil or because of its exceptional archaeological or ethnographic, bibliographic or artistic importance.

§ 1 The property referred to in this Article shall only be considered an integral part of the national historical or artistic heritage after being registered separately or in groups in one of the four record books of heritage (known as “Livro de Tombo”), referred to in Art. 4 of this law.

§ 2 Natural monuments, as well as sites and landscapes that it is important to preserve and protect due to a remarkable feature with which they have been endowed by (sic) nature or agents are also subject to listing by (sic) human industry. (Brazil 1937)

Based on this legislation, both IPHAN and the ANM created ordinances and guidelines to implement inspection. To define what objects of protection are within its scope, IPHAN uses the instrument of “registration”, which has application rules that have been defined in infra-legal regulations (Brazil 1937). It implies the selection of an object, individually or locally, based on criteria of local, regional, or national identity, whether material or cultural, with a whole special framework and a long process of analysis. Consequently, fossils in general are not considered or protected by IPHAN.

Concerning fossil management, within the scope of processes followed by institutional actors linked to mining, Ordinance No. 155/2016 (Brazil 2016), issued by the DNPM, is currently in force and is the responsibility of the National Mining Agency. In Title IV of this regulation are the procedures related to authorization and prior communication for the extraction of fossils, which do not characterize size or situation, entailing the same interpretation of procedures for application in deposits with different natures, such as diatomites, siliceous rocks formed by accumulation of diatomaceous algae, or limestones with nanofossils, typical of mining areas in the cement industry, or rocks where dinosaur fossils are found when exposed by road construction, which recently occurred in São Paulo (CNN Brazil 2021a, b).

Article 2 of Ordinance No. 542/2014 of the DNPM (currently ANM) defines fossil as “remains, vestiges or results of the activity of an organism that is more than 11,000 years old or, concerning an extinct organism, with no age limit, preserved in natural systems, such as rocks, sediments, soils, cavities, amber, ice and others, and which are destined for museums, teaching establishments or other scientific purposes”. Fossil deposits are considered “any natural system that contains one or more fossils” (DNPM 2014). Ordinance No. 155/2016, in Article 297 (DNPM 2016), reaffirms these definitions and advances the rescue and disposal of fossils. However, this definition of fossiliferous deposits, lacking a classification of the real importance of a deposit, obliges the indistinct preservation of all sedimentary rocks with some kind of fossil, including those with microfossils.

Without characterizing the size, importance, and/or situation of a fossiliferous deposit in limestones, shales, sandstones, and diatomites or of past life remains, such as dinosaur footprints, the legal possibilities to question the use of these rocks are opened when obtaining mineral goods. For example, in an ambiguous and long-winded way, Article 309 allows an entrepreneur to determine palaeontological rescue in mining areas concurrently with mining activity.

Under the same Ordinance No. 155/2016 (Brazil 2016), the extraction of fossils is related to collecting for scientific or educational objectives without economic purposes. Article 299 defines the authorization or communication of fossil extraction as “activities related to technical projects of palaeontological rescue or scientific projects and activities of a scientific, technical or didactic nature”. The sole paragraph of the same article prohibits granting an authorization for the extraction of fossils for the specific purpose of marketing.

Palaeontological rescue, on the other hand, is defined in Article 299 as the “exhaustive collection of fossils from the place of occurrence in order to mitigate the imminent risk of destruction or irreversible damage, also including the measures that are necessary for its scientific documentation” (Brazil 2016). The same article also identifies (a) palaeontological rescue as “planning the extraction of fossils from the fossiliferous deposit for palaeontological rescue purposes”; (b) scientific project as “planning palaeontological research and its execution involving, among other activities, the extraction of fossils for the purposes of scientific studies, composition of the collection of a scientific institution or exhibition for the dissemination of knowledge”; and (c) scientific, technical or didactic activities as “activities not linked to a technical or scientific project, such as field excursions linked to scientific events (congress, symposium, workshop, seminar, etc.) and excursions linked to the curricular subjects of courses of a technical or higher level”.

Concerning palaeontological research, the regulation relates the activities to be developed during the stage of

obtaining the Installation Licence (LI), which require a palaeontological rescue program and financial endorsement by the entrepreneur in addition to information about the depositary institution. At the end of the fossil extraction activities, information related to the work that was carried out must be presented (Brazil 2016).

The importance of fossil heritage management through the actions carried out by universities, museums, and research centres should also be highlighted (Boas et al. 2013; Lima and Carvalho 2020a, b, c). The effective protection and management of ex situ heritage, of the collections resulting from teaching and research activities in addition to donations from professionals not involved in these activities, are inputs of great importance for educational actions, the popularization of science, and increases in scientific knowledge and in applications for prospecting for mineral resources (Carvalho 2018; Carvalho et al. 2021; Henriques et al. 2011; Henriques and Pena dos Reis 2015, 2019; Pena dos Reis and Henriques 2009).

In summary, it appears that Brazil's legal and normative regulations maintain the vision of fossils conceived by Getúlio Vargas in the 1940s, essentially having macrofossils as their main point of concern. The underlying idea is that a fossil will "always" be detectable and capable of being "withdrawn" from its rocky context. This understanding, due to a lack of clarity, technical rigor, and clarifying infra-legal provisions, promotes profound legal instability among mining companies that work with a "mass of micro- or nanofossils", which constitute a rock per se. Although these are also elements of palaeontological heritage, they are almost always a direct object of mining and crushing (Fig. 4). Accordingly, extremely important information cannot be obtained from these rocks to help unravel the evolution of life on the planet, to facilitate palaeogeographic interpretations and extremely useful age indications that could guide future research on mineral and energy resources in the country.

Fossils in Brazil: Mineral or Cultural Heritage?

As highlighted by Viana and Carvalho (2019), there is a great weakness in the current legislation and, in its compliance, the result of different interpretations of the responsibilities for palaeontological heritage and of the very concept of fossils. Delphim (2004) noted a lack of legal instruments and effective acts for the defence and safeguarding of palaeontological heritage in Brazil. The duality between a fossil as an item of cultural heritage under the responsibility of the National Historical and Artistic Heritage Institute as a rock constituent that is object of mineral exploration, an activity managed by the National Mining Agency, demands an in-depth reflection to define the best conservation strategies

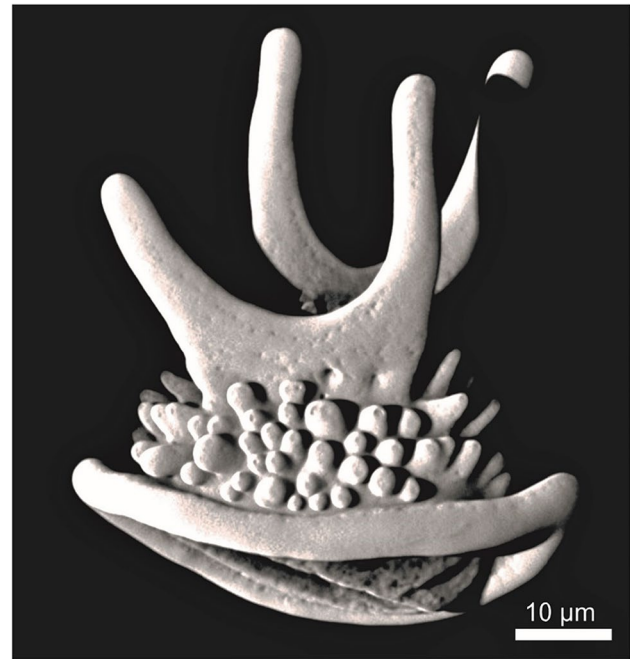


Fig. 4 Microscopic fossils, such as palynomorphs, can occur in the millions in a few cubic centimetres of rock. Some have great relevance, such as index fossils, with which biostratigraphic correlation and application in the oil industry is possible. In the illustration, the pollen *Elaterosporites protensus* is a guide fossil from an Early Cretaceous biozone in Brazil. Their small size and abundance and the lack of public interest in them render them irrelevant in discussion forums about the preservation of palaeontological heritage. Photograph by Elisabete Pedrão Ferreira

(Barreto and Polck 2021; Lima and Carvalho 2020a, b, c; Santos et al. 2019) and the feasibility of relevant studies.

Since the first legal regulation in Brazil for the protection of fossils (Decree-Law No. 4,146/1942, Brazil 1942), there has always been a recognition that these constitute a mineral heritage. However, the Brazilian Constitution of 1988, in Article 216 (Brazil 1988), offered a new interpretation of this.

Palaeontological sites came to be considered part of Brazilian cultural heritage. It is important to emphasize that the situation of a fossil was not treated as an isolated element but as part of a natural set, composing a deposit to be preserved. This situation led to simplistic and incomplete interpretations about the meanings of fossils and palaeontological sites, such as those presented by Marcon et al. (2014), Ribeiro and Iannuzzi (2009), and Dresch (2007), who considered them part of Brazilian cultural heritage and thus in conflict with the mineral extraction industry.

According to the legislation, every fossil is a mineral heritage of the Brazilian state. However, the existing regulations do not clarify what criteria and procedures must be carried out in the areas where there are fossils, which would make it possible to distinguish the fossil specimens or type sections of biostratigraphic interest that are susceptible to or

important for preservation. Scientific methodologies, such as those proposed by Boas et al. (2013), Page (2003), Pena dos Reis and Henriques (2009), and Santos et al. (2019), for the preservation of this type of heritage are not defined. Such ambiguity pervades lawsuits, stoppages of projects, destructions of fossil material, social conflicts, and the criminalization of citizens and professionals, fostering the sale of fossils.

This situation has been exacerbated by analyses that only link the cultural character of fossils, such as those by Ribeiro and Iannuzzi (2009). On the same basis, Dresch (2007) listed fossils as cultural heritage, indicating the need for their protection by the National Historical and Artistic Heritage Institute (IPHAN) and for the management of fossil extraction by the National Department of Mineral Production (currently, the Ministry of Mining). For this author, due to the character of fossils as union heritage, it would be impossible to have private collections.

However, not all fossils can be considered cultural heritage, either for legal reasons or because they represent elements of economic interest that are strategic for industrial activity. Sedimentary rocks, typically constituted by the skeletal remains of fossil organisms, macroscopic or microscopic, have enormous applicability in engineering works, the chemical industry, and agriculture. This is the case for Moroccan phosphate deposits, where every year thousands of complete skeletons of mosasaurs, turtles, plesiosaurs, dinosaurs, birds, pterosaurs, and fishes are crushed to make fertilizer. This intrinsic character of fossils as rock formers led Gesicki and Santucci (2011) to differentiate between fossils with heritage value, potentially destined for museums and educational establishments and other scientific purposes, and fossils as mineral resources in accordance with Item 42, Opinion No. 107/2010/PROGE. These are the cases in which fossils are an exploited mineral resource, e.g. stromatolites with *Conophyton* sp. from the carbonates of the Itaiacoca Group (Proterozoico, State of São Paulo), to produce lime and cement (Sallun Filho et al. 2013).

Some analyses have demonstrated successful strategies for geoconservation that navigate mineral exploration and the preservation of fossiliferous occurrences. Gesicki and Santucci (2011) have cited the occurrences of fossils of *Mesosaurus*, invertebrates, and trace fossils among the Irati Group (Paraná Basin, Permian) in mining areas. Another example relates to the outcrops of Pedreira Poty (Paulista municipality, state of Pernambuco), the first location where the Cretaceous-Tertiary boundary in Brazil was described (Albertão and Martins 2006). This succession includes the carbonates of the Gramame and Maria Farinha formations (Pernambuco-Paraíba Basin), which demonstrate the global dimensions of the impact of an asteroid in Mexico 65 million years ago (Albertão 1993; Albertão and Martins 2006). In 2018, a geoconservation strategy was created that reconciled

mining activities and the preservation of geological heritage with guided tours and infographics (Barreto and Polck 2021). Interestingly, some palaeontological museums have in their collections no less than 40% of specimens that have been donated by anonymous collectors or mining companies (Ismar de Souza Carvalho and Alcina Magnólia Barreto – CONFEA-CREA meeting, on September 9, 2021, oral information).

The paradox arising from the inclusion of the concept of fossils as cultural heritage in mineral extraction activities led the National Historical and Artistic Heritage Institute (IPHAN) to standardize the topic in Ordinance No. 375/2018, which defined the Material Cultural Heritage Policy–PPCM (IPHAN 2018). Only when there is evidence of the existence of values related to the identity, actions, or memory of the different groups that make up Brazilian society will the possibility of protection as a cultural heritage be evaluated. One example is the fossils described by Vialou and Vialou (2019), whose ornaments, made with *Glossotierium lettsomi* ossicles, demonstrate the coexistence of megafauna and prehistoric man 27 thousand years ago in Brazil. This notion that a fossil becomes a cultural heritage only in cases where its relationship with human history is proven has also been defended by international authors, such as Nudds (2001).

The International Context of the Heritage Significance of Fossils

The definition of a fossil as a mineral or cultural asset is generally related to social and historical values, which are related to use, tradition, function, and social perception. These same factors are decisive concerning the possibility for selling fossils or their characterizations as objects of interest to a nation's identity.

Mining law definitions, i.e. whether fossils are valued as individual possessions or significant heritage and the requisite legislation on the extraction, trade, and management of palaeontological sites, vary in different countries. In Australia, the Mobile Cultural Heritage Protection Act has been in place since 1986, and it prevents the export of valuable cultural and scientific materials, including fossils. However, legislation on the protection, collection, and sale of fossils varies according to the regulations of each state, which is not a determining factor in cases of vandalism or theft (Percival 2014).

In the USA and the UK, until a few years ago, archaeology had specific legislation, but there were no specific laws protecting fossils. However, in 2009, the 111th Congress included fossils in the Omnibus Public Land Management Act (USA 2016). The right to the possession of these, in general, is agreed upon between landowners and those who

carry out fossil collection through contracts or formal permissions. Disputes over fossils removed without authorization can result in lawsuits (Sheldon and Chewing 2000). Davis (2001) has mentioned that the illegally fossil trade that is conducted in the USA and the UK can be classified as theft.

China, through the Cultural Relics Protection Act of 1982, initially protected only vertebrates of scientific value. However, new legislation implemented in 2011 protects a broader range of fossils and creates clear rules for the work of international researchers in conjunction with that of Chinese researchers (Liston 2014). The export of fossils from China thus has strict legal controls, and any material taken from China must be returned to the country before the publication of salient research (Liston and You 2015).

The main palaeontological sites in England are protected as sites of special scientific interest, preventing damage that is related to development and protecting against the inappropriate collection of fossils. Larwood (2001) has suggested that the trade in fossils in the UK has positive overall effects, and Besterman (2001) has shown that a significant number of important fossils in the collections of museums in the UK were acquired through purchases.

A unique situation is that of Myanmar, where the extraction of amber is legal and this material is widely exported and used for jewellery and crafts. However, many fossil specimens are included in this amber, which leads to legal conflicts between the value of amber as a gem for industrial application and its value as a palaeontological heritage (Barrett et al. 2021).

According to Percival (2014), governments should be cautious when developing regulations that restrict the collection of fossils. He has indicated that there is a need for a balance between measures to protect important palaeontological heritage and for carrying out recreational fossil collection as a hobby or for educational activities.

There are still major issues at the international level to be resolved regarding the heritage value of fossils and what is the best mechanism to carry out their management, especially for rare specimens with high scientific value. Conversely, regarding fossils with wide occurrence, the debate is more simplistic, and the greatest concern is the legality of extracting and selling fossils.

Recently, the publication of articles describing new Brazilian fossil species that are housed in foreign institutions has instigated a broad debate in Brazil and internationally on the repatriation of fossils. Any illegally exported material must be subject to appropriate legal procedures. The main question concerns the legality of holotypes that are housed outside Brazil, an issue to be resolved by Brazilian foreign affairs.

However, concerning rare specimens, which are clearly protected by UNESCO resolutions, repatriation must be

carried out, whether due to the provisions of legal regulations or moral issues, given a focus on decolonization, as museums in the global north have historically acquired collections from the global south (Cisneros et al. 2021; Caldwell et al. 2021). Such decolonization is a controversial subject. For example, in the fire that destroyed the National Museum in Rio de Janeiro, Brazil, on September 2, 2018, many valuable artefacts were destroyed, and this disaster was certainly a great loss for world science. In this context, the need for copies or other specimens in different institutions is justified; it protects the cultural and scientific heritage of humanity and the planet and facilitates restoration in case of disaster, e.g. the fire at the National Museum, where even international collections were lost.

The Sacralization of Fossils and Their Best Use for Society

In almost all sedimentary areas, during the construction of roads, wells, and houses and in mining, the occurrence of fossils is common (Figs. 5 and 6). Thus, the argument that all this natural property is cultural heritage and must be preserved leads to its “sacralization” as untouchable objects, implying the suspension of all mineral activities or civil works in sedimentary areas in an extreme legal analysis of the current legislation. This interpretation leads to conflict and to the absence of adequate protections for fossils and fossiliferous deposits in Brazil, enabling the immobilization of mining fronts or civil works. This situation has a strong social and scientific impact, as these places are important areas of employment generation and have been important sources for new discoveries. The commercial collection of fossils could also provide employment in poor rural areas.

Greater paradoxes are evident when examining the possibility of the alienation or even the sale of fossils. Although formally prohibited, the sale of specimens routinely occurs in Brazil in a legal manner. The sedimentary rocks that are cut to be used process of industrialization of sedimentary rocks (Fig. 7), where blades are cut to be used as a coating, are generally carriers of fossils, as demonstrated by Francischini et al. (2020) and Martill (2001). In many situations, these specimens are crushed for use in the production of cement, agricultural, or industrial inputs, making it impossible to use them for other purposes (Fig. 8). There are also anachronistic bureaucratic requirements that limit the formal donations by research institutions and museums of common examples of their collections for elementary and secondary schools to use them as pedagogical elements that stimulate scientific curiosity among young Brazilians.

Even with all the laws that exist in Brazil, there is no adequate preservation of the fossiliferous heritage. Bétard

Fig. 5 Cretaceous algal bioherms of Solenoporaceae in the Sergipe Basin. The opening of the BR-101 highway in the municipality of Rosário do Catete (State of Alagoas, Brazil) facilitated the chance encounters with these fossils, which are typically used in landfills or discarded



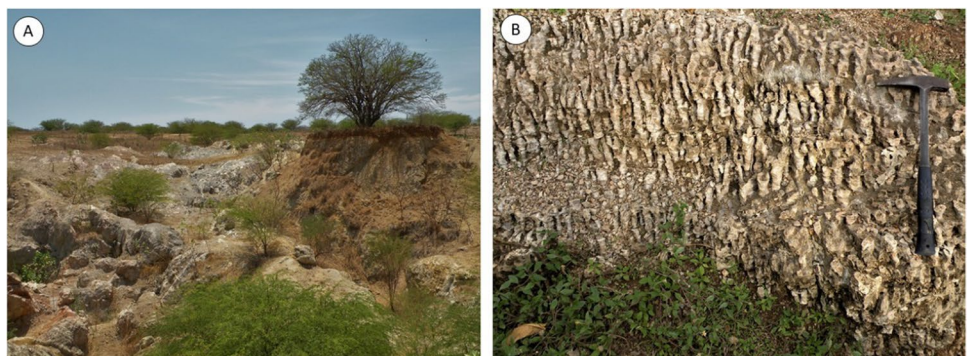
Fig. 6 Fossils are recurrent elements in some deposits of economic interest, such as coal. In the mine tailings (A) of the Faxinal Mine (Arroio dos Ratos, State of Rio Grande do Sul), the rocks of the Rio Bonito Formation (Permian, Paraná Basin) often contain plant fossils, such as *Glossopteris* sp. (B). Photography by Isabela Degani Schmidt



Fig. 7 Due to legal restrictions on the use of fossils in educational and commercial trades, their destruction occurs in large mining fronts, such as ornamental rock (A) or cement production. An example of this situation is observed in the Cretaceous deposits of the Crato Formation (Arairipe Basin, State of Ceará) in disposals of rocks with high fossiliferous content (B)



Fig. 8 Fossils are also important elements for the production of goods of industrial interest, e.g. phosphate. Mining front (A) in phosphate rocks originated from Proterozoic microbes (B) from the Irecê Basin (Salitre Formation, State of Bahia)



et al. (2018) have cited the problem of the illegal collection of fossils in the Araripe Geopark area, a byproduct of mining activity (Martill 2001). As shown by Jasper (2010), fossil specimens from this region are generally available for sale on the Internet, many of which are of exceptional scientific value (Boas et al. 2013). According to Lima (1990) and Jasper (2010), instead of banning such sales, it would be more profitable to regulate them, making collector allies in the preservation of heritage and fostering the expansion of collections and knowledge about the history of the planet embodied in Brazilian lands. Another important argument in favour of the sale of fossils is that this activity favours the rescue and storage of materials, which would otherwise be degraded by the action of weathering (Larson 2001) or using rocks that contain them as materials for industrial use.

Given these examples, which include authorizations for mining and for the sale of mineral and rock specimens of aesthetic beauty, it is not reasonable that the current regulations allow the destruction of fossils as industrial material at negligible values while prohibiting sales per fossil specimen. For example, sales of fragments of common, abundant, or already known and described specimens should be permitted for commercial purposes. This unresolved situation leads to illegal offers through international electronic product sales pages (Ebay 2021).

Based on current legal provisions, in a mining area, all underground mineral resources are granted by the Brazilian state to the concessionaire that holds the mineral rights, including fossils when they are not classified as cultural heritage. Creating regulations that allow the sale of fossils that are not rare and of interest to museums and other similar institutions would be a path to alternative income for people in areas where there are fossils, curbing both the trafficking of these materials and organized crime.

There is a demand for new legal parameters in Brazil that is associated with geoconservation strategies regarding control in mining areas and engineering works, which will allow important advances in scientific knowledge, popularizations of geosciences, and increases in tourism and heritage education in the most diverse regions of the country.

Fossil Protection Mechanisms in Brazil: a New Heritage Perception

A new perception about the heritage value of fossils demands a different standardization from the one that currently exists, with the need for a clear definition of what fossils should be preserved, since the National Mining Agency in Brazil allows rocks that contain them, such as stromatolites, microbials, coquinas, or even paving slabs with macrofossils and microfossils (Fig. 9), to be sold as mineral products, generally with a value of less than US \$10.00 per ton.

According to Piranha et al. (2011), the difficulty protecting Brazilian geodiversity stems from both the management mechanisms and the low representation of geoscience content in school curricula. This is the main reason for the lack of knowledge about geological heritage and for the existence of gaps in legislation and normative documents regarding the management and indiscriminate use of natural resources. Furthermore, excessive bureaucracy and pseudolegal protections are harmful to the dissemination of scientific content. Many common fossil specimens could be donated to schools and used for educational purposes. However, current Brazilian legislation discourages these initiatives due to a mistaken legal understanding, not technical aspects, which implies that a fossil should only be under the tutelage of a university, museological institution, or similar organization. It is only possible to transfer fossils to schools when managers assume all the risk of any damage that may occur to the transferred material.

Despite all existing legal provisions, which essentially entail the criminalization of the possession of fossils by private individuals, concerning the stoppage of engineering works and mining activities, the effective protection of deposits that are rich in fossils has not had an effect. Specifically, the sale of fossil material is subject to the misinterpretation of current legislation, is not considered a valid mechanism for protecting fossils, and is considered a taboo topic in Brazilian academia, despite being widely discussed internationally (Besterman 2001; De Miguel et al. 2021; Fidalgo and Fernández-Martínez 2021; Larson 2001; Larwood 2001; Liston 2014; Liston and You 2015; Percival 2014).

The first consistent critical assessment of the pros and cons of fossil trading in Brazil was provided by Lima (1990),



Fig. 9 Cretaceous laminated limestone from the Crato Formation (Araripe Basin, Ceará State). The laminated rocks, despite occasionally lacking macrofossils, originate from microbial mats, which are elements of fossiliferous heritage and generally contain pollen and microfossils of bacteria, crustaceans, and algae

who analysed the social, economic, and scientific implications of the sale of fossils. Subsequently, Carvalho (1993) undertook an exhaustive survey of extant legislation that could be applied to the sale and possession of fossils, concluding that any type of commercialization was criminalized. The punitive character Carvalho proposed has been replicated in different studies and collections of legislation (SBP 2021) and has served as a basis for misguided public policies for the protection of fossiliferous heritage.

Decree-Law No. 4,146/42 (Brazil 1942), which postulates that fossiliferous deposits are the property of the nation, has driven incorrect interpretations of the right to possess and sell fossiliferous material in Brazil. The fact that a property is a property of the nation does not mean that the state cannot carry out the donation or sale of it. This situation is well characterized by the legal assignment of the right to mine and possess mineral goods that exist in the soil and subsoil, which is based on Brazilian mineral legislation.

Structuring a system to modify the current legal situation will demand more effective inspection actions by the National Mining Agency and the promotion of scientific knowledge and of Brazilian mineral potential. It is necessary to immediately advance, for the control and management of building, a national register of palaeontological sites similar to the existing register of archaeological heritage sites. Equally relevant is the development of procedures that allow the prior and technical assessment of the palaeontological potential of sedimentary areas that are destined for mineral extractive projects or of those linked to civil works. It is necessary to separate and standardize the different stages of such research, structuring the salient diagnosis, prospecting, and rescue measures. Annual mining reports must also contain information of this nature.

During all these stages, the presence of a specialist must be ensured to assess the rarity and scientific value of specimens with due monitoring by the ANM. The destination of a fossil can be a museum or another similar institution or commercialization. In these last two cases, it is imperative to seal and conduct mining inspection as a guarantor that public assets are not being degraded.

In the case of places where the occurrence of fossils is common, the existence of a palaeontological program during the development stage of a project, whether civil work or a mineral activity, could ensure the preservation of any fossils that are found and provide legal certainty for entrepreneurs in the mining area, similar to civil engineering sites in Switzerland. Monitoring programs related to other objects (e.g. caves) are common in mining and civil construction projects, and the standardization of a palaeontological program would not only be the best method in Brazil but also expand scientific knowledge. The construction of geoconservation strategies that are associated with mining fronts and the development of civil works will constitute an important

advance in scientific dissemination, tourism, and education in the most diverse regions of the country.

Conclusion

Fossils in Brazil, based on legal and scientific criteria, are part of the nation's mineral heritage and can be mined as constituents of rocks. Only in situations where the existence of value for the identity, action, or memory of the different groups that make up Brazilian society is verified will fossils' protection be evaluated as cultural heritage. Brazilian legislation has some solid foundations that can be used in infra-legal standardization processes, which expand the possibilities for preserving fossiliferous heritage. However, for legal stability and for the validation of the value and importance of fossils, a different standardization from the one that currently exists is needed, with a clear definition of which fossils should be preserved. Decree-Law No. 4,146/42, which postulates that fossiliferous deposits are the property of the nation, does not indicate that they cannot be traded, since an asset's status as the property of the nation does not mean that the state cannot carry out the donation or sale of it. The right to mine and own mineral goods existing in the soil and subsoil are very well founded in Brazilian mineral legislation, and the use of Decree-Law No. 4,146/42 as a legal impediment to fossil commercialization is totally fallacious. It appears that the difficulty of protecting Brazilian geodiversity stems from management mechanisms, excessive bureaucracy, and pseudolegal protection as well as from the lack of educational actions that effectively identify the patrimonial value of fossils. Using new legal regulations that revise and unify the numerous laws presented here, it will be possible to guarantee the legal security of fossils, the better use of mineral resources, and the effective protection of Brazil's palaeontological heritage. On the other hand, it is also necessary to strengthen actions at the international level to curb the global trafficking of fossils and to institute measures that mandate the return of illegally extracted materials, especially specimens with high scientific value.

Acknowledgements To the Brazilian Federation of Geologists (FEBRAGEO) for creating the working group to discuss legislation on fossils in Brazil. To Kevin Page and two anonymous reviewers whose suggestions were important to the improvement of the final version of the manuscript. To Ricardo Latgé Milward de Azevedo for his contributions to the debate on the subject. To Isabela Degani Schmidt and Elisabete Pedrão Ferreira for providing some of the photographs. To the Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro (Faperj, Proc. E-26/200.828/2021, Brazil, to I.S.C.), the National Council for Scientific and Technological Development (CNPq, Brazil 311962/2018-1 to F.A.G.V.R. and 303596/2016-3 to I.S.C.), for the financial support and Coordination for the Improvement of Higher Education Personnel—Brazil (CAPES)—code 001, for the scholarship granted to the first author.

Funding Open Access funding enabled and organized by Projekt DEAL.

Declarations

Competing Interests The authors declare no competing interests.

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